Project Done on Behalf of
Ninham Shand Consulting Services

AIR QUALITY IMPACT ASSESSMENT FOR THE PROPOSED NEW COAL-FIRED POWER STATION (KENDAL NORTH) IN THE WITBANK AREA

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EXECUTIVE SUMMARY

1. INTRODUCTION

Airshed Planning Professionals (Pty) Limited was appointed by Ninham Shand Consulting to undertake an air quality impact assessment for a proposed new coal-fired power station.

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 5400 MW.

Two sites were identified for the construction of the proposed power station and the ashing operations. The sites are located to the north west of the existing Kendal North Power Station, and to the west of Witbank, in the Mpumalanga and Gauteng provinces.

Residential areas in the vicinity of the proposed operations include Ogies and Phola situated east of the proposed sites.

The terms of reference of the *air quality impact assessment component* were as follows:

- 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.

1.1 Study Limitation 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:

- 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. (In the assessment of mercury reference was however made to a guideline value given for mercury concentrations which is intended to screen for risks due to all exposure pathways.)

- 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 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 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 Kendal 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 generated with CALMET. From these three years, one year (providing the most conservative results) was used for dispersion modelling purposes. 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.

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

- Source parameters and emission rates 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 additional 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.

2. BASELINE AIR QUALITY

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 exceed short-term air quality limits at Kendal 2 (monitoring station) within exceedance of such limits modelled to occur at the nearby residential area of Phola.

  The power station in the study area is likely to be the main contributing source to the ambient SO_2 ground level concentrations 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 mining operations (not quantified in the current study) and potentially household fuel burning within Phola. The highest ground level concentrations due to the Kendal 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 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 predicted to be exceeded at Phola.

  - Predicted sulphur dioxide concentrations were within limits indicative of potential low to medium corrosion levels over the study area (based on dose-response thresholds developed abroad).

  - Predicted sulphur dioxide concentrations exceeded 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 to potentially exceed over the entire study area.

- Kendal Power Station contributes to ambient **nitrogen oxide** and nitrogen dioxide concentrations in the region, with short-term international air quality limit exceedances predicted, to occur over sections in the study area. However, other significant low level sources of NO_x anticipated to occur in the region include combustion within coal discard dumps (not quantified in the current study), vehicle tailpipe emissions, household fuel burning and infrequent veld burning (not quantified in the current study).

- Ambient **PM10** concentrations due to cumulative sources were predicted to exceed the current SA Standards (as given in the second schedule of the Air Quality Act) and the more stringent SANS and EC limit values over built up residential areas. These exceedances are primarily due to the domestic fuel burning activities in the area.

  The contribution of all power stations to primary and secondary particulates was simulated. (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 operations, vehicle entrainment from roadways and veld burning. Household fuel burning also constitutes 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 Kendal 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 dump. Ground level concentrations due to gaseous mercury are predicted to be well within health effect screening levels.

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.

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:

Scenario	No. of Units	Site	Stack Height (m)	SO_2 Control Efficiency
A.1	6 x 900 MW	Site X	150	0%
B.1	6 x 900 MW	Site Y	150	0%
C.1	6 x 900 MW	Site X	220	0%
D.1	6 x 900 MW	Site Y	220	0%
E.1	6 x 900 MW	Site X	300	0%
F.1	6 x 900 MW	Site Y	300	0%
A.2	6 x 900 MW	Site X	150	90%
B.2	6 x 900 MW	Site Y	150	90%
C.2	6 x 900 MW	Site X	220	90%
D.2	6 x 900 MW	Site Y	220	90%
E.2	6 x 900 MW	Site X	300	90%
F.2	6 x 900 MW	Site Y	300	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_2 hourly concentrations were predicted to exceed SA nitric oxides standard and the SANS/EC limit respectively (including cumulative concentrations due to existing sources of emissions). The daily and annual average ground level concentrations are within relevant standards. Although the coal fired power stations in the area contribute to the ambient oxides of nitrogen concentrations, the main sources of NO_x emissions in the area include domestic fuel burning and vehicle tailpipe emissions. (Appendix D).

Airborne Fine Particulates and Dust Deposition

Predicted PM10 concentrations due to all sources in the study area were within the SA daily and annual standards but exceeded the SANS and EC daily limit values in the vicinity (within 10 km east) of the ash dump. Public exposure within this area is restricted to scattered farmsteads with an average residential density of ~5 persons/km². Other areas of exceedance were over built up areas with ground level concentrations originating from low-level sources of emission (i.e. domestic fuel burning).

Maximum monthly dustfall rates were typically “moderate” (i.e. 250 - 500 mg/m²/day) immediately downwind of the proposed Kendal North 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 - Uncontrolled

Emissions from the existing Kendal 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 due to basecase and all proposed configurations. At Phola the SA 10-minute standard is exceeded for basecase and all proposed configurations.

- Under current operations there is predicted to be compliance with the UK hourly sulphur dioxide standard at Phola. This standard is however exceeded at Phola with the addition of six 900 MW units.

- The increase of the stack height from 220 m to 300 m is predicted to result in relatively small reductions in cumulative ground level maximum.

It may be concluded that the addition of 6 new 900 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. The extension of the height of the stack by 80 m, from 220 m to 300 m, is not sufficient to negate the need for considering abatement measures.

Sulphur Dioxide - Controlled

Changes in projected ground level sulphur dioxide concentrations and limit value exceedances were simulated for a 90% control efficiency for three proposed power station configurations, viz. Scenario A and B (150 m stack), Scenario C and D (220 m stack) and Scenario E and F (300 m stack) at two different sites, viz. Site X and Site Y. Observations made regarding compliance implications of various power station configurations given controlled emissions were as follows:

- Even given a 90% control efficiency for all power station configurations, cumulative sulphur dioxide concentrations would exceed the SA 10-minute standard at the maximum impact zone and at Phola and the SA daily standard in the maximum impact zone and Phola – primarily due to emissions from the existing Kendal Power Station.

- With the addition of six new units operating coincident with the existing Kendal 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 base case. 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 Phola 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 conditions are predicted to be associated with “high” health risks within the Phola residential area. The California EPA Acute Reference Exposure Level for sulphur dioxide (above which mild respiratory effects may occur) is predicted to be exceeded by ~80% for highest hourly ground level concentrations in the vicinity of Phola. Cumulative sulphur dioxide concentrations given the operation of an additional six 900 MW units at the sites proposed is projected to increase this concentrations to exceed the California EPA Acute reference exposure up to 150% for a 150m stack. The implementation of sulphur dioxide abatement measures comprising a 90% control efficiency would not significantly increase the exceedance of this health threshold above baseline levels.

Significance of stack height – If uncontrolled the proposed power station with a 150 m stack would result in the most significant non-compliance with SO_2 limits and pose the greatest risk to sensitive receptors. Reduced impact potentials can be realised through the extension to ~220 m. Further increments in the stack height were predicted to realise only minor further reductions in ground level concentrations and were associated with potentially more persons being exposed to sulphur dioxide concentrations in excess of air quality limits (due to the larger sphere of influence of the power station).

Significance of site selection – Compliance and exposure potential results for the two candidate sites were mixed[(1)] with neither of the sites being identified as being considerably better than the other site. It is therefore recommended that the site selection be assessed in terms of other criteria.

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: 4.5 million to 1: 10 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.

Ground level concentrations due to gaseous mercury are predicted to be well within health effect screening levels.

Potential for Vegetation Injury and Corrosion

The operation of a 5400 MWe power station at the proposed sites is predicted to result in potential "high" risks for vegetation damage and "medium" risks for corrosion over a large section of the study area if uncontrolled (based on dose-response thresholds derived abroad). Sulphur dioxide abatement with a 90% control efficiency would result in the potential for corrosion and vegetation damages for these areas being similar to baseline levels. It should be noted, however, that the dose-response thresholds are based on studies abroad and may be conservative, given that much of the research supporting such thresholds was undertaken in more humid climates. It is therefore recommended that research be undertaken locally to determine local dose-response thresholds.

Contribution to Greenhouse Gas Emissions

The emissions from the proposed 5400 MWe power station would increase the energy sectors emissions by 12.8% and would increase the country's contribution to global warming by 9.7%

[1] For the uncontrolled scenario, a new power station at Site X results in a slightly fewer SO_2 exceedance events with respect to the SA 10-minute and average daily concentrations limits than at Site Y, in the area of maximum ground level concentration. However, when comparing the impact of the power station at Phola, Site Y resulted in fewer exceedances of the SA standards than at Site X. For the controlled scenario, Site X resulted in fewer exceedances than at Site Y, in the area of maximum ground level concentrations, but there was no difference in exceedances at Phola.

3. MITIGATION RECOMMENDATIONS

Compliance with ambient air quality standards given for sulphur dioxide cannot be achieved by 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 90% control efficiency would be required for the proposed 5400 MWe power station to ensure that it could operate coincident with the existing Kendal Power Station without substantial changes in the magnitude, frequency or spatial extent of non-compliance, nor significant increment in health risks. 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 Phola 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 95%. Eskom will be investigating FGD as the abatement technology to use. The highest removal efficiencies are achieved by wet scrubbers, greater 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.

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AIR QUALITY IMPACT ASSESSMENT FOR THE PROPOSED NEW COAL-FIRED POWER STATION IN THE WITBANK AREA

1. INTRODUCTION

Airshed Planning Professionals (Pty) Limited was appointed by Ninham Shand Consulting Services to undertake an air quality impact assessment for a proposed new coal-fired power station. The proposed sites will be located to the north west of the existing Kendal North Power Station, and to the west of Witbank, in the Mpumalanga and Gauteng provinces (Figure 1.1).

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 *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.

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.

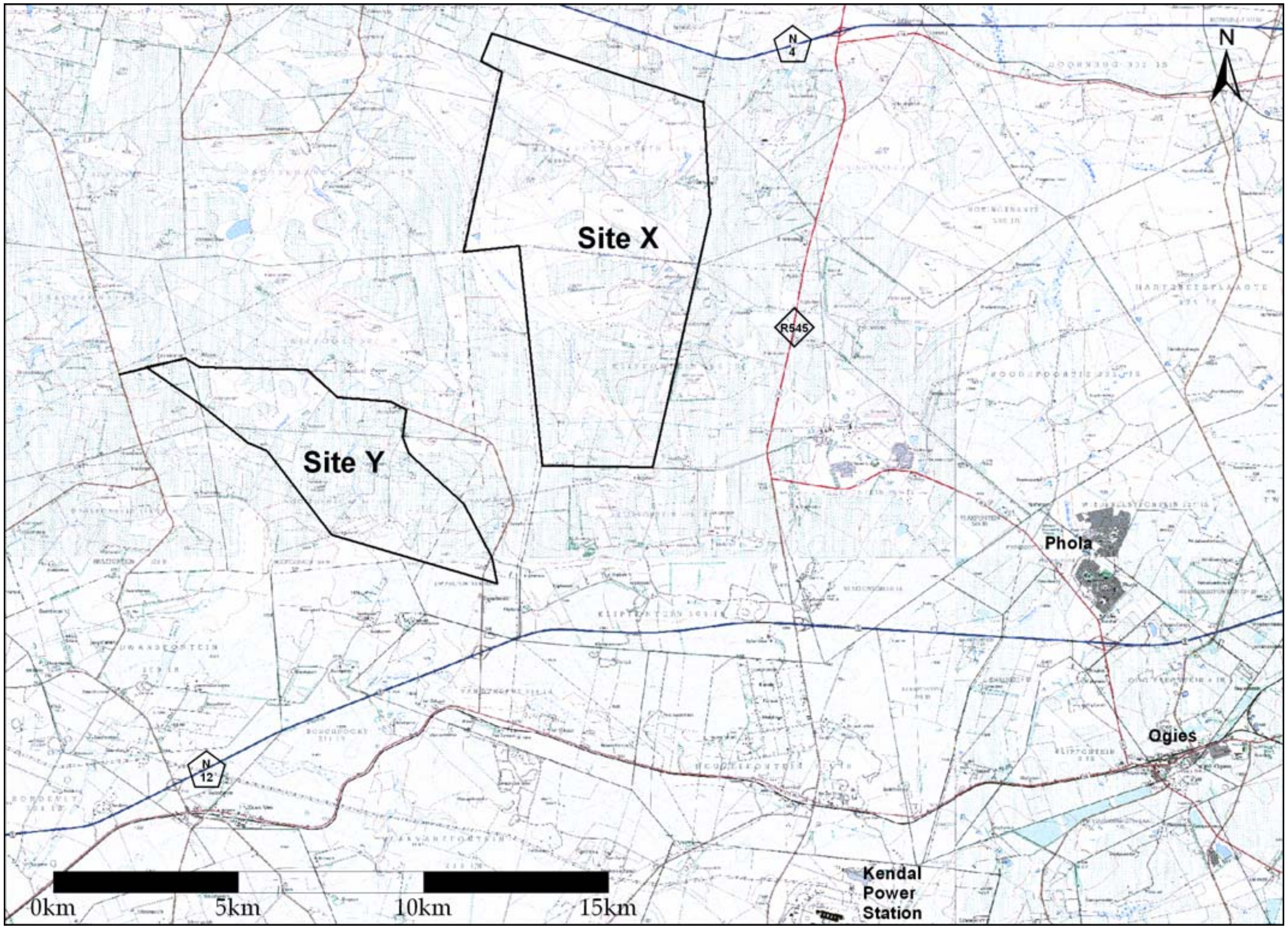

Figure 1.1: Location of the proposed sites for the new coal-fired power station near Witbank. The new power station is proposed for development in the vicinity of the existing Kendal Power Station.

The terms of reference for 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.

1.2 Project Description

1.2.1 Proposed Technology

The proposed power station is coal-fired and will source coal from local coalfields. The planned power station is given as having an electricity generation capacity of approximately 5400 MW. The project comprises a power plant and associated plant (terrace area) as well as coal storage and ashing facilities (covering ~1000 ha). It is estimated that approximately 21 million tpa of coal would be needed to supply the power station.

The proposed power station would be similar to the existing Matimba Power Station in terms of design and dimensions. Other infrastructures related to the power station include a coal stockpile, conveyor belts, an ash dump and transmission lines.

The proposed power station will make use of pulverized fuel combustion (PF) where the coal is pulverised and then blown into a furnace to be combusted at high temperatures. The heat is then used to generate the steam that drives the steam turbine and generator.

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 pulverised fuel (PF) station with a thermal efficiency of up to 40%.

1.2.2 Proposed Sites

Nine potential sites were subjected to a site selection process, where potential sites were identified, screened and two alternative sites (viz. Site X and Site Y) were ultimately selected to be assessed in the current study. The two sites were selected based on a specialist workshop that ranked the potential sites with respect to technical, social and biophysical criteria. Site X and Site Y (Figure 1.1) emerged as the most preferred sites to be considered.

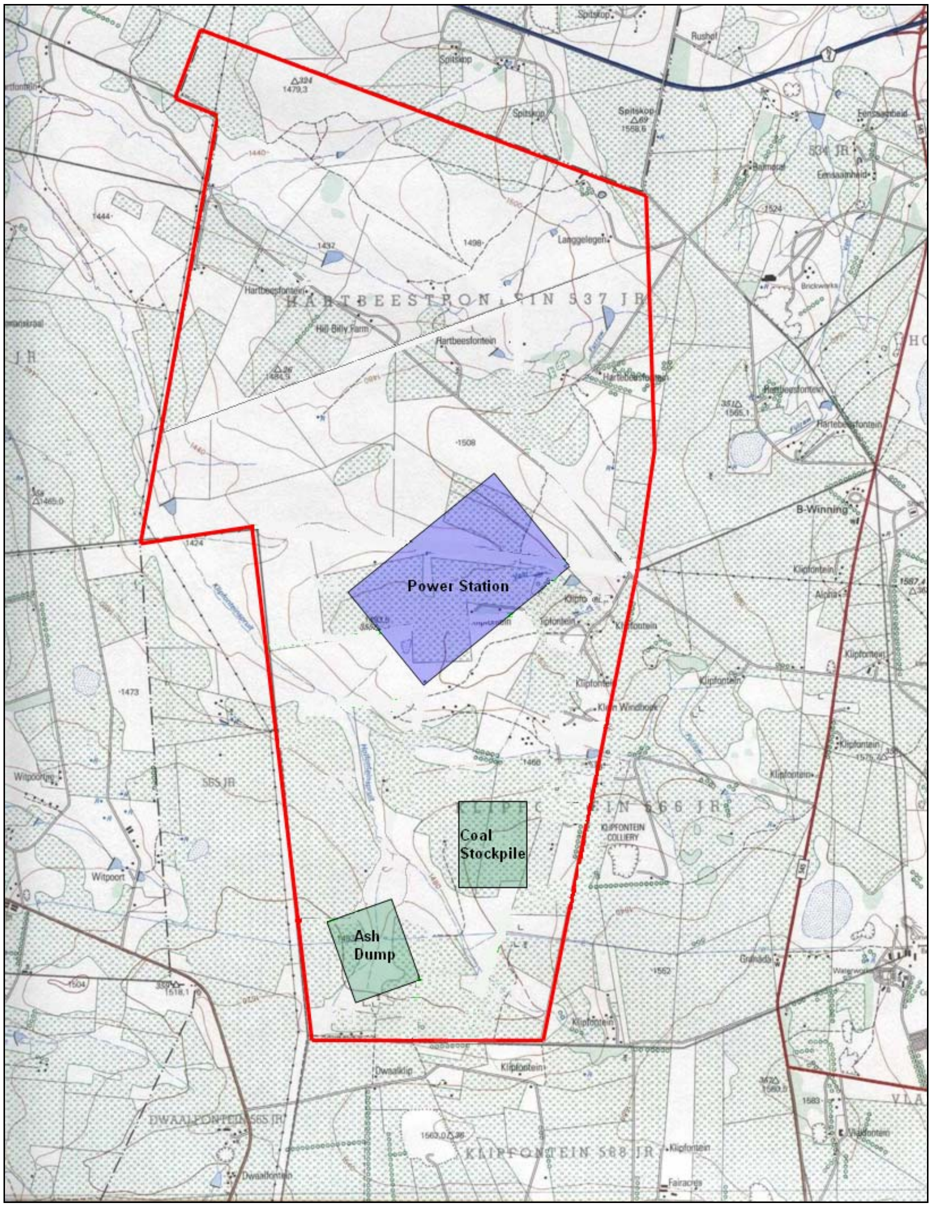

Figure 1.2: Location of the proposed locations of infrastructure development for Site X.

The layout for the proposed **power station**, **coal stockpile** and the **ashing operations** for Site X and Site Y are illustrated in Figure 1.2 and Figure 1.3 respectively.

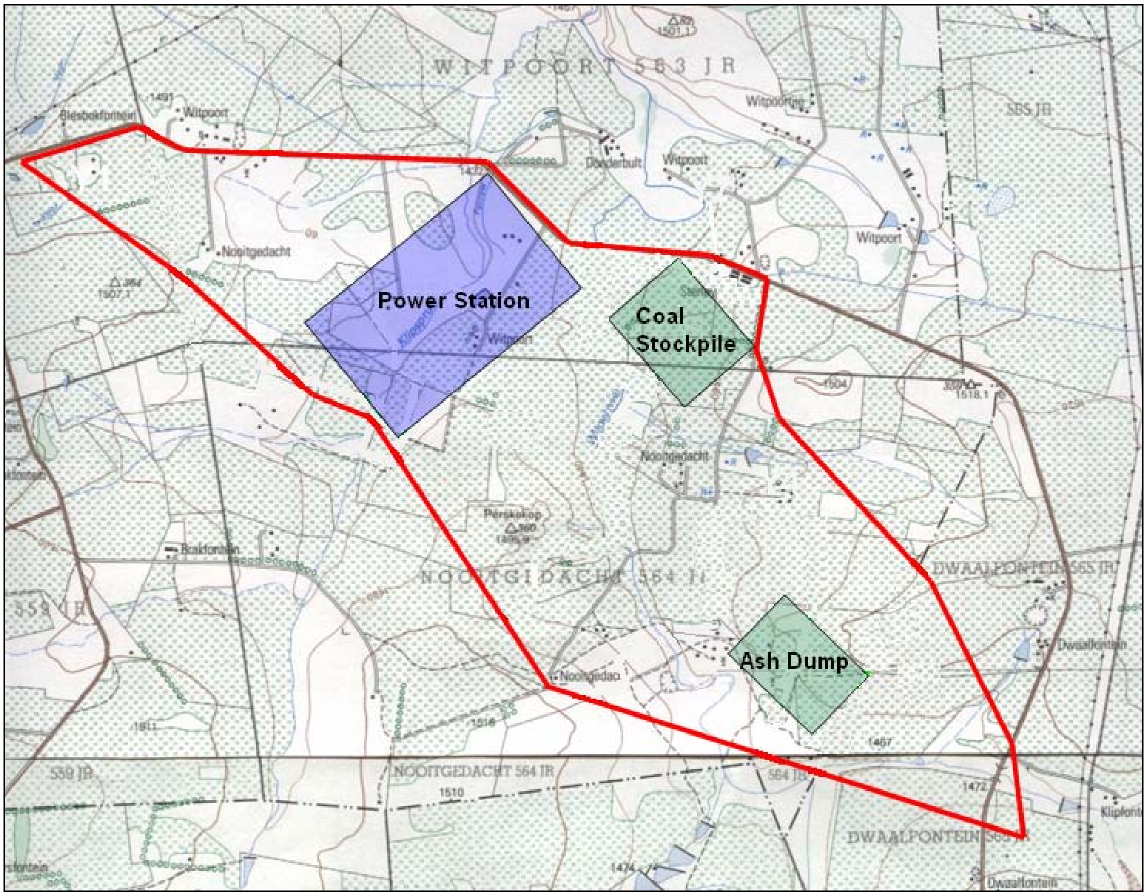

Figure 1.3: Location of the proposed locations of infrastructure development for Site Y.

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.

Residential areas in the immediate vicinity of the proposed operations include Phola and Ogies located ~10-18 km east of the proposed sites, with smaller populated areas of Voltargo, Cologne, Klippoortjie, Madressa, Witcons, Saaiwater, Tweefontein, Klipplaat, etc. The largest residential development within a 30km radius is Witbank (Figure 1.4).

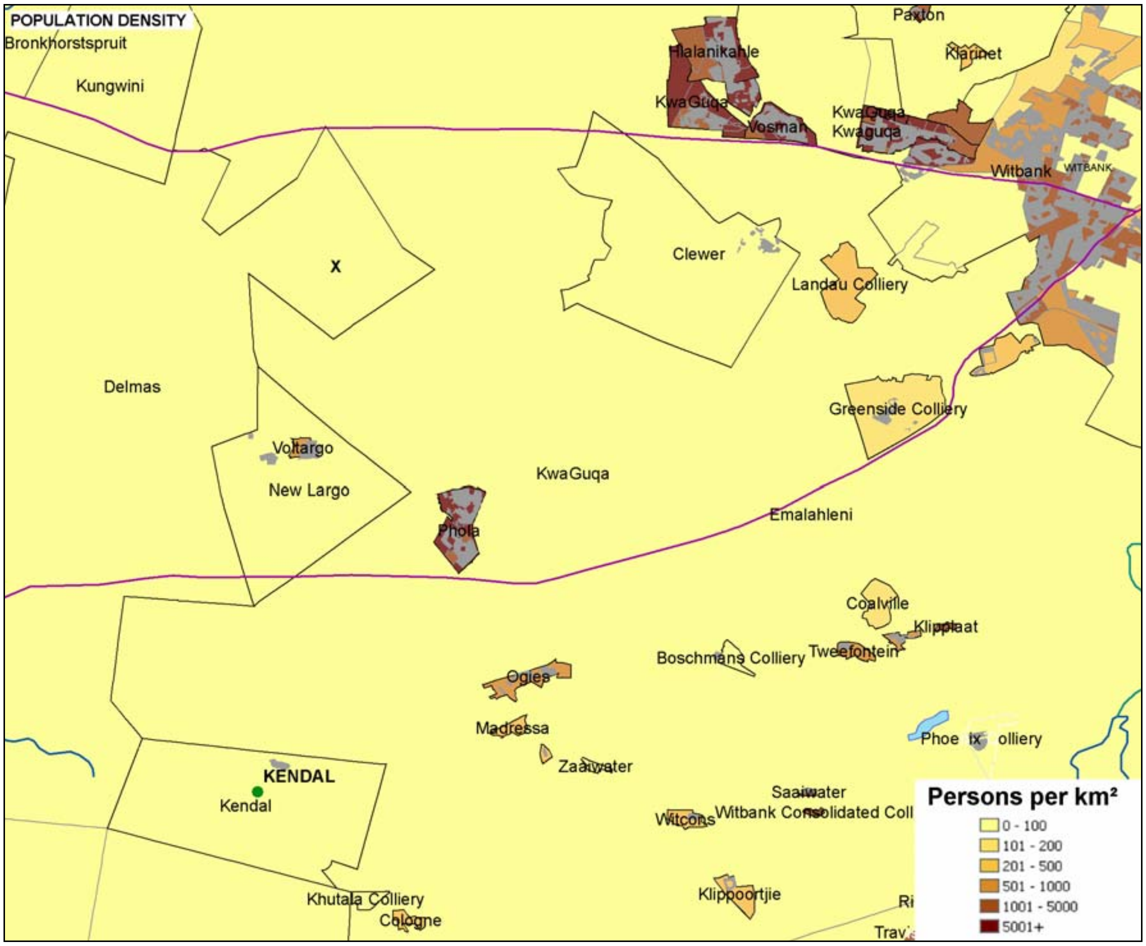

Figure 1.4: Population density of the surrounding area of the proposed Kendal North Power Station.

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:

- 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. (In the assessment of mercury reference way however made to a guideline value given for mercury concentrations which is intended to screen for risks due to all exposure pathways.)

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- 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 Kendal 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 generated with CALMET. From these three years, one year (providing the most conservative results) was used for dispersion modelling purposes. 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.

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- 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.

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 new coal-fired power station (Kendal North) 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.

2. LICENSING OF SCHEDULED PROCESSES AND AMBIENT AIR QUALITY CRITERIA

2.1 Licensing of the Scheduled Processes

The Air Pollution Prevention Act, Act 45 of 1965 is scheduled to be replaced in its entirety by the National Environmental Management: Air Quality Act, Act 39 of 2004. The Air Quality Act was assented to by the President and gazetted on 24 February 2005. On 11 September 2005 the Air Quality Act came into force, with the exclusion of sections 21, 22, 36 to 49, 51(1)(f), 51(3), 60 and 61, most of which deal with the licensing of "listed activities". Given that the legislative context is currently in transition, it is necessary to consider the implications of both the APPA and the AQA as they pertain to the proposed plant's operations.

Under the APPA air pollution control was administered at a national level by the Department of Environmental Affairs and Tourism. This Act regulates the control of noxious and offensive gases emitted by industrial processes, the control of smoke and wind borne dust pollution, and emissions from diesel vehicles. The implementation of the act is charged to the Chief Air Pollution Control Officer (CAPCO).

All power stations are listed under Process 29 in the second schedule of the APPA and are controlled by CAPCO through Best Practicable Means (BPM) using registration certificates. Scheduled processes represent processes listed in the Second Schedule of the Act that have the potential to release potentially significant quantities of pollutants. BPM represents an attempt to restrict emissions while having regard to local conditions, the prevailing extent of technical knowledge, the available control options, and the cost of abatement.

In the future, under the Air Quality Act, the permitting of "Scheduled Processes" by CAPCO (DEAT) will be replaced by the licensing of "Listed Activities" by local government. District municipalities and metropolitan municipalities are tasked with such licensing[(2)]. During the transitional phase a provisional registration certificate will continue to be valid for a period of two years. A registration certificate will remain valid for a period of four years, with the registration certificate holder being required to lodge a renewal application with the licensing authority within the first three years of the four-year period.

Eskom will need to apply for a registration certificate for its proposed power station (Kendal North) under the APPA given that the clauses dealing with "listed activities" under the Air Quality Act are not yet in force and that the APPA registration certification process is still being implemented (Appendix A).

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[2] Provincial government may become responsible for this function in the event that: (i) local government is unable to fulfil the function, (ii) local government requests that the function be taken by province, or (iii) local government is undertaking a listed activity requiring licensing.

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.

2.2 Local and International Ambient Air Quality Guidelines and Standards

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. The ambient air quality limits are intended to indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. 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(3) are reflected together with limits published by the WHO, EC, World Bank, UK, Australia and US-EPA.

2.2.1 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

[3] 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.

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).

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 2.1. 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 2-1: 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)	40(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 35 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.

During the 1990s the World Health Organisation (WHO) stated that no safe thresholds could be determined for particulate exposures and responded by publishing linear dose-response relationships for PM10 and PM2.5 concentrations (WHO, 2005). This approach was not well accepted by air quality managers and policy makers. As a result the WHO Working Group of Air Quality Guidelines recommended that the updated WHO air quality guideline document contain guidelines that define concentrations which, if achieved, would be expected to result in significantly reduced rates of adverse health effects. These guidelines would provide air quality managers and policy makers with an explicit objective when they were tasked with setting national air quality standards. Given that air pollution levels in developing countries frequently far exceed the recommended WHO air quality guidelines (AQGs), the Working Group also proposed interim targets (IT) levels, in excess of the WHO AQGs themselves, to promote steady progress towards meeting the WHO AQGs (WHO, 2005). The air quality guidelines and interim targets issued by the WHO in 2005 for particulate matter are given in Tables 2.2 and 2.3.

Table 2-2. WHO air quality guideline and interim targets for particulate matter (annual mean) (WHO, 2005)

Annual Mean Level	PM10 (µg/m³)	PM2.5 (µg/m³)	Basis for the selected level
WHO interim target-1 (IT-1)	70	35	These levels were estimated to be associated with about 15% higher long-term mortality than at AQG
WHO interim target-2 (IT-2)	50	25	In addition to other health benefits, these levels lower risk of premature mortality by approximately 6% (2-11%) compared to WHO-IT1
WHO interim target-3 (IT-3)	30	15	In addition to other health benefits, these levels reduce mortality risks by another approximately 6% (2-11%) compared to WHO-IT2 levels.
WHO Air Quality Guideline (AQG)	20	10	These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to PM2.5 in the American Cancer Society (ACS) study (Pope *et al.*, 2002 as cited in WHO 2005). The use of the PM2.5 guideline is preferred.

Table 2-3. WHO air quality guideline and interim targets for particulate matter (daily mean) (WHO, 2005)

Annual Mean Level	PM10 (µg/m³)	PM2.5 (µg/m³)	Basis for the selected level
WHO interim target-1 (IT-1)	150	75	Based on published risk coefficients from multi-centre studies and meta-analyses (about 5% increase of short-term mortality over AQG)
WHO interim target-2 (IT-2)*	100	50	Based on published risk coefficients from multi-centre

Annual Mean Level	PM10 (µg/m³)	PM2.5 (µg/m³)	Basis for the selected level
			studies and meta-analyses (about 2.5% increase of short-term mortality over AQG)
WHO interim target-3 (IT-3)**	75	37.5	Based on published risk coefficients from multi-centre studies and meta-analyses (about 1.2% increase of short-term mortality over AQG)
WHO Air Quality Guideline (AQG)	50	25	Based on relation between 24-hour and annual levels

* 99th percentile (3 days/year)

** for management purposes, based on annual average guideline values; precise number to be determined on basis of local frequency distribution of daily means

2.2.2 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 2.4.

Table 2-4: 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 Power Guidelines)			150(h)	80(h)
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 24 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).

It is important to note that the WHO air quality guidelines (AQGs) published in 2000 for sulphur dioxide have recently been revised (WHO, 2005). Although the 10-minute AQG of 500 µg/m³ has remained unchanged, the previously published daily guideline has been significantly reduced from 125 µg/m³ to 20 µg/m³. The previous daily guideline was based on epidemiological studies. WHO (2005) makes reference to more recent evidence which suggests the occurrence of health risks at lower concentrations. Although WHO (2005) acknowledges the considerable uncertainty as to whether sulphur dioxide is the pollutant responsible for the observed adverse effects (may be due to ultra-fine particles or other correlated substances), it took the decision to publish a stringent daily guideline in line with the precautionary principle. The WHO (2005) stipulates an annual guideline is not needed for the protection of human health, since compliance with the 24-hour level will assure sufficiently lower levels for the annual average. Given that the 24-hour WHO AQG of 20 µg/m³ is anticipated to be difficult for some countries to achieve in the short term, the WHO (2005) recommends a stepped approach using interim goals as shown in Table 2.5.

Table 2-5. WHO air quality guidelines and interim guidelines for sulphur dioxide (WHO, 2005)

	24-hour Average Sulphur Dioxide (µg/m³)	10-minute Average Sulphur Dioxide (µg/m³)
WHO interim target-1 (IT-1) (2000 AQF level)	125	
WHO interim target-2 (IT-2)	50(a)	
WHO Air Quality Guideline (AQG)	20	500

(a) Intermediate goal based on controlling either (i) motor vehicle (ii) industrial emissions and/or (iii) power production; this would be a reasonable and feasible goal to be achieved within a few years for some developing countries and lead to significant health improvements that would justify further improvements (such as aiming for the guideline).

2.2.3 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 2.6. In addition, South Africa also publishes standards for oxides of nitrogen (NO_x).

Table 2-6: 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)[4]	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 (2000, 2005)	-	200(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). Not to be exceeded more than 18 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). AQGs remain unchanged according to WHO (2005).

[4] On 9 June 2006 the Department of Environmental Affairs and Tourism gazetted new air quality standards for public comment (90 day comment period given). The proposed NO_2 standards are given as 200 µg/m³ for highest daily and 40 µg/m³ for annual averages (in line with the SANS limits) (Government Gazette No. 28899, 9 June 2006).

2.2.4 Air Quality Standards for Metals

Air quality guidelines and standards are issued by various countries, including South Africa, for lead (Table 2.7). 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 2.8. No air quality limits have been set for such metals in South Africa to date.

Table 2-7 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 2-8 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/m³)
Arsenic	6
Cadmium	5
Nickel	20

2.2.5 Dust Deposition

Foreign dust deposition standards issued by various countries are given in Table 2.9. 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 2-9: Dust deposition standards issued by various countries

Country	Annual Average Dust Deposition Standards (based on monthly monitoring) (mg/m^2/day)	Maximum Monthly Dust Deposition Standards (based on 30 day average) (mg/m^2/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 Washington Wyoming	 200 175 200 (urban, 50 percentile of monthly value) 300 (urban, 84 percentile of monthly value) 267 183 (residential areas) 366 (industrial areas) 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 2.10. Proposed target, action and alert thresholds for ambient dust deposition are given in Table 2.11.

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 2-10: 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 2-11: 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.

2.2.6 Summary

In the assessment of all of the above mentioned guidelines/ standards the following will be used for the compliance assessment for the current study:

	10 min max µg/m^3	1 hour max µg/m^3	24 hour max µg/m^3	1 month µg/m^3	Annual avg. µg/m^3
PM10[5]					
SA standard (NEMAQA)			*180*		*60*
SANS limits (SANS1929:2004)			*75 limit 50 target*		*40 limit 30 target*
Proposed SA standard (gazette 28899, 9 June 2006)			*75*		*40*
SO_2					
SA standard (NEMAQA)	***500***		***125***		***50***
SANS limits (SANS1929:2004)	***500***		***125***		***50***
Proposed SA standard (gazette 28899, 9 June 2006)	***500***	***350***	***125***		***50***
NO_2					
SA standard (NEMAQA)	***940***	***376***	***188***	***150***	***94***
SANS limits (SANS1929:2004)		***200***			***40***
Proposed SA standard (gazette 28899, 9 June 2006)		***200***			***40***

2.3 Inhalation Health Risk Evaluation Criteria for Metals (and Sulphur Dioxide as well as Nitrogen 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).

[5] PM10 refers to particulate matter with an average aerodynamic diameter of less than 10 µm

(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 2.12.

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)[6].

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 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.*

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6 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.

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 2.12), 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 2-12 Health risk criteria for non-carcinogenic exposures via the inhalation pathway

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+)
	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Arsenic					0.19 (4 hrs)	0.03				0.1	0.01
Barium										50	5
Bismuth											
Cadmium		0.005 (GV)				0.02				0.1	0.01
chromium (II) and (III) compounds										1	0.1
chromium (VI) compounds				0.1		0.2		1.0		0.1	0.01
Cobalt								0.1		0.2	0.02
Copper					100 (1 hr)					10	1
Gallium											
Germanium											
Lead		0.5(GV)									
Manganese		0.15 (GV)		0.05		0.2			0.04	2	0.2
Mercury		1(GV)		0.3	1.8 (1 hr)	0.09			0.2	0.25	0.025
Nickel & compounds					6 (1 hr)	0.05		0.2	0.09	0.15	0.015
Niobium											
Nitrogen dioxide	See Table 2.13	See Table 2.13			470 (1 hr)(a)						
Rhiobium											
Selenium						20				2	0.2
Strontium										20	2
Sulphur dioxide	See Table 2.13	See Table 2.13			660 (1 hr)(a)		26.2				
Thorium											
Tin										20	2
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	5
Zirconium										50	5

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 2-13 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 ($\mu g/m^3$)	Uncertainty Factor	Guideline Value ($\mu g/m^3$)	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

2.3.1 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 2.14.

Table 2-14 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

2.3.2 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 x 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.

2.4 UK Banding Approach and Dose-response Thresholds for Criteria Pollutants

2.4.1 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 2.15 and 2.16.

2.4.2 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 2.17 (Ferris, 1978; Godish, 1990; .Harrison, 1990; Quint *et al*., 1996; WHO, 2000).

Table 2-15 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 2-16 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.

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 2-17 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.

2.5 Potential for Damage to Metals

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). However, no local dose-response thresholds have been developed for corrosion occurring due to sulphur dioxide exposures. Reference was therefore made to cause-effective relationships from the general literature in assessing corrosion potentials. It is recognised that this approach may be conservative.

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 2.1. The natural background corrosivity in the area is "low". The corrosion rate (r_{corr}) is specified in the International Standard ISO 9226, given in Table 2.18 with the corrosivity classes given in Table 2.19. 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).

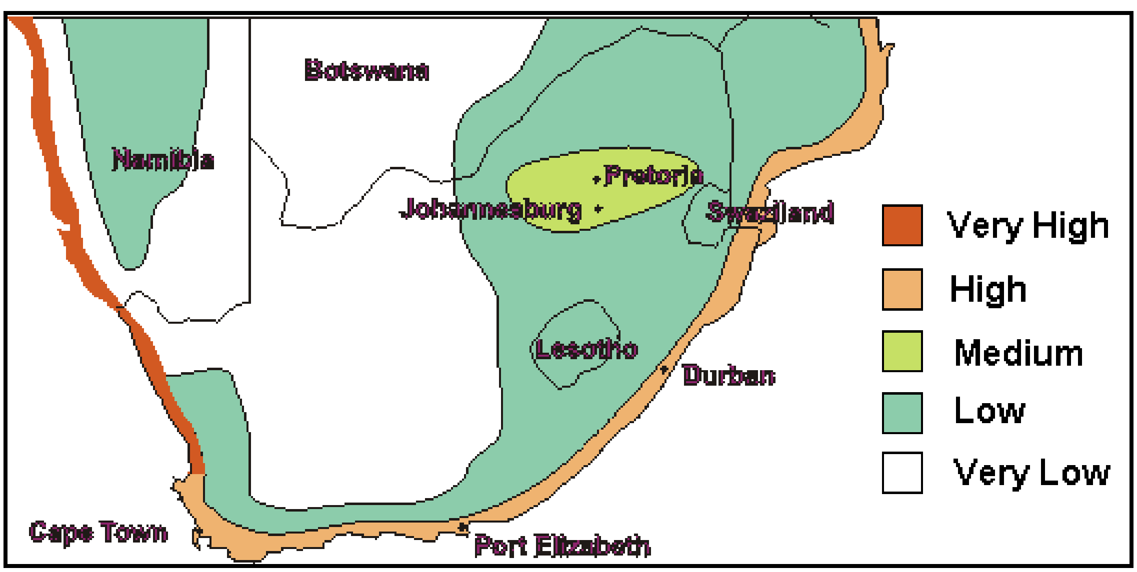

Figure 2.1 Corrosivity map of South Africa.

Table 2-18 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/(m^2.yr)	0-10	0-0.7	0-0.9	Negligible
	µm/yr	0-1.3	0-0.1	0-0.1	
C2	g/(m^2.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/(m^2.yr)	200-400	5-15	5-12	0.6-2
	µm/yr	25-50	0.7-2.1	0.6-1.3	
C4	g/(m^2.yr)	400-650	15-30	12-25	2-5
	µm/yr	40-80	2.1-4.2	1.3-2.8	
C5	g/(m^2.yr)	650-1500	30-60	25-50	5-10
	µm/yr	80-200	4.2-8.4	2.8-5.6	

Table 2-19 Categories of corrosivity (ISO 9226)

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

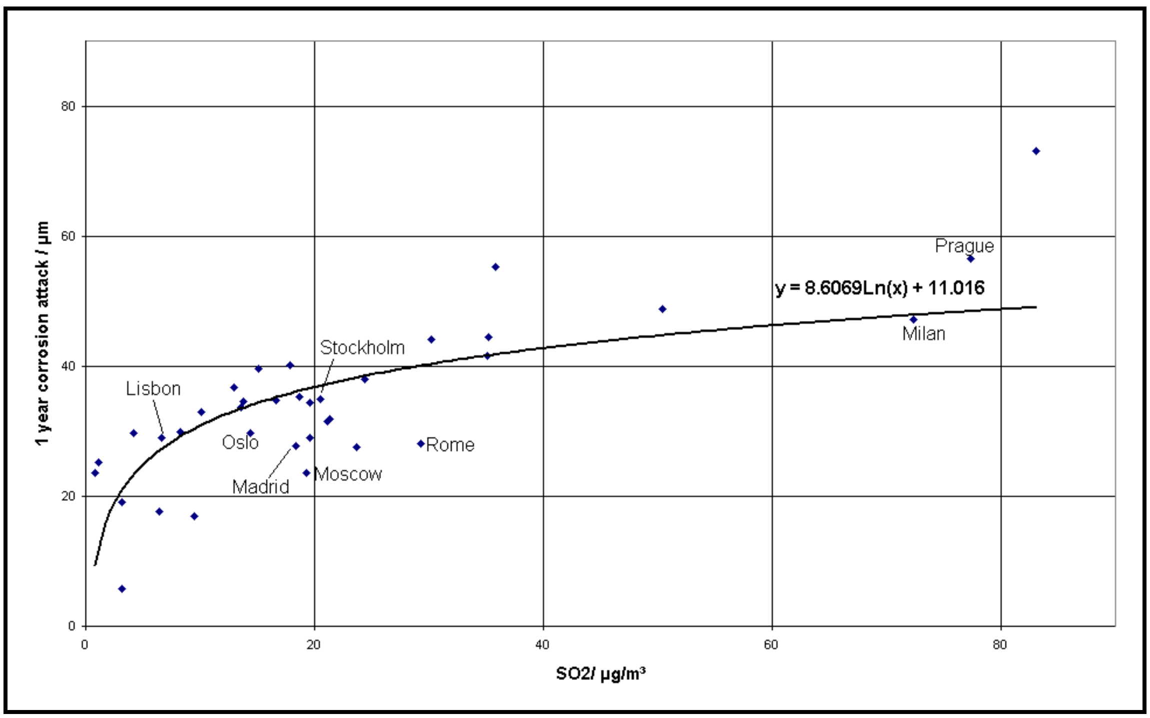

Figure 2.2 Corrosion attack of unsheltered carbon steel exposed in various European cities to SO_2 concentration, as analysed in the UN ECE exposure program during the period September 1987 to August 1988 (Tidblad and Kucera, 2003).

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 2.20 provides calculated corrosion rates occurring due to SO_2 exposures without natural corrosivity action and associated ground level concentration levels.

Table 2-20 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

2.6 Vegetation Exposures to Air Pollution

2.6.1 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).

Unfortunately, no dose-response relationships have been derived in South Africa for air pollution exposures by vegetation. Studies of air pollution impacts at the ecosystem scale have not been performed in South Africa. Small scale exploratory studies did not provide conclusive findings. Research was carried out in the study region in the early 1990s when farmers in the industrial highveld speculated that deterioration of the grassland was attributable to air pollution. It was, however, later thought that grazing pressure, fire management and climate play a greater role in influencing vegetation than air pollution impacts (van Tienhoven *et al*., 2002). Given the absence of local dose-response relationships reference was make to dose-response thresholds for vegetation exposure to SO_2 concentrations from the literature in determining the potential which exists for vegetation injury. It is recognised that this approach may be conservative given that much of the research supporting such thresholds was undertaken in more humid climates.

Relationships between plant injury and SO_2 dosages are given in Table 2.21.

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 2-21 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 2.22.

Table 2-22. Thresholds specified by certain countries and organisations for vegetation and ecosystems

Pollutant	Averaging Period	Threshold (ppb/ppm)	Threshold (µg/m³ or mg/m³)
Sulphur dioxide	annual average	3.7 - 11.1 ppb(a) 7.4 ppb(b)	10 - 30 µg/m³(a) 20 µg/m³ (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

2.6.2 Oxides of Nitrogen

Direct exposure to NO_x may cause growth inhibitions in some plants (Table 2.23). 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 2-23 Injury to plants caused by various dosages of NO_2.

Symptoms	Concentration (µg/m³)	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 2.24.

Table 2-24. 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

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 Witbank
- Eskom's monitoring site in close vicinity to the proposed Kendal North, viz. Kendal 2

3.1 Synoptic Climatology and Regional Atmospheric Dispersion Potential

3.1.1 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.

3.1.2 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 3.1. 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).

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).

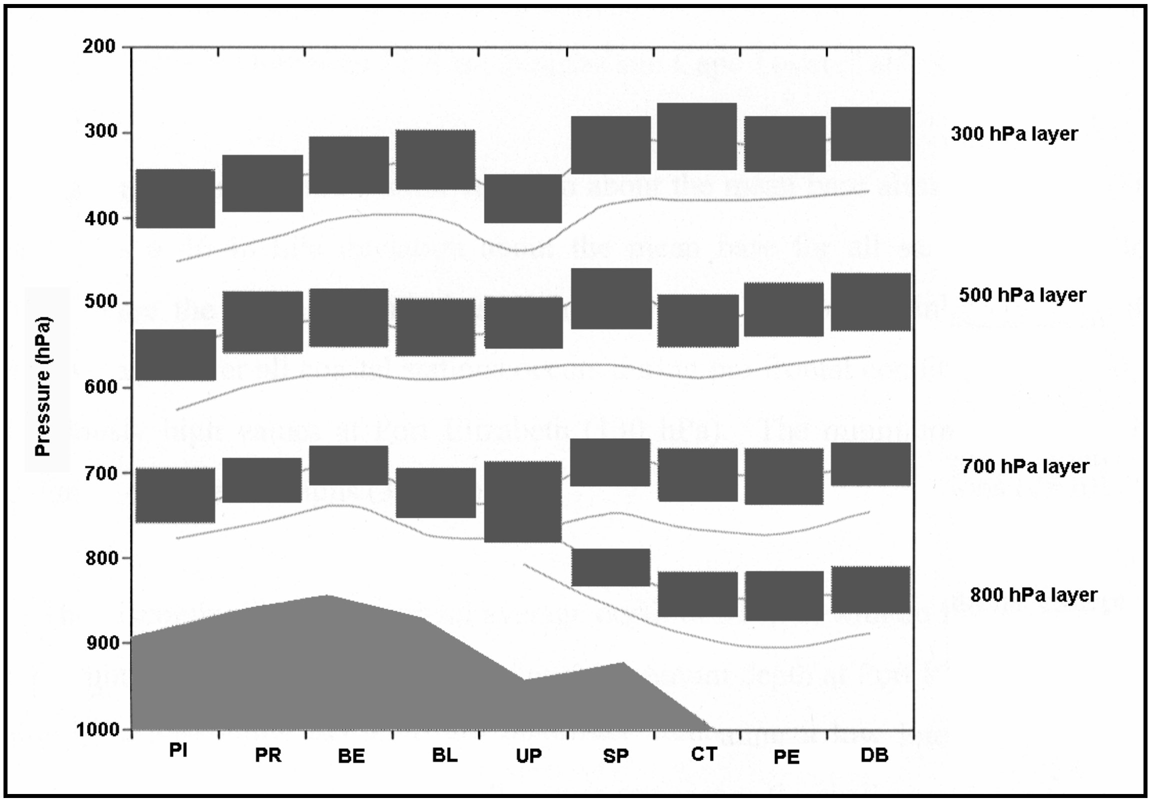

Figure 3.1: Mean annual stable layers (shaded) over Pietersburg (PI), Pretoria (PR), Bethlehem (BE), Bloemfontein (BL), Upington (UP), Springbok (SP), Cape Town (CT), Port Elizabeth (PE) and Durban DB). Upper and lower 95% confidence limits for the base heights of the layers are shown in each case (after Cosijn, 1996).

