



# **AIR QUALITY IMPACT ASSESSMENT**

Prepared for

**GWAYANG DEVELOPMENT ZONE  
GEORGE, WESTERN CAPE**

**FINAL REPORT  
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**C H Albertyn, PrEng**



**Lethabo Air Quality Specialists (Pty) Ltd**  
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P.O. Box 2174, Noorsekloof, 6331  
info@laqs.co.za  
www.laqs.co.za

Tel: (+27) 64 880 8694  
Fax: (+27) 86 536 5597



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# AIR QUALITY IMPACT ASSESSMENT

## GWAYANG DEVELOPMENT ZONE, GEORGE

### 1 INTRODUCTION

Cape Environmental Assessment Practitioners (Cape EAPrac) provides environmental consulting services to a variety of industries and projects. One such project, planned by the George Municipality (GM), is the development of an industrial, commercial and residential zone on the western boundary of the town of George in the Western Cape Province.

Notice of the intended development was circulated for comment to various governmental departments. The Garden Route District Municipality (GRDM) raised concerns about potential odour-related complaints by future tenants of the planned development as it is located immediately adjacent to the Gwayang landfill site, wastewater treatment plant (WWTP) and a medical waste incinerator.

GRDM suggested that a specialist air quality impact assessment should be carried out to determine potential spread of odours in the area and Lethabo Air Quality Specialists (Pty) Ltd (LAQS) was subsequently appointed to do such an assessment. LAQS carried out a dispersion modelling study to investigate the potential spread of odours from cumulative sources of odorous emissions in the area. In such an investigation, the variation in ground-level concentrations is not important, but rather the area over which concentrations above odour detection limits may be exceeded.

This report describes the procedure followed by LAQS and details the outcome of its investigations. It is accepted that various pollutants may be emitted from a variety of sources, but this investigation focuses on odorous emissions and their potential impact areas.

### 2 RELEVANT GOVERNMENT REGULATIONS

The following Government Regulations apply to this air quality impact assessment and are referred to in the report where applicable.

- 1 "List of Activities That Result in Atmospheric Emissions" as published in Government Notice 893 of 22 November 2018 (GN893), as amended.
- 2 "National Ambient Air Quality Standards" as published in Government Notice 1210 of 24 December 2009 (GN1210).
- 3 "Regulations Regarding Air Dispersion Modelling" as published in Government Notice GN R.533 of 11 July 2014 (GN R.533).



### 3 ODOROUS EMISSION SOURCES

LAQS carried out a dispersion modelling study to determine the degree to which odorous emissions would disperse over the planned development area. The dispersion study was done in accordance with GN R.533.

It must be pointed out that not all odorous emissions may be offensive to all people, as discussed in Section 9. However, odours may still be detectable, and all odours are, therefore, included in this assessment.

In addition to the activities immediately adjacent to the planned development zone, some industrial sources of odorous emissions are in operation to the east of the planned development zone.

LAQS compiled the following list of sources of potentially odorous emissions:

- Gwayang landfill site
- George WWTW
- Averda hazardous waste incinerator
- George Crematorium
- PG Bison Sawmills

#### 3.1 GWAYANG LANDFILL SITE

It is generally accepted that the main gaseous pollutant emitted from landfill operations is methane, but it is not generally regarded as odorous. According to the USEPA, many other gaseous compounds are generated as well, including the following odorous compounds:

- Carbon disulphide ( $\text{CS}_2$ )
- Hydrogen sulphide ( $\text{H}_2\text{S}$ )
- Ethyl mercaptan ( $(\text{CH}_3)_2\text{SH}$ )
- Methyl mercaptan ( $\text{CH}_3\text{SH}$ )
- Dimethyl sulphide ( $(\text{CH}_3)_2\text{S}_2$ )

#### 3.2 GEORGE WWTW

According to a study done in South Korea, the odorous compounds listed below are associated with wastewater treatment works.

- Ammonia ( $\text{NH}_3$ )
- Hydrogen sulphide
- Methyl mercaptan
- Dimethyl sulphide
- Dimethyl disulphide
- Trimethylamine ( $(\text{CH}_3)_3\text{N}$ )



As can be seen from the list, the odorous compounds are similar to those emitted from landfill sites, with a few exceptions (ammonia and trimethylamine).

### 3.3 INDUSTRIAL SOURCES

In addition to the Averda medical waste incineration plant located to the west of the zone, various industries are located east of the planned development site, but only two may potentially emit odours to atmosphere. These are George Crematorium and PG Bison.

The processes used by the three industries are included in GN893 and their emissions controlled accordingly. Emission limits were detailed in atmospheric emission licenses (AELs). Until a few years ago, the process of timber drying was also included in GN893 but has since been removed from the list and no specific emission limits apply to the timber drying process.

Summarised details of the operations are:

#### **Averda:**

Averda destroys medical waste materials through a process of pyrolysis and operates continuously throughout the day and seven days per week. Pollution abatement equipment is installed.

#### **George Crematorium:**

The crematorium operates two cremators in which a maximum of 10 cremations may be carried out per day in each cremator. Maximum emissions are generated during the first 10 to 15 minutes of the cremation process and are manifested by visible emissions. During the cremation process, various organic compounds are emitted, albeit at low concentration, some of which may be odorous. No dedicated pollution abatement equipment is installed.

#### **PG Bison:**

PG Bison dries timber in drying ovens, using an indirect drying method. While the aim is to dry the timber by evaporating water contained in the wood, some organic compounds are also released, some of which, e.g. terpenes, may be odorous. No dedicated pollution abatement equipment is installed.

## 4 ODOUR DETECTION LIMITS

A review of extensive research on the impact of odours was done by Jon H Ruth and published in the article "*Odor Thresholds and Irritation Levels of Several Chemical Substances*", American Industrial Hygiene Association Journal in 1986.

The following odour detection thresholds are given:



Compound	Odour threshold, $\mu\text{g}/\text{m}^3$		Odour characteristic
	Low	High	
Ammonia ( $\text{NH}_3$ )	26.6	39600	Pungent, irritating
Hydrogen sulphide ( $\text{H}_2\text{S}$ )	0.7	14	Rotten eggs
Methyl mercaptan ( $\text{CH}_3\text{SH}$ )	0.04	82	Decayed cabbage
Dimethyl sulphide ( $(\text{CH}_3)_2\text{S}$ )	2.5	50.6	Decayed vegetables
Dimethyl disulphide ( $(\text{CH}_3)_2\text{S}_2$ )	1	346	Vegetable sulphide
Trimethylamine ( $(\text{CH}_3)_3\text{N}$ )	0.8	0.8	Ammoniacal, fishy

**Table 1: Odorous compounds**

Odour detection thresholds are usually determined by means of a panel of adjudicators duly trained in the detection of odours. For some researchers, the threshold at which a single member of the odour panel detects an odour is assumed to be the detection threshold concentration. For others, the odour detection threshold is the concentration at which 50% of the panel detect an odour, while others assume the detection level to be the point where all panel members detect an odour. As a result, there is a substantial difference in the reported odour detection thresholds, as can be seen from Table 1.

As an indication of the possible spread of odours, LAQS decided on an average odour detection threshold of  $1 \mu\text{g}/\text{m}^3$  for the combined gases, excluding ammonia. It is accepted that this level is close to the lower detection levels but is regarded as a conservative approach. Due to the high odour detection threshold, i.e. 26.6 times greater, ammonia is excluded from this assessment.

## 5 DISPERSION MODEL DESCRIPTION

The dispersion modelling study was carried out with EnviMan, a GIS-based emissions management software suite produced by Narsil AB in Sweden. The dispersion modelling component of the suite consists of the following four modules:

evMapper: A map manipulation tool

evEmissioner: An extensive, relational emissions data base

evMet: A meteorological data management program

evPlanner: The actual dispersion model



## 5.1 evMAPPER

evMapper is a digital map compiler. It is used to define GIS data sets and map sets to be used by all EnviMan GIS modules. It can import a variety of digital maps and structure the data in suitable forms, e.g. sheets, objects, etc.

It is the basis of the EnviMan GIS suite as it defines all co-ordinates for subsequent use by the various EnviMan modules.

## 5.2 evEMISSIONER

evEmissioner is a comprehensive, relational emissions data base that locates sources of emissions at fixed co-ordinates on the map compiled with evMapper. Sources are placed on the map by the user and the co-ordinates are generated automatically by evMapper.

evEmissioner can handle particulate and gaseous emissions from the following types of sources:

- Point sources, e.g. industrial stacks
- Area sources, e.g. landfill sites
- Grid sources, e.g. complete informal settlement areas
- Line sources, e.g. motor vehicle emissions

A combination of point and area sources is applicable to this investigation.

## 5.3 evMET

evMet uses meteorological data collected at ground level to calculate boundary scaling data sets used in dispersion modelling studies. Of primary importance are those parameters that define scaling of the boundary air layer. These are:

- Wind speed
- Wind direction
- Temperature
- Relative humidity
- Solar radiation or cloud cover

## 5.4 evPLANNER

evPlanner is the dispersion module of the EnviMan suite and links with evMapper, evEmissioner and evMet to simulate the dispersion of air pollutant emissions. It is designed to run simulations of air quality based on emission data created in evEmissioner for the following scenarios:

- Hypothetical weather definitions, i.e. user-supplied information about temperature, wind speed, wind direction, cloud cover, etc.
- True weather period, i.e. using recorded data from a weather monitoring station to simulate plume dispersion hour-by-hour over a user-defined period



- Statistical weather period, i.e. using a pre-calculated sample of various weather conditions that typically occur during a year. This allows the creation of annual air quality maps for comparison against national guidelines and limit values.

