Appendix G

Air quality Report prepared for the Original Development Proposal

AIR QUALITY – ODOUR AND DUST: LIGHT HORSE BUSINESS CENTRE DEVELOPMENT APPLICATION

4 April 2008

Prepared for
Environmental Resources Management Australia Pty Ltd

On behalf of
Light Horse Business Centre

by

Holmes Air Sciences
Suite 2B, 14 Glen St
Eastwood NSW 2122
Phone : (02) 9874 8644
Fax : (02) 9874 8904
Email : has@holmair.com.au

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1. INTRODUCTION

ThaQuarry Pty Ltd and ACN 114 843 453 Pty Ltd seek project approval for the construction and operation of a resource recovery facility (including a materials processing centre (MPC) and waste transfer station (WTS)), and a class 2 inert and solid waste landfill at Eastern Creek, in Sydney's west. Project approval is sought under Part 3A of the *Environmental Planning and Assessment Act, 1979*.

Holmes Air Sciences have been engaged by Environmental Resources Management Pty Ltd (ERM) on behalf of the proponent to assess the air quality and odour impacts of the project, as part of the overall environmental assessment. The application process is to be managed on behalf of both parties by ThaQuarry Pty Ltd under the project name Light Horse Business Centre.

A conventional approach has been adopted for this assessment which follows the procedures outlined by the NSW Department of Environment and Climate Change (DECC) in their document titled "Approved Methods for the Modelling and Assessment of Air Pollutants in NSW" (**DEC, 2005a**). The guidelines specify how assessments based on the use of air dispersion models should be undertaken. They include guidelines for the preparation of meteorological data, emissions data and relevant air quality criteria. The approach taken in this assessment follows as closely as possible the approaches suggested by the guidelines.

2. LOCAL SETTING AND PROJECT DESCRIPTION

The site is located at Eastern Creek in the central western suburbs of Sydney NSW. It comprises four land parcels, identified as Lot 2 on Deposited Plan (DP) 262213, Lot 10 on DP 241859, Lot 1 on DP 400697 and Lot W on DP 419612. For this assessment, a Study Area was set up which includes the project site and surrounding lands. The location of the site and the Study Area is shown in **Figure 1**.

The site was formerly used as a hard rock quarry and quarrying ceased in September 2006. The nearest sensitive receptors are concentrated to the north of the site, in the suburb of Minchinbury, approximately 550 metres (m) from the northern edge of the quarry pit, on the northern side of the M4 Motorway.

The area is predominantly flat to undulating, however, a deep void exists on the project site in the form of the former quarry pit. There are existing 30 m high, steep banked stockpiles of excavated quarry overburden material located to the north and west of the quarry pit. As part of the project, these will be reshaped to form amenity berms up to 10 m high. The base of the quarry is approximately 150 m below the surrounding ground-level. **Figure 2** shows the terrain in the study area, including the quarry pit.

Once operational, the facility will accept inert and solid wastes from construction and demolition, commercial and industrial waste streams complying with acceptable waste of non-putrescible class 2 facilities, and green waste clean ups. It will have the ability to accept up to 2 million tonnes per annum (Mtpa) of waste. It is estimated that there will be a total of 148,400 vehicle movements at the site per year with vehicle sizes ranging between 1 and 40 tonnes. The waste will either be recovered, sent to landfill or if required sent to an appropriate offsite facility.

An estimated 50 to 80% of total waste accepted onto the site (1 to 1.6 Mtpa, based on maximum capacity intake) will go through the recovery process and be recycled. The remaining 20 to 50% (0.4 to 1 Mpta, based on maximum capacity intake) will be sent to landfill.

Incoming waste will be classified at the primary weighbridge based on advice from the carrier, inspection of the carrier's documentation and verification of this information by visual inspection using the weighbridge camera. This will be verified by visual inspection by a spotter at the unloading area. Any non-complying materials identified will be sent offsite. Liquid wastes, medical wastes, toxic and hazardous wastes and putrescible materials will not be received at the facility.

Some material brought onto the site will be identified outright as unsuitable for recovery and will be directed to the landfill or to the WTS, from where it will be transported to the landfill or off-site as appropriate. Materials to be sent to landfill will be loaded to on-site dump trucks (two 40 t dump trucks and one 50 t dump truck) and transferred to the landfill facility in the base of the quarry. Segregated loads of recoverable materials will be unloaded directly at the appropriate segregated stockpile. Mixed loads suitable for recovery will be unloaded at the MPC, where sorting will take place within a partially enclosed MPC/WTS building fitted with mist sprays. Segregated recoverable materials will be placed at the appropriate stockpile for either sale or recycling.

To recover resources for recycling, on-site processing of waste will occur by sorting, chipping, shredding, composting, screening, sieving, crushing and/or grinding, and some recycled products will also be blended. The recycled materials (that is, saleable products) will be stored on the site until sold.

Greenwaste material will be shredded and stockpiled in windrows. Up to 20,000 t of greenwaste may be stockpiled on site at any one time. The water collected from a sump at the green/timber waste stockpiles will be re-circulated by pumping from the sump and allowing it to gently seep out of perforated pipes at several locations across the windrow, to aid in the greenwaste composting process, with any excess directed to a leachate treatment plant. After a resting period of eight weeks the product will be tested and available for sale or alternatively be blended, tested and available for sale.

This assessment assumes that the maximum of 2 Mtpa of material will be delivered to the site. It is estimated that 1,250,000 tpa will go either to the MPC or to the appropriate segregated stockpile and of this:

- 250,000 tpa will be sent to landfill;
- 170,000 tpa will be sent off-site (no reprocessing);
- 170,000 tpa will require crushing only;
- 250,000 tpa will require crushing and screening;
- 370,000 tpa will require screening only;
- 30,000 tpa will require shredding only; and
- 10,000 tpa will require shredding and screening;

The remaining 750,000 tpa received will go directly to the WTS for transfer to the landfill. Thus, it is assumed that a total of 1 Mtpa of material will be sent off-site, either with or without on-site processing, and 1 Mtpa of material will be sent to landfill.

The layout of the site is shown in **Figure 3**. When fully operational the facility will include the following:

- raised enclosed MPC/WTS structure;
- wheel washing station;
- inwards/ outwards weighbridge for vehicles entering the facility and one way dump truck weighbridge facility for loads entering the land filling area;
- administration building which will include employee amenities, administration offices, training rooms, first aid facilities, logistics central control and communications centre;
- workshop building and plant storage bays, for maintenance and service activities for site trucks, plant and equipment;
- bunded above ground double skin diesel fuel tanks;
- light and heavy vehicle parking areas;
- internal roads;
- hardstand processing and stockpile areas;
- paved sales areas;
- leachate drainage works including sump and leachate wells;
- non-leachate site drainage/ stormwater system, including naturalized channels, pipework, culverts, sumps, tanks and detention ponds;
- water treatment facilities;
- telemetry controlled water spray and sprinkler system, with provision for manual override, installed at stockpile areas and earthern berms;
- noise, dust, windspeed and water quality monitoring systems;
- lighting;
- security fencing and gates for the resource recovery facility (RRF) and landfill; and
- earthern amenity berms to a height of ten metres to the west, north and south of the RRF, to be constructed from overburden stockpiles on site and landscaped.

Three screens will operate to sort and separate products. One mobile and one fixed crusher will also be used on-site to process screened materials, mainly oversized material that will be recycled. Other equipment will include excavators, front-end loaders (FELs), forklifts, a bulldozer, water cart, two compactors for the landfill and haul trucks.

All roads leading to and from the facility will be paved. The route down to the base of the landfill, while unpaved, is a hard rock surface and is considered to have a low propensity for dust generation. Water suppression will be used along this road for dust mitigation, as described in **Section 4.5**, and surface sealing by spray binders will be considered if necessary.

Natural wind breaks and physical barriers will be used to aid with reducing dust emissions off-site. Sprinkler systems will also be installed for stockpile areas and vehicles. Further details of proposed mitigation measures are provided in **Section 4.5**.

Operations at the facility will generally be conducted seven days per week between the hours of 6 am and 10 pm. Landfill activities will not occur after 6 pm.

The proponent will draw on experience from operation of a similar facility at Alexandria. Some experience from the operations at Alexandria, together with an air quality assessment for nearby activities (**Heggies, 2006**), have assisted with the development of this assessment.

3. EXISTING ENVIRONMENT

This section describes the dispersion meteorology, local climatic conditions and existing dust levels in the area.

3.1 Dispersion Meteorology

The dispersion models used for this assessment, AUSPLUME and CALPUFF, require information about the dispersion characteristics of the area. In particular, data are required on wind speed, wind direction, atmospheric stability class[1] and mixing height[2]. Meteorological data from St Marys and Horsley Park have been reviewed for this study.

DECC have listed requirements for meteorological data that are used for air dispersion modelling in their *Approved Methods* (**DEC, 2005a**). The requirements are as follows:

- Data must span at least one year;
- Data must be 90% complete; and
- Data must be representative of the area in which emissions are modelled.

The DECC operate a weather station at St Marys, approximately 5 km to the west of the project site, which measures (among other parameters) wind speed, wind direction and temperature. Data for 2004 are available and have been processed into a form suitable for use in the dispersion models. There were 8,784 hours available which represents 100% of the year. While wind patterns may vary from year to year the 2004 data will contain most meteorological conditions that occur in the area.

At Horsley Park, the Bureau of Meteorology operate an automatic weather station at the equestrian centre. This site is approximately 5 km to the south of the proposed site. Measurements include temperature, wind speed, wind direction and sigma-theta (a measure of the fluctuation of the horizontal wind direction). Holmes Air Sciences had data available for 2005 from this site. There were 8,424 hours recovered which represents 96% of the year.

Figures 4 and **5** show annual and seasonal wind-roses, prepared from the St Marys and Horsley Park wind data respectively.

It can be seen that, annually at the St Marys site, the most common winds are from the south-southwest and south (refer **Figure 4**). These winds are evident in all seasons, to various degrees. In summer, winds from the east-southeast are also common. In 2004 the percentage of calm conditions (when winds are less than or equal to 0.5 m/s) was 19.3% and the average wind speed was 1.8 m/s.

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[1] In dispersion modelling, stability class is used to categorise the rate at which a plume will disperse. In the Pasquill-Gifford stability class assignment scheme, as used in this study, there are six stability classes A through to F. Class A relates to unstable conditions such as might be found on a sunny day with light winds. In such conditions plumes will spread rapidly. Class F relates to stable conditions, such as occur when the sky is clear, the winds are light and an inversion is present. Plume spreading is slow in these circumstances. The intermediate classes B, C, D and E relate to intermediate dispersion conditions.

[2] The term mixing height refers to the height of the turbulent layer of air near the earth's surface into which ground-level emissions will be rapidly mixed. A plume emitted above the mixed-layer will remain isolated from the ground until such time as the mixed-layer reaches the height of the plume. The height of the mixed-layer is controlled mainly by convection (resulting from solar heating of the ground) and by mechanically generated turbulence as the wind blows over the rough ground.

At the Horsley Park site, winds in 2005 (**Figure 5**) were predominantly from the southwest, although winds from the north were also common. Some similarities between this site and the St Marys site are evident but the percentage of calm conditions was only 6% at Horsley Park, which was lower than at St Marys (19%). Average wind speed at Horsley Park in 2005 was 3.2 m/s.

To use the wind data to assess dispersion, it is necessary to also have available data on atmospheric stability. For the St Marys site, atmospheric stability was derived from information on cloud cover (Mascot) and wind speed. A stability class was determined for each pair of wind speed and wind direction observations by the method of Turner (**Turner, 1970**). Stability class for Horsley Park was calculated for each hour of the meteorological data using sigma-theta (a measure of the fluctuation of the horizontal wind direction) according to the method recommended by the US EPA (**US EPA, 1986**). **Table 1** shows the frequency of occurrence of the stability categories expected in the area.

The most common stability class at St Marys was determined to be F class. This is consistent with the low wind speeds measured at this site and would suggest that the dispersion conditions are such that pollutant emissions disperse slowly for a significant proportion of the time. In contrast, D class was determined to occur most often at the Horsley Park site, due to the higher average wind speeds. Under D class conditions pollutant emissions will disperse rapidly.

Table 1 : Frequency of occurrence of stability classes in the study area

Stability Class	St Marys, 2004 data	Horsley Park, 2005 data
A	2.9	12.7
B	20.8	5.5
C	14.8	10.3
D	15.0	43.0
E	6.4	16.6
F	40.1	11.9
Total	100	100

From the review of data from two nearby meteorological stations, there were some similarities in the wind directions although wind speeds exhibited some differences. The St Marys data were selected for the dispersion modelling as the data were 100% complete and, due to the relatively high proportion of poor dispersion conditions, were likely to produce more conservative results. Joint wind speed, wind direction and stability class frequency tables for the St Marys data are provided in **Appendix A**.

3.2 Local Climatic Conditions

The Bureau of Meteorology also collects climatic information from Prospect Dam, to the east of the study area. Meteorological data collected from this station over a period of 114 years are summarised in **Table 2** (**Bureau of Meteorology, 2003**). Temperature and humidity data consist of monthly averages of 9 am and 3 pm readings. Also presented are monthly averages of maximum and minimum temperatures. Rainfall data consist of mean and median monthly rainfall and the average number of raindays per month.

Temperature data show that January is typically the warmest month with a mean daily maximum of 28°C. July is the coldest month with a mean daily minimum temperature of 6.1°C. Rainfall data collected at Prospect Dam show that March is the wettest month with a mean rainfall of 98 mm over 11 rain days. Annually the area experiences, on average, 879 mm of rain per year.

Table 2 : Climate information for the study area

Element	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean daily maximum temperature - deg C	28.0	27.7	26.1	23.5	20.1	17.2	16.7	18.4	20.9	23.4	25.0	27.2	22.8
Highest daily Max Temp - deg C	44.7	42.5	39.5	37.1	29.4	25.6	26.5	29.4	35.0	39.0	41.2	42.7	44.7
Mean daily minimum temperature - deg C	17.5	17.7	16.1	13.0	10.2	7.5	6.1	6.8	9.3	12.1	14.1	16.4	12.3
Lowest daily Min Temp - deg C	10.0	10.8	7.9	4.5	1.2	0.1	0.0	0.0	2.6	4.5	6.9	7.8	0.0
Mean 9am air temp - deg C	21.0	20.8	19.6	16.7	13.4	10.4	9.3	10.8	14.1	17.0	18.1	20.4	16.0
Mean 9am wet bulb temp - deg C	18.3	18.5	17.3	14.5	11.8	8.8	7.5	8.5	11.0	13.5	15.1	17.0	13.5
Mean 9am dew point - deg C	16.4	16.9	15.4	12.5	10.1	6.7	5.1	5.7	7.6	10.2	12.4	14.5	11.1
Mean 9am relative humidity - %	76.0	80.0	78.0	77.0	81.0	79.0	77.0	72.0	67.0	67.0	71.0	71.0	75.0
Mean 3pm air temp - deg C	26.6	26.3	24.8	22.4	19.2	16.4	15.9	17.4	19.6	21.8	23.4	25.7	21.7
Mean 3pm wet bulb temp - deg C	20.0	20.0	18.8	16.5	14.4	11.9	10.9	11.6	13.1	15.2	16.9	18.6	15.7
Mean 3pm dew point - deg C	15.6	15.8	14.5	11.5	9.9	7.1	5.1	4.9	6.3	9.1	11.6	13.5	10.4
Mean 3pm relative humidity - %	53.0	55.0	55.0	53.0	57.0	56.0	51.0	46.0	45.0	48.0	50.0	50.0	51.0
Mean monthly rainfall – mm	95.9	92.2	98.2	75.9	73.6	75.6	59.3	52.2	48.1	59.2	72.4	76.1	878.5
Median (5th decile) monthly rainfall - mm	72.6	58.9	78.3	55.1	39.7	39.0	34.8	31.1	41.2	43.3	61.6	56.0	851.8
Mean no. of rain days	10.6	10.5	10.8	9.4	9.2	9.4	7.6	8.0	8.6	9.2	9.3	9.8	112.3
Highest monthly rainfall - mm	426.7	519.1	380.7	363.5	556.0	531.3	323.7	458.5	186.3	269.0	391.3	338.1	
Lowest monthly rainfall - mm	3.9	2.8	5.1	2.0	1.8	1.0	0.0	0.0	0.0	0.0	0.8	2.2	
Highest recorded daily rainfall - mm	161.2	164.6	153.9	163.1	314.2	163.4	143.5	321.0	96.5	102.1	126.2	154.9	321.0
Mean no. of clear days	6.6	5.2	6.8	8.9	9.2	10.1	11.5	13.5	11.7	8.5	6.9	7.2	106.2
Mean no. of cloudy days	12.5	11.8	12.0	8.2	9.8	8.5	6.7	6.5	7.3	9.5	11.2	10.8	114.7
Mean daily evaporation - mm	5.5	5.0	4.1	3.1	2.1	1.7	1.9	2.6	3.7	4.5	5.1	6.0	3.8

Climate averages for Station: 067019 PROSPECT DAM. Commenced: 1887; Last record: 2001; Latitude (deg S): -33.8193; Longitude (deg E): 150.9127; State: NSW

Source : Bureau of Meteorology (2003)

3.3 Existing Air Quality

Existing air quality (in terms of dust levels) has been determined from air quality monitoring undertaken in the area. The DECC measures particulate matter (PM_{10}) concentrations at St Marys (5 km to the west of the project site) using a Tapered Element Oscillating Microbalance (TEOM). This is the closest known air quality monitoring station to the project site. In addition, monitoring of dust deposition has been carried out at two locations near to the northern boundary of the site, by Hanson Construction Materials. The monitoring data are discussed below.