3.2 Meso-scale Climatology and Atmospheric Dispersion Potential

3.2.1 Meso-Scale Wind Field

Annual wind roses for the period 2001 to 2003 are presented in Figure 3.2 and Figure 3.3 for the Eskom monitoring station (Kendal 2) and the Weather Service Station (Witbank) respectively.

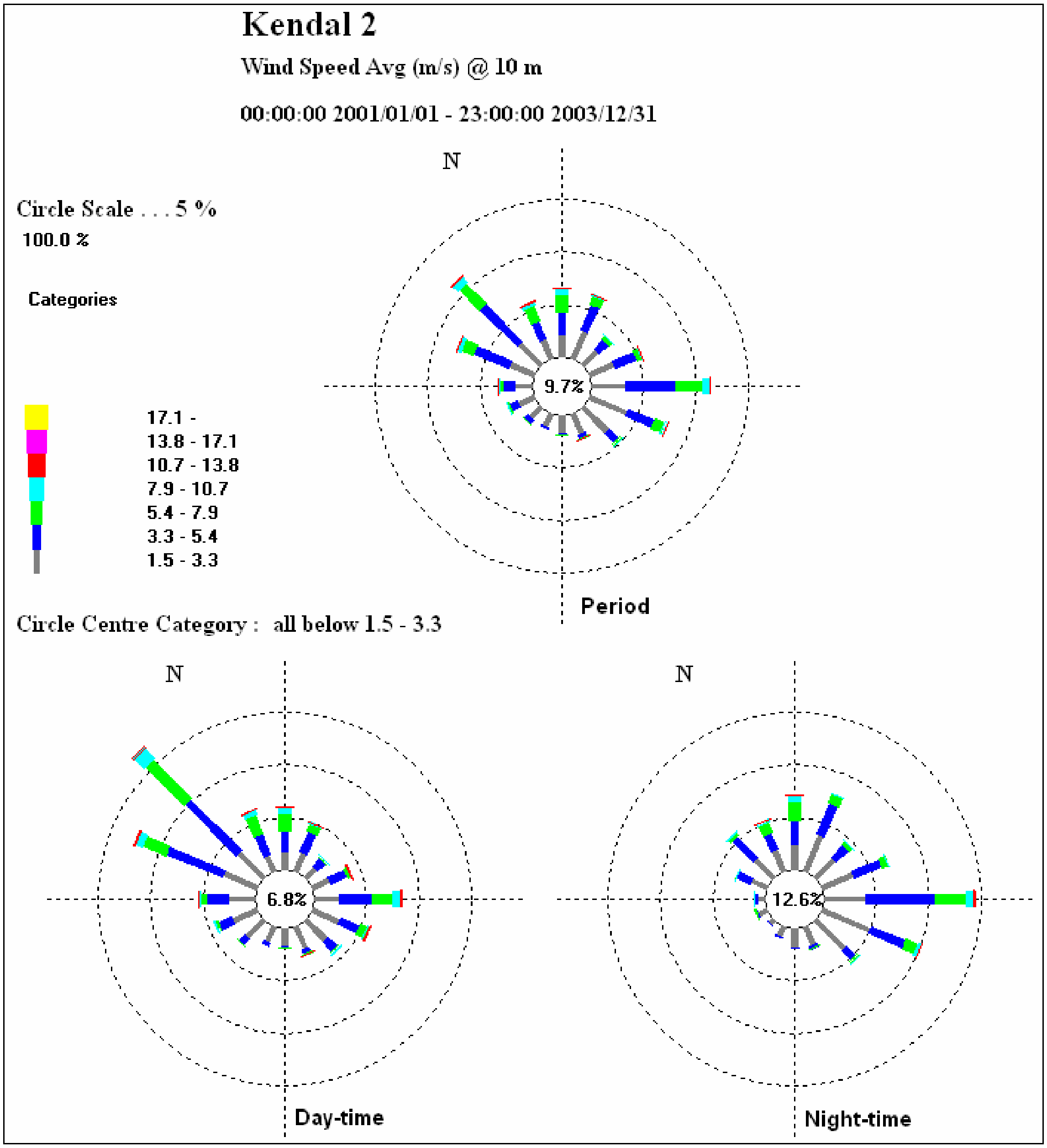

Figure 3.2. Annual average and day/night time wind roses for Kendal 2 (2001-2003).

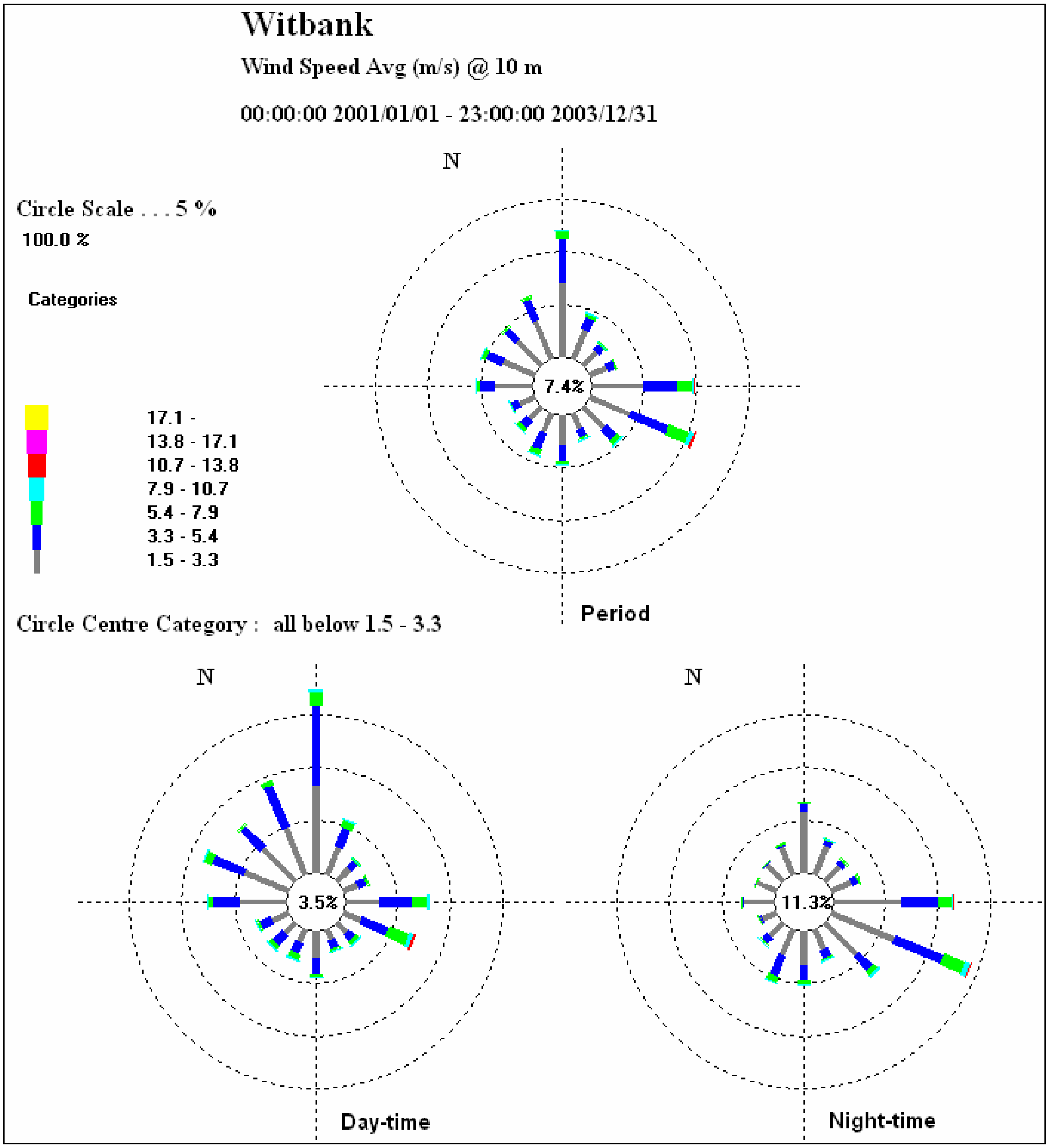

Figure 3.3. Annual average and day/night time wind roses for Witbank (2001-2003).

The wind regime largely reflects the synoptic scale circulation. The flow field is dominated by northerly to northwesterly wind, with the prevalence of the northerly component clearly reflecting the anticyclonic circulations which dominates the region throughout much of the year. Calm periods and low wind speeds are more prevalent during the night-time, as is to be expected. The gentle slope of the terrain may account for the increased frequency of occurrence of northwesterly wind during the day-time and increased southeasterly winds during the night-time. Differential heating and cooling of the air along a slope typically results in down-slope (katabatic) flow at night, with low-level up-slope (anabatic) airflow occurring during the day. Thermo-topographical induced flow is not, however, anticipated to represent an important component in the airflow over the study area due to the small gradients of terrain features. Although significant differences are evident between day-time and night-time wind speeds, no strong diurnal shift in the wind field characteristic of more uneven terrain is evident.

During winter months (July to August), the enhanced influence of westerly wave disturbances is evident in the increased frequency of northwesterly and west-northwesterly winds at Kendal 2 (Figure 3.4) and Witbank (Figure 3.5) respectively. An increase in the frequency of easterly winds during summer months (December to February) reflects the influence of easterly wave systems at Kendal 2 and Witbank respectively. Autumn and winter months are associated with a greater frequency of calm wind conditions, with the smallest number of calms occurring during spring and summer months.

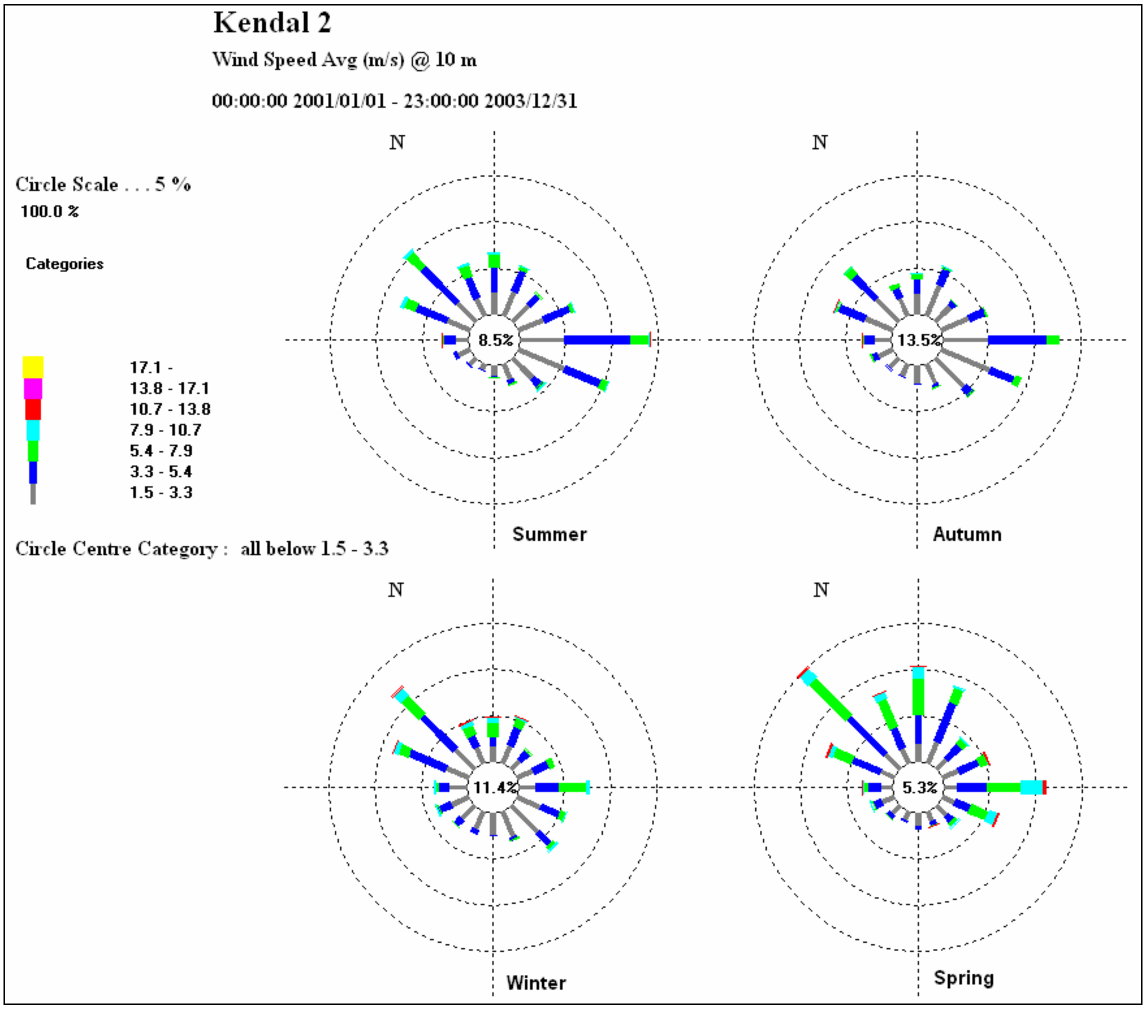

Figure 3.4. Seasonal average wind roses for Kendal 2 for the period 2001 to 2003.

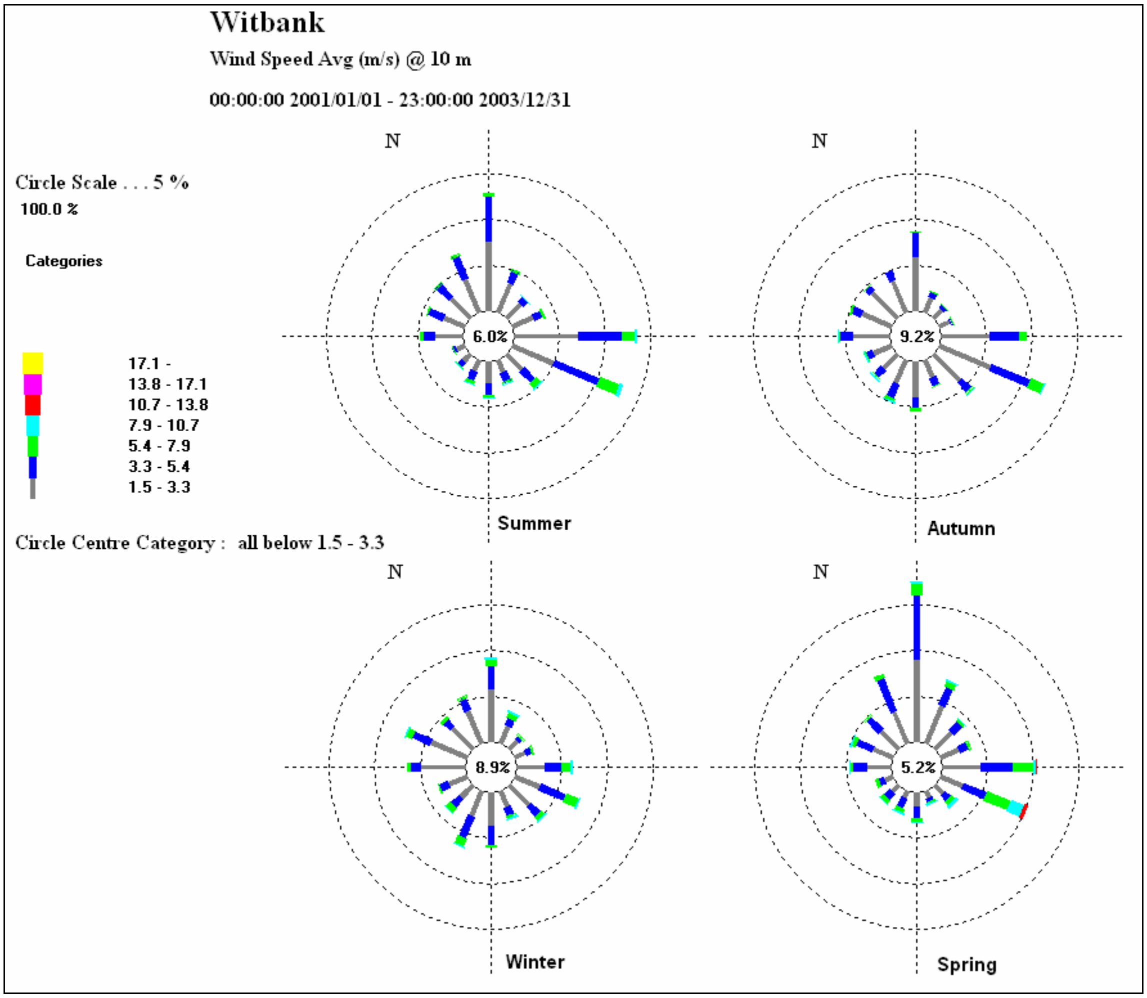

Figure 3.5. Seasonal average wind roses for Witbank for the period 2001 to 2003.

3.2.2 Ambient Temperature

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher the plume is able to rise), and determining the development of the mixing and inversion layers. Long-term average (2003) maximum, mean and minimum temperatures for Kendal 2 and Witbank are given in Table 3.1 and Table 3.2 respectively. The diurnal temperature profile for the year 2003 for Kendal 2 and Witbank is illustrated in Figure 3.6 and Figure 3.7 respectively.

Table 3.1 Long-term minimum, maximum and mean temperature for Kendal 2

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Maximum	31	32	32	29	24	20	22	24	29	30	30	32
Mean	21	22	20	18	13	10	10	12	18	20	21	22
Minimum	15	15	12	11	6	4	3	4	10	13	14	15

Annual maximum, minimum and mean temperatures for Kendal 2 are given as 32°C, 3°C and 17°C, respectively, based on the 2003 record. Average daily maximum temperatures range from 32°C in December to 20°C in July, with daily minima ranging from 15°C in January to 3°C in July.

Table 3.2 Long-term minimum, maximum and mean temperature for Witbank

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Maximum	25	27	27	25	21	17	19	19	24	26	25	27
Mean	20	21	20	18	14	11	11	12	17	19	20	22
Minimum	15	16	14	12	8	6	5	6	10	13	15	16

For Witbank during the period 2003, the annual maximum, minimum and mean temperatures are given as 27°C, 5°C and 17°C, respectively. Average daily maximum temperatures range from 27°C in December to 17°C in June, with daily minima ranging from 16°C in December to 5°C in July.

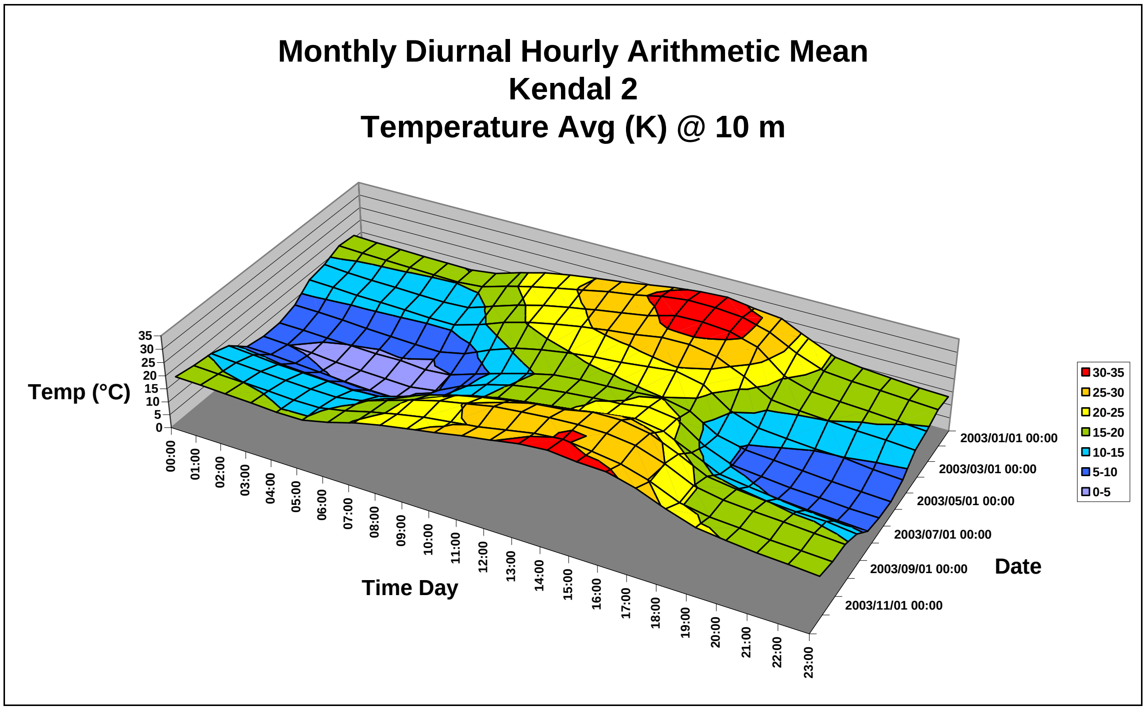

Figure 3.6 Diurnal temperature profile for Kendal 2 for the period 2003.

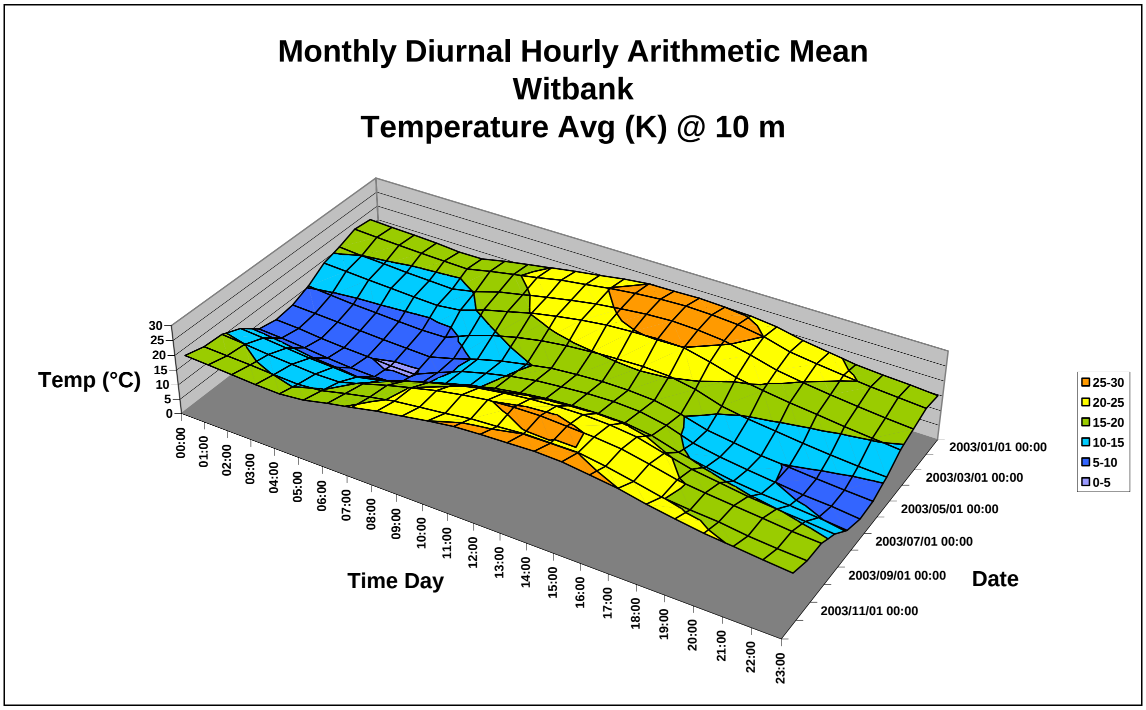

Figure 3.7 Diurnal temperature profile for Witbank for the period 2003.

3.2.3 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 3.3.

Table 3.3 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.

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 discussed in Section 4.1. Ground level air pollution measurements undertaken in the region are primarily from APOLCOM and Eskom monitors (Section 4.2). Unfortunately for the current study, permission to assess APOLCOM data could not be attained.

4.1 Existing Sources of Atmospheric Emission

Sources of SO_2 and NO_x that occur in the region include Eskom power stations, industrial emissions, blasting operations at mines and spontaneous combustion of discard at coal mines, veld burning, vehicle exhaust emissions and household fuel burning. The highest ground level concentrations due to the Eskom Power Station stack emissions are expected to occur during unstable conditions when the plume is forced to ground in relatively close proximity to the power station.

Various local and far-a-field sources are expected to contribute to the suspended fine particulate concentrations in the region with the Eskom Power Stations predicted to contribute only marginally to such concentrations. Local sources include wind erosion from exposed areas, fugitive dust from agricultural and mining operations, particulate releases from industrial operations, vehicle entrainment from roadways and veld burning. Household fuel burning also constitutes a significant 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 South Africa, has been found to contribute significantly to background fine particulate concentrations over the interior (Andrea *et al.*, 1996; Garstang *et al*., 1996; Piketh, 1996).

4.1.1.1 Wind-blow Dust from Eskom's Ash Dams and Dumps

A preliminary study was undertaken to quantify wind-blown dust from Eskom's ash dams and dumps for simulation in the current study. Parameters which have the potential to impact on the rate of emission include the extent of surface compaction, moisture content, ground cover, the shape of the dam, 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 ash dam. The calculation of an emission rate for every hour of the simulation period was carried out using the ADDAS model. This model, developed by Airshed for specific use by Eskom in the quantification of fugitive emissions from its ash dumps, is based on the dust emission model proposed by Marticorena 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).

Site layout maps were obtained, where available, to determine the location, dimensions and orientations of the ash dumps. Where no such maps were available reference was made to recent satellite imagery and topographical maps. Particle size distribution data from the Matimba ash dump (Table 4.1) were used in the emission estimates given that no site-specific data in this regard could be obtained.

Table 4.1 Particle size distribution for the materials found on the ash dump

Ash		Ash	
µm	**Fraction**	**µm**	**fraction**
600	0.0472	68.33	0.072
404.21	0.0269	56.09	0.0669
331.77	0.0296	46.03	0.0607
272.31	0.0336	37.79	0.0537
223.51	0.0404	31.01	0.0471
183.44	0.0503	25.46	0.0407
150.57	0.0609	17.15	0.0628
123.59	0.0687	14.08	0.0528
101.44	0.0728	7.78	0.0285
83.26	0.0739	3.53	0.0105

4.1.2 Materials handling

Materials handling operations associated with the activities at the power station includes the transfer of coal 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 quantity of dust generated from the tipping of coal material was based on the average amount of material retrieved monthly for the year 2003 (1 797 tph of coal was assumed to be handled at the power station). 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 2.6% was assumed for the coal.

4.1.3 Heavy Metal Releases from Kendal Power Station – Stacks, coal and Ash Dump Operations

The trace metal composition of fly ash and coarse ash generated at Kendal Power Station was obtained from a study undertaken previously by Eskom Holding's Chemical Technologies Division (Delport, November 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 (ppm)	Coarse Ash (ppm)	Fly Ash (ppm)
Arsenic (As)	2.95	3.64	13.95
Barium (Ba)	505.28	1133.37	962.36
Bismuth (Bi)	1.49	4.00	3.38
Cobalt (Co)	4.82	9.49	7.25
Chromium (Cr)	57.02	356.39	275.94
Copper (Cu)	16.76	23.26	25.72
Gallium (Ga)	16.89	18.64	24.31
Germanium (Ge)	1.98	3.18	4.34
Lead (Pb)	20.38	44.39	52.61

Trace Element	Raw Coal (ppm)	Coarse Ash (ppm)	Fly Ash (ppm)
Mercury (Hg)	0.44	0.02	0.13
Nickel (Ni)	25.69	77.95	77.95
Niobium (Nb)	17.61	14.85	13.02
Rhiobium (Rb)	14.67	30.52	33.73
Selenium (Se)	498.27	1121.11	1154.84
Thorium (Th)	3.90	39.74	49.89
Tin (Sn)	3.59	6.36	10.64
Tungsten (W)	2.55	9.06	11.88
Uranium (U)	2.97	10.25	10.96
Vanadium (V)	41.71	80.09	78.54
Yiddium (Y)	24.36	44.18	45.32
Zinc (Zn)	18.64	110.23	26.06
Zirconium (Zr)	143.67	184.26	179.80

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, 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 based exclusively on the site-specific data.

Work, however, 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.

Thus for the current study mercury emissions were quantified in three ways to determine the maximum likely emissions, viz.:

- Based on the total mercury content of the coal being combusted (Table4.5);
- Based on emission factors from the European Environment Agency (EEA) Emissions Inventory Guidelebook – Combustion in Energy & Transformation Industries (15 February 1996) (Tables 4.6 and 4.7);
- Based on emission factors included in the European Commission Integrated Pollution Prevention & Control (IPPC) Draft Document on Best Available Technology for Large Combustion Plants (November 2004) (Tables4.8 and 4.9).

The relevant coal data and emissions factors are documented and the estimated emissions based on such presented in Tables 4.2 to 4.6 for the existing Kendal Power Station. In the application of the EEA emission factors reference was made to the more conservative of the two factors given (i.e. power station has dust control but no FGD in place). Similarly, in the application of the IPPC emission factors the emission factors given for power stations using an ESP but no scrubber desulphisation were applied.

Table 4.2 Predicted maximum possible mercury emissions based on the quantity of coal combusted and the mercury content of the coal as measured at the existing Kendal Power Station

Power Station	Coal (tpa)	Hg Content of Coal (%)	Maximum Possible Hg Emissions (tpa)
Current Kendal (max, 2003)	15,746,000	4.38E-05	6.90

Table 4.3 Mercury emission factors for coal-fired power stations from the European Environment Agency (EEA) Emissions Inventory Guidelebook – Combustion in Energy & Transformation Industries (15 February 1996)

Emission Control Measures in Place	Mercury Emission Factor for Coal-fired Power Stations	
	Minimum (g/Mg coal)	Maximum (g/Mg coal)
Dust control (particulate loading in clean gas stream of 50 mg/Nm³)	0.05	0.2
Dust control & FGD (particulate loading in clean gas stream of 20 mg/Nm³)	0.02	0.08

FGD – fluidized gas desulphurisation

Table 4.4 Estimated mercury emissions based on the emission factors given in European Environment Agency (EEA) Emissions Inventory Guidelebook – Combustion in Energy & Transformation Industries (15 February 1996) as published for coal-fired power stations with dust control in place only (no FGD)

Power Station	Estimated Mercury Emissions	
	Minimum Hg Emissions based on Minimum Mercury Emission Factor given for Dust Controlled Power Stations (tpa)	Maximum Hg Emissions – based on the Maximum Mercury Emission Factor given for Dust Controlled Coal-Fired Power Stations (tpa)
Current Kendal (max, 2003)	0.79	3.15

Table 4.5 Mercury emission factors for coal-fired power stations from the European Commission Integrated Pollution Prevention & Control (IPPC) Draft Document on Best Available Technology for Large Combustion Plants (November 2004)

Emission Control Measures in Place	Mercury Emission Factor for Coal-fired Power Stations		
	Minimum Hg Emissions (µg/m³)	Average Hg Emissions (µg/m³)	Maximum Hg Emissions (µg/m³)
Hg concentration in gas stream downstream of ESP	0.3	4.9	35
HG concentration downstream of ESP and wet scrubber desulphurisation	0		5

Table 4.6 Estimated mercury emissions based on IPPC emission factors given for mercury concentrations downstream of an ESP (no wet scrubber desulphurization)

Power Station	Minimum Hg Emissions (tpa)	Average Hg Emissions (tpa)	Maximum Hg Emissions (tpa)
Current Kendal (max, 2003)	0.03	0.53	3.81

A synopsis of the maximum mercury emission rates estimated on the basis of the coal composition, EEA and IPPC emission factors is given in Table 4.7. The emissions estimated on the IPPC emission factors and the EEA emission factors are relatively similar, whereas on the basis of site-specific coal qualities the mercury emissions are higher.

Table 4.7 Comparison of estimated mercury emissions based on mercury content of Kendal coal, IPPC emission factors and EEA emission factors

Power Station	Maximum Hg Emissions based on Coal Quality (tpa)	Maximum Hg Emissions based on IPPC Emission Factors (tpa)	Maximum Hg Emissions based on EEA Emission Factors(tpa)
Current Kendal (max, 2003)	6.90	3.81	3.15

4.1.4 Elevated Eskom Sources

The largest source of emissions at the Eskom Power Stations is the main stacks. Source parameters for these sources required for input to the dispersion modelling study, as provided by Eskom personnel, is summarised in Table 4.8.

Annual emission rates for SO_2, NO_x (as NO and NO_2) and PM10 are presented in Table 4.9 as provided by Eskom personnel.

Table 4.8 Stack parameters for current Eskom power stations (excluding Kendal)

Station	Number of Stacks	Height (m)	Diameter (m)	Exit Velocity (m/s)	Temperature (°K)
Hendrina	2	155	11.14	19.42	402
Arnot	2	195	11.06	20.25	411
Kriel	2	213	14.3	16.62	403
Kendal	2	275	13.51	24.08	399
Matla 1-3	1	213	14.3	19.4	397
Matla 4-6	1	275	12.47	25.51	397
Duvha	2	300	12.47	23.78	403
Lethabo	2	275	11.95	25.28	399
Tutuka	2	275	12.3	24.9	403
Majuba	2	220	12.3	29.83	403

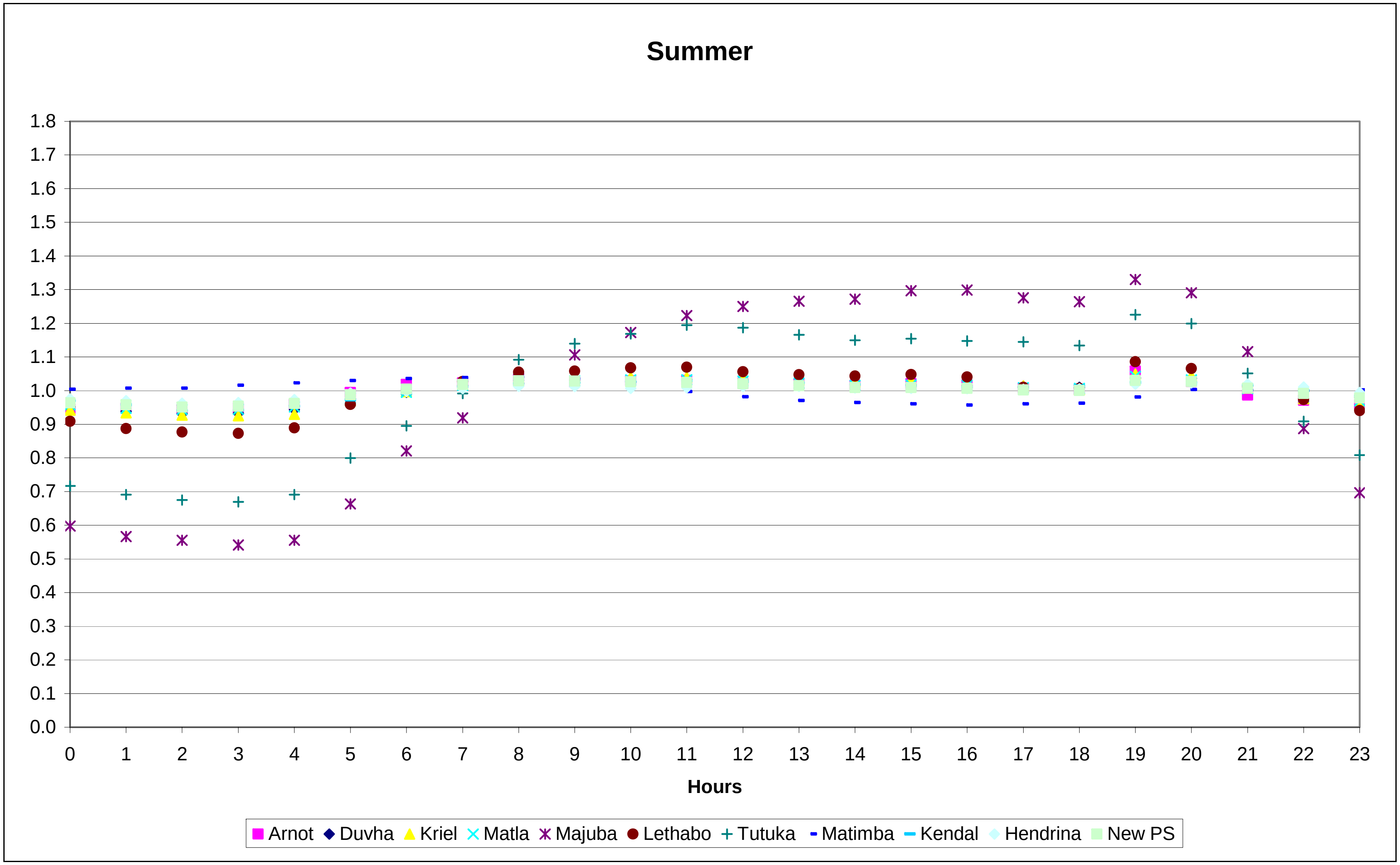

Figure 4.1. Diurnal profile for summer for all current Eskom power stations based on the energy output for 2003

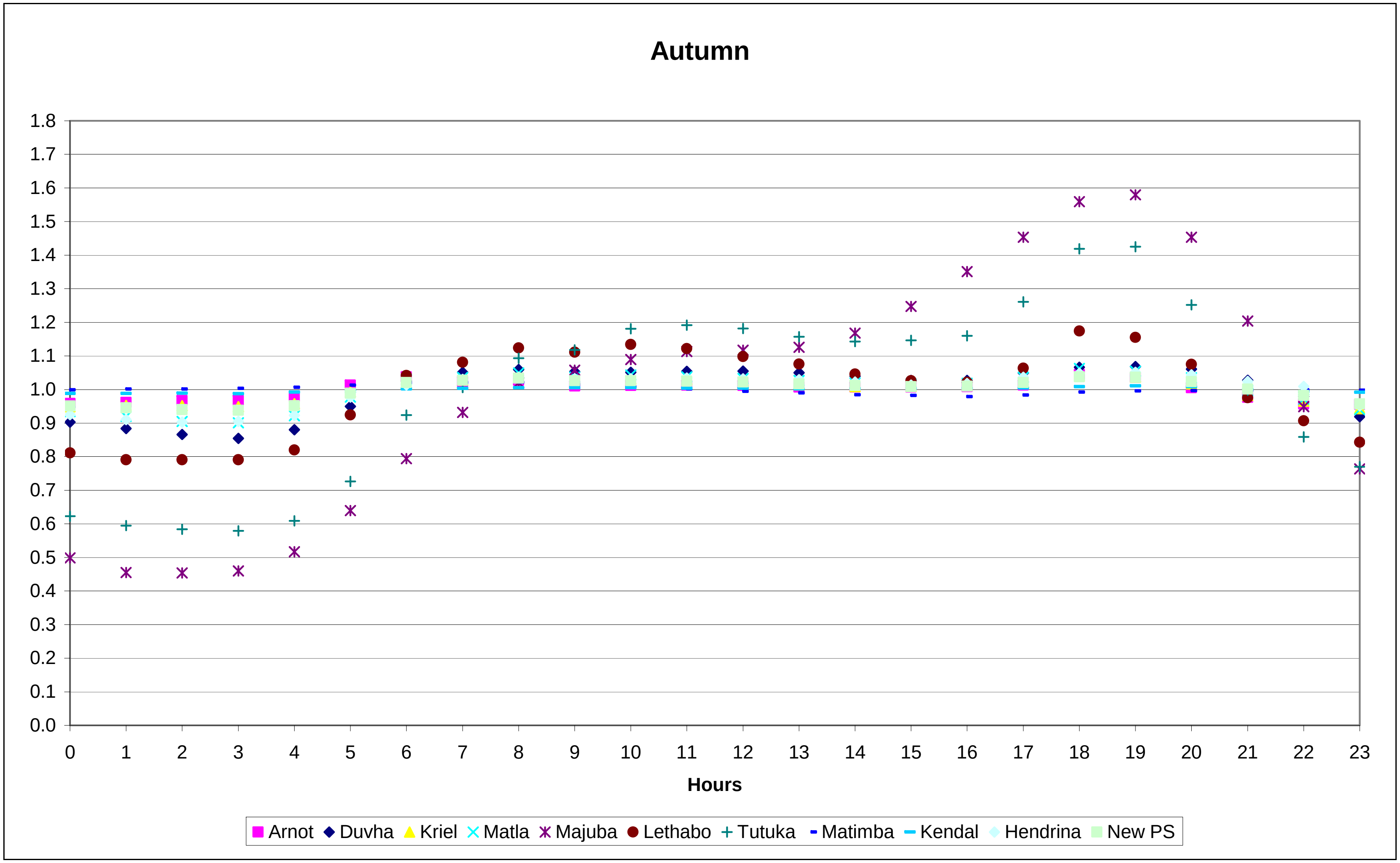

Figure 4.2. Diurnal profile for autumn for all current Eskom power stations based on the energy output for 2003

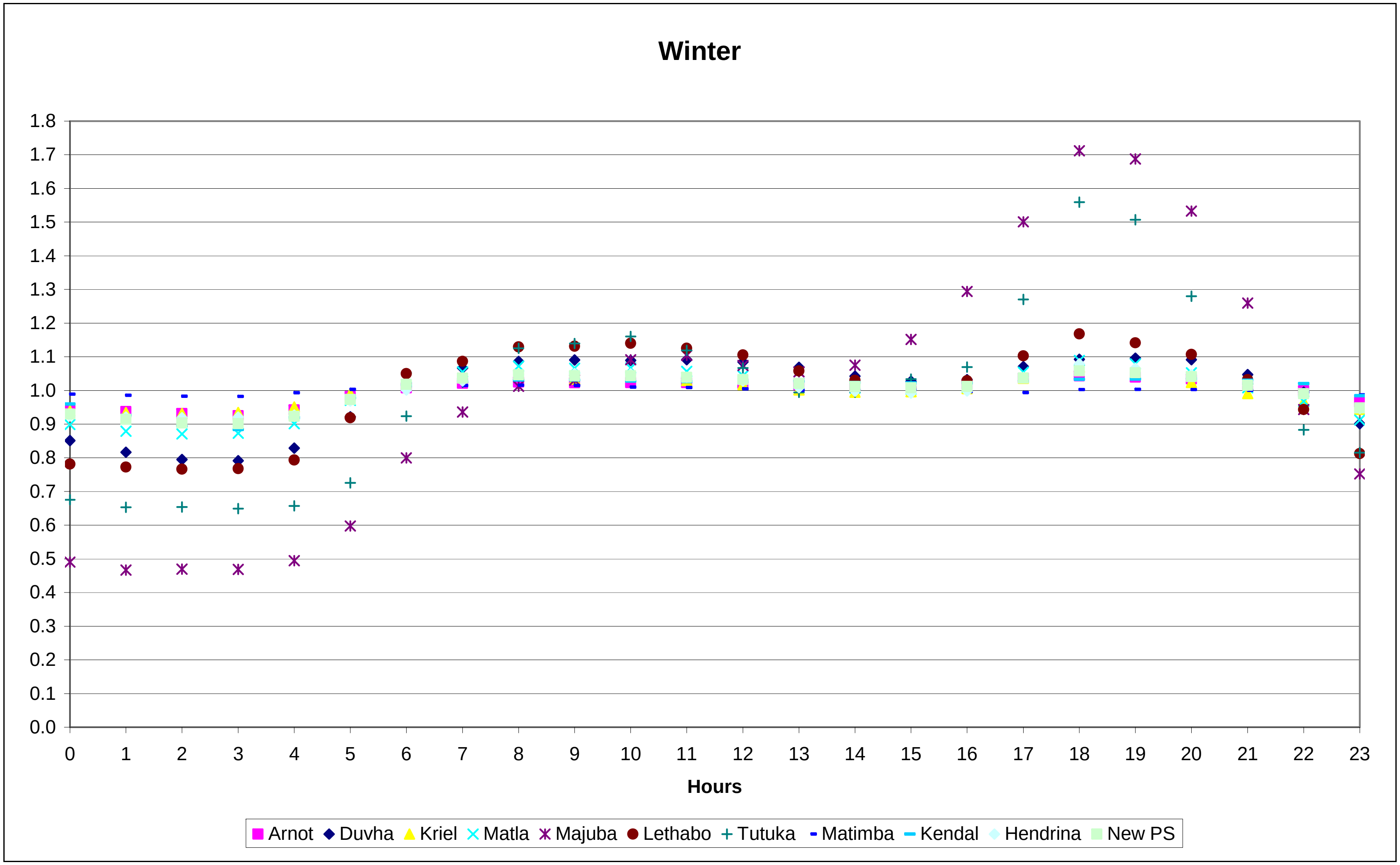

Figure 4.3. Diurnal profile for winter for all current Eskom power stations based on the energy output for 2003

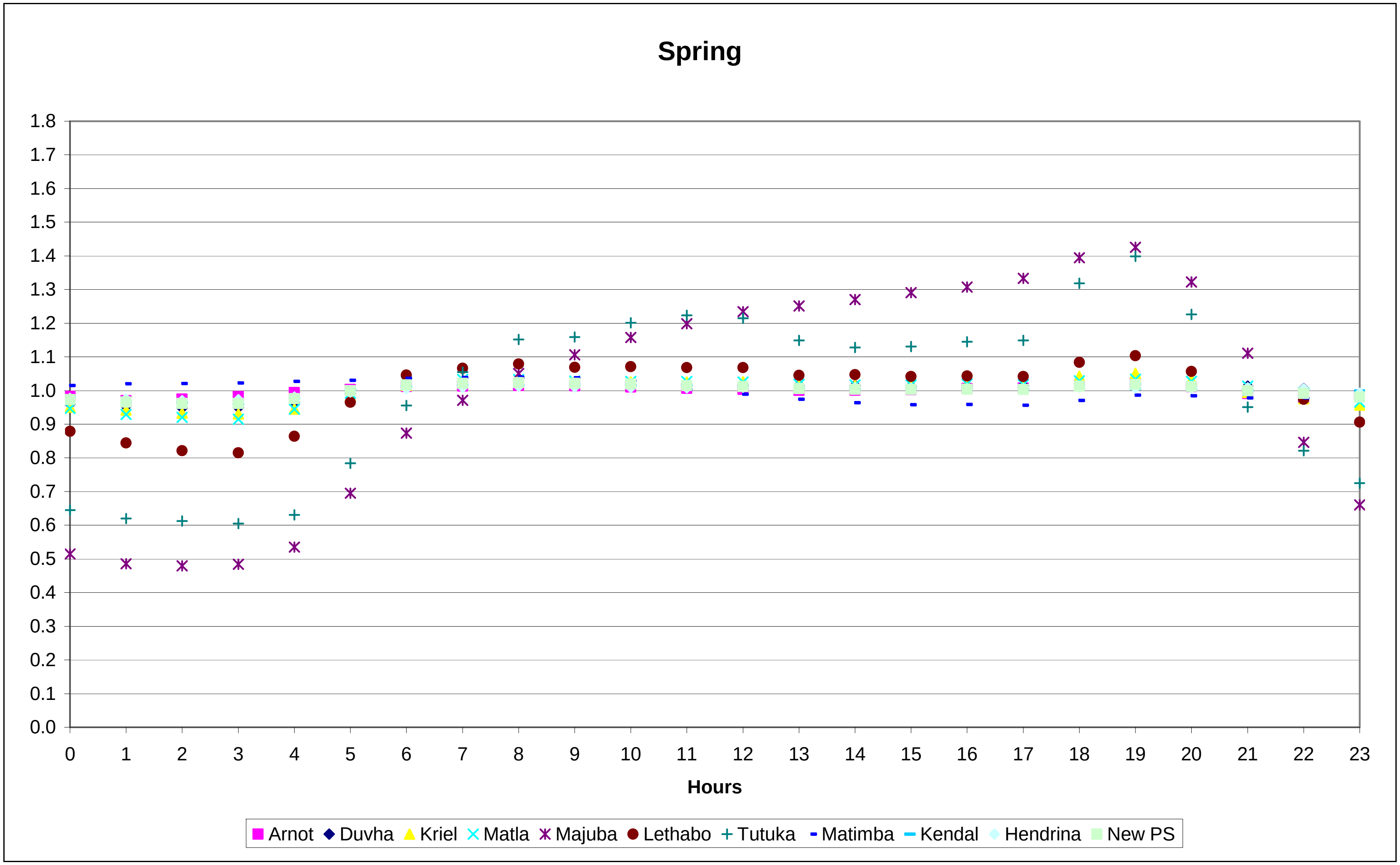

Figure 4.4. Diurnal profile for spring for all current Eskom power stations based on the energy output for 2003

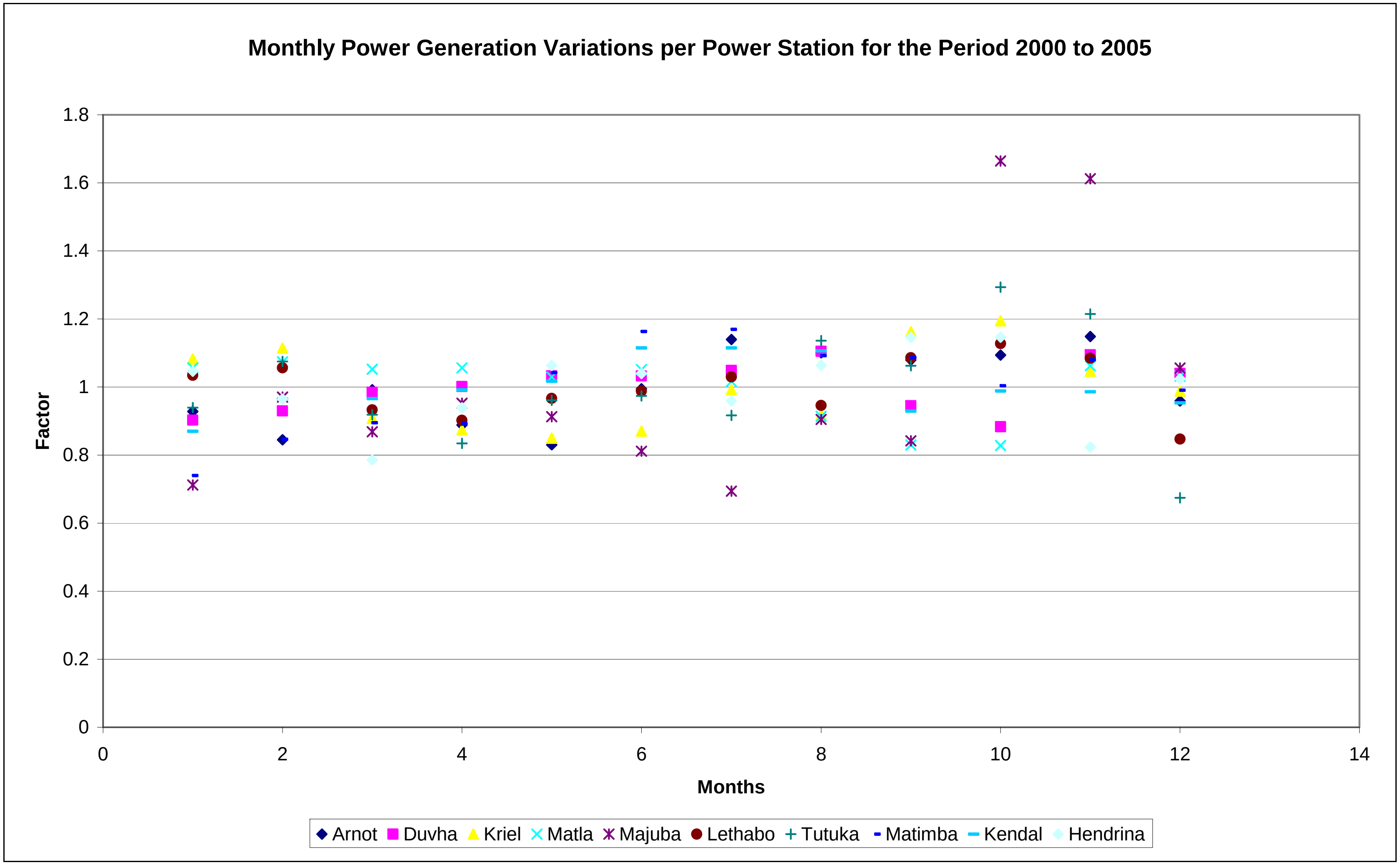

Figure 4.5 Monthly profile for all current Eskom power stations based on the energy output for 2000 to 2005.