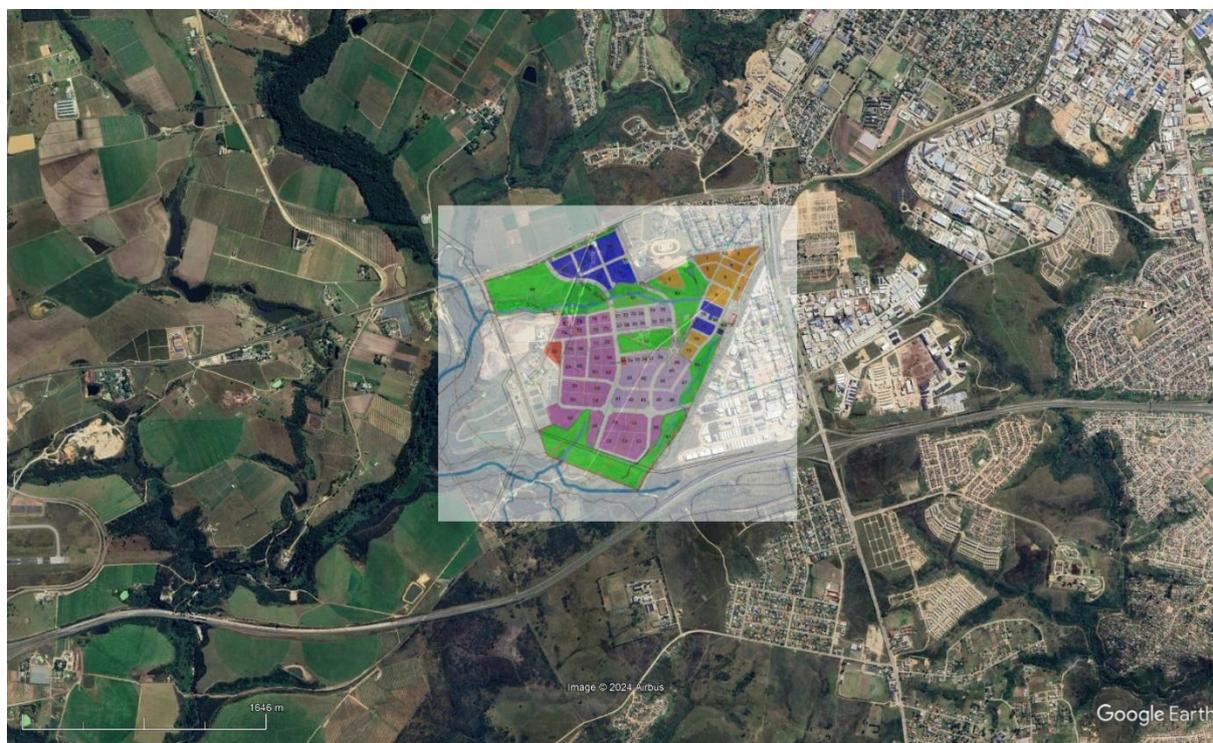
Of these scenarios, the statistical period is applicable to the study of odour dispersion from all sources.

evPlanner makes use of three different dispersion models, two of which are aimed at motor vehicle emissions. The third is the Aermol dispersion model and is used for calculating the dispersion of emissions from point, area and grid sources. Aermol is an USEPA-approved Gaussian plume dispersion model and is capable of simulating dispersion of pollutants over a distance up to approximately 50 km from the source. Aermol is also listed as an acceptable model in GN R.533.

## 6 MODEL INPUT DATA

### 6.1 MAP AREA

LAQS imported a digital map of the area into evMapper. The map covers an area of 8.2 x 4.9 km and covers the planned development zone and industrial area of George located to the east of the zone. The area is shown in Figure 1.



**Figure 1: Location of planned development area**

The map is shown in Figure 1 with the source and receptor areas indicated in highlighted areas.



The emissions data base (evEmissioner) links with the map and places emission sources on specific locations, as defined by the user.

## 6.2 EMISSIONS

### 6.2.1 Gwayang Landfill Site

No measured emissions data is available, and emissions of odorous gases were determined using the USEPA's Landgas Emissions Model (LandGEM). The model requires, inter alia, the following input parameters, with data provided by GM:

- Year of commencement of operation (2005)
- Year of closure of the site (2029)
- Annual volume of municipal waste dumped on site (111 840 m<sup>3</sup>)

The model uses the following first-order equation to estimate annual decomposition rate in a landfill site:

$$Q_{gas} = \sum_{i=1}^n \sum_{j=0.1}^1 kL_o \left(\frac{M_i}{10}\right) e^{-kt_{ij}}$$

Where

$Q_{gas}$  = annual gas generation in the year of the calculation (m<sup>3</sup>/year)

$i$  = 1-year time increment

$N$  = (year of the calculation) - (initial year of waste acceptance)

$J$  = 0.1-year time increment

$K$  = Gas generation rate (year-1)

$L_o$  = potential gas generation capacity (m<sup>3</sup>/Mg)

$M_i$  = mass of waste accepted in the  $i$ th year (Mg)

$t_{ij}$  = age of the  $j$ th section of waste mass  $M_i$  accepted in the  $i$ th year (decimal years, e.g., 3.2 years)

LandGEM is based on this first-order decomposition rate equation for quantifying emissions from the decomposition of landfilled waste in municipal solid waste (MSW) landfills. The software provides a relatively simple approach to estimating landfill gas emissions and model defaults are based on empirical data from U.S. landfills.

LandGEM is considered a screening tool and the better the input data, the better the estimates. Often, there are limitations with the available data regarding waste quantity and composition, variation in design and operating practices over time, and changes occurring over time that impact the emissions potential. Changes to landfill operation, such as operating under wet conditions through leachate recirculation or other liquid additions, will result in generating more gas at a faster rate.

The model estimates that the maximum emissions will occur in the year following closure of the site, i.e., 2030 and LAQS used these maximum emissions for the dispersion model. The estimated emissions in 2030 are shown in Table 2.



Compound	Annual emissions, tons	Contribution, %
Carbon disulphide	0.025	2.2
Hydrogen sulphide	0.69	60.8
Ethyl mercaptan	0.081	7.1
Methyl mercaptan	0.068	6.0
Dimethyl sulphide	0.274	24.0
<b>Total odours</b>	<b>1.142</b>	

**Table 2: Annual Gwayang landfill site emissions**

As the odour detection threshold of these compounds are very low and of the same order of magnitude, LAQS combined all emissions into a single pollutant, loosely named “odours”.

LandGEM estimates annual emissions from the year of commencement, i.e., 2005, to a period of more than 100 years after closure of the site and the full list of annual emissions is given in Annexure A.

### 6.2.2 Wastewater Treatment Works

The WWTW is a continuous operation and not subject to specific operating schedules or maintenance shutdowns. The latter are scheduled as part of normal plant operating procedures. Emissions will, therefore, occur continuously and the quantity of emissions are directly related to the quantity of wastewater passing through the treatment process.

The WWTW currently treats 10.4 million litres of waste water per day, but a process of upgrading has been initiated that will result in a treatment capacity of up to 22 million litres per day. LAQS used the upgraded capacity as basis for estimating emissions from the site.

Ideally, emissions from a WWTW need to be measured over an extended period of time to obtain reliable emissions data. In the absence of measured data, LAQS relied on emission factors (EFs) published in literature. It must be pointed out that reliable emission factors for wastewater treatment works are difficult to obtain due to the many factors that affect emissions from any such operations, e.g. waste throughput, composition of waste materials, age of the plant, technology used, diligence of maintenance, ambient temperature, etc.

As a first iteration, LAQS used the emission factors published by the Australian National Pollution Inventory (NPI) and these are:

- Ammonia 2.2 g/m<sup>3</sup> effluent treated
- Total hydrocarbons (THC): 1.07 g/m<sup>3</sup> effluent treated

The NPI emission factors are based on fairly old research, dating from 1991 to 1998, and does not make provision for the effect of modern technologies.



A detailed research project conducted in South Korea in 2008 yielded substantially more useful information, as published in the article “*Emission Characteristics and Factors of Selected Odorous Compounds at a Wastewater Treatment Plant*” by Eui-Chan Jeon, et al; Department of Earth & Environmental Sciences, Sejong University, South Korea. This research provided the following emission factors for various odorous compounds from various WWTP operations:

Operation	Emission factors, $\mu\text{g}/\text{m}^3$ effluent				
	Hydrogen sulfide	Methyl mercaptan	Dimethyl sulfide	Dimethyl disulfide	Trimethyl amine
Primary Settling Basin	16	5	2	177	2
Aeration Basin	51	6	30	76	3
Final Settling Basin	7	0	2	17	1
<b>Total</b>	<b>74</b>	<b>12</b>	<b>34</b>	<b>270</b>	<b>6</b>

**Table 3: WWTW Emission Factors**

As is the case with emissions from the landfill site, LAQS combined all emissions into a single pollutant, loosely named “odours” and used the total of the emission factors listed in Table 3 to estimate annual emissions. In addition, LAQS based its emissions calculation on the planned future treatment capacity of the WWTP.

The estimated annual emissions of “odours” was calculated to be 0.007 tons per annum. This excludes ammonia of which an estimated 0.017 tons per annum may be emitted. This is approximately three times greater than the total of the rest of the compounds, but it must be borne in mind that its detection threshold is approximately 26.6 times greater than the rest.

### 6.2.3 Industrial Emissions

LAQS made some assumptions in the process of estimating emissions where sufficient information was not available. Invariably the assumptions implied that all organic compounds emitted from the various sources consisted entirely of odorous compounds. This approach is an over-estimation of odorous emissions, especially for PG Bison, as not all organic compounds can be regarded as odorous.

The emissions from Averda’s operations were based on the results of emission measurements conducted at the various industries, kindly provided by GRDM. These results included flue gas temperature and velocities, as well as pollutant concentrations. The annual emissions were based on flue gas parameters measured during 2024 and the official emission limits that apply to the process. The annual emissions may vary from year to year due to fluctuations in flue gas parameters.