Quarterly air quality monitoring reports are prepared by the DECC and the reports for 2004, 2005 and 2006 (**DEC, 2005b, 2006 and 2007**) have been reviewed to obtain information on PM_{10} concentrations in the area. **Table 3** below summarises the TEOM measurements at St Marys. The monitoring data represent the contribution of many sources of particulate matter around the St Marys site, including local sources (for example, traffic and construction activities) as well as widespread events such as bushfires and dust storms. The St Marys site is in a similar environment to the project site and the data are therefore considered to be relevant for the purposes of this assessment.

Table 3 : Summary of DECC PM_{10} monitoring data for St Marys

Year	Average for year ($\mu g/m^3$)	Maximum 24-hour average in year ($\mu g/m^3$)
2004	17	49
2005	19	55
2006	20	71

The TEOM measurements of PM_{10} presented in **Table 3** show that maximum 24-hour averages can exceed DECC's 24-hour average 50 $\mu g/m^3$ criterion on occasions (refer **Table 5**). The highest measurements were generally recorded in the summer months, when bushfires are commonly a contributing factor. The annual average PM_{10} concentrations have been below the DECC's annual average 30 $\mu g/m^3$ criterion (refer **Table 5**).

Annual average TSP concentrations can be estimated from measured PM_{10} concentrations by assuming that 40% of the TSP was PM_{10}. This relationship was obtained from data collected by co-located TSP and PM_{10} monitors operated for reasonably long periods of time in the Hunter Valley (**NSW Minerals Council, 2000**). Application of this relationship to the existing PM_{10} data (20 $\mu g/m^3$ for annual average PM_{10} in 2006, the year with the highest measurements) indicates that annual average TSP concentrations in the area are of the order of 50 $\mu g/m^3$, which is less than the DECC assessment criterion of 90 $\mu g/m^3$.

As part of a concept plan prepared for Hanson Construction Materials Pty Limited, for a proposed development adjacent to the southeastern boundary of the project site, Heggies Australia prepared an air quality impact assessment (**Heggies, 2006**) which presented dust deposition monitoring results for the area. Dust deposition was measured for Hanson Construction Material at two locations ("Wonderland" and "Freeway") to monitor activities at the quarry (refer to **Figure 1** for approximate locations of dust monitors). The monitoring results for the period between January 2004 and July 2006 are shown below in **Table 4**.

Table 4 : Measured dust deposition levels in the area

Site	Monitoring period	Average insoluble solids ($g/m^2/month$)
"Wonderland"	January 2004 to July 2006	2.4
"Freeway"	January 2004 to July 2006	0.9
Average	-	**1.6**

Source: Heggies, 2006

Measured dust deposition levels were below the DECC's total deposited dust criterion of 4 $g/m^2/month$ (refer **Table 6**). The average for both sites was 1.6 $g/m^2/month$ and this level has been taken to be representative of the existing deposition levels at the project site. It is noted that the Hanson data were collected when quarrying was occurring on the project site and the quarry activities would have contributed to the measured levels shown in **Table 4**.

In summary, the following background levels have been taken to apply both at the project site and at the nearest sensitive residential receptors:

- Annual average PM_{10} concentrations of 20 $\mu g/m^3$;
- Annual average TSP concentration of 50 $\mu g/m^3$; and
- Annual average dust deposition of 1.6 g/m^2/month.

Existing 24-hour hour average PM_{10} concentrations vary from day to day. Monitoring of PM_{10} concentrations at St Marys showed that 24-hour average concentrations can exceed the 50 $\mu g/m^3$ criterion on occasions (refer **Table 3**). In fact, in many parts of NSW the criterion is exceeded a few times each year, predominantly due to natural events such as bushfires and dust storms. Taking 2004 as an example, the highest 24-hour average PM_{10} concentration recorded at the St Marys site was 49 $\mu g/m^3$, which only permits a 1 $\mu g/m^3$ contribution from a project before the criterion is exceeded. This complicates the assessment process as projects with quite small PM_{10} contributions may still demonstrate exceedances when the background levels are high. In other years, 2005 and 2006 in particular, the highest 24-hour average PM_{10} concentrations exceeded the 50 $\mu g/m^3$ criterion and by taking the approach of adding maximum background levels to project levels would prohibit any project contribution.

For this study, 24-hour average PM_{10} concentrations have been assessed by examining model predictions at the nearest sensitive receptors. An objective was to determine the probability of the project causing exceedences of 50 $\mu g/m^3$ at these locations. This is discussed further in **Section 4.4**.

4. DUST ASSESSMENT

This section provides an assessment of the air quality impacts of the project. In particular, dust impacts are predicted and assessed. The assessment uses a computer-based dispersion model to predict ground-level dust concentrations and deposition levels in the vicinity of the facility. Model predictions have been compared to relevant air quality criteria after taking account of the existing air quality, where relevant.

In summary, **Section 4** provides information on the following:

- Air quality criteria;
- Methods used to estimate dust emissions from the facility;
- Methods for predicting dust impacts; and
- Expected dispersion and dust deposition patterns due to emissions from the facility and a comparison of the predicted dust concentration and deposition levels with DECC assessment criteria.

4.1 Dust Assessment Criteria

When assessing any project with a potential for significant air emissions, it is necessary to compare the impacts of the project with relevant air quality criteria. Air quality criteria are used to assess the potential for ambient air quality to give rise to adverse health or nuisance effects.

Table 5 and **Table 6** summarise the current air quality assessment criteria noted by the DECC (**DEC, 2005a**). Generally, the air quality criteria relate to the total burden of dust in the air and not just the dust from the project being assessed. In other words, some consideration of background levels needs to be made when using these criteria to assess impacts. The estimation of appropriate background levels for this assessment is discussed in **Section 3.3**.

Table 5 : DECC assessment criteria for particulate matter concentrations

Pollutant	Criterion	Averaging Period	Agency
Total suspended particulate matter (TSP)	90 $\mu g/m^3$	Annual mean	National Health & Medical Research Council
Particulate matter < 10 μm (PM_{10})	50 $\mu g/m^3$	24-hour maximum	DECC
	30 $\mu g/m^3$	Annual mean	DECC long-term reporting goal

In addition to health impacts, airborne dust also has the potential to cause nuisance impacts by depositing on surfaces. **Table 6** shows the maximum acceptable increase in dust deposition from the existing deposition levels, as well as the maximum acceptable total deposited dust, that is, background plus project. The criteria for dust deposition levels are set to protect against nuisance impacts (**DEC, 2005a**).

Table 6 : DECC criteria for dust deposition

Pollutant	Averaging period	Maximum increase in deposited dust level	Maximum total deposited dust level
Deposited dust	Annual	2 g/m^2/month	4 g/m^2/month

4.2 Estimated Dust Emissions

Dust emissions will arise from various activities at the site. Total dust emissions from the project have been estimated by analysing the activities proposed to take place at the site during operations.

The proposed activities have been combined with emission factors developed, both locally and by the US EPA, to estimate the amount of dust produced from the operations. The emission factors applied are considered to be the most up to date methods for determining dust generation rates. The fraction of fine, inhalable and coarse particles for each activity has been taken into account for the dispersion modelling.

The operational description provided by the proponent has been used to determine haul road distances and routes, stockpile and pit areas, activity operating hours, truck sizes and other details that are necessary to estimate dust emissions for a typical year of operation.

The most significant dust generating activities from the proposed operations have been identified and the respective dust emission estimates are presented in **Table 7**. It should be noted that a proportion of the materials received, and stockpiled, will have a low propensity for dust generation. These materials include glass, plastic, paper, metals and cardboard. For the purposes of the emission calculations, all materials processed at the site have been considered to have a potential for dust generation. This is a conservative approach.

Details of the calculations of the dust emissions are presented in **Appendix B**. The estimated emissions take account of proposed air pollution controls including active controls such as watering of stockpiles, load-out points and haul routes to minimise dust emissions. Details on the proposed dust mitigation measures are provided in **Section 4.5**.

Table 7 : Estimated dust emissions due to the proposed operations

ACTIVITY	TSP emission rate (kg/y)		
	Year 0	Year 13	Year 20
Vehicles coming to site (paved)	20,776	20,776	20,776
Dumping material at MPC or segregated stockpile	3,757	3,757	3,757
Dumping material at WTS	2,254	2,254	2,254
Loading material by FEL for processing	3,757	3,757	3,757
Loading and sorting material by excavator	12,523	12,523	12,523
Screening material	3,938	3,938	3,938
Crushing material	270	270	270
Loading material to stockpiles	6,262	6,262	6,262
Loading material to trucks	10,019	10,019	10,019
Hauling material to landfill (unpaved, inc return)	92,312	27,694	23,078
Vehicles leaving site (paved)	20,776	20,776	20,776
Dumping material to landfill	10,019	10,019	10,019
Wind erosion from exposed landfill area	7,247	7,247	7,247
Wind erosion from soil stockpiles	412	412	412
Wind erosion from other stockpiles	329	329	329
Total dust (kg)	**194,651**	**130,032**	**125,417**

It can be seen from **Table 7** that the operations are estimated to emit 194,651 kg of dust in the early stages of operation, of which dust from road haulage to landfill is the most significant dust generating activity. In practice, the dust emissions will be controlled through regular cleaning of paved roads, watering of unsealed surfaces and application of binding agents to reduce this source of dust to the minimum practicable (see **Section 4.5** for discussion on dust mitigation measures). The assessment of impacts is therefore conservative.

Lower dust emissions are expected in the mid-term and final stages of landfilling due to the shorter haul distance into the quarry pit. The initial stage (Year 0) represents the worst-case scenario.

4.3 Approach to Dust Assessment

The approach taken for the dust assessment was as follows:

- Estimate annual dust emissions of each activity associated with the operations (refer **Section 4.2**);
- Provide emissions and meteorological information to a computer-based dispersion model to predict dust concentrations in the region and at nearest sensitive receptors; and
- Compare predicted concentrations with relevant air quality criteria.

This section is provided so that technical reviewers can appreciate how the modelling of different particle size categories was carried out.

Off-site dust levels from the project have been predicted using AUSPLUME (Version 6.0). AUSPLUME is an advanced Gaussian dispersion model developed on behalf of the Victorian EPA (**VEPA, 1986**) and is based on the United States Environmental Protection Agency's Industrial Source Complex (ISC) model. It is widely used throughout Australia and is regarded as a "state-of-the-art" model. AUSPLUME is the model required for use by the DECC unless project characteristics dictate otherwise (**DEC, 2005a**).

The modelling has been based on the use of three particle-size categories (0 to 2.5 μm - referred to as $PM_{2.5}$, 2.5 to 10 μm and 10 to 30 μm). Mass emission rates in each of these size ranges have been determined using the factors derived from the **SPCC (1986)** study and TSP emission rates calculated using emission factors derived primarily from **US EPA (1985)** work (see **Appendix B**).

The distribution of particles in each particle size range, as determined from the **SPCC (1986)** study, is as follows:

- $PM_{2.5}$ is 4.7% of the TSP;
- $PM_{2.5\text{-}10}$ is 34.4% of TSP; and
- $PM_{10\text{-}30}$ is 60.9% of TSP.

Modelling was done using three AUSPLUME source groups with each group corresponding to a particle size category. Each source in the group was assumed to emit at the full TSP emission rate and to deposit from the plume in accordance with the deposition rate appropriate for particles with an aerodynamic diameter equal to the geometric mean of the limits of the particle size range, except for the $PM_{2.5}$ group, which was assumed to have a particle size of 1 μm. The predicted concentrations in the three plot output files for each group were then combined according to the weightings above (see bullet points preceding this paragraph) to determine the concentration of PM_{10} and TSP.

The AUSPLUME model also has the capacity to take into account dust emissions that vary in time, or with meteorological conditions. This has proved particularly useful for simulating emissions for operations where wind speed is an important factor in determining the rate at which dust is generated.

For the current study, the operations were represented by a series of volume sources located according to the positions of the dust sources as they would be for the scenario being modelled. **Figure 6** shows the location of the modelled dust sources. Three scenarios were modelled, representative of Years 0, 13 and 20 of operations respectively; that is, the initial, mid-term and final stages of landfilling. This was to represent the potential range of impacts as landfilling operations progressed closer to the surface.

Estimates of emissions for each source were developed on an hourly time step taking into account the activities that would take place at that location. Thus, for each source, for each hour, an emission rate was determined which depended upon the level of activity and the wind speed. It is important to do this in the AUSPLUME model to ensure that long-term average emission rates are not combined with worst-case dispersion conditions which are associated with light winds. Light winds at a project site such as this would correspond with periods of low dust generation (because wind erosion and other wind dependent emissions rates will be low) and also correspond with periods of poor dispersion. If these measures are not taken then the model has the potential to significantly overstate impacts.

Dust concentrations and deposition rates from the project have been predicted over the area shown in **Figure 1**. Terrain has been considered in the modelling.

Pit retention was considered an important factor to include in the dispersion modelling given the large height difference between the local ground level and the floor of the quarry pit. For the purposes of the dispersion modelling the calculation determines the fraction of dust emitted in the pit which will escape the pit. The relationship used is dependent on the gravitational settling velocity of the particles and wind speed and is given by **Equation 1** below (**US EPA, 1995**).

$$\varepsilon = \frac{1}{\left(1 + \frac{v_g}{(\alpha U_r)}\right)} \qquad \textbf{Equation 1}$$

where:
ε = escape fraction for the particle size category
V_g = gravitational settling velocity (m/s)
U_r = approach wind speed at 10 m (m/s)
α = proportionality constant in the relationship between flux from the pit and the product of U_r and concentration in the pit (0.029)

To model the effect of pit retention, the emissions from sources within the quarry pit have therefore been reduced to account for the fact that much of the coarser dust would remain trapped in the pit.

As an example of modelling emissions with pit retention, particles in the $PM_{2.5}$ (FP) category are taken to have a gravitational settling velocity of 0.0000914 m/s. For a 1 m/s approach wind speed, the fraction of particles that escape the pit is estimated by Equation 1 to be 0.997 – that is, almost all of the particles in this size range escape the pit. Under the same wind conditions the escaped fraction for the PM_{10-30} (RE) particles, with an assumed gravitational settling velocity of 0.106328 m/s, would be 0.21 – that is, only 21% of these particles escape the pit.

The modelling has been performed using the meteorological data discussed in **Section 3.1** and the dust emission estimates from **Section 4.2**. It has been assumed that each activity will occur for the hours given in the project description (refer **Section 2**), except for wind erosion sources which have been modelled for 24-hours per day. Model predictions have been made at 125 discrete receptors (including nearest residences) located in the study area shown in **Figure 1**. The location of these receptors has been chosen to provide finer resolution closer to the dust sources and nearby receptors. The AUSPLUME model input files can be provided in electronic form on request.

Dust impacts and model predictions using the AUSPLUME model are presented as contour plots in **Figure 7** and are discussed in **Section 4.4**.

