REVISED ASSESSMENT OF ODOURS FROM PROPOSED ALLAWUNA LANDFILL

Prepared for

Bowman and Associates

by

ENVALL

Environmental Alliances Pty Ltd

March 2015

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1. INTRODUCTION

ENVALL has been engaged by Bowman and Associates to undertake an odour impact assessment of for a proposed Class II or Class III putrescible waste disposal landfill in Allawuna in the Shire of York.

The proposed location is shown in Figure 1. The York township is approximately 15 km to the east. Access is from Great Southern Highway which is a little over 2 kms north of the site at its closest point.

The landfill is proposed to receive between 150,000 and 250,000 tonnes of Municipal Solid Waste (MSW) and Commercial and Industrial waste per annum. The initial design is for a total volume of approximately 5,600,000 m^3 over a 20 year operating period.

This report describes the results of a study to estimate the level of odours from the proposed Landfill. The assessment is based on the Landfill operations at a maximum capacity of 250,000 tonnes of waste per annum.