Emissions from timber drying operations at PG Bison do not occur through a stack, but are vented from drying chambers and measured emission from this process are not available. LAQS subsequently estimated annual emissions from the maximum capacity of the plant and emission factors generated Environment Canada's Wood Products Operations.

Organic compound emissions from George Crematorium were estimated from emission factors given in EMEP/EEA's Emission Inventory Guidebook.

LAQS attempted to estimate annual emissions as reliably as possible, taking into account that not all sources emit pollutants on a continuous basis for 24 hours per day, 7 days per week and 52 days of the year. The George Crematorium, e.g., only operate for 10 hours per day and five days of the week and 220 days year.

The following annual emissions of total odours were estimated:

Source	Emissions	Contribution, %
Averda	0.096	4.8
George Crematorium	0.026	1.3
PG Bison	1.863	93.9
<b>Total</b>	<b>1.985</b>	

**Table 4: Estimated Annual Odorous Emissions, tons**

Total odorous emissions for the sources are estimated to be:

Source	Annual emissions	Contribution, %
Gwayang Landfill	1.142	36.4
Wastewater Treatment	0.007	0.2
Industries	1.985	63.3
<b>Total</b>	<b>3.134</b>	

**Table 5: Total Annual Odorous Emissions, tons**

This may not seem to be much, but it must be borne in mind that the odour threshold limits are extremely low.

The stacks serving Averda and George Crematorium were regarded as point sources. Compulsory details for point sources (industrial stacks) are:

- Height of stack
- Internal diameter of stack



- External diameter of stack
- Flue gas temperature
- Flue gas velocity
- Height and width of adjacent structures that could influence the wind profile

Emissions from point sources are directly linked to the operational profile of each process, i.e. time of day, hours per day, etc. Relevant data of each stack was obtained from the AELs kindly provided by GRDM.

The landfill site, WWTW and PG Bison's drying chambers were regarded as area sources as the drying chambers do not have stacks. Compulsory information required for area source emissions are:

- Area over which emissions occur
- Height of release above ground level
- Definition of pollutants
- Emission rates of pollutants

All of the required information was obtained from either AELs or provided by GM.

The total emissions from area sources were assumed to be released evenly from the whole of the operational area of each source.

#### **Output units:**

Given an input of tons per annum, the output of evPlanner is in units of micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ). Input values of kilograms yield ground-level concentrations of nanograms per cubic metre ( $\text{ng}/\text{m}^3$ )

## **6.3 METEOROLOGICAL DATA**

Two sets of meteorological data were evaluated for use in this project, i.e. locally measured data and internationally simulated data.

### **6.3.1 Locally Measured Data**

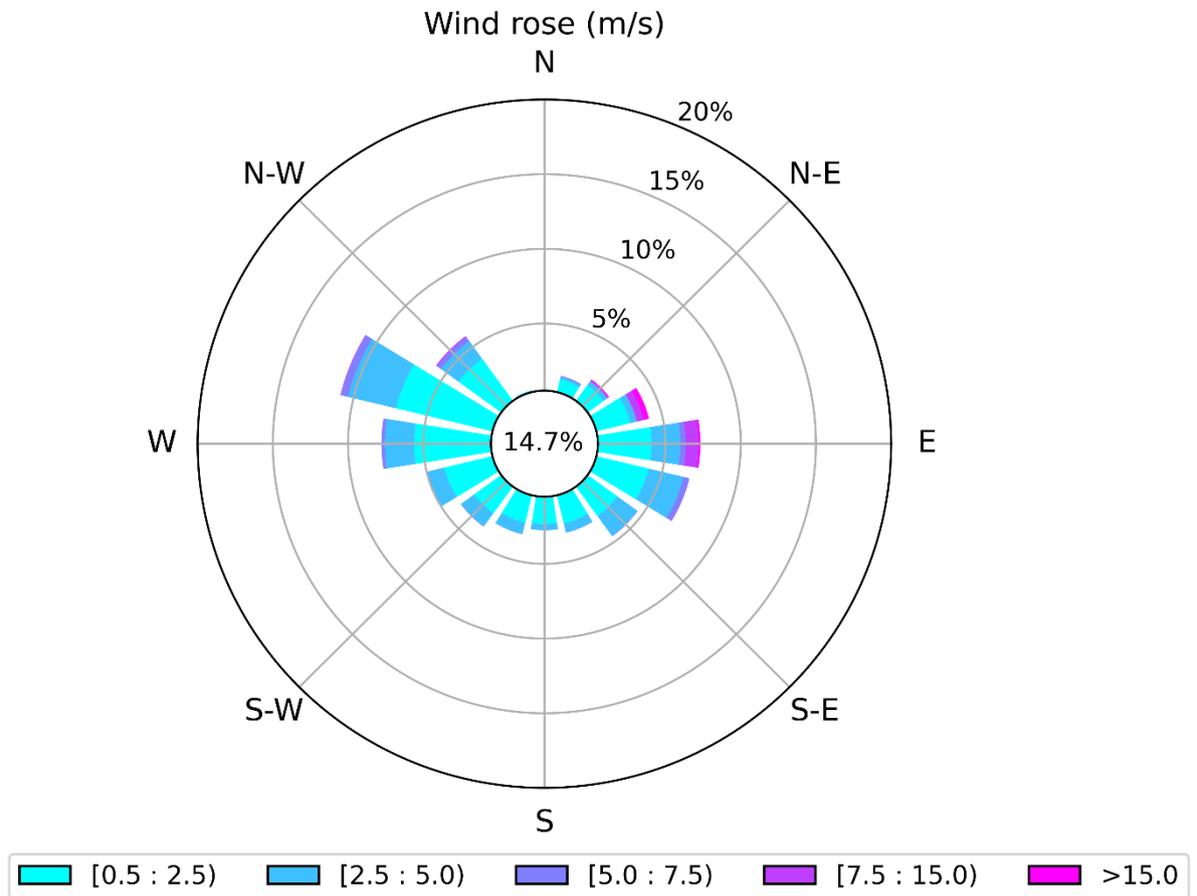
The Western Cape Province operates an ambient air quality monitoring station that is located in Mission Road in George and data from this station is reported to the South African Air Quality Information System (SAAQIS). LAQS obtained meteorological data for this station for the period of 1 January 2021 to 31 December 2024. The use of locally measured data is preferred in GN R.533.

Analysis of this data yielded the following:

- Approximately 17% of the data was missing
- A key parameter required for dispersion modelling, i.e. solar radiation, is not recorded at this monitoring station.
- No information is available to indicate if the meteorological sensors at the monitoring station are calibrated annually.



The wind speed and direction data recorded at the Western Cape Province’s air quality monitoring station shows the following distribution of winds:



**Figure 2: Frequency of Wind Direction; measured data**

The locally recorded data shows that the predominant wind directions are westerly and easterly. As the distribution of winds show the direction from which winds arrive, the dispersion of pollutants will occur in opposite directions, i.e. away from the sources.

### 6.3.2 Simulated Data

Initially, LAQS did not regard the measured data as reliable and an extensive set of meteorological data for George was procured from MeteoBlue in Switzerland. The use of simulated data is accepted in the GN R.533.

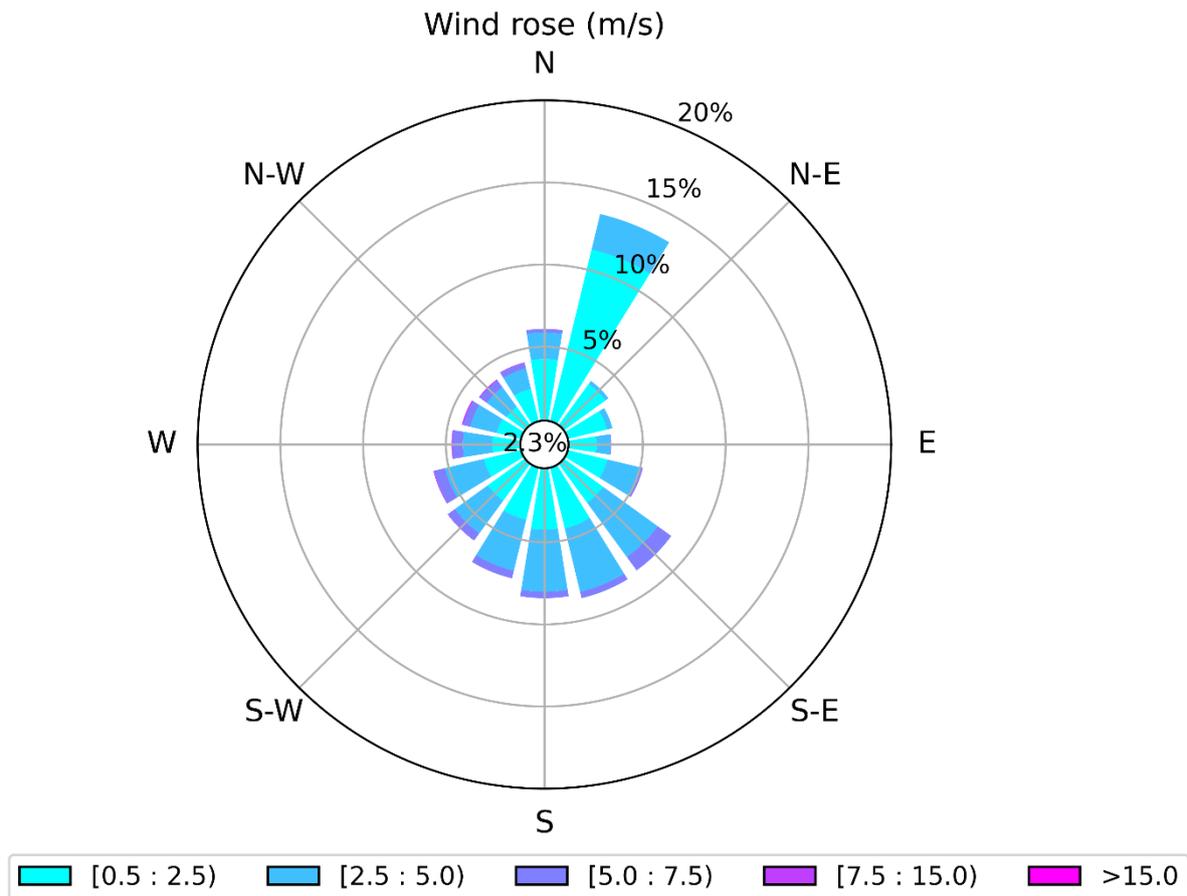
MeteoBlue is a Swiss organisation that generates simulated meteorological data using highly sophisticated algorithms. The use of simulated data is accepted in the "Regulations Regarding Air Dispersion Modelling", published in Government Notice R.533 of 11 July 2014 (GN R.533).