4.4 Assessment of Dust Impacts

Dust concentrations from proposed operations have been presented as isopleth diagrams in **Figure 7** showing the following:

1. Predicted maximum 24-hour average PM_{10} concentration;
2. Predicted annual average PM_{10} concentration;
3. Predicted annual average TSP concentration; and
4. Predicted maximum 1-day average dust deposition.

The contour plots in **Figure 7** are associated with Year 0 (initial stages) of landfilling operations, which is representative of the worst case impact since the haulage distance to landfill over unsealed surfaces would be at a maximum. This haul distance reduces over time.

In examining the maximum 24-hour average contour plot it should be noted that this does not represent the dispersion pattern for any particular day, but shows the highest predicted 24-hour average concentrations that occurred at each location for the worst day in the year. The maxima are used to show concentrations which can possibly be reached under the modelled conditions. It should also be noted that the contour plots show predicted concentrations due only to modelled dust sources for the facility.

Table 8 summarises the dispersion model predictions for two nearby receptor locations. The receptor locations are shown in **Figure 6**. Results show the project only contribution as well as the cumulative impacts of emissions from this project and existing sources in the area.

Table 8 : Dust model predictions at nearby sensitive receptors

Receptor ID	Due to project only			Existing levels (2006, refer Section 3.3)	Total (maximum year from project + existing)	Criteria
	Year 0	Year 13	Year 20			
Maximum 24-hour average PM_{10} ($\mu g/m^3$)						
R1	**39**	28	27	71	**110**	50
R2	**18**	9	9	71	**89**	50
Annual average PM_{10} ($\mu g/m^3$)						
R1	**5.6**	4.5	4.4	20	25.6	30
R2	**1.3**	0.9	0.9	20	21.3	30
Annual average TSP ($\mu g/m^3$)						
R1	**7.0**	5.6	5.5	50	57	90
R2	**1.4**	1.0	1.0	50	51.4	90
Annual average dust deposition ($g/m^2/month$)						
R1	**0.3**	0.3	0.3	1.6	1.9	4
R2	**0.1**	0.1	0.1	1.6	1.7	4

Table 8 shows that the model results for annual average PM_{10}, TSP and dust deposition at these receptors, including the cumulative results, are within relevant DECC criteria. However, the approach of adding maximum measured to maximum predicted 24-hour average PM_{10} concentrations will rarely show compliance with the 50 $\mu g/m^3$ criterion. This is because the maximum measured value of 71 $\mu g/m^3$ does not permit any project contribution before 50 $\mu g/m^3$ is exceeded (note that the maximum PM_{10} for the same year as the meteorological data file, 2004, was 49 which only permits 1 or 2 $\mu g/m^3$ from the project before an exceedance is predicted). The high estimated dust emissions in Year 0 produce higher model predictions than for subsequent years.

The potential 24-hour average PM_{10} impacts have been investigated further by examining the predicted frequency of PM_{10} concentrations, due to the project in Year 0, occurring at the two nearby receptors. **Figure 8** shows a time series of model predictions at the nearest receptors while **Figure 9** presents the same data in histogram form. If it were assumed that the existing annual average PM_{10} concentration (say, 20 $\mu g/m^3$) occurred every day of the year then the assessment would be very much simplified as a maximum project contribution of around 30 $\mu g/m^3$ or more would be the point at which air quality impacts would be observed - assuming 50 $\mu g/m^3$ is the level at which impacts occur. However, existing PM_{10}

concentrations will vary from day to day so **Table 9** has been constructed to show the approximate number of days when the cumulative PM_{10} concentration will exceed 50 $\mu g/m^3$ for various background levels.

Table 9 : Predicted number of days when PM_{10} concentration exceeds 50 $\mu g/m^3$

Assumed background PM_{10} level ($\mu g/m^3$)	Permitted contribution from project before exceedance is predicted ($\mu g/m^3$)	Approximate number of exceedances of 50 $\mu g/m^3$ per year	
		R1	R2
20	30	4	0
30	20	9	0
40	10	68	2

From the information in **Table 9** it can be seen that, as the existing background levels increase, the potential for cumulative impacts (above 50 $\mu g/m^3$) also increases. When the background concentration is at the average level of 20 $\mu g/m^3$, then there would be 4 days in the year when the project would cause an exceedance of 50 $\mu g/m^3$ at the nearest receptor. The probability of the project causing an exceedance of 50 $\mu g/m^3$ increases, with increasing background levels.

While annual average dust concentrations and deposition levels are predicted to comply with ambient air quality criteria, this assessment has highlighted a potential for the project to cause exceedances of the 24-hour average PM_{10} criterion, even in background concentrations are at average levels. The project will therefore need to be subject to air quality management procedures to ensure that the possibility of adverse short-term air quality impacts is minimised. Dust mitigation measures are discussed in **Section 4.5** below.

Potential cumulative air quality impacts of the project with the adjacent Hanson activities have been considered by examining dispersion model results presented in the air quality impact assessment for the Hanson site (**Heggies, 2006**). This study showed that the predicted maximum 24-hour average PM_{10} concentration from the Hanson facility was 2.1 $\mu g/m^3$ at the nearest assessed residential receptor (R1). This is a small increment which would not affect the conclusions of this study and so no further assessment has been undertaken.

It is understood that a future subdivision is proposed for areas to the west of the project site however plans have not been approved. Based on the results of the dispersion modelling some areas of the development land may experience dust impacts of similar magnitude to those predicted for receptor 1 discussed above if not properly managed. Air quality monitoring would assist in the determination of dust levels due to project operations.

4.5 Dust Mitigation Measures

This section describes the management actions that will be put in place to minimise dust emissions from site activities. The proposed dust mitigation measures will include the following:

- Spray mists and sprinkler systems for crushing, grinding and chipping operations:
- Spray mists on all material stockpiles;
- Construction of perimeter berms around the main area of operations to provide a barrier for dust emissions;

- Spray mists and sprinkler systems on the perimeter berms;
- Wetting of vehicles with potentially dusty loads, prior to unloading;
- Cleaning spills of potentially dust materials immediately;
- Wheel wash for all vehicles travelling off-site;
- Water carts operated as required; and
- Use of onboard reservoirs on site dump trucks to allow wetting whilst in motion.
- Sealing of operational surfaces at the RRF

The calculations of dust emissions have considered each of the mitigation measures above and, where appropriate, dust emissions have been reduced according to NPI control factor estimates (see Table 3 of **NPI, 2001**). The assumed reductions in emissions are provided in **Appendix B**.

In practice, the dust emissions are likely to be controlled beyond the level assumed in the modelling, however given that the air dispersion modelling has highlighted the potential for short-term air quality impacts to occur, the operations will need to adopt best practice mitigation measures.

4.5.1 Air Quality Management Plan

An Air Quality Management Plan (AQMP) is proposed to ensure that dust emissions are minimised to the most practical. An AQMP will be developed and included in the LEMP and EWMP to be developed for the Project, with a focus on activities which generate the most significant emissions – in this instance those associated with haulage movements and transfer and loading activities.

Further detail on a number of management measures proposed for the facility are outlined below.

Watering Of Haul Roads
Dust emissions will be controlled through regular cleaning of paved roads, watering of unsealed surfaces and application of binding agents to reduce this source of dust to the minimum practicable.

Lower dust emissions are expected in the mid-term and final stages of landfilling due to the shorter haul distance into the quarry pit. The initial stage (Year 0) represents the worst-case scenario.

A 'low level' of watering, between 1-2litres/minute, will be applied to unsealed roads. Onboard reservoirs will be used on site dump trucks to allow wetting whilst in motion. In addition wetting of potentially dusty loads will be undertaken prior to unloading and all vehicles travelling off-site will be required to pass through a wheel wash.

Dust Suppression
Water sprays will be used to minimise particulate emissions to the atmosphere from crushing, grinding and chipping operations. Dust suppression will be employed through spray mists on all material stockpiles.

Perimeter Berms
Perimeter berms approximately 10 metres in height will be constructed, in order to provide a barrier for dust emissions. These berms will be vegetated, which when mature will serve as

further mitigation of off-site emissions from dust. Spray mists and sprinkler systems will be installed on the perimeter berms.

4.5.2 Monitoring

In addition to the measures listed above, a real-time dust monitoring and reactive control system will help to identify activities that may lead to off-site air quality impacts. The dust monitoring can be used to assess compliance with the DECC's ambient air quality criteria and access to the data in real-time will enable site operators to modify activities, as required, to minimise dust emissions and off-site impacts.

A minimum of one real time monitor (eg DustTrak, TEOM, E-Bam, E-Sampler) should be used to identify real-time impacts and delineate short term concentrations. The application of real-time air monitoring equipment will provide important information on short-term air quality not obtainable from high volume air sampling or deposition jars.

The data from such a system would enable identification of potential "trouble spots" during routine operations and provide the evidence to enable appropriate repairs or engineering solutions to be developed. The data from such a system would also enable records of operational dust levels to be maintained and provide opportunity to implement mitigation measures (*eg* increased watering of haul roads) based upon monitoring peaks.

The monitoring location should be determined through an assessment of potential suitable locations on site. The dispersion modelling, and meteorological data used indicates key impacts and receptors to the north or north-west of the facility and this would be the preference for a monitoring location.

4.6 Construction Impacts

Dust emissions from construction works have the potential to cause nuisance impacts if not properly managed. In practice, it is not possible to realistically quantify impacts using dispersion modelling. To do so would require knowledge of weather conditions for the few weeks that work will be taking place in each location on the site.

Air quality impacts during construction would largely result from dust generated during earthworks and other engineering activities associated with the plant construction. These activities will generally be conducted behind earthen berms. The total amount of dust generated would depend on the silt and moisture content of the soil, the types of operations being carried out, exposed area, frequency of water spraying and speed of machinery. The detailed approach to construction will depend on decisions that will be made by the successful contractor and changes to the construction methods and sequences are expected to take place during the construction phase.

As construction is likely to continue for approximately six months, it is important that exposed areas be stabilised as quickly as possible and that appropriate dust suppression methods be used to keep dust impacts to a minimum. It is desirable that monitoring be carried out during the construction phase of the project to assess compliance with DECC criteria. Monitoring may include dust deposition gauges, at the closest residences or other sensitive receptors, to assess compliance.

Proper dust management will require the use of water carts, the defining of trafficked areas, the imposition of site vehicle speed limits and constraints on work under extreme unfavourable weather conditions, such as dry wind conditions.

5. ODOUR ASSESSMENT

This section provides an assessment of the odour impacts of the project. The assessment uses a computer-based dispersion model to predict odour levels from the project, in the local area.

In summary, **Section 5** provides information on the following:

- Odour assessment criteria;
- Estimated odour emissions from the facility;
- Methods for predicting impacts from the estimated odour emissions; and
- Expected patterns of off-site odour levels due to emissions from the site operations and a comparison between the model predictions and DECC assessment criteria.

5.1 Odour Assessment Criteria

This section evaluates odour in terms of measurement and air quality criteria that relate to odour. There is still considerable debate in the scientific community about appropriate odour criteria as determined by dispersion modelling.

5.1.1 Measurement of Odour

Odour is measured using panels of people who are presented with samples of odorous gas diluted with decreasing quantities of clean odour-free air. The panellists then note when the smell becomes detectable. Odour in the air is then quantified in terms of odour units which is the number of dilutions required to bring the odour to a level at which 50% of the panellists can just detect the odour. This process is known as olfactometry.

Olfactometry can involve a "forced-choice" end point or a "free choice" endpoint. The "forced-choice" method is where panellists identify from multiple sniffing ports, the one port where odour is detected, regardless of whether they are sure they can detect odour. The "free choice" endpoint is a "yes/no" decision where panellists are required to say whether or not they can detect odour from one sniffing port. Forced-choice olfactometry generally detects lower odour levels than free choice olfactometry.

In both the "forced-choice" and "free choice" cases, odorous air is presented to the panellists in increasing concentrations. For the forced-choice method, where there are multiple ports for each panellist, the concentration is increased until all panellists consistently distinguish the port with the sample from the blanks. For a yes/no olfactometer (which has only one sniffing port) one method used is to increase the concentration of odour in the sample until all panellists respond. The sample is then shut off and once all panellists cease to respond, the sample is introduced again at random dilutions and the panellists are asked whether they can detect the odour.

An Australian Standard (AS/NZS 4323.3.2001) for olfactometry has been developed which is consistent with the European Standard, CEN. This enables results between laboratories to be more uniform.

An odour unit is a difficult unit to define precisely. Historically it has been the level at which 50% of the population can just detect that there is an odour present. The standard (AS/NZS 4323.3.2001) defines 1 odour unit (ou) as that concentration of odorant(s) at standard conditions that elicits a physiological response from a panel (detection threshold) equivalent to that elicited by one Reference Odour Mass (ROM) evaporated into 1 cubic metre of neutral gas at standard conditions.

Some of the terms in this definition require further explanation as follows:

- Standard conditions for olfactometry are a temperature of 0°C (273K) and normal atmospheric pressure (101.3 kPa) on a wet basis.
- Neutral gas is air or nitrogen that is treated in such a way that it is as odourless as possible.
- One ROM evaporated into one cubic metre of neutral gas at standard conditions is the mass of a substance that will elicit the D_{50} physiological response assessed by a panel in conformity with the standard and has by definition a concentration of 1 ou.
- The D_{50} physiological response is the dose at which 50% of a population can detect a sensory stimulus.
- The detection threshold is the highest dilution factor at which the sample has a probability of 0.5 of eliciting with certainty the correct perception that an odour is present. This dilution factor will be too high for the sample to be recognised.
- It is common to use n-butanol as a reference gas and for this compound one ROM is 132 μg which, when evaporated into 1 cubic metre of neutral gas at standard conditions, produces a concentration of 40 ppb. Panellists are usually screened for sensitivity to n-butanol and the panel threshold reported as part of the odour measurement procedure. There is a requirement that a panellist's sensitivity to the reference material falls between 0.5 and two times the accepted reference value which for butanol is 20–80 ppb.

The purpose of these very precise definitions is to improve the repeatability and accuracy of odour measurements.

As with all sensory methods of identification there is variability between individuals. Consequently the results of odour measurements depend on the way in which the panel is selected and the way in which the panel responses are interpreted. The process by which these imprecise measurements are translated into regulatory criteria is still being refined. However, the DECC has recently published a Technical Framework for the assessment of odour from stationary sources, which includes recommendations for odour criteria (**DECC, 2006**). These are explained below and have been used for this assessment.

5.1.2 Odour Criteria

The determination of air quality criteria for odour and their use in the assessment of odour impact is recognised as a difficult topic in air pollution science. The topic has received considerable attention in recent years and the procedures for assessing odour impacts using dispersion models have been refined considerably.

The DECC has in recent times attempted to refine odour criteria and the way in which they should be applied with dispersion models to assess the likelihood of nuisance impact arising from the emission of odour.

There are two factors that need to be considered:

1. what "level of exposure" to odour is considered acceptable to meet current community standards in NSW; and
2. how can dispersion models be used to determine if a source of odour meets the criteria which are based on this acceptable level of exposure.

The term "level of exposure" has been used to reflect the fact that odour impacts are determined by several factors. The most important factors (the so-called **FIDOL** factors) are:

- the **F**requency of the exposure;
- the **I**ntensity of the odour;
- the **D**uration of the odour episodes;
- the **O**ffensiveness of the odour, and
- the **L**ocation of the source.

In determining the offensiveness of an odour it needs to be recognised that for most odours the context in which an odour is perceived is also relevant. Some odours, for example the smell of sewage, hydrogen sulfide, butyric acid, landfill gas etc., are likely to be judged offensive regardless of the context in which they occur. Other odours such as the smell of jet fuel may be acceptable at an airport, but not in a house, and diesel exhaust may be acceptable near a busy road, but not in a restaurant.

In summary, whether or not an individual considers an odour to be a nuisance will depend on the FIDOL factors outlined above and although it is possible to derive formulae for assessing odour annoyance in a community, the response of any individual to an odour is still unpredictable. Odour criteria need to take account of these factors.

The DECC Technical Framework includes some recommendations for odour criteria. The criteria have been refined by DECC to take account of population density in a particular area. **Table 10** lists the odour certainty thresholds, to be exceeded not more than 1% of the time, for different population densities.

