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AIR QUALITY IMPACT ASSESSMENT FOR THE PROPOSED ESKOM LANDFILL SITE IN MEDUPI

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EXECUTIVE SUMMARY

The development of a landfill and hazardous waste storage facility has been proposed for the new Eskom Medupi Power Station in the Waterberg District Municipality in the Limpopo Province. Gondwana Environmental Solutions (GES) was appointed by Envirolution Consulting to undertake an air quality assessment of the proposed landfill. The main objective of the assessment was to determine the potential impact of emissions from the landfill processes on the surrounding air quality.

An initial baseline assessment was undertaken which includes a review of available meteorological data. The potential impact of emissions from the proposed landfill on the surrounding environment was evaluated through the compilation of an emissions inventory and subsequent dispersion modelling. Comparison with the South African ambient air quality standards was made to determine compliance in terms of potential health impacts.

A baseline assessment was undertaken through a review of available meteorological data from Lephalale for the period 2006 - 2008. Based on this assessment:

- Wind direction at Lephalale is north-north-east with lesser wind components from the north-east and north,

- A significant diurnal variation in wind direction is observed at Lephalale. Between 00:00 – 06:00, winds are predominantly from the north-east with a component from the north-north-east. Between 06:00 – 12:00 winds are predominantly from the north-north-east, with additional components from the north-east and north. Winds remain from the north-north-east during the afternoon, with components from north and north-north-west. During the evening (18:00 – 24:00), winds blow from the north-east and north-north-east .An increase in calm conditions is observed during the night.

- A significant seasonal variation in wind direction is observed at Lephalale. During summer (DJF), winds are predominantly from the north-east with a component from the north-north-east. Autumn (MAM) is also characterised by winds that are predominantly from the north-east, with components from the north, north-north-west and north-west. Winds blow from the north-north-east during the winter season (JJA) with components from north and north-east. During the Spring (SON) a similar pattern is observed with winds remaining from the north-north-east, north-east and north with a component from the north-north-west. An increase in calm conditions is observed during the winter season.

Predicted emissions from the landfill were evaluated to determine the impact of the proposed landfill on the surrounding air quality. The main conclusions can be summarised as follows:

- Emissions from the proposed Eskom landfill are predicted to be transported a few hundred meters downwind towards the north-west and south east and to a lesser extent, towards the western areas in respect of the landfill. This is due to the prevailing meteorological conditions in Lephalale.

- Predicted emissions of PM10 during the construction phase exceed the National daily and annual ambient air quality standards. Predicted emissions of TSP during the construction phase exceed the ambient air quality standards (Schedule 2, Section 63 of the National Air Quality Act of 2004) and pose a short-term health risk to inhabitants in the neighbouring areas.

- Predicted emissions of PM10 during the operational phase do not exceed the National daily and annual ambient air quality standards. Predicted emissions of TSP during the operational phase do not exceed the ambient air quality standards (Schedule 2, Section 63 of the National Air Quality Act of 2004), and do not pose a health risk to inhabitants in the neighbouring areas.

All the proposed Sites 5A, 5B and 5C are optimal for the development of the proposed landfill. It is recommended that additional studies with site-specific meteorological data should be done to establish more precisely the impacts on neighbouring areas, as well as odour and health risk studies. Such a campaign can be undertaken using a mobile air quality monitoring station which provides continous, real-time data of pollutant concentrations as well as meteorological parameters.

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LIST OF ABBREVIATIONS

AQA	-	National Environmental Management: Air Quality Act (Act No. 39 of 2004)
CH_4	-	Methane
CO	-	Carbon monoxide
CO_2	-	Carbon dioxide
DEAT	-	Department of Environmental Affairs and Tourism
DJF	-	December, January, February
EIA	-	Environmental Impact Assessment
JJA	-	June, July, August
H_2S	-	Hydrogen sulphide
MAM	-	March, April, May
NH_3	-	Ammonia
NO	-	Nitric oxide
NO_2	-	Nitrogen dioxide
NO_x	-	Oxides of nitrogen
O_3	-	Ozone
PM10	-	Particulate matter with an aerodynamic diameter of less than 10 µm
ppb	-	Parts per billion
ppm	-	Parts per million
SON	-	September, October, November
SO_2	-	Sulphur dioxide
SO_x	-	Oxides of sulphur
$\mu g/m^3$	-	Micrograms per cubic meter
USEPA	-	United States Environmental Protection Agency
VOC	-	Volatile Organic Compounds
WHO	-	World Health Organisation

1. INTRODUCTION

The development of a landfill and hazardous waste storage facility has been proposed for the new Medupi Power Station in the Waterberg District Municipality within Limpopo Province. Gondwana Environmental Solutions (GES) was appointed by Envirolution Consulting to undertake an air quality assessment of the proposed landfill. The main objective of the assessment was to determine the potential impact of emissions from the landfill on the surrounding air quality.

In terms of the Environmental Impact Assessment (EIA) Regulations published in terms of Section 24(5) of the National Environmental Management Act (NEMA, No 107 of 1998), Eskom requires authorization from the National Department of Environmental Affairs and Tourism (DEAT) for the undertaking of the proposed project. As part of this process, a specialist air quality investigation is required. An initial baseline assessment was undertaken which includes a review of available meteorological data for Lephalale. The potential impact of emissions from the proposed landfill on the surrounding environment was evaluated through a qualitative and quantitative desktop assessment of the possible gaseous compounds and particulate matter which may be released from the landfill site and associated processes, and subsequent dispersion modeling. Comparison with the South African proposed ambient air quality standards was made to determine compliance in terms of the potential for human health impacts.

The likelihood of these emissions exceeding the relevant air quality standards and the cumulative impact of these emissions on the existing ambient air quality in the area is discussed. The potential for fugitive dust emissions from the on-site processes is also be addressed. The most significant potential pollutants emitted from the landfill site and associated processes are inhalable particulates (PM10), TSP (Total Suspended Particulates) and gaseous emissions, most notably, methane (CH_4) and carbon dioxide (CO_2).

1.1. Terms of Reference

The terms of reference required to evaluate the potential impact that emissions from the landfill will have on the surrounding environmental are as follows:

- Detailed literature review of emissions from the landfill and associated processes,

- Review of potential health effects associated with these activities,
- Description of the general surroundings of the site as well as the relevant site specific environment,
- Evaluate meteorological data to determine the prevailing meteorological conditions and the influence on pollution dispersion and dilution in the area,
- Identify and quantify pollutants released from the landfill
- Predict pollutant concentrations and the distribution of emissions from the landfill,
- Analyse predicted concentrations to determine compliance with the South African ambient air quality standards;
- Recommend the implementation of mitigation measures to minimise the potential for air quality impacts, including a detailed air quality monitoring programme.

1.2. Outline of Report

An overview of the site location, including surrounding receptors and topography is given in **Section 2**. The South African air quality legislation and ambient air quality standards for the criteria pollutants are provided in **Section 3**. **Section 4** describes the health impacts of the criteria pollutants. The local meteorological conditions influencing the dilution and dispersion of pollution in the area are described in **Section 5**. The air quality impact assessment, comprising of an emissions inventory and dispersion modeling simulations, is given in **Section 6**. The report summary and recommendations are presented in **Section 7**.

2. BACKGROUND

Eskom envisage constructing and operating the proposed development within a 30 km radius of the existing Matimba and proposed Medupi Power Stations, and the Eskom construction village. The proposed development will also cater for two future power stations proposed in the Waterberg area (Coal A and B). The proposed location for this development falls within the boundaries of Eskom owned property.

2.1. Site Location

The proposed landfill is located adjacent to the Medupi Power Station which is being constructed 15 km from the town of Lephalale in Limpopo Province. There were five proposed sites for the scoping phase, and these were located on the farms Grootvallei 515 LQ and Farm Grootestryd (Figure 1). Farm Grootvlei is located adjacent to the Medupi Power Station which is currently under construction, and Farm Grootestryd is located near the existing Matimba Power Station. The scoping phase included specialist input which resulted in Sites 1 to 4 on Grootvallei Farm being excluded for the EIA. Site 5 was subdivided into 3 options for the construction of the landfill. These options were labeled as 5A, 5B and 5C. The EIA entailed the recommendation by the relevant specialists for an optimal site.

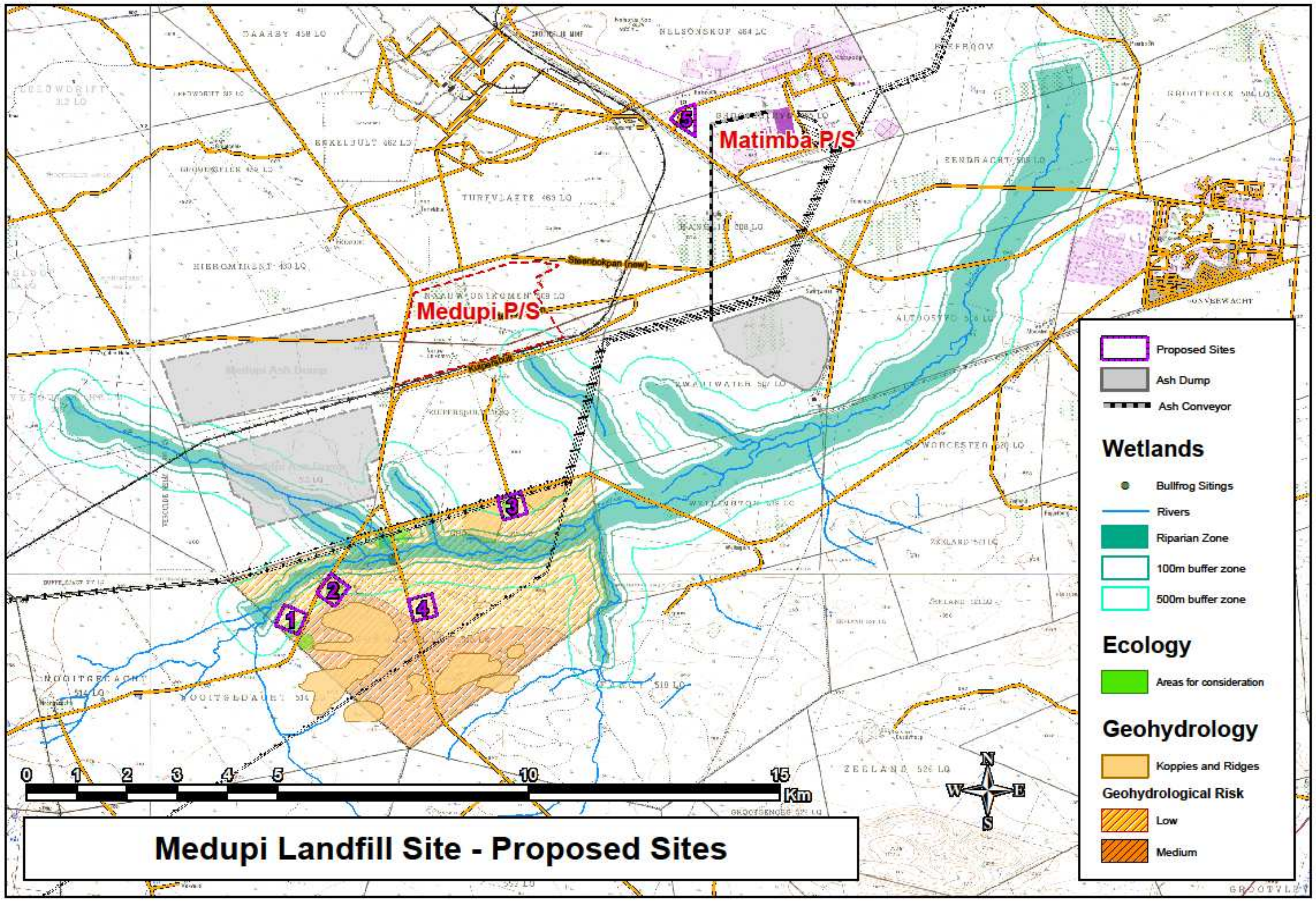


Figure 1: **Proposed Sites (Numbers 1 to 5)**

Land use surrounding the proposed landfill is predominantly used for power generation, coal mining and agriculture. Sensitive receptors in the area include the existing Eskom construction village, the residential area of Onverwacht and the Marapong informal settlement near Matimba Power Station. The proposed site is characterised by open bushveld.

2.2. Topography

Topography surrounding the proposed landfill is characterised as gently undulating surrounded by mountainous regions The Waterberg District is characterised by its distinct topography with a significant portion of the District covered in mountainous terrain (Figure 2). The general fall of the land is from the high-lying areas in the south and east to the lower lying areas in the north and west.

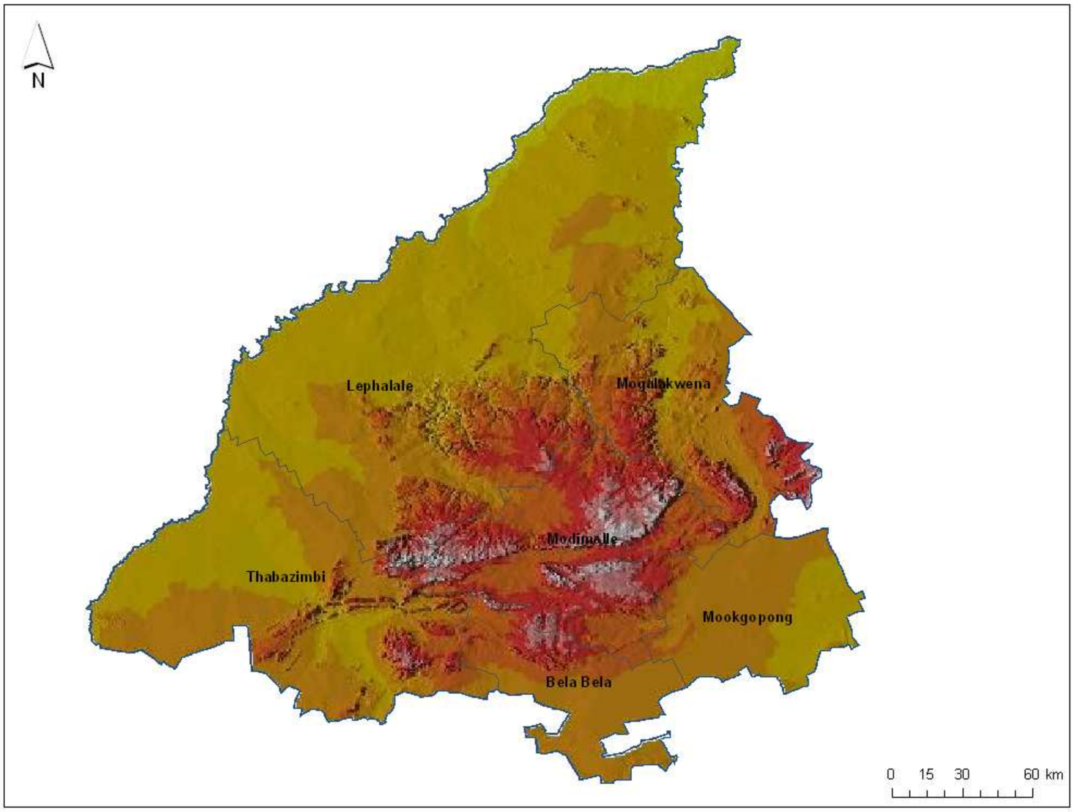


Figure 2: **Topography surrounding the proposed landfill**

2.3. General Overview of Landfills

According to the Department of Water Affairs and Forestry (1998), landfilling is environmentally acceptable if properly undertaken. Unfortunately, if not undertaken to sufficiently high standards', landfilling has the potential to have an adverse impact on the environment. This impact may be divided into short term impacts and long term impacts. Short-term impacts include problems such as noise, flies, odour, air pollution, unsightliness and windblown litter. Such nuisances are generally associated with a waste disposal operation and should cease with the closure of the landfill.