The distribution of winds in the George area, based on the simulated data, is shown graphically in Figure 3 below. The figure shows that the predominant wind directions are mostly from a



westerly to south-easterly direction, with a fairly high incidence of winds from a north of north-easterly direction.

Dispersion of pollutants will, therefore, be mainly easterly to north-westerly and south of south-easterly due to the spike in wind direction.



**Figure 3: Frequency of Wind Direction; simulated data**

### 6.3.3 Meteorology Data Discussion

As stated in Section 6.3.1, the data downloaded from the SAAQIS system was incomplete and missed a key parameter, i.e., solar radiation. However, discussions with GRDM showed that complaints about odours from PG Bison were reported in the past from a residential area located to the east of the plant. This implies a relatively high frequency of winds from a westerly direction, which is supported by the measured data, but not the simulated data.

Based on the complaint history, LAQS decided that the measured data was probably more reliable than the simulated data in this instance and used the measured data as basis for the dispersion modelling activities. This viewpoint is supported by the location of George relative to the Outeniqua Mountains and the ocean, where weather conditions are largely influenced by frontal systems that pass along the coast from west to east.



A key parameter, i.e. solar radiation, is not measured at the monitoring station and LAQS subsequently supplemented the measured data with solar radiation data from the simulated data set for the 5-year time period. This yielded a data set that is regarded as more representative of the area than the simulated data.

This data set was used as input data for evMet. The data set covered a period of five years (January 2021 to December 2024) and is regarded as reliable and of sufficient quality for calculating a boundary layer scaling set. Parameters covered are:

- Wind speed
- Wind direction
- Temperature
- Relative humidity
- Solar radiation

## **6.4 evPLANNER**

evPlanner does not require any user input as it extracts data from evMapper, evEmissioner and evMet.

# **7 MODEL RELIABILITY**

## **7.1 evEMISSIONER**

The results contained in this report must be interpreted with care.

As was stated in Section 6, measured emissions data for the Gwayang landfill site and WWTW are not available, and emission factors were used to estimate annual emissions. As pointed out in that Section, actual emissions are dependent on a number of factors, while the emission factors used are of a general nature.

LAQS used the maximum estimated emissions from the landfill site (2030 data) and the design capacity of the WWTW after upgrading has been completed.

In addition, LAQS made the assumption that all organic compounds emitted from the three industries listed in Section 3 consist entirely of odorous compounds. This is an overestimation as not all organic compounds are necessarily odorous.

Furthermore, the outcomes are based on all sources operating at full design capacity. Should any plant operate on a lower throughput rate, emissions will decrease accordingly, resulting in lesser impacts on the planned development.

Therefore, an unquantifiable degree of uncertainty exists in the estimated ground-level concentrations and the outcome of this assessment must be used as indication of odour spreads only.

## **7.2 evMET**

The meteorological data procured by LAQS is comprehensive and there are no gaps in the simulated data supplied by MeteoBlue, while some gaps in data (about 17%) exists in the



locally measured data. The simulated dataset contains all of the necessary parameters required for detailed dispersion modelling purposes, while the measured data did not include solar radiation, a key component.

MeteoBlue uses complex statistical techniques in conjunction with thousands of observations to remove systematic errors from our forecasts to provide accurate local weather conditions. In addition, MeteoBlue conducts extensive and regular verification of its and other simulation models, comparing them to actual measurement and observation data.

Nevertheless, the complaint history showed that the locally measured data is probably more representative than the simulated data and should, therefore, provide more representative details of the dispersion of odours.

### **7.3 evPLANNER**

As was stated previously, the user provides no direct data input to evPlanner. It uses Aermod, a USEPA approved Gaussian plume dispersion model and accepted model in GN R.533, and there is no reason to doubt the reliability of the dispersion calculations.

## **8 RESULTS**

LAQS modelled the dispersion of odours that may be emitted from the sources described in Section 3 for comparison of results against odour threshold limits.

All simulations were carried out for a receptor height of 2 metres above ground level and a plume dispersion period of 60 minutes. This simulation period ensured that very low winds, e.g. 1 m/s, would carry pollutants from the plant to the nearest residential area.

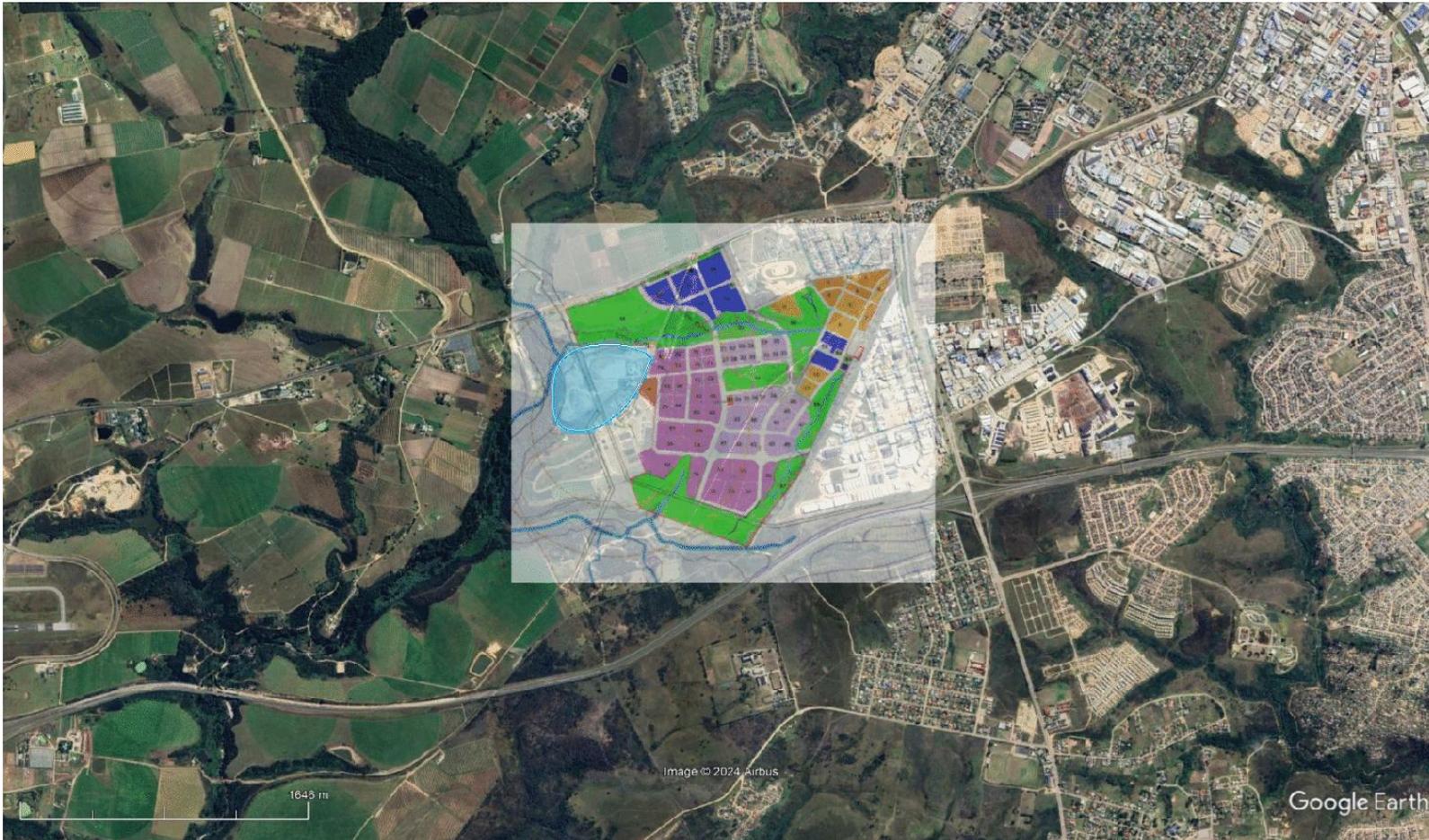
The approach was to determine both annual average ground-level concentrations and 95-percentile concentrations (the levels below which concentrations will occur for 95% of the time) of combined odorous compounds. A 95-percentile level was randomly chosen and represents a period of approximately 438 hours per year. Please note that the indication of the number of hours does not imply consecutive hours, but a total of number of hours spread throughout a year.

The dispersion of odours is shown graphically in Figures 4 to 7 below.