Table 10 : DECC odour assessment criteria

Population of affected community	Odour performance criteria (nose response odour certainty units at the 99th percentile)
Rural single residence (≤2)	7
~10	6
~30	5
~125	4
~500	3
Urban (>2000) and/or schools and hospitals	2

The difference between odour criteria is based on considerations of risk of odour impact rather than differences in odour acceptability between urban and rural areas. For a given odour level there will be a wide range of responses in the population exposed to the odour. In a densely populated area there will therefore be a greater risk that some individuals within the community will find the odour unacceptable than in a sparsely populated area.

The criteria assume that 7 odour units at the 99th percentile would be acceptable to the average person, but as the number of exposed people increases there is a chance that sensitive individuals would be exposed. The criterion of 2 odour units at the 99th percentile is considered to be acceptable for the whole population.

It is common practice to use dispersion models to determine compliance with odour criteria. This introduces a complication because Gaussian dispersion models are only able to directly predict concentrations over an averaging period of 3-minutes or greater. The human nose, however, responds to odours over periods of the order of a second or so. During a 3-minute period, odour levels can fluctuate significantly above and below the mean depending on the nature of the source.

To determine more rigorously the ratio between the one-second peak concentrations and three-minute and longer period average concentrations (referred to as the peak-to-mean ratio) that might be predicted by a Gaussian dispersion model, the DECC commissioned a study by Katestone Scientific Pty Ltd (see **Katestone 1995** and **1998**). This study recommended peak-to-mean ratios for a range of odour source types. The ratio is also dependent on atmospheric stability and the distance from the source. A summary table of these ratios is presented in **Appendix C**.

The DECC Technical Framework (**DECC, 2006**) takes account of this peaking factor and the criteria shown in **Table 10** are based on nose-response time.

5.2 Estimated Odour Emissions

Potential odour sources from the project are the active tipping and capped areas of the landfill, the leachate dam/trench and windrows associated with composting of greenwaste on-site. In dispersion modelling terms, these represent "area" sources.

Odour emissions from area sources are probably the most difficult to measure for a variety of reasons. Firstly the source is often heterogeneous. For example in the case of landfill sites, there will be different odour emission rates from different sections of the landfill. Secondly, unlike stack emissions, area emission rates are dependent upon atmospheric conditions including wind speed, degree of turbulence, temperature, etc. This clearly adds another level of complexity to odour assessments.

The landfill will be categorised as a Class 2 landfill, with no putrescible waste to be landfilled. However, a small volume of biodegradable materials may be landfilled and could produce odours over time. One of the objectives of the project however is to maximise recycling at the RRF and to minimise biodegradable material to landfill. To estimated odour emissions from the landfill, previous studies of emissions from Class 2 landfills were used. These studies were undertaken in the 1990s, during which time Class 2 landfills accepted a wider range of materials, including a higher volume of organic and biodegradable material than is proposed for this project. Odour emissions would therefore have been higher than those that will occur for the current project. Nevertheless, the odour emission data from these landfills (referred to as "standard" Class 2 odour emissions), is assumed to have relevance to this assessment, provided a suitable odour reduction factor is applied.

There are limited odour emissions data available for Class 2 landfills. Measurements made for a non-putrescible landfill site after six months of operations (**CEE, 1994**) have indicated levels of approximately 0.5 ou.m^3/m^2/min (certainty units). Due to decomposition of biodegradable material over time, odours from the landfill area will reach their maximum after a number of years of operation (perhaps 2 years), when it is estimated that emissions may increase by a factor of about 14 (**CEE, 1994**) from levels six months into operations. Therefore, to model for a worst-case scenario it is necessary to take into account the potential increase in odour over time to approximately 7 ou.m^3/m^2/min (or 0.117 ou.m^3/m^2/s). These worst-case emissions however, will not occur over the whole landfill area. As the landfill progresses, emissions from the previously capped cells will rise to a peak and then fall again.

This variation in emission rates from a given landfill area over time may occur in a similar fashion to that suggested by the **Maunsell (1994)** model in **Figure 10**. Assuming that the peak for the proposed landfill operation will be approximately 0.117 ou.m^3/m^2/s, the profile of this landfill gas model was applied to the current study to estimate the emissions for the time period specified in **Figure 10** (30 years). To account for variability in emissions across the landfill area, the average emission rate was then calculated and taken to apply for the whole landfill area. This value (0.051 ou.m^3/m^2/s) was taken to be representative of "standard" Class 2 odour emissions. As discussed above, it was then necessary to apply a proportionate reduction factor, to more accurately estimate emissions from proposed landfill operations, which will accept a low proportion of organic and biodegradable material

At the waste management and Class 2 landfill facility operated by the proponent at Alexandria, the total amount of organic or biodegradable material received in 2006 was 5,282 tonnes. In the past at a standard Class 2 landfill operation, all of this would have been landfilled. However, under the modern operating conditions most of these materials were recovered or recycled and, of the 5,282 tonnes of organic and potentially biodegradable materials, only 32 tonnes actually went to landfill. Thus, less than 1% was landfilled [32 / 5282 = 0.6%]. Odour emissions from capped areas have therefore been taken to be 1% of the standard historical Class 2 odour emissions.

In addition to odours from capped areas, there may be small quantities of odour emitted from the active tipping face. Odour measurements from the covered active tipping face at the proponent's Alexandria facility have been collected by **The Odour Unit (2006)** and are considered to be representative of emissions from this project, given that the two facilities will accept similar materials. Odour emissions from two different surfaces were measured; shipping container alternate daily cover and virgin excavated natural material (VENM) cover. The higher of these measurement data have been used for the modelling which is the more conservative approach.

Odour emissions from the greenwaste windrows were taken to be equivalent to measurements on greenwaste at Australian Native Landscapes operations at Eastern Creek (**Holmes Air Sciences, 2003**). It has been assumed that the total area of the greenwaste windrows occupies no more than 5,000 m^2. Odour emissions from the leachate dam/trench were taken from measurements made at the Eastern Creek landfill (**Holmes Air Sciences, 2003**) and assume aerobic conditions.

Table 11 provides the quantitative information on each odour source used in the dispersion modelling. Odour emissions in the dispersion model have been multiplied by the recommended peak-to-mean ratios for different source types (see **Appendix C**) to predict odour levels for nose response times. Peak-to-mean factors for the near-field have been applied for the purposes of this assessment. For area sources, these factors have numerical values of 2.5 for unstable and neutral atmospheric conditions and 2.3 for stable conditions in the near field.

Table 11 : Odour sources and emissions used in the dispersion modelling

Source	Area (m^2)	SOER ($ou.m^3/m^2/s$)	SOER with peak-to-mean ($ou.m^3/m^2/s$)		TOER with peak-to-mean ($ou.m^3/s$)	
			Neutral (2.5)	Stable (2.3)	Neutral (2.5)	Stable (2.3)
Capped areas	220,000	0.00051*	0.0013	0.0012	280	258
Covered tip face	450	3.83	9.58	8.81	4309	3964
Greenwaste windrows	5,000	0.105	0.263	0.242	1313	1208
Leachate pond/trench	30	0.069	0.173	0.159	5	5

** 1% of estimated average odour emissions from standard Class 2 landfills*
SOER = Specific Odour Emission Rate. TOER = Total Odour Emission Rate.

The odour emissions shown in **Table 11** have been taken to represent the "upper limit" of emissions from the project, given the tight controls on materials that will be accepted for landfill, the low proportion of biodegradable materials and the assumed maximum extents of odour emitting surfaces. For example, the capped area is assumed to be 22 hectares, which is the maximum landfill area and will only be reached after 20 years.

Also, landfill gas monitoring at the Alexandria site (**EMR, 2005 and 2006**) has found that there have been negligible methane emissions detected from the landfill cap.

In addition, the proponent has proposed the use of a product referred to as "BioMagic". BioMagic is a solution which acts as an oxidising agent to speed up the bacteria consumption of waste in order to reduce or eliminate odours. This product is proposed for use on any identified odour source at the site including the greenwaste stockpiles, composting products, the active tipping face and uncovered tipping areas. The product has the potential to control odour emissions from many of the sources listed in **Table 11**, although no emission reduction has been assumed for the dispersion modelling.

5.3 Approach to Odour Assessment

The approach taken for the odour assessment was to use estimated odour emissions (refer **Table 11**), meteorological information and a dispersion model to predict off-site odour levels from the facility. Model predictions were then compared with the DECC's odour assessment criteria.

The dispersion model used was CALPUFF (Version 6.113). CALPUFF is an advanced computer-based dispersion model that simulates the dispersion of emissions by representing emissions as a series of puffs emitted sequentially. Provided the rate at which the puffs are emitted is sufficiently rapid, the puffs will overlap and the serial release will represent a continuous release. The advantage of the puff modelling approach over the steady state Gaussian models such as ISCST3 and AUSPLUME, which have also been widely used in source dispersion assessments in the past, is that the progress and dispersion of each individual puff can be treated separately and can be made to account for local wind conditions and the way in which wind conditions at a particular place vary with time. This is particularly important for areas with complex terrain that would influence wind patterns, such as the quarry void at the project site.

The CALPUFF model makes use of wind fields generated by the CALMET model. CALMET generates a three-dimensional wind field on an hourly basis by taking observations of winds at selected locations and interpolating these to produce information on wind speed and direction at a grid of regularly spaced points covering the area of interest. Modifications that are imposed on this interpolated wind field (by topography and differential heating and differential surface roughness) are then applied to the winds at each grid point to develop a final wind field.

A wind field has been generated for each hour of the 2004 calendar year using meteorological data collected by DECC at St Marys. The CALMET model has essentially used the data from the St Marys site to determine wind patterns over the entire modelling domain (that is, for the area shown in **Figure 1**), given information on the local landuse and terrain features. In addition, the wind data from St Marys have been used as input to the CSIRO's prognostic model (The Air Pollution Model, TAPM) in order to generate upper air information on higher altitude winds and temperature profiles as required by the CALMET model. TAPM is a prognostic model which has the ability to generate meteorological data for any location in Australia (from 1997 onwards) based on synoptic information determined from the six hourly Limited Area Prediction System (LAPS) (**Puri *et al.*, 1997**). The model is discussed further in the accompanying user manual (see **Hurley, 2002**).

A summary of the data and parameters used as part of the meteorological component of this study are shown in **Table 12**.

Table 12 : Summary of meteorological parameters used for this study

TAPM (v 2.0)	
Number of grids (spacing)	4 (30 km, 10 km, 3 km, 1 km)
Number of grids point	25 x 25 x 25
Year of analysis	Jan 2004 to Dec 2004
Centre of analysis	33°49' S, 150°48.5' E
Data assimilation	St Marys
CALMET (v 5.5)	
Meteorological grid domain	5 km x 5 km
Meteorological grid resolution	0.1 km
Number of grid cells	50 x 50 x 9
Surface meteorological stations	St Marys for wind velocity and temperature. Cloud cover from Sydney Airport (BoM). Ceiling height, pressure and relative humidity by TAPM.
Upper air meteorological station	Data extracted from TAPM simulation for proposed site
Simulation length	8784 hours (Jan 2004 to Dec 2004)
Mode	Diagnostic wind module

The odour modelling has been performed using the CALMET meteorological information as described above with the odour emission information from **Section 5.2**. The way in which the model has been used in this study has been to predict the 1-hour average odour levels (expressed in odour units) at 125 receptors around the site. The receptor locations are the same as those used for the dust modelling and have been chosen to provide greater resolution near the modelled emission sources.

Plots of the odour levels at the 99th percentile have been compiled (refer **Figure 11**), showing the extent to which odours are predicted to occur for 99% of the time. This allows for direct comparison with the DECC's odour assessment criteria.

5.4 Assessment of Odour Impacts

Odour modelling results are shown in **Figure 11**. The contours extend further to the north and south, consistent with the predominant wind patterns in the area (refer **Figure 4**). It can be seen that the most stringent DECC odour criteria, 2 odour units, does not extend into any residential areas, suggesting that adverse odour impacts from the project would not occur.

Table 13 shows the model results for two nearby sensitive receptor locations. These receptor locations are shown in **Figure 6**.

Table 13 : Odour model predictions at two nearby sensitive receptors

Receptor ID	Predicted 99th percentile nose-response odour levels (odour units)	Criteria
R1	1.1	2
R2	0.3	2

As the model results for the nearby sensitive receptors are below the DECC's most stringent odour criteria of 2 odour units, the predicted odour impacts of the proposed activities have been taken to be acceptable.

Some caution should however be given to the model results as a reduction to odour emissions has been assumed on the basis that limited odour generating material will be landfilled. Should the quantity of biodegradable material accepted at the landfill be higher than anticipated, the potential for adverse odour impacts will also increase.

It is worth noting that the experience and measurements associated with the Alexandria facility suggest that there will be limited odour generating material going to landfill. In addition, recent changes to licensing under the Protection of the Environment Operations Act encourage the recycling of all materials where possible.

5.5 Odour Mitigation Measures

It is anticipated that landfill gas monitoring will be a standard licence condition and this will be conducted periodically to identify whether the activities generate significant odour. Gas monitoring will be undertaken following *Environment Guidelines: Solid Waste Landfills*. **(DECC, 1996)**. Monitoring is proposed to be conducted monthly for initial operations and, if no adverse impacts are observed, will be reduced to quarterly after six months of operations and to annually after 18 months of operation. Monitoring of landfill gas (methane and hydrogen sulfide) will be undertaken using a suitable landfill gas monitor.

Landfill gas extraction will be provided for by the site operation in the event that gas or odour emissions are detected.

As discussed in **Section 5.2**, a product known as BioMagic will be tested on key odour sources to minimise emissions. It would be useful if the effectiveness of this product can be demonstrated, for example through odour sampling.

6. CONCLUSIONS

This report has assessed the dust and odour impacts associated with the proposed materials processing centre, waste transfer station and non-putrescible Class 2 inert and solid waste landfill facility at Eastern Creek. Dispersion modelling has been used to predict off-site dust and odour levels due to the proposed activities.

The dust modelling results showed that annual average PM_{10}, TSP and deposition levels at nearest sensitive receptors would be below the DECC's assessment criteria, even when considering existing levels. The dust modelling is conservative and impacts are likely to be lower than predicted. The dispersion modelling has highlighted a potential for exceedances of the DECC's 24-hour average PM_{10} criterion at nearest receptors, due to project activities. Best practice dust mitigation measures as well as continuous dust monitoring with real-time strategies should be considered once the facility is operational to minimise the potential for adverse impacts and to ensure that air quality criteria are not exceeded at nearest receptors.

Odour levels at nearest receptors were predicted to be below the most stringent assessment criterion noted by the DECC. The results therefore suggested that there would be no adverse odour impacts associated with the project. Modelling assumed that some reduction to "standard" odour emissions from Class 2 landfills was appropriate and landfill gas monitoring would be important to show that the odour emissions are as low as anticipated.

7. REFERENCES

Bureau of Meteorology (2003)
Climatic Averages Australia, Bureau of Meteorology website, www.bom.gov.au

Consulting Environmental Engineers (1994)
"Report on predictive odour modelling" report prepared by Belair T for Pacific Waste in Land and Environment Court proceedings.

DEC (2005a)
"Approved Methods for the Modelling and Assessment of Air Pollutants in NSW", NSW EPA, August 2005, www.epa.nsw.gov.au .

DEC (2005b)
Quarterly air quality monitoring reports for 2004. Available for download from www.epa.nsw.gov.au .

DEC (2006)
Quarterly air quality monitoring reports for 2005. Available for download from www.epa.nsw.gov.au .

DEC (2007)
Quarterly air quality monitoring reports for 2006. Available for download from www.epa.nsw.gov.au .

DECC (2006)
"Technical framework: Assessment and management of odour from stationary sources in NSW". November 2006. Available for download from www.epa.nsw.gov.au .

EMR (2005, 2006)
Alexandria Landfill Site: Environmental Monitoring Results for year ending 30th November 2005 and year ending 30th November 2006.

Heggies (2006)
"Concept plan for the redevelopment of Lot 11 DP 558723, Lot 1 DP 200697 and Lot 2 DP 262213 Eastern Creek NSW. Air Quality Impact Assessment". Prepared for Hansen Construction Materials Pty Ltd, 15 November 2006, by Heggies Australia Pty Ltd.

Holmes Air Sciences (2003)
"Odour Audit: Eastern Creek – Stage 2". Prepared for NECS on behalf of Waste Service NSW, December 2003.

Hurley, P J (2002)
"The Air Pollution Model (TAPM) Version 2 : User Manual", CSIRO Atmospheric Research Internal Paper No. 25, April 2002

Katestone Scientific (1995)
"Evaluation of Peak-to-Mean Ratios for Odour Assessments" Katestone Scientific Pty Ltd.