Long term impacts include problems such as pollution of the water regime and landfill gas generation. Such problems are generally associated with incorrect landfill site selection, design, preparation or operation and may persist long after the landfill site has been closed.

Since landfills differ from one another in terms of size, type and potential threat to the environment, a classification system has been developed, whereby landfills can be differentiated (Table 1). Waste types are grouped into two classes, namely, General waste and Hazardous waste.

2.3.1. General Waste

General waste is a generic term for waste that, because of its composition and characteristics, does not pose a significant threat to public health or the environment if properly managed. Examples include domestic, commercial, certain industrial waste and builders' rubble. General waste may have insignificant quantities of hazardous substances dispersed within it, for example, batteries, insecticides, weed-killers and medical waste discarded on domestic and commercial premises. General waste may be disposed of on any permitted landfill (DWAF, 1998).

General waste can produce leachate with an unacceptably high pollution potential. This may result from waste decomposition, together with the infiltration and/or percolation of water. Therefore, under certain conditions general waste disposal sites must have leachate management systems. Therefore, in addition to being sub divided in terms of size of operation, general waste landfills are subdivided in terms of their potential to generate significant leachate.

2.3.2. Hazardous Waste

Hazardous waste is waste which can, even in low concentrations, have a significant adverse effect on public health and/or the environment. This would be because of its inherent chemical and physical characteristics, such as toxic, ignitable, corrosive, carcinogenic or other properties.

The following types of waste should be regarded as potentially hazardous:

- Inorganic waste - Acids and alkalis, Cyanide waste, Heavy metal sludge's and solutions, Waste containing appreciable proportions of fibrous asbestos.
- Oily waste - Wastes primarily from the processing, storage and use of mineral oils.
- Organic waste - Halogenated solvent residues, non-halogenated solvent residues, Phenolic waste, PCB waste, paint and resin waste, biocide waste and organic chemical residues.

- Putrescible organic waste – Waste from the production of edible animal and vegetable oils, slaughter houses, tanneries and other animal and vegetable based products.
- High volume/low hazard waste--Waste that contains small quantities of highly dispersed hazardous substances. This waste presents a relatively low hazard. Examples are harbour dredge spoils, sewage sludge, soils and builders' rubble, which are contaminated by heavy metals, oils and other pollutants.
- Miscellaneous waste---Infectious waste such as diseased human/animal tissues, soiled bandages and syringes which are commonly referred to as 'medical waste', redundant chemicals or medicines, laboratory waste, explosive waste from manufacturing operations or redundant munitions.

Hazardous wastes are allocated a hazard rating. The hazard rating is based on acute mammalian toxicity, ecotoxicity, environmental fate, chronic toxicity and other criteria.

Hazardous waste is thus classified into:

Hazard Rating 1: Extreme Hazard

Hazard Rating 2: High Hazard

Hazard Rating 3: Moderate Hazard

Hazard Rating 4: Low Hazard.

Table 1: Landfill Classification System.

WASTE CLASS	G General Waste				H Hazardous Waste	
SIZE OF LANDFILL OPERATION	C Communal Landfill	S Small Landfill	M Medium Landfill	L Large Landfill	H:h Hazard Rating 3&4	H:H Hazard Rating 1&2
SITE WATER BALANCE	B-	B+	B-	B+		
MINIMUM REQUIREMENTS						

NOTES

B- = No significant leachate will be generated in terms of the Site Water Balance (Climatic Water Balance calculations plus Site Specific Factors), so that a leachate management system is not required.

B+ = Significant leachate will be generated in terms of the Site Water Balance (Climatic Water Balance calculation and Site Specific Factors), so that a leachate management system is required.

h = A containment landfill which accepts **H**azardous waste with Hazard Ratings 3 and 4.

H = A containment landfill which accepts all **H**azardous waste, i.e. with Hazard Ratings 1, 2, 3 and 4.

2.4. Description of the Proposed Eskom Landfill

Eskom is presently constructing a 6 x 800 MW (4800 MW total capacity) coal-fired power station known as Medupi Power Station. The power station is located 15 km from the town of Lephalale in Limpopo Province. The construction of the Medupi Power Station will result in the generation of both general and hazardous waste. It should be noted that the waste dump which exists at the town of Lephalale is not licensed and therefore, in terms of Eskom's Safety Health and Environment (SHE) Policy and commitment to legal compliance, cannot be utilised for the disposal of the waste generated.

The proposed facility will be designed such that it will accommodate the general as well as hazardous waste from the Medupi and Matimba Power Stations, as well as the anticipated Waterberg Power Stations and the nearby Eskom construction village in Marapong. The hazardous waste that will be stored is mainly oily waste and therefore is considered to be a low hazard. The facility will comprise of amongst others: access roads, water pipelines for potable water, the waste disposal site, and distribution lines for providing electricity to the facility.

During the construction of the Medupi Power Station, it is anticipated that construction waste will be generated until 2014 after which the station will transition into an operational phase. Approximately half of this will be hazardous waste and half general waste. It is anticipated that the existing Matimba Power Station will generate the same amount of waste, with a 50% split between hazardous and general waste for the remainder of its operating life, whereas the two proposed Waterberg Coal Fired Power Stations are anticipated to generate waste volumes that are slightly higher than that for the Medupi Power Station. These power plants are anticipated to have a life span of 50 years. The total anticipated waste generated from the four power stations over their total life is expected to be approximately 1,200,000 m^3 of waste split between general and hazardous waste.

3. AIR QUALITY LEGISLATION AND STANDARDS

3.1. National Ambient Air Quality Standards

The Department of Environmental Affairs and Tourism issued ambient air quality guidelines for several criteria pollutants, including particulates, sulphur dioxide, oxides of nitrogen, lead, ozone and carbon monoxide. The Air Quality Act of 2004 adopted these guidelines as National ambient air quality standards. On 2 June 2006, the Minister of Environmental Affairs and Tourism announced his intention of setting new ambient air quality standards in terms of Section 9(1)(a) and (b) of the Air Quality Act. The proposed new standards were published for public comment in the Government Gazette of 9 June 2006. Since then, updated draft National standards with allowable frequencies of exceedance and compliance timeframes have been proposed (Table 2).

The revised National Ambient Standards have been published for public comment on the 13th of March 2009 (Government Gazette 31987, Notice 263).

Table 2 gives an overview of the revised National Ambient Standards, as well as reference methods and compliance dates for criteria pollutants.

Table 2: Proposed National Standards for Ambient Air Quality as of 13 March 2009.

National Ambient Air Quality Standards for Sulphur Dioxide (SO_2)				
AVERAGING PERIOD	**LIMIT VALUE (µg/m^3)**	**LIMIT VALUE (ppb)**	**FREQUENCY OF EXCEEDANCE**	**COMPLIANCE DATE**
1 hour	350	134	88	Immediate
24 hours	125	48	4	Immediate
1 year	50	19	0	Immediate
The reference method for the analysis of SO_2 shall be ISO 6767.				

National Ambient Air Quality Standards for Nitrogen Dioxide (NO_2)				
AVERAGING PERIOD	**LIMIT VALUE (µg/m^3)**	**LIMIT VALUE (ppb)**	**FREQUENCY OF EXCEEDANCE**	**COMPLIANCE DATE**
1 hour	200	106	88	Immediate
1 year	40	21	0	Immediate
The reference method for the analysis of NO_2 shall be ISO 7996.				

National Ambient Air Quality Standards for Particulate Matter (PM_{10})				
AVERAGING PERIOD	**LIMIT VALUE (µg/m^3)**	**LIMIT VALUE (ppb)**	**FREQUENCY OF EXCEEDANCE**	**COMPLIANCE DATE**
24 hour	75		4	Immediate
1 year	40		0	Immediate
The reference method for the determination of the PM_{10} fraction of suspended particulate matter shall be EN 12341.				

National Ambient Air Quality Standards for Ozone (O_3)				
AVERAGING PERIOD	**LIMIT VALUE (µg/m^3)**	**LIMIT VALUE (ppb)**	**FREQUENCY OF EXCEEDANCE**	**COMPLIANCE DATE**
8 hours (running)	120	61	11	Immediate
The reference method for the analysis of ozone shall be the UV photometric method as described in ISO 13964.				

National Ambient Air Quality Standards for Benzene (C_6H_6)				
AVERAGING PERIOD	**LIMIT VALUE (µg/m^3)**	**LIMIT VALUE (ppb)**	**FREQUENCY OF EXCEEDANCE**	**COMPLIANCE DATE**
1 year	5	1.6	0	Immediate
The reference methods for the sampling and analysis of benzene shall either be EPA compendium method TO-14 A or method TO-17.				

National Ambient Air Quality Standard for Lead (Pb)				
AVERAGING PERIOD	**LIMIT VALUE (µg/m^3)**	**LIMIT VALUE (ppb)**	**FREQUENCY OF EXCEEDANCE**	**COMPLIANCE DATE**
1 year	0.5		0	Immediate
The reference method for the analysis of lead shall be ISO 9855.				

National Ambient Air Quality Standards for Carbon Monoxide (CO)				
AVERAGING PERIOD	**LIMIT VALUE (mg/m^3)**	**LIMIT VALUE (ppm)**	**FREQUENCY OF EXCEEDANCE**	**COMPLIANCE DATE**
1 hour	30	26	88	Immediate
8 hour (calculated on 1 hourly averages)	10	8.7	11	Immediate
The reference method for analysis of CO shall be ISO 4224.				

3.2. Dust Deposition

Dust deposition has to date been evaluated according to the following criteria:

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 1200 $mg/m^2/day$ threshold level has typically been used in practice as an action level, with exceedances of this dustfall rate indicating the need for investigating the specific causes of high dustfall and for taking remedial steps. "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 above-mentioned dustfall guidelines is that they are purely descriptive, without specific guidance for action or remediation not being made explicit in the guidelines. SANS 1929:2004 stipulates that dustfall rates be evaluated against a four-band scale, as presented in Table 3. Target, action and alert thresholds for ambient dust deposition are given in Table 4.

Table 3: Bands of dustfall rates proposed for adoption (SANS 1929:2004)

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 < 1200	Permissible for heavy commercial and industrial
3	ACTION	1200 < D < 2400	Requires investigation and remediation if two sequential months lie in this band, or more than three occur in a year.
4	ALERT	2400 < D	Immediate action and remediation required following the first exceedance. Incident report to be submitted to relevant authority.

Table 4: Target, action and alert thresholds for ambient dustfall (SANS 1929)

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	1200	30 days	Three within any year, not sequential months.
ALERT THRESHOLD	2400	30 days	None. First exceedance requires remediation and compulsory report to authorities.

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.

3.3. Minimum Requirements for Waste Disposal by Landfill

Minimum Requirements for the Waste Disposal by Landfill: Section 20 of the Environment Conservation Act, 1989 (Act 73 of 1989) stipulates that no person may dispose of waste unless under the authority of a permit issued by the Minister of Environmental Affairs and Tourism. Waste disposal sites are regulated by the Department of Environmental Affairs and Tourism (DEAT) by means of the *Minimum Requirements for the Waste Disposal by Landfill* (DWAF, 1998, Second Series). These guidelines initially drafted and administered by DWAF and now in their 3rd revision and administered by DEAT, deal with waste disposal by landfill, handling, classification and disposal of hazardous waste, and water monitoring at waste management facilities.

Depending on the landfill classification and size landfill requirements may include:

- Various types of landfill lining and capping systems
- Operational controls, e.g. daily cover of work surface with cover material
- Gas monitoring and management systems
- Restrictions on ambient methane concentrations.

Typical problems associated with landfill operations in South Africa which are associated with atmospheric emission potentials include: fires, inadequate daily cover practices and acceptance of hazardous waste types by general landfill operations. DEAT and the Gauteng Department of Agriculture, Conservation and Environment (GDACE) have started to initiate coordinated programmes to address such non-compliance issues. The evaluation checklist used by both DEAT and GDACE personnel for site inspection purposes are both based on the Minimum Requirements. It is also notable that the DEAT is currently in the process of revising the Minimum Requirements (Third Revision) document and that the revision is expected to deal more holistically with the management of atmospheric emissions and impacts of landfill operations.

National Waste Management Strategies and Action Plans (NWMS) (DEAT, 1999): This sets out numerous strategies and plans on how to manage and especially minimise or prevent waste. The first three components selected for implementation are health care waste, recycling and a waste information system. It also advocates a tiered approach to waste management with waste prevention, treatment and recycling being prioritised, has important implications for local landfill operations.

The Policy on Pollution Prevention, Waste Minimisation, Impact Management and Remediation: This policy outlines government's thinking in relation to pollution and waste management and encompasses all domestic and industrial sectors. *The White Paper on Integrated Pollution and Waste Management* (DME, 2000) advocates a shift from the focus on waste disposal and impact control (i.e. end-of-pipe) to integrated waste management and prevention as well as minimisation.

The Polokwane Declaration on Waste Management states that the government, business and civil society need to join in common efforts toward the accomplishment of the goal for reduction of waste generation and disposal by 50% and 25% respectively by 2012, and develop a plan for “zero waste” by 2022.