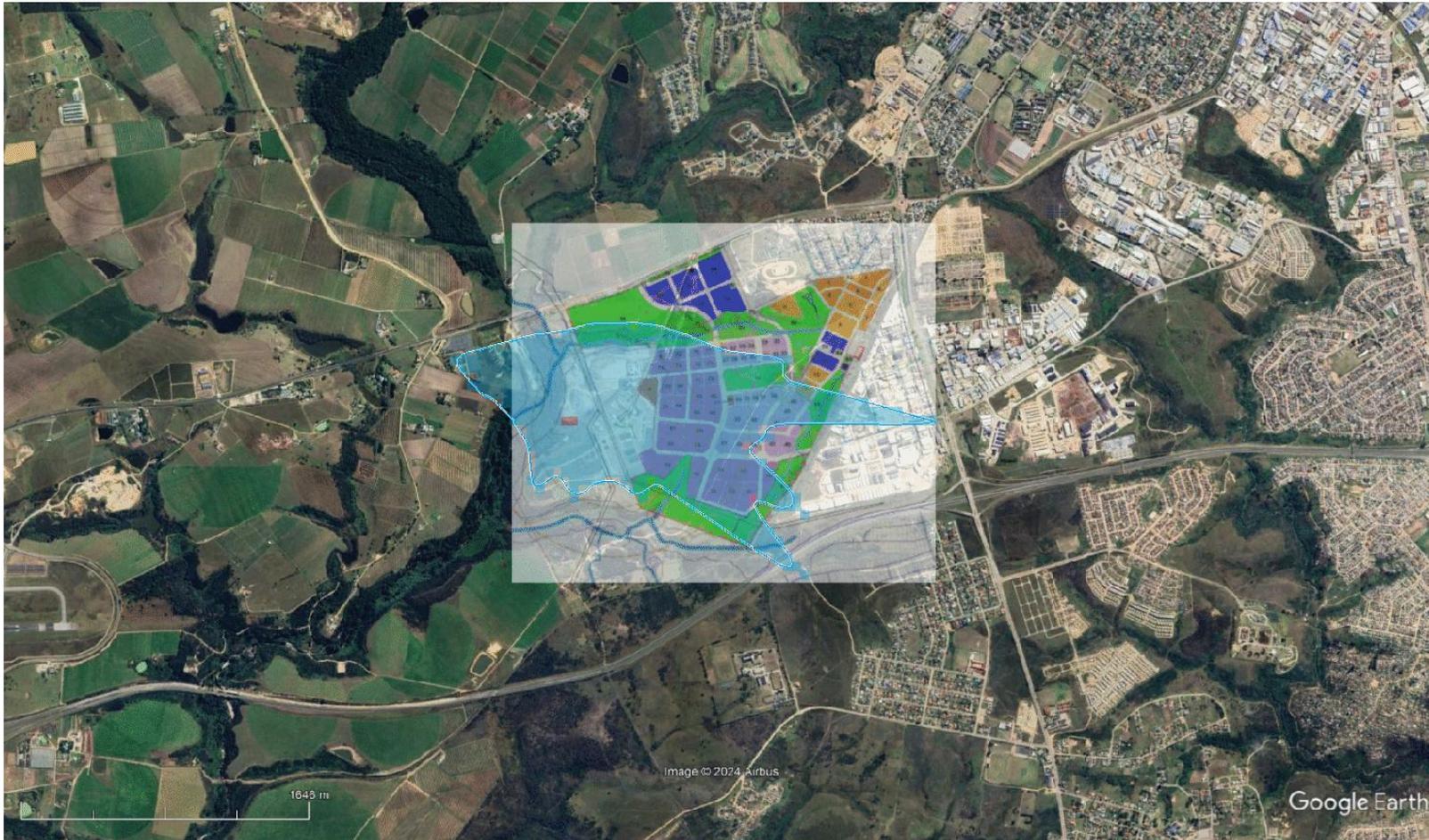
Figures 4 and 5 respectively show the annual average and 95-percentile dispersion of odours emitted from the landfill site, WWTW and Averda only. This indicates the potential impact area of odorous emissions located to the west of the planned development area.

Figures 6 and 7 respectively show the annual average and 95-percentile dispersion of odours, based on all sources discussed in this report, showing the cumulative impact of all sources.

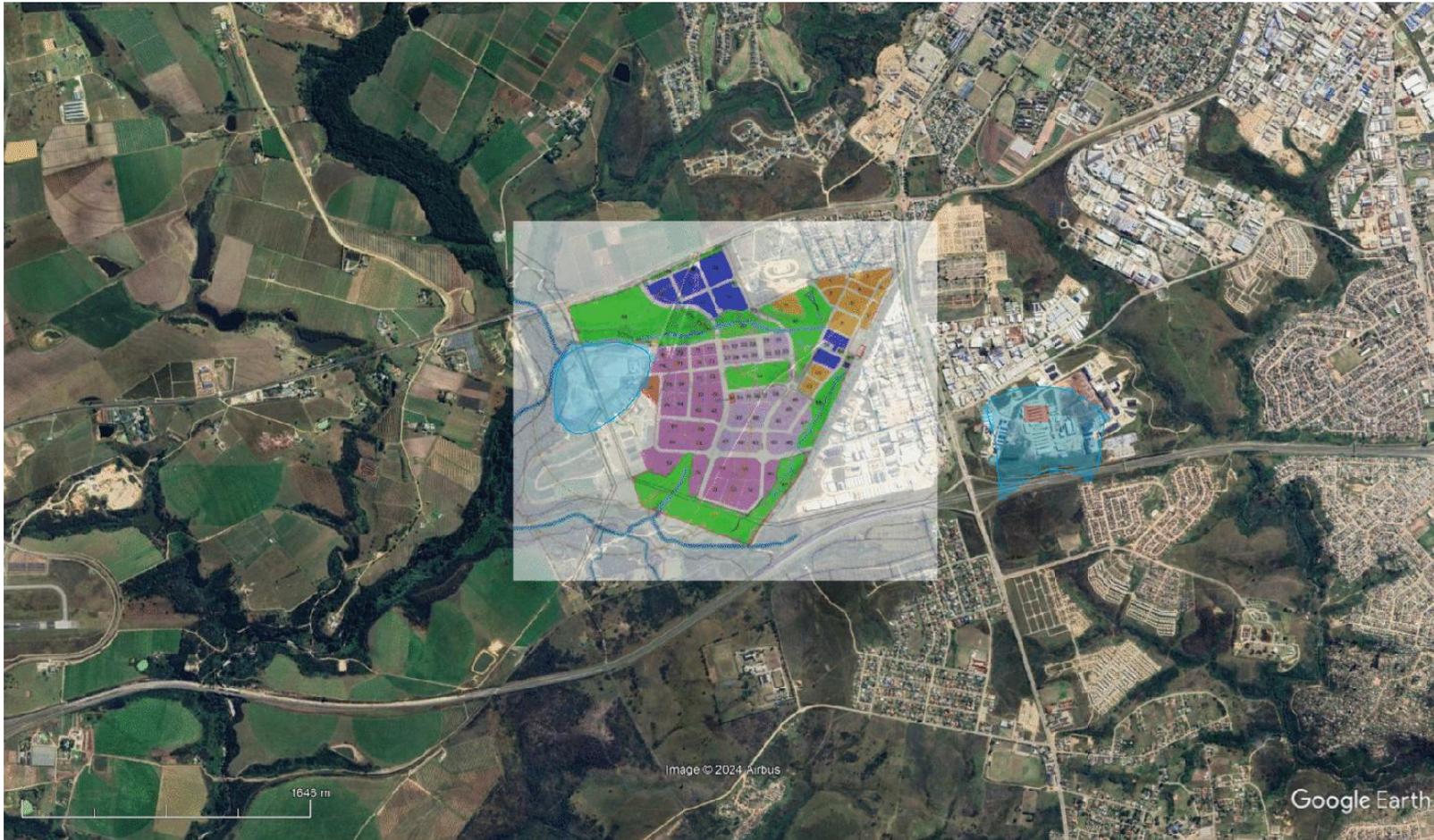
It must be noted that the aim of this study was not to determine specific ground-level concentrations, but to indicate areas over which the simulated ground-level concentrations are expected to exceed odour threshold limits.



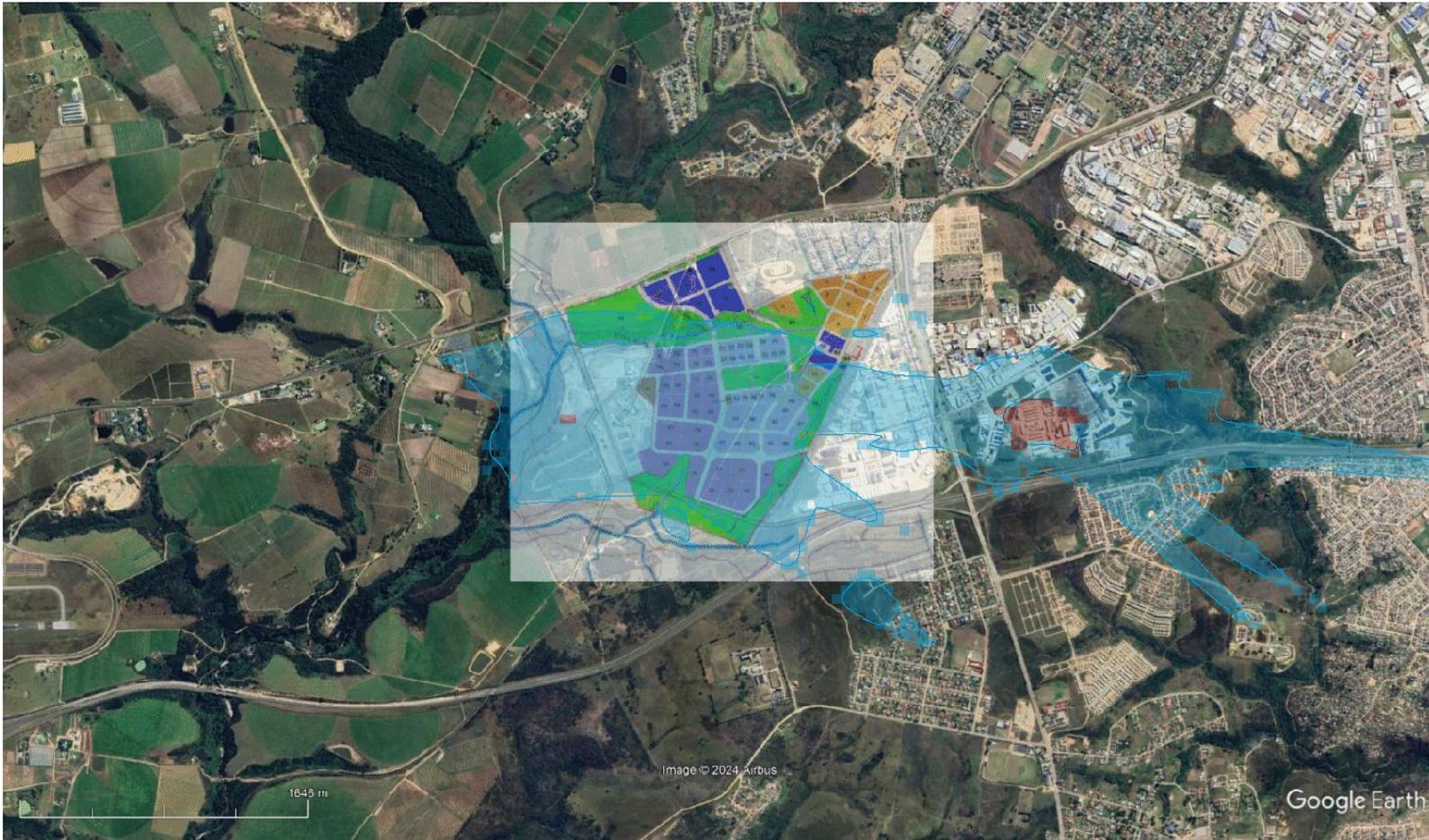
**Figure 4: Annual Average Detectable Odour Area; Averda, Landfill and WWTP operations**