Table 4.9 Emissions (in tonnes per annum) for current operating conditions for 2003.

Power Station	SO_2 (tpa)	NO (tpa)(a)	NO_2 (tpa)(b)	Particulates (tpa)(c)
	2003	2003	2003	2003
Hendrina	90,875	29,936	937	2,898
Arnot	89,870	30,971	969	17,999
Kriel	134,340	43,315	1,355	8,611
Kendal	321,441	73,282	2,293	3,495
Matla	221,466	61,291	1,918	4,827
Duvha	182,076	46,488	1,455	3,017
Lethabo	171,929	76,374	2,390	5,776
Tutuka	122,551	34,067	1,066	5,234
Majuba	98,976	25,780	807	550

Notes:
(a) 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).
(b) 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).
(c) Particulate emissions assumed to be PM10 due to the gas abatement technology in place

Monthly and diurnal emission variations were calculated based on the energy outputs per day (given for the period 2000 – 2005) and per hour (given for the period 2003) respectively for the current Eskom power stations. Eskom personnel provided the energy outputs as well as the total emissions per year. The diurnal and monthly variations for all current power stations are given in Figure 4.1 to Figure 4.5.

4.1.5 Other Sources of Atmospheric Emission

Sources, other than Eskom's power stations, which contribute to ambient air pollutant concentrations within the study region include:

- Stack, vent and fugitive emissions from industrial operations;
- Fugitive emissions from mining operations, including mechanically generated dust emissions and gaseous emissions from blasting and spontaneous combustion of discard coal dumps;
- Vehicle entrainment of dust from paved and unpaved roads;
- Vehicle tailpipe emissions;
- Household fuel combustion (particularly use of coal and wood);
- Biomass burning (veld fires); and,

- Various other fugitive dust sources, e.g. agricultural activities and wind erosion of open areas.

Atmospheric emissions were quantified and simulated for the following sources during the current study:

- Gaseous and particulate emissions from industrial operations and non-Eskom power stations;
- Household fuel burning, including the burning of coal, wood and paraffin for lighting, heating and cooking purposes;
- Fugitive emissions from open cast coal mining operations;
- Wind-blown dust emissions from Eskom's ash dumps and dams; and
- Vehicle tailpipe emissions.

The extent and spatial location of atmospheric emissions from vehicle entrainment, biomass burning and spontaneous combustion that contribute significantly to air pollution concentrations in certain parts of the study area could not be accurately quantified and were therefore omitted from the simulations.

4.1.5.1 Industrial Emissions and Non-Eskom Power Generation

Industrial sources within the Mpumalanga region include the following:

- Emissions from coal combustion by metallurgical and petrochemical industries represents the greatest contribution to total emissions from the industrial / institutional / commercial fuel use sector within the Mpumalanga region.

- The metallurgical group is estimated to be responsible for at least ~50% of the particulate emissions from this sector. This group includes iron and steel, ferro-chrome, ferro-alloy and stainless steel manufacturers (includes Highveld Steel & Vanadium, Ferrometals, Columbus Stainless, Transalloys, Middelburg Ferrochrome).

- Petrochemical and chemical industries are primarily situated in Secunda (viz. Sasol Chemical Industries). The use of coal for power generation and the coal gasification process represent significant sources of sulphur dioxide emissions. (Particulate emissions are controlled through the implementation of stack gas cleaning equipment.)

- Other industrial sources include: brick manufacturers which use coal (e.g. Witbank Brickworks, Quality Bricks, Corobrik, Hoeveld Stene, Middelwit Stene) and woodburning and wood drying by various sawmills (Bruply, Busby, M&N Sawmills) and other heavy industries (use coal and to a lesser extent HFO for steam generation). The contribution of fuel combustion (primarily coal) by institutions such as schools and hospitals to total emissions is relatively due to the extent of emissions from other groups.

In addition to the Eskom power stations, three other coal-fired power stations located within the modelling domain generate electricity for the national grid, viz. Pretoria West and Rooiwal situated within Tshwane and Kelvin located within Joburg. In the estimation of emissions for the coal-fired power stations reference was made to emission factors provided by Eskom (Eskom, 2000; 2002) and US Environmental Protection Agency AP42 Emission Factors given for external combustion of bituminous coal (EPA, 1998).

Emissions from the industrial and non-Eskom power generation sectors were quantified based on emissions data obtained from industries, data which were already in the public domain and emission estimates from emission factor application. The relative extent of sulphur dioxide, particulate and nitrogen oxide emissions from industrial sources is illustrated in Figures 4.6, 4.7 and 4.8 respectively.

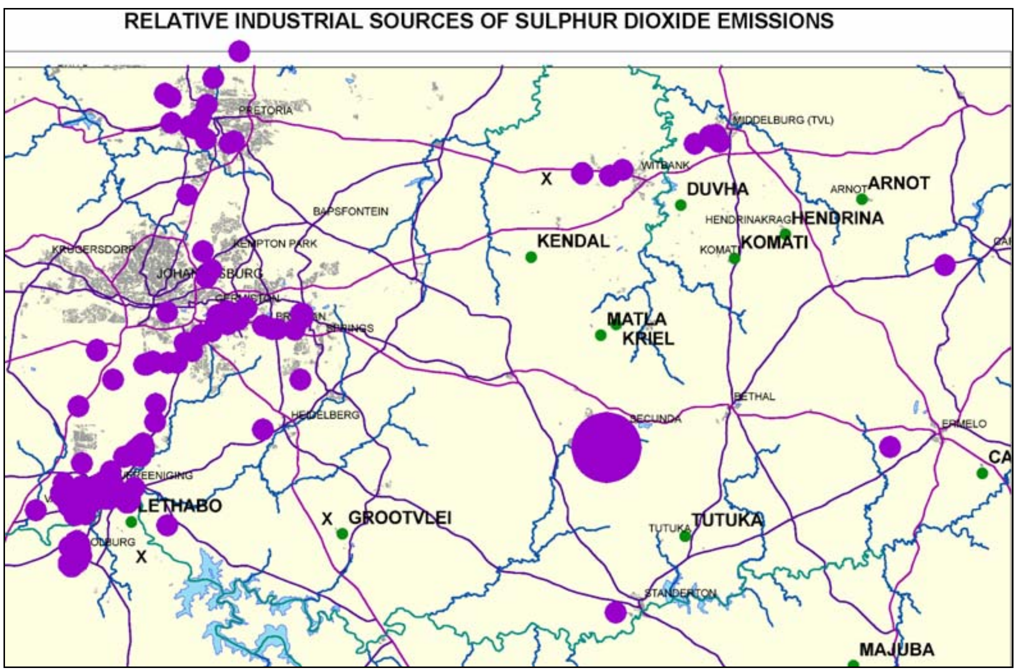

Figure 4.6 Relative extent of sulphur dioxide emissions from industrial and non-Eskom power generation operations within the study area

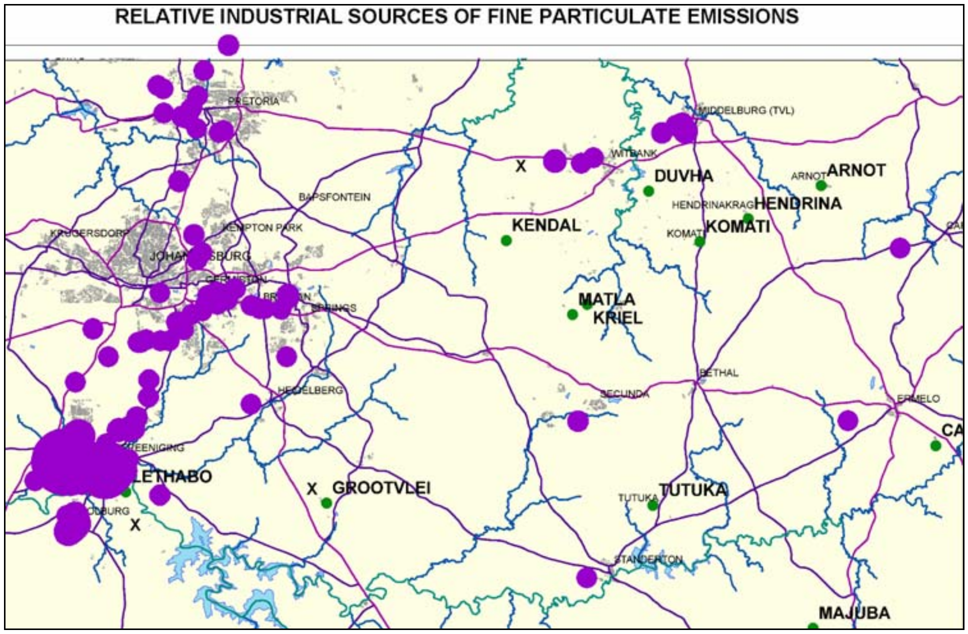

Figure 4.7 Relative extent of fine particulate emissions from industrial and non-Eskom power generation operations within the study area

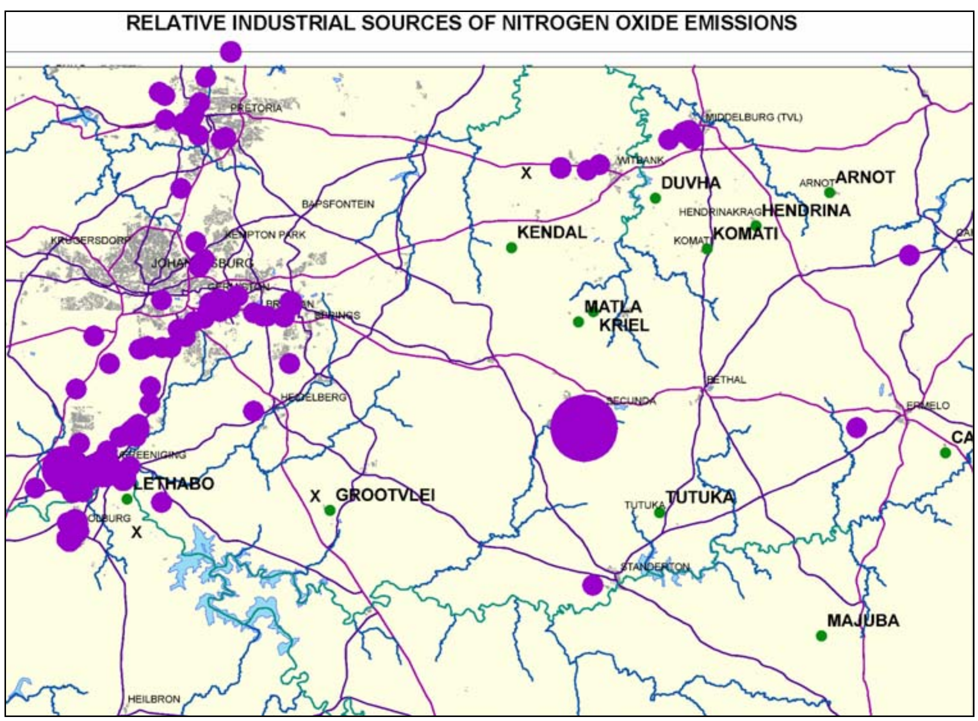

Figure 4.8 Relative extent of nitrogen oxide emissions from industrial and non-Eskom power generation operations within the study area

Sasol Secunda is a significant source but relatively isolated source of SO_2 and NO_x emissions on the Mpumalanga highveld. Iron and steel and related industries situated in Witbank and Middelburg represent smaller but more numerous sources. A number of significant sources are situated in the Vaal Triangle, Ekurhuleni Metro and within Tshwane Metro, particularly west of the Pretoria CBD.

Although a large area was considered for the inclusion of emission sources, the study focussed on a 20km radius from the proposed new power station sites.

4.1.5.2 Household Fuel Burning

Despite the intensive national electrification programme a large number of households continue to burn fuel to meet all or a portion of their energy requirements. The main fuels with air pollution potentials used by households within the study region are coal, wood and paraffin. These fuels continue to be used for primarily two reasons: (i) rapid urbanisation and the growth of informal settlements has exacerbated backlogs in the distribution of basic services such as electricity and waste removal, and (ii) various electrified households continue to use coal due particularly to its cost effectiveness for space heating purposes and its multi-functional nature (supports cooking, heating and lighting functions). The distribution patterns of fuel use are linked with the former townships and informal residential areas.

Coal is relatively inexpensive and is easily accessible in the region due to the proximity of the region to coal mines and the well-developed local coal merchant industry. 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. Wood burning is less widely used compared to coal burning. Although many of the wood burning residential areas tend to coincide with areas of coal burning there are some exceptions where only wood is burned, e.g. Johannesburg inner city and sections of Turfontein. The main pollutants emitted from the combustion of paraffin are NO_2, particulates carbon monoxide and polycyclic aromatic hydrocarbons. The use of paraffin is of concern not only due to emissions from its combustion within the home, but also due to its use being associated with accidental poisonings (primarily of children), burns and fires.

The numbers and spatial distribution of households using various fuel types were estimated based on energy use statistics and household numbers from the 2001 Census. Typical monthly fuel use figures, given by Afrane-Okese (1995) for various house types, were used together with the numbers of households using the various fuel types to estimate the total quantities of fuels being consumed. Quantities of fuels used were estimated on a community-by-community basis and selected emission factors applied to calculate resultant emissions. The emission factors selected for use in the study are given in Table 4.10. Total annual household fuel consumption and associated emissions for the entire study are summarised in Table 4.11.

Table 4.10 Emission factors selected for use in the estimation of atmospheric emission occurring as a result of coal, paraffin and wood combustion by households

Fuel	Emission Factors		
	SO_2 (g/kg)	NO (g/kg)	PM10 (g/kg)
Coal	11.6(a)	4(d)	12(f)
Paraffin	0.1(b)	1.5(e)	0.2(e)
Wood	0.2(c)	1.3(c)	17.3(c)

(a) Based on sulphur content of 0.61% and assuming 95% of the sulphur is emitted. The lowest percentage sulphur content associated with coal used by local households was used due to previous overpredictions of sulphur dioxide concentrations within residential coal burning areas. Previous predictions were significantly above measured sulphur dioxide concentrations. With the assumption of a sulphur content of 0.61%, predicted sulphur dioxide concentrations are slightly above, but within an order of magnitude, of measured concentrations.

(b) Based on sulphur content of paraffin (<0.01% Sulphur).

(c) Based on US-EPA emission factor for residential wood burning (EPA, 1996).

(d) Based on the AEC household fuel burning monitoring campaign (Britton, 1998) which indicated that an average of 150 mg/MJ of Nox was emitted during cooking and space heating. Given a calorific value of 27 Mj/kg, the emission rate was estimated to be ~4 g/kg.

(e) US-EPA emission factors for kerosene usage (EPA, 1996).

(f) Initially taken to be 6 g/kg based on 2001 synopsis of studies pertaining to emissions from household coal burning (Scorgie *et al*., 2001). Results from simulations using this emission factor undertaken as part of the current study indicated that fine particulate concentrations within household coal burning areas are underpredicted by a factor of two. This emission factor was therefore scaled to 12 g/kg in order to facilitate the more accurate simulation of airborne fine particulates within household coal burning areas.

Table 4.11. Estimated total annual household fuel consumption and associated emissions for the study area

Fuel Combusted	Number of Households(a)	Quantity of Fuel Used(a)	Annual Emissions		
		(tpa)	PM10 (tpa)	SO_2 (tpa)	NO_x (tpa)
Coal burning households	340 123	340 109	2041 (93.4%)	3 945 (99.7%)	1 360 (88.1%)
Wood burning households	34 490	7 036	122 (5.6%)	1 (0.0%)	9 (0.6%)
Paraffin burning households	471 201	116 481	23 (1.1%)	12 (0.3%)	175 (11.3%)
TOTAL			**2 186**	**3 958**	**1 544**

(a) Extrapolated based on household energy use data from THE 2001 Census and typical individual household fuel use figures published by Afrane-Okese (1995).
(b) Emissions estimated based on emission factors given in Table

Emissions were calculated individually for a total of 120 area sources so as to accurately account for spatial distributions in fuel consumption intensivities and hence emissions.

The demand for residential space heating, and hence the amount of fuel burning, has been found to be strongly dependent on the minimum daily temperature. *Seasonal* trends in space heating needs, and therefore in coal burning emissions, were estimated by calculating the quantity of "heating-degree-days" (HDD), i.e. the degrees below a minimum daily temperature of 8°C (Annegarn and Sithole, 1999). *Diurnal* trends in fuel burning, documented in the local literature, were also taken into account in estimating temporal variations in household fuel burning emissions (Annegarn and Grant, 1999).

Taking seasonal and diurnal variations in fuel use, and therefore emissions, into account it was estimated that the maximum emissions during a hour of peak burning (e.g. cold winter day, between 06h00 and 07h00 or 18h00 and 20h00) were a factor of 10 higher than an hourly emission rate taken as an average throughout the year.

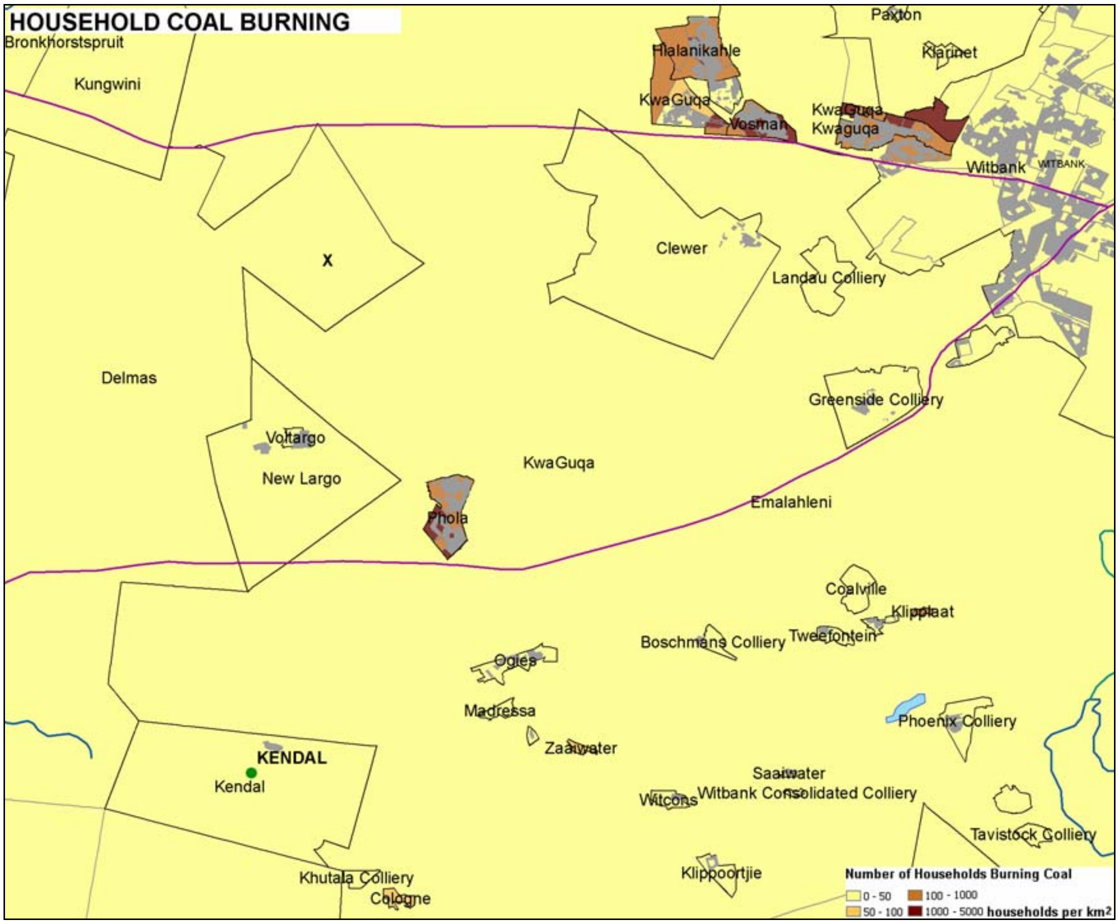

Figure 4.9 Spatial distribution in households coal burning in the study area

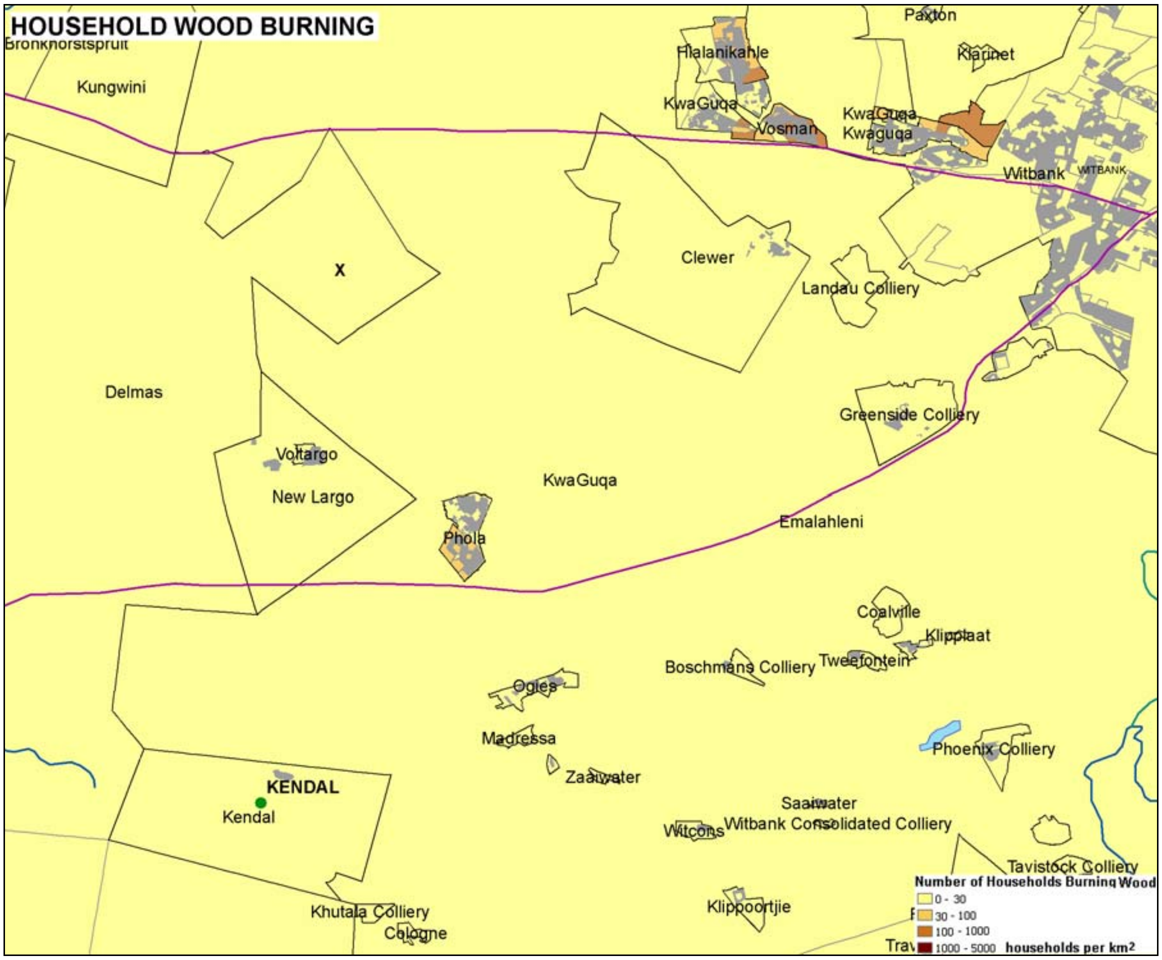

Figure 4.10 Spatial distribution in households wood burning in the study area

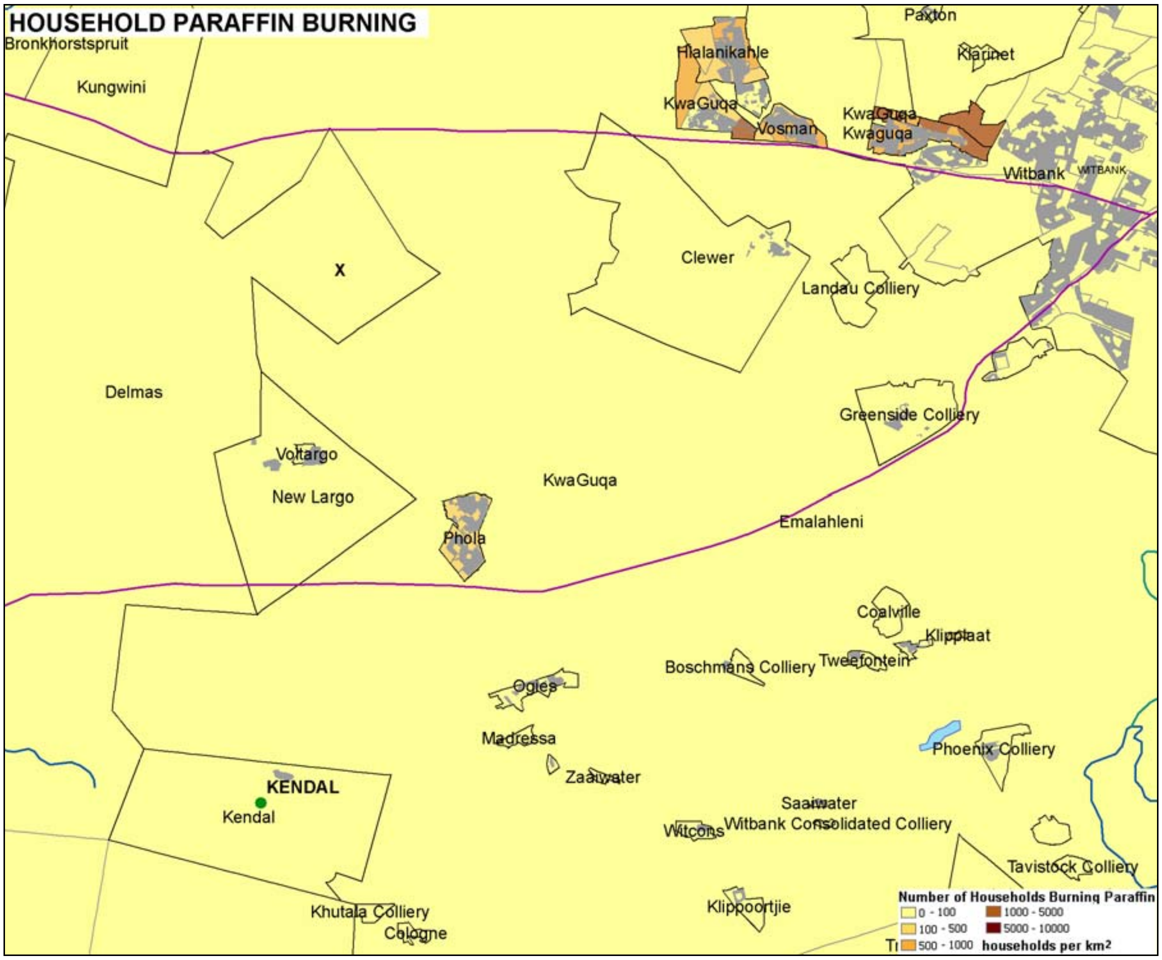

Figure 4.11 Spatial distribution in households paraffin burning in the study area

4.1.5.3 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), hydrocarbon compounds (HC), sulphur dioxide (SO_2), nitrogen oxides (NO_x) and particulate matter (PM). Secondary pollutants include nitrogen dioxide (NO_2), photochemical oxidants (e.g. ozone), hydrocarbon compounds (HC), sulphur acid, sulphates, nitric acid and nitrate aerosols. Emission estimates where undertaken for sulphur dioxide (SO_2), nitrous oxide (NO), nitrogen dioxide (NO_2) and particulate matter (PM) for the current study.

In the estimation of petrol-driven vehicle emissions the following steps were followed:

- The petrol-driven vehicle fleets were characterised based on the 1992 technology mix and the 1995 engine capacity profiles collated for the Vehicles Emission Project (Terblanche, 1995).
- Technology mix information is given in Terblanche (1995) for, Johannesburg, the Vaal Triangle and Pretoria. The Johannesburg and Vaal Triangle data were taken to be representative of the technology mix and engine capacities within the Mpumalanga Highveld region.
- A more recent national vehicle population data base was obtained from Stellenbosch Automotive Engineering to supplement the spatially-resolved 1992 technology mix and 1995 engine capacity data obtained from Terblanche (1995). The national vehicle parc data, obtained by Stellenbosch Automotive Engineering for use in the recent Octane Study, comprises detailed information on petrol-driven vehicles sold between 1970 and 2002 including: engine capacity, need for lead replacement petrol, presence of fuel injection and catalytic converters (etc.). The 1995 spatially-resolved engine capacity data were found to be very similar to the more current national vehicle population information and were therefore retained for use in the emissions estimations. The more recent national data however provided valuable data on the percentage of vehicles within the current live population which are fitted with catalytic converters (7.3%) and on the growth rate of catalytic converter use in new vehicles (47.3% of new cars purchased in 2002 were equipped with catalytic converters, with an annual average growth rate of 3.9% noted based on the 1990-2002 period).
- Annual unleaded petrol sales data, obtained from SAPIA per magisterial district for 2004, were used to estimate the total vehicle kilometers traveled using fuel consumption rates suited to each engine capacity class and general fuel type. (Petrol consumption rates range from 7.7 to 15.1 liters per 100 km) (Wong, 1999).
- Locally developed emission factors published by Wong (1999) were applied taking into account variations in such factors for different energy capacities. Emission factors used are given in Table 4.12. Emissions were calculated by multiplying the emission factors by the total vehicle kilometers traveled (VKT) estimated on the basis of the 2004 fuel sales data.

Table 4.12 Emission factors for petrol and diesel-driven vehicles.

Pollutant	Units	Petrol-driven Vehicles		Diesel-driven Vehicles	
		Sources: Wong (1999)	Sources: Wong (1999)	Sources: Wong (1999)[a]	Sources: Stone (2000)
		Catalytic	Non-catalytic	Diesel - LCVs	Diesel - M&H
NO_X	g/km	0.93	2.15	1.82	11.68
SO_2	g/km	0.015	0.043	0.796	1.54
Particulates	g/km	-	-	0.293	0.64

(a) Emission factors given by Wong (1999) for diesel-driven LCVs within the coastal areas assumed to be representative of highveld areas.

In the estimation of diesel-driven vehicle emissions the following steps were followed:

- Average percentages of light commercial vehicles (LCVs) and medium and heavy commercial vehicles (M&HCVs) within the national diesel vehicle fleet were obtained from Stone (2000).
- Diesel consumption rates were obtained for LCVs, MCVs and HCVs for coastal and highveld applications from Stone (2000) and Wong (1999). Such rates varied from 10.5 to 24.4 litres per 100 km.
- Annual diesel sales data, obtained from SAPIA per magisterial district for 2004, were used to estimate the total vehicle kilometres travelled using fuel consumption rates suited to each vehicle weight category.
- Locally developed emission factors published by Stone (2000) were applied taking into account variations in vehicle weight categories and altitudes (coastal, highveld factors) (Table 4.12). Emissions were calculated by multiplying the emission factors by the total vehicle kilometres travelled (VKT) estimated on the basis of the 2004 fuel sales data.

Table 4.13 Total annual emissions due to vehicles within the study area

Area	Emissions tpa			
	SO_2	NO	NO_2	PM
Witbank	148.70	7,536.26	837.36	477.06
Kriel	6.76	332.12	36.90	15.51
Highveld Ridge	62.60	3,098.58	344.29	156.90
Delmas	28.57	1,442.56	160.28	88.39
Bronkhorstspruit	27.02	1,313.55	145.95	53.58

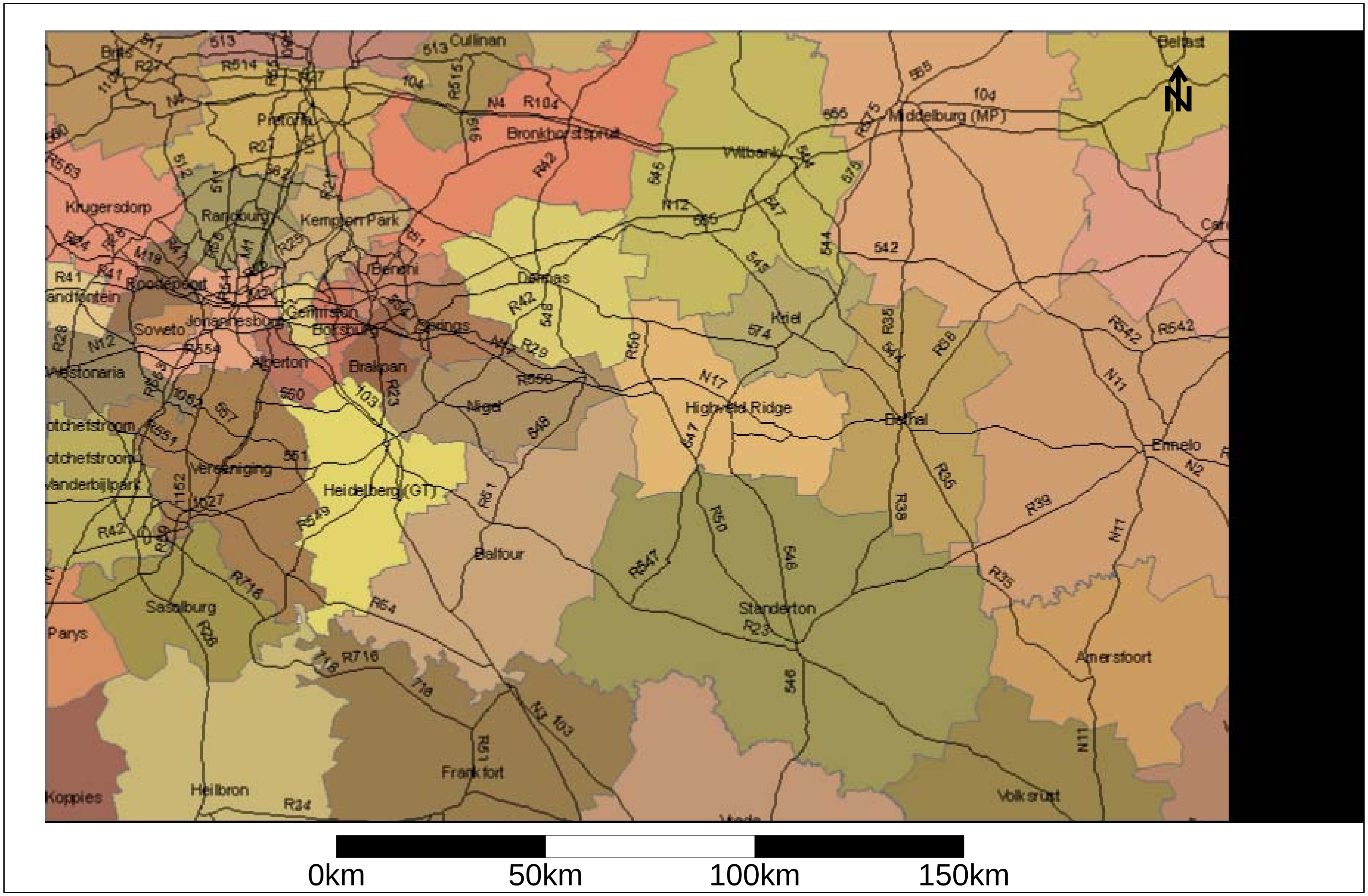

Figure 4.12 Road network and magisterial districts within the study area.

The vehicle emissions were calculated per magisterial district within the study area (Table 4.13). These emissions were assigned to various national and regional routes (see Figure 4.12) by applying vehicle count data obtained from Mikros Traffic Monitoring (Pty) Ltd for the period 2004 and 2005. The remaining emissions data that could not be assigned to specific routes were then distributed over the remaining regional roads within Mpumalanga and the Vaal Triangle.

As the routes were assumed to be straight lines (see Figure 4.13), the length of the roads obtained were multiplied by a factor of 1.4 to accommodate the curved nature of these sources. In addition, based on vehicle emissions from the N4, it was calculated that 20% and 10% of the fuel usage from light and heavy commercial vehicles respectively, would be used outside the study area. As the routes within the Johannesburg and Pretoria magisterial districts are largely congested, emissions were assigned to the main national routes that pass over this area (i.e. the N4, N1, M1, N12, N17 and the N3). The remaining emissions were distributed over area sources assigned to built-up areas (see Figure 4.14).

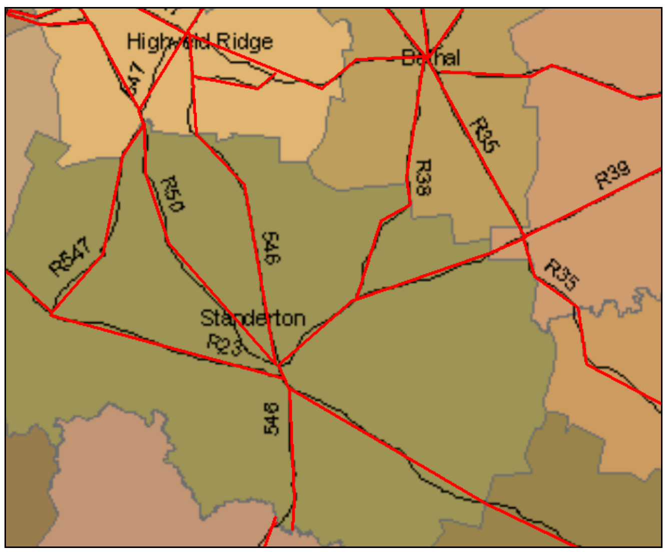

Figure 4.13 The layout of the road sources for dispersion modelling purposes.

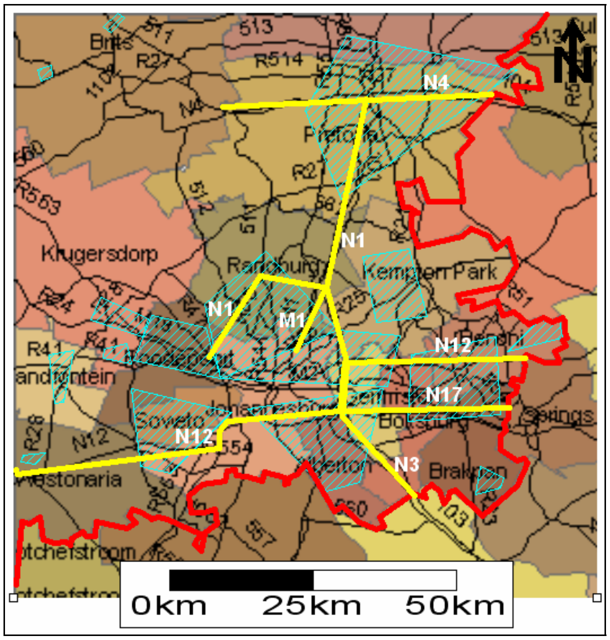

Figure 4.14 Spatial apportionment of vehicle emissions over Pretoria, Johannesburg and surrounding areas

4.1.5.4 Fugitive Dust Emissions from Open Cast Mining

Open-cast mining operations located within the study area were identified using the Department of Minerals and Energy's (2006) directory entitled *Operating and Developing Coal Mines in the Republic of South Africa 2005.* The location of these mines, primarily collieries, and the extent of the open cast pits were informed by 1:50 000 topographical maps and the Eskom Coalfields Map of South Africa published by Barker & Associates (5th Edition – 2001). A list of the open cast mines situated within the study area is given in Table 4.14.

Table 4.14 Open-cast mines situated within the study area

Mining House	Colliery	Underground Operations	Scale of Open-cast Operations (tpa Producted)	PS Supplied
ANGLO AMERICAN - ANGLO COAL	Kleinkopje Colliery		4400	
ANGLO AMERICAN - ANGLO COAL	Landau Colliery		3400	
ANGLO AMERICAN - ANGLO COAL	Goedehoop Colliery		600	
ANGLO AMERICAN - ANGLO COAL	Kriel Colliery	x	4000	Kriel PS
ANGLO AMERICAN - ANGLO COAL	New Vaal Colliery		15100	Lethabo PS
GLENCORE COAL INVESTMENTS - DUIKER MINING LIMITED	Waterpan Colliery	x	300	
Mpumalanga Collieries Division	Tselentis Colliery	x	1200	
Mpumalanga Collieries Division	Spitzkop Colliery	x	1190	
GLENCORE COAL INVESTMENTS - DUIKER MINING LIMITED	Atcom (TESA)		2300	
iMpunzi Collieries Division	Arthur Taylor Colliery	x	2340	

Mining House	Colliery	Underground Operations	Scale of Open-cast Operations (tpa Producted)	PS Supplied
EYSIZWE COAL	Glisa Colliery	x	300	
COASTAL FUELS	Droogvallei Section		120	
GOLANG COAL - ANKER, ESKOM ENTERPRISES & SEBENZA MINING	Golang Colliery	x	ND	
GOLANG COAL - ANKER, ESKOM ENTERPRISES & SEBENZA MINING	Golfview Section		1100	
METOREX - WAKEFIELD INVESTMENTS	Bankfontein Section		391	
STUART COAL GROUP	Stuart Coal Delmas Coliery		492	
SUMO COLLIERY	Kopermyn Colliery		400	
WOESTALLEEN COLLIERY	Weostalleen Colliery		700	
B&W MINING	Wesselton Colliery		900	
BENICON COAL	Mavella Colliery		ND	
FERGUSON-TOLMAY COAL	Haasfontein Colliery		500	
GEDULD BRICKWORKS & COAL MINING	Graspan Colliery		1000	
KUYASA MINING	Ikhwezi Colliery		800	Kendal PS
SASOL LIMITED - SASOL MINING	Sigma Mine		4200	
SASOL LIMITED - SASOL MINING	Wonderwater Section		ND	
SASOL LIMITED - SASOL MINING	Syferfontein Colliery		3600	
BHP Billiton - Ingwe Coal Corporation Limited	Optimum Colliery		13100	Hendrina PS
BHP Billiton - Ingwe Coal Corporation Limited	Eikeboom Section		ND	
BHP Billiton - Ingwe Coal Corporation Limited	Khutala		600	
BHP Billiton - Ingwe Coal Corporation Limited	Rietspruit Colliery	x	2700	
BHP Billiton - Ingwe Coal Corporation Limited	Douglas Colliery	x	5000	
BHP Billiton - Ingwe Coal Corporation Limited	Middelburg Mine		17000	Duvha PS

Open cast mines are associated with significant dust emissions, sources of which include land clearing, blasting and drilling operations, materials handling, vehicle entrainment, crushing, screening (etc.). In order to provide a detailed estimate of the emissions from each mine based on emission factor equations significant information would need to obtained on the operations at each mine (e.g. timing and number of blasts, type and quantity of explosives used, truck capacities, haulage routes, crusher capacities, dust mitigation measures in place and their associated control efficiencies, etc.). The collection of such information and the compilation of detailed mine-specific emissions inventories were not within the scope of the current study. Instead reference was made to previously compiled mine-specific emission inventories compiled for collieries, with relationships being sought between the scale of the operation (tpa production) and the total estimated PM10 emissions.