Katestone Scientific (1998)
"Report from Katestone Scientific to Environment Protection Authority of NSW, Peak-to-Mean Ratios for Odour Assessments".

Maunsell (1994)
"Report on landfill gas" report prepared by Bateman C S and Winders C for Pacific Waste in Land and Environment Court proceedings.

NPI (2001)
"Emission estimation technique manual for mining – Version 2.3". 5 December 2001. ISBN: 0 642 54700 9.

NSW Minerals Council (2000)
"Technical Paper – Particulate Matter and Mining Interim Report".

Puri, K., Dietachmayer, G. S., Mills, G. A., Davidson, N. E., Bowen, R. A., and Logan, L. W. (1997)
"The BMRC Limited Area Prediction System, LAPS". Aust. Met. Mag., **47**, 203-223

SPCC (1986)
"Particle size distributions in dust from open cut coal mines in the Hunter Valley", Report Number 10636-002-71, Prepared for the State Pollution Control Commission of NSW (now DEC) by Dames & Moore, 41 McLaren Street, North Sydney, NSW 2060.

The Odour Unit (2006)
Odour sample measurement results for Alexandria landfill. Measurements made 19 Oct 2006.

Turner, D.B. (1970)
"Workbook of Atmospheric Dispersion Estimates", United States Environmental Protection Agency, Office of Air Programs, Research Triangle Park, North Carolina, Revised 1970, Office of Air Programs Publication Number AP-26.

US EPA (1985 and updates)
"Compilation of Air Pollutant Emission Factors", AP-42, Fourth Edition United States Environmental Protection Agency, Office of Air and Radiation Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina 27711. Note this reference is now a web-based document.

US EPA (1986)
"Guideline on air quality models (revised)", Prepared by the United States Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711, EPA-450/2-78-027R.

US EPA (1995)
"User's Guide for the Industrial Source Complex (ISC3) Dispersion Models - Volume 1 User's Instructions" and "Volume 2 Description of Model Algorithms" US Environmental Protection Agency, Office of Air Quality Planning and Standards Emissions, Monitoring and Analysis Division, Research Triangle Park, North Carolina 27711.

VEPA (1986)
"The Ausplume Gaussian Plume Dispersion Model", Environment Protection Authority, Olderfleet Buildings, 477 Collins Street, Melbourne Victoria 3000, Publication Number 264.

APPENDIX A
JOINT WIND SPEED, WIND DIRECTION AND STABILITY CLASS FREQUENCY TABLES

STATISTICS FOR FILE: C:\Jobs\LtHorse\metdata\StMarys\stm2004.aus
MONTHS: All
HOURS : All
OPTION: Frequency

PASQUILL STABILITY CLASS 'A'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.001025	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001025
NE	0.001480	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001480
ENE	0.000455	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000455
E	0.000455	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000455
ESE	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000228
SE	0.000455	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000455
SSE	0.000569	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000569
S	0.001138	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001138
SSW	0.000569	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000797
SW	0.000569	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000569
WSW	0.000455	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000455
W	0.000683	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000683
WNW	0.000683	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000683
NW	0.000911	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000911
NNW	0.001708	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001821
N	0.000797	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000911
CALM									0.016166
TOTAL	0.012181	0.000455	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.028802

MEAN WIND SPEED (m/s) = 0.59
NUMBER OF OBSERVATIONS = 253

PASQUILL STABILITY CLASS 'B'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.005920	0.005237	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.011270
NE	0.004440	0.001935	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.006375
ENE	0.003985	0.000797	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.004895
E	0.003643	0.002391	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.006261
ESE	0.003301	0.004212	0.001594	0.000000	0.000000	0.000000	0.000000	0.000000	0.009107
SE	0.004098	0.004440	0.001708	0.000000	0.000000	0.000000	0.000000	0.000000	0.010246
SSE	0.003985	0.005123	0.001252	0.000000	0.000000	0.000000	0.000000	0.000000	0.010360
S	0.012523	0.006944	0.001594	0.000114	0.000000	0.000000	0.000000	0.000000	0.021175
SSW	0.008766	0.004895	0.001480	0.000114	0.000000	0.000000	0.000000	0.000000	0.015255
SW	0.004098	0.002732	0.001708	0.000000	0.000000	0.000000	0.000000	0.000000	0.008538
WSW	0.002163	0.002391	0.001252	0.000000	0.000000	0.000000	0.000000	0.000000	0.005806
W	0.001480	0.001480	0.000797	0.000000	0.000000	0.000000	0.000000	0.000000	0.003757
WNW	0.002277	0.000797	0.000683	0.000114	0.000000	0.000000	0.000000	0.000000	0.003871
NW	0.005464	0.001594	0.000683	0.000000	0.000000	0.000000	0.000000	0.000000	0.007741
NNW	0.017077	0.013661	0.000683	0.000000	0.000000	0.000000	0.000000	0.000000	0.031421
N	0.014117	0.017304	0.001480	0.000000	0.000000	0.000000	0.000000	0.000000	0.032901
CALM									0.019012
TOTAL	0.097336	0.075934	0.015369	0.000342	0.000000	0.000000	0.000000	0.000000	0.207992

MEAN WIND SPEED (m/s) = 1.57
NUMBER OF OBSERVATIONS = 1827

PASQUILL STABILITY CLASS 'C'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.001252	0.002277	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.003643
NE	0.001594	0.001025	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002618
ENE	0.001252	0.001366	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.002618
E	0.001594	0.002049	0.001480	0.000114	0.000000	0.000000	0.000000	0.000000	0.005237
ESE	0.001366	0.002505	0.004895	0.001138	0.000000	0.000000	0.000000	0.000000	0.009904
SE	0.001366	0.001935	0.002960	0.001594	0.000000	0.000000	0.000000	0.000000	0.007855
SSE	0.003074	0.002618	0.003188	0.000911	0.000000	0.000000	0.000000	0.000000	0.009791
S	0.008197	0.005009	0.002732	0.001594	0.000000	0.000000	0.000000	0.000000	0.017532
SSW	0.005351	0.003415	0.003757	0.001708	0.000000	0.000000	0.000000	0.000000	0.014230
SW	0.002277	0.001935	0.002163	0.001708	0.000000	0.000000	0.000000	0.000000	0.008083
WSW	0.000683	0.001935	0.002505	0.000911	0.000000	0.000000	0.000000	0.000000	0.006034
W	0.000683	0.001252	0.003301	0.001025	0.000000	0.000000	0.000000	0.000000	0.006261
WNW	0.000342	0.000569	0.002618	0.002505	0.000000	0.000000	0.000000	0.000000	0.006034
NW	0.001594	0.000797	0.001821	0.000683	0.000000	0.000000	0.000000	0.000000	0.004895
NNW	0.002277	0.004554	0.001025	0.000455	0.000000	0.000000	0.000000	0.000000	0.008311
N	0.004212	0.006034	0.000342	0.000228	0.000000	0.000000	0.000000	0.000000	0.010815
CALM									0.024362
TOTAL	0.037113	0.039276	0.032901	0.014572	0.000000	0.000000	0.000000	0.000000	0.148224

MEAN WIND SPEED (m/s) = 2.27
NUMBER OF OBSERVATIONS = 1302

PASQUILL STABILITY CLASS 'D'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.000114	0.001252	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001366
NE	0.000342	0.002391	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.002960
ENE	0.000342	0.003074	0.000683	0.000000	0.000000	0.000000	0.000000	0.000000	0.004098
E	0.000342	0.004440	0.003757	0.000228	0.000000	0.000000	0.000000	0.000000	0.008766
ESE	0.000228	0.004554	0.014913	0.007400	0.000911	0.000114	0.000000	0.000000	0.028119
SE	0.000342	0.002277	0.007855	0.005351	0.000911	0.000114	0.000000	0.000000	0.016849
SSE	0.000569	0.002505	0.003871	0.000683	0.000114	0.000000	0.000000	0.000000	0.007741
S	0.003188	0.001708	0.002277	0.001366	0.000569	0.000000	0.000000	0.000000	0.009107
SSW	0.001821	0.002960	0.003643	0.003415	0.002163	0.001138	0.000342	0.000000	0.015483
SW	0.001366	0.001594	0.002618	0.002505	0.000342	0.000000	0.000000	0.000000	0.008424
WSW	0.000228	0.001138	0.002618	0.001935	0.001025	0.000114	0.000000	0.000000	0.007058
W	0.000114	0.001480	0.002505	0.001025	0.000911	0.000114	0.000000	0.000000	0.006148
WNW	0.000228	0.001366	0.003415	0.002618	0.002391	0.000228	0.000000	0.000000	0.010246
NW	0.000342	0.000569	0.002846	0.002163	0.000569	0.000455	0.000000	0.000000	0.006944
NNW	0.001025	0.001480	0.001935	0.001138	0.000228	0.000000	0.000000	0.000000	0.005806
N	0.001252	0.002732	0.001025	0.000683	0.000342	0.000000	0.000000	0.000000	0.006034
CALM									0.004781
TOTAL	0.011840	0.035519	0.054189	0.030510	0.010474	0.002277	0.000342	0.000000	0.149932

MEAN WIND SPEED (m/s) = 3.70
NUMBER OF OBSERVATIONS = 1317

PASQUILL STABILITY CLASS 'E'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.000000	0.000569	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000569
NE	0.000000	0.001138	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001138
ENE	0.000000	0.000911	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000911
E	0.000000	0.003301	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.003301
ESE	0.000000	0.005123	0.000797	0.000000	0.000000	0.000000	0.000000	0.000000	0.005920
SE	0.000000	0.006148	0.000683	0.000000	0.000000	0.000000	0.000000	0.000000	0.006831
SSE	0.000000	0.004668	0.000683	0.000000	0.000000	0.000000	0.000000	0.000000	0.005351
S	0.000000	0.006148	0.000342	0.000000	0.000000	0.000000	0.000000	0.000000	0.006489
SSW	0.000000	0.007400	0.001252	0.000000	0.000000	0.000000	0.000000	0.000000	0.008652
SW	0.000000	0.003529	0.000569	0.000000	0.000000	0.000000	0.000000	0.000000	0.004098
WSW	0.000000	0.002846	0.000569	0.000000	0.000000	0.000000	0.000000	0.000000	0.003415
W	0.000000	0.002163	0.000683	0.000000	0.000000	0.000000	0.000000	0.000000	0.002846
WNW	0.000000	0.003529	0.000455	0.000000	0.000000	0.000000	0.000000	0.000000	0.003985
NW	0.000000	0.001821	0.000342	0.000114	0.000000	0.000000	0.000000	0.000000	0.002277
NNW	0.000000	0.003074	0.000455	0.000000	0.000000	0.000000	0.000000	0.000000	0.003529
N	0.000000	0.004895	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.005123
CALM									0.000000
TOTAL	0.000000	0.057263	0.007058	0.000114	0.000000	0.000000	0.000000	0.000000	0.064435

MEAN WIND SPEED (m/s) = 2.46
NUMBER OF OBSERVATIONS = 566

PASQUILL STABILITY CLASS 'F'

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.006148	0.000797	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.006944
NE	0.007400	0.000911	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.008311
ENE	0.003415	0.000683	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.004098
E	0.004212	0.001252	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.005464
ESE	0.003188	0.002163	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.005578
SE	0.004098	0.002505	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.006603
SSE	0.015369	0.002277	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.017646
S	0.056011	0.007172	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.063183
SSW	0.056466	0.009563	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.066257
SW	0.027095	0.002960	0.000455	0.000000	0.000000	0.000000	0.000000	0.000000	0.030510
WSW	0.008880	0.001480	0.000114	0.000000	0.000000	0.000000	0.000000	0.000000	0.010474
W	0.004668	0.001708	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.006375
WNW	0.003757	0.001366	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.005123
NW	0.003188	0.001708	0.000342	0.000000	0.000000	0.000000	0.000000	0.000000	0.005237
NNW	0.006148	0.002277	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.008652
N	0.018101	0.003074	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.021175
CALM									0.128985
TOTAL	0.228142	0.041894	0.001594	0.000000	0.000000	0.000000	0.000000	0.000000	0.400615

MEAN WIND SPEED (m/s) = 0.90
NUMBER OF OBSERVATIONS = 3519

ALL PASQUILL STABILITY CLASSES

Wind Speed Class (m/s)

WIND SECTOR	0.50 TO 1.50	1.50 TO 3.00	3.00 TO 4.50	4.50 TO 6.00	6.00 TO 7.50	7.50 TO 9.00	9.00 TO 10.50	GREATER THAN 10.50	TOTAL
NNE	0.014458	0.010132	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.024818
NE	0.015255	0.007400	0.000228	0.000000	0.000000	0.000000	0.000000	0.000000	0.022883
ENE	0.009449	0.006831	0.000797	0.000000	0.000000	0.000000	0.000000	0.000000	0.017077
E	0.010246	0.013434	0.005464	0.000342	0.000000	0.000000	0.000000	0.000000	0.029485
ESE	0.008311	0.018556	0.022427	0.008538	0.000911	0.000114	0.000000	0.000000	0.058857
SE	0.010360	0.017304	0.013206	0.006944	0.000911	0.000114	0.000000	0.000000	0.048839
SSE	0.023566	0.017190	0.008994	0.001594	0.000114	0.000000	0.000000	0.000000	0.051457
S	0.081056	0.026981	0.006944	0.003074	0.000569	0.000000	0.000000	0.000000	0.118625
SSW	0.072974	0.028461	0.010360	0.005237	0.002163	0.001138	0.000342	0.000000	0.120674
SW	0.035405	0.012750	0.007514	0.004212	0.000342	0.000000	0.000000	0.000000	0.060223
WSW	0.012409	0.009791	0.007058	0.002846	0.001025	0.000114	0.000000	0.000000	0.033242
W	0.007628	0.008083	0.007286	0.002049	0.000911	0.000114	0.000000	0.000000	0.026070
WNW	0.007286	0.007628	0.007172	0.005237	0.002391	0.000228	0.000000	0.000000	0.029941
NW	0.011498	0.006489	0.006034	0.002960	0.000569	0.000455	0.000000	0.000000	0.028005
NNW	0.028233	0.025159	0.004326	0.001594	0.000228	0.000000	0.000000	0.000000	0.059540
N	0.038479	0.034153	0.003074	0.000911	0.000342	0.000000	0.000000	0.000000	0.076958
CALM									0.193306
TOTAL	0.386612	0.250342	0.111111	0.045537	0.010474	0.002277	0.000342	0.000000	1.000000

MEAN WIND SPEED (m/s) = 1.76
NUMBER OF OBSERVATIONS = 8784

FREQUENCY OF OCCURENCE OF STABILITY CLASSES

A : 2.9%
B : 20.8%
C : 14.8%
D : 15.0%
E : 6.4%
F : 40.1%

STABILITY CLASS BY HOUR OF DAY

Hour	A	B	C	D	E	F
01	0000	0000	0000	0021	0022	0323
02	0000	0000	0000	0020	0023	0323
03	0000	0000	0000	0015	0019	0332
04	0000	0000	0000	0017	0021	0328
05	0000	0000	0029	0022	0018	0297
06	0000	0022	0145	0032	0009	0158
07	0000	0115	0180	0041	0001	0029
08	0026	0192	0120	0028	0000	0000
09	0042	0196	0085	0043	0000	0000
10	0037	0244	0055	0030	0000	0000
11	0048	0255	0049	0014	0000	0000
12	0046	0259	0048	0013	0000	0000
13	0031	0242	0071	0022	0000	0000
14	0020	0168	0142	0036	0000	0000
15	0002	0092	0151	0121	0000	0000
16	0001	0041	0122	0202	0000	0000
17	0000	0001	0068	0271	0010	0016
18	0000	0000	0027	0188	0072	0079
19	0000	0000	0010	0062	0115	0179
20	0000	0000	0000	0032	0094	0240
21	0000	0000	0000	0028	0057	0281
22	0000	0000	0000	0015	0043	0308
23	0000	0000	0000	0024	0038	0304
24	0000	0000	0000	0020	0024	0322

STABILITY CLASS BY MIXING HEIGHT

Mixing height	A	B	C	D	E	F
<=500 m	0027	0369	0495	0190	0566	3519
<=1000 m	0152	0859	0348	0190	0000	0000
<=1500 m	0074	0599	0459	0866	0000	0000
<=2000 m	0000	0000	0000	0058	0000	0000
<=3000 m	0000	0000	0000	0013	0000	0000
>3000 m	0000	0000	0000	0000	0000	0000