**Figure 5: 95-percentile Hourly Odour Detectable Areas, Averda, Landfill and WWTP operations**



**Figure 6: Annual Average Odour Detectable Areas; All Sources**



**Figure 7: 95-percentile Hourly Odour Detectable Areas, All Sources**



The following can be derived from Figures 4 to 7:

- On average, as is shown in Figures 4 and 6, odours may be detectable in the immediate surrounds of the various odour sources, although the odour recognition thresholds are not breached. Therefore, someone may smell something but will not be able to identify it.
- Figures 5 and 7 show that the odours may be detected over a much larger area for about 5% of the time (438 hours), but the odour detection threshold may only be breached in the vicinity of the landfill site and PG Bison.

Please note that the figures above do not indicate the ground-level concentrations, but only the areas over which odours may be detected on and off during any given year.

## 9 ODOURS

The ability to perceive an odour varies widely among individuals. More than a thousand-fold difference between the least and the most sensitive individuals in acuity have been observed in studies conducted by the Iowa State University in the USA. Differences between individuals are, in part, attributable to age, smoking habits, gender, nasal allergies, head colds, etc. In addition, their surroundings may influence the perceived odour, e.g. uncontrolled odour sources, e.g., random municipal waste dumping, etc., may mask some odours. As a result, it is quite common for members of the same community to experience odours differently and report accordingly, usually resulting in a wide spread of odour descriptors and intensities.

Generally, the olfactory sensory nerves atrophy from the time of birth to the extent that only 82 percent of the acuity remains at the age of 20; 38 percent at the age of 60 and 28 percent at the age of 80. Consequently, olfactory acuity and like or dislike of an odour decrease with age.

Some investigators have defined odour threshold as the point where there is a detectable difference from background. Another definition of an odour threshold value (OTV) is the minimum identifiable odour or recognition threshold.

Both may be properly considered odour thresholds. However, experience has shown that the *detection threshold* (first change from background) is less reliable and difficult to reproduce as it often relies on a poorly defined judgment of the observer. Often there is confusion as to the definition of the first change as well as changes that can occur in the background odour.

The *recognition odour threshold* can be defined as the concentration at which 50 percent of the human panel can identify the odorant or odour, and such concentrations may be orders of magnitude higher than the detection threshold values.

Different compounds have different OTVs. Some OTVs may be very low, e.g. low parts per billion (ppb) range, while others are substantially higher, e.g. parts per million (ppm) range.

It is possible for an odorous compound with a relatively high odour threshold to be present in concentrations above that level, thus masking the presence of other odorous compounds. As the gases travel through, and disperse into, the atmosphere, the concentration of that compound may reduce to a level below its odour threshold at which point it may no longer be



detected, and other odorous compounds may come to the fore. As a result, the perceived odours may change over distance and time.

## 9.1 ODOUR CHARACTERISTICS

Odours are usually described by the following four parameters:

- **Odour detection threshold** is the lowest odorant concentration necessary for detection by a certain percentage of the population, normally 50%. This concentration is defined as 1 odour unit.
- **Odour intensity** is the perceived strength of an odour above its threshold. In the USA it is usually determined by an odour panel and is described in categories which progress from “not perceptible”, then “very weak”, through to “extremely strong”.
- **Hedonic tone** is the degree to which an odour is perceived as pleasant or unpleasant. Such perceptions differ widely from person to person, and are strongly influenced, inter alia, by previous experience and emotions at the time of odour perception.
- **Odour character** is basically what the odour smells like. It allows one to distinguish between different odours.

## 9.2 HEDONIC EVALUATION

Panels of trained observers were used in the USA to characterise various odours and classify them on a scale ranging from "highly unpleasant" to "very pleasant". The scale used for these evaluations ranged from -4 (highly unpleasant) to +4 (very pleasant).

The following odour descriptors and equivalent evaluations resulted:

Cadaverous (dead animal)	-3.75
Putrid, foul, decayed	-3.74
Sewer odour (typically H <sub>2</sub> S)	-3.68
Cat urine	-3.64
Faecal (like manure)	-3.36
Rancid	-3.14
Fermented (rotten fruit)	-2.76
Ammonia	-2.47
Sulphurous	-2.45

A substantial degree of correlation between odours and unpleasantness resulted from similar studies conducted in the UK.



### 9.3 ODOUR DETECTION LIMITS

As mentioned in Section 4, the following odour threshold values and odour recognition values apply to the various odorous compounds:

Compound	Odour threshold, $\mu\text{g}/\text{m}^3$		Odour characteristic
	Low	High	
Hydrogen sulphide ( $\text{H}_2\text{S}$ )	0.7	14	Rotten eggs
Methyl mercaptan ( $\text{CH}_3\text{SH}$ )	0.04	82	Decayed cabbage
Dimethyl sulphide ( $(\text{CH}_3)_2\text{S}$ )	2.5	50.6	Decayed vegetables
Dimethyl disulphide ( $(\text{CH}_3)_2\text{S}_2$ )	1	346	Vegetable sulphide
Trimethylamine ( $(\text{CH}_3)_3\text{N}$ )	0.8	0.8	Ammoniacal, fishy

**Table 6: Odour Threshold Values**

The following can be derived from the table:

- Methyl mercaptan has the lowest lower detection threshold, but its higher detection threshold is quite high.
- Hydrogen sulphide has an extremely low odour detection limit (equivalent to  $0.7 \mu\text{g}/\text{m}^3$  at  $25^\circ\text{C}$ ) and its recognition threshold is only one order of magnitude higher at approximately  $7 \mu\text{g}/\text{m}^3$  at  $25^\circ\text{C}$ . This implies that an average person may detect its typical rotten egg odour at fairly low concentrations and its hedonic value implies that the odour is more unpleasant.
- Dimethyl disulphide's lower detection threshold is low, but its higher detection threshold is the highest of the compounds listed.

The display scales used for Figures 3 to 7 are based on the odour detection limits shown in Table 6 and not the recognition limits. They indicate, therefore, the areas over which odours may be detected from time-to-time, without the odours being recognised.

## 10 CONCLUSIONS AND RECOMMENDATIONS

The outcome of the dispersion modelling study shows that some odours may be detectable on average along the western boundary of the planned development zone and over the industrial area to the east of the development zone.

For an estimated 5% of the time the areas over which odours may be detected increase in size, covering virtually the whole of the planned development zone. It is notable that the odour recognition threshold is not exceeded over the development zone, but the model



estimates that this threshold may be exceeded in the vicinity of the landfill site as well as over the industrial area to the east of the development zone.

It is not possible to state when such incidents may occur, and how long odours may be detectable, as these are totally dependent on meteorological conditions that contribute to poor dispersion of air pollutants. The most likely period of detectable odours is during the early morning hours of winter months when the air layer is stable, and wind speeds are low.

The proposed upgrades to the WWTP include technologies that will result in reduced odorous emission, thus resulting in a lower odour footprint. However, it is not possible to estimate the efficiency of such technologies at this stage.

Furthermore, LAQS' assumption that all volatile organic compounds emitted from wood drying operations at PG bison consist of odorous compounds must be interpreted with care. The main organic compounds that may be emitted are loosely termed as "terpenes".

Terpenes are widespread in nature, mainly in plants as constituents of essential oils. Terpenes are found in plant species such as pine trees, spices (sage, rosemary, caraway, cumin, clove, and thyme), etc. Terpenes have characteristics such as fragrance, taste, and colour that primarily act as pesticides and repel parasites. They also have various antimicrobial properties to help the plant build immunity against bacteria, plasmodium, fungi, and viruses.

Terpenes are, therefore, odorous, but the odours may not necessarily be regarded as offensive, or malodorous, and will not result in the same public reaction as any of the compounds listed in Table 6. While some complaints have been made about odorous emissions from PG Bison's operations, these complaints were infrequent and were made by a few people only.