3.3.1. Buffer and Management Zone Projections

Buffer zones, or set back distances, represent separations between the registered landfill site boundary and any adjacent residential areas or sensitive developments. Such buffer zones are established to ensure that a landfill operation does not have an adverse impact on *quality of life and/or public health*. The establishment and maintenance of buffer zones is enforceable in terms of the Health Act, 1977 (Act 63 of 1977), which makes provision for measures necessary to prevent any nuisance, unhygienic or offensive condition that is harmful to health (DWAF, 1998a).

Although the width of the buffer zone is prescribed for communal and small landfills, such zones need to be independently defined for all other landfills based on the classification of the landfill and on site-specific factors which may influence the landfill’s impact on the environment (DWAF, 1998a). The extent of gaseous emission is largely dependent on the composition of the waste accepted at the landfill and the waste treatment and management methods applied. The amount of vehicle activity at the site, and the control efficiency of fugitive dust abatement measures implemented determine the particulate emission rate. The atmospheric dispersion of gaseous and particulate emissions is a function of the macro- meso- and micro-scale ventilation potentials characterising the site.

It is recommended by the Department of Water Affairs and Forestry (1998a) that scientific investigations, which could include air dispersion modelling and health risk assessments, be undertaken to determine the width of buffer zones for large and hazardous waste landfills. Buffer zone widths are ultimately approved by the relevant government departments, on the basis of the investigations undertaken and following consultation with interested and affected parties (I&AP). In regards to the definition of a buffer zone for waste disposal site it is recommended that a distinction be made between:

- *Management zones* - indicative of the odour and dust impact areas, with reductions in the extent of such impact areas requiring the implementation of emission reduction measures at the waste disposal site.
- *Buffer zones* - delineated exclusively on the basis of health impact zones and of crucial importance in terms of determining land use potentials.

4. CRITERIA POLLUTANTS AND ASSOCIATED HEALTH AND ENVIRONMENTAL IMPACTS

Deteriorating urban air quality has implications for human health, climate and visibility. An overview of the criteria pollutants and associated human health and environmental impacts is discussed in the section below.

4.1. Human Health Impacts

4.1.1. Particulate Matter

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

In terms of health impacts, particulate air pollution is associated with effects of the respiratory system (WHO, 2000). Particle size is important for health because it controls where in the respiratory system a given particle deposits. Fine particles have been found to be more damaging to human health than coarse particles as larger particles are less respirable in that they do not penetrate deep into the lungs compared to smaller particles (Manahan, 1991). Larger particles are deposited into the extrathoracic part of the respiratory tract while smaller particles are deposited into the smaller airways leading to the respiratory bronchioles (WHO, 2000).

Short-term exposure

Recent studies suggest that short-term exposure to particulate matter leads to adverse health effects, even at low concentrations of exposure (below 100 µg/m^3). Morbidity effects associated with short-term exposure to particulates include increases in lower respiratory symptoms, medication use and small reductions in lung function.

Long-term exposure

Long-term exposure to low concentrations (~10 μg/m^3) of particulates is associated with mortality and other chronic effects such as increased rates of bronchitis and reduced lung function (WHO, 2000). Those most at risk include the elderly, individuals with pre-existing heart or lung disease, asthmatics and children.

4.1.2. Volatile Organic Compounds

Volatile Organic Compounds (VOCs) are organic chemicals that easily vapourise at room temperature and are colourless. VOCs are released from vehicle exhaust gases either as unburned fuels or as combustion products, and are also emitted by the evaporation of solvents and motor fuels. Short-term exposure to VOCs can cause eye and respiratory tract irritation and damage, headaches, dizziness, visual disorders, fatigue, loss of coordination, allergic skin reactions, nausea, and memory impairment, damage the bone marrow and even death. Long-term exposure to high levels of VOCs has been linked to an increase in occurrence of leukaemia. VOCs can also cause damage to the liver, kidneys and central nervous system.

4.1.2.1. Benzene

Benzene in air exists predominantly in the vapour phase, with residence times varying between a few hours and a few days, depending on the environment, climate and the concentration of other pollutants. The only benzene reaction, which is important in the lower atmosphere, is the reaction with hydroxy radicals. The products of this reaction are phenols and aldehydes, which react quickly and are removed from air by rain.

Benzene is a natural component of crude oil, and petrol contains 1 – 5% by volume. Benzene is produced in large quantities from petroleum sources and is used in the chemical synthesis of ethyl benzene, phenol, cyclohexane and other substituted aromatic hydrocarbons. Benzene is emitted from industrial sources as well as from combustion sources such as motor engines, wood combustion and stationary fossil fuel combustion. The major source is exhaust emissions and evaporation losses from motor vehicles, and evaporation losses during the handling, distribution and storage of petrol.

Information on health effects from short-term exposure to benzene is fairly limited. The most significant adverse effects from prolonged exposure to benzene are haematotoxicity, genotoxicity and carcinogenicity. Chronic benzene exposure can result in bone marrow depression expressed as leukopenia, anaemia and/or thrombocytopenia, leading to pancytopenia and aplastic anaemia. Based on this evidence, C_6H_6 is recognized to be a human and animal carcinogen. An increased mortality from leukemia has been demonstrated in workers occupationally exposed (WHO, 2000).

4.1.2.2. Toluene

Toluene is produced from the catalytic conversion of petroleum and aromatization of aliphatic hydrocarbons and as a by-product of the coke oven industry. The bulk of production is in the form of a benzene-toluene-xylene mixture that is used in the back blending of petrol to enhance octane ratings. Toluene is used as a solvent, carrier or thinner in the paint, rubber, printing, cosmetic, adhesives and resin industries, as a starting material for the synthesis of other chemicals and as a constituent of fuels (WHO, 2000).

Toluene is believed to be the most prevalent hydrocarbon in the atmosphere. Reactions with hydroxy radicals are the main mechanisms by which toluene is removed from the atmosphere. The lifetime of toluene can range from a few days in summer to a few months in winter (WHO, 2000).

The short-term and long-term effects of toluene on the Central Nervous System are of great concern. Toluene may also cause developmental decrements and congential abnormalities in humans. The potential effects of toluene exposure on reproduction and hormonal imbalances in women are also of concern. Men occupationally exposed to toluene at 5 – 25 ppm have also been shown to exhibit hormonal imbalances. Limited information suggests an association between occupational toluene exposure and spontaneous abortions at an average concentration 88 ppm. Toluene has minimal effects on the liver and kidney, except in cases of toluene abuse. Studies have not indicated that toluene is carcinogenic (WHO, 2000).

Table 5: Short-term and long-term health effects associated with exposure to PM, and CO_2 (after WHO, 2004).

Pollutant	Short-term exposure	Long-term exposure
Particulate matter	• Lung inflammatory reactions • Respiratory symptoms • Adverse effects on the cardiovascular system • Increase in medication usage • Increase in hospital admissions • Increase in mortality	• Increase in lower respiratory symptoms • Reduction in lung function in children • Increase in chronic obstructive pulmonary disease • Reduction in lung function in adults • Reduction in life expectancy • Reduction in lung function development

4.2. Existing Sources of Atmospheric Emissions in Lephalale Area

A comprehensive emissions inventory has not been completed for the region to date. The establishment of such an inventory is not within the scope of the current study. Instead, source types present in the area are noted with the aim of identifying pollutants that may be of importance in terms of their cumulative impacts.

Existing sources of atmospheric emission which occur in the vicinity of the identified landfill sites include:

- Existing Matimba Power Station and its associated ash dump
- Construction of the Medupi power station
- Grootegeluk opencast coal mining operations,
- Potential veld fires,
- Sewage works (Farm Nelsonskop),
- Wind-blown dust from open areas and agricultural activities,
- Household fuel combustion,
- Vehicle exhaust releases and road dust entrainment along paved and unpaved roads in the area,
- Burning of the municipal waste dump,
- Cross-boundary pollution from biomass burning and industrial activities.

Ambient air pollutant concentrations within the Lephalale region occur not only due to local sources but also as a result of emissions from various remote sources. Regionally-transported air masses comprising well mixed concentrations of 'aged' (secondary) pollutants are known to represent a significant component of ambient fine particulate concentrations within the South African interior. Such air masses contain pollutants released from various remote sources including elevated releases from distant industrial operations and power generation facilities and large scale biomass burning in neighbouring countries. Typical pollutants which circulate within such regionally-transported polluted air masses include nitrates, ammonium nitrate and sulphates.

The quantification of background particulate concentration, which is of particular importance given the nature of the proposed development, is complicated due to the large number of sources of this pollutant. Sources of particulates also include a significant proportion of fugitive emissions from diffuse sources (e.g. vehicle-entrained dust from roadways, wind-blown dust from stockpiles and open areas, dust generated by materials handling) which are more difficult to quantify than are emissions from point sources.

Emissions from landfills are a concern in terms of the potential for health effects and the odours generated. Landfills are important sources of the greenhouse gases such as CH_4 and CO_2, which account for approximately 40 – 60% of all landfill emissions. Landfill gases also contain trace amounts of non-methane organic compounds, including various hazardous air pollutants and VOCs (USEPA, 1995). Odorous emissions from landfills can also be a severe public nuisance.

Based on air quality impact assessments conducted for general and hazardous waste disposal sites (Liebenberg-Enslin and Petzer, 2005) found that within 500 m of the landfill severe health effects occur, odour is potentially an issue between 200 m and 5 km depending on the management of the facility Environmental Impacts.

5. METEOROLOGICAL OVERVIEW

Meteorological data was obtained from the Agricultural Research Council (ARC) Bergfontein meteorological station located at Lephalale for the period 2006 – 2008. This station is located approximately 15 km from the proposed landfill sites and is not considered to be site representative because it is not located at any of the proposed sites.

The predominant wind direction at Lephalale is north-north-east (10 %) with lesser wind component from the north-east (9.5%) and north (6.5%) (Figure 3). Wind speeds are generally slow to moderate with no wind speeds exceeding 6 m/s being recorded. Wind speeds of less than 1 m/s, which are designated as calm, occur 47.18 % of the time.

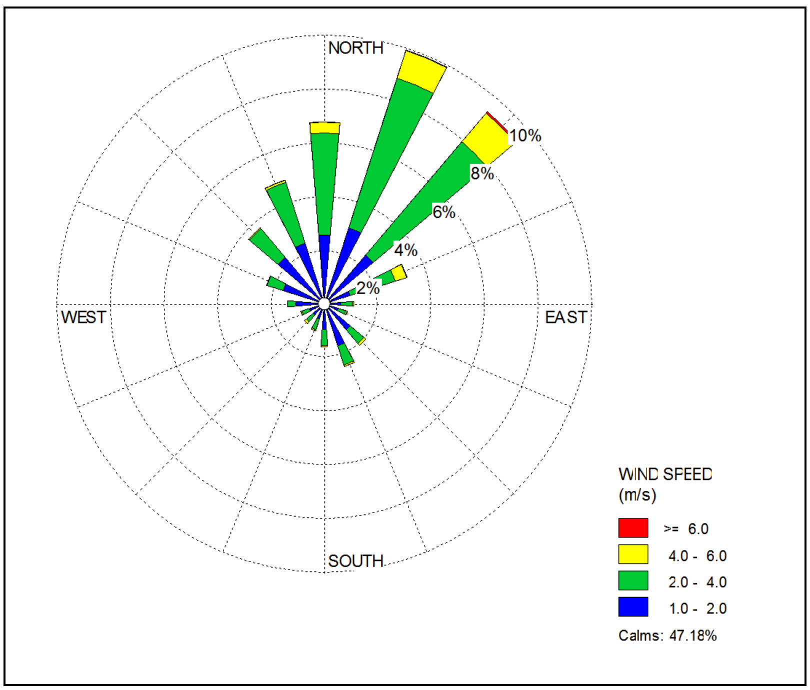


Figure 3: Surface wind rose for Bergfontein Meteorological Station in Lephalale for the period 2006 – 2008.

A significant diurnal variation in wind direction is observed at Lephalale (Figure4). Between 00:00 – 06:00, winds are predominantly from the north-east (7.5 %) with an additional component from the north-north-east (4.8 %). Between 06:00 – 12:00 winds are predominantly from the north-north-east (13 %), with additional components from the north-east (11.8 %) and north (9%). Winds remain from the north-north-east (14%) during the afternoon (12:00 – 18:00), with additional components from north (12.1 %) and north-

north-west (11.6 %). During the evening (18:00 – 24:00), winds blow from the north-east (9%) and north-north-east (7.9 %). An increase in calm conditions is observed during the night (61.61%).

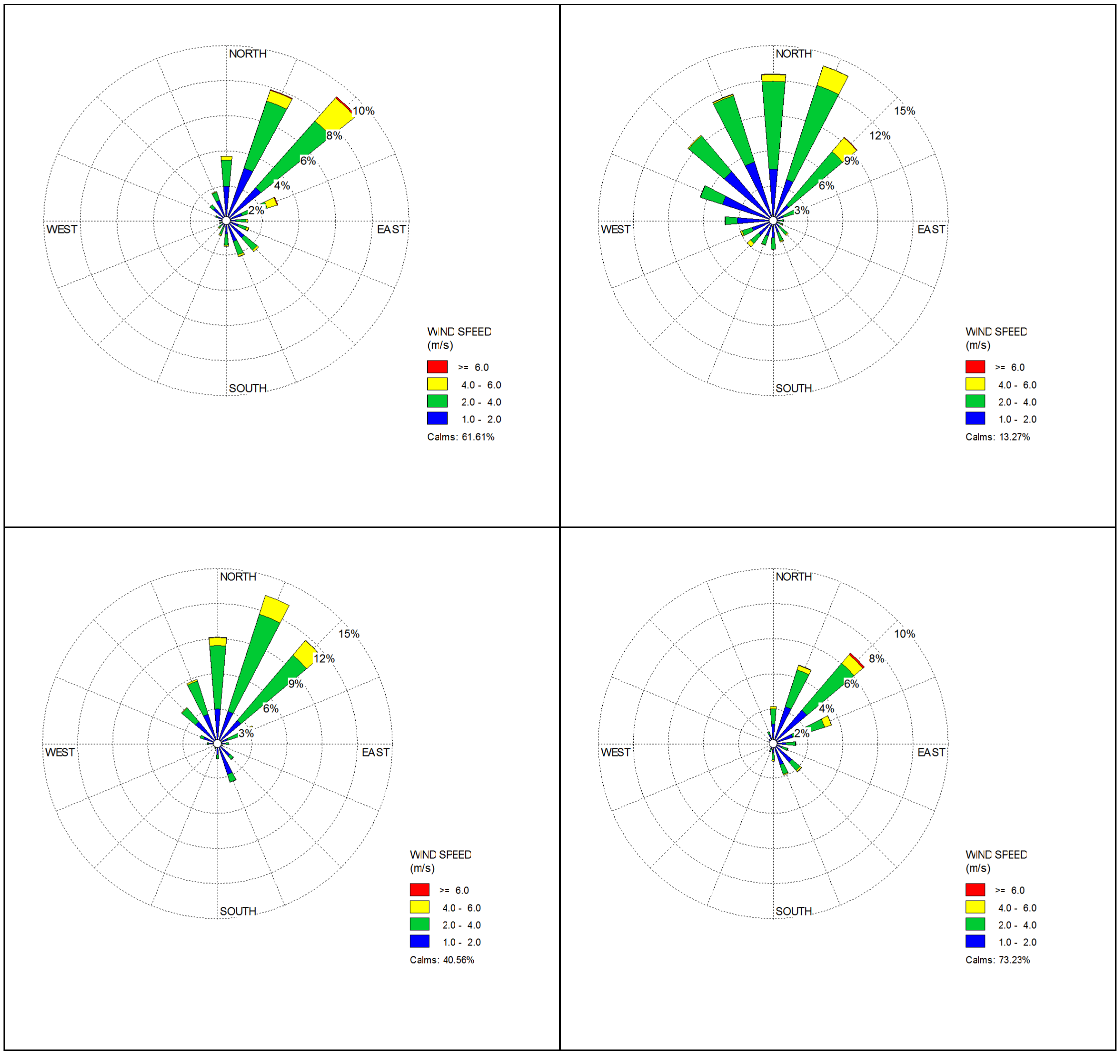


Figure 4: **Diurnal variation of winds at Bergfontein meteorological station in Lephalale for the period 2006 – 2008 between 00:00 – 06:00 (top left), 06:00 – 12:00 (top right), 12:00 – 18:00 (bottom left) and 18:00 – 24:00 (bottom right).**

A significant seasonal variation in wind direction is observed at Lephalale (Figure 5). During summer (DJF), winds are predominantly from the north-east (13 %) with an additional component from the north-north-east (12.2 %). Autumn (MAM) is also characterised by winds that are predominantly from the north-east (7 %), with additional components from the north (4.3 %), north-north-west (4.3%) and north-west (4.3%).