MIXING HEIGHT BY HOUR OF DAY

Hour	0000 to 0100	0100 to 0200	0200 to 0400	0400 to 0800	0800 to 1600	1600 to 3200	Greater than 3200
01	0318	0019	0013	0000	0013	0003	0000
02	0314	0032	0007	0001	0011	0001	0000
03	0322	0025	0010	0000	0007	0002	0000
04	0319	0028	0009	0001	0005	0004	0000
05	0322	0031	0004	0000	0005	0004	0000
06	0209	0092	0059	0001	0002	0003	0000
07	0121	0061	0119	0064	0001	0000	0000
08	0000	0070	0123	0173	0000	0000	0000
09	0000	0000	0100	0193	0073	0000	0000
10	0000	0000	0000	0232	0134	0000	0000
11	0000	0000	0000	0146	0220	0000	0000
12	0000	0000	0000	0092	0274	0000	0000
13	0000	0000	0000	0000	0366	0000	0000
14	0000	0000	0000	0000	0366	0000	0000
15	0000	0000	0000	0000	0366	0000	0000
16	0000	0000	0000	0000	0366	0000	0000
17	0016	0004	0006	0000	0339	0001	0000
18	0072	0061	0019	0001	0208	0005	0000
19	0169	0090	0036	0002	0061	0008	0000
20	0230	0072	0034	0006	0022	0002	0000
21	0271	0048	0022	0006	0016	0003	0000
22	0301	0037	0018	0000	0006	0004	0000
23	0297	0036	0018	0003	0009	0003	0000
24	0309	0027	0017	0001	0009	0003	0000

APPENDIX B
ESTIMATED DUST EMISSIONS

ESTIMATED DUST EMISSIONS (Year 0 – worst case)

ACTIVITY	TSP emission/year	Intensity	units	Emission factor	units	Variable 1	units	Variable 2	units	Variable 3	units
Vehicles COMING TO site (paved)	20776	148400	trips/year			0.7	km/one way trip	0.2	kg/VKT		
Dumping material to MPC or segregated stockpile	3757	1250000	t/y	0.01002	kg/t	1.215	average (ws/2.2)^1.3	0.5	moisture content - %	70	% dust control
Dumping material to WTS	2254	750000	t/y	0.01002	kg/t	1.215	average (ws/2.2)^1.3	0.5	moisture content - %	70	% dust control
Loading material by FEL for processing	3757	1250000	t/y	0.01002	kg/t	1.215	average (ws/2.2)^1.3	0.5	moisture content - %	70	% dust control
Loading and sorting material by excavator	12523	1250000	t/y	0.01002	kg/t	1.215	average (ws/2.2)^1.3	0.5	moisture content - %		
Screening material	3938	630000	t/y	0.01250	kg/t	50	% dust control by water sprays				
Crushing material	270	200000	t/y	0.00270	kg/t	50	% dust control by water sprays				
Loading material to stockpiles	6262	1250000	t/y	0.01002	kg/t	1.215	average (ws/2.2)^1.3	0.5	moisture content - %	50	% dust control
Loading material to trucks	10019	2000000	t/y	0.01002	kg/t	1.215	average (ws/2.2)^1.3	0.5	moisture content - %	50	% dust control
Hauling material to landfill (unpaved, inc return)	92312	23078	trips/year			4	km/return trip	1.0	kg/VKT		
Vehicles LEAVING site (paved)	20776	148400	trips/year			0.7	km/one way trip	0.2	kg/VKT		
Dumping material to landfill	10019	1000000	t/y	0.01002	kg/t	1.215	average (ws/2.2)^1.3	0.5	moisture content - %		
Wind erosion from exposed landfill area	7247	22	ha	329.4	kg/ha/y	112	Av no. of raindays	4	silt content - %	2.4818	% of winds above 5.4 m/s
Wind erosion from soil stockpiles	412*	1	ha	823.5	kg/ha/y	112	Av no. of raindays	10	silt content - %	2.4818	% of winds above 5.4 m/s
Wind erosion from other stockpiles	329*	2	ha	329.4	kg/ha/y	112	Av no. of raindays	4	silt content - %	2.4818	% of winds above 5.4 m/s

** includes 50% reduction by water sprays*

The dust emission inventories have been prepared using the operational description of the proposed activities provided by the proponent. Estimated emissions are presented for all significant dust generating activities associated with the operations. The relevant emission factors used for the study are described below.

Hauling material / product over road surfaces

After the application of water the emission factor used for trucks hauling material on unsealed surfaces was 1 kg per vehicle kilometre travelled (kg/VKT). For sealed surfaces, 0.2 kg/VKT has been used.

Loading / dumping /transferring material

Each tonne of material loaded will generate a quantity of TSP that will depend on the wind speed and the moisture content. Equation 1 shows the relationship between these variables.

Equation 1

$$E_{TSP} = k \times 0.0016 \times \left(\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \right) \qquad kg/t$$

where,

E_{TSP} = *TSP emissions*

$k = 0.74$

U = *wind speed(m/s)*

M = *moisture content (%)*

[where $0.25 \le M \le 4.8$*]*

Wind erosion

The emission factor for wind erosion is given in Equation 2 below.

Equation 2

$$E_{TSP} = 1.9 \times \left(\frac{s}{1.5}\right) \times \left(\frac{365 - p}{235}\right) \times \left(\frac{f}{15}\right) \qquad \text{kg/ha/day}$$

where,

s = silt content (%)

p = number of raindays per year, and

f = percentage of the time that wind speed is above 5.4 m/s

A summary of dust emission estimates for each activity, activity type, location of emission sources and activity hours is provided below. The location of the sources can be obtained from **Figure 6**. AUSPLUME model input files can be provided on request.

```
 -------------------------------      19-Dec-2007 10:55
  DUST EMISSION CALCULATIONS V2
 -------------------------------

 Output emissions file  : C:\Jobs\LHBC_ERM\ausplume\emiss.src
 Meteorological file    : C:\Jobs\LHBC_ERM\metdata\StMarys\stm2004.aus
 Number of dust sources : 18
 Number of activities   : 15
 No-blast conditions    : None
 Wind sensitive factor  : 0.829 (1.092 adjusted for activity hours)
 Wind erosion factor    : 20.269

  -----ACTIVITY SUMMARY-----
 ACTIVITY NAME : Vehicles COMING TO site (paved)
 ACTIVITY TYPE : Wind insensitive
 DUST EMISSION : 20776 kg/y
 FROM SOURCES  : 10
1 2 3 4 5 6 7 8 9 10
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0

 ACTIVITY NAME : Dumping material to MPC or segregated stockpile
 ACTIVITY TYPE : Wind sensitive
 DUST EMISSION : 3757 kg/y
 FROM SOURCES  : 1
6
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0

 ACTIVITY NAME : Dumping material to WTF
 ACTIVITY TYPE : Wind sensitive
 DUST EMISSION : 2254 kg/y
 FROM SOURCES  : 4
7 8 9 10
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0

 ACTIVITY NAME : Loading material by FEL for processing
 ACTIVITY TYPE : Wind sensitive
 DUST EMISSION : 3757 kg/y
 FROM SOURCES  : 1
6
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0

 ACTIVITY NAME : Loading and sorting material by excavator
 ACTIVITY TYPE : Wind sensitive
 DUST EMISSION : 12523 kg/y
 FROM SOURCES  : 3
6 7 8
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0

 ACTIVITY NAME : Screening material
 ACTIVITY TYPE : Wind insensitive
 DUST EMISSION : 3938 kg/y
 FROM SOURCES  : 4
7 8 9 10
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0

 ACTIVITY NAME : Crushing material
 ACTIVITY TYPE : Wind insensitive
 DUST EMISSION : 270 kg/y
 FROM SOURCES  : 4
7 8 9 10
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0

 ACTIVITY NAME : Loading material to stockpiles
 ACTIVITY TYPE : Wind sensitive
 DUST EMISSION : 6262 kg/y
 FROM SOURCES  : 4
7 8 9 10
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0

 ACTIVITY NAME : Loading material to trucks
 ACTIVITY TYPE : Wind sensitive
 DUST EMISSION : 10019 kg/y
 FROM SOURCES  : 5
6 7 8 9 10
 HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0
```

```
ACTIVITY NAME : Hauling material to landfill (unpaved, inc return)
ACTIVITY TYPE : Wind insensitive
DUST EMISSION : 92312 kg/y
FROM SOURCES  : 13
6 7 8 9 10 11 12 13 14 15 16 17 18
HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

ACTIVITY NAME : Vehicles LEAVING site (paved)
ACTIVITY TYPE : Wind insensitive
DUST EMISSION : 20776 kg/y
FROM SOURCES  : 10
1 2 3 4 5 6 7 8 9 10
HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

ACTIVITY NAME : Dumping material to landfill
ACTIVITY TYPE : Wind sensitive
DUST EMISSION : 10019 kg/y
FROM SOURCES  : 4
12 13 17 18
HOURS OF DAY  :
0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0

ACTIVITY NAME : Wind erosion from exposed landfill area
ACTIVITY TYPE : Wind erosion
DUST EMISSION : 7247 kg/y
FROM SOURCES  : 10
4 5 6 12 13 14 15 16 17 18
HOURS OF DAY  :
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

ACTIVITY NAME : Wind erosion from soil stockpiles
ACTIVITY TYPE : Wind erosion
DUST EMISSION : 412 kg/y
FROM SOURCES  : 4
7 8 9 10
HOURS OF DAY  :
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

ACTIVITY NAME : Wind erosion from other stockpiles
ACTIVITY TYPE : Wind erosion
DUST EMISSION : 329 kg/y
FROM SOURCES  : 4
7 8 9 10
HOURS OF DAY  :
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

Pit retention sources: 7
12 13 14 15 16 17 18
```

APPENDIX C
PEAK-TO-MEAN RATIOS

Table C1 : Recommended factors for estimating peak concentrations for different source types, distances and stabilities

Source type	Stability	Near field				Far field			p
		i_{max}	x_{max}	P/M 60	P/M 3	i	P/M 60	P/M 3	
Area	Neutral, Convective	0.5	500 – 1000	2.5	1.9	0.4	2.3	1.7	0.15
	Stable	0.5	300 – 800	2.3	1.7	0.3	1.9	1.4	0.10
Line	Neutral, Convective	1.0	350	6	2.8	0.75	6	2.8	0.25
	Stable	1.0	250	6	2.8	0.65	6	2.8	0.25
Surface point	Neutral	2.5	200	25	10	1.2	5 - 7	3	0.2
	Stable	2.5	200	25	10	1.2	5 - 7	3	0.2
	Convective	2	1000	12	7	0.6	3 - 4	2.5	0.15
Tall point	Neutral, Stable	4.5	5 h	35	8	1.0	6	1.3	0.5
	Convective	2.3	2.5 h	17	4	0.5	3	1.1	0.5
Wake affected point	Neutral, Convective	0.4	-	2.3	1.4	-	2.3	1.4	0.1
Volume	Neutral, Convective	0.4	-	2.3	1.4	-	2.3	1.4	0.1

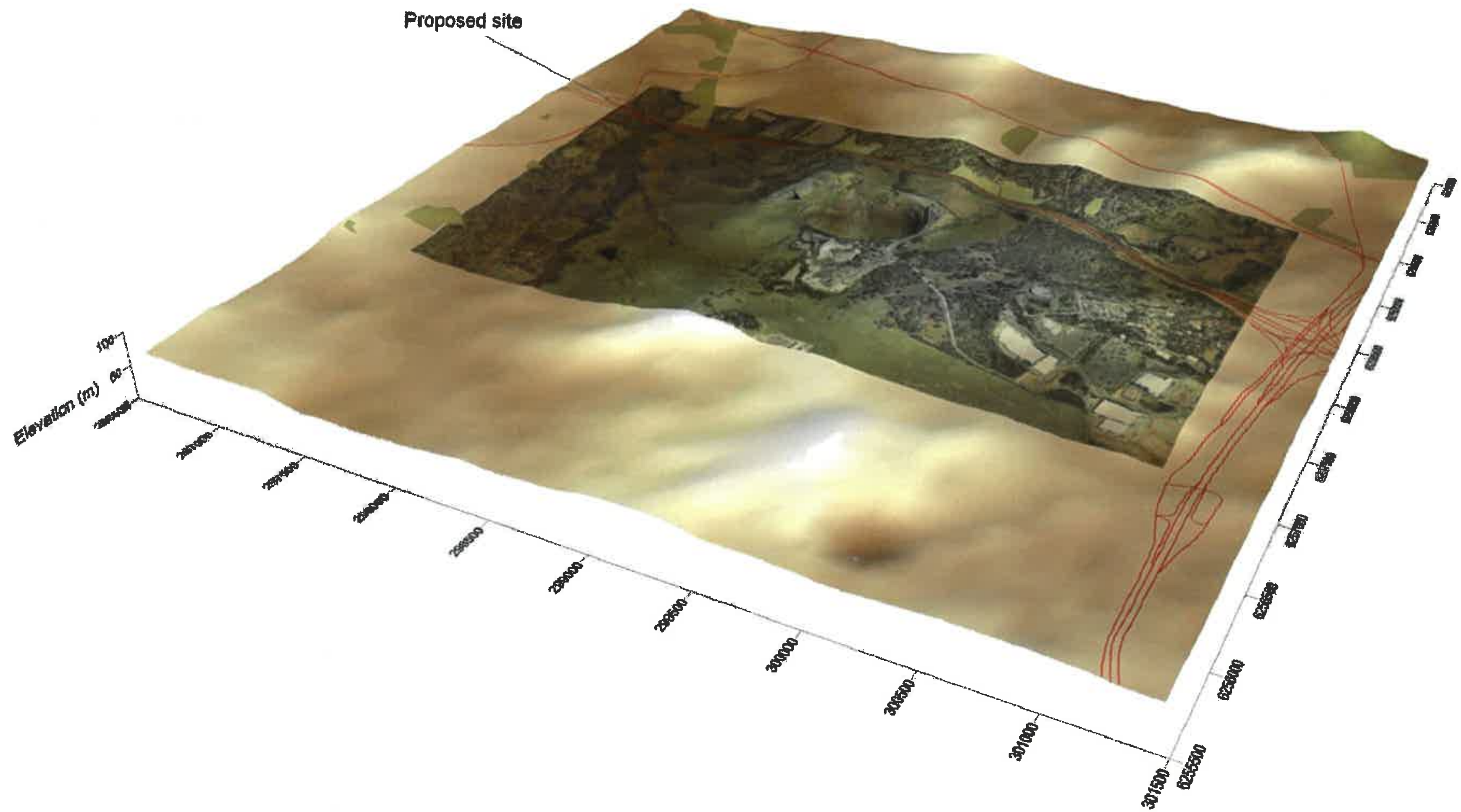
i_{max} is maximum centreline intensity of concentration
x_{max} is the approximation location of i_{max} in metres
P/M 60 is the peak-to-mean ratio for long averaging times (typically 1 hour), at a probability of 10^{-3}
P/M 3 is the best estimates of the peak-to-mean ratio for 3 minute averages, at probability 10^{-3}
p is the averaging time power law exponent
h is stack height