LAQS concludes that some odours may be detectable over the planned development zone, but at low intensity and infrequently. Unfortunately, it is not possible to state categorically that no odour-related complaints may arise as the hedonic tone and odour character of odours differ from person to person.

LAQS recommends that continuous odour detection is carried out along the western boundary of the developments zone once occupation of the zone commences. This will provide first-hand details of the concentration of odorous gases, albeit not all of them, so that any subsequent complaint can be dealt with effectively.

LAQS recommends further that an odour awareness clause is included in any property ownership and/or usage rights for the proposed development area.

## **11 POTENTIAL REGULATORY STEPS**

The results discussed in this report reflect the current situation and are based on odorous emissions only. However, of the odorous emissions generated by the three sources immediately adjacent to the western boundary of the development zone, as discussed in Section 6.2, emissions from the Gwayang landfill site amount to approximately 1.142 tons per annum of a total of approximately 1.245 tons per annum, or 91.7% of odorous emissions.

These emissions are based on the maximum estimated emissions which should occur a year after the planned shutdown of the site in 2029. Thereafter emissions will start to decrease



exponentially, as is shown in Annexure A. Even though emissions will continue for decades thereafter, the landfill site should be seen as a “temporary” source, in which emissions will decrease to levels where odours will become negligible over time.

It is likely that additional sources of air pollutant emissions may be formed as the industrial area of the planned development zone becomes populated. As only vague industry descriptions are available at this stage, it is not possible to give an idea of conditions that may prevail once the development area has been saturated by tenants.

Only when details of planned industrial settling become available can the potential cumulative impact of emissions be investigated. In doing so it must be borne in mind that potential impacts may not only add to the pool of odorous emissions, but to the emissions of other pollutants as well, e.g. PM10 particulates, sulphur dioxide, nitrogen oxides, etc.

It must also be borne in mind that existing regulatory measures will have to be applied and that some additional measures may need to be promulgated. The following scenarios serve as possible regulatory suggestions:

### **11.1 LISTED ACTIVITIES**

Control measures for industries included in GN893 are in place and are being enforced. Therefore, if such an industry wishes to locate in the new development area it will have to go through the existing environmental authorisation procedures in which due attention is paid to the environmental impact of the industry.

In this process, due attention is paid to pollution minimisation, including stipulation of a requirement to install best available pollution prevention technologies by the relevant licensing authorities, should the need arise.

No additional requirements are suggested.

### **11.2 NON-LISTED ACTIVITIES**

It is likely that some industries not included in GN893 may wish to settle in the new zone, some of which may cause odorous and/or visible emissions on a continuous basis. Such industries pose a risk to effective air quality management as regulatory tools are limited to municipal bylaws. An example is a company that may wish to produce pet food for which raw materials will be transported to site, including potentially odorous products like fishmeal. In a mixing or blending process fugitive odorous emissions may escape, resulting in complaints. True to human nature, the main sources of odours in the area, i.e. the landfill site and WWTW, will become the scapegoats and stringent measures will be required to prevent such occurrences.

It is suggested that it becomes mandatory for all industrial activities that may wish to locate to the area to submit full process descriptions for evaluation for potential environmental impacts, be it air, water, waste, noise, etc., prior to construction. This information should be evaluated in detail by GM and the assistance and opinion of GRDM and/or specialist consultants should be sought, if and when necessary and in the event of uncertainties arising.

As far as air quality is concerned, it is suggested that each industry that may emit pollutants to atmosphere, as judged by GM from the detailed process description, carry out a cumulative



air quality impact assessment for the area, the results of which should be compared against official ambient air quality standards as published in GN 1210. In cases where ambient air quality standards do not exist, estimated ground-level concentrations should be compared against international published health risk data, e.g., the USEPA's Integrated Risk Information System (IRIS).

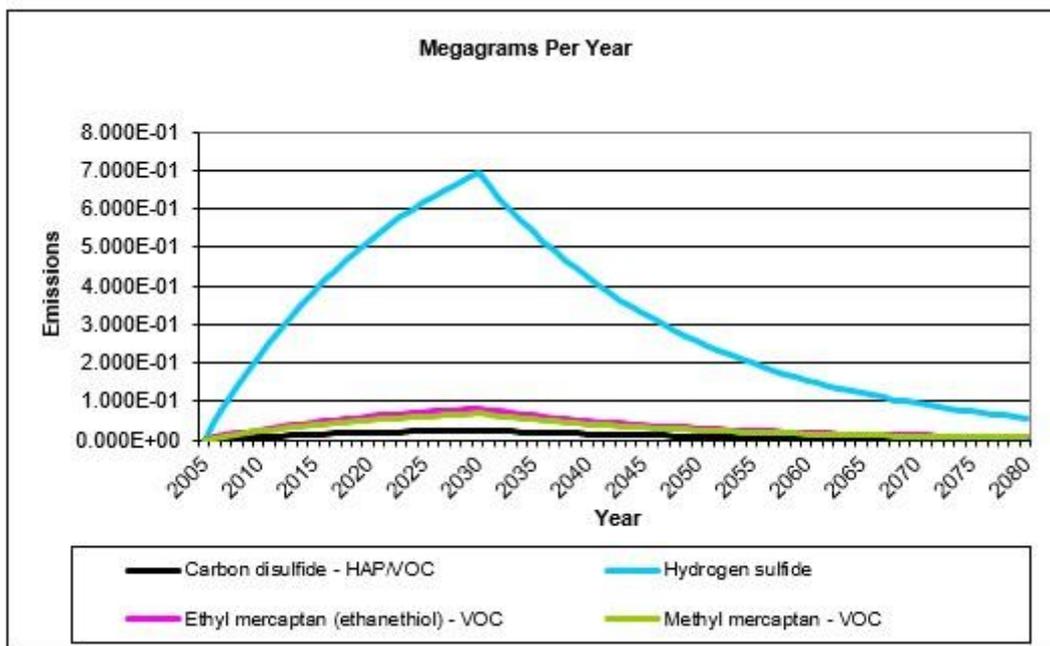
It is suggested that the relevant existing municipal bylaws are examined for potential expansion to give more power to environmental enforcement by GM, within the current framework of national legislation.



## ANNEXURE A

### ANNUAL GASEOUS EMISSIONS ESTIMATED BY LANDGEM

Expected landfill gas emissions profile:





Year	Annual emissions, tons				
	Carbon disulphide	Hydrogen sulphide	Ethyl mercaptan	Methyl mercaptan	Dimethyl sulphide
2005	0	0	0	0	0
2006	1.7E-03	4.7E-02	5.5E-03	4.7E-03	1.874E-02
2007	3.3E-03	9.3E-02	1.1E-02	9.1E-03	3.656E-02
2008	4.9E-03	1.4E-01	1.6E-02	1.3E-02	5.351E-02
2009	6.3E-03	1.8E-01	2.1E-02	1.7E-02	6.964E-02
2010	7.7E-03	2.2E-01	2.5E-02	2.1E-02	8.498E-02
2011	9.1E-03	2.5E-01	2.9E-02	2.5E-02	9.957E-02
2012	1.0E-02	2.9E-01	3.3E-02	2.8E-02	1.135E-01
2013	1.2E-02	3.2E-01	3.7E-02	3.1E-02	1.267E-01
2014	1.3E-02	3.5E-01	4.1E-02	3.5E-02	1.392E-01
2015	1.4E-02	3.8E-01	4.5E-02	3.8E-02	1.512E-01
2016	1.5E-02	4.1E-01	4.8E-02	4.0E-02	1.625E-01
2017	1.6E-02	4.4E-01	5.1E-02	4.3E-02	1.733E-01
2018	1.7E-02	4.6E-01	5.4E-02	4.6E-02	1.836E-01
2019	1.8E-02	4.9E-01	5.7E-02	4.8E-02	1.934E-01
2020	1.8E-02	5.1E-01	6.0E-02	5.0E-02	2.027E-01
2021	1.9E-02	5.4E-01	6.2E-02	5.3E-02	2.116E-01
2022	2.0E-02	5.6E-01	6.5E-02	5.5E-02	2.200E-01
2023	2.1E-02	5.8E-01	6.7E-02	5.7E-02	2.280E-01
2024	2.1E-02	6.0E-01	6.9E-02	5.8E-02	2.356E-01
2025	2.2E-02	6.1E-01	7.2E-02	6.0E-02	2.429E-01
2026	2.3E-02	6.3E-01	7.4E-02	6.2E-02	2.497E-01
2027	2.3E-02	6.5E-01	7.6E-02	6.4E-02	2.563E-01
2028	2.4E-02	6.6E-01	7.7E-02	6.5E-02	2.625E-01
2029	2.4E-02	6.8E-01	7.9E-02	6.7E-02	2.685E-01
<b>2030</b>	<b>2.5E-02</b>	<b>6.9E-01</b>	<b>8.1E-02</b>	<b>6.8E-02</b>	<b>2.741E-01</b>
2031	2.4E-02	6.6E-01	7.7E-02	6.5E-02	2.607E-01
2032	2.3E-02	6.3E-01	7.3E-02	6.2E-02	2.480E-01
2033	2.1E-02	6.0E-01	7.0E-02	5.9E-02	2.359E-01