Winds blow from the north-north-east (7.5%) during the winter season (JJA) with additional components from north (5.5 %) and north-east (5.8 %). During the Spring (SON) a similar pattern is observed with winds remaining from the north-north-east (14.8%), north-east (12 %) and north (10%) with a component from the north-north-west (7%). An increase in calm conditions is observed during the winter season (59.06%).

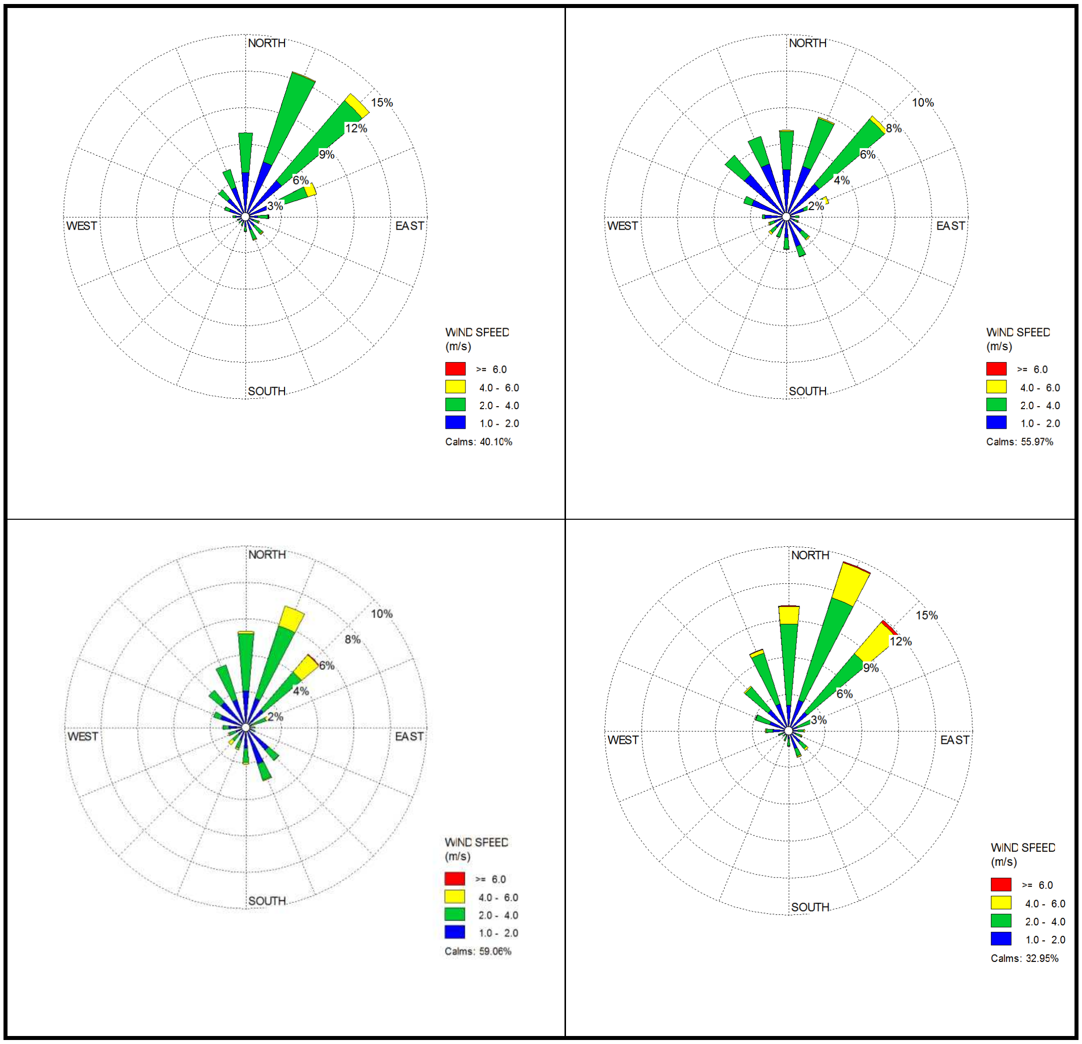


Figure 5: **Seasonal variation of winds in Bergfontein meteorological station in Lephalale for the period 2006 – 2008 during summer (DJF) (top left), autumn (MAM) (top right), winter (JJA) (bottom left) and spring (SON) (bottom right).**

6. AIR QUALITY IMPACT ASSESSMENT

6.1. Methodology

The activities within the framework of the proposed development and its construction and operational phases give rise to certain impacts. For the purpose of assessing these impacts, the project has been divided into four phases from which impacting activities can be identified, namely:

a. **Status Quo Assessment** – The current situation of the site taking cognizance of the disturbance and the impacts remaining while operating,
b. **Pre-construction phase** – All activities on site up to the start of the construction, not including the transport of materials, but including the initial site preparations. This also includes the impacts, which would be associated with planning.
c. **Construction phase** - All the construction and construction related activities on site until the contractor leaves the site.
d. **Operational phase** - All activities including the operation and maintenance of the proposed development.

6.2. Emissions Methodology

Under standard operating practices, a G:L:B$^-$ landfill site is characterised by two main sources of gaseous emissions, namely (i) the working face, and (ii) the landfill portions of the landfill. Sources of fugitive dust emissions include: vehicle-entrained dust from unpaved roads, materials handling operations (e.g. waste movement, compaction and tipping operations), wind erosion from open areas and soil cover, and vehicle activity on the landfill site, including general vehicle traffic (excavators, bulldozers, compactors, trucks, etc.) and earthmoving activities.

In assessing the impact of fugitive dust emissions a distinction needs to be made between Total Suspended Particulates (TSP) and respirable particulates. Although TSP may be defined as all particulates with an aerodynamic diameter of less than 100 µm, an effective upper limit of 30 µm aerodynamic diameter is frequently assigned. Respirable particulates are generally defined as particulate matter with an aerodynamic diameter of less than 10 µm (PM10). PM10 has health implication since it represents particles of a size that would be deposited in, and damaging to the lungs.

In the quantification of TSP and PM10 emissions use was made of the comprehensive set of emission factors published by the US Environmental Protection Agency (US-EPA) in its AP-42 document *Compilation of Air Pollution Emission Factors* and emission factors published in Australian *National Pollutant Inventory* Emission Estimation Technique (EET) Manuals. Empirically derived *predictive emission factor equations* are available for vehicle entrained dust from roadways, aeolian erosion from open areas, and for bulldozer and materials handling operations.

For the purpose of estimating fugitive dust emissions and resultant airborne particulate concentrations and dustfall rates, the rate of deposition is 24 000 tonnes per year. During the landfills lifetime of fifty years an estimated ~1,200,00 tonnes of waste will be landfilled requiring the use of ~300,000 tonnes of cover material, given the waste deposition rate of approximately 92 tpd and the cover ratio of 1:4. It was assumed that the landfill will be operational for 8 hours a day and 5 days a week.

6.2.1. Vehicle-Entrained Dust from Unpaved Roads

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

Although the main access road will be paved, on-site roads will remain unpaved.

The AP-42 (USEPA, 1998) emission factor equation for wheel generated dust on unpaved roads used in the quantification of emissions is given as follows:

$$EF_i = k_i \times \left(\frac{s}{12}\right)^A \times \left(\frac{W}{3}\right)^B \div \left(\frac{M}{0.2}\right)^C \qquad \text{kg/VKT}$$

where:

k_i = 2.82 for particles less than 30 micrometres aerodynamic diameter

k_i = 0.733 for particles less than 10 micrometres aerodynamic diameter

s = silt content of road surface material %

W = mean vehicle weight (tonnes)

M = surface material moisture content %

A = empirical constant: 0.8 (for PM10) & 0.8 (for TSP)

B = empirical constant: 0.4 (for PM10) & 0.5 (for TSP)

C = empirical constant: 0.3 (for PM10) & 0.4 (for TSP)

(i) = particle size category.

This gives us refined formulae for TSP and PM10 emissions as follows:

$$E_{TSP} = 2.82 \times \left(\frac{s}{12}\right)^{0.8} \times \left(\frac{W}{3}\right)^{0.5} \div \left(\frac{M}{0.2}\right)^{0.4} \qquad E_{PM10} = 0.733 \times \left(\frac{s}{12}\right)^{0.8} \times \left(\frac{W}{3}\right)^{0.4} \div \left(\frac{M}{0.2}\right)^{0.3}$$

where,

E = emissions in kg of particulates per vehicle kilometre travelled (vehicle kilometres travelled)

s = silt content of road surface material (%)

W = mean vehicle weight (tonnes)

M = surface material moisture content, %.

The mean silt content given by the US-EPA is being typical for disposal routes at municipal solid waste landfills (i.e. 6.4%) (US EPA – Unpaved roads). Haul trucks were assumed to have a payload capacity of 5 tonnes and an average weight of 13 tonnes. The maximum vehicle speed on-site was given as being in the order of about 4 km/hr.
The maximum length of all the unpaved on-site roads was estimated for each of the modeling scenarios; however the average width of roads was assumed to be 10 m for all the scenarios.

The rate of erosion for TSP and PM10 was estimated to be ~0.95 tpa and 0.32 tpa, respectively.

6.2.2. Wind Erosion of Open Areas

Dust emissions due to the erosion of open storage piles and exposed areas occur when the threshold wind speed is exceeded (Cowherd *et al.*, 1988; EPA, 1995). The threshold wind speed is dependent on the erosion potential of the exposed surface, which is expressed in terms of the availability of erodible material per unit area (mass/area). Any factor which binds the erodible material or otherwise reduces the availability of erodible material on the surface thus decreases the erosion potential of the surface. Studies have shown that when the threshold wind speeds are exceeded, particulate emission rates tend to decay rapidly due to the reduced availability of erodible material (Cowherd *et al.*, 1988).

It is anticipated that significant amounts of dust will be eroded from the open areas at the Eskom site under wind speeds of greater than 5.4 m/s (i.e. threshold friction velocity of 0.26 m/s). Fugitive dust generation resulting from wind erosion under high winds (i.e. > 5.4 m/s) is directly proportional to the wind speed. The relationship for the annual average wind erosion from a continuously active site is given as:

$$E_{TSP} = 1.9 \times \left(\frac{s}{1.5}\right) \times \left(\frac{365-p}{235}\right) \times \left(\frac{f}{15}\right)$$

where,

E_{TSP}=Total Suspended Particulate emission factor, kg/d/ha

s=silt content of aggregate (%)

p=number of days with > 0.25 mm of precipitation per year

f=percentage of time that the unobstructed wind speed exceeds 5.4 m/s.

The US-EPA recommends (EPA, 1992) that in this situation, the PM10 fraction of the TSP is about 50%. Subsequently, the PM10 fraction of fugitive dust is given as:

$$E_{PM10} = 1.9 \times \left(\frac{s}{1.5}\right) \times \left(\frac{365-p}{235}\right) \times \left(\frac{f}{15}\right) \times 0.5$$

The rate of erosion for TSP and PM10, was estimated to be ~0.11 tpa and 0.05 tpa, respectively. These figures are given solely to provide an indication of the magnitude of wind generated dust. Emission rates used as input to the dispersion simulations varied hourly, based on hourly wind speed and monthly rainfall data.

6.2.3. Material Handling Operations

The quantity of dust being generated from material transfer operations, i.e. dumping of waste on landfill surface, depends on various climatic parameters, such as wind speed and precipitation, in addition to non-climatic parameters such as the nature 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. High moisture contents decrease the potential for dust emission, since moisture promotes the aggregation and cementation of fines to the surfaces of larger particulates.

The following predictive emission factor equations were used to estimate emissions for miscellaneous material transfer operations at the Eskom landfill site:

$$E_{TSP} = 0.74 \times 0.0016 \times \left(\frac{U}{2.2}\right)^{1.3} \times \left(\frac{M}{2}\right)^{-1.4}$$

$$E_{PM10} = 0.35 \times 0.0016 \times \left(\frac{U}{2.2}\right)^{1.3} \times \left(\frac{M}{2}\right)^{-1.4}$$

where,

E_{TSP}= Total Suspended Particulate emission factor (kg dust / Mg transferred)

E_{PM10}= Inhalable Particulate emission factor (kg dust / Mg transferred)

U = mean wind speed (m/s)

M = material moisture content (%)

Fugitive dust emissions were estimated from the handling of waste and soil (cover material). The moisture content of the cover material was given as 12%, with the moisture content of the waste given as 30% which is the standard figure (NPI, 2005).