Source: **Katestone Scientific (1998)**

FIGURES

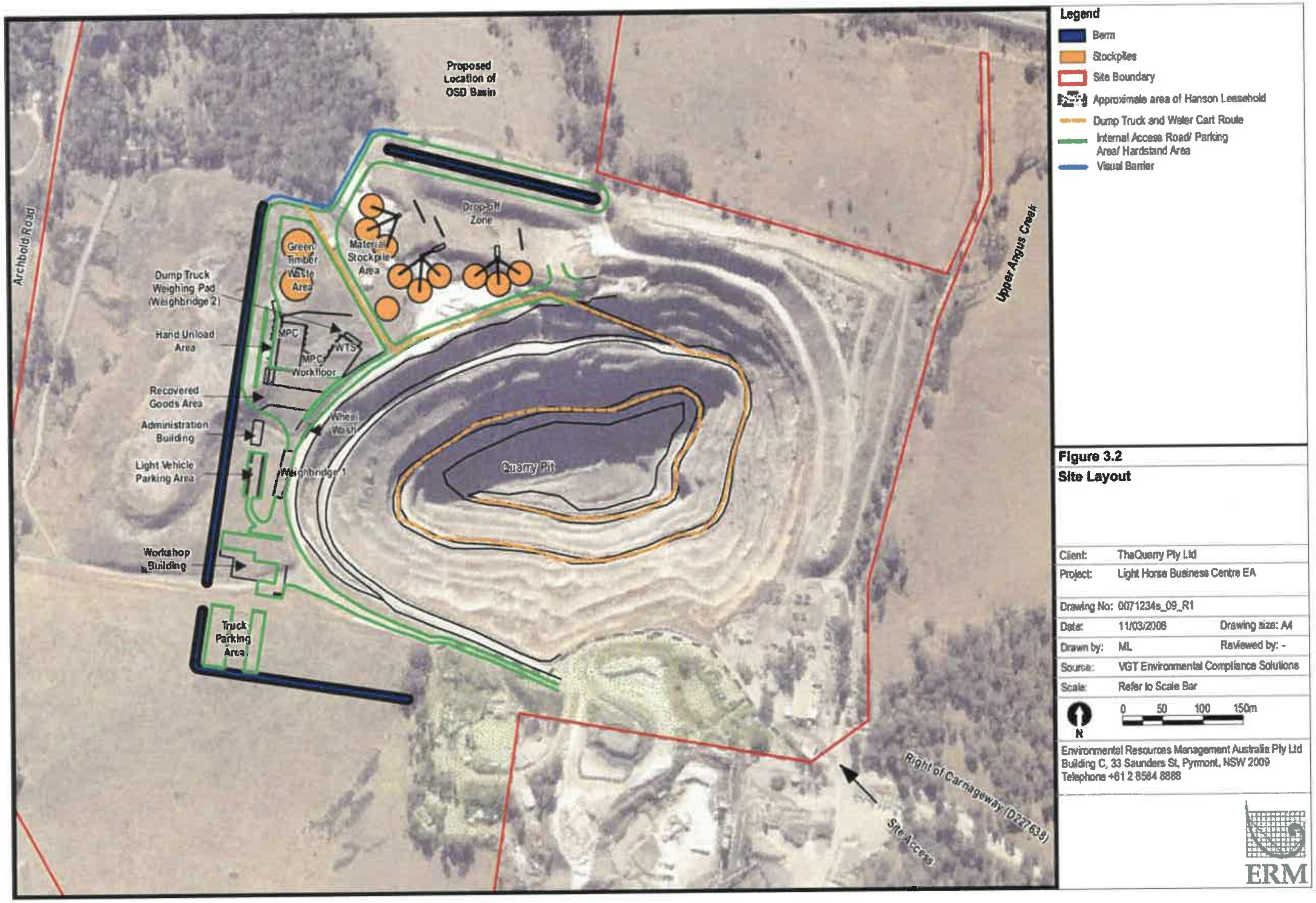
Location of study area

FIGURE 1



Pseudo three-dimensional representation of the local terrain

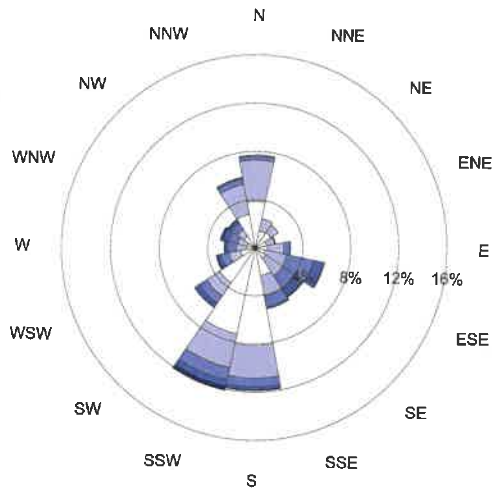
FIGURE 2



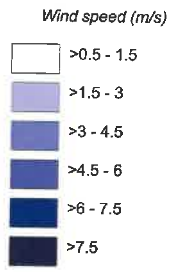
Site layout

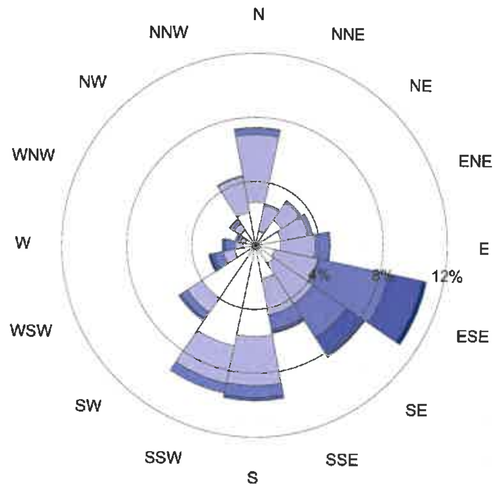
FIGURE 3

Annual and seasonal windroses for St Marys (2004)

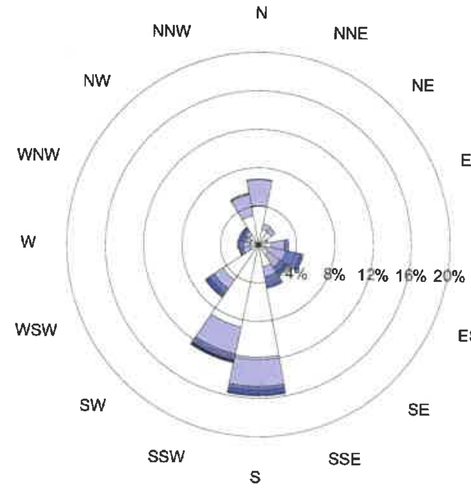


Annual
Calms = 19.3%

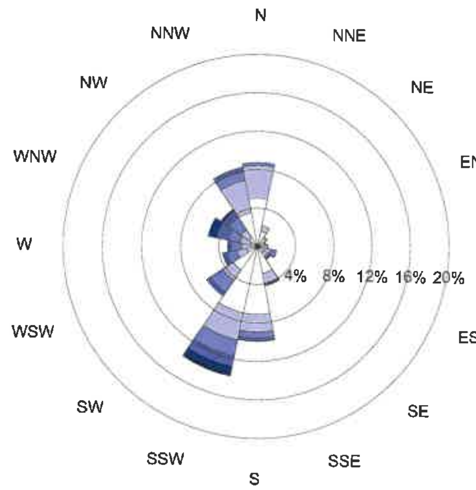




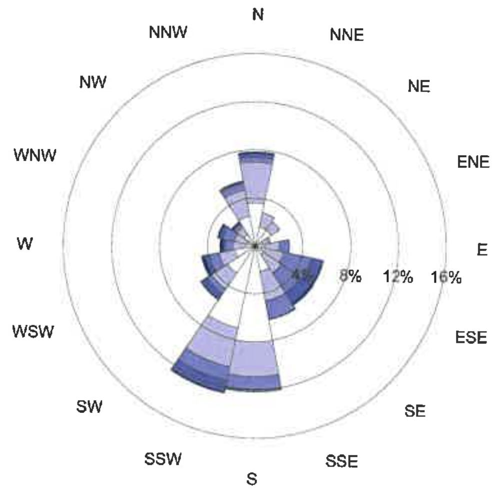
Summer
Calms = 15.8%



Autumn
Calms = 22.4%



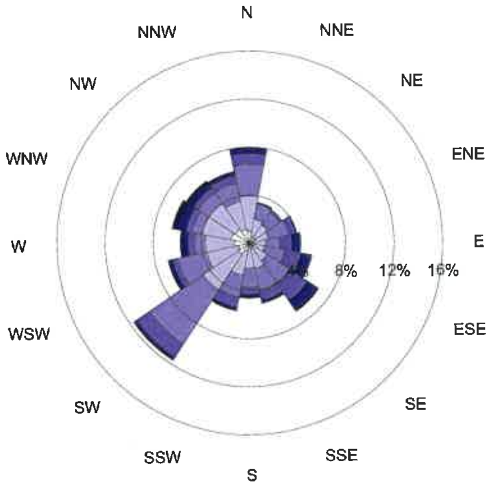
Winter
Calms = 23.1%



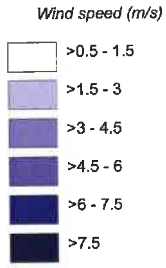
Spring
Calms = 16.0%

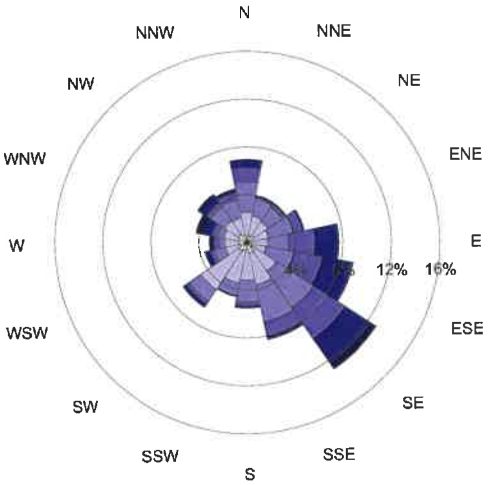
FIGURE 4

Annual and seasonal windroses for Horsley Park (2005)

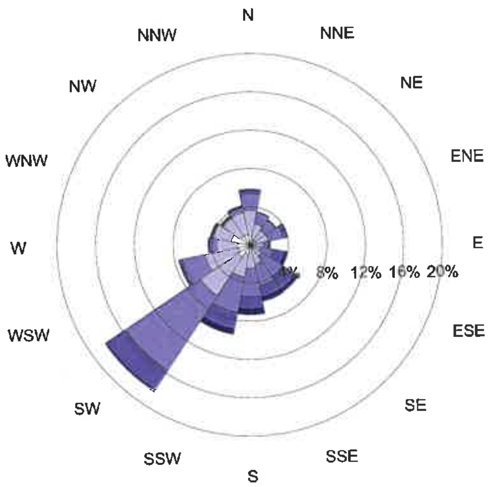


Annual
Calms = 6.1%

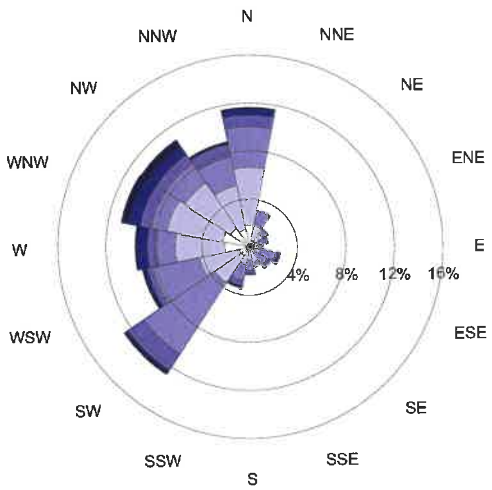




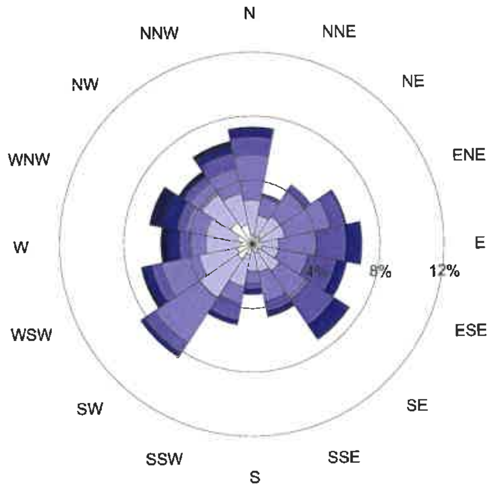
Summer
Calms = 5.4%



Autumn
Calms = 6.4%

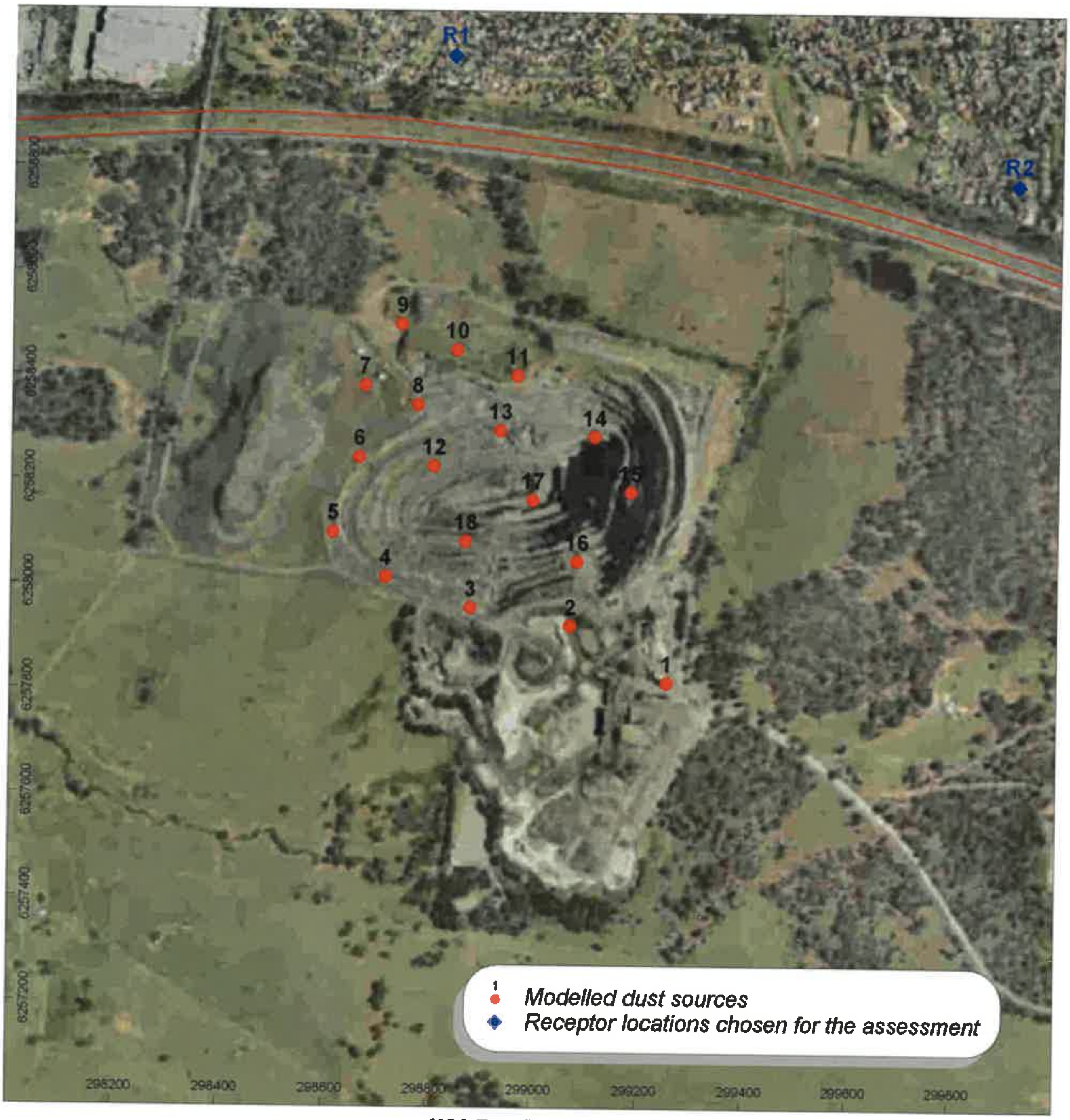


Winter
Calms = 6.2%



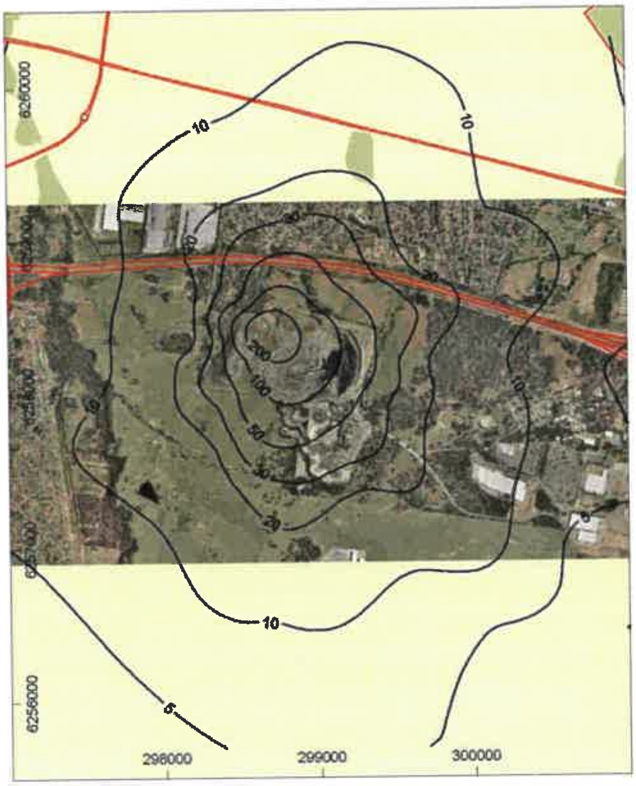
Spring
Calms = 6.4%

FIGURE 5

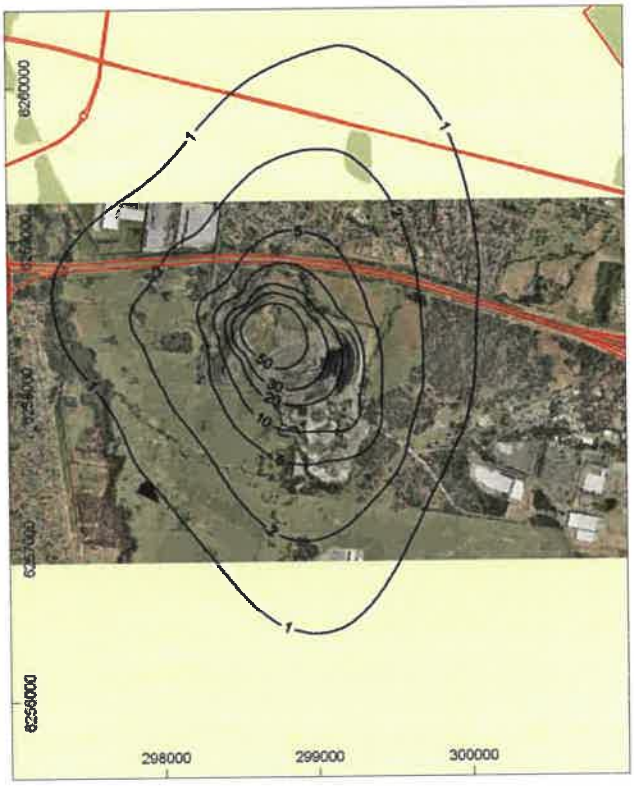


MGA Zone 56 (GDA 94)