2034	2.0E-02	5.7E-01	6.6E-02	5.6E-02	2.244E-01
2035	1.9E-02	5.4E-01	6.3E-02	5.3E-02	2.135E-01
2036	1.9E-02	5.1E-01	6.0E-02	5.0E-02	2.031E-01
2037	1.8E-02	4.9E-01	5.7E-02	4.8E-02	1.932E-01
2038	1.7E-02	4.7E-01	5.4E-02	4.6E-02	1.837E-01
2039	1.6E-02	4.4E-01	5.2E-02	4.3E-02	1.748E-01
2040	1.5E-02	4.2E-01	4.9E-02	4.1E-02	1.663E-01
2041	1.4E-02	4.0E-01	4.7E-02	3.9E-02	1.582E-01
2042	1.4E-02	3.8E-01	4.4E-02	3.7E-02	1.504E-01
2043	1.3E-02	3.6E-01	4.2E-02	3.6E-02	1.431E-01
2044	1.2E-02	3.4E-01	4.0E-02	3.4E-02	1.361E-01
2045	1.2E-02	3.3E-01	3.8E-02	3.2E-02	1.295E-01
2046	1.1E-02	3.1E-01	3.6E-02	3.1E-02	1.232E-01
2047	1.1E-02	3.0E-01	3.5E-02	2.9E-02	1.172E-01
2048	1.0E-02	2.8E-01	3.3E-02	2.8E-02	1.114E-01
2049	9.7E-03	2.7E-01	3.1E-02	2.6E-02	1.060E-01
2050	9.2E-03	2.6E-01	3.0E-02	2.5E-02	1.008E-01
2051	8.7E-03	2.4E-01	2.8E-02	2.4E-02	9.592E-02
2052	8.3E-03	2.3E-01	2.7E-02	2.3E-02	9.125E-02
2053	7.9E-03	2.2E-01	2.6E-02	2.2E-02	8.680E-02
2054	7.5E-03	2.1E-01	2.4E-02	2.0E-02	8.256E-02
2055	7.2E-03	2.0E-01	2.3E-02	1.9E-02	7.854E-02
2056	6.8E-03	1.9E-01	2.2E-02	1.9E-02	7.471E-02
2057	6.5E-03	1.8E-01	2.1E-02	1.8E-02	7.106E-02
2058	6.2E-03	1.7E-01	2.0E-02	1.7E-02	6.760E-02
2059	5.9E-03	1.6E-01	1.9E-02	1.6E-02	6.430E-02
2060	5.6E-03	1.5E-01	1.8E-02	1.5E-02	6.116E-02
2061	5.3E-03	1.5E-01	1.7E-02	1.4E-02	5.818E-02
2062	5.0E-03	1.4E-01	1.6E-02	1.4E-02	5.534E-02
2063	4.8E-03	1.3E-01	1.6E-02	1.3E-02	5.264E-02
2064	4.6E-03	1.3E-01	1.5E-02	1.2E-02	5.008E-02
2065	4.3E-03	1.2E-01	1.4E-02	1.2E-02	4.763E-02



2066	4.1E-03	1.1E-01	1.3E-02	1.1E-02	4.531E-02
2067	3.9E-03	1.1E-01	1.3E-02	1.1E-02	4.310E-02
2068	3.7E-03	1.0E-01	1.2E-02	1.0E-02	4.100E-02
2069	3.6E-03	9.9E-02	1.1E-02	9.7E-03	3.900E-02
2070	3.4E-03	9.4E-02	1.1E-02	9.2E-03	3.710E-02
2071	3.2E-03	8.9E-02	1.0E-02	8.8E-03	3.529E-02
2072	3.1E-03	8.5E-02	9.9E-03	8.3E-03	3.357E-02
2073	2.9E-03	8.1E-02	9.4E-03	7.9E-03	3.193E-02
2074	2.8E-03	7.7E-02	9.0E-03	7.5E-03	3.037E-02
2075	2.6E-03	7.3E-02	8.5E-03	7.2E-03	2.889E-02
2076	2.5E-03	7.0E-02	8.1E-03	6.8E-03	2.748E-02
2077	2.4E-03	6.6E-02	7.7E-03	6.5E-03	2.614E-02
2078	2.3E-03	6.3E-02	7.3E-03	6.2E-03	2.487E-02
2079	2.2E-03	6.0E-02	7.0E-03	5.9E-03	2.365E-02
2080	2.1E-03	5.7E-02	6.6E-03	5.6E-03	2.250E-02
2081	2.0E-03	5.4E-02	6.3E-03	5.3E-03	2.140E-02
2082	1.9E-03	5.2E-02	6.0E-03	5.1E-03	2.036E-02
2083	1.8E-03	4.9E-02	5.7E-03	4.8E-03	1.937E-02
2084	1.7E-03	4.7E-02	5.4E-03	4.6E-03	1.842E-02
2085	1.6E-03	4.4E-02	5.2E-03	4.3E-03	1.752E-02
2086	1.5E-03	4.2E-02	4.9E-03	4.1E-03	1.667E-02
2087	1.4E-03	4.0E-02	4.7E-03	3.9E-03	1.586E-02
2088	1.4E-03	3.8E-02	4.4E-03	3.7E-03	1.508E-02
2089	1.3E-03	3.6E-02	4.2E-03	3.6E-03	1.435E-02
2090	1.2E-03	3.5E-02	4.0E-03	3.4E-03	1.365E-02
2091	1.2E-03	3.3E-02	3.8E-03	3.2E-03	1.298E-02
2092	1.1E-03	3.1E-02	3.6E-03	3.1E-03	1.235E-02
2093	1.1E-03	3.0E-02	3.5E-03	2.9E-03	1.175E-02
2094	1.0E-03	2.8E-02	3.3E-03	2.8E-03	1.117E-02
2095	9.7E-04	2.7E-02	3.1E-03	2.6E-03	1.063E-02
2096	9.2E-04	2.6E-02	3.0E-03	2.5E-03	1.011E-02
2097	8.8E-04	2.4E-02	2.8E-03	2.4E-03	9.617E-03



2098	8.3E-04	2.3E-02	2.7E-03	2.3E-03	9.148E-03
2099	7.9E-04	2.2E-02	2.6E-03	2.2E-03	8.702E-03
2100	7.5E-04	2.1E-02	2.4E-03	2.1E-03	8.278E-03
2101	7.2E-04	2.0E-02	2.3E-03	2.0E-03	7.874E-03
2102	6.8E-04	1.9E-02	2.2E-03	1.9E-03	7.490E-03
2103	6.5E-04	1.8E-02	2.1E-03	1.8E-03	7.125E-03
2104	6.2E-04	1.7E-02	2.0E-03	1.7E-03	6.777E-03
2105	5.9E-04	1.6E-02	1.9E-03	1.6E-03	6.447E-03
2106	5.6E-04	1.6E-02	1.8E-03	1.5E-03	6.132E-03
2107	5.3E-04	1.5E-02	1.7E-03	1.4E-03	5.833E-03
2108	5.1E-04	1.4E-02	1.6E-03	1.4E-03	5.549E-03
2109	4.8E-04	1.3E-02	1.6E-03	1.3E-03	5.278E-03
2110	4.6E-04	1.3E-02	1.5E-03	1.2E-03	5.021E-03
2111	4.4E-04	1.2E-02	1.4E-03	1.2E-03	4.776E-03
2112	4.1E-04	1.2E-02	1.3E-03	1.1E-03	4.543E-03
2113	3.9E-04	1.1E-02	1.3E-03	1.1E-03	4.321E-03
2114	3.7E-04	1.0E-02	1.2E-03	1.0E-03	4.111E-03
2115	3.6E-04	9.9E-03	1.2E-03	9.7E-04	3.910E-03
2116	3.4E-04	9.4E-03	1.1E-03	9.2E-04	3.719E-03
2117	3.2E-04	9.0E-03	1.0E-03	8.8E-04	3.538E-03
2118	3.1E-04	8.5E-03	9.9E-04	8.4E-04	3.365E-03
2119	2.9E-04	8.1E-03	9.4E-04	7.9E-04	3.201E-03
2120	2.8E-04	7.7E-03	9.0E-04	7.6E-04	3.045E-03
2121	2.6E-04	7.3E-03	8.5E-04	7.2E-04	2.897E-03
2122	2.5E-04	7.0E-03	8.1E-04	6.8E-04	2.755E-03
2123	2.4E-04	6.6E-03	7.7E-04	6.5E-04	2.621E-03
2124	2.3E-04	6.3E-03	7.4E-04	6.2E-04	2.493E-03
2125	2.2E-04	6.0E-03	7.0E-04	5.9E-04	2.372E-03
2126	2.1E-04	5.7E-03	6.7E-04	5.6E-04	2.256E-03
2127	2.0E-04	5.4E-03	6.3E-04	5.3E-04	2.146E-03
2128	1.9E-04	5.2E-03	6.0E-04	5.1E-04	2.041E-03
2129	1.8E-04	4.9E-03	5.7E-04	4.8E-04	1.942E-03



2130	1.7E-04	4.7E-03	5.4E-04	4.6E-04	1.847E-03
2131	1.6E-04	4.4E-03	5.2E-04	4.4E-04	1.757E-03
2132	1.5E-04	4.2E-03	4.9E-04	4.1E-04	1.671E-03
2133	1.4E-04	4.0E-03	4.7E-04	3.9E-04	1.590E-03
2134	1.4E-04	3.8E-03	4.5E-04	3.8E-04	1.512E-03
2135	1.3E-04	3.6E-03	4.2E-04	3.6E-04	1.438E-03
2136	1.2E-04	3.5E-03	4.0E-04	3.4E-04	1.368E-03
2137	1.2E-04	3.3E-03	3.8E-04	3.2E-04	1.302E-03
2138	1.1E-04	3.1E-03	3.7E-04	3.1E-04	1.238E-03
2139	1.1E-04	3.0E-03	3.5E-04	2.9E-04	1.178E-03
2140	1.0E-04	2.8E-03	3.3E-04	2.8E-04	1.120E-03
2141	9.7E-05	2.7E-03	3.1E-04	2.6E-04	1.066E-03
2142	9.2E-05	2.6E-03	3.0E-04	2.5E-04	1.014E-03
2143	8.8E-05	2.4E-03	2.8E-04	2.4E-04	9.642E-04
2144	8.4E-05	2.3E-03	2.7E-04	2.3E-04	9.172E-04
2145	7.9E-05	2.2E-03	2.6E-04	2.2E-04	8.725E-04