The relationship, y = -3E-05x + 0.5518, was derived where y = tonnes PM10 per kt coal, and x is the kt of coal producted. Based on the production rates of the mines listed in Table 4.14 it was estimated that a total of ~25 470 tpa PM10 is released. Based on dispersion simulations, taking potential pit retention into account, it was estimated that a total of ~3057 tpa PM10 is likely to leave the boundaries of the mine and contribute to ambient air pollutant concentrations.

4.1.5.5 Biomass Burning

In order to estimate the extent of biomass burning the average area burned within the region was estimated during a previous study (Scorgie *et al*., 2005). Satellite imagery was obtained to identify and quantify burn scar areas. Burn scar images generated included 5-year composite scar plots (1995-2000) and plots indicating the extent of areas burned during a single fire season. A synopsis of the information generated is presented in Table 4.15.

Table 4.15. Extent of area burnt - given as a composite area for the 1995-2000 period, as a total area for the 2000 fire season and indicating average and peak burn areas over 10-day periods.

Conurbation / Region	Total Area of region km^2	Total area burnt km^2 over dataset 1995-2000	Area burnt during fire season 2000	Average % of area burnt in 10 days	Peak % of area burnt in 10 days	Average km^2 of area burnt in 10 days	Peak km^2 of area burnt in 10 days	Average km^2 of area burnt per year
Johannesburg	7 560	2 112	168	0.22%	0.28%	16.37	20.97	597.69
Vaal Triangle	2 434	615	25	0.20%	0.13%	4.77	3.07	174.02
Mpumalanga Highveld	37 271	4 304	472	0.09%	0.16%	33.36	58.98	1217.75
Tshwane	4 579	1 086	127	0.18%	0.35%	8.41	15.85	307.14

The percentage of the total modelling domain predicted to have been burnt during the 1995-2000 period was estimated to have been ~16%. Emission factors derived during SARAFI-2000 (Southern African Fire-Atmosphere Research Initiative), as published by Andreae *et al.* (2000), were obtained for application in the estimation of atmospheric emissions from veld fires (Table 4.16).

Table 4.16. Emission factors used in the quantification of atmospheric emissions from biomass burning

Pollutant	Emission Factor	Unit
NO_X	3.1	g / kg dry matter
SO_2	0.6	g / kg dry matter
TPM	10	g / kg dry matter
PM2.5	5	g / kg dry matter

The quantity of "dry matter" per unit area is approximately 4.5 ton per hectare for savanna areas. Total annual emissions were estimated based on the average annual area burnt taking into account the composite 1995-2000 burn scar areas. Peak emissions were calculated based on the maximum area burnt in any 10-day period.

4.1.5.6 Synopsis of Estimated Emissions from "Other Sources"

The total emissions in tonnes per annum for each of the source groups quantified during the study are summarised in Table 4.17. Industry and power generation comprised the most significant contributor to sulphur dioxide and fine particulate emissions.

Table 4.17 Estimated total annual emissions from 'other sources' within the study area

Pollutant	Emissions (tpa)						
	Industrial & Non-Eskom Power Generation	**Household Fuel Burning**	**Vehicles**	**Open Cast Mining (Fugitive Dust)**	**Ash Dumps (Wind Entrainment)**	**Biomass Burning**	**TOTAL**
PM10 (tpa)	23008	4371	6352	3057	1917	5167	43873
SO_2 (tpa)	311784	3958	3373			620	319735
NO (tpa)	152224	1544	163418			3204	320390
Pollutant	**Percentage Contribution to Total Emissions from 'Other Sources'**						
	Industrial & Non-Eskom Power Generation	**Household Fuel Burning**	**Vehicles**	**Open Cast Mining (Fugitive Dust)**	**Ash Dumps (Wind Entrainment)**	**Biomass Burning**	**TOTAL**
PM10 (tpa)	49.9	9.5	13.8	6.6	9.0	11.2	89
SO_2 (tpa)	97.5	1.2	1.1			0.2	100
NO (tpa)	47.5	0.5	51.0			1.0	100

Vehicle exhaust emissions and industrial releases are the most significant sources of NO emissions with industry also constituting the predominant source of sulphur dioxide emissions due to 'other sources' quantified. Significant sources of low level PM10 emissions include industry, household fuel burning, vehicles, open cast mining and biomass burning.

4.2 Measured Baseline Air Quality

Eskom operates two ambient air quality monitoring stations within the study region, viz. the Kendal 2 monitoring station and recently established (May 2006) Kendal B monitoring station. Ambient SO_2, NO_x and PM_{10} concentrations are recorded at these stations in addition to various meteorological parameters such as wind speed and direction. Reference was made to data from the monitoring stations primarily for the purpose of validating predicted air pollution concentrations from the simulation of estimated emissions due to existing sources.

The Kendal 2 station is located within the zone of maximum ground level concentration (GLC) occurring due to the existing Kendal Power Station's emissions. The Kendal B station is situated in the vicinity of the old Wilge Power Station that is relatively close to the more eastern candidate site for the proposed Kendal North power station.

4.2.1 Kendal 2 Monitoring Station

The data availability of the Kendal 2 monitoring station for the period 2001 to 2005 is given in Table 4.18. It should be noted that the Kendal 2 monitoring station was specifically situated to be in the zone of maximum ground level concentration occurring due to the Kendal Power Station, also taking into account background concentrations of other sources. Air pollutant concentrations recorded at this station should therefore not be taken as being indicative of ambient air quality in the broader area. Measurements from this station do however provide important information on the maximum ground level concentrations which can be expected to occur in the vicinity of the Kendal Power Station and are useful in validating dispersion model results. Dispersion model results, presented in the subsequent section, are used to understand spatial variations in air pollutant concentrations across the study domain.

Table 4.18 Data availability for the current Kendal 2 monitoring station. Data availabilities of less than 70% are indicated in bold print.

Monitoring station	Pollutant	Data availability (%)				
		2001	**2002**	**2003**	**2004**	**2005**
Kendal 2	SO_2	**62**	**43**	**25**	98	98
	NO_2	87	93	98	88	74
	PM10	91	93	98	NM	89

NM – Not Measured

Maximum hourly, daily and period average air pollutant concentrations recorded at the Kendal 2 station for the period 2004 to 2005 are given in Table 4.19. The frequencies of exceedance of the relevant limits for SO_2, NO_2 and PM10 are summarized in Table 4.20

Table 4.19 Monitored ground level concentrations (µg/m³) at the Kendal 2 monitoring station [(a)].

Pollutant	Period	Highest hourly concentration (µg/m³)	Highest daily concentration (µg/m³)	Annual average concentration (µg/m³)
SO_2	2001	**1408**	**220**	31
	2002	**1777**	**286**	43
	2003	**2112**	**381**	47
	2004	**2175**	**302**	35
	2005	**1887**	**274**	40
NO_2	2001	172	51	14
	2002	**726**	64	14
	2003	145	56	15
	2004	152	33	12
	2005	**201**	71	16
PM10	2001	699	**215**	**87**

Pollutant	Period	Highest hourly concentration (µg/m³)	Highest daily concentration (µg/m³)	Annual average concentration (µg/m³)
	2002	2705	**739**	**68**
	2003	2431	**199**	**57**
	2004	NM	NM	NM
	2005	597	92	24

(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 SA standard, SANS, EC, WHO daily SO_2 limit of 125 µg/m³, the SA annual SO_2 standard of 50 µg/m³, the SA annual NO_2 standard of 96 µg/m³, the SA daily NO_2 standard of 191 µg/m³ and the SA daily NO_2 standard of 382 µg/m³, the SA annual PM10 standard of 60 µg/m³ and the SA daily PM10 standard of 180 µg/m³.

Table 4.20 Frequencies of exceedance of selected air quality limits as recorded at Kendal 2 monitoring stations during the 2001 to 2005 period.

Period	SO_2 hourly limit of 350 µg/m³ (hrs)	SO_2 daily limit of 125 µg/m³ (days)	NO_2 hourly limit of 200 µg/m³ (hrs)	PM10 daily limit of 75 µg/m³ (days)	PM10 daily limit of 50 µg/m³ (days)
2001	56	6	0	151	209
2002	166	20	2	36	92
2003	202	27	0	15	54
2004	117	12	0	NM	NM
2005	153	16	2	8	38

NM – Not measured

Sulphur dioxide concentrations have been measured to exceed the EC hourly limit[(7)]during the 2001-5 period. The daily limit issued by the SA, SANS, WHO and EC is exceeded during all five years at Kendal 2. No exceedance of the DEAT and SANS annual limit given for the protection of human health (50 µg/m³) was measured to occur at Kendal 2. The EC annual limit issued for the protection of ecosystems (20 µg/m³) was however exceeded at Kendal 2 for the five year period.

Nitrogen dioxide concentrations have been measured to be within air quality limits for most years. At the Kendal 2 station the SA standard and SANS limit given for hourly averages were both measured to have been exceeded during 2002. During 2005 the SANS hourly limit was marginally exceeded.

Particulate matter concentrations have been measured to exceed short-term (highest daily) SANS and EC limits. Even the lenient SA standard was observed to have been exceeded at the Kendal 2 for the period 2001 to 2003. The long-term measurements of PM10 exceeded the SANS limit (40 µg/m³) at Kendal 2 and in turn the EC annual limit (30 µg/m³) for the period 2001 to 2003.

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[7] No DEAT or SANS limits are issued for SO_2 for an hourly averaging period. An exceedance of the EC hourly limit (350 µg/m³), which represent an equivalence air quality objective, is however likely to indicate an exceedance of the DEAT and SANS limits given for a 10-minute averaging period (500 µg/m³).

Measured frequencies of exceedance (hours/year; days/year) are summarised in Table 4.20. Reference should be made to the number of available data (Table 4.18), so as to provide the context within which to interpret the significance of the reported frequencies. Significant frequencies of exceedance of sulphur dioxide limits have been measured to occur at Kendal 2. Exceedances of hourly nitrogen dioxide limits were recorded to occur relatively infrequently (only 2 hours per year at Kendal 2). Frequencies of exceedance of the PM10 limit of 75 µg/m³ and 50 µg/m³ occurred at Kendal 2.

Average SO_2 pollution roses for Kendal 2 for the period 2005 are presented in Figure 4.15. Such roses indicate that increased concentrations at the Kendal 2 site coincide with mainly with airflow with a northwesterly component (during which time the wind blows from the Kendal Power Station towards the monitoring site). Peak pollutant concentrations were noted to occur between 10h00 and 16h00, with peaks at noon (Figure 4.16). This diurnal trend is generally indicative of ground level concentrations occurring due to elevated stack, with the plume typically being “brought to ground” during periods of atmospheric instability. Such vertical turbulence due to convective mixing occurs during the daytime with peaks during the window period indicated above.

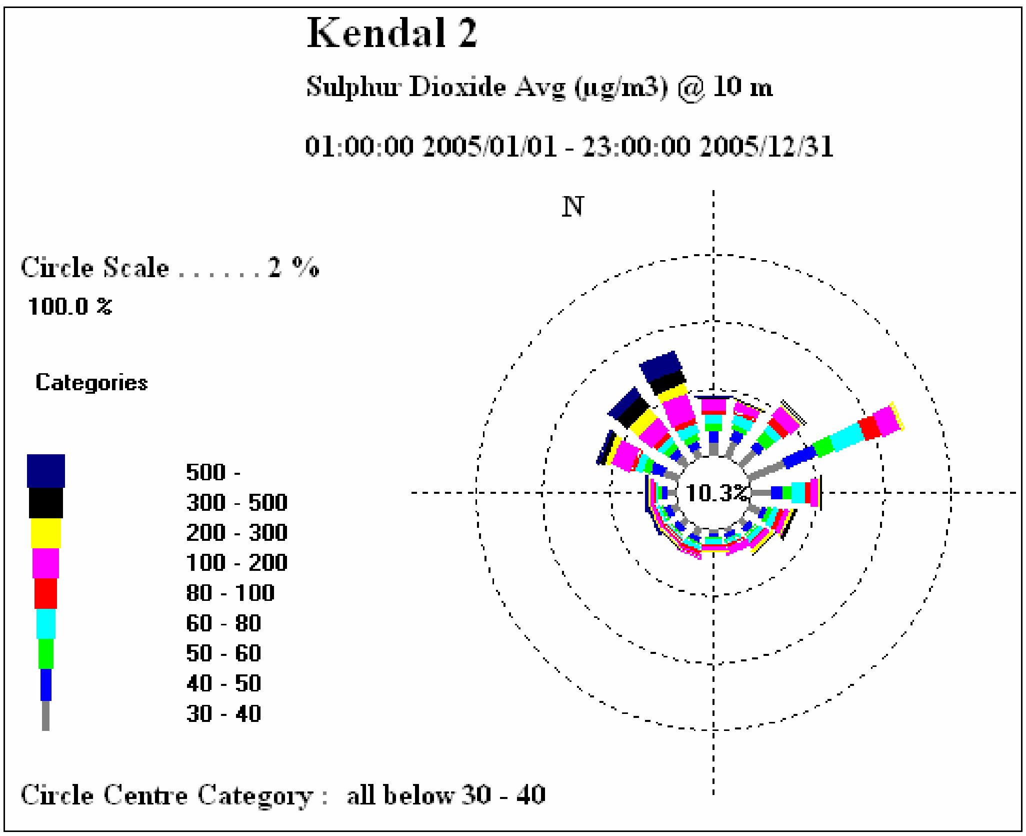


Figure 4.15 SO_2 pollution rose for the period 2005 for the Kendal 2 monitoring station.

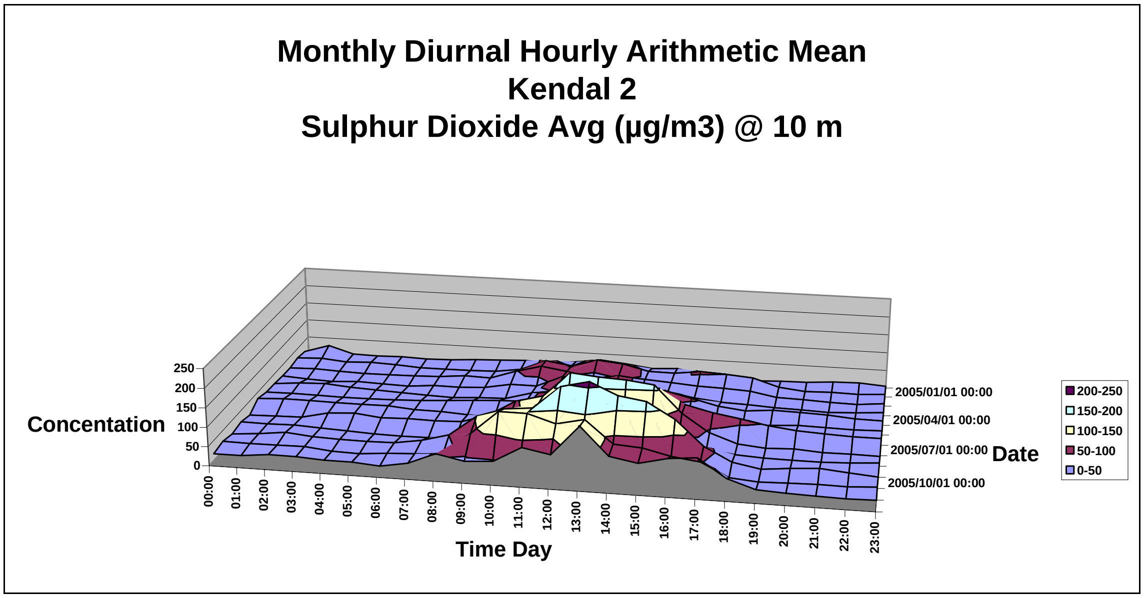


Figure 4.16 Diurnal profile of SO_2 ground level concentrations at the Kendal 2 monitoring station.

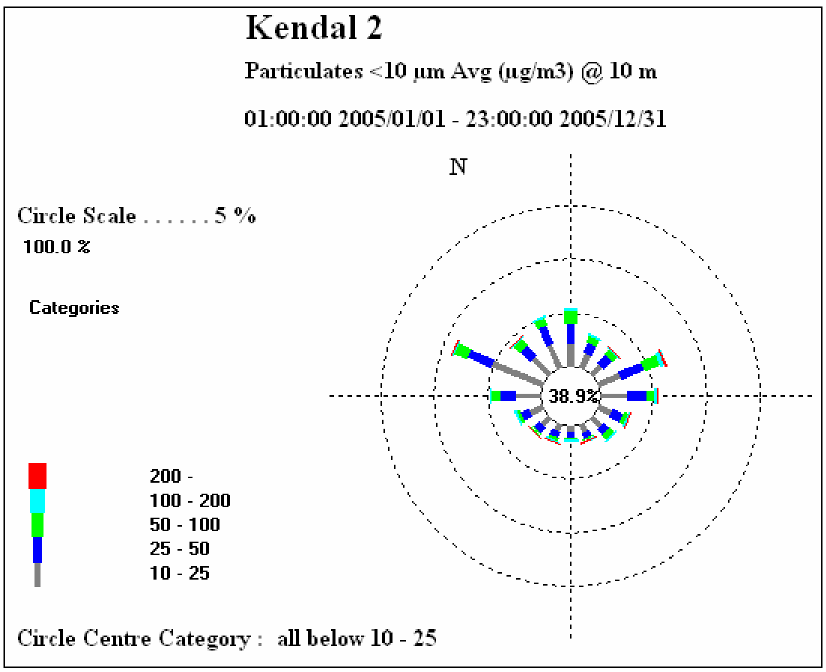


Figure 4.17 PM10 pollution rose for the period 2005 for the Kendal 2 monitoring station.

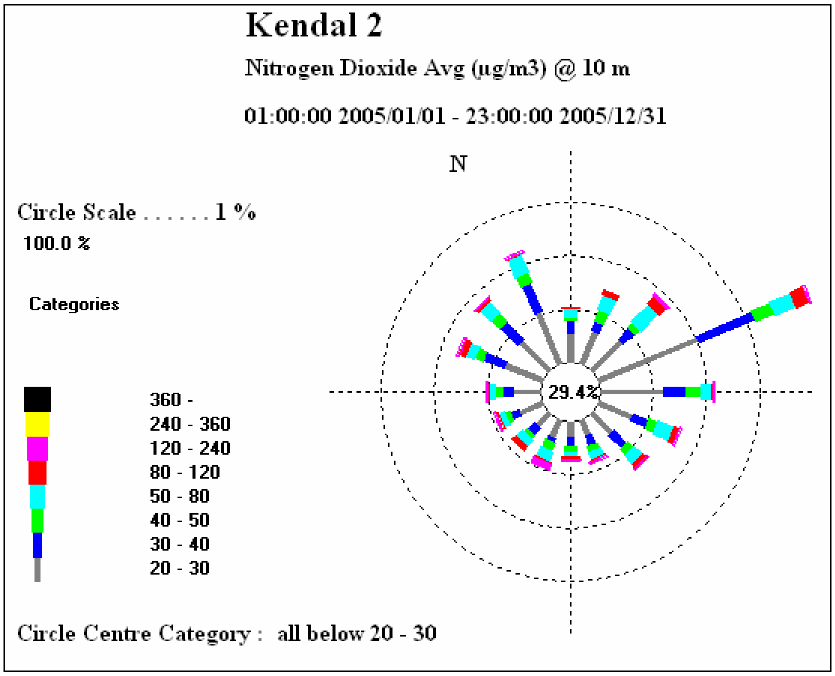


Figure 4.18 NO_2 pollution rose for the period 2005 for the Kendal 2 monitoring station.

The highest frequency of inhalable particulate matter tends to coincide with west-northwesterly airflow (Figure 4.17) with a large portion of NO_2 ground level concentrations coming from the east-northeast (Figure 4.18).

4.2.2 Kendal B Monitoring Station

The Kendal B monitoring station has been in operation since May 2006. Information regarding the data availability (Table 4.21) and measured concentrations was obtained from the Resource and Strategy Division at Eskom on the 13 November 2006 for inclusion into this study.

Table 4.21: Percentage data recovered per parameter monitored (%) at Kendal B.

Month	SO_2	NO_2	PM10	Overall Data Recovery
May	83.6	83.6	59.5	79.5
June	70.4	71.2	44.6	65.8
July	87.0	53.0	88.6	81.3
August	66.5	0	98.5	73.1
September	32.6	0	25.0	51.5
October	98.8	0	0	60.0

Table 4.22 Highest SO_2 concentrations (µg/m³).

Month	Highest Hourly Mean	Highest Daily Mean	Highest Monthly Mean	%Data Captured
May	256.8	54.2	17.3	83.6
June	439.8	78.3	33.5	70.4
July	274.8	120.1	41.4	87.0
August	327.2	92.7	39.8	66.5
September	322.0	138.7	70.2	32.6
October	253.6	66.7	23.0	98.8

Table 4.23 Highest NO_2 concentrations (µg/m³).

Month	Highest Hourly Mean	Highest Daily Mean	Highest Monthly Mean	%Data Captured
May	82.0	22.0	10.3	83.6
June	52.1	16.7	10.2	71.2
July	42.0	13.9	4.0	53.0
August	-	-	-	0
September	-	-	-	0
October	-	-	-	0

Table 4.24 Highest PM10 concentrations (µg/m³).

Month	Highest Hourly Mean	Highest Daily Mean	Highest Monthly Mean	%Data Captured
May	210	70.4	30.2	59.5
June	152.0	17.1	15.1	44.6
July	32.9	14.5	9.0	88.6
August	31.6	10.4	3.5	98.5
September	25.5	10.4	5.7	25.0
October	-	-	-	0

4.3 Modelled Air Pollutant Concentration and Deposition due to Current Baseline Conditions

4.3.1 Dispersion Modelling Methodology

Atmospheric dispersion modelling was undertaken for the existing Kendal 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 is also outlined in Appendix B.

4.3.2 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.

4.3.3 Dispersion Model Results

4.3.3.1 Results for Criteria Pollutants

Isopleth plots illustrating predicted sulphur dioxide, nitrogen dioxide and PM10 concentrations and dust deposition rates occurring due to current baseline conditions are presented in Appendix C. A synopsis of the maximum hourly, daily and annual sulphur dioxide, nitrogen dioxide and PM10 concentrations occurring due to current baseline conditions, within the absolute zone of maximum and within neighbouring residential areas, is given in Table 4.25.

Predicted NO and NO_2 daily and annual concentrations were predicted to be well within local and international air quality limits. The highest predicted hourly NO and NO_2 ground level concentrations within the *zone of maximum ground level concentration area* were predicted to exceed the relevant limits/standards by ~ 35%. No exceedances of NO and NO_2 air quality limits were predicted to occur within the neighbouring residential areas of Phola.

The highest predicted daily and annual PM10 concentrations exceeded relevant SANS limits by more than 100%. The predicted highest daily PM10 concentrations at Phola exceeds the SANS limit by 60%. Maximum monthly dustfall rates were typically "slight" (i.e. <250 mg/m²/day) immediately downwind of the Kendal ash dump.

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. Within the residential area of Phola, short-term SO_2 ground level concentrations were predicted to exceeded EC hourly air quality limit (and calculated to exceed the SA 10-minute air quality limit). Daily sulphur dioxide concentrations were simulated to be within the air quality limits given for this averaging period at these residential areas.

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

- the *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 SO_2 air quality limits and health risk, vegetation damage and corrosion potential thresholds are illustrated in Figure 4.19. A synopsis is given in Table 4.25 of the frequencies of exceedance of air quality limits and thresholds for selected sensitive receptors and therefore the potential that exists for non-compliance and impacts. The distances of exceedance of NO_2 and PM10 SANS short-term limits are illustrated in Figure 4.20.

Table 4.25 Predicted SO_2, NO, NO_2 and PM10 concentrations occurring due to current baseline conditions – 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 [(a)]	4603	299	44	1012	62	9	269	41	8	191	83
Phola	**1151**	119	29	270	11.5	2.2	190	33	5.9	45	5.8
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	**13.15**	**2.40**	0.88	**1.35**	0.17	0.05	**1.34**	0.22	0.20	**2.55**	**2.08**
Phola	**3.29**	0.95	0.58	0.36	0.03	0.01	0.95	0.18	0.15	0.60	0.15

(a) Within a 25km radius from the proposed Kendal North Power Station sites

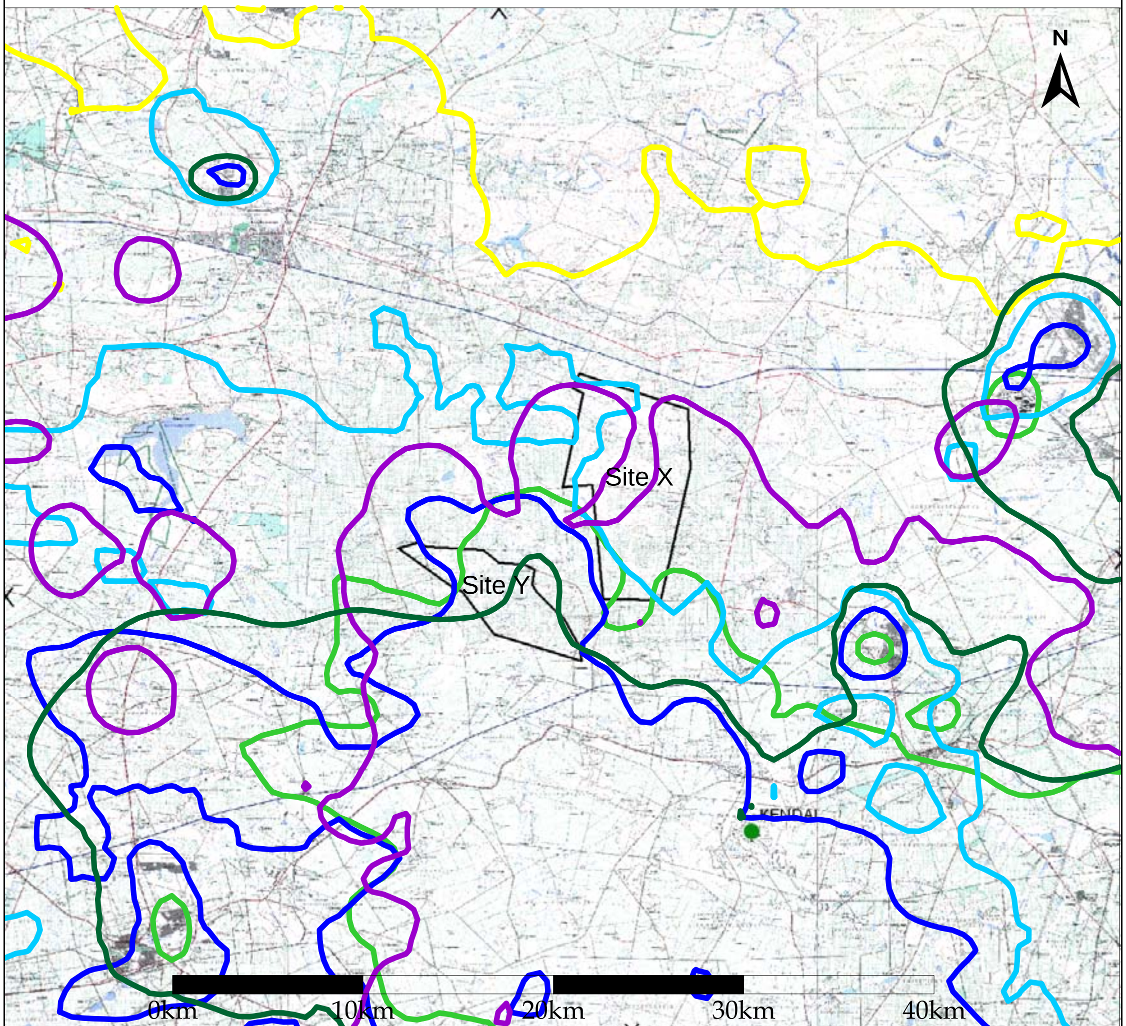
Table 4.26 Potential for non-compliance, health effects, vegetation damage and corrosion occurring due to sulphur dioxide concentrations occurring as a result of current baseline conditions

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 SA 10-minute Limit of 500 µg/m³ (no permissible frequencies) / Freq Exc EC Hourly Limit of 350 µg/m³ (EC permits 24, 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	4603	229	44	2.2	medium	3.5	2.2	high	low(a)	278	28	FALSE	FALSE
Residential areas	Phola	1151	119	29	1.5	medium	0.9	1.5	moderate	moderate	16	2	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.

Predicted Distance of Exceedance of SO2 Air Quality Limits and Thresholds for Health Risk, Vegetation Damage and Corrosion Potential due to Current Sources of Emission



- Non-compliance with SA 10-minute SO2 limit (500 µg/m³; 10 min/year)
- Non-compliance with UK, EC hourly SO2 limit (350 µg/m³; 24 hrs+/year)
- Non-compliance with SA daily SO2 standard (125 µg/m³; 1 day+/year)
- Non-compliance with EC daily SO2 limit (125 µg/m³; 3 days+/year)
- Single exceedance of California EPA Acute Reference Exposure Level given for SO2 (660µg/m³ - associated with potential for mild respiratory effects)
- Single exceedance of the EC annual SO2 limit for the protection of ecosystems and the threshold for potentially "medium" corrosivity (20 µg/m³)

Figure 4.19 Areas over which various SO_2 air quality limits and health, vegetation injury and material damage thresholds are exceeded due to existing baseline conditions.

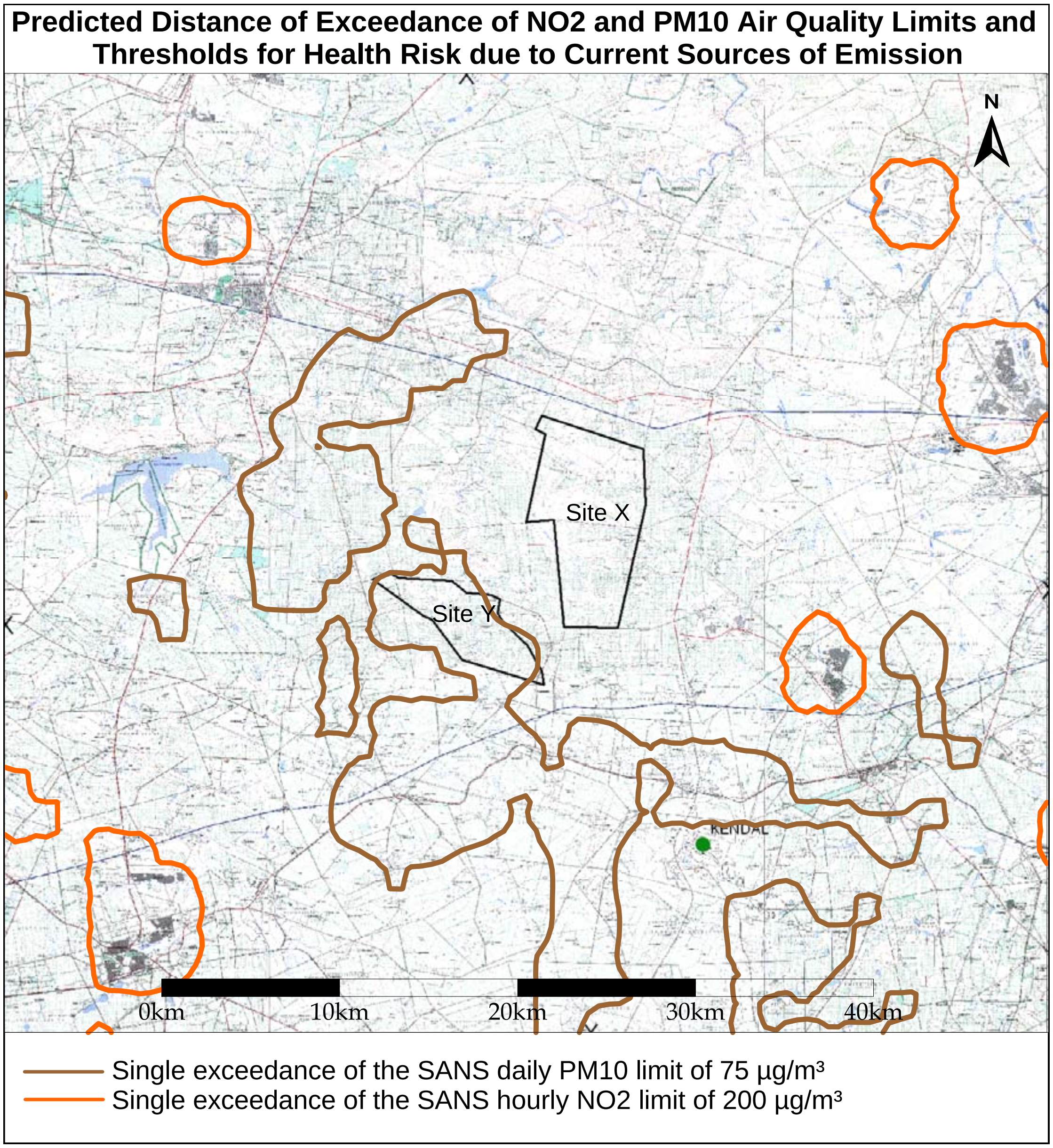


Figure 4.20 Areas over which NO_2 and PM10 SANS short-term limits are exceeded due to existing baseline conditions.

Table 4.27 Predicted ambient trace metal concentrations (in the PM10 range) due to existing Kendal 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	Annual Average	Acute Health Threshold	Sub-acute 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	Annual Average Concentration as a Fraction of the Chronic Threshold
As	1.10E-03	2.16E-04	1.46E-05	0.19		0.03	0.00581		0.00049
Ba	1.14E-01	1.69E-02	1.33E-03	50		5	0.00227		0.00027
Bi	3.58E-04	5.49E-05	4.35E-06						
Co	9.99E-04	1.43E-04	1.12E-05			0.1			0.00011
Cr	2.79E-02	4.27E-03	2.90E-04			0.1			0.00290
Cu	3.50E-03	5.03E-04	3.93E-05	100		1	0.00003		0.00004
Ga	3.45E-03	4.92E-04	3.86E-05						
Ge	4.69E-04	7.15E-05	5.66E-06						
Pb	5.17E-03	8.15E-04	6.45E-05			0.5			0.00013
Hg	6.78E-05	8.05E-06	6.90E-07	1.8		0.09	0.00004		0.00001
Ni	7.10E-03	1.21E-03	9.04E-05	6		0.05	0.00118		0.00181
Nb	3.07E-03	3.97E-04	3.26E-05						
Rb	3.55E-03	5.45E-04	4.32E-05						
Se	1.21E-01	1.86E-02	1.47E-03			20			0.00007
Th	4.09E-03	7.72E-04	5.24E-05						
Sn	9.70E-04	1.65E-04	1.24E-05	20		2	0.00005		0.00001
W	9.69E-04	1.84E-04	1.25E-05	10		1	0.00010		0.00001
U	9.68E-04	1.70E-04	1.20E-05			0.3			0.00004
V	9.33E-03	1.39E-03	1.09E-04		0.2			0.00694	
Y	5.43E-03	8.05E-04	6.34E-05						
Zn	5.55E-03	5.35E-04	4.21E-05	50		5	0.00011		0.00001
Zr	2.82E-02	3.93E-03	3.12E-04	50		5	0.00056		0.00006

All local and international air quality limit values for sulphur dioxide considered are predicted to be exceeded for hourly and daily averaging periods within the vicinity of the proposed new Kendal North Power Station sites. Within the residential area of Phola, predicted hourly sulphur dioxide concentrations exceed the EC and SA allowable frequencies of exceedance. SA limits are more stringent that EC limits given that no permissible frequencies have been set by DEAT (non-compliance therefore assumed to coincide with one exceedance per year), 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 ***medium*** potential exists for vegetation damage, corrosion and health effects due to sulphur dioxide concentrations. The potential for infrequent mild respiratory effects occurring in the Phola area was classified as “moderate” given that the threshold associated with the potential for such effects was exceeded 16 hours per year.

4.3.3.2 Results for Heavy Metals

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 and coal storage pile are given in Table 4.27. 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 the table. Fractions of greater than 1 indicate an exceedance of the threshold. No inhalation-related, non-carcinogenic health thresholds were predicted to be exceeded.

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 4.28). 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 million to 1: 22.5 million.

Table 4.28 Cancer risks calculated due to inhalation exposures to individual carcinogens predicted to be emitted from existing Kendal 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	45,517,434	15,878,175
Nickel	A	46,084,809	29,106,195
Lead	B2	1,292,014,603	1,292,014,603
Total incremental cancer risk across all carcinogens quantified		22,500,876	10,192,593

4.3.3.3 Health Risk Screening for Total Mercury Emissions

In the simulation of ambient mercury concentrations and resultant air quality impacts reference was made to the maximum emission rates (i.e. 6.9 tpa for current Kendal operations). The maximum highest hourly, highest daily and annual average ground level mercury concentrations occurring as a result of existing Kendal Power Station emissions are given in Table 4.29.

Table 4.29 Predicted mercury concentrations given existing Kendal Power Station emissions with reference to applicable guidelines intended to protect human health.

	PREDICTED MERCURY CONCENTRATIONS GIVEN EXISTING AND PROPOSED 4800 MW POWER STATION OPERATIONS		
	Highest Hourly (µg/m³)	Highest Daily (µg/m³)	Annual Average (µg/m³)
Predicted Maximum Total Hg GLCs (µg/m³)	0.16	0.03	0.002
	RELEVANT GUIDELINES (µg/m³)		
WHO Guideline Value			1.00
US-EPA inhalation reference concentration			0.30
Texas Effect Screening Levels	0.25		0.025
California RELs	1.8		0.09
DEAT Mercury Guideline (a)			0.04

REL – reference exposure level; GLCs – ground level concentrations; DEAT – Department of Environmental Affairs and Tourism
(a) Published in DEAT document "Technical Background Document for Mercury Waste Disposal" (2001).

The predicted maximum hourly, daily and annual average concentrations were well-within the most stringent of the guidelines given for public exposures to ambient mercury concentrations intended for the inhalation pathway (e.g. WHO, US-EPA inhalation reference concentrations, Californian RELs).

It is noted that the major pathway for mercury exposures is ingestion rather than inhalation. For this reason reference was made to the DEAT mercury guideline which was intended to be protective given multiple pathways of exposure. This guideline value (given as 0.04 µg/m³ for chronic exposures) was derived during a recent study initiated by the Department of Environmental Affairs and Tourism. This study included health-risk based research relating to human exposure to mercury and engineering reviews of treatment and disposal options for mercury waste. The purpose of such studies was twofold: (i) to support the drafting of national regulations for mercury waste disposal; and (ii) to provide specific guidance on how best to deal with the mercury waste stockpiled at the Thor Chemical's plant at Cato Ridge, Kwazulu-Natal. The health risk study determined that ambient long-term concentrations of mercury of lower than 0.04 µg/m³ would not result in unacceptable multi-pathway risk given local environments. This guidance is currently being used by the DEAT to assess the acceptability of mercury waste treatment and disposal options.

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 exceed short-term (hourly, daily) air quality limits at the Kendal 2 monitoring station.

  The Eskom power stations in the vicinity of the monitor is expected 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. The highest ground level concentrations due to the 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. Other significant sources of sulphur dioxide emissions in the immediate study area include household coal burning, industrial emissions (e.g. Highveld Steel & Vanadium), and spontaneous combustion from coal discards.

  The comparison of measured and predicted sulphur dioxide concentrations to thresholds indicative of the potential for health, potential corrosion and potential 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 predicted to be exceeded at Phola.

- Measured and predicted sulphur dioxide concentrations were within limits indicative of medium corrosion potentials.

- Measured and predicted sulphur dioxide concentrations exceeded the EC annual sulphur dioxide limit of 20 µg/m³ that aims to protect ecosystems. This exceedance was predicted to occur for approximately 60 km east west of the existing Kendal Power Station.

- Exceedances of the EC hourly **nitrogen dioxide** limits are predicted to occur but are limited in magnitude, frequency and spatial extent. Although coal-fired power stations add to the ambient concentrations, other sources of NO_x anticipated to occur in the region include combustion within coal discard dumps, other industry emissions, vehicle tailpipe emissions, household coal, wood and paraffin burning and infrequent but significant veld burning.

- Ambient **PM10** concentrations were predicted to slightly exceed the current lenient SA Standards (as given in the second schedule of the Air Quality Act). The highest PM10 concentrations were predicted over household fuel burning areas due to low-level emissions from such areas during periods of poor atmospheric dispersion (night-time).

- Based on the screening of the potential for health risks occurring due to inhalation exposures to trace metals released from existing Kendal 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 potential for health risks associated with long-term public exposures to mercury emissions from coincident operations of the existing Kendal Power Station are predicted to be low even given the potential for multi-pathway exposures.

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.

5. EMISSIONS INVENTORY FOR PROPOSED OPERATING CONDITIONS

5.1 Proposed Kendal North Power Station

Sources associated with the construction phase of the proposed power station project are discussed and their emissions quantified in Section 5.1.1. Various possible power station configurations were evaluated for the operational phases. These configurations are presented in Section 5.1.2 and the source and emissions data for such scenarios presented.

5.1.1 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 (kg/month)	PM10 Emissions (kg/month)
Power station	269	94

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.

5.1.2 Operational Phase

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 and wind entrainment from the ash dump.

5.1.2.1 Power Stack Emissions (Criteria Pollutants)

Power station configuration options which were included in the study are as follows:

Scenario	No. of Units	Proposed Site	Stack Height (m)	SO_2 Control Efficiency
A.1	6 x 900 MW	Site X	150	0%
B.1	6 x 900 MW	Site Y	150	0%
C.1	6 x 900 MW	Site X	220	0%
D.1	6 x 900 MW	Site Y	220	0%
E.1	6 x 900 MW	Site X	300	0%
F.1	6 x 900 MW	Site Y	300	0%
A.2	6 x 900 MW	Site X	150	90%
B.2	6 x 900 MW	Site Y	150	90%
C.2	6 x 900 MW	Site X	220	90%
D.2	6 x 900 MW	Site Y	220	90%
E.2	6 x 900 MW	Site X	300	90%
F.2	6 x 900 MW	Site Y	300	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 5.1 and 5.2). 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 5-1 Stack parameters for proposed Kendal North Power Station operations

Power Station Configuration	Number of Stacks	Height (m)	Diameter (m)	Exit Velocity (m/s)	Temperature (°K)
6 x 900 MW (5400 MWe)	2	150, 220 or 300(a)	12.82	26.00	403

(a) Stack height dependent on scenario.

Table 5-2 Emission rates for the proposed power station configurations, assuming 0% control efficiency for sulphur dioxide

Capacity	Technology	Annual Emission Rates					
		SO_2	PM	NO_x [(a)]	NO [(b)]	NO_2 [(c)]	Units
5400 MWe	PF	364 082	**7 947**	87 361	55 835	1 747	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).

Diurnal variations in the emissions projected for the proposed new power stations were based on average temporal energy output profiles (provided by Eskom personnel for the period 2003) for all the existing power stations excluding Tutuka, Lethabo and Majuba (Figure 5.1). No monthly emission variation was assumed for the proposed new power station.

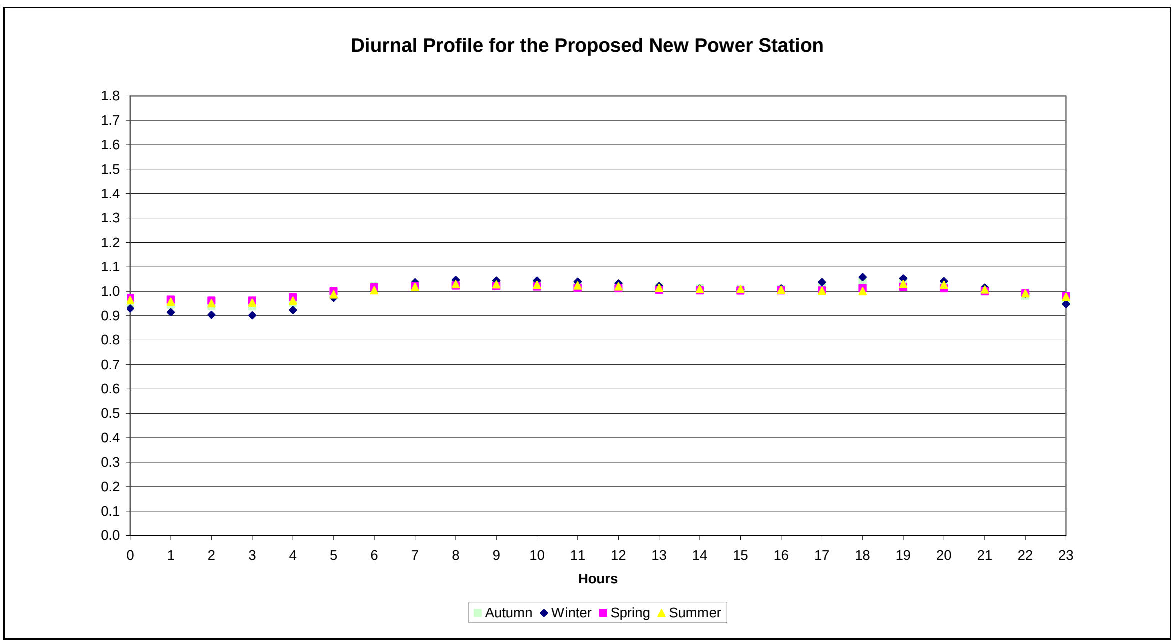


Figure 5.1 Diurnal emissions profile for the proposed new power station

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 are 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	N_2O
		kT/ann	kT/ann
5400 MWe	21,088,567	36,831	0.422

5.1.2.2 Fugitive Dust Emissions

(a) Wind Blown dust from the Ash dump and Coal Storage Pile

Source specific information regarding the nature of the source, the percentage of exposed surface area and the type of material was not available for the current study. Use was therefore made from similar operations. The workable surface of the ash dump was given to be between 100% (initially) and 6% (end of life). For simulation purposes the assumption was made that 20% of the ash dump would be exposed to wind erosion based on similar operations. The location, dimensions and orientations of the ash dump as well as the coal storage pile was attained from site location maps provided.

The source parameters used in the simulations for the ash dump can be found in Table 5.3. Table 5.4 show the particle size distribution used in the simulations.

Table 5-3 Source parameters pertaining to the ash dump and coal storage pile

Source	Height (m)	X length (m)	Y length (m)	Moisture (%)	Clay (%)	Bulk density (g/cm³)
Ash Dump	40	~1000[(a)]	~1000[(a)]	13.45	1	0.771
Coal Storage Pile	5	~1000[(a)]	~1000[(a)]	2.6	7	0.900

(a) Footprint of site layout map

Table 5-4 Particle size distribution for the materials found on the ash dump

Ash		Coal	
µm	**fraction**	**µm**	**fraction**
600	0.0472	75	0.28
404.21	0.0269	45	0.16
331.77	0.0296	30	0.2
272.31	0.0336	15	0.07
223.51	0.0404	10	0.1
183.44	0.0503	5	0.05
150.57	0.0609	2.5	0.07
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		

(b) Materials handling

Materials handling operations associated with the activities at the proposed power station includes the transfer of coal by means of tipping, loading and off-loading of trucks. The quantity of dust generated from the tipping of coal material was based on the average amount of material retrieved monthly (2 407 tph of coal was assumed to be handled at the proposed power station). 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 2.6% was assumed for the coal.

5.1.2.3 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 Kendal Power Station (see subsection 4.1.1.3). 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.

A synopsis of the maximum mercury emission rates estimated on the basis of the coal composition, EEA and IPPC emission factors as discussed in Section 4.1.1.3 is given in Table 5.5. The emissions estimated on the IPPC emission factors and the EEA emission factors are relatively similar, whereas on the basis of site-specific coal qualities the mercury emissions are higher.