The PM10 fraction of the TSP was assumed to be 50%. Total annual emissions were estimated to be 2.86E-04 tpa for TSP and 1.35E-04 tpa for PM10. Emissions rates from waste handling were generally low, as was expected, due to the high moisture content of the waste being handled.

6.3. Synopsis of Fugitive Dust Emissions

A synopsis of fugitive dust emission estimated to occur as a result of the proposed activities of the Eskom landfill is given in Table 16. Total TSP and PM10 emissions were calculated to be 1.18 tpa and 0.59 tpa respectively. These values were used as an input into the dispersion model.

Vehicle entrainment from on-site unpaved roads was determined to be responsible for almost 90% of the TSP and more than 85 % of the PM10 emissions from the site. Wind erosion accounted for 10.21 % of TSP and 14.43 % of PM10 emissions. Emissions for materials handling and wind erosion from open areas were dependant on calculated average wind speed and percentage of time when this wind speed exceeded 5.4 m/s.

Table 6: Annual particulate emissions estimated due to fugitive dust emissions from Eskom landfill activities.

Source	Annual Particulate Emissions		Contribution to Total Annual Particulate Emissions	
	TSP (tpa)	PM10 (tpa)	TSP (%)	PM10 (%)
Wind erosion of open areas	0.108	0.054	10.21	14.43
Materials handling	2.86E-04	1.35E-04	0.03	0.04
Vehicle-entrainment from on-site unpaved roads (uncontrolled)	0.95	0.32	89.77	85.53
TOTAL	1.18	0.59	**100**	**100**

6.4. Dispersion Modelling

6.4.1. Model Overview and Data Requirements

ADMS 4 is a PC-based, Gaussian plume dispersion model developed by Cambridge Environmental Research Consultants. ADMS 4 is a new generation air dispersion model, which is characterised by two main features:

- The atmospheric boundary layer properties are described using two parameters: the boundary layer depth and the Monin-Obukhov length.
- Dispersion under convective meteorological conditions uses a skewed Gaussian concentration distribution.

ADMS 4 is designed with specific reference to industrial applications. Applications include odour modelling, environmental impact assessment and risk assessment.

The maximum number of sources that can be modelled in ADMS 4 is 300. Of these: up to 300 may be point or jet sources, and within the limit of 300, up to 30 line sources, 30 area sources and 30 volume sources, may be modelled simultaneously.

A meteorological pre-processor calculates the required boundary layer parameters from input data which includes wind speed, day, time, cloud cover or wind speed, surface heat flux and boundary layer height. Meteorological data may be raw, hourly averaged or statistically analysed data. ADMS 4 uses the complex terrain model, FLOWSTAR to calculate the flow and turbulence fields that are then used to enhance the calculation of dispersion.

The user defines the pollutant, averaging time (which may be an annual average or a shorter period), which percentiles and exceedance values to calculate, whether a rolling average is required or not and the output units. The output options are designed to be flexible to cater for the variety of air quality limits, which can vary from country to country, and can change.

ADMS 4 can also be used to model the rate of dry and wet deposition to the ground, odours, plume visibility, radioactivity and chemical reactions between NO_x and O_3.

6.4.2. Dispersion Simulations

Data input into the model included hourly meteorological data with wind speed, wind direction, temperature, precipitation and solar radiation for 2006 to 2008. Dispersion simulations of highest daily TSP and PM10 concentrations, as well as annual average TSP and PM10 concentrations were undertaken for future operations at the Eskom landfill site. Comparison of the predicted concentrations was made with the relevant ambient air quality standards for PM10 and the TSP standards given in Schedule 2 of Section 63 in the Air Quality Act 39 of 2004.

6.4.2.1. Construction Phase

6.4.2.1.1. Predicted Concentrations

Construction activities, although a temporary source of emissions, can result in a considerable impact on any community directly associated with the area under construction. Mitigative measures are available in order to limit this impact (Table 10). It must, however, be stated that it is often difficult to mitigate certain construction activities. The constant movement of surface material by dozing, scraping, blasting etc. results in the disturbance of the surface layer, limiting the effectiveness of the measures used.

During the construction phase which was assumed to occur in the total area of 20ha for Site 5. Construction was also assumed to last for a full calendar year. The main conclusions are summarised as follows for Site 5 (Figures 6 – 7):

- PM10 – Predicted maximum daily concentrations and annual average concentrations exceed the National ambient air quality daily average standard of 180 µg/$m^3$and annual average of 60 µg/m^3, respectively,
- TSP – Predicted maximum daily and annual average concentrations exceed their respective daily average standard of 300 µg/m^3 and annual average standard of 100 µg/m^3.

All the simulations were undertaken for the worst-case scenario, assuming that the landfill is operational 8 hours a day and 5 days a week. Exceedances of the respective PM10 and TSP standards during the construction phase are temporary. Therefore, the potential for health impacts exists on the surrounding communities (Marapong and Onverwacht) (Figures 8 – 9) although these will be short-term impacts.

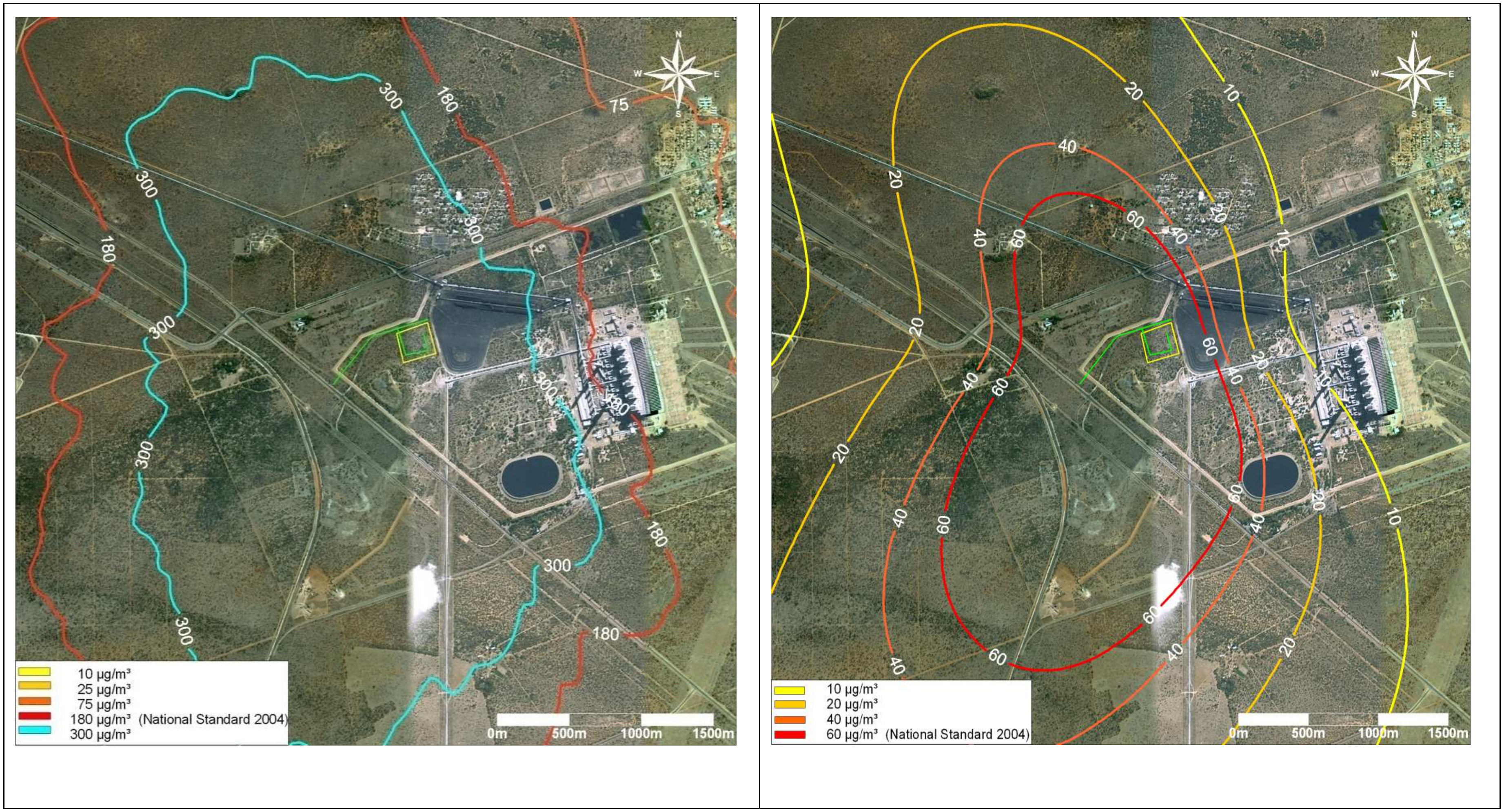


Figure 6: **Predicted highest daily (left) and annual average (right) PM10 concentrations (µg/m^3) during the construction phase at Site 5 of the proposed Eskom Landfill Site.**

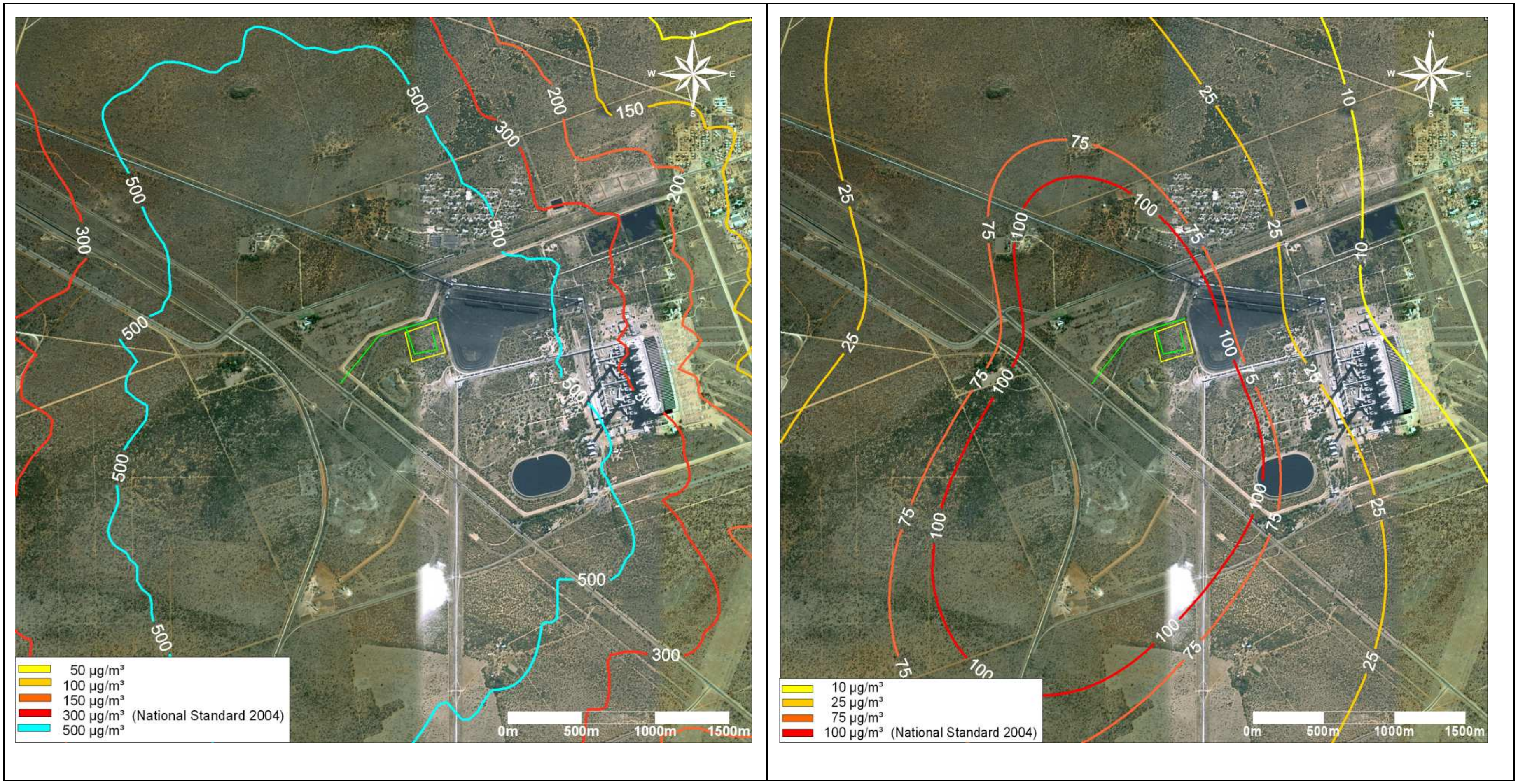


Figure 7: **Predicted highest daily (left) and annual average (right) TSP concentrations (µg/m^3) during the construction phase at Site 5 of the proposed Eskom Landfill Site.**