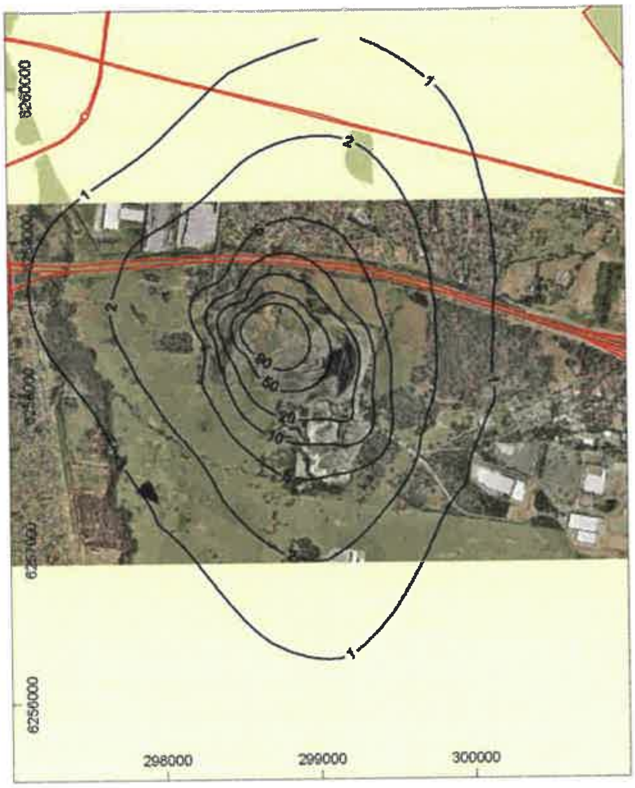
Location of modelled dust sources and receptors



Maximum 24-hour average PM_{10} - µg/m^3



Annual average PM_{10} - µg/m^3



Annual average TSP - µg/m^3

Annual average dust deposition - g/m^2/month

Predicted dust concentration and deposition levels due to proposed operations

FIGURE 7

Time series of predicted 24-hour average PM_{10} concentrations at nearest receptors

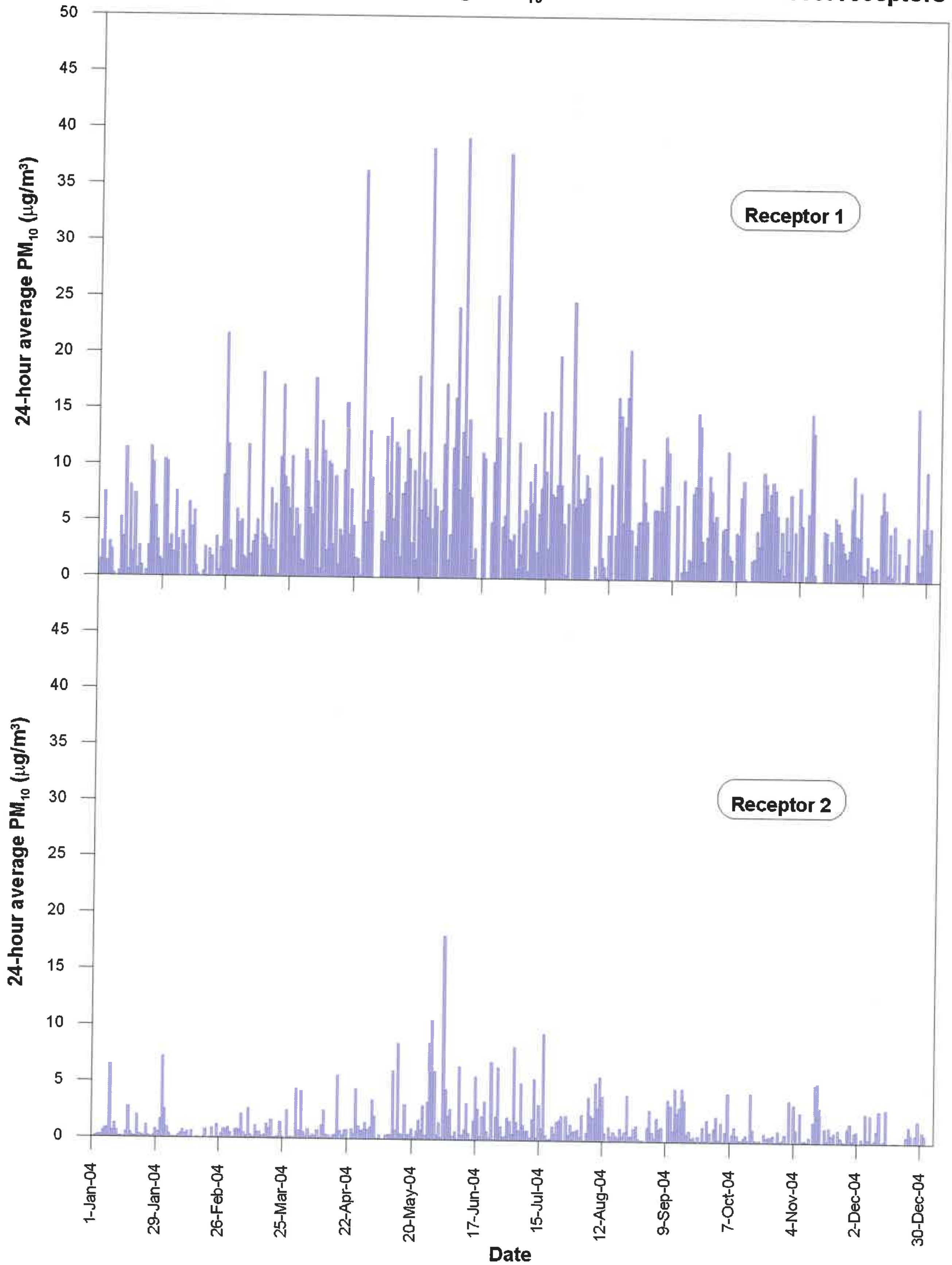
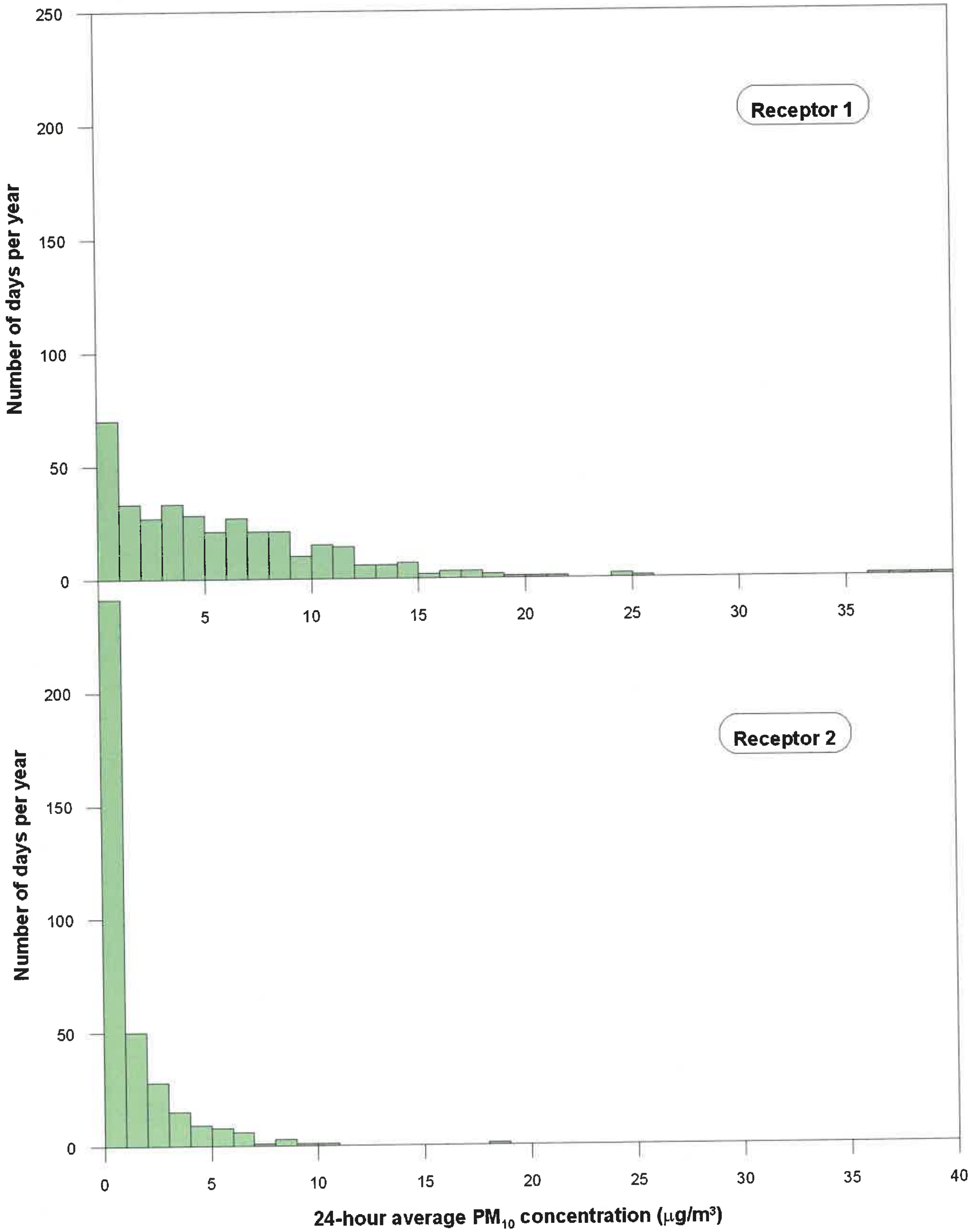


FIGURE 8

Histogram of predicted 24-hour average PM_{10} concentrations at nearest receptors



Landfill gas model

Standard gas curves: Waste input 1,000,000 m^3)

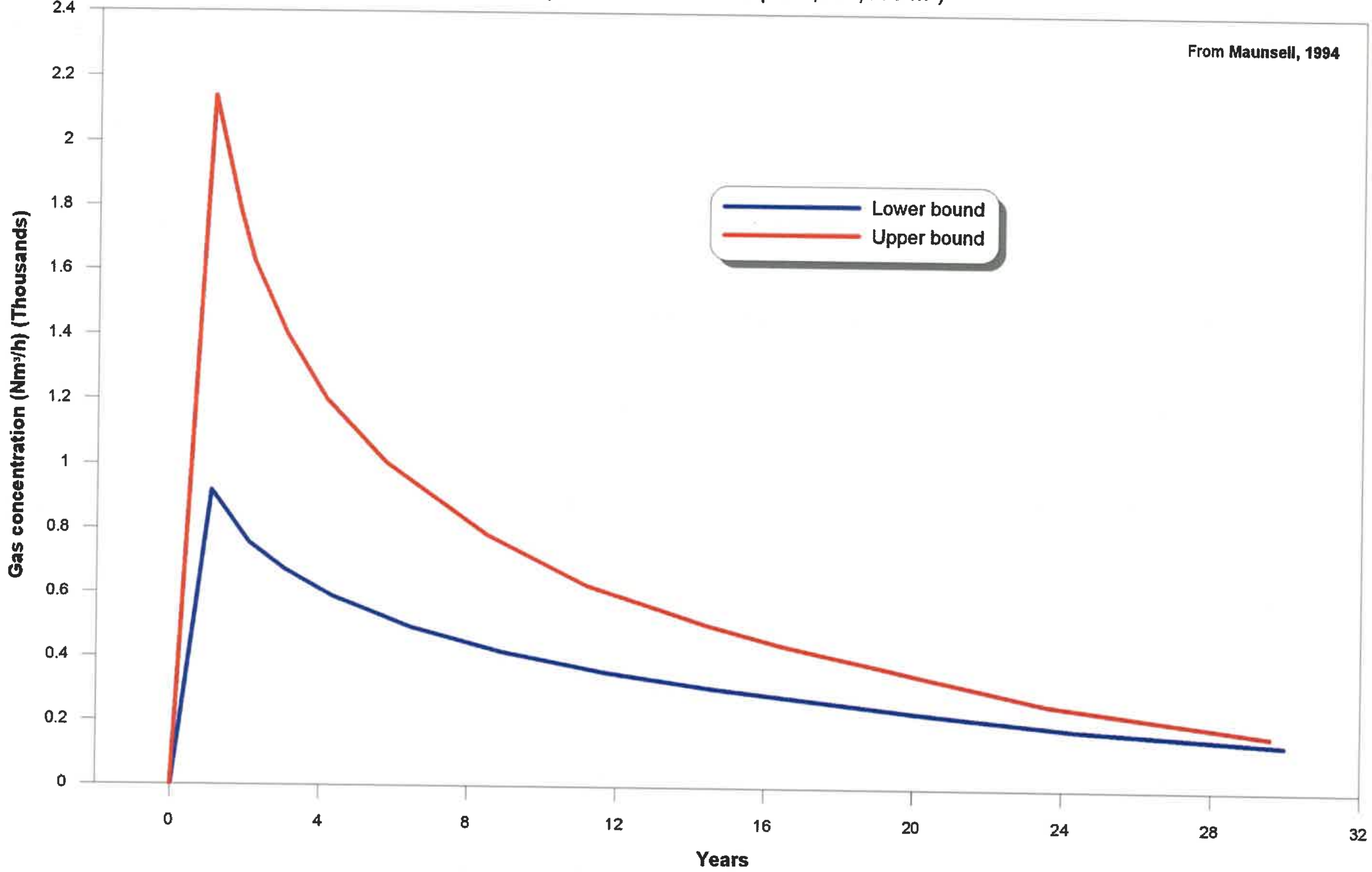


FIGURE 10

MGA Zone 56 (GDA 94)

Predicted 99th percentile nose-response odour levels (odour units)

Assumptions:
Total capped area size = 22 ha
1% of solid waste Class 2 average odour emissions
Cover active tipping face at 450 m^2
Greenwaste composting area at 5,000 m^2