Table 5-5 Comparison of estimated mercury emissions based on mercury content of Kendal coal, IPPC emission factors and EEA emission factors

Power Station	Maximum Hg Emissions based on Coal Quality (tpa)	Maximum Hg Emissions based on IPPC Emission Factors (tpa)	Maximum Hg Emissions based on EEA Emission Factors(tpa)
Future Kendal (max, 2009)	7.21	3.81	3.29
Proposed Kendal North Power Station	10.55	3.70	4.82

5.2 Future Eskom Power Station Operating Conditions

The power stations included in the future baseline scenario include the return to service and existing power stations. In future Eskom will increase the current coal usage due to deteriorating coal qualities. Future emissions for existing power stations were based on projected 2009 emissions (Table 5.5) as provided by Eskom personnel. The future return to service power stations were assumed to operate at peak load factors during the periods 06h00 to 09h00 and 18h00 to 20h00. For Komati and Grootvlei a base and peak load of 30% and 90% was assumed. For Camden the base load of 50% was assumed with a peak load of 90%. Parameters for the future and proposed sources of emissions are given in Table 5.6.

Table 5-6 Emissions (in tonnes per annum) for future and proposed operating conditions

Power Station	SO_2 (tpa)	NO (tpa)[(a)]	NO_2 (tpa)[(b)]	Particulates (tpa)[(c)]
Hendrina	98,503	32,449	1,015	3,141
Arnot	99,756	34,378	1,076	19,979
Kriel	147,160	47,448	1,485	9,433
Matla	224,602	62,159	1,945	4,896
Duvha	215,801	55,099	1,724	3,575

Power Station	SO_2 (tpa)	NO (tpa)[(a)]	NO_2 (tpa)[(b)]	Particulates (tpa)[(c)]
Lethabo	186,490	82,843	2,592	6,266
Kendal	336,084	76,620	2,398	3,654
Tutuka	168,564	46,858	1,466	7,199
Majuba	152,008	39,594	1,239	845
Camden (50% base)	19,729	7,727	592	4,938
Camden (90% peak)	35,512	13,908	1,066	8,889
Komati (30% base)	31,474	8,760	274	3,324
Komati (90% peak)	94,423	26,280	822	9,972
Grootvlei (30% base)	18,568	7,149	402	4,569
Grootvlei (90% peak)	55,705	21,447	1,206	13,707

Notes:

(a) 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).

(b) 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).

(c) Particulate emissions assumed to be PM10 due to the gas abatement technology in place

Table 5-7 Stack parameters for Eskom power stations for future baseline conditions

Station	Number of Stacks	Height (m)	Diameter (m)	Exit Velocity (m/s)	Tempera-ture (°K)
Hendrina	2	155	11.14	19.42	402
Arnot	2	195	11.06	20.25	411
Kriel	2	213	14.3	16.62	403
Matla 1-3	1	213	14.3	19.4	397
Matla 4-6	1	275	12.47	25.51	397
Duvha	2	300	12.47	23.78	403
Lethabo	2	275	11.95	25.28	399
Kendal	2	275	13.51	24.08	399
Tutuka	2	275	12.3	24.9	403
Majuba	2	220	12.3	29.83	403
Camden (50% base)	4	154.5	8.74	8	429
Camden (90% peak)	4	154.5	8.74	12.42	429
Komati (30% base)	2	121	10	8	416
Komati (90% peak)	2	121	10	14.13	416
Grootvlei (30% base)	2	152.4	8.99	8	401
Grootvlei (90% peak)	2	152.4	8.99	17.61	401

5.3 Other Sources of Atmospheric Emission

Sources, other than Eskom's power stations, which contribute to ambient air pollutant concentrations within the study region, have been discussed in Section 4.1.3. For future conditions, these sources were assumed to be consistent with current operating conditions.

6. COMPLIANCE AND AIR QUALITY IMPACT ASSESSMENT

6.1 Dispersion Model Results

Atmospheric dispersion modelling was undertaken for the proposed Kendal North 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 sources of emissions. The validation process 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 4.3.2.

In order to establish the potential for cumulative air quality impacts the proposed power station configurations were simulated together with the existing emissions from non-Eskom sources as well as proposed operations from Eskom sources.

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 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.

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.

Impact assessments were undertaken for the following power station configurations:

Scenario	No. of Units	Site	Stack Height (m)	SO_2 Control Efficiency
A.1	6 x 900 MW	Site X	150	0%
B.1	6 x 900 MW	Site Y	150	0%
C.1	6 x 900 MW	Site X	220	0%
D.1	6 x 900 MW	Site Y	220	0%
E.1	6 x 900 MW	Site X	300	0%
F.1	6 x 900 MW	Site Y	300	0%
A.2	6 x 900 MW	Site X	150	90%
B.2	6 x 900 MW	Site Y	150	90%
C.2	6 x 900 MW	Site X	220	90%
D.2	6 x 900 MW	Site Y	220	90%
E.2	6 x 900 MW	Site X	300	90%
F.2	6 x 900 MW	Site Y	300	90%

6.2.1 Nitrogen Oxides

Predicted NO and NO_2 hourly concentrations were predicted to exceed the SA NO standard and the SANS/EC NO_2 limit respectively (including cumulative concentrations due to existing sources of emissions). The daily and annual average ground level concentrations are within relevant standards. Although the existing and new coal fired power stations in the area contribute to the ambient oxides of nitrogen concentrations, other significant sources of NO_x emissions in the area include domestic fuel burning, vehicle tailpipe emissions and other industrial activity. (Appendix D). The contributions of such sources are clearly evident given the zones of predicted maximum ground level concentrations.

6.2.2 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, and wind erosion from the ash dumps) 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 daily limit values in the vicinity (within 10 km east) of the ash dump. Public exposure within this area is restricted to scattered farmsteads with an average residential density of ~5 persons/km^2. Other areas of exceedance are over industrial and household fuel burning area with ground level concentrations originating from low-level sources of emission (i.e. domestic fuel burning, industrial fugitives).

Maximum monthly dustfall rates were typically "moderate" (i.e. 250 - 500 mg/m^2/day) immediately downwind of the proposed Kendal North ash dump and materials handling section of the power station, with "slight" dustfalls (i.e. < 250 mg/m^2/day) occurring beyond these areas.

6.2.3 Sulphur Dioxide - Uncontrolled

Emissions from the existing Kendal 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 power station configurations. A synopsis of the maximum sulphur dioxide concentrations and frequencies of exceedance of the short-term air quality limits is given in Table 6.1 for all emission scenarios. The areas of exceedance of the SA daily standard and the UK hourly limit are illustrated in Figures 6.1 and 6.2 respectively for current operations and emission scenarios A, B, C, D and E. A single exceedance of the 10-minute SA limit was beyond the study area and was therefore not illustrated. Ground level maximum concentrations and frequencies of exceedance are given in the zone of maximum impact and at Phola.

Table 6-1 Maximum sulphur dioxide concentrations and frequencies of exceedances or air quality limits predicted to occur due to base case operations and cumulatively as a result of uncontrolled emissions from various proposed power station configurations (within ~25km radius from proposed Kendal North Power Station sites)

Receptor Point	Emission Scenario (cumulative for proposed PS, includes existing sources of 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	Current Operations	4603	299	44	278	28	FALSE	FALSE
	Future Operations (Basecase)	4814	324	49	296	35	FALSE	FALSE
	Scenario A - uncontrolled	5879	388	73	446	57	FALSE	FALSE
	Scenario B - uncontrolled	4814	438	70	470	64	FALSE	FALSE
	Scenario C - uncontrolled	4814	346	66	394	51	FALSE	FALSE
	Scenario D - uncontrolled	4814	350	67	429	54	FALSE	FALSE
	Scenario E - uncontrolled	4814	343	61	366	48	FALSE	FALSE
	Scenario F - uncontrolled	5170	348	63	389	47	FALSE	FALSE
Phola	Current Operations	1151	119	29	16	2	FALSE	TRUE
	Future Operations (Basecase)	1206	135	34	19	6	FALSE	TRUE
	Scenario A - uncontrolled	1366	222	57	182	28	FALSE	FALSE
	Scenario B - uncontrolled	1206	188	49	110	21	FALSE	FALSE
	Scenario C - uncontrolled	1279	159	51	99	19	FALSE	FALSE
	Scenario D - uncontrolled	1206	153	48	77	16	FALSE	FALSE
	Scenario E - uncontrolled	1206	158	47	68	14	FALSE	FALSE
	Scenario F - uncontrolled	1206	158	45	45	10	FALSE	FALSE

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 due to base case and all proposed configurations. At Phola the SA 10-minute standard is exceeded for base case and all proposed configurations.

- Under current and future basecase operations there is predicted to be compliance with the UK hourly sulphur dioxide standard at Phola. Non-compliance is predicted for an additional six 900 MW units regardless of the variations in stack location and height considered.

- Emission scenarios A and B, comprising 150 m stack heights at sites X and Y respectively, resulting in the greatest cumulative concentrations within the most affected residential areas. Within the zone of maximum ground level concentration, these emission scenarios resulted in a 5% to 60% increase in the sulphur dioxide concentrations and a 60% to 130% increase in the frequencies of exceedance of hourly and daily limits. Comparatively, the "best-case" emission scenario for Phola was scenario F (i.e. 300 m stack located at site y). This scenario was however still predicted to result in significant increases in the magnitude and frequency of exceedance of air quality limits given for sulphur dioxide.

- Effect of increased stack height: An increase in stack height from 150 m to 220 m (at site x) was predicted to reduce the frequency of exceedance of hourly limits by ~45% at Phola, with the further increase in stack height from 220 m to 300 m served to reduce hourly frequencies of exceedance by ~30%.

It may be concluded that the addition of 6 new 900 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 within neighbouring residential areas. The venting of emissions from a 300 m high stack would be insufficient to negate the need for abatement measures being considered.

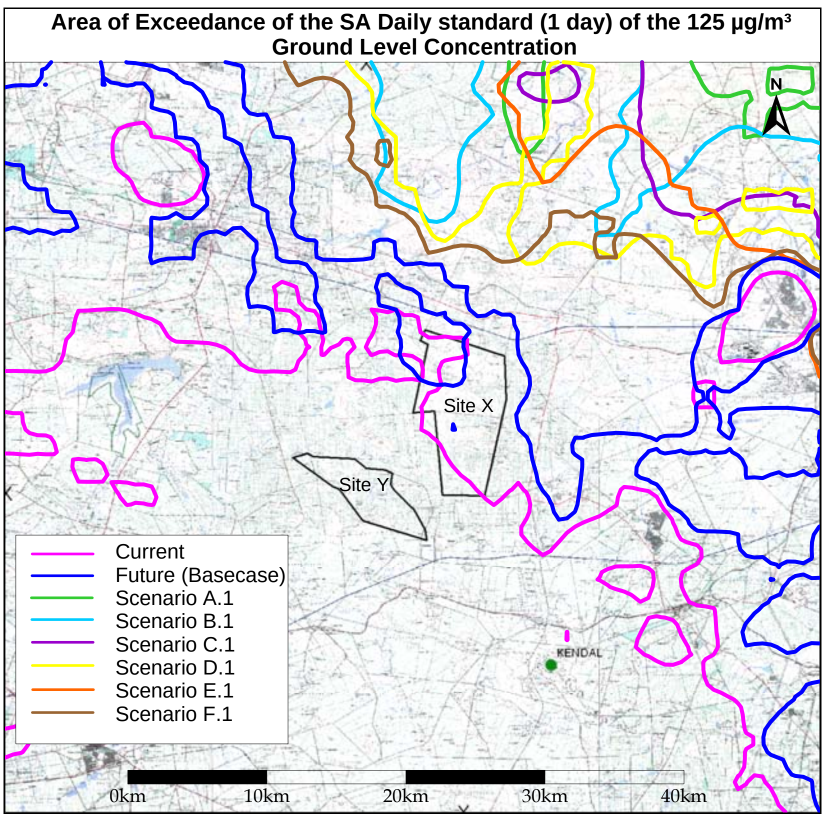


Figure 6.1 Predicted area of a single exceedance of the SA daily SO_2 standard due to all sources of emissions together with uncontrolled emissions from various of the proposed power station configurations.

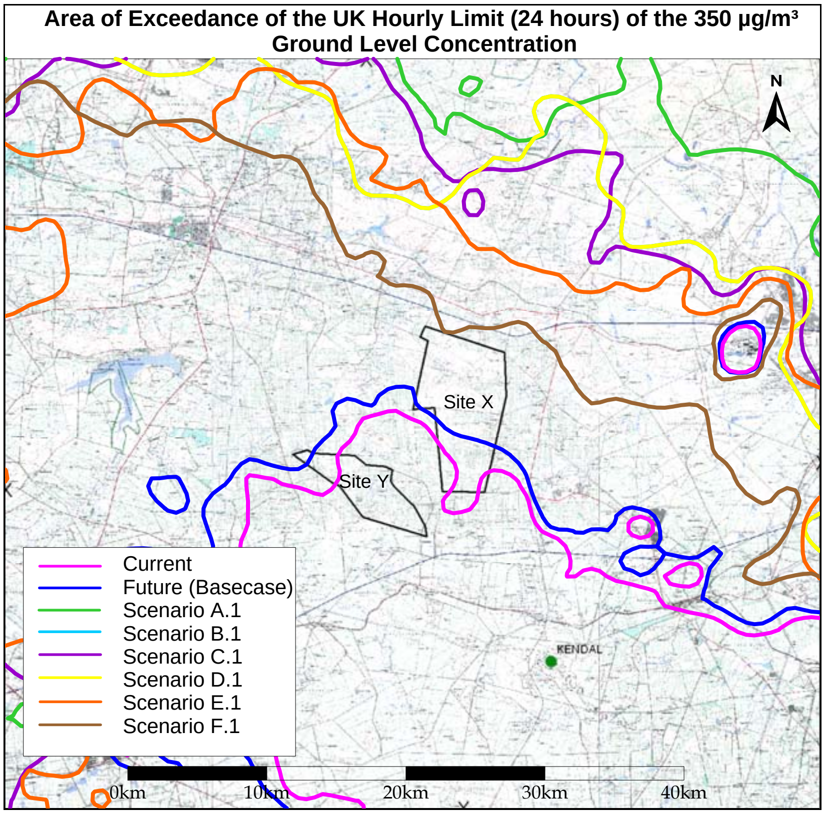


Figure 6.2 Predicted area of exceedance of the UK hourly SO_2 standard (permits a maximum of 24 exceedances per year) due to all sources of emissions together with uncontrolled emissions from various of the proposed power station configurations.

6.2.4 Sulphur Dioxide - Controlled

Changes in projected ground level sulphur dioxide concentrations and limit value exceedances were simulated for a 90% control efficiency for three proposed power station configurations, viz. Scenario A and B (150 m stack), Scenario C and D (220 m stack) and Scenario E and F (300 m stack) at two different sites, viz. Site X and Site Y. A synopsis of the maximum sulphur dioxide concentrations and frequencies of exceedance of the short-term air quality limits is given in Table 6.2. The areas of exceedance of the SA 10-minute standard, the SA daily standard and the UK hourly limit are illustrated in Figures 6.3 to 6.5 for Scenarios A given control efficiencies of 90%. Scenarios B, C, D, E and F were not illustrated to avoid confusion as they show a similar footprint to Scenario A. (Base case results are also depicted in the plots for comparative purposes.)

Table 6-2 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 (within ~25km radius from proposed Kendal North Power Station sites)

Receptor Point	Emission Scenario (cumulative for proposed PS, includes existing sources of 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 24, 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	Current Operations	4603	299	44	278	28	FALSE	FALSE
	Future Operations (Basecase)	4814	324	49	296	35	FALSE	FALSE
	Scenario A - 90% CE	4814	326	51	302	35	FALSE	FALSE
	Scenario B - 90% CE	4814	326	51	308	35	FALSE	FALSE
	Scenario C - 90% CE	4814	326	51	302	35	FALSE	FALSE
	Scenario D - 90% CE	4814	327	51	308	35	FALSE	FALSE
	Scenario E - 90% CE	4814	326	50	301	35	FALSE	FALSE
	Scenario F - 90% CE	4814	326	51	308	35	FALSE	FALSE
Phola	Current Operations	1151	119	29	16	2	FALSE	TRUE
	Future Operations (Basecase)	1206	135	34	19	6	FALSE	FALSE
	Scenario A - 90% CE	1206	135	36	19	7	FALSE	FALSE
	Scenario B - 90% CE	1206	135	35	19	7	FALSE	FALSE
	Scenario C - 90% CE	1206	135	35	19	7	FALSE	FALSE
	Scenario D - 90% CE	1206	135	36	19	7	FALSE	FALSE
	Scenario E - 90% CE	1206	135	35	19	7	FALSE	FALSE
	Scenario F - 90% CE	1206	135	35	19	7	FALSE	FALSE

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

- Even given a 90% control efficiency for all power station configurations, cumulative sulphur dioxide concentrations would exceed the SA 10-minute standard at the maximum impact zone and at Phola and the SA daily standard in the maximum impact zone, and Phola – primarily due to emissions from the existing Kendal Power Station.

- With the addition of six new units operating coincident with the existing Kendal 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 non-compliance with the 10-minute limit in terms of frequencies of exceedance at Phola would be in line with future baseline conditions.

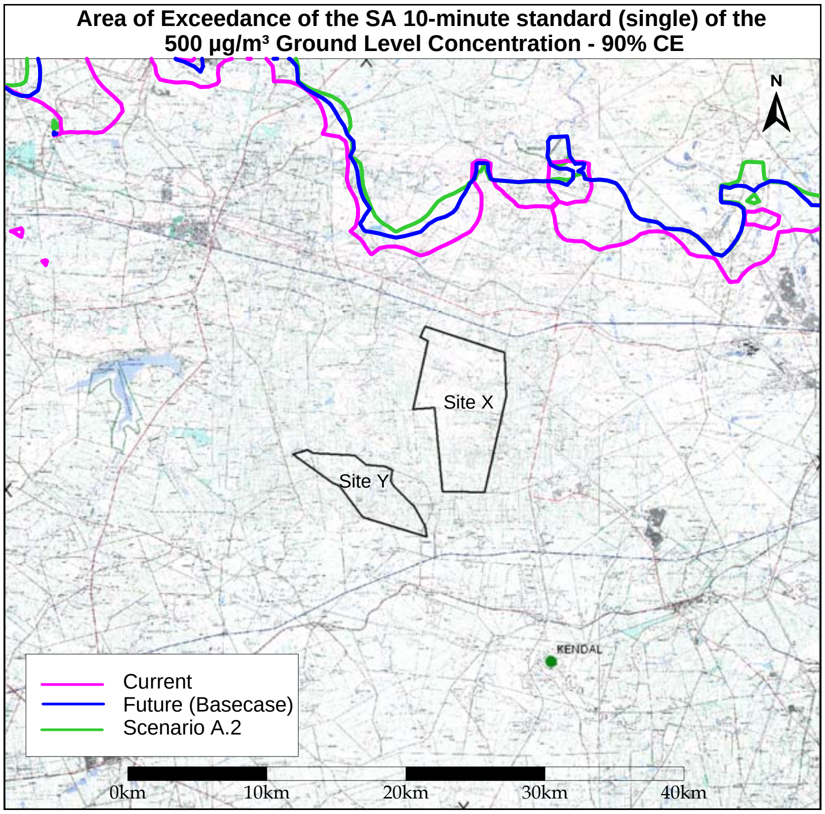


Figure 6.3 Predicted area of a single exceedance of the SA 10-minute SO_2 standard due to Scenario A emissions and existing Kendal PS emissions, given 90% sulphur dioxide abatement efficiencies.

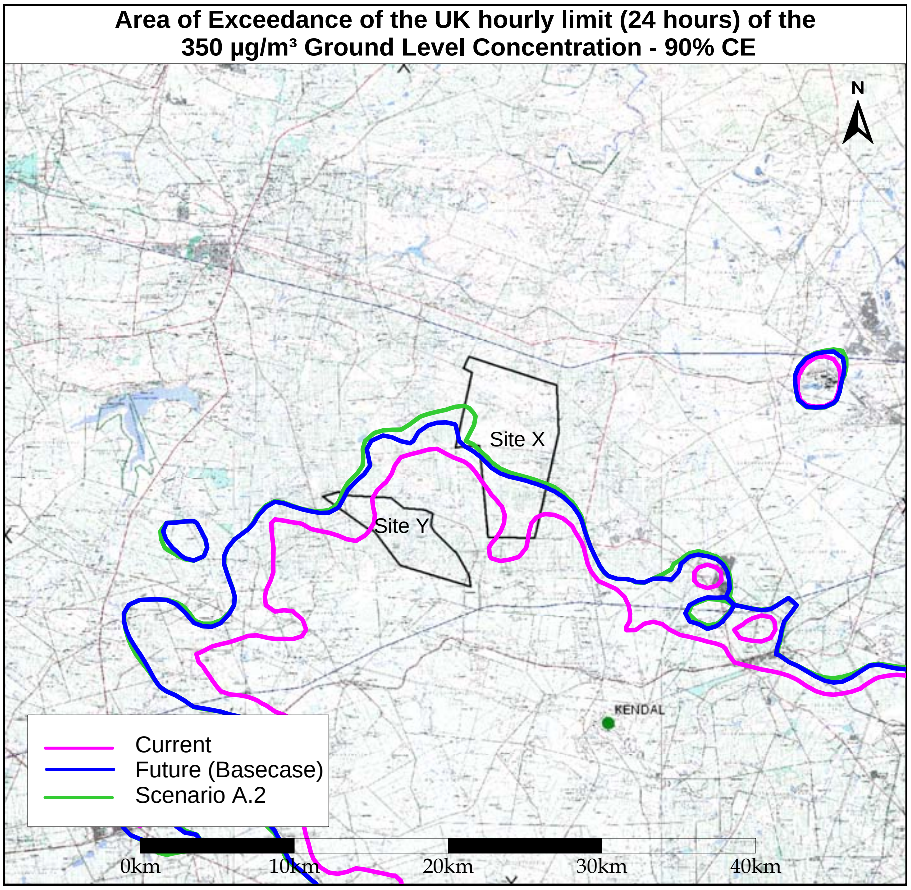


Figure 6.4 Predicted area of a single exceedance of the SA daily SO_2 standard due to Scenario A emissions and existing Kendal PS emissions, given 90% sulphur dioxide abatement efficiencies.

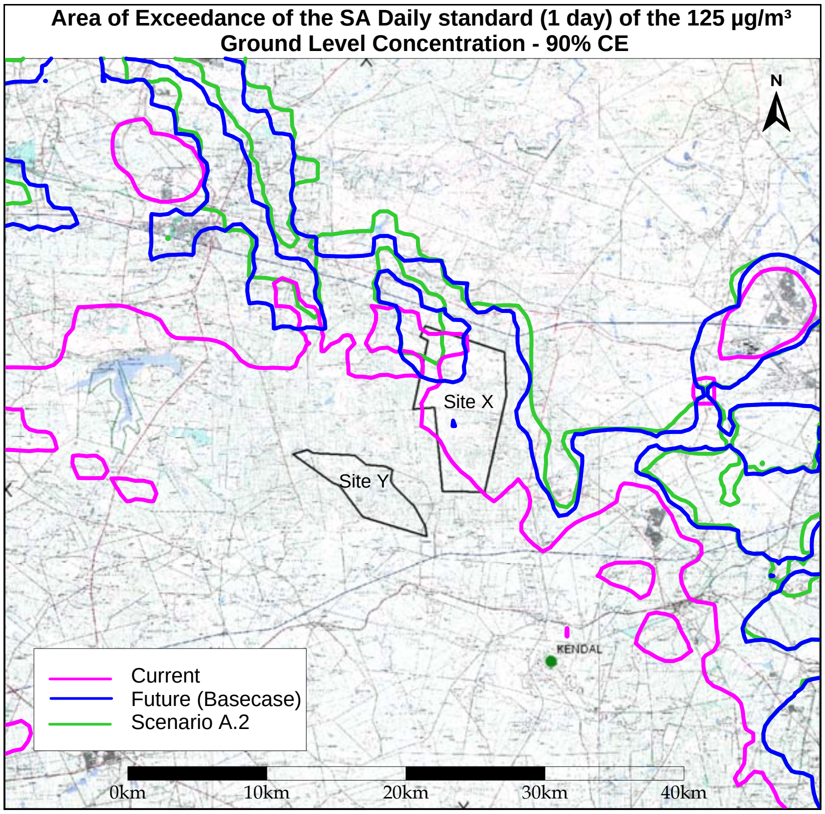


Figure 6.5 Predicted area of exceedance of the UK hourly SO_2 standard (permits a maximum of 24 exceedances per year) due to Scenario A emissions and existing Kendal PS emissions, given 90% sulphur dioxide abatement efficiencies.

6.3 Potential for Health Effects

6.3.1 Baseline Health Risks

Health risks related to exposures to air pollution concentrations occurring as a result of fuel-burning emissions were recently assessed for several regions including the Mpumalanga Highveld, as part of the NEDLAC "Dirty Fuels" study (Scorgie *et al*., 2004). Fuel burning sources quantified in this study included industrial fuel burning, power generation, vehicle exhaust emissions and household fuel burning. Air pollution exposure related respiratory hospital admissions were predicted to be in the order of ~8700 cases per year within the Mpumalanga Highveld region. Significant risks are associated with indoor exposures within fuel burning households. Exposures to emissions from power generation and industrial emissions were also identified as important sources of risk in this region. The contribution of vehicle exhaust emissions to health risks was less significant in this region.

6.3.1.1 Indoor exposures within fuel burning households

Household coal and wood burning is a significant source of indoor air pollution and is associated with significant health impacts. Health effects range from acute respiratory infections and upper respiratory tract illnesses to carbon monoxide poisoning, heart disease and cancer. Indoor air pollution from coal burning has been established as one of the risk factors for the development of acute respiratory illnesses (ARI). Data from local epidemiological studies indicate that acute respiratory infections (ARI) are one of the leading causes of death in black South African children (Terblanche *et al*., 1993).

Residential areas within the study region where household fuel burning is prevalent (specifically during the winter time for space heating purposes) include Phola, Botleng (near Delmas), Kungwini / Zithobeni (near Bronkhorstpruit) and Vosman, Hlalanikahle and KwaGuqa (near Witbank). Elevated health risks are expected to occur in these areas due to inhalation exposures to indoor and ambient air pollutant concentrations, specifically fine particulates, arising due to fuel burning. Maximum highest daily PM10 concentrations (~200 µg/m³) and annual average PM10 concentrations (~80 µg/m³) predicted for these areas are well in excess of air quality and health limits.

6.3.1.2 Increment in health risks due to sulphur dioxide concentrations

Elevated sulphur dioxide concentrations in the study area are associated with significant health risk potentials, particularly where such concentrations coincide with elevated fine particulate concentrations such as in household fuel burning areas.

Sulphur dioxide concentrations occurring due to base case conditions are predicted to be associated with potentially “high” health risks within the Phola residential area. The California EPA Acute Reference Exposure Level for sulphur dioxide (above which mild respiratory effects may occur) having been predicted to be exceeded in this residential area. Exceedances of the reference exposure level were however infrequent. Whether or not health effects occur is dependent on whether persons sensitive to the impacts of sulphur dioxide are exposed at the time of the exceedance.

6.3.2 Proposed Exposures to Sulphur Dioxide Concentrations

Based on the health-related dose-response thresholds for sulphur dioxide outlined in Section 2.4.2 and the classification of risks due to various sulphur dioxide concentrations by the UK (Section 2.4.1) 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 6.6 to 6.12 for basecase and proposed uncontrolled power station configurations, and in Figures 6.13 for Scenario A.2 (150 m stack) incorporating 90% control efficiency. Scenario B.2, C.2, D.2, E.2 and F.2 show similar impact to Scenario A.2 and thus were not included. 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 area of Phola 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 Phola residential area.

Sulphur dioxide concentrations occurring due to existing conditions are predicted to be associated with "high" health risks within the Phola residential area. The California EPA Acute Reference Exposure Level for sulphur dioxide (above which mild respiratory effects may occur) is predicted to be exceeded by ~80% for highest hourly ground level concentrations in the vicinity of Phola. Cumulative sulphur dioxide concentrations given the operation of an additional six 900 MW units at the sites proposed is projected to increase this concentrations to exceed the California EPA Acute reference exposure up to 150% for a 150m stack. The implementation of sulphur dioxide abatement measures comprising a 90% control efficiency would not significantly increase the exceedance of this health threshold above baseline levels.

A control efficiency of 90% would be required for all six units to prevent increments in health risk potentials above baseline conditions.

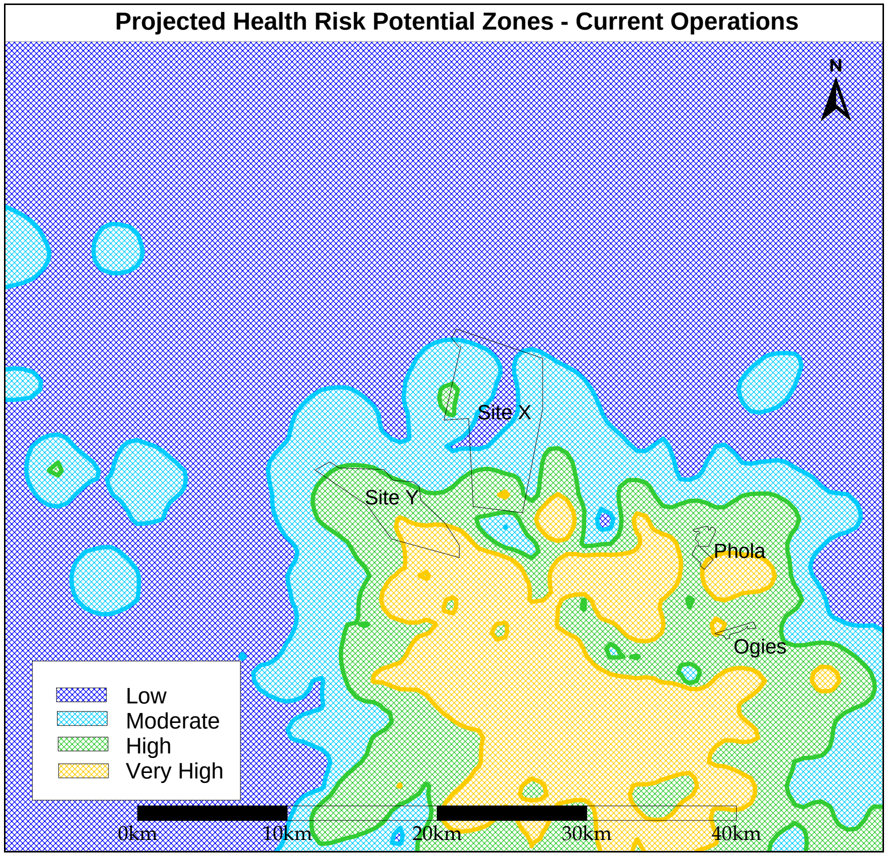


Figure 6.6 Projected health risk potential zones for current Operations

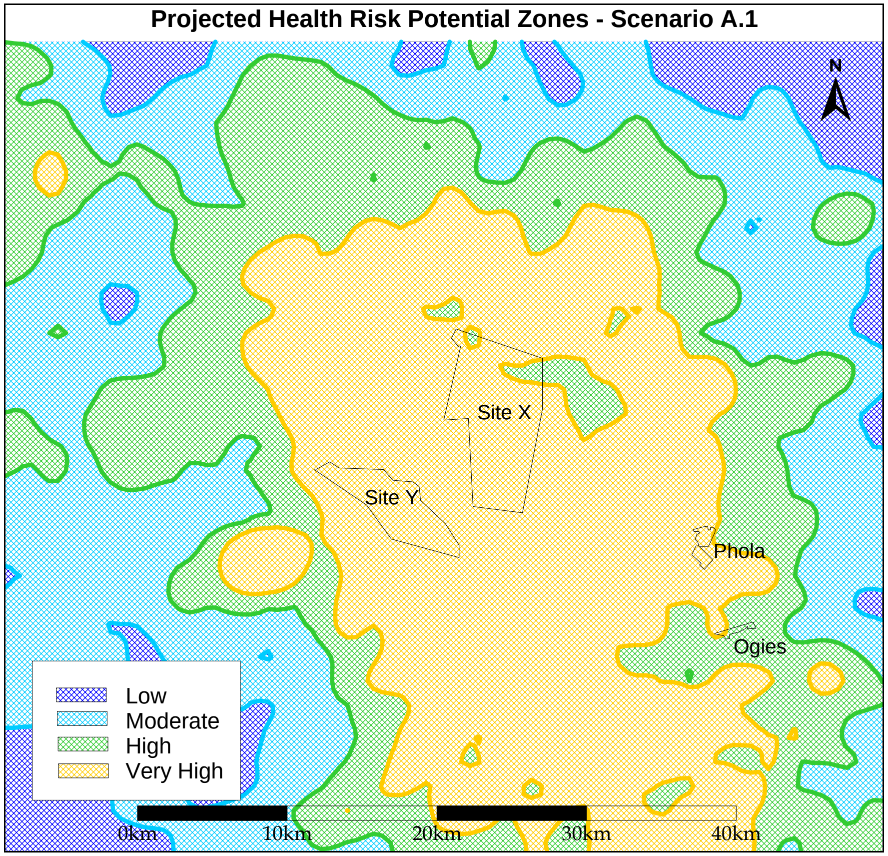


Figure 6.7 Projected health risk potential zones for Scenario A1 Operations (i.e. 6 x 900 MW PF units, 150 m stack, uncontrolled, at Site X)

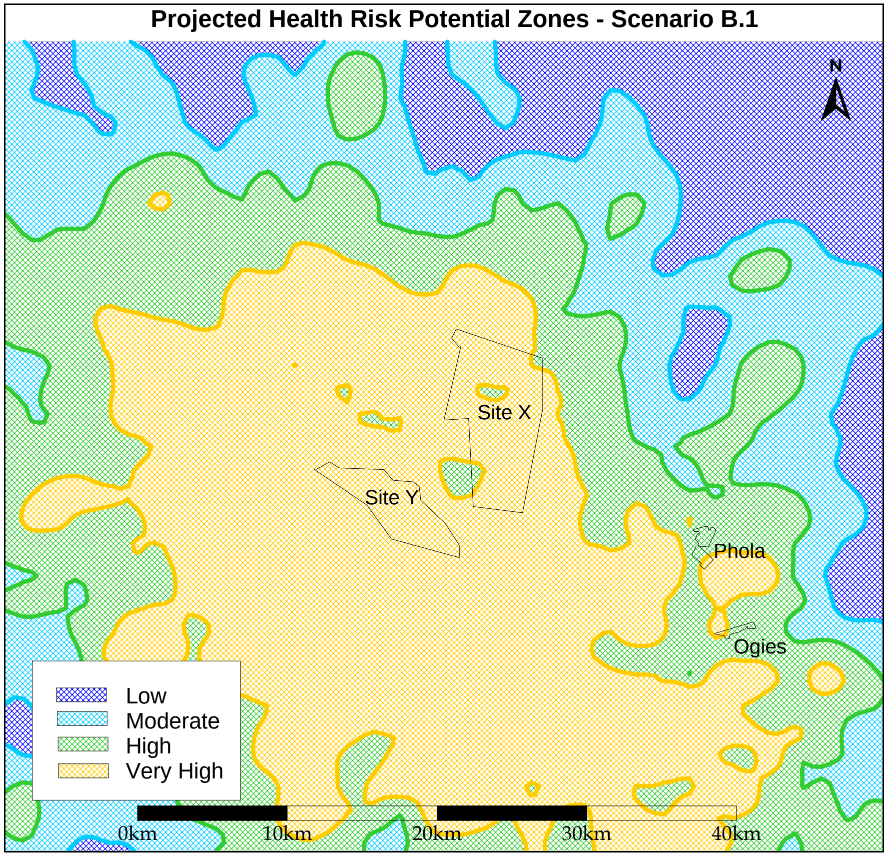


Figure 6.8 Projected health risk potential zones for Scenario B1 Operations (i.e. 6 x 900 MW PF units, 150 m stack, uncontrolled, at Site Y)

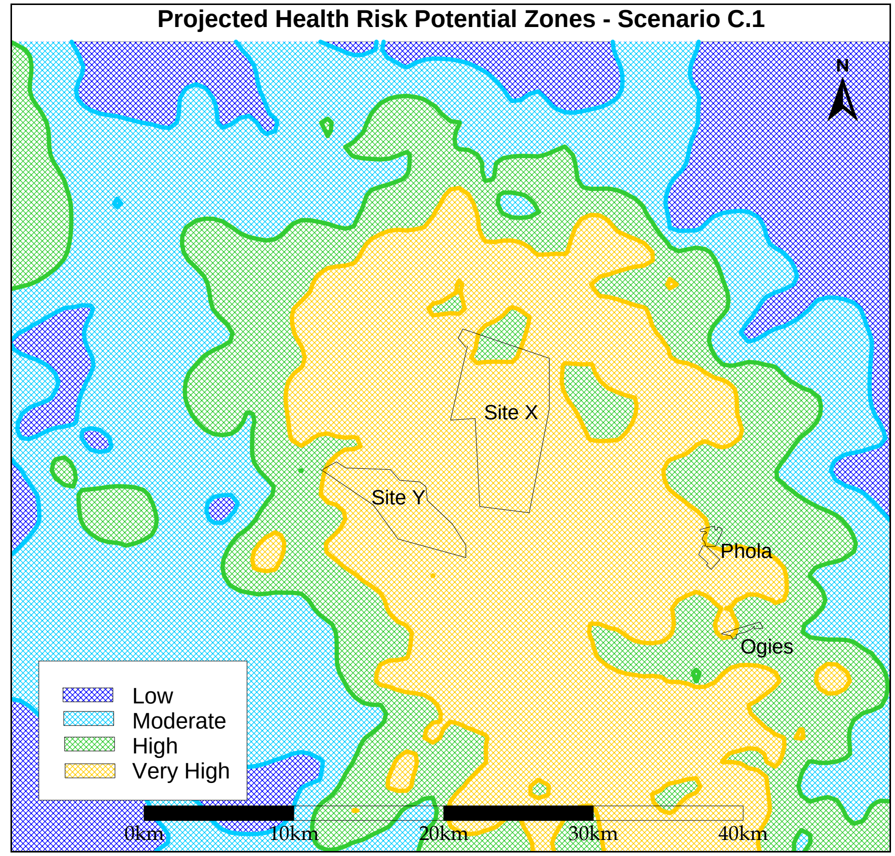


Figure 6.9 Projected health risk potential zones for Scenario C1 Operations (i.e. 6 x 900 MW PF units, 220 m stack, uncontrolled, at Site X)

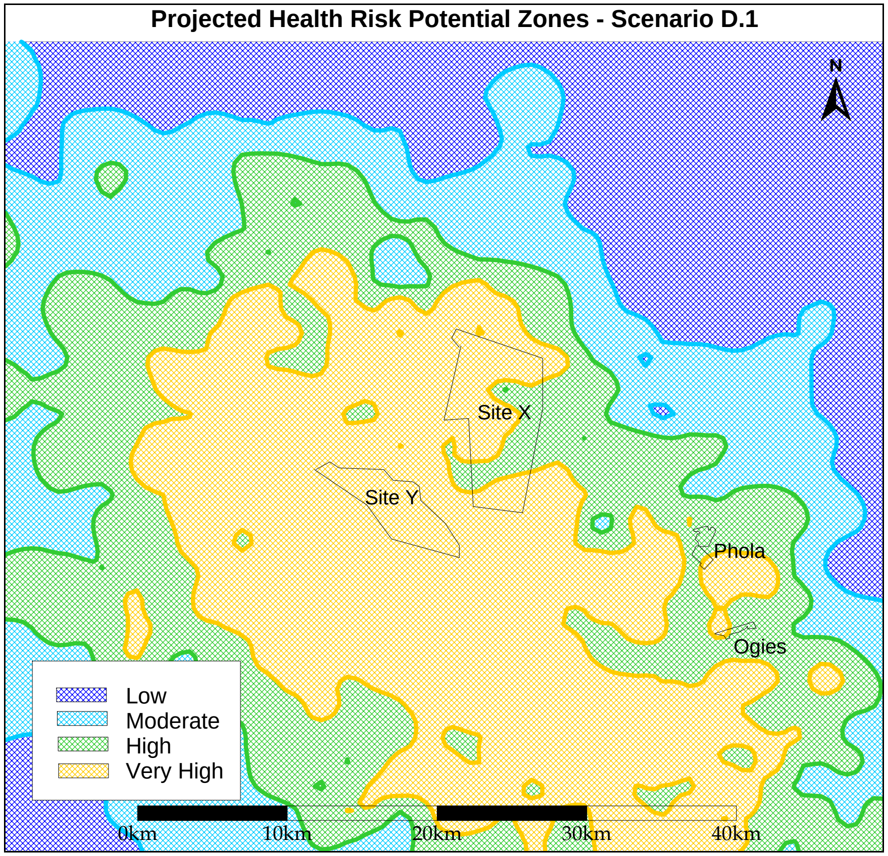


Figure 6.10 Projected health risk potential zones for Scenario D1 Operations (i.e. 6 x 900 MW PF units, 220 m stack, uncontrolled, at Site Y)

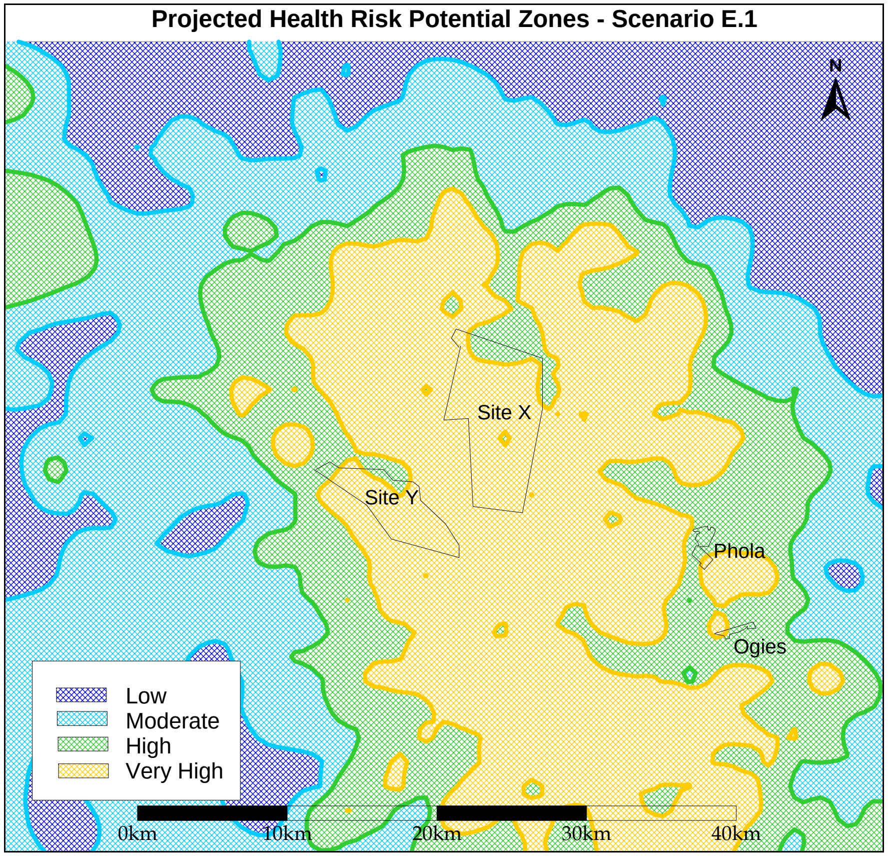


Figure 6.11 Projected health risk potential zones for Scenario E1 Operations (i.e. 6 x 900 MW PF units, 300 m stack, uncontrolled, at Site X)

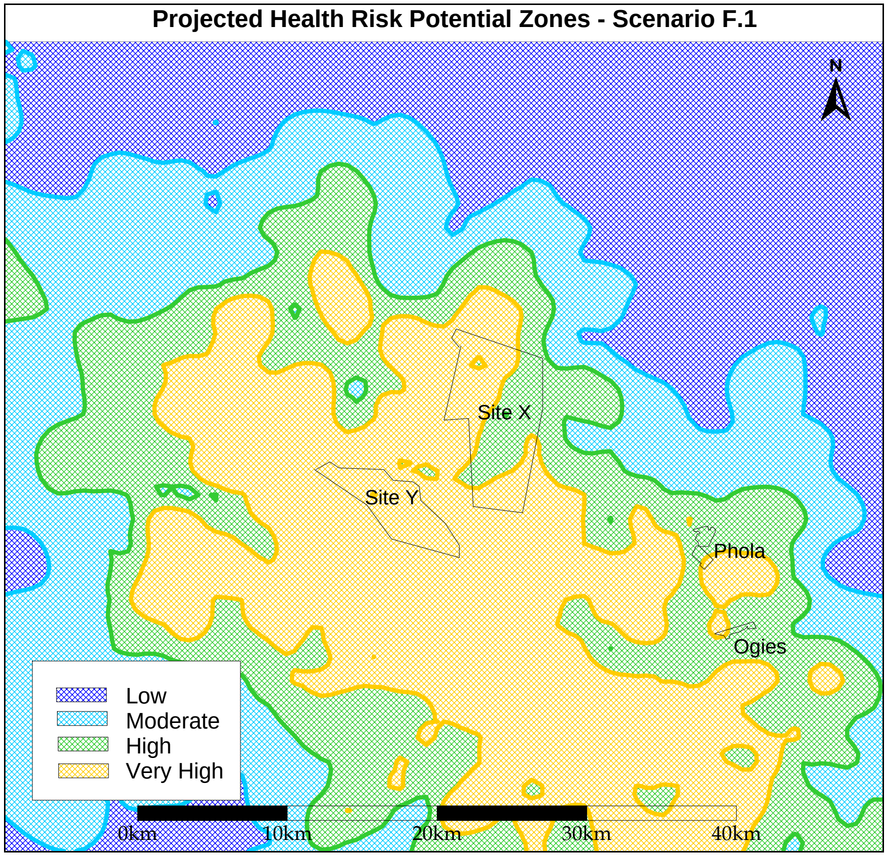


Figure 6.12 Projected health risk potential zones for Scenario F1 Operations (i.e. 6 x 900 MW PF units, 300 m stack, uncontrolled, at Site Y)

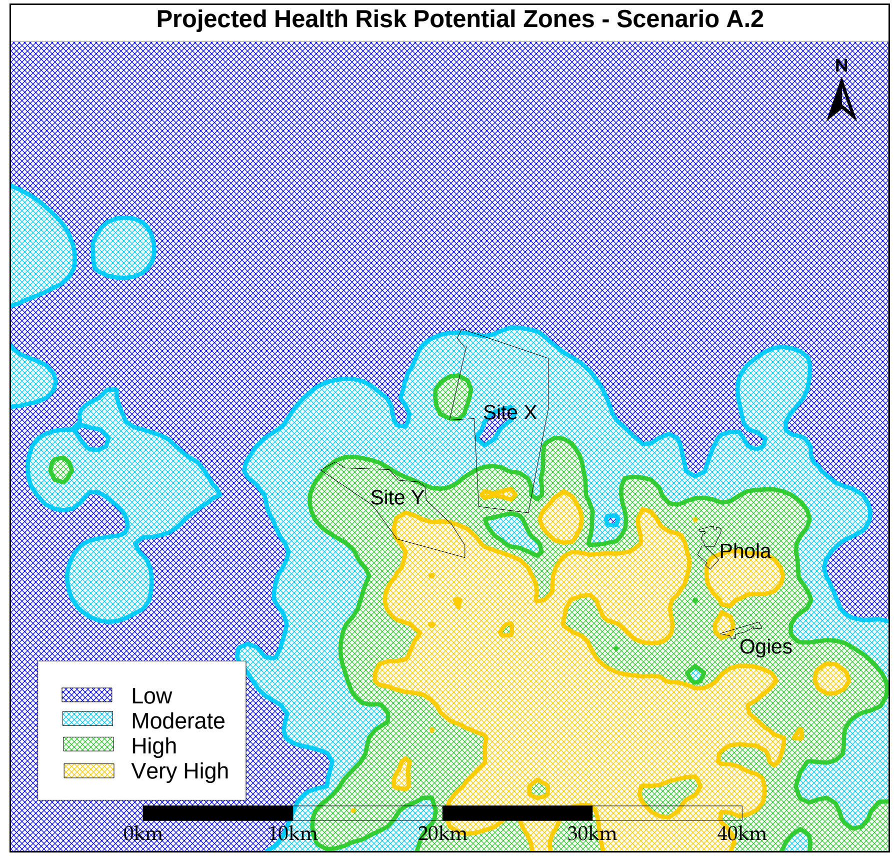


Figure 6.13 Projected health risk potential zones for Scenario A2 Operations (i.e. 6 x 900 MW PF units, 150 m stack, 90% CE, at Site X)

Table 6-3 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 hourly sulphur dioxide concentrations (µg/m³)
	Phola
Current Operations	high
Future Operations (Basecase)	high
Scenario A1 – 6 x 900 MW Units, Site X, 150 m stack - 0% CE	high
Scenario B1 – 6 x 900 MW Units, Site Y, 150 m stack - 0% CE	high
Scenario C1 – 6 x 900 MW Units, Site X, 220 m stack - 0% CE	high
Scenario D1 – 6 x 900 MW Units, Site Y, 220 m stack - 0% CE	high
Scenario E1 – 6 x 900 MW Units, Site X, 300 m stack - 0% CE	high
Scenario F1 – 6 x 900 MW Units, Site Y, 300 m stack - 0% CE	high
Scenario A2 – 6 x 900 MW Units, Site X, 150 m stack - 90% CE	high
Scenario B2 – 6 x 900 MW Units, Site Y, 150 m stack - 90% CE	high
Scenario C2 – 6 x 900 MW Units, Site X, 220 m stack - 90% CE	high
Scenario D2 – 6 x 900 MW Units, Site Y, 220 m stack - 90% CE	high
Scenario E2 – 6 x 900 MW Units, Site X, 300 m stack - 90% CE	high
Scenario F2 – 6 x 900 MW Units, Site Y, 300 m stack - 90% CE	high

(a) All proposed power station configurations simulated together with the projected sources of emissions (Eskom and non-Eskom sources) to determine potential for cumulative sulphur dioxide concentrations.