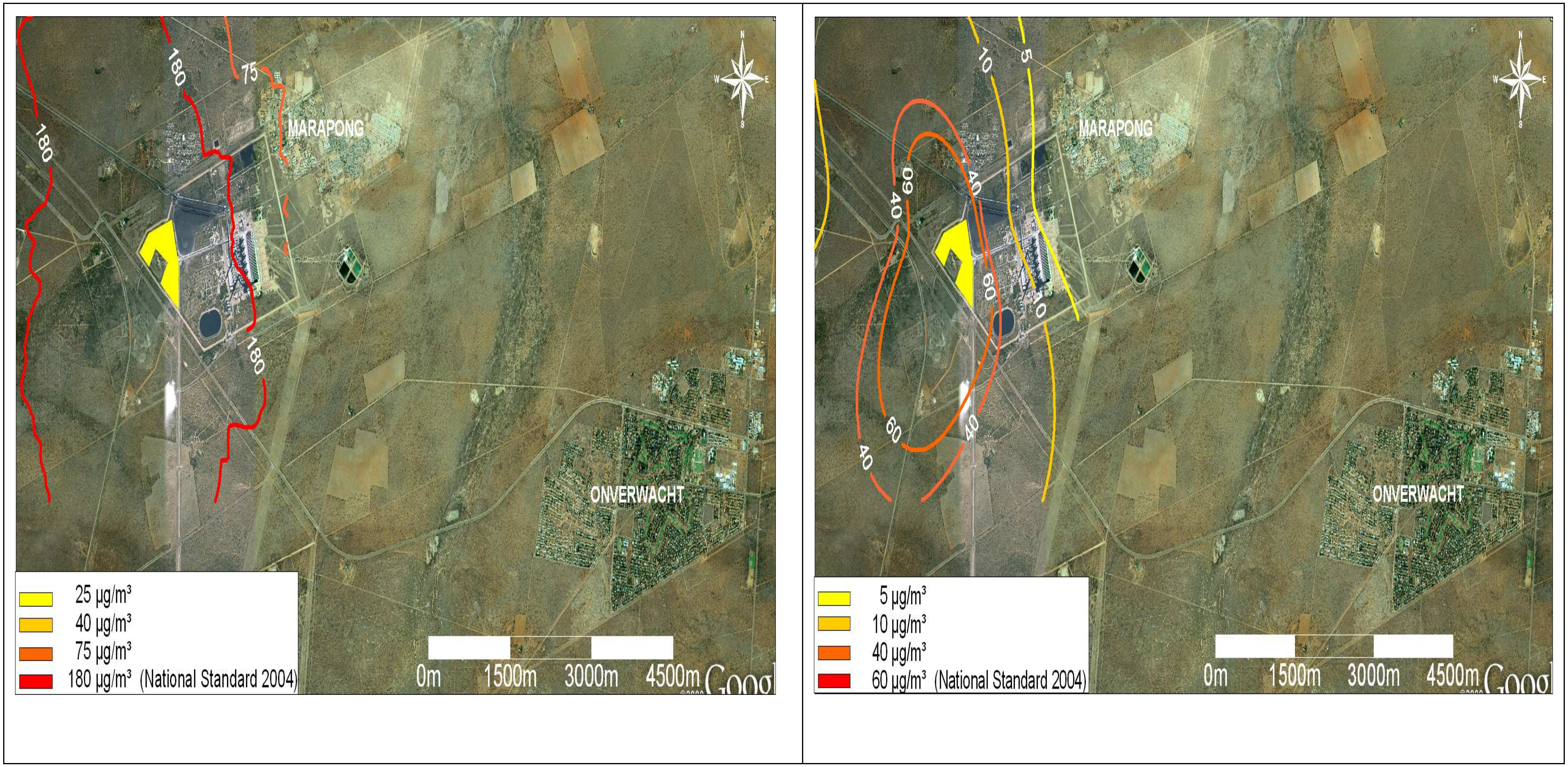


Figure 8: Predicted highest daily (left) and annual average (right) PM10 concentrations (µg/m^3) during the construction phase at Site 5 of the proposed Eskom Landfill Site in relation to the sensitive receptors (Maropong and Onverwacht).

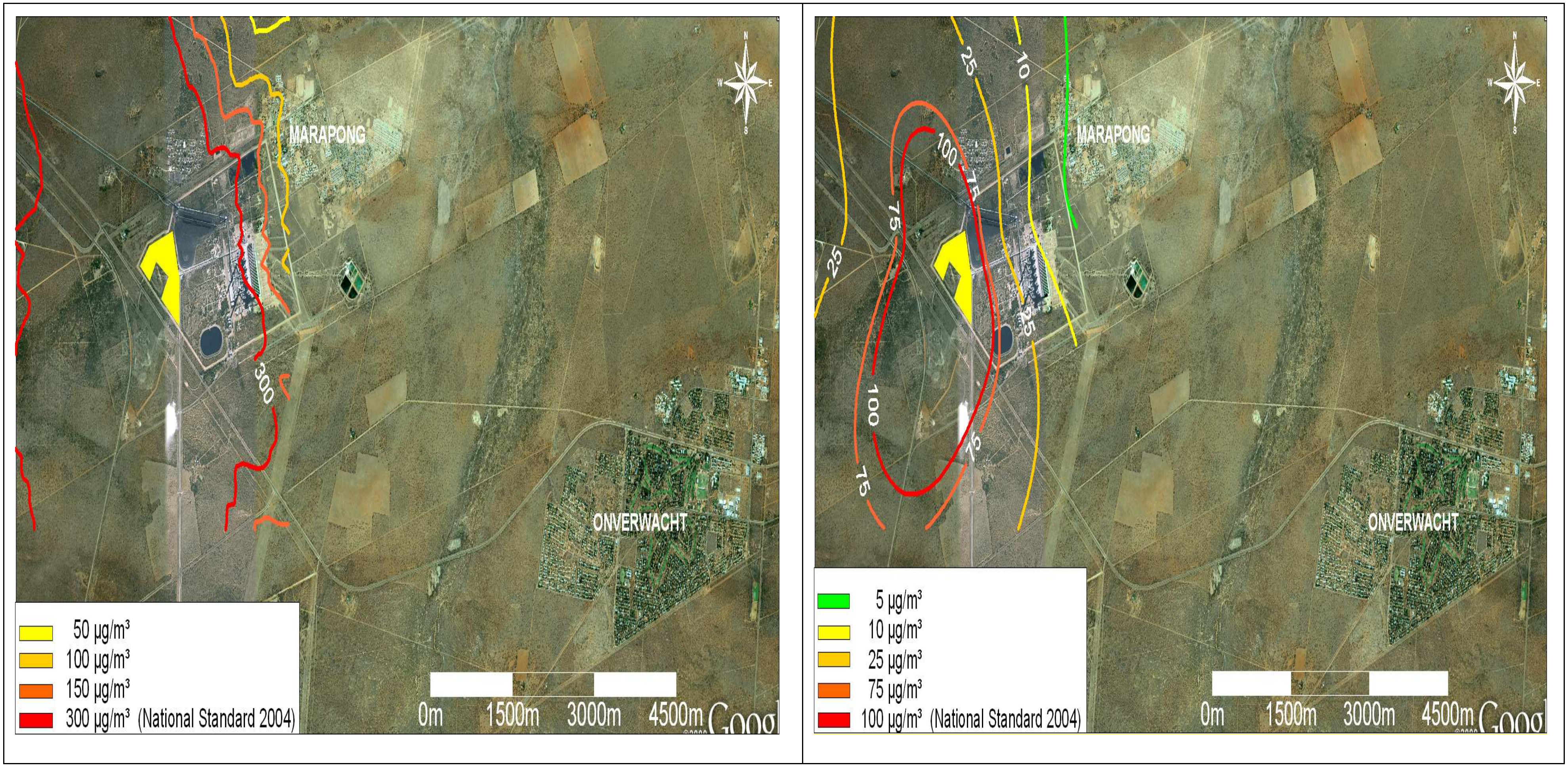


Figure 9: Predicted highest daily (left) and annual average (right) TSP concentrations (µg/m^3) during the construction phase at Site 5 of the proposed Eskom Landfill Site in relation to the sensitive receptors (Maropong and Onverwacht).

6.4.2.2. *Operational Phase*

6.4.2.2.1. Prediction Concentrations

During the operational phase, PM10 and TSP emissions are associated with vehicle entrainment on the unpaved roads, as well as gaseous and particulate emissions (diesel-driven vehicles) from vehicle exhausts. The main conclusions can be summarised as follows for the proposed sites 5A, 5B and 5C, respectively (Figures 10 – 25):

- PM10 – Predicted maximum daily concentrations and annual average concentrations fall below the National ambient air quality daily average standard of 180 µg/$m^3$and annual average of 60 µg/m^3, respectively,
- TSP – Predicted maximum daily concentrations and annual average concentrations are in compliance with the daily average standard of 300 µg/m^3 and the annual average standard of 100 µg/m^3, respectively.

All the concentration values for the operational phase are well within the boundary of the proposed landfill for all the sites, respectively. The predicted annual averages for PM10 and TSP do not pose any health risk to inhabitants in the neighbouring areas (See Appendix B), and are not considered to influence the ambient air quality.

6.4.2.2.2. Odour

Odour emissions from a landfill can be a severe public nuisance. Dispersion Modelling was used in this study for the prediction of concentrations of the criteria pollutants; however odour modelling is an even more difficult task. Traditional dispersion modelling differs from odour dispersion modelling, particularly for receptor characterisation (odour perception, averaging time etc). It is for this reason that odour dispersion modelling was not included in the scope of this study.

The predominant wind direction in Lephalale is north-north-east which implies that potential odour from the proposed landfill will be blown away from the sensitive receptors (Marapong and Onverwacht). Site 5 is optimally situated to minimize the transfer of odour from the landfill. However this does not account for a sudden change in wind direction in the event of a storm.

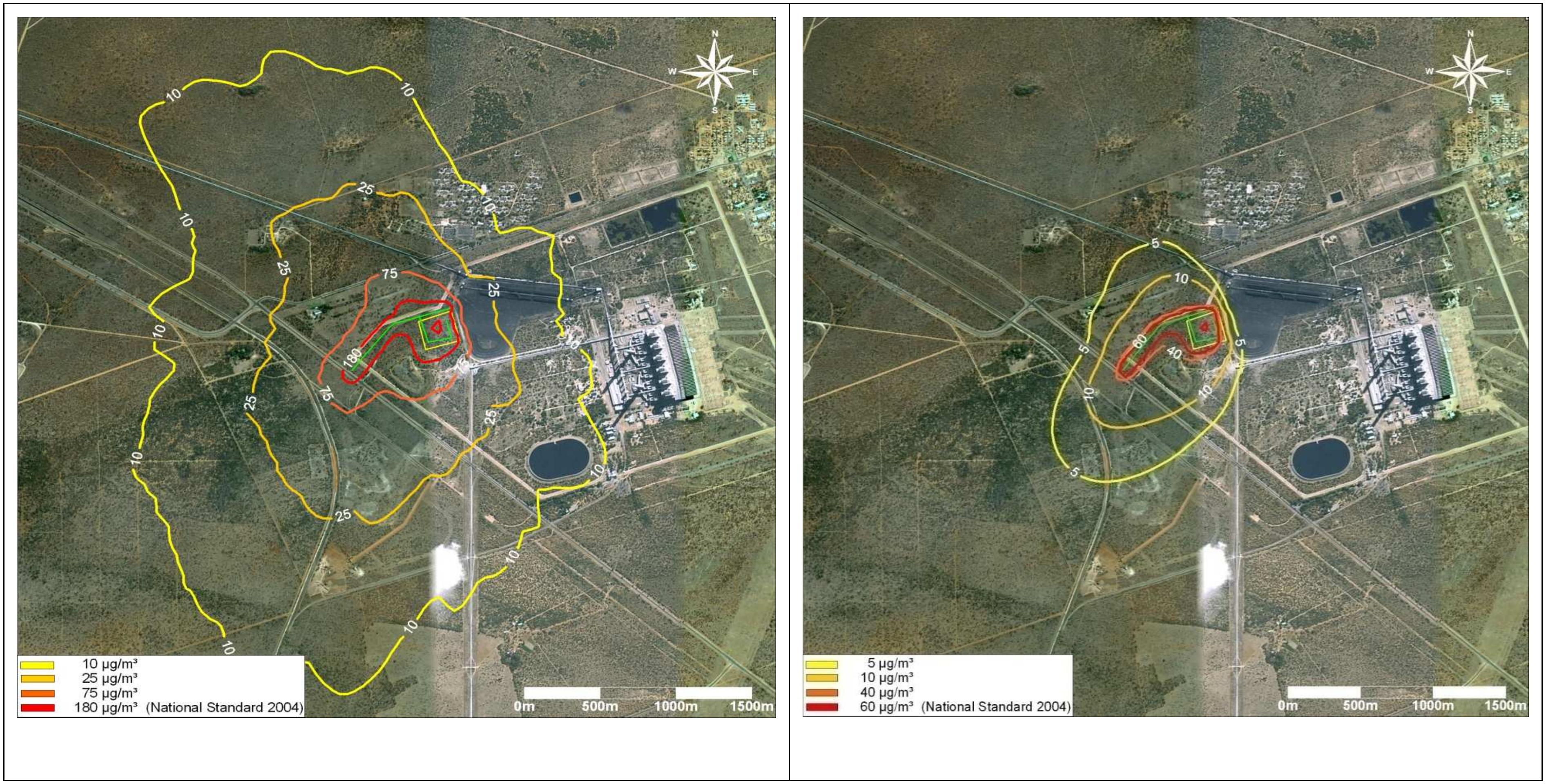
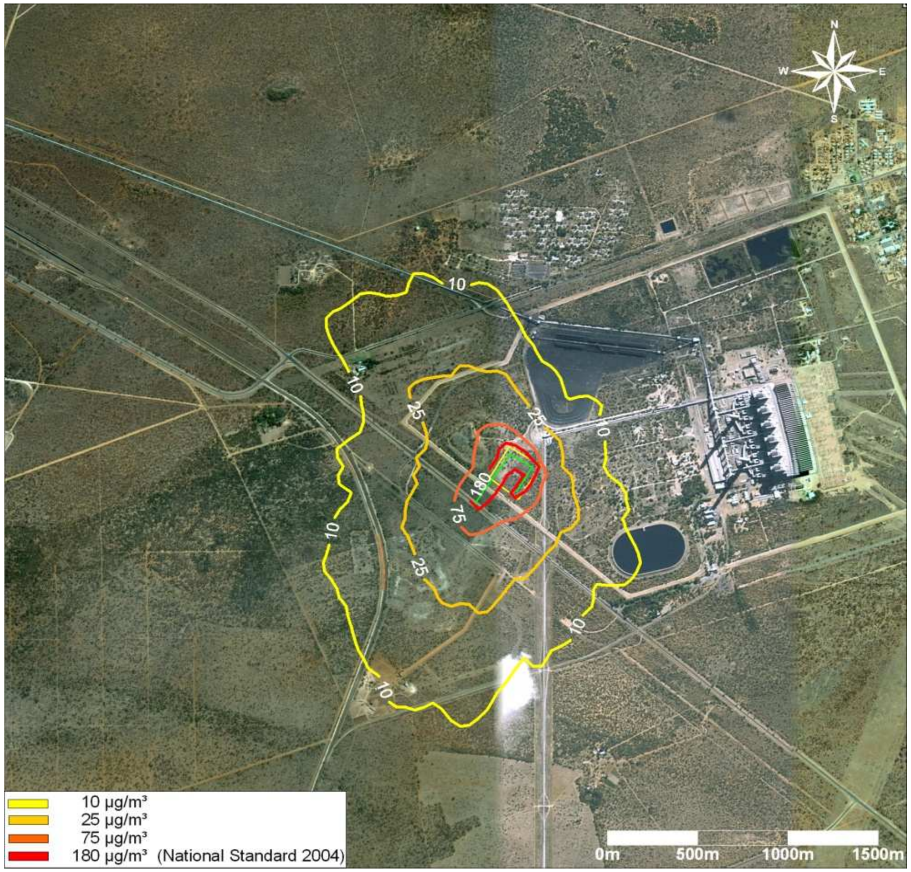


Figure 10: **Predicted highest daily (left) and annual average (right) PM10 concentrations (µg/m³) during the operational phase at Site 5A of the proposed Eskom Landfill Site.**

Figure 11: Predicted highest daily (left) and annual average (right) TSP concentrations (µg/m^3) during the operational phase at Site 5A of the proposed Eskom Landfill Site.



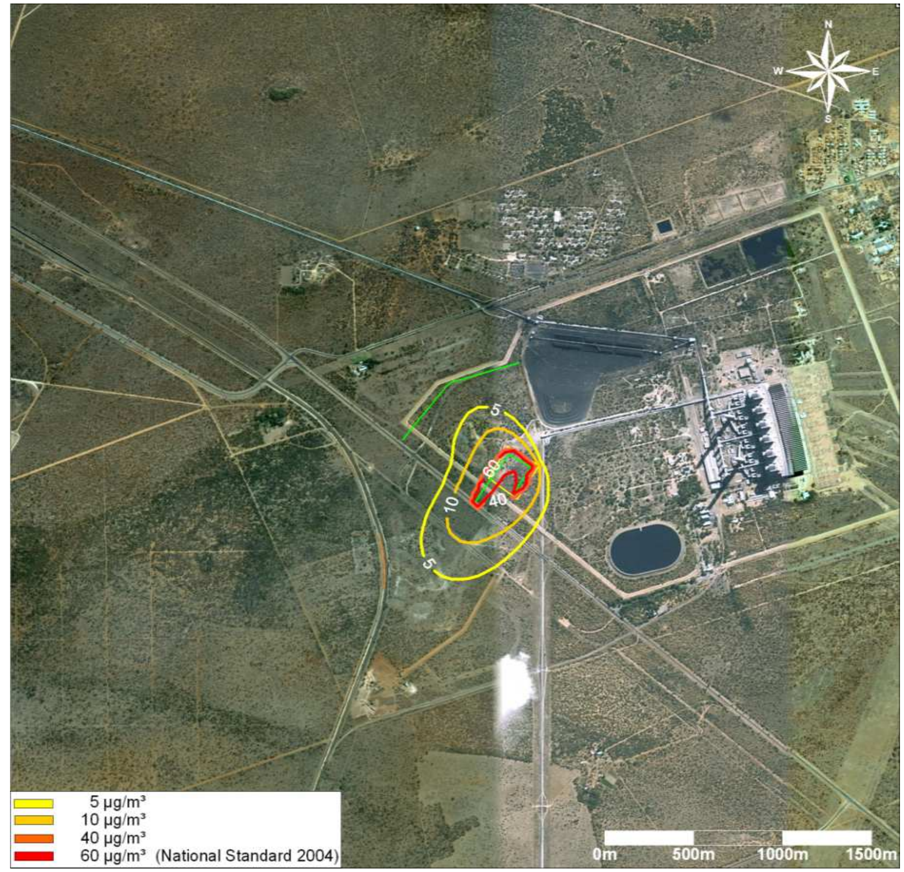


Figure 12: **Predicted highest daily (left) and annual average (right) PM10 concentrations (µg/m^3) during the operational phase at Site 5B of the proposed Eskom Landfill Site.**

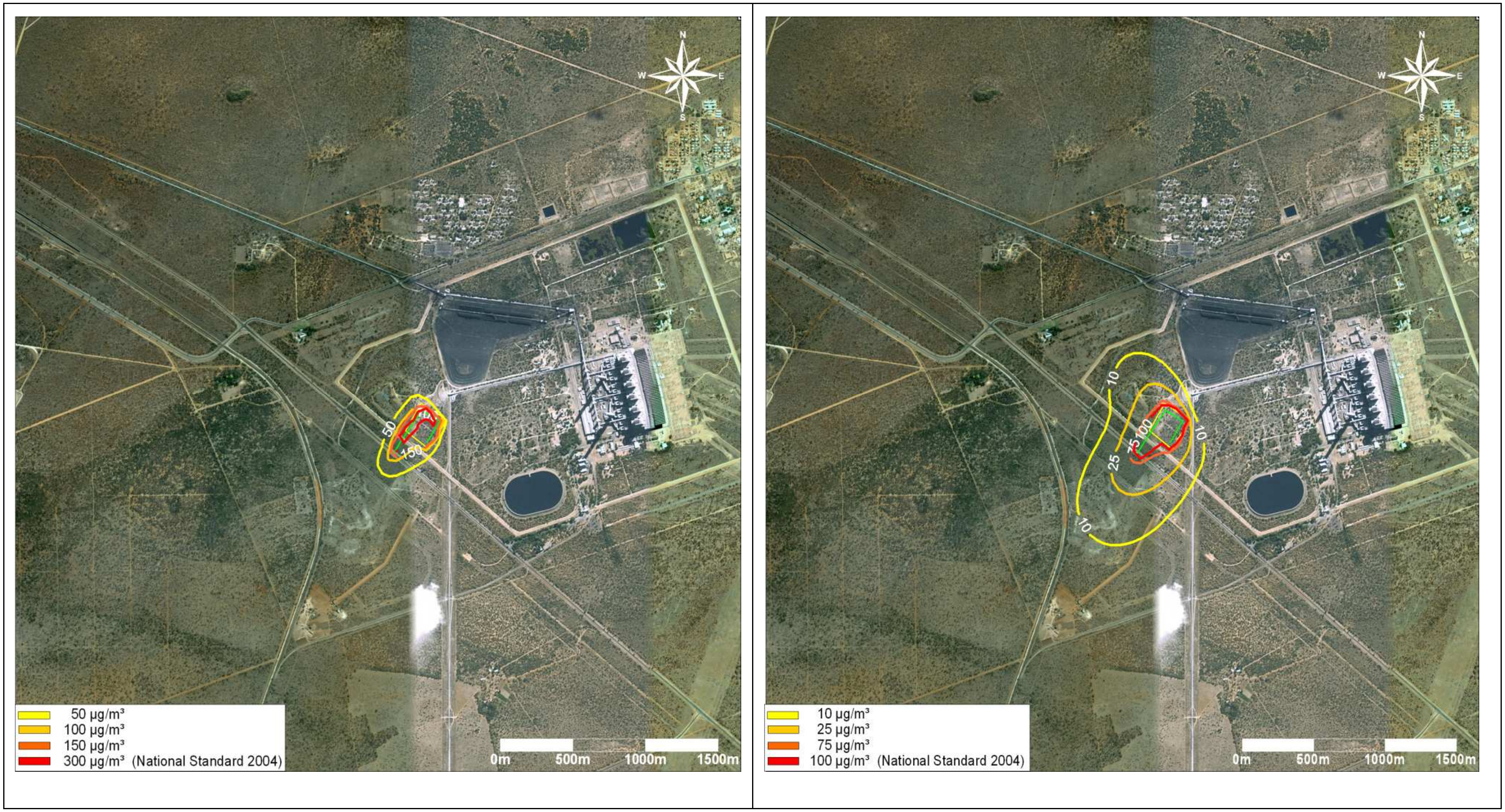


Figure 13: **Predicted highest daily (left) and annual average (right) TSP concentrations (µg/m^3) during the operational phase at Site 5B of the proposed Eskom Landfill Site.**

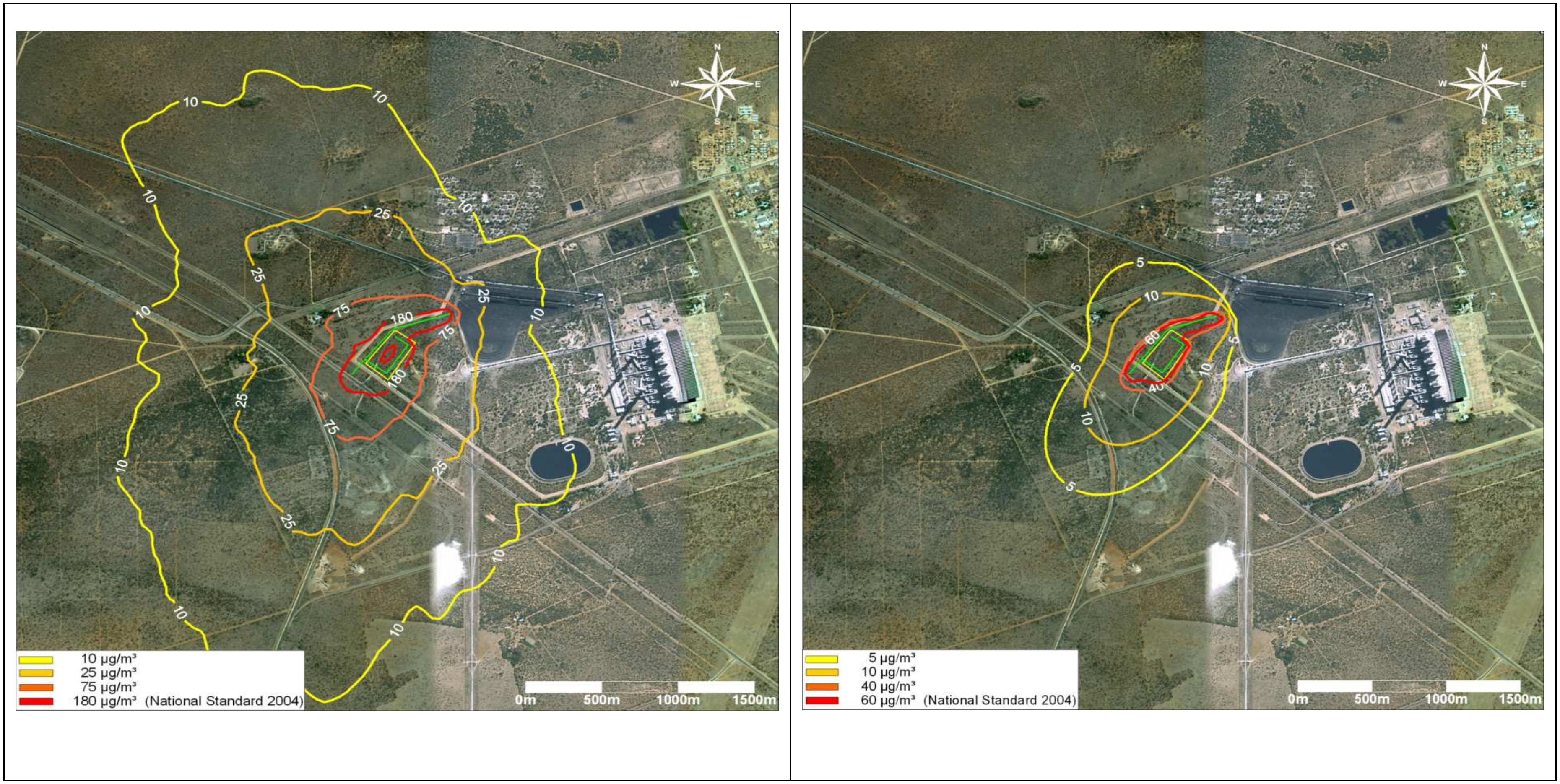


Figure 14: Predicted highest daily (left) and annual average (right) PM10 concentrations (µg/m³) during the operational phase at Site 5C of the proposed Eskom Landfill Site.

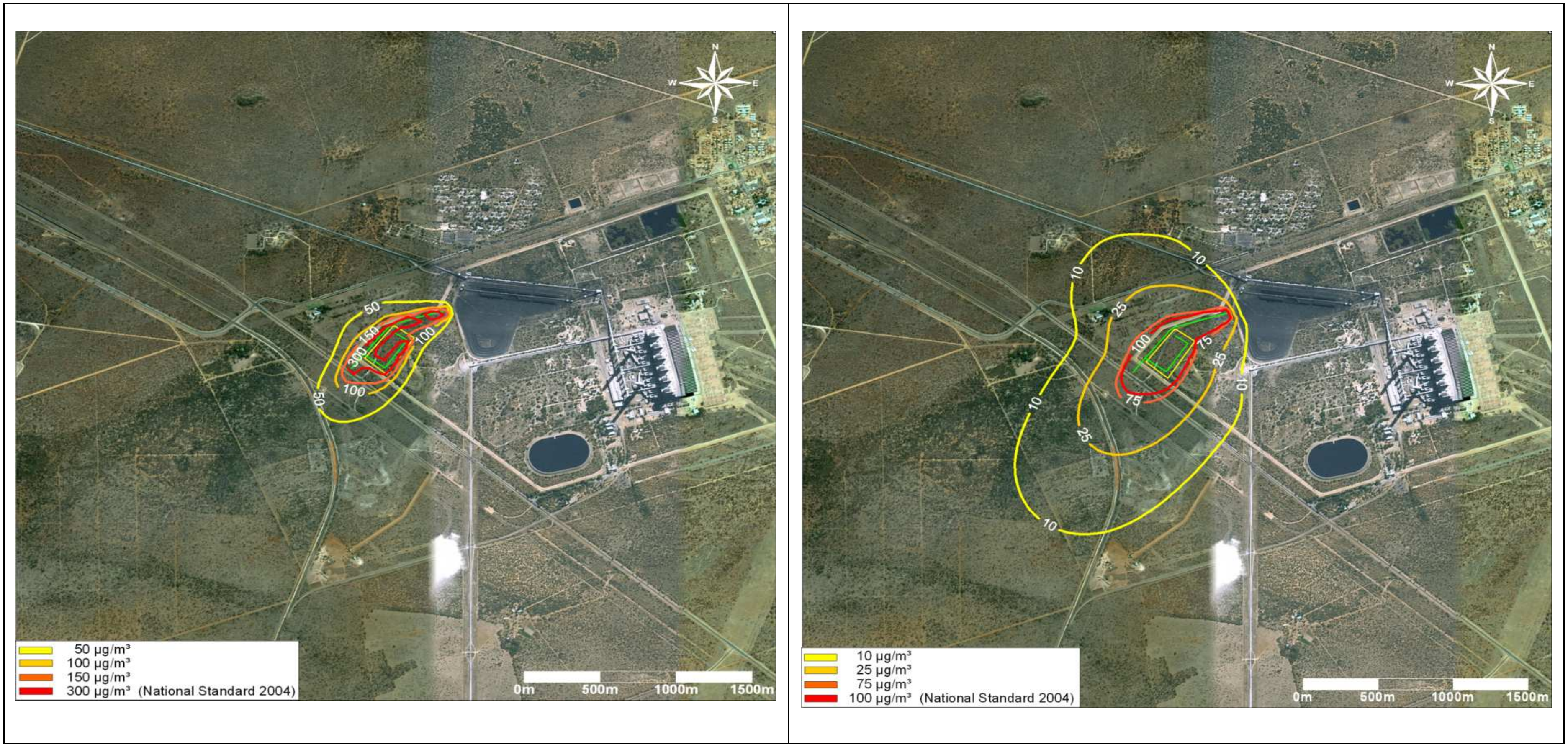


Figure 15: **Predicted highest daily (left) and annual average (right) TSP concentrations (µg/m^3) during the operational phase at Site 5C of the proposed Eskom Landfill Site.**

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6.4.3. Impact Assessment Criteria

The assessment of the impacts has been conducted according to a synthesis of criteria required by the guideline documents of the NEMA EIA regulations of 2006.