Important point 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.)

The exposure potential due to the various scenarios is given in **Appendix G**. From the additional exposure potential due to the activities of the proposed new power station, it is concluded that for uncontrolled scenarios, Site X is more preferable than Site Y with a stack height of 220m to 300m. For controlled scenarios Site X is the preferable location for the power station with a 220m stack height.

6.3.3 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 Kendal Power Station operations in addition to a proposed 5400 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 6.4). Cancer risks were calculated to be very low, with total incremental cancer risks across all carcinogens quantified to be in the range of 1: 4.5 million to 1: 10 million.

Table 6-4 Cancer risks calculated due to inhalation exposures to individual carcinogens predicted to be emitted from the existing Kendal Power Station and proposed (5400 MWe) Kendal North 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	19,921,504	6,949,362
Nickel	A	21,073,406	13,309,520
Lead	B2	608,446,968	608,446,968
Total incremental cancer risk across all carcinogens quantified		10,071,131	4,531,534

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 dumps. 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 6.5. 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.

In the simulation of ambient mercury concentrations and resultant air quality impacts reference was made to the maximum emission rates (i.e. 10.55 tpa for proposed Kendal North operations). The maximum highest hourly, highest daily and annual average ground level mercury concentrations occurring as a result of existing Kendal and Proposed Kendal North Power Station emissions is given in Table 6.6.

The predicted maximum hourly, daily and annual average concentrations were well-within the most stringent of the guidelines given for public exposures to ambient mercury concentrations intended for the inhalation pathway (e.g. WHO, US-EPA inhalation reference concentrations, Californian RELs).

Table 6-5 Predicted ambient trace metal concentrations (in the PM10 range) due to existing Kendal and proposed Kendal North 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	Annual Average	Acute Health Threshold	Sub-acute 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	Annual Average Concentration as a Fraction of the Chronic Threshold
As	3.60E-03	4.93E-04	3.35E-05	0.19		0.03	0.01893		0.00112
Ba	5.12E-01	5.91E-02	2.67E-03	50		5	0.01025		0.00053
Bi	1.55E-03	1.84E-04	9.01E-06						
Co	4.75E-03	5.30E-04	2.16E-05			0.1			0.00022
Cr	7.01E-02	9.64E-03	6.61E-04			0.1			0.00661
Cu	1.65E-02	1.85E-03	7.60E-05	100		1	0.00017		0.00008
Ga	1.66E-02	1.84E-03	7.33E-05						
Ge	2.05E-03	2.41E-04	1.16E-05						
Pb	2.17E-02	2.63E-03	1.37E-04			0.5			0.00027
Hg	3.92E-04	3.87E-05	8.76E-07	1.8		0.09	0.00022		0.00001
Ni	2.82E-02	3.52E-03	1.98E-04	6		0.05	0.00470		0.00395
Nb	1.64E-02	1.70E-03	5.13E-05						
Rb	1.53E-02	1.82E-03	8.97E-05						
Se	5.20E-01	6.19E-02	3.07E-03			20			0.00015
Th	7.39E-03	1.44E-03	1.16E-04						
Sn	3.92E-03	4.87E-04	2.71E-05	20		2	0.00020		0.00001
W	3.10E-03	4.23E-04	2.85E-05	10		1	0.00031		0.00003
U	3.40E-03	4.41E-04	2.71E-05			0.3			0.00009
V	4.22E-02	4.86E-03	2.19E-04		0.2			0.02431	
Y	2.46E-02	2.83E-03	1.27E-04						
Zn	1.82E-02	2.01E-03	7.93E-05	50		5	0.00036		0.00002
Zr	1.39E-01	1.51E-02	5.68E-04	50		5	0.00278		0.00011

Table 6-6 Predicted mercury concentrations given existing Kendal and proposed Kendal North Power Station emissions with reference to applicable guidelines intended to protect human health.

	PREDICTED MERCURY CONCENTRATIONS GIVEN EXISTING AND PROPOSED 4800 MW POWER STATION OPERATIONS		
	Highest Hourly (µg/m³)	**Highest Daily (µg/m³)**	**Annual Average (µg/m³)**
Predicted Maximum Total Hg GLCs (µg/m³)	0.18	0.04	0.003
	RELEVANT GUIDELINES (µg/m³)		
WHO Guideline Value			1.00
US-EPA inhalation reference concentration			0.30
Texas Effect Screening Levels	0.25		0.025
California RELs	1.8		0.09
DEAT Mercury Guideline (a)			0.04

REL – reference exposure level; GLCs – ground level concentrations; DEAT – Department of Environmental Affairs and Tourism
(a) Published in DEAT document "Technical Background Document for Mercury Waste Disposal" (2001).

It is noted that the major pathway for mercury exposures is ingestion rather than inhalation. For this reason reference was made to the DEAT mercury guideline which was intended to be protective given multiple pathways of exposure. This guideline value (given as 0.04 µg/m³ for chronic exposures) was derived during a recent study initiated by the Department of Environmental Affairs and Tourism. This study included health-risk based research relating to human exposure to mercury and engineering reviews of treatment and disposal options for mercury waste. The purpose of such studies was twofold: (i) to support the drafting of national regulations for mercury waste disposal; and (ii) to provide specific guidance on how best to deal with the mercury waste stockpiled at the Thor Chemical's plant at Cato Ridge, Kwazulu-Natal. The health risk study determined that ambient long-term concentrations of mercury of lower than 0.04 µg/m³ would not result in unacceptable multi-pathway risk given local environments. This guidance is currently being used by the DEAT to assess the acceptability of mercury waste treatment and disposal options.

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 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

A synopsis of vegetation injury and corrosion potential characterisation is discussed in Appendix E. The potential for vegetation damage and corrosion due to current predicted ambient sulphur dioxide concentrations is classifiable as “low” to “medium” to the north and south of the proposed Kendal North Power station sites respectively (Figure 6.14). A small portion of the study area was classified as “high” vegetation damage over the existing Kendal Power Station site. The operation of a 5400 MWe power station at the proposed site is predicted to result in “high” risks for vegetation damage and “medium” risks for corrosion over a large portion of the study area should no sulphur dioxide abatement measures be implemented (Figure 6.15 to Figure 6.20). Sulphur dioxide abatement with a 90% control efficiency would result in the potential for corrosion and vegetation damages being classified as “medium” over a large portion of the study area and “high” vegetation injury over the existing Kendal Power Station area (Figure 6.21).

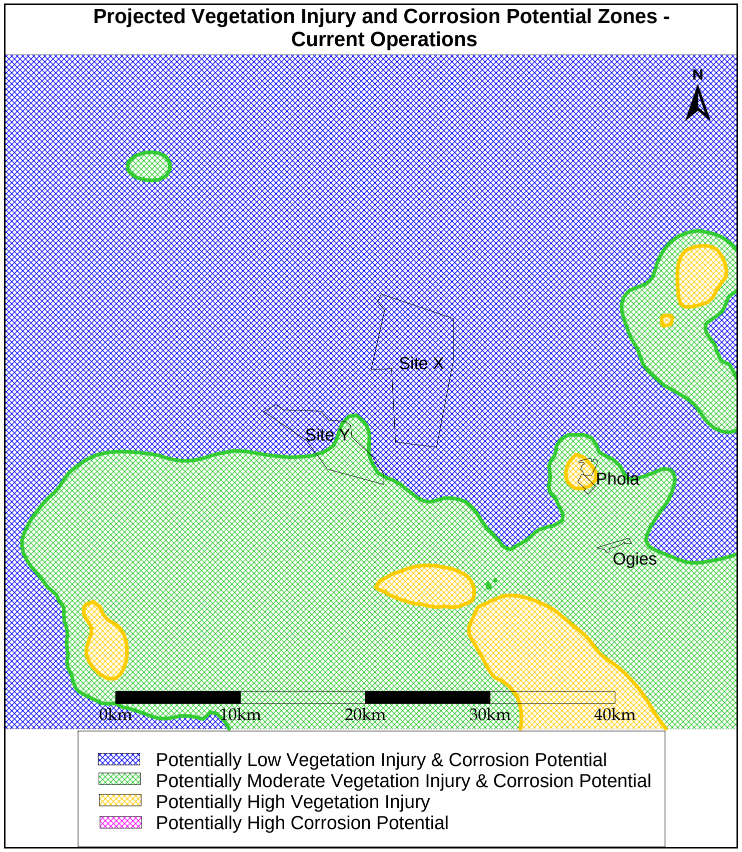


Figure 6.14 Projected vegetation damage and corrosion potential zones for Current Operations

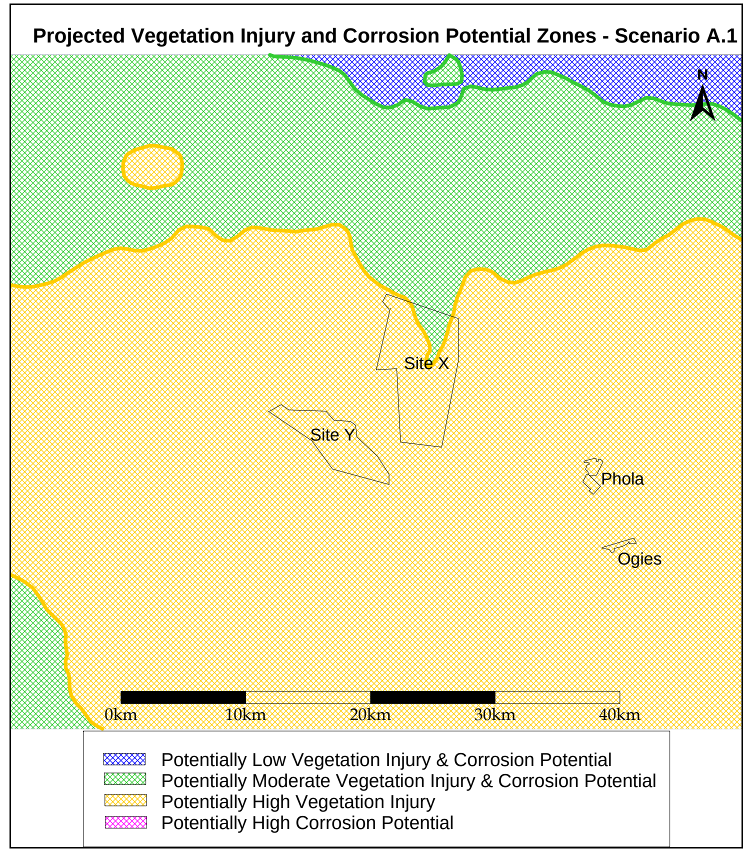


Figure 6.15 Projected vegetation damage and corrosion potential zones for Scenario A1 Operations(i.e. 6 x 900 MW units, Site X, 150 m stack, no control efficiency)

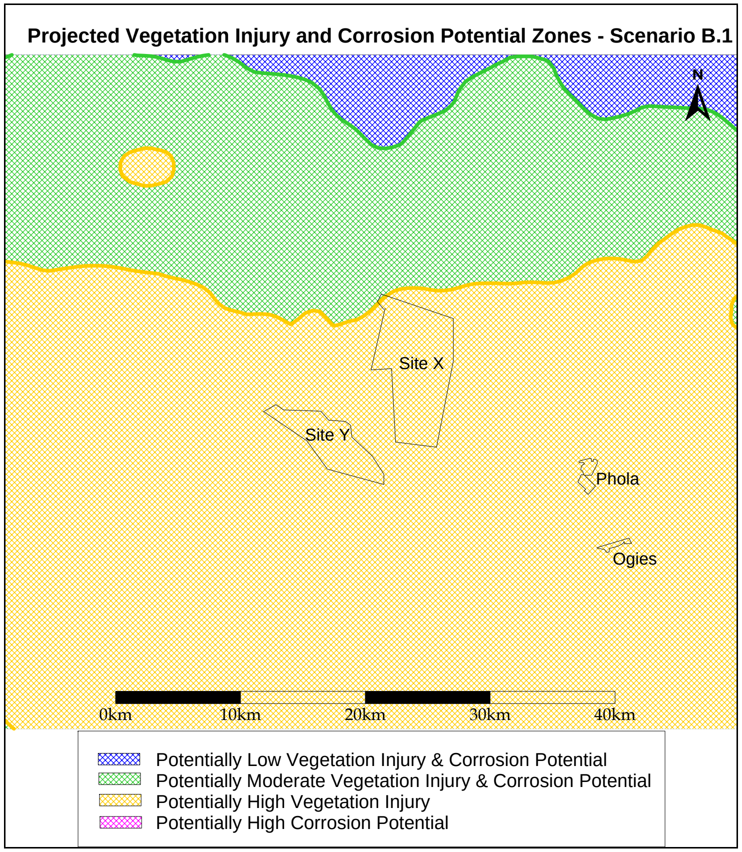


Figure 6.16 Projected vegetation damage and corrosion potential zones for Scenario B1 Operations(i.e. 6 x 900 MW units, Site Y, 150 m stack, no control efficiency)

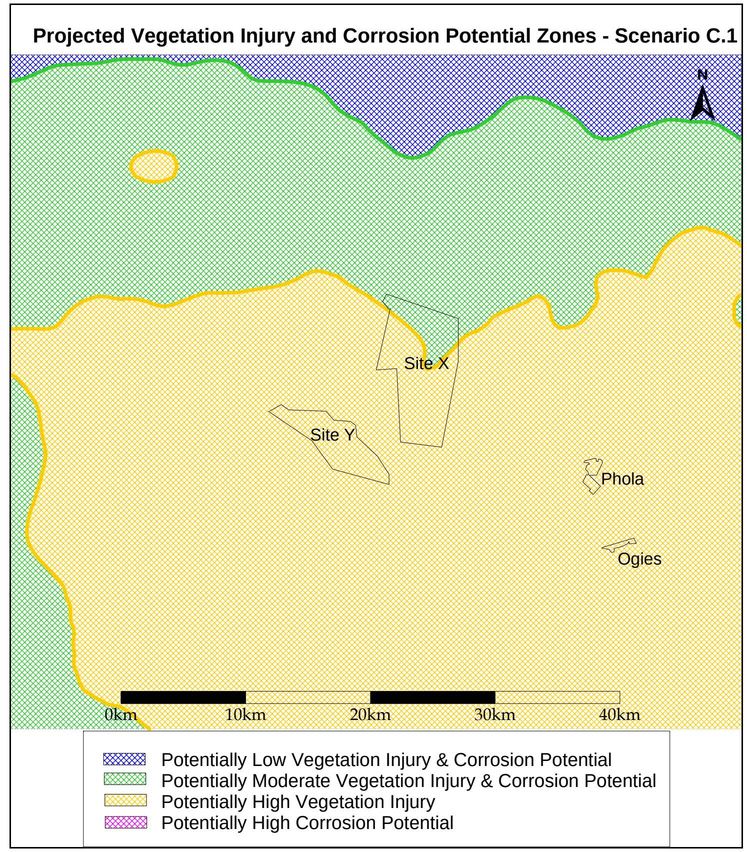


Figure 6.17 Projected vegetation damage and corrosion potential zones for Scenario C1 Operations(i.e. 6 x 900 MW units, Site X, 220 m stack, no control efficiency)

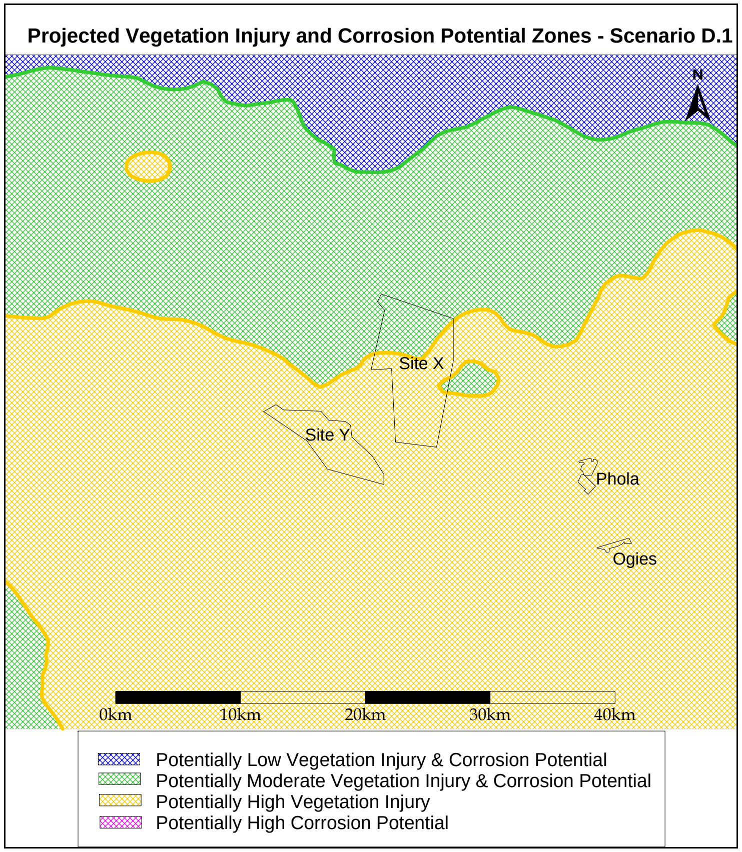


Figure 6.18 Projected vegetation damage and corrosion potential zones for Scenario D1 Operations(i.e. 6 x 900 MW units, Site Y, 220 m stack, no control efficiency)

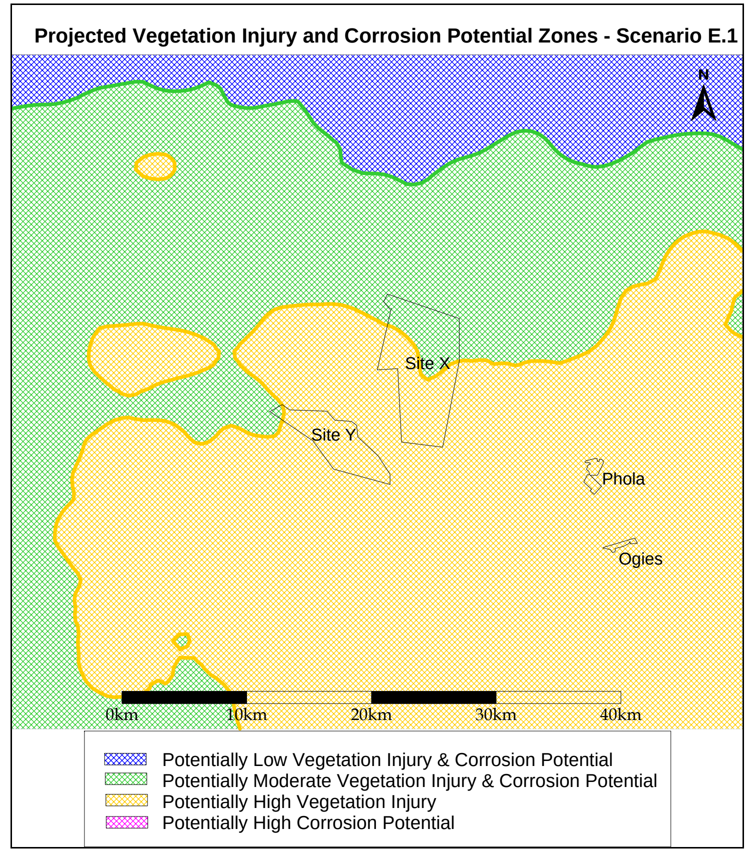


Figure 6.19 Projected vegetation damage and corrosion potential zones for Scenario E1 Operations(i.e. 6 x 900 MW units, Site X, 300 m stack, no control efficiency)

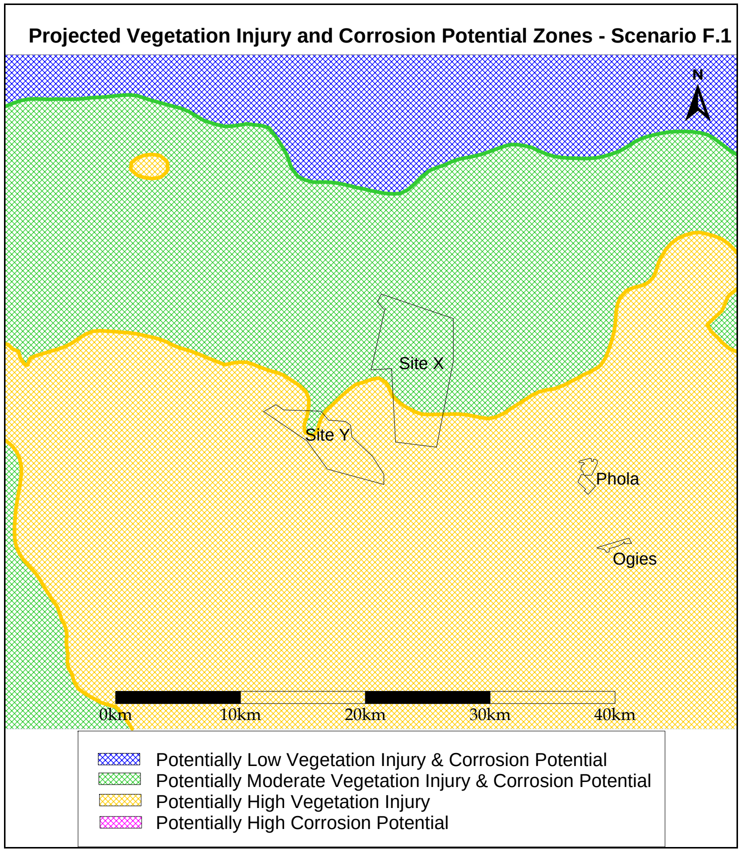


Figure 6.20 Projected vegetation damage and corrosion potential zones for Scenario F1 Operations(i.e. 6 x 900 MW units, Site Y, 300 m stack, no control efficiency)

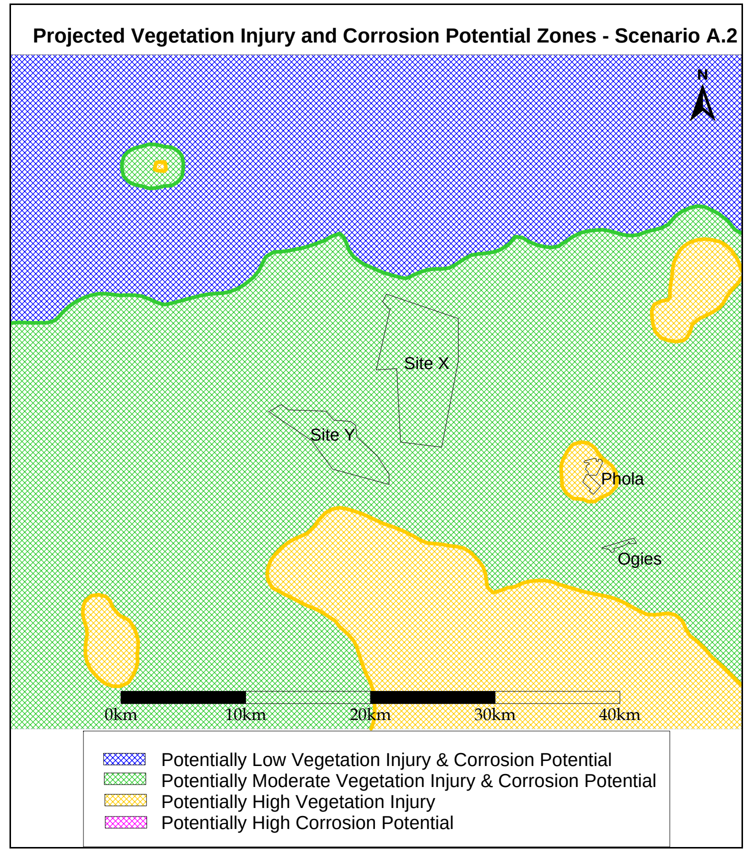


Figure 6.21 Projected vegetation damage and corrosion potential zones for Scenario A1 Operations(i.e. 6 x 900 MW units, Site X, 150 m stack, 90% control efficiency) – Scenario B2, C2, D2, E2 and F2 similar in impact over the study area to Scenario A2.

6.5 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[(8)] (Table 6.7). Total greenhouse gas emissions reported to be emitted within South Africa for the year 1994, expressed as CO_2 equivalents, are given in Table 6.8. No more recent data are available.

Table 6-7 Calculated CO_2 equivalent emissions from proposed power station operations

		Annual Emissions		Annual Emissions
		CO_2	N_2O	CO_2 Equivalent
Power Station Capacity	**Coal Consumption (tpa)**	**kT/ann**	**kT/ann**	**kT/ann**
5400 MWe	21,088,567	29,895	0.342	36,831

Table 6-8 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 5400 MWe power station would increase the energy sectors emissions by 12.8% and would increase the country's contribution to global warming by 9.7%

[8] 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).

7. RECOMMENDATIONS AND CONCLUSIONS

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 exceed short-term air quality limits at Kendal 2 within exceedance of such limits modelled to occur at the nearby residential area of Phola.

  The Kendal 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 mining operations (not quantified in the current study) and potentially household fuel burning within Phola. The highest ground level concentrations due to the Kendal 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 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 predicted to be exceeded at Phola.

  - Predicted sulphur dioxide concentrations were within limits indicative of low to medium corrosion potentials over the study area.

  - Predicted sulphur dioxide concentrations exceeded 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 to be exceeded over the entire study area.

- Kendal Power Station contributes to ambient **nitrogen oxide** and nitrogen dioxide concentrations in the region, with short-term international air quality limit exceedances predicted, to occur over sections in the study area. However, other significant low level sources of NO_x anticipated to occur in the region include combustion within coal discard dumps (not quantified in the current study), vehicle tailpipe emissions, household fuel burning and infrequent veld burning (not quantified in the current study).

- Ambient **PM10** concentrations were predicted to exceed the current lenient SA Standards (as given in the second schedule of the Air Quality Act) and the more stringent SANS and EC limit values over built up residential areas.

  The contribution of the Kendal Power Station to primary and secondary particulates was simulated. (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 operations, vehicle entrainment from roadways and veld burning. Household fuel burning also constitutes 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 Kendal 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 dump. Ground level concentrations due to gaseous mercury are predicted to be well within health effect screening levels.

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.

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:

Scenario	No. of Units	Site	Stack Height (m)	SO_2 Control Efficiency
A.1	6 x 900 MW	Site X	150	0%
B.1	6 x 900 MW	Site Y	150	0%
C.1	6 x 900 MW	Site X	220	0%
D.1	6 x 900 MW	Site Y	220	0%
E.1	6 x 900 MW	Site X	300	0%
F.1	6 x 900 MW	Site Y	300	0%
A.2	6 x 900 MW	Site X	150	90%
B.2	6 x 900 MW	Site Y	150	90%
C.2	6 x 900 MW	Site X	220	90%
D.2	6 x 900 MW	Site Y	220	90%
E.2	6 x 900 MW	Site X	300	90%
F.2	6 x 900 MW	Site Y	300	90%

7.2.1 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.)

7.2.1.1 Nitrogen Oxides

Predicted NO and NO_2 hourly concentrations were predicted to exceed SA nitric acid standard and the SANS/EC limit respectively (including cumulative concentrations due to existing sources of emissions). The daily and annual average ground level concentrations are within relevant standards. Although the coal fired power stations in the area contribute to the ambient oxides of nitrogen concentrations, other sources of NO_x emissions in the area include domestic fuel burning, vehicle tailpipe emissions and other industrial activity. (Appendix D).

7.2.1.2 Airborne Fine Particulates and Dust Deposition

Predicted PM10 concentrations were within the SA daily and annual standards but exceeded the SANS and EC daily limit values in the vicinity (within 10 km east) of the ash dump. Public exposure within this area is restricted to scattered farmsteads with an average residential density of ~5 persons/km². Other areas of exceedance are over built up areas with ground level concentrations originating from low-level sources of emission (i.e. domestic fuel burning).

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

7.2.1.3 Sulphur Dioxide - Uncontrolled

Emissions from the existing Kendal 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 due to basecase and all proposed configurations. At Phola the SA 10-minute standard is exceeded for basecase and all proposed configurations.

- Under current operations there is predicted to be compliance with the UK hourly sulphur dioxide standard at Phola. This standard is however exceeded at Phola with the addition of six 900 MW units.

- The increase of the stack height from 220 m to 300 m is predicted to result in relatively small cumulative reductions in ground level maximum.

It may be concluded that the addition of 6 new 900 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. The extension of the height of the stack by 80 m, from 220 m to 300 m, is not sufficient to negate the need for considering abatement measures.

7.2.1.4 Sulphur Dioxide Emissions - Controlled

Changes in projected ground level sulphur dioxide concentrations and limit value exceedances were simulated for a 90% control efficiency for three proposed power station configurations, viz. Scenario A and B (150 m stack), Scenario C and D (220 m stack) and Scenario E and F (300 m stack) at two different sites, viz. Site X and Site Y. Observations made regarding compliance implications of various power station configurations given controlled emissions were as follows:

- Even given a 90% control efficiency for all power station configurations, cumulative sulphur dioxide concentrations would exceed the SA 10-minute standard at the maximum impact zone and at Phola and the SA daily standard in the maximum impact zone and Phola – primarily due to emissions from the existing Kendal Power Station.

- With the addition of six new units operating coincident with the existing Kendal 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 Phola would be *marginally* higher than for current operations.

7.2.2 Potential for Health Effects due to Proposed Power Station Operations

Sulphur dioxide concentrations occurring due to existing conditions are predicted to be associated with “high” health risks within the Phola residential area. The California EPA Acute Reference Exposure Level for sulphur dioxide (above which mild respiratory effects may occur) is predicted to be exceeded by ~80% for highest hourly ground level concentrations in the vicinity of Phola. Cumulative sulphur dioxide concentrations given the operation of an additional six 900 MW units at the sites proposed is projected to increase this concentrations to exceed the California EPA Acute reference exposure up to 150% for a 150m stack. The implementation of sulphur dioxide abatement measures comprising a 90% control efficiency would not significantly increase the exceedance of this health threshold above baseline levels.

Significance of stack height – If uncontrolled the proposed power station with a 150 m stack would result in the most significant non-compliance with SO_2 limits and pose the greatest risk to sensitive receptors. Reduced impact potentials can be realised through the extension to ~220 m. Further increments in the stack height were predicted to realise only minor further reductions in ground level concentrations and were associated with potentially more persons being exposed to sulphur dioxide concentrations in excess of air quality limits (due to the larger sphere of influence of the power station).

Significance of site selection – Compliance and exposure potential results for the two candidate sites were mixed(9) with neither of the sites being identified as being considerably better than the other site. It is therefore recommended that the site selection be assessed in terms of other criteria.

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: 4.5 million to 1: 10 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.

Ground level concentrations due to gaseous mercury are predicted to be well within health effect screening levels.

7.2.3 Potential for Vegetation Injury and Corrosion

The operation of a 5400 MWe power station at the proposed sites is predicted to result in "high" risks for vegetation damage and "medium" risks for corrosion over a large section of the study area if uncontrolled. Sulphur dioxide abatement with a 90% control efficiency would result in the potential for corrosion and vegetation damages for these areas being similar to baseline levels. It should be noted, however, that the dose-response thresholds

[9] For the uncontrolled scenario, a new power station at Site X results in a slightly fewer SO_2 exceedance events with respect to the SA 10-minute and average daily concentrations limits than at Site Y, in the area of maximum ground level concentration. However, when comparing the impact of the power station at Phola, Site Y resulted in fewer exceedances of the SA standards than at Site X. For the controlled scenario, Site X resulted in fewer exceedances than at Site Y, in the area of maximum ground level concentrations, but there was no difference in exceedances at Phola.

are based on studies abroad and may be conservative, given that much of the research supporting such thresholds was undertaken in more humid climates. It is therefore recommended that research be undertaken locally to determine local dose-response thresholds.

7.2.4 Contribution to Greenhouse Gas Emissions

The emissions from the proposed 5400 MWe power station would increase the energy sectors emissions by 12.8% and would increase the country's contribution to global warming by 9.7%

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 90% control efficiency would be required for the proposed 5400 MWe power station to ensure that it could operate coincident with the existing Kendal Power Station without substantial changes in the magnitude, frequency or spatial extent of non-compliance, nor significant increment in health risks. 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 Phola 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.

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APPENDIX A –

EXTRACT FROM DEAT ‘GUIDELINES FOR SCHEDULED PROCESSES’ (1994)

EXTRACT FROM DEAT 'GUIDELINES FOR SCHEDULED PROCESSES' (1994)

PROCESS 29: POWER GENERATION PROCESSES

Power generation processes: That is to say, processes in which-

(a) fuel is burned for the generation of electricity for distribution to the public or for purposes of public transport;

(b) boilers capable of burning fuel at a rate of not less than 10 tons per hour are used to raise steam for the supply or energy for purposes other than those mentioned in (a) above;

(c) a fuel burning appliance is used that is not controlled in terms of Part III of this Act, excluding appliances in private dwellings.

(a) Basic Information

(i) Low sulphur content of coal is detrimental to efficacy of electrofilter units.
(ii) 1 Ton/h coal produces 10 t/h steam = $\pm$ 22 GJ/h.
(iii) Standard cubic metre (Sm^3 means at 101,3 KPa and 0^{o}C.

(b) Guidelines

II PF plants:

(i) Existing plants: fly-ash emission limits:

discretion of control officer - gas conditioning if possible in which case the guidelines are as follows:

(1) 3-field electrofilter : 270 mg/Sm^3 (actual m^3)

(2) 2-field electrofilter : 320 mg/Sm^3 (actual m^3)

(ii) New Plants:

(1) not more than 100 mg/Sm^3 fly-ash.

(2) "Low NOx" burners must be used.

(3) All new plants to be fitted with opacity monitors - aim at 30% opacity - optical monitor must be fitted with time integrator having six minute intervals. Electrofilters to be fitted with secondary ammeters and voltmeters.

(4) At least 70% of sulphur in the coal must be removed or captured.

APPENDIX B –

ATMOSPHERIC DISPERSION SIMULATION METHODOLOGY

Dispersion Model Selection

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

Most regulatory dispersion models, such as the widely used Industrial Source Complex (ISC) model and the relatively new AERMOD model, are based on the steady-state plume assumption, with meteorological inputs for these models assuming a horizontally uniform flow field. Usually the winds are derived from a single point measurement, which is often made at a nearby non-complex terrain site. The meteorological processors for the regulatory models do not adjust the winds to reflect terrain effects. The steady-state flow fields either do not or only partially reproduce the terrain-induced spatial variability in the wind field. In addition to which, the straight-line trajectory assumption of the plume models cannot easily handle curved trajectories associated with terrain-induced deflection or channelling. These limitations of plume models can significantly affect the models ability to correctly represent the spatial area of impact from sources in complex terrain, in addition to the magnitude of the peak values in certain instances.

CALPUFF is a regional Lagrangian Puff model suitable for application in modelling domains of 50 km to 200 km. Due to its puff-based formulation the CALPUFF model is able to account for various effects, including spatial variability of meteorological conditions, dry deposition and dispersion over a variety of spatially varying land surfaces. The simulation of plume fumigation and low wind speed dispersion are also facilitated.

CALPUFF requires as a minimum the input of hourly average surface meteorological data. In order to take full advantage of the model's ability to simulate spatially varying meteorological conditions and dispersion within the convective boundary layer it is, however, necessary to generate a three-dimensional wind field for input to the CALPUFF model. The CALMET model may be used to generate such a three-dimensional wind field for input to the CALPUFF model.

The CALMET meteorological model contains a diagnostic wind field module that includes parameterized treatments of terrain effects, including slope flows, terrain channelling and kinematic effects, which are responsible for highly variable wind patterns. CALMET uses a two-step procedure for computing wind fields. An initial guess wind field is adjusted for terrain effects to produce a Step 1 wind field. The user specifies the vertical layers through which the domain wind is averaged and computed, and the upper air and surface meteorological stations to be included in the interpolation to produce the spatially varying guess field. The Step 1 (initial guess) field and wind observational data are then weighted through an objective analysis procedure to produce the final (Step 2) wind field. Weighting is undertaken through assigning a radius of influence to stations, both within the surface layer and layers aloft. Observational data are excluded from the interpolation if the distance between the station and a particular grid point exceeds the maximum radius of influence specified (EPA, 1995; Scire and Robe, 1997; Robe and Scire, 1998).

By using CALMET and CALPUFF in combination it is possible to treat many important complex terrain effects, including spatial variability of the meteorological fields, curved plume trajectories, and plume-terrain interaction effects. Maximum hourly average, maximum daily average and annual average concentrations will be simulated through the application of CALPUFF, using as input the relevant emissions data and the three-dimensional CALMET data set.

Chemical Transformation Modelling

CALPUFF allows for first order chemical transformation modelling to determine gas phase reactions for SO_x and NO_x. Chemical transformation rates were computed internally by the model using the RIVAD/ARM3 Scheme. This scheme allows for the separate modelling of NO_2 and NO, whereas the default MESOPUFF II Scheme only makes provision for the combined modelling of NO_x. The RIVAD/ARM3 scheme treats the NO and NO_2 conversion process in addition to the NO_2 and total NO_3 and SO_2 to SO_4 conversions, with equilibrium between gaseous HNO_3 and ammonium nitrate aerosol. The scheme uses user-input ozone data (together with modelled radiation intensity) as surrogates for the OH concentration during the daytime when gas phase free radical chemistry is active.

Dispersion Model Data Requirements

Receptor Locations and Modelling Domain

A modelling domain was defined in order to encapsulate the existing power stations and the RTS and proposed power stations, and the maximum impact zones of such stations. The extent of this domain is demonstrated in Figure B.1. The meteorology was modelled and the dispersion of pollutants simulated for the entire area covering ~160 km (east-west) by 108 km (north-south), with ambient ground-level concentrations and deposition levels being predicted for over 17 280 receptor points. The regular Cartesian receptor grid selected has a resolution of 1 770 m by 1 770 m. Discrete receptor points were specified for each of the monitoring station locations to facilitate the simulation of concentrations and deposition at these locations for application in the validation and calibration of the model.

Meteorological Data Inputs

CALMET was used to simulate the meteorological field within the study area, including the spatial variations – both in the horizontal and in the vertical - and temporal variations in the windfield and atmospheric stability. *Upper air data* required by CALMET include pressure, geopotential height, temperature, wind direction and wind speed for various levels. No upper air monitoring stations are located within the Mpumalanga Highveld region with the nearest SAWS station being located at Irene, Tshwane Municipality. Use was therefore made of

ETA-model data for twelve locations as obtained from the SAWS. Twice daily data were obtained for five sounding levels. The initial guess field in CALMET was therefore determined as a combined weighing of surface winds at nine Eskom monitoring stations and ten SAWS stations, vertically extrapolated using Similarity Theory (Stull, 1997) and upper air winds. Eskom monitoring stations for which data were obtained were Verkykkop, Elandsfontein, Kendal 2, Leandra, Majuba 1, Majuba 3, Makalu, Palmer, and Camden. The SAWS stations used in the study were Johannesburg, Irene, Vereeniging, Witbank, Leandra, Ermelo, Standerton, Newcastle, Verkykkop and Bethal (see Figure B.1).

The CALMET meteorological model requires hourly average *surface data* as input, including wind speed, wind direction, mixing depth, cloud cover, temperature, relative humidity, pressure and precipitation. The mixing depth is not readily measured and needed to be calculated based on readily available data, viz. temperature and predicted solar radiation. The daytime mixing heights were calculated with the prognostic equations of Batchvarova and Gryning (1990), while night-time boundary layer heights were calculated from various diagnostic approaches for stable and neutral conditions. The data availability for each of the surface and upper-air stations used in the current study is given in Table B.1.

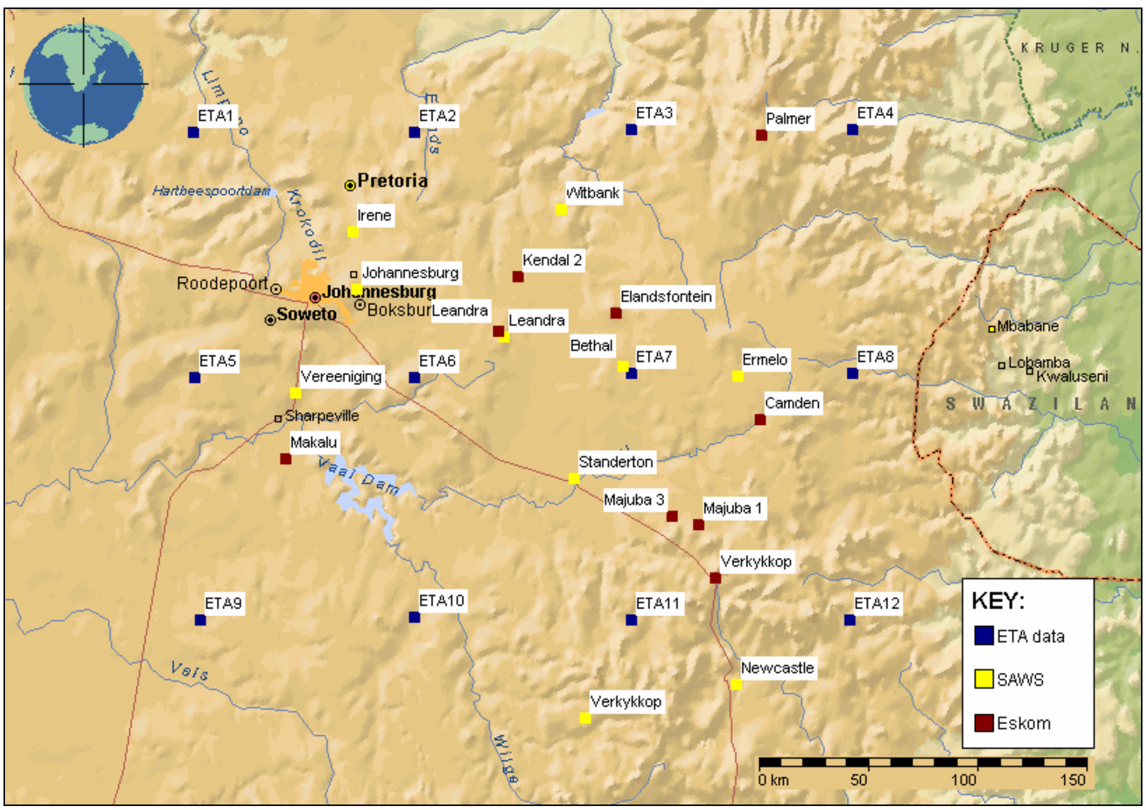

Figure B.1 Location of the ETA-model data points as well as Eskom and SAWS surface monitoring stations for which data were obtained for the simulation of the meteorological field.

A three dimensional meteorological data set for the region was output by the CALMET model for application in the CALPUFF model. This data set parameterised spatial (horizontal and vertical) and temporal variations in the parameters required to model the dispersion and removal of pollutants, including: vertical wind speed, wind direction, temperature, mixing depths, atmospheric stability, (etc.). Meteorological parameters were projected at various heights above the ground, viz.: 20m, 200m, 500m, 1500m, and 3000m. In projecting vertical changes in the windfield, temperature (etc.) it was possible to accurately parameterize the atmospheric conditions characteristic of within valley layers, transitional layers and atmospheric layers located above the terrain. The three-dimensional data set was generated for the base-case years selected (2001 to 2003) and comprised hourly averages for each parameter, thus providing information for each time interval required by the non-steady state CALPUFF dispersion model. For the current study, the base case meteorological year of 2001 was selected for dispersion modelling purposes, giving the most conservative impact results.

Table B.1 Data availability for surface and upper air data for the period 2001 to 2003.

Data	Station	Period		
		2001	2002	2003
Surface data (SAWS)	Johannesburg	100%	100%	96%
	Irene	99%	91%	92%
	Vereeniging	92%	89%	89%
	Witbank	100%	98%	94%
	Leandra (1)	4%	4%	4%
	Ermelo	100%	100%	99%
	Standerton	90%	97%	95%
	Newcastle	92%	100%	95%
	Verkykkop (1)	4%	4%	4%
	Bethal	12%	12%	10%
Surface data (Eskom)	Verkykkop (VE)	74%	34%	90%
	Elandsfontein (EL)	100%	91%	79%
	Kendal 2 (K2)	93%	96%	100%
	Leandra (LS)	92%	100%	100%
	Majuba 1 (J1)	100%	84%	96%
	Majuba 3 (J3)	82%	88%	93%
	Makalu (MA)	94%	100%	100%
	Palmer (PR)	97%	92%	79%
	Camden (CD) (2)	0%	0%	52%
Upper air data	ETA	100 %	42 %	76%

Notes:
(1) These SAWS stations only record precipitation once a day.
(2) Camden monitoring station was commissioned in 2003.

Source and Emissions Data Inputs

Source parameter requirements for input into the CALPUFF model include stack height, diameter, exit temperature, exit velocity, elevation of stack base above sea level and co-ordinates. Emissions per sources are also required as input to the model (see Section 4 for input source data for the current study).

Model Accuracy and Verification

Comparisons between CALPUFF results, and results generated by the Industrial Source Complex Model Short Term version 3 (ISCST3) model, have shown that CALPUFF is generally more conservative (Strimatis et al., 1998). The ISC model typically produces predictions within a factor of 2 to 10 within complex topography with a high incidence of calm wind conditions. When applied in flat or gently rolling terrain, the USA-EPA (EPA 1986) considers the range of uncertainty of the ISC to be -50% to 200%. CALPUFF predictions have been found to have a greater correlation with observations, with more predictions within a factor of 2 of the observations when compared to the ISC model (Strimatis et al., 1998). It has generally been found that the accuracy of off-the-shelf dispersion models improve with increased averaging periods. The accurate prediction of instantaneous peaks are the most difficult and are normally performed with more complicated dispersion models specifically fine-tuned and validated for the location. The duration of these short-term, peak concentrations are often only for a few minutes and on-site meteorological data are then essential for accurate predictions.

In order to assess whether the dispersion model selected and populated is predicting in the correct order of magnitude, dispersion model results are compared to air pollutant concentrations measured at air quality monitoring stations.

Validation of Dispersion Model Results

In the verification of dispersion model results, predicted concentrations arising due to cumulative basecase emissions from Eskom and other sources were compared to measured concentrations recorded at Eskom and other monitoring stations. Data from the Eskom monitoring stations of Camden (CD), Elandsfontein (EL), Majuba 1 (J1), Majuba 3 (J3), Kendal 2 (K2), Leandra (LS), Makalu (MA), Palmer (PR) and Verkykkop (VE) were compared to simulated results at the monitoring sites. Air quality monitoring data from non-Eskom owned monitoring stations which are in the public domain were also collated to demonstrate model performance in areas where no monitoring is conducted by Eskom. A synopsis of the stations used, the station/data owners and the period of monitoring available is given in Table B.2.

Table B.2 Air quality monitoring data from, available in the public domain, used for verification of dispersion model results

Station	Data Owner	PM10	SO2	NOx
Sasolburg Industrial	Sasol	July 2001 - July 2002	July 2001 - July 2002	July 2001 - July 2002
Boiketlong	Sasol		July 2001 - July 2002	
AJ Jacobs	Sasol		July 2001 - July 2002	
Sasolburg Hospital	Sasol		July 2001 - July 2002	
Bertha Village	New Vaal	2000-2001		
Vanderbijlpark CBD	Mintek	1990-1,1994-5	1992-3	1992-3
Vereeniging	Mintek	1990-1,1994-5		
Orange Farm	City of Joburg	2004-5	2004-5	
Buccleuch	City of Joburg	2005	2005	2005
Alexandra	City of Joburg	Jan 2003 - Sep 2004	Jan 2003 - Sep 2004	Jan 2003 - Sep 2004
Kempton Park	Airkem	2002-3	2002-3	2002-3
Diepsloot	City of Joburg	June - Nov 2004		
Rosslyn	Tshwane Metro		Nov 2003 - July 2004	Nov 2003 - July 2004
Clewer Park	APOLCOM	2000-1	2000-1	2000-1
Strydompark	Mintek	1996-9		
Soweto	CSIR		Jan 1990 - June 1993	Jan 1990 - June 1993
New Town	City of Joburg	April 1999 - June 2002		
Bosjesspruit	Sasol	July 2001 to June 2002	July 2001 to June 2002	July 2001 to June 2002

Modelled SO_2, NO_x and PM10 *concentrations* simulated for current Eskom Power station operations and "other (quantifiable) sources" are compared to monitored concentrations (as recorded by Eskom during 2003) in Table B.3. Measured and modelled highest hourly, highest daily and annual average air pollutant concentrations are given in the table for each of the Eskom monitoring stations. The ratio between measured and modelled concentrations is also presented. Given that the US-EPA gives the range of uncertainty in dispersion model results as being –50% to 200% only model predictions falling outside of this range when compared to monitored concentrations were flagged as being unrepresentative (i.e. measured to modelled ratios of <0.5 or >2.0). Flagged values are indicated in bold print in the table. The measured and modelled frequencies of exceedance of air quality limits are compared in Table B.4.

Table B.3 Comparison of monitored and modelled air pollutant concentrations for current baseline operations (Eskom Power Stations and "other sources", 2003)

Monitoring Station	Measured SO_2 (µg/m³)			Measured NO_2 (µg/m³)			Measured PM10 (µg/m³)		
	Highest hourly	Highest daily	Annual average	Highest hourly	Highest daily	Annual average	Highest hourly	Highest daily	Annual average
Verkykkop	366	78	14	114	36	9	292	51	15
Elandsfontein	741	138	28	106	25	7	820	202	42
Kendal2	**2112**	**381**	**47**	**144**	**56**	**15**	**2431**	**199**	**57**
Leandra	563	117	23	NM	NM	NM	672	114	46
Majuba1	560	129	18	NM	NM	NM	180	37	19
Majuba3	560	129	18	NM	NM	NM	1265	208	32
Makalu	798	101	19	87	44	14	445	122	26
Palmer	408	147	16	72	24	4	314	57	26

Camden	249	48	9	94	21	4	707	91	23
	Modelled SO_2 (µg/m³)			**Modelled NO_2 (µg/m³)**			**Modelled PM10 (µg/m³)**		
	Highest hourly	**Highest daily**	**Annual average**	**Highest hourly**	**Highest daily**	**Annual average**	**Highest hourly**	**Highest daily**	**Annual average**
Verkykkop	239	36	5	67.0	11.4	1.4	67	22	2
Elandsfontein	490	152	26	137.7	51.4	8.0	154	56	5
Kendal2	**2430**	**374**	**41**	**172.3**	**36.0**	**6.0**	**119**	**53**	**6**
Leandra	362	142	21	143.9	41.8	6.2	102	46	6
Majuba1	1382	184	18	101.4	24.8	3.0	104	39	3
Majuba3	1007	125	13	134.5	17.5	3.2	128	43	3
Makalu	705	88	17	166.4	21.9	3.9	415	55	11
Palmer	75	29	2	27.0	8.3	0.7	32	11	1
Camden	138	57	10	44.4	16.1	3.2	70	29	3
	Ratio between Measured and Modelled SO_2 Concentrations			**Ratio between Measured and Modelled NO_2 Concentrations**			**Ratio between Measured and Modelled PM10 Concentrations**		
	Highest hourly	**Highest daily**	**Annual average**	**Highest hourly**	**Highest daily**	**Annual average**	**Highest hourly**	**Highest daily**	**Annual average**
Verkykkop	0.65	**0.46**	**0.36**	0.59	**0.32**	**0.16**	**0.23**	**0.42**	**0.12**
Elandsfontein	0.66	1.10	0.94	1.30	**2.06**	1.15	**0.19**	**0.28**	**0.13**
Kendal2	**1.15**	**0.98**	**0.87**	**1.20**	**0.64**	**0.40**	**0.05**	**0.26**	**0.10**
Leandra	0.64	1.22	0.90				**0.15**	**0.40**	**0.13**
Majuba1	1.80	1.19	0.64				0.58	1.06	**0.17**
Majuba3	1.80	0.97	0.71				**0.10**	**0.21**	**0.11**
Makalu	0.88	0.87	0.88	1.91	0.50	**0.28**	0.93	**0.45**	**0.42**
Palmer	**0.18**	**0.20**	**0.14**	**0.37**	**0.35**	**0.17**	**0.10**	**0.19**	**0.03**
Camden	0.55	1.18	1.15	**0.47**	0.77	0.80	**0.10**	**0.31**	**0.15**

Comparison of Modelled and Predicted SO_2

Generally there was *very good comparison between the monitored and predicted ground level SO_2 concentrations* at the various monitoring sites, with most of the monitoring stations falling within the accuracy range of the model, i.e. ratio of >0.5 and <2.0 (Tables B.2 and B.3).

At the *Palmer* (PR) station the predicted ground level concentrations were lower than the monitored concentrations for highest hourly (all three years), highest daily (2003) and annual averaging periods (2003). This could be attributed to other sources not being accounted for at the monitoring site during modelling. Similarly, "other sources" located to the south of the modelling domain and not included in the simulations are likely to have resulted in the underprediction of annual average sulphur dioxide concentrations recorded at Verkykkop monitoring station. Due to improved estimates of household coal burning emissions from areas located east of Sasolburg (Zamdela) it was possible to improve the sulphur dioxide concentration predictions at Makalu.

Table B.4 Comparison of monitored and modelled frequencies of exceedance of air quality limits due to current baseline operations (Eskom Power Stations and "other sources", 2003) (Data availabilities given in brackets after measured frequencies.)

Monitoring Station	Frequencies of Exceedance (hours or days per year) of:													
	Hourly EC SO_2 limit of 350 µg/m³		Daily SANS SO_2 limit of 125 µg/m³		Hourly SA NO_2 limit of 382 µg/m³		Hourly SANS NO_2 limit of 200 µg/m³		Daily NO_2 limit of 191 µg/m³		Daily SANS PM10 limit of 75 µg/m³		Daily EC PM10 limit of 50 µg/m³	
	Measured	Predicted	Measured	Predicted	Measured	Predicted	Measured	Predicted	Measured	Predicted	Measured	Predicted	Measured	Predicted
Verkykkop	1 (36%)	0	0 (36%)	0	0 (76%)	0	0 (76%)	0	0 (76%)	0	0 (98%)	0	1 (98%)	0
Elandsfontein	3 (68%)	6	1 (68%)	2	0 (42%)	0	0 (42%)	0	0 (42%)	0	22 (77%)	0	59 (77%)	2
Kendal2	**202(25%)**	**204**	**27 (25%)**	**17**	**0 (98%)**	**0**	**0 (98%)**	**0**	**0 (98%)**	**0**	**15 (98%)**	**0**	**54 (98%)**	**2**
Leandra	19 (21%)	**2**	0 (21%)	**1**	NM	0	NM	0	NM	0	18 (99%)	0	32 (99%)	0
Majuba1	28(11%)	35	1 (11%)	1	NM	0	NM	0	NM	0	0 (97%)	0	0 (97%)	0
Majuba3		14		1	NM	0	NM	0	NM	0	9 (57%)	0	27 (57%)	0
Makalu	6 (73%)	7	0 (73%)	0	0 (99.6%)	0	0 (99.6%)	0	0 (99.6%)	0	16 (95%)	0	45 (95%)	4
Palmer	2 (73%)	0	2 (73%)	0	0 (78%)	0	0 (78%)	0	0 (78%)	0	0 (78%)	0	7 (78%)	0
Camden	0 (67%)	0	0 (67%)	0	0 (67%)	0	0 (67%)	0	0 (67%)	0	4 (67%)	0	42 (67%)	0

NM – not measured

Comparison of Modelled and Predicted NO_2

Measured and monitored nitrogen oxide concentrations compared relatively well at most of the station with the exception of Palmer and Verkkykkop for reasons given above. Annual nitrogen dioxide levels at the Kendal 2 and Makalu sites are also underpredicted (Table B.2 and B.3). Although predicted highest daily nitrogen dioxide concentrations were found to be higher than those measured at Elandsfontein, it is notable that the data availability at this station is only 42% for 2003.

Comparison of Modelled and Predicted PM10

Although predicted ground level concentrations for PM10 did not compare well with monitored data at the various Eskom monitoring stations despite the formation of secondary pollutants being accounted for in the modelling (Table B.2 and B.3). This is to be expected given that certain sources anticipated to contribute significantly to suspended particulate concentrations at these locations could either not be accounted for in the modelling (most notably veld burning, vehicle entrainment along unpaved roads) or are located outside of the modelling domain (long-range regional aerosols from distant biomass burning and aeolian dust).

APPENDIX C –

ATMOSPHERIC DISPERSION SIMULATION RESULTS – AIR POLLUTANT CONCENTRATIONS AND DUST DEPOSITION RATES DUE TO CURRENT BASELINE CONDITIONS

Scenario	Pollutant	Averaging Period	Figure No.
Current Baseline Conditions	Sulphur dioxide	Highest hourly	C.1
		Highest daily	C.2
		Annual average	C.3
		Frequency of exceedance of hourly limit of 350 µg/m³	C.4
		Frequency of exceedance of daily limit of 125 µg/m³	C.5
	Nitrogen dioxide	Highest hourly	C.6
		Annual average	C.7
		Frequency of exceedance of hourly limit of 200 µg/m³	C.8
	PM10	Highest daily	C.9
		Annual average	C.10
		Frequency of exceedance of daily limit of 75 µg/m³	C.11
	Dustfall	Maximum monthly dustfall rate	C.12

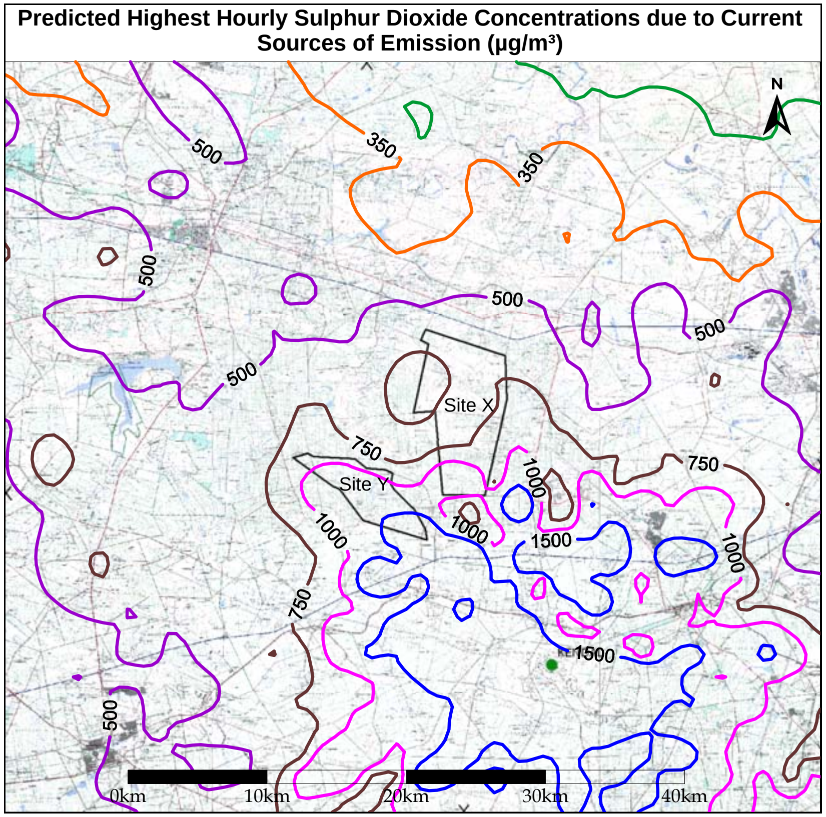

Figure C.1 Predicted highest hourly average sulphur dioxide due to current baseline conditions

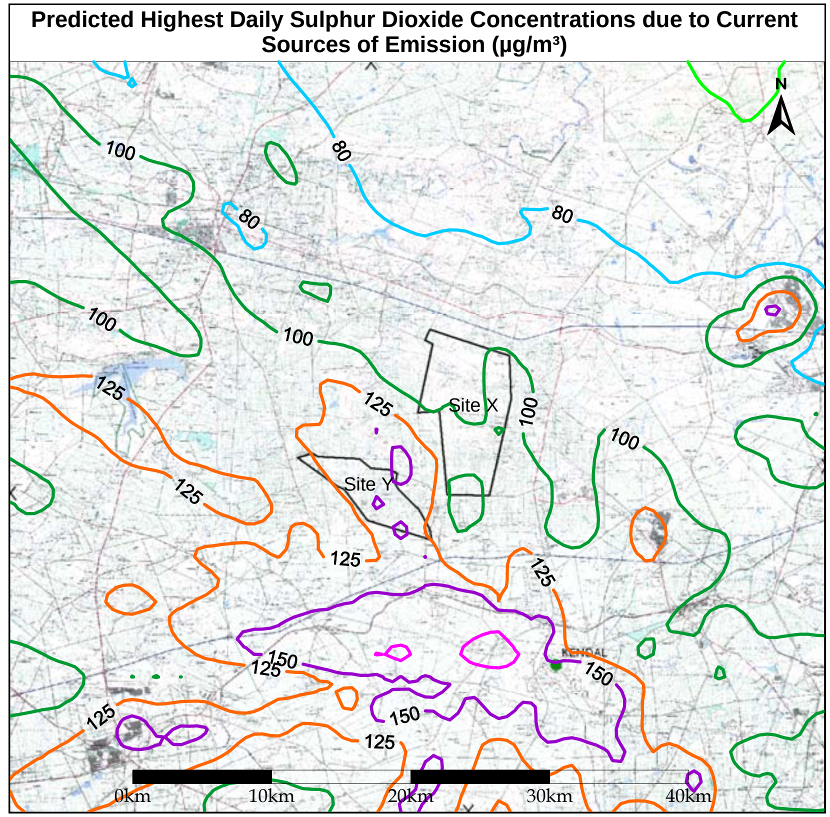

Figure C.2 Predicted highest daily average sulphur dioxide due to current baseline conditions

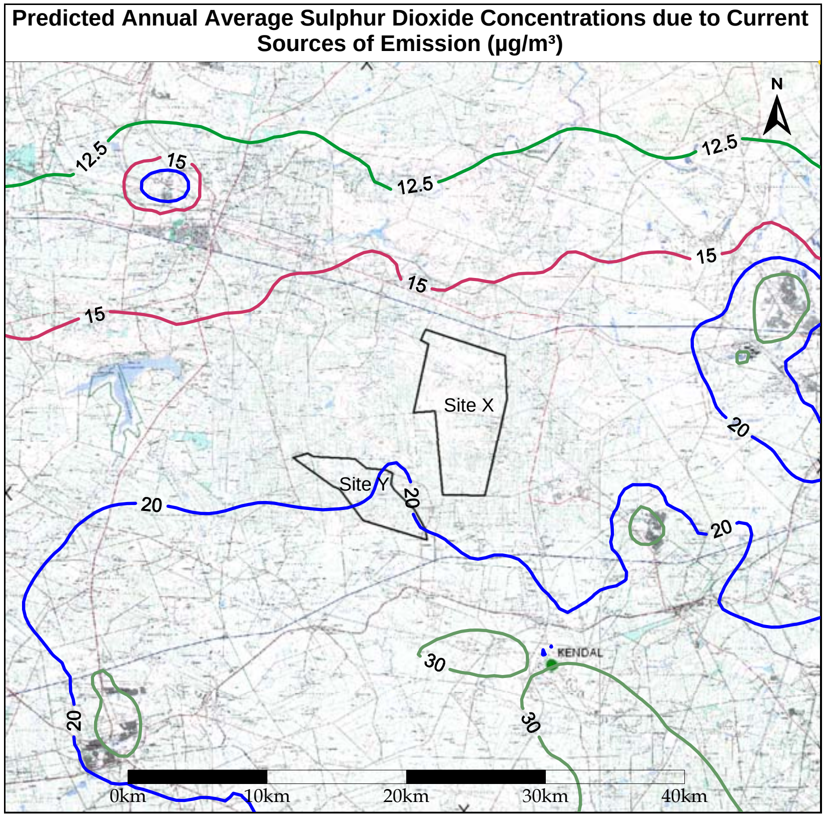

Figure C.3 Predicted annual average sulphur dioxide due to current baseline conditions

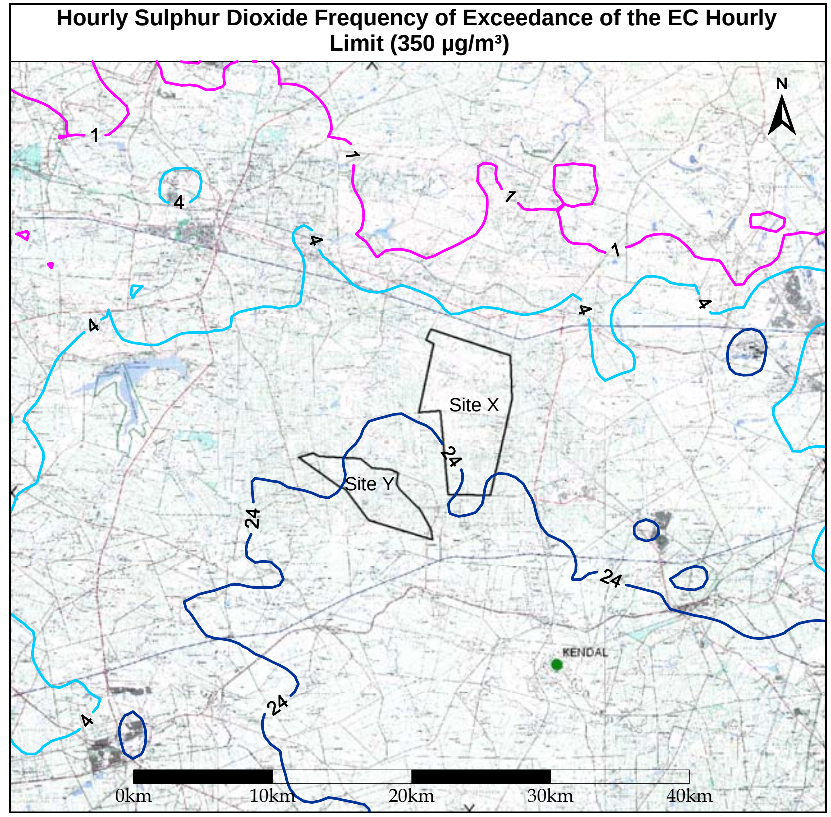

Figure C.4 Predicted frequencies of exceedance of the EC hourly sulphur dioxide limit of 350 µg/m³ due current baseline conditions

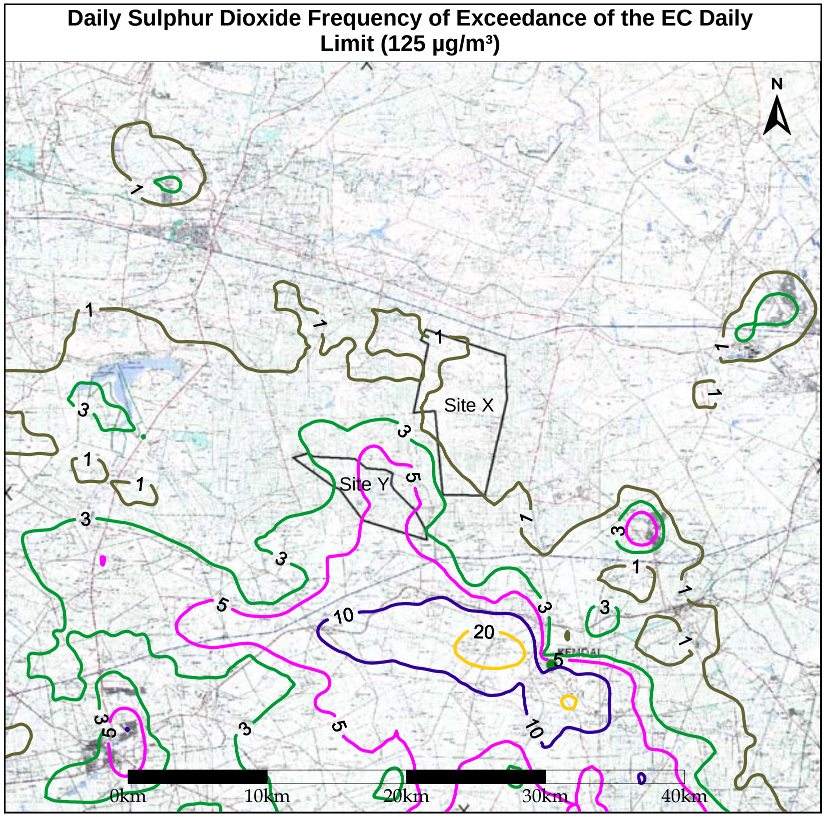

Figure C.5 Predicted frequencies of exceedance of the SA daily sulphur dioxide limit of 125 µg/m³ due current baseline conditions

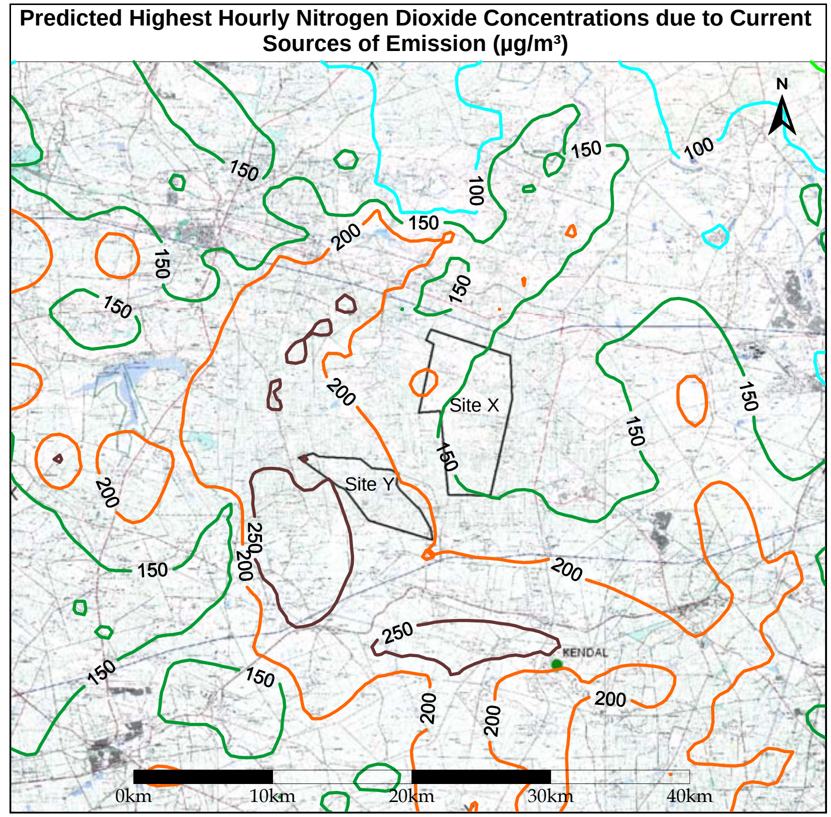

Figure C.6 Predicted highest hourly average nitrogen dioxide due to current baseline conditions

Predicted Annual Average Nitrogen Dioxide Concentrations due to Current Sources of Emission (µg/m³)

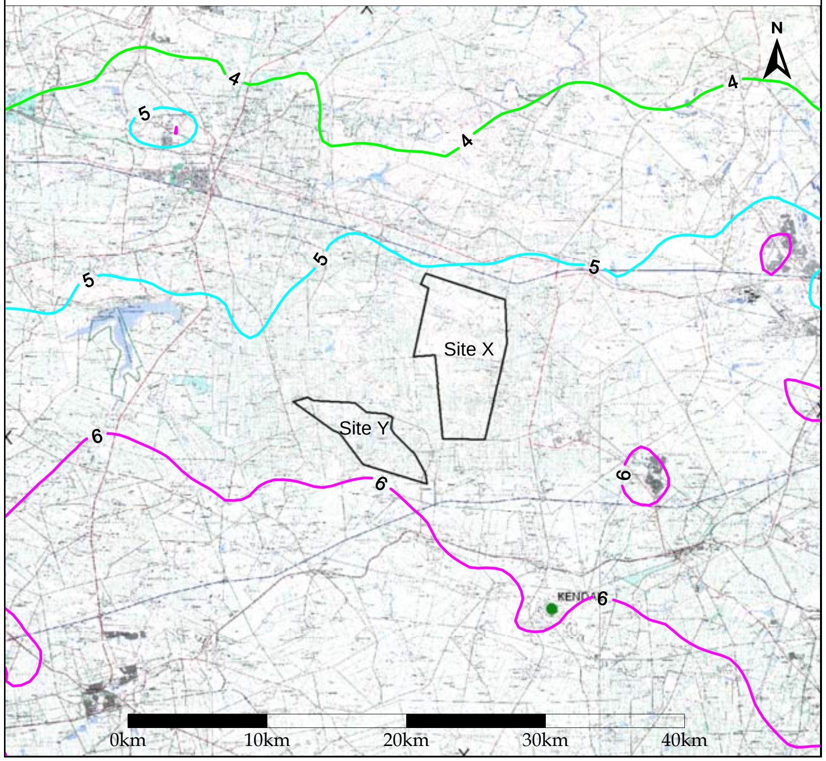

Figure C.7 Predicted annual average nitrogen dioxide due to current baseline conditions

Hourly Nitrogen Dioxide Frequency of Exceedance of the EC Hourly Limit (200 µg/m³)

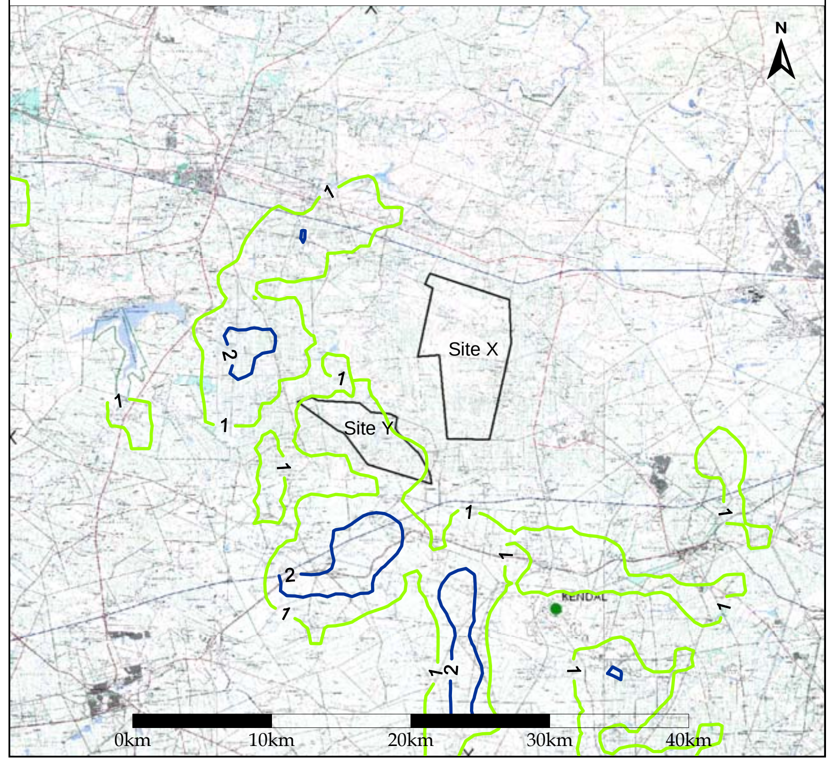

Figure C.8 Predicted frequencies of exceedance of the SANS hourly nitrogen dioxide limit of 200 µg/m³ due current baseline conditions

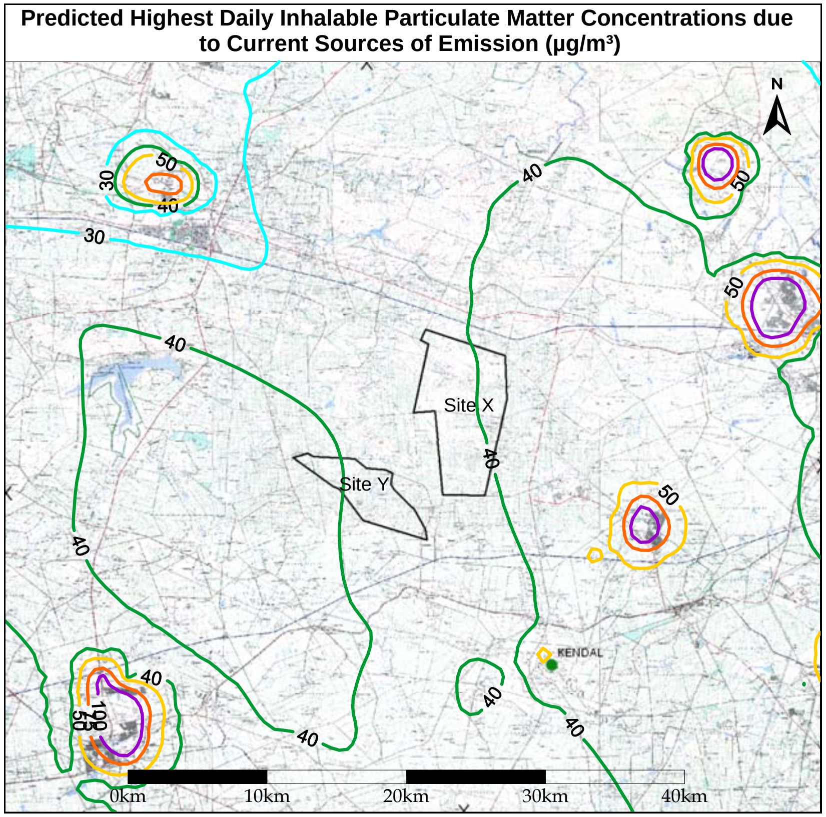

Figure C.9 Predicted highest daily average PM10 concentrations due to current baseline conditions

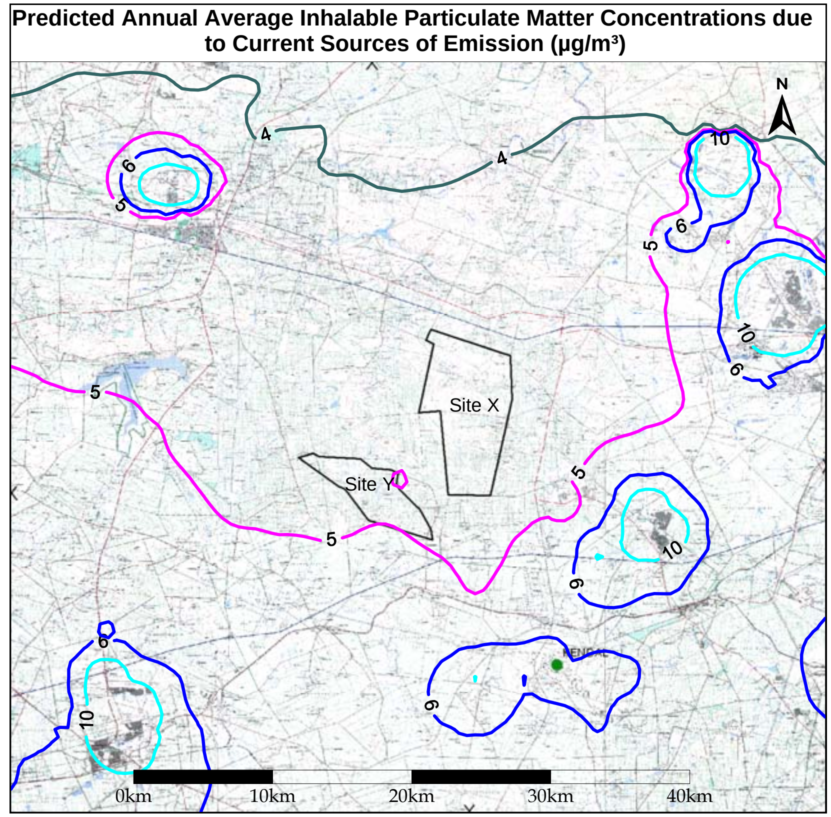

Figure C.10 Predicted annual average PM10 concentrations due to current baseline conditions

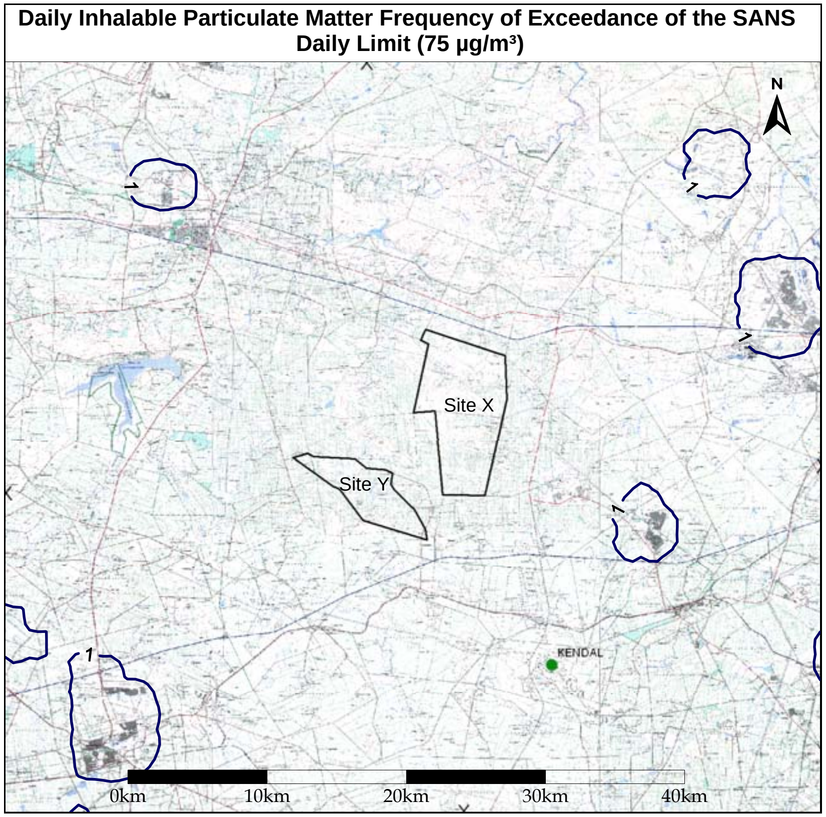

Figure C.11 Predicted frequencies of exceedance of the SANS daily PM10 limit of 75 µg/m³ due current baseline conditions

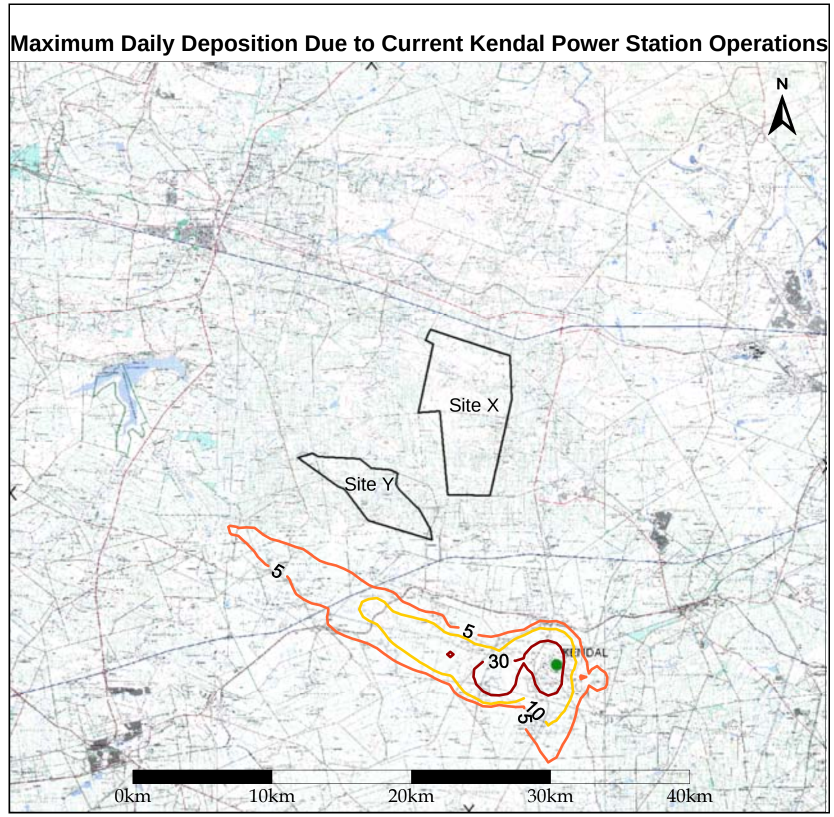

Figure C.12 Predicted maximum monthly dustfall rate due to current baseline conditions

APPENDIX D –

PROPOSED KENDAL NORTH POWER STATION - ATMOSPHERIC DISPERSION SIMULATION RESULTS – MAXIMUM HOURLY, DAILY AND ANNUAL CONCENTRATIONS DUE TO VARIOUS POWER STATION CONFIGURATION SCENARIOS

NOTE: PM10 Concentrations given in tables is due exclusively to stack emissions – including primary particulate releases and secondary particulate formation following atmospheric conversion of SOx and NOx emissions. Total PM10 concentrations due to all sources, stacks and fugitive dust sources, are depicted in Appendix F.

Power station configuration options which were included in the study are as follows:

Scenario	**No. of Units**	**Proposed Site**	**Stack Height (m)**	**SO_2 Control Efficiency**
A.1	6 x 900 MW	Site X	150	0%
B.1	6 x 900 MW	Site Y	150	0%
C.1	6 x 900 MW	Site X	220	0%
D.1	6 x 900 MW	Site Y	220	0%
E.1	6 x 900 MW	Site X	300	0%
F.1	6 x 900 MW	Site Y	300	0%
A.2	6 x 900 MW	Site X	150	90%
B.2	6 x 900 MW	Site Y	150	90%
C.2	6 x 900 MW	Site X	220	90%
D.2	6 x 900 MW	Site Y	220	90%
E.2	6 x 900 MW	Site X	300	90%
F.2	6 x 900 MW	Site Y	300	90%

SCENARIO A.1 - Predicted SO_2, NO, NO_2 and PM10 concentrations occurring – 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 ($\mu g/m^3$)	Highest Daily ($\mu g/m^3$)	Annual Average ($\mu g/m^3$)	Highest Hourly ($\mu g/m^3$)	Highest Daily ($\mu g/m^3$)	Annual Average ($\mu g/m^3$)	Highest Hourly ($\mu g/m^3$)	Highest Daily ($\mu g/m^3$)	Annual Average ($\mu g/m^3$)	Highest Daily ($\mu g/m^3$)	Annual Average ($\mu g/m^3$)
GLC Maximum [(a)]	**5879**	**388**	**73**	**1060**	65	12	**347**	53	10	**198**	**85**
Phola	**1366**	**222**	**57**	240	35	9	205	41.6	9.9	120	28
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 $\mu g/m^3$)	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	**16.80**	**3.10**	**1.46**	**1.41**	0.17	0.06	**1.73**	0.28	0.26	**2.65**	**2.12**
Phola	**3.90**	**1.78**	**1.14**	0.32	0.09	0.05	1.03	0.22	0.25	1.60	0.70

(a) Within a 25km radius from the proposed Kendal North Power Station sites

SCENARIO B.1 - Predicted SO_2, NO, NO_2 and PM10 concentrations occurring – 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 [(a)]	**4814**	**438**	**70**	1060	65	11	**328**	71	11	**197**	85
Phola	**1206**	**188**	49	240	35	8	200	42	9.8	**120**	28
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	**13.75**	**3.50**	**1.40**	**1.41**	0.17	0.06	**1.64**	0.38	0.27	**2.63**	**2.12**
Phola	**3.45**	**1.50**	0.98	0.32	0.09	0.04	1.00	0.22	0.25	**1.60**	0.70

(a) Within a 25km radius from the proposed Kendal North Power Station sites

SCENARIO C.1 - Predicted SO_2, NO, NO_2 and PM10 concentrations occurring – 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 [(a)]	**4814**	**346**	**66**	**1060**	65	11	**311**	56	10	**197**	85
Phola	**1279**	**159**	**51**	240	30	8.5	185	41	9.4	**120**	28
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	**13.75**	**2.77**	**1.32**	**1.41**	0.17	0.06	**1.55**	0.30	0.25	**2.62**	**2.12**
Phola	**3.65**	**1.27**	**1.02**	0.32	0.08	0.05	0.93	0.22	0.24	**1.60**	0.70

(a) Within a 25km radius from the proposed Kendal North Power Station sites

SCENARIO D.1 - Predicted SO_2, NO, NO_2 and PM10 concentrations occurring – 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 [(a)]	**4814**	**350**	**67**	**1060**	65	11	**295**	59	10	**196**	**85**
Phola	**1206**	**153**	48	240	32	8	180	39.8	9.5	**120**	28
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	**13.75**	**2.80**	**1.34**	**1.41**	0.17	0.06	**1.48**	0.32	0.26	**2.61**	**2.12**
Phola	**3.45**	**1.22**	0.96	0.32	0.09	0.04	0.90	0.21	0.24	**1.60**	0.70

(a) Within a 25km radius from the proposed Kendal North Power Station sites

SCENARIO E.1 - Predicted SO_2, NO, NO_2 and PM10 concentrations occurring – 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 [(a)]	**4814**	**343**	**61**	**1060**	65	11	**336**	48	10	**196**	**85**
Phola	**1206**	**158**	47	240	30	8	180	40.3	9	**120**	28

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	**13.75**	**2.75**	**1.23**	**1.41**	0.17	0.06	**1.68**	0.26	0.25	**2.61**	**2.11**
Phola	**3.45**	**1.26**	0.94	0.32	0.08	0.04	0.90	0.21	0.23	**1.60**	0.70

(a) Within a 25km radius from the proposed Kendal North Power Station sites

SCENARIO F.1 - Predicted SO_2, NO, NO_2 and PM10 concentrations occurring – 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 [(a)]	**5170**	**348**	**63**	**1060**	65	10	**292**	59	10	**196**	**85**
Phola	**1206**	**158**	45	240	32	8	180	41	9.2	**120**	28
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	**14.77**	**2.78**	**1.26**	**1.41**	0.17	0.06	**1.46**	0.31	0.25	**2.61**	**2.12**
Phola	**3.45**	**1.26**	0.90	0.32	0.09	0.04	0.90	0.22	0.23	**1.60**	0.70

(a) Within a 25km radius from the proposed Kendal North Power Station sites

SCENARIO A.2 - Predicted SO_2, NO, NO_2 and PM10 concentrations occurring – 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 [(a)]	**4814**	**326**	**51**	**1060**	65	12	**347**	53	10	**198**	**84**
Phola	**1206**	**135**	36	240	35	9	**205**	41.6	9.9	**120**	28

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	**13.75**	**2.61**	**1.02**	**1.41**	0.17	0.06	**1.73**	0.28	0.26	**2.63**	**2.11**
Phola	**3.45**	**1.08**	0.72	0.32	0.09	0.05	**1.03**	0.22	0.25	**1.60**	0.70

(a) Within a 25km radius from the proposed Kendal North Power Station sites

SCENARIO B.2 - Predicted SO_2, NO, NO_2 and PM10 concentrations occurring – 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 [(a)]	**4814**	**326**	**51**	**1060**	65	11	**328**	71	11	**197**	**84**
Phola	**1206**	**135**	35	240	35	8	200	42	9.8	**120**	28

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	**13.75**	**2.61**	**1.03**	**1.41**	0.17	0.06	**1.64**	0.38	0.27	**2.62**	**2.11**
Phola	**3.45**	**1.08**	0.70	0.32	0.09	0.04	1.00	0.22	0.25	**1.60**	0.70

(a) Within a 25km radius from the proposed Kendal North Power Station sites

SCENARIO C.2 - Predicted SO_2, NO, NO_2 and PM10 concentrations occurring – 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 [(a)]	**4814**	**326**	**51**	**1060**	65	11	**311**	56	10	**196**	**84**
Phola	**1206**	**135**	36	240	30	8.5	185	41	9.4	**120**	30

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	**13.75**	**2.61**	**1.01**	**1.41**	0.17	0.06	**1.55**	0.30	0.25	**2.61**	**2.11**
Phola	**3.45**	**1.08**	0.72	0.32	0.08	0.05	0.93	0.22	0.24	**1.60**	0.75

(a) Within a 25km radius from the proposed Kendal North Power Station sites

SCENARIO D.2 - Predicted SO_2, NO, NO_2 and PM10 concentrations occurring – 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 [(a)]	**4814**	**327**	**51**	**1060**	65	11	**295**	59	10	**196**	**84**
Phola	**1206**	**135**	35	240	32	8	180	39.8	9.5	**120**	28
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	**13.75**	**2.61**	**1.02**	**1.41**	0.17	0.06	**1.48**	0.32	0.26	**2.61**	**2.11**
Phola	**3.45**	**1.08**	0.70	0.32	0.09	0.04	0.90	0.21	0.24	**1.60**	0.70

(a) Within a 25km radius from the proposed Kendal North Power Station sites

SCENARIO E.2 - Predicted SO_2, NO, NO_2 and PM10 concentrations occurring – 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 (a)	**4814**	**326**	**50**	**1060**	65	11	**336**	48	10	**196**	**84**
Phola	**1206**	**135**	35	240	30	8	180	40.3	9	**120**	28
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	**13.75**	**2.61**	**1.01**	**1.41**	0.17	0.06	**1.68**	0.26	0.25	**2.61**	**2.11**
Phola	**3.45**	**1.08**	0.70	0.32	0.08	0.04	0.90	0.21	0.23	**1.60**	0.70

(a) Within a 25km radius from the proposed Kendal North Power Station sites

SCENARIO F.2 - Predicted SO_2, NO, NO_2 and PM10 concentrations occurring – 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 [(a)]	**4814**	**326**	**51**	**1060**	65	10	**292**	59	10	**196**	**84**
Phola	**1206**	**135**	35	240	32	8	180	41	9.2	**120**	28
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	**13.75**	**2.61**	**1.01**	**1.41**	0.17	0.06	**1.46**	0.31	0.25	**2.61**	**2.11**
Phola	**3.45**	**1.08**	0.70	0.32	0.09	0.04	0.90	0.22	0.23	**1.60**	0.70

(a) Within a 25km radius from the proposed Kendal North Power Station sites

APPENDIX E –

PROPOSED KENDAL NORTH POWER STATION – POTENTIAL FOR COMPLIANCE WITH AIR QUALITY LIMITS, HEALTH RISKS, VEGETATION INJURY AND CORROSION

SCENARIO A.1 - Potential for non-compliance, health effects, vegetation damage and corrosion occurring due to sulphur dioxide concentrations

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 SA 10-minute Limit of 500 µg/m³ (no permissible frequencies) / Freq Exc EC Hourly Limit of 350 µg/m³ (EC permits 24, 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	5879	388	73	3.7	medium	4.5	3.7	high	low(a)	446	57	FALSE	FALSE
Residential areas	Phola	1366	222	57	2.9	medium	1.1	2.9	high	moderate	182	28	FALSE	FALSE

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.

SCENARIO B.1 - Potential for non-compliance, health effects, vegetation damage and corrosion occurring due to sulphur dioxide concentrations

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 (99[th] 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 SA 10-minute Limit of 500 µg/m³ (no permissible frequencies) / Freq Exc EC Hourly Limit of 350 µg/m³ (EC permits 24, 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	4814	438	70	3.5	medium	3.7	3.5	high	low(a)	470	64	FALSE	FALSE
Residential areas	Phola	1206	188	49	2.5	medium	0.9	2.5	moderate	moderate	110	21	FALSE	FALSE

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.

SCENARIO C.1 - Potential for non-compliance, health effects, vegetation damage and corrosion occurring due to sulphur dioxide concentrations

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 SA 10-minute Limit of 500 µg/m³ (no permissible frequencies) / Freq Exc EC Hourly Limit of 350 µg/m³ (EC permits 24, 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	4814	346	66	3.3	medium	3.7	3.3	high	low(a)	394	51	FALSE	FALSE
Residential areas	Phola	1279	159	51	2.6	medium	1.0	2.6	high	moderate	99	19	FALSE	FALSE

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.

SCENARIO D.1 - Potential for non-compliance, health effects, vegetation damage and corrosion occurring due to sulphur dioxide concentrations

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 SA 10-minute Limit of 500 µg/m³ (no permissible frequencies) / Freq Exc EC Hourly Limit of 350 µg/m³ (EC permits 24, 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	4814	350	67	3.3	medium	3.7	3.3	high	low(a)	429	54	FALSE	FALSE
Residential areas	Phola	1206	153	48	2.4	medium	0.9	2.4	high	moderate	77	16	FALSE	FALSE

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.

SCENARIO E.1 - Potential for non-compliance, health effects, vegetation damage and corrosion occurring due to sulphur dioxide concentrations

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 SA 10-minute Limit of 500 µg/m³ (no permissible frequencies) / Freq Exc EC Hourly Limit of 350 µg/m³ (EC permits 24, 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	4814	343	61	3.1	medium	3.7	3.1	high	low(a)	366	48	FALSE	FALSE
Residential areas	Phola	1206	158	47	2.4	medium	0.9	2.4	high	moderate	68	14	FALSE	FALSE

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.

SCENARIO F.1 - Potential for non-compliance, health effects, vegetation damage and corrosion occurring due to sulphur dioxide concentrations

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 SA 10-minute Limit of 500 µg/m³ (no permissible frequencies) / Freq Exc EC Hourly Limit of 350 µg/m³ (EC permits 24, 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	5170	348	63	3.2	medium	4.0	3.2	high	low(a)	389	47	FALSE	FALSE
Residential areas	Phola	1206	158	45	2.3	medium	0.9	2.3	high	moderate	45	10	FALSE	FALSE

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.

SCENARIO A.2 - Potential for non-compliance, health effects, vegetation damage and corrosion occurring due to sulphur dioxide concentrations

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 SA 10-minute Limit of 500 µg/m³ (no permissible frequencies) / Freq Exc EC Hourly Limit of 350 µg/m³ (EC permits 24, 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	4814	326	51	2.5	medium	3.7	2.5	high	low(a)	302	35	FALSE	FALSE
Residential areas	Phola	1206	135	36	1.8	medium	0.9	1.8	moderate	moderate	19	7	FALSE	FALSE

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.

SCENARIO B.2 - Potential for non-compliance, health effects, vegetation damage and corrosion occurring due to sulphur dioxide concentrations

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 SA 10-minute Limit of 500 µg/m³ (no permissible frequencies) / Freq Exc EC Hourly Limit of 350 µg/m³ (EC permits 24, 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	4814	326	51	2.6	medium	3.7	2.6	high	low(a)	308	35	FALSE	FALSE
Residential areas	Phola	1206	135	35	1.8	medium	0.9	1.8	moderate	moderate	19	7	FALSE	FALSE

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.

SCENARIO C.2 - Potential for non-compliance, health effects, vegetation damage and corrosion occurring due to sulphur dioxide concentrations

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 SA 10-minute Limit of 500 µg/m³ (no permissible frequencies) / Freq Exc EC Hourly Limit of 350 µg/m³ (EC permits 24, 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	4814	326	51	2.5	medium	3.7	2.5	high	low(a)	302	35	FALSE	FALSE
Residential areas	Phola	1206	135	36	1.8	medium	0.9	1.8	moderate	moderate	19	7	FALSE	FALSE

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.

SCENARIO D.2 - Potential for non-compliance, health effects, vegetation damage and corrosion occurring due to sulphur dioxide concentrations

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 SA 10-minute Limit of 500 µg/m³ (no permissible frequencies) / Freq Exc EC Hourly Limit of 350 µg/m³ (EC permits 24, 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	4814	327	51	2.6	medium	3.7	2.6	high	low(a)	308	35	FALSE	FALSE
Residential areas	Phola	1206	135	35	1.8	medium	0.9	1.8	moderate	moderate	19	7	FALSE	FALSE

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.

SCENARIO E.2 - Potential for non-compliance, health effects, vegetation damage and corrosion occurring due to sulphur dioxide concentrations

Receptor Category	Receptor Name	Predicted SO_2 Concentration (µg/m³): Highest Hourly (99th Percentile)	Predicted SO_2 Concentration (µg/m³): Highest Daily	Predicted SO_2 Concentration (µg/m³): Annual Average	Corrosion Potential: Annual Average as Fraction of Threshold for "Medium" Corrosivity (20 µg/m³)	Corrosion Potential: Potential for Corrosion	Potential for Vegetation Injury and Ecosystem Damage: Highest Hourly as Fraction of Hourly Threshold of 1300 µg/m³	Potential for Vegetation Injury and Ecosystem Damage: Annual Average as Fraction of EC Annual Limit for Protection of Ecosystems (20 µg/m³)	Potential for Vegetation Injury and Ecosystem Damage: Potential for Vegetation Damage	Potential for Health Effects: Health Risk Categorisation based on Highest Hourly Average	Compliance Potential: Freq Exc SA 10-minute Limit of 500 µg/m³ (no permissible frequencies) / Freq Exc EC Hourly Limit of 350 µg/m³ (EC permits 24, UK 24)	Compliance Potential: Freq Exc SA Daily Limit of 125 µg/m³ (EC & UK permit 3)	Compliance Potential: Compliance with SA Standards	Compliance Potential: Compliance with UK Standards
Maximum	GLC Maximum	4814	326	50	2.5	medium	3.7	2.5	high	low(a)	301	35	FALSE	FALSE
Residential areas	Phola	1206	135	35	1.8	medium	0.9	1.8	moderate	moderate	19	7	FALSE	FALSE

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.

SCENARIO F.2 - Potential for non-compliance, health effects, vegetation damage and corrosion occurring due to sulphur dioxide concentrations

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 SA 10-minute Limit of 500 µg/m³ (no permissible frequencies) / Freq Exc EC Hourly Limit of 350 µg/m³ (EC permits 24, 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	4814	326	51	2.5	medium	3.7	2.5	high	low(a)	308	35	FALSE	FALSE
Residential areas	Phola	1206	135	35	1.8	medium	0.9	1.8	moderate	moderate	19	7	FALSE	FALSE

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.

APPENDIX F –

ISOPLETH PLOTS DEPICTING TOTAL FINE PARTICULATE CONCENTRATIONS AND DUSTFALL RATES DUE TO CURRENT AND PROPOSED POWER STATION EMISSIONS (STACK AND FUGITIVE EMISSIONS; PRIMARY AND SECONDARY PARTICULATES)

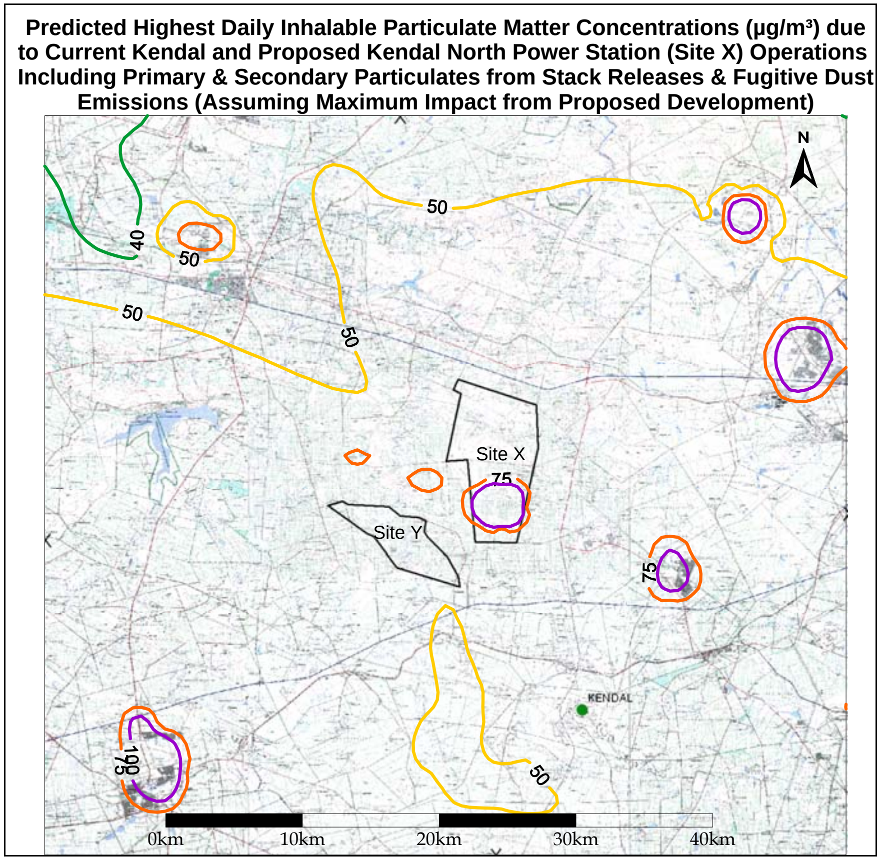

Figure F.1 Highest daily PM10 ground level concentrations due to current Kendal and Proposed Kendal North (at Site X) Power station operations (also including all non-Eskom sources)

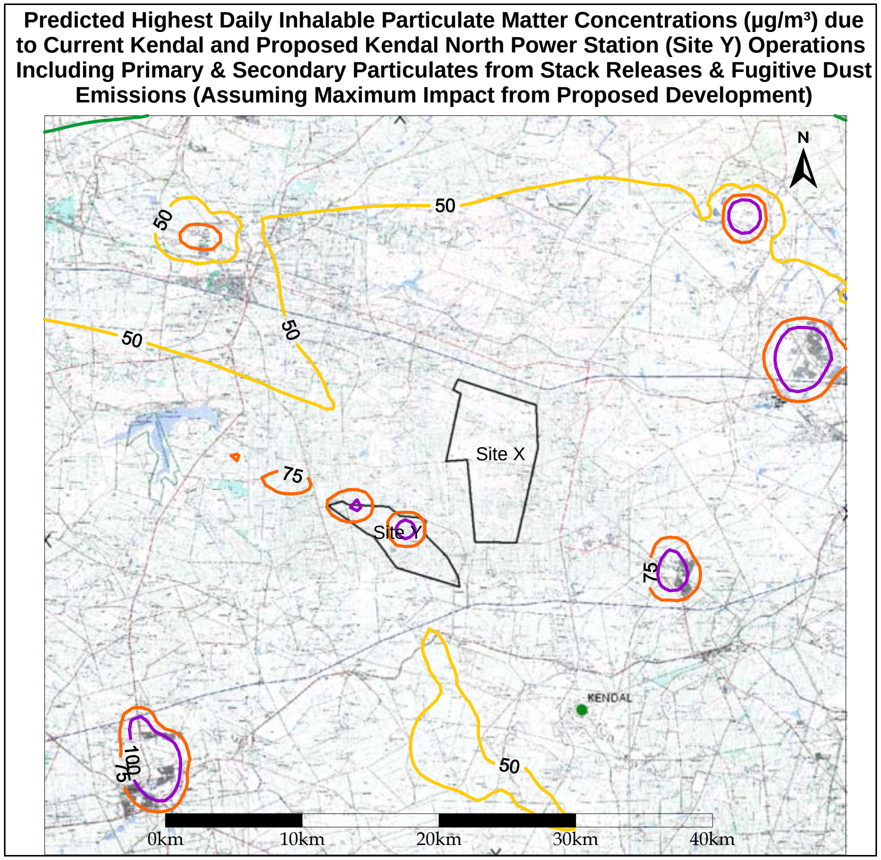

Figure F.2 Highest daily PM10 ground level concentrations due to current Kendal and Proposed Kendal North (at Site Y) Power station operations (also including all non-Eskom sources)

Predicted Annual Average Inhalable Particulate Matter Concentrations (µg/m³) due to Current Kendal and Proposed Kendal North Power Station (Site X) Operations Including Primary & Secondary Particulates from Stack Releases & Fugitive Dust Emissions (Assuming Maximum Impact from Proposed Development)

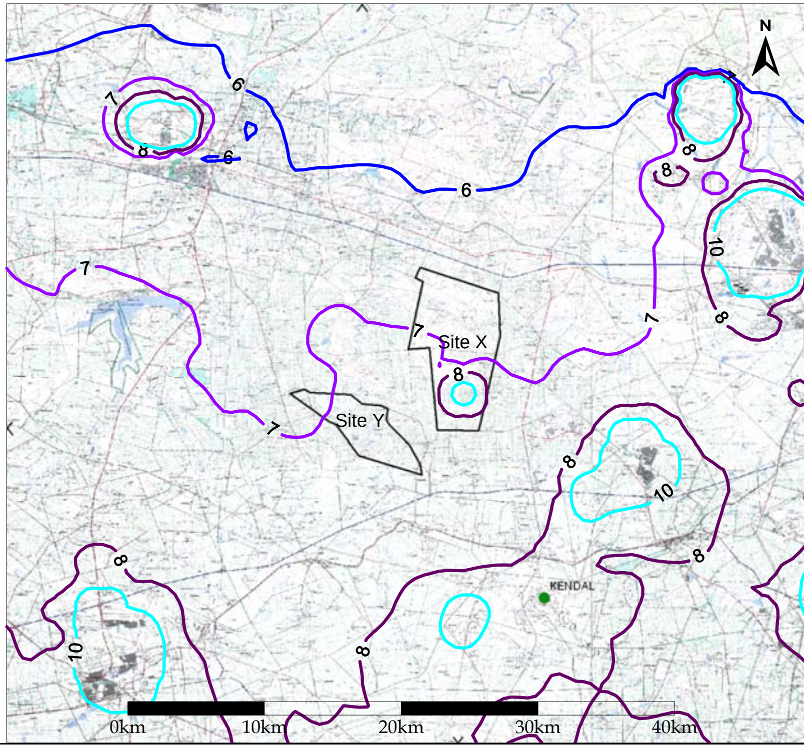

Figure F.3 Annual average PM10 ground level concentrations due to current Kendal and Proposed Kendal North (at Site X) Power station operations (also including all non-Eskom sources)

Predicted Annual Average Inhalable Particulate Matter Concentrations (µg/m³) due to Current Kendal and Proposed Kendal North Power Station (Site Y) Operations Including Primary & Secondary Particulates from Stack Releases & Fugitive Dust Emissions (Assuming Maximum Impact from Proposed Development)

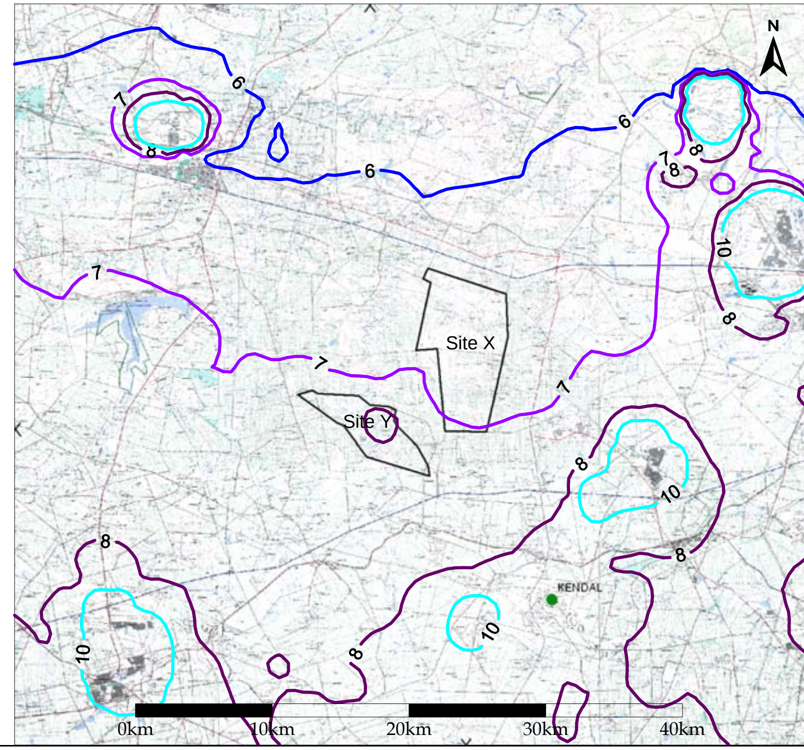

Figure F.4 Annual average PM10 ground level concentrations due to current Kendal and Proposed Kendal North (at Site Y) Power station operations (also including all non-Eskom sources)

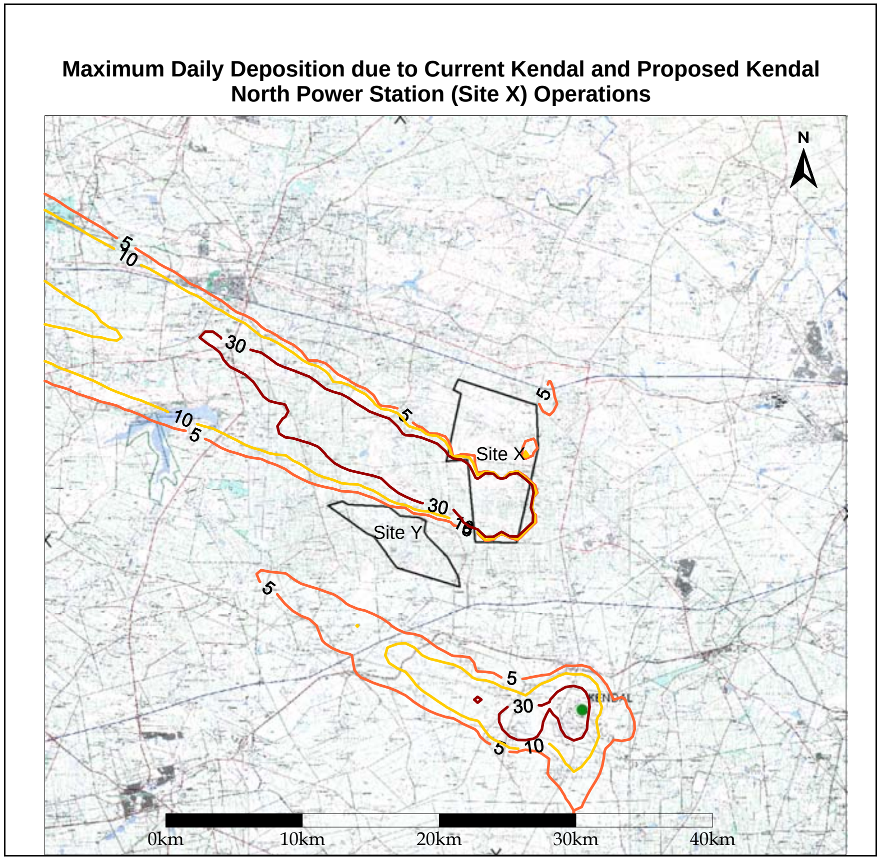

Figure F.5 Maximum daily depostion due to current Kendal and Proposed Kendal North (at Site X) Power station operations

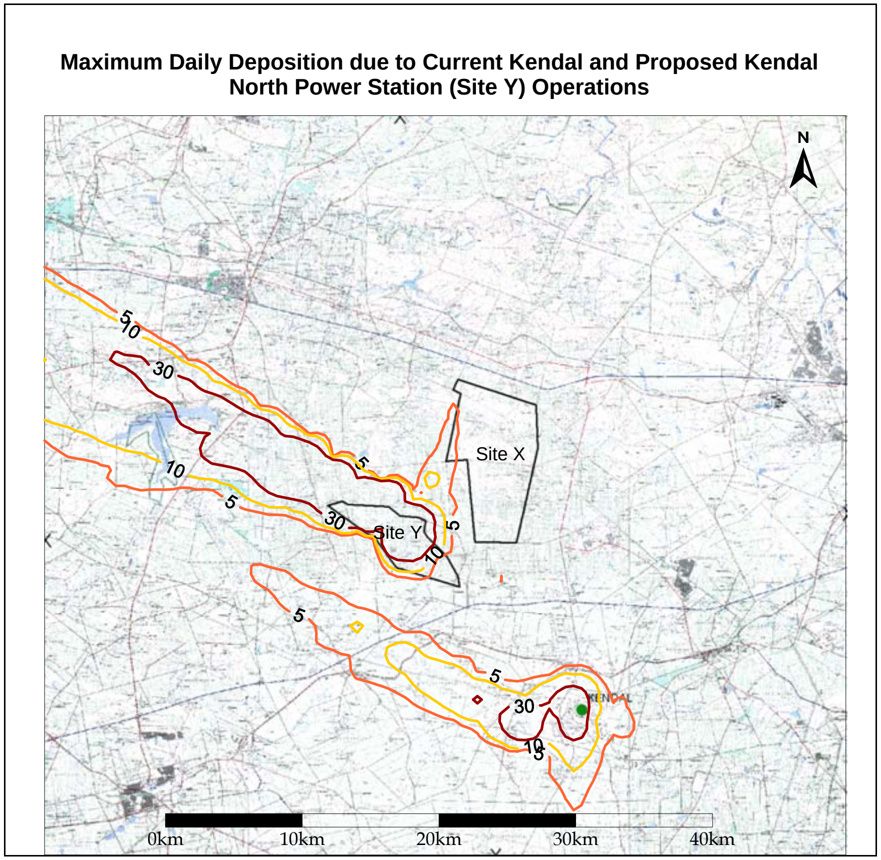

Figure F.6 Maximum daily depostion due to current Kendal and Proposed Kendal North (at Site Y) Power station operations

APPENDIX G –

EXPOSURE POTENTIAL DUE TO THE INTRODUCTION OF THE PROPOSED NEW COAL_FIRED POWER STATION

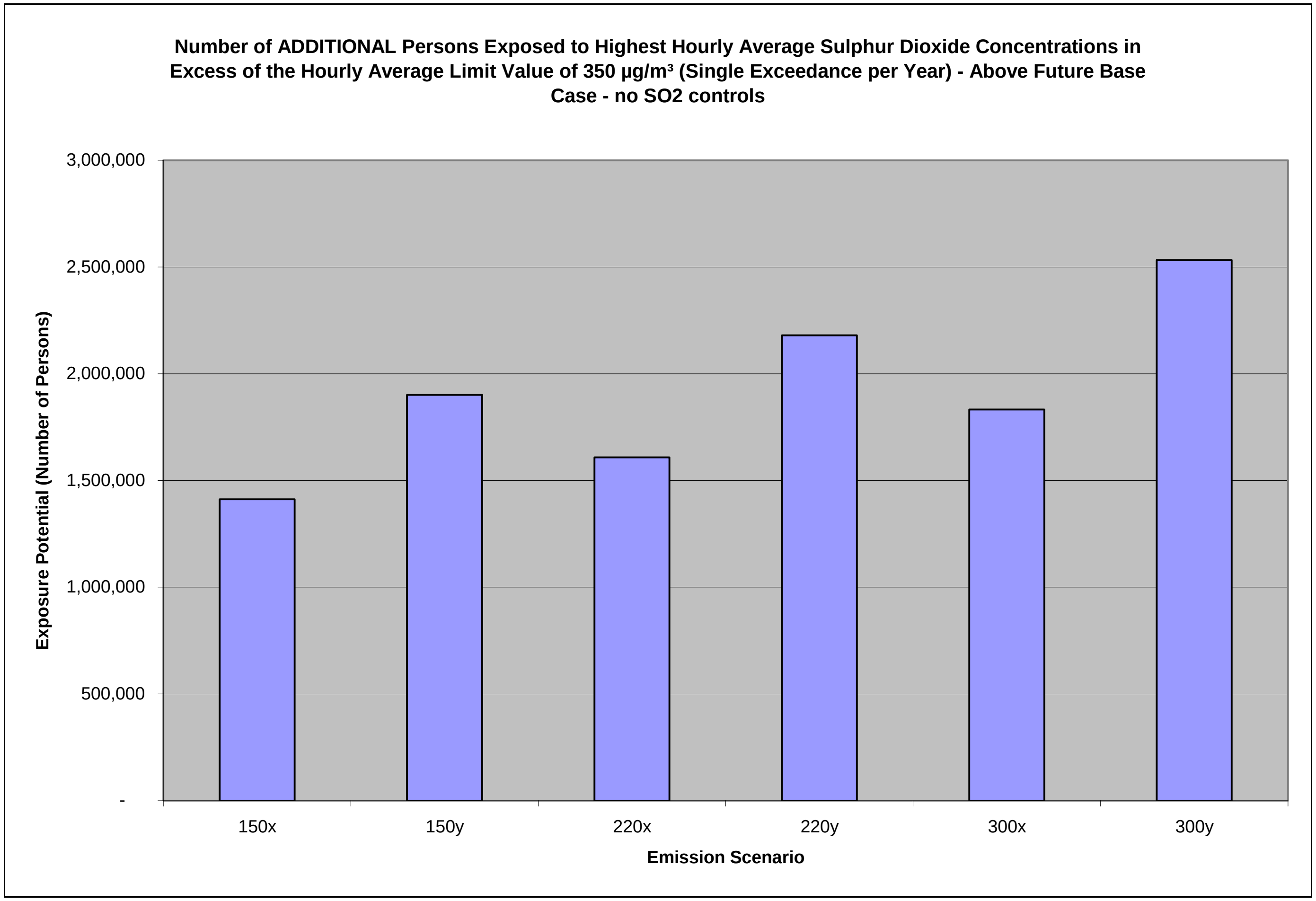

Figure G.1 Additional exposure potential to SO_2 hourly ground level concentrations in excees of the EC hourly limit due to the activities of the proposed new power station <u>with no</u> SO_2 controls in place.

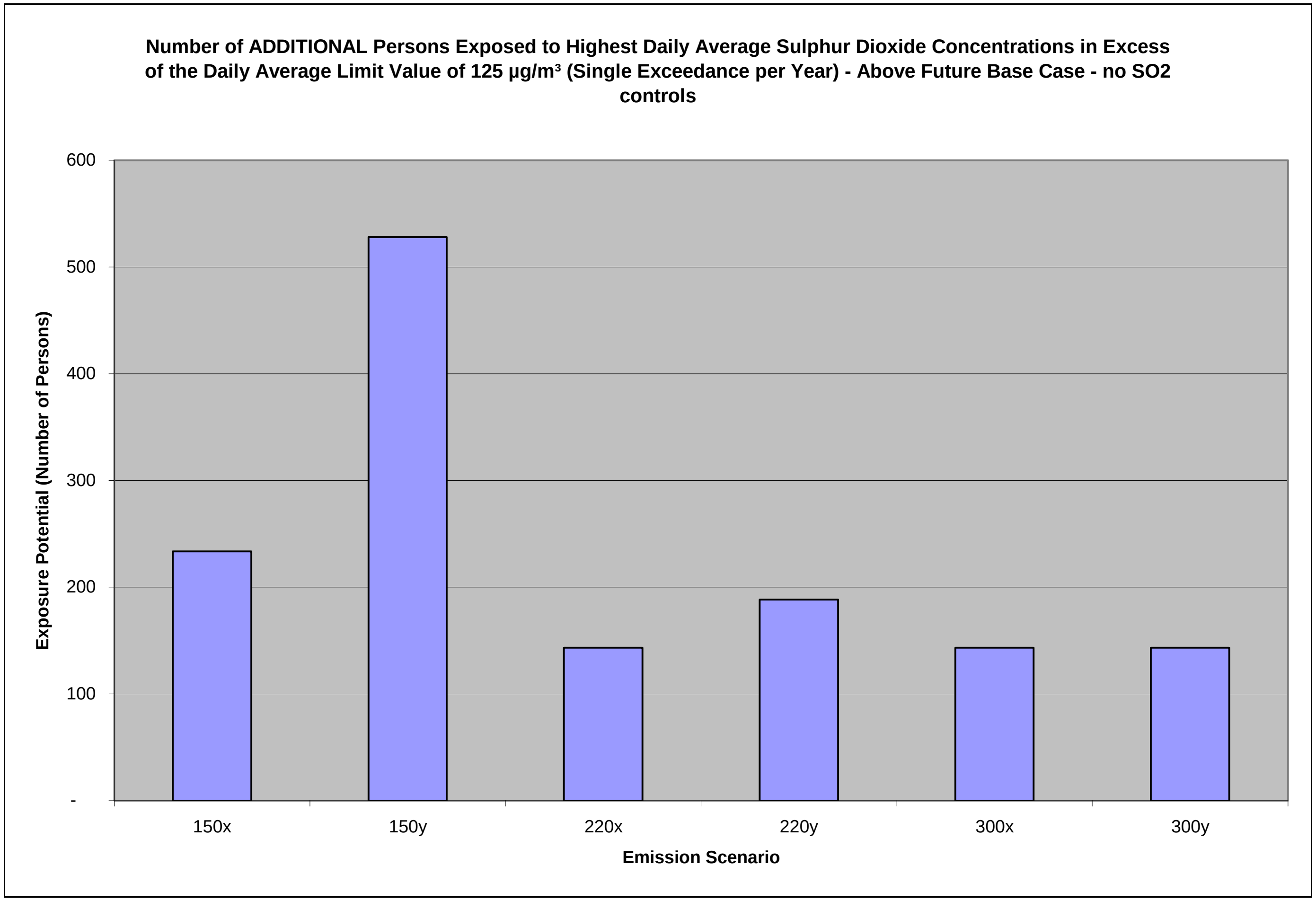

Figure G.2 Additional exposure potential to SO_2 daily ground level concentrations in excees of the EC daily limit due to the activities of the proposed new power station <u>with no</u> SO_2 controls in place.

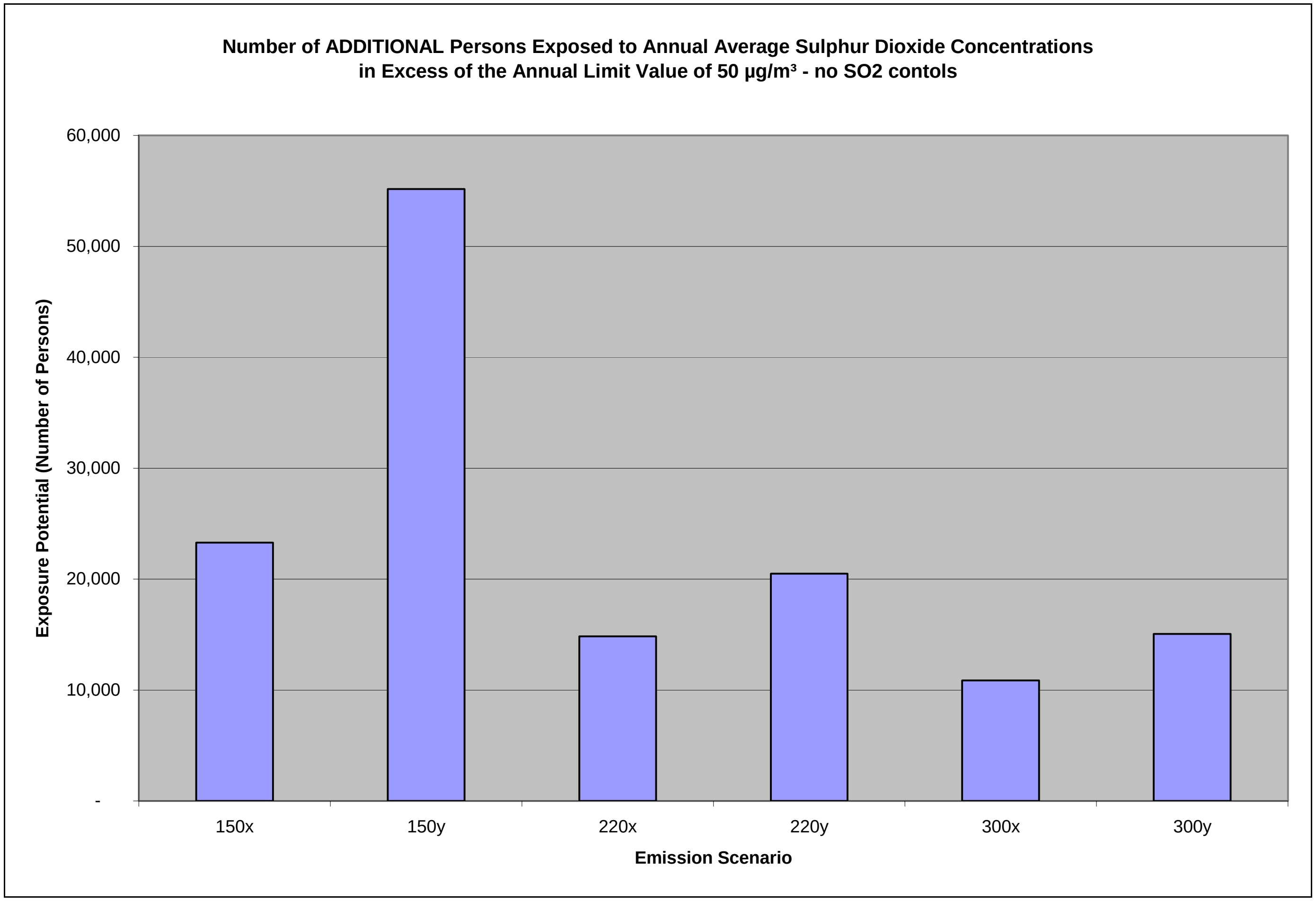

Figure G.3 Additional exposure potential to SO_2 annual ground level concentrations in excees of the EC annual limit due to the activities of the proposed new power station <u>with no</u> SO_2 controls in place.

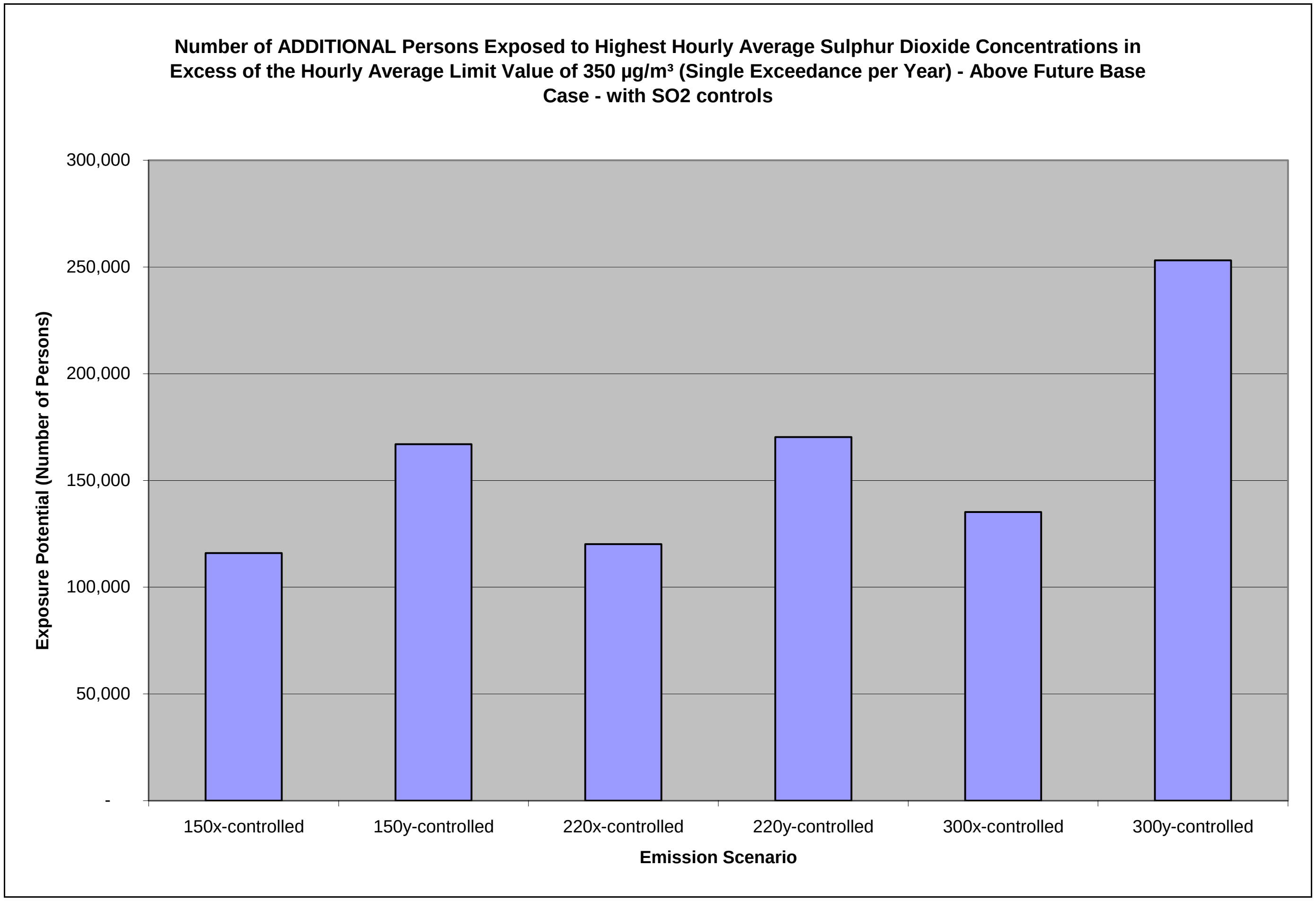

Figure G.4 Additional exposure potential to SO_2 hourly ground level concentrations in excees of the EC hourly limit due to the activities of the proposed new power station <u>with</u> SO_2 controls in place.

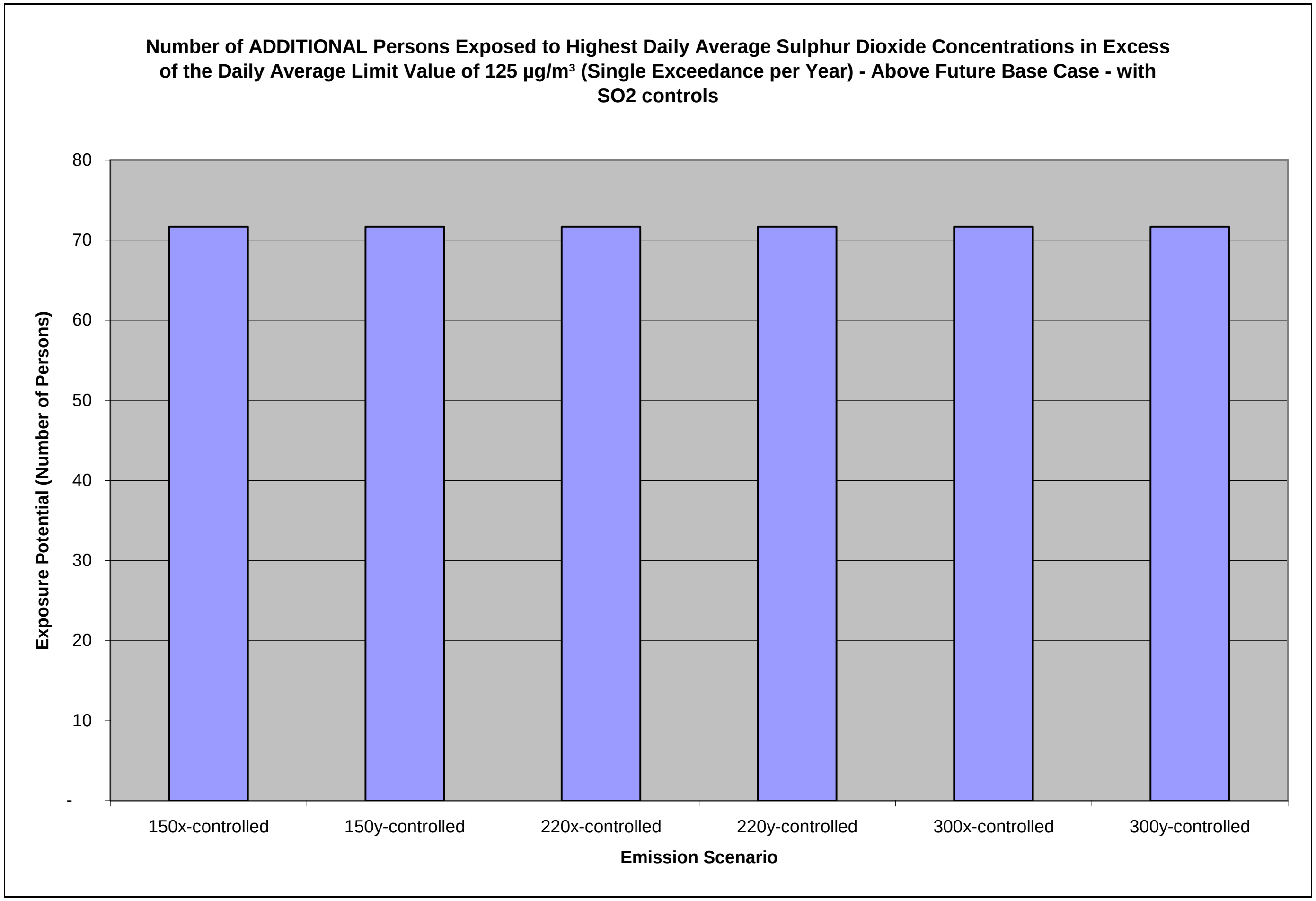

Figure G.5 Additional exposure potential to SO_2 daily ground level concentrations in excees of the EC daily limit due to the activities of the proposed new power station with SO_2 controls in place.

APPENDIX H –

EXPOSURE OF CHICKENS TO SULPHUR DIOXIDE CONCENTRATIONS

Experiments clearly show that SO_2 has harms the cardiopulmonary system of the chicken.

Effects observed-bronchial clearance

A number of studies have investigated the nasal mucociliary transport rates in chickens after exposure to various SO_2 concentrations and durations of exposure. Wakabayashi et al. (1977) exposed chickens to SO_2 intermittently for 16 hours a day for 7 days at concentrations of 1.4 to 66 ppm (3 665 to 172 761 µg/m³). The mucociliary transport in the nasal mucus membranes was observed. Peaks of increased intranasal transport time with intervening recovery periods were observed at all concentrations. Transport in the sinus was decreased at concentrations above 10 ppm (26 761 µg/m³).

Ukai et al. (1984) also investigated mucociliary function in chickens. After exposure to concentrations between 18 and 40 ppm (47 117 to 104 703 µg/m³), a deceleration of turbinate clearance was observed, as was a decrease in sinus clearance rates.

A previous study (Ukai et al., 1983) found similar decreases in turbinate clearance in chickens for both continuous and intermittent SO_2 exposure for 1 hour, 4 times/day for 2 days at concentrations between 4 and 40 ppm (10 470 to 104 703 µg/m³). Majima et al. (1985) also observed decreases in mucociliary transport rate in chickens exposed to 6 ppm SO_2 16 hours a day for 7 days.

Effects observed-bronchoconstriction or specific airway resistance

No effects on tidal volume or respiratory frequency were observed in chickens exposed to 100 ppm (261 759 µg/m³) SO_2 breathing through their nostrils and mouth, but a small, statistically significant increase in minute volume was observed (Fedde and Kuhlman, 1979). At 500 ppm SRaw decreased; at 1000 ppm (2 617 587 µg/m³) SRaw initially decreased, then subsequently increased. Also at 1000 ppm, respiratory frequency and minute volume decreased. The effects seen at 1000 ppm were increased at 5000 ppm (13 087 935 µg/m³). All exposures lasted 60 minutes

Respiratory System – Biochemical

Majima et al. (1985) investigated the elastic recoil distance both *in vivo* and *in vitro* of nasal mucous from chickens exposed to 6 ppm (15 706 µg/m³)SO_2 for 16 hours a day for 7 days. They observed a decrease in the recoil distance *in vivo*, but not *in vitro* after SO_2 exposure. Okuyama et al. (1979) exposed chickens to levels of SO_2 ranging from 3.4 to 18.5 ppm (8 900 to 48 425 µg/m³)for between 1 and 14 days to investigate any histological changes in the tracheal mucosa. At all exposure levels, there was an increase in infiltrating mononuclear and polymorphonuclear cells, acid phosphatase positive cells, the number of plasma cells and lymphocytes, acid mucins, and in the number of mitotic figures. There were also changes in mucus type and a decrease in neutral mucins. At the highest concentration (18.5 ppm), the mucosa-to-wall ratio doubled and some mucosal damage was observed. Bauer

(1981) exposed chickens to 350 to 400 ppm (916 155 to 1 047 035 µg/m³)SO_2 for three hours to investigate the biochemistry of tracheobronchial secretions. A significantly increased mucus output (320%) was observed in the chickens exposed to SO_2 compared to controls; however, glycoprotein output increased by only 50%. Therefore, the glycoprotein concentration was lowered to approximately one third of the concentration in the control group. No differences were observed in the carbohydrate pattern of the glycoproteins between the exposed and non-exposed chickens.

Cardiovascular System

Several studies investigated changes in heart rate with SO_2 exposure. A single high quality study found no differences in heart rate or blood pressure in chickens exposed to 100 ppm (261 759 µg/m³)SO_2 for 1 hour (Fedde and Kuhlmann, 1979). A statistically significant increase in heart rate was observed upon exposure to 5000 ppm (13 087 935 µg/m³)for one hour. Most of the chickens exposed at this level died.

General Biochemical Effects

Fedde and Kuhlman (1979) exposed male chickens to concentrations of SO_2 up to 5000 ppm (13 087 935 µg/m³)for 60 minutes by inhalation, either through tracheal cannulae or with intact respiratory systems. They observed no changes in arterial blood gases and pH at 100 ppm; however, there were statistically significant decreases in blood pH and increases in blood CO_2 at 5000 ppm with both methods of inhalation. In addition, statistically significant decreases in blood O_2 were observed in those birds with intact respiratory systems.

Immunological System

Okuyama et al (1979) observed an increase in the number of macrophages, lymphocytes, plasma cells and neutrophils in the epithelium and lamina propria of chickens exposed to 3.4 to 18.5 ppm (8 900 to 48 425 µg/m³) for 1 to 14 days.

Predicted SO_2 ground level concentrations with the operation of Kendal North

With the location of the proposed new power station, a concern was raised regarding the exposure of chickens to sulphur dioxide (SO_2) emissions. Hourly and daily ground level concentrations at the chicken farm (in the close proximity to the proposed power station sites) due to future cumulative operations were predicted to be ~ 4000 µg/m³ and 210 µg/m³ respectively, using the worst case scenario of the proposed Kendal North Power Station (150m stack height with no SO_2 controls). These levels are below observed cardiopulmonary effects observed in chickens. Although predicted concentrations appear low enough not to warrant any concern regarding health risks to chickens, it should be noted that the above-mentioned exposure testing does not reflect the impact of long-term exposure at low SO_2 concentrations.