A. Nature of Impact

This is an appraisal of the type of effect the proposed activity would have on the affected environmental component. The description should include what is being affected, and how.

B. Extent

The physical and spatial size of the impact. This is classified as:

i) Site

The impact could affect the whole, or a measurable portion of the above-mentioned properties.

ii) Local

The impacted area extends only as far as the activity, e.g. a footprint.

iii) Regional

The impact could affect the area including the neighbouring farms the transport routes and the adjoining towns.

C. Duration

This is the lifetime of the impact. This is measured in the context of the lifetime of the proposed base.

i) Short term

The impact will either disappear with mitigation or will be mitigated through natural process in a span shorter than any of the phases.

ii) Medium term

The impact will last up to the end of the phases, where after it will be entirely negated.

iii) Long term

The impact will continue or last for the entire operational life of the development, but will be mitigated by direct human action or by natural processes thereafter.

iv) Permanent

The only class of impact, which will be non-transitory. Mitigation either by man or natural process will not occur in such a way or in such a time span that the impact can be considered transient.

D. Intensity

Is the impact destructive or benign? Does it destroy the impacted environment, alter its functioning, or slightly alter it? These are rated as:

i) Low

The impact alters the affected environment in such a way that the natural processes or functions are not affected.

ii) Medium

The affected environment is altered, but function and process continue, albeit in a modified way.

iii) High

Function or process of the affected environment is disturbed to the extent where it temporarily or permanently ceases. This will be a relative evaluation within the context of all the activities and the other impacts within the framework of the project.

E. Probability

This describes the likelihood of the impacts actually occurring. The impact may occur for any length of time during the life cycle of the activity, and not at any given time. The classes are rated as follows:

i) Improbable

The possibility of the impact occurring is very low, due either to the circumstances, design or experience.

ii) Probable

There is a possibility that the impact will occur to the extent that provisions must be made therefore.

iii) Highly probable

It is most likely that the impacts will occur at some or other stage of the development. Plans must be drawn up before the undertaking of the activity.

iv) Definite

The impact will take place regardless of any prevention plans, and there can only be relied on mitigatory actions or contingency plans to contain the effect.

F. Determination of Significance

Significance is determined through a synthesis of impact characteristics. Significance is an indication of the importance of the impact in terms of both physical extent and time scale, and therefore indicates the level of mitigation required.

The classes are rated as follows:

i) No significance

The impact is not substantial and does not require any mitigatory action.

ii) Low

The impact is of little importance, but may require limited mitigation.

iv) Medium

The impact is of importance and therefore considered to have a negative impact. Mitigation is required to reduce the negative impacts to acceptable levels.

v) High

The impact is of great importance. Failure to mitigate, with the objective of reducing the impact to acceptable levels, could render the entire development option or entire project proposal unacceptable. Mitigation is therefore essential.

Table 7: Construction Phase Impact Assessment.

Impact	Nature of Impact	Extent	Duration	Intensity	Probability	Significance	
						With Mitigation	Without Mitigation
Vehicle Tailpipe Emissions	PM10, TSP	Local	Short-term	Low	Definite	Low	Low
Wind Erosion of open areas	PM10, TSP	Site	Short	Low	Definite	Low	Low
Materials Handling	PM10, TSP	Site	Short	Low	Definite	Low	Low
Vehicle entrainment from on-site unpaved roads	PM10, TSP	Local	Short	Medium	Definite	Low	Low

Table 8: Operational Phase Impact Assessment.

Impact	Nature of Impact	Extent	Duration	Intensity	Probability	Significance	
						With Mitigation	Without Mitigation
Vehicle Tailpipe Emissions	PM10, TSP	Site	Long-term	Low	Definite	Low	Low
Wind Erosion of open areas	PM10, TSP	Site	Long	Low	Definite	Low	Low
Materials Handling	PM10, TSP	Site	Long	Low	Definite	Low	Low
Vehicle entrainment from on-site unpaved roads	Pm10, TSP	Local	Long	Low	Definite	Low	Low

6.5. Mitigation Measures

The pollution from the proposed landfill largely depends on the manner in which the facility is managed, specifically with regard to the effective design, implementation and ongoing review of landfill gas and fugitive dust mitigation and monitoring systems. Proposed management, mitigation and monitoring requirements are discussed in the subsequent subsections for the operational, closure and post-closure phases of the landfill.

6.5.1. Compliance with DWAF Minimum Requirements

The landfill operator must ensure compliance with DWAF *Minimum Requirements*. The following aspects are of particular significance in terms of avoiding air quality impacts:

- Daily covering of working face with adequate cover material
- Prevent acceptance of hazardous wastes
- Site access control to avoid illegal dumping
- Minimise odours from stored leachate, e.g. through storing leachate in tanks, treating leachate or applying odour controls to the leachate pond
- Prevention of all on-site fires
- Avoid residential settlement within the agreed buffer zone
- Maintenance of as small a working face as practical
- Immediate covering of malodorous wastes, e.g. putrescible general wastes and use of odour suppressants in extreme cases
- Progressive rehabilitation though application of final cover or capping, topsoiling and vegetation of completed cells.

Field studies indicate that emissions, as estimated using LandGEM, are a factor of 2 orders lower for temporary cover areas and more than 4 order lower for final cover areas (Bogner *et al.*, 2003). *This implies that by applying a temporary cover to filled cells and retaining a limited working face Eskom landfill operators could reduce air pollution with* *the buffer zone then being based on the area of exceedance of the PM10 reference level.*

6.5.2. Waste Composition Inventory and Inspection

The composition, leachability, long-term behaviour and general properties of the waste to be landfilled must be known as precisely as possible. The landfill operator must ensure that a register is kept throughout the life of the facility of the quantities and characteristics of the waste deposited. Information collated should indicate origin of the waste, type of waste, date of delivery, identity of the producer or collector in the case of municipal waste. This information should be made available to the competent local, provincial and national authorities when requested.

In addition to registering the waste at the site access, regular visual inspection of the waste at the point of deposit should be undertaken to ensure that only non-hazardous waste is being accepted at the site.

6.5.3. Landfill Gas Management and Control

Landfills in the USA are required to implement active landfill gas extraction in the event that their Non-Methane Organic Compound (NMOC) emissions exceed 50 ton/year. Significant emission reductions can be realised through the implementation of gas extraction. (e.g. at the Olinda municipal landfill in Southern California measured emission rates were greater than 1000 $g/m^2/d$ prior to installation of a gas collection system. After a gas collection system was installed, measured gas flux rates were reported to be less than 10 $g/m^2/d$ (Bogner and Scott, 1997)). It should however be noted that the extraction and flaring of landfill gas gives rise to gaseous products of combustion (sulphur oxides, nitrogen oxides, particulates, carbon monoxide, etc.).

It is recommended that appropriate measures must be taken in order to control the accumulation and migration of landfill gas. Ideally landfill gas should be collected, treated and used. If the gas collected cannot be used to produce energy, it should be flared. The collection, treatment and use of landfill gas should be carried out in a manner which minimises damage to or deterioration of the environment and risk to human health.

6.5.4. Fugitive Dust Mitigation

Control measures which should be adopted during the operational period to reduce the potential for fugitive dust emissions are presented in Table 9. Control techniques for fugitive dust sources generally involve watering, chemical stabilisation and the reduction of surface wind speed through the use of wind breaks and source enclosures.

Table 9: Dust control measures implementable during the operational phase.

Activity	Recommended Control Measure(s)
Material handling (soil, waste)	Mass transfer reduction
	Drop height reduction
	Wind speed reduction through sheltering
	Wet suppression
Vehicle entrainment from unpaved roads	Wet suppression or chemical stabilisation of unpaved roads
	Reduction of unnecessary traffic
	Strict speed control
	Avoid track-on onto neighbouring paved roads
Vehicle entrainment from the paved access road	Regular sweeping or vacuuming of the paved access road to restrict the silt loading on the roadway
	Avoidance of track on from unpaved roads (e.g. wheel wash bays)
	Avoidance of spillage of waste onto road surface through ensuring waste haul trucks maintain the necessary freeboard
Open areas – wind erosion	Reduction of extent of open areas through careful planning and progressive vegetation
	Reduction of frequency of disturbance
	Compaction and stabilisation (chemical or vegetative) of disturbed soil
	Introduction of wind-breaks

Emissions from unpaved roads are expected to be the main source of fugitive dust generated during the operational phase of the landfill. Total emissions from unpaved roads are usually reduced by speed control, paving or watering. Research has shown that traffic control measures aimed at speed reduction may result in control efficiencies of 50%, while paving was found to provide for control efficiencies of between 50 and 90% (Evans *et al.* 1983). Watering programmes, whereby the surface moisture content of the unpaved road is doubled, may result in a control efficiency of up to 75% (Cowherd *et al.* 1988; EPA 1992).

For materials handling operations, control efficiencies of 56 to 81% have been reported for fine dust (less than 3.5 μm) at application intensities of 6.7 to 7.1 litres of water per tonne of material being handled, respectively. The construction of windbreaks and source enclosures has been suggested to reduce fugitive dust due to wind erosion. However, these are not always practical due to the size of many fugitive dust sources (Cowherd *et al.*, 1988; EPA, 1996). The control efficiency of wind fences is dependent on the physical dimensions of the fence relative to the source being controlled. In general, a porosity of 50% appears to be optimum to the control of fugitive dust in most applications.

Taking into consideration the applicability and cost effectiveness of these mitigation measures, the following is recommended:

- The implementation of dust abatement measures for on-site roadways is considered imperative. The adoption of measures able to afford control efficiencies of at least 60% would be required. Control efficiencies of more than 75% are recommended given that elevated PM10 concentrations can occur in the region.
- The implementation of an effective watering programme would allow for a 75% reduction in the dust entrainment from the unpaved haul roads. (The addition of chemical surfactants would serve to reduce the amount of water required or further increase the control efficiency, up until ~90%).
- Extensive windbreaks around the landfill area can reduce the particle pollution in the surrounding areas of the landfill. The extension of the windbreak will reduce the effective wind speed during times of increased potential for wind erosion. Windbreak height and density are the two most important factors that determine the effectiveness of a windbreak.

Elevated fine particulate concentrations, in excess of EC air quality standards, occur across Johannesburg and over much of the country with the highest concentrations having been recorded within the main impact zones of industrial and mining operations and within and adjacent to household fuel burning areas (Scorgie *et al.*, 2004).

7. SUMMARY AND RECOMMENDATIONS

A baseline assessment was undertaken through a review of available meteorological data from Bergfontein Meteorological Station in Lephalale. Based on this assessment:

- Wind direction at Lephalale is north-north-east with lesser wind components from the north-east and north,
- A significant diurnal variation in wind direction is observed at Lephalale Between 00:00 – 06:00, winds are predominantly from the north-east with an additional component from the north-north-east. Between 06:00 – 12:00 winds are predominantly from the north-north-east, with additional components from the north-east and north. Winds remain from the north-north-east during the afternoon, with additional components from north and north-north-west. During the evening (18:00 – 24:00), winds blow from the north-east and north-north-east (7.9 %). An increase in calm conditions is observed during the night (61.61%).

The air quality impact assessment was undertaken through the compilation of an emissions inventory and subsequent dispersion modelling simulations. Predicted emissions from the landfill were evaluated to determine the impact of the construction and operations of the proposed landfill on the surrounding air quality.

- Emissions from the proposed Eskom Landfill are predicted to be transported a few hundred meters downwind towards the north-west and south-east and in a lesser extent towards the western areas in respect of the landfill, due to the meteorological impact,
- Predicted emissions of PM10 and TSP exceed the National Ambient air quality Standards during the construction phase, and will pose a short-term threat to human health. The implementation of control technologies and mitigation measures on should ensure that pollutant levels remain below concentrations at which health effects are observed,
- Predicted emissions of PM10 and TSP during the operational phase are below the national ambient air quality standards and do not pose a health risk to inhabitants in the neighbouring areas,
- Additional studies with site-specific meteorological data should be done to establish more precisely the impacts on neighbouring areas, as well as odour and health risk studies.

In general, predicted emissions from the landfill are not considered to influence the ambient air quality within the surrounding areas in a way that would pose a threat to human health.

7.1. Assumptions and Limitations

- Emissions emanating from **all** existing sources in the area were not quantified nor were resultant ambient air pollutant concentrations due to such sources simulated. The assessment of existing or baseline air quality in the study region was therefore restricted to ambient air quality impacts due to proposed Eskom Landfill only.
- Routine emissions from the landfill operation's activities were estimated and modelled. Atmospheric releases occurring as a result of accidents and very poor site maintenance was not accounted for, e.g. fires and development of leaks in cell walls (daylighting).
- Only three years of hourly average meteorological data was available for input to the air dispersion modelling. This data was not site-specific, but obtained from ARC from their Bergfontein Automatic Weather Station.
- In the estimation of fugitive dust impacts maximum rates of waste disposal were assumed for the closure year (2060).
- Odour dispersion modelling is a difficult task and was therefore excluded from the scope of this study.

7.2. Recommendations

- Sites 5A, 5B and 5C are all optimal for the development of the proposed landfill because all the access roads will be paved and their location relative to the predominant wind direction implies that potential odour and dust will not impact on the sensitive receptors.
- Implement an ambient air quality monitoring programme to determine ambient pollutant concentrations in the residential areas surrounding the Landfill Site.
- Implement mitigation measures for reduction of air quality impacts on continuous basis.
- Long-term dust fallout monitoring.

8. CONCLUSION

An air quality impact assessment was undertaken to evaluate the air quality impact of emissions from the proposed landfill site and associated activities. Simulations of predicted emissions show PM10 and TSP concentrations to be low during the operational phase for Sites 5A, 5B and 5C, respectively. An ambient air quality monitoring programme is recommended in order to accurately quantify ambient pollutant concentrations on-site and in the surrounding residential areas.

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APPENDIX A

LANDGEM REPORT

APPENDIX B

DISPERSION SIMULATIONS FOR THE OPERATIONAL PHASE PREDICTED CONCENTRATIONS IN RELATION TO THE SENSITVE RECEPTORS FOR SITES 5A, 5B AND 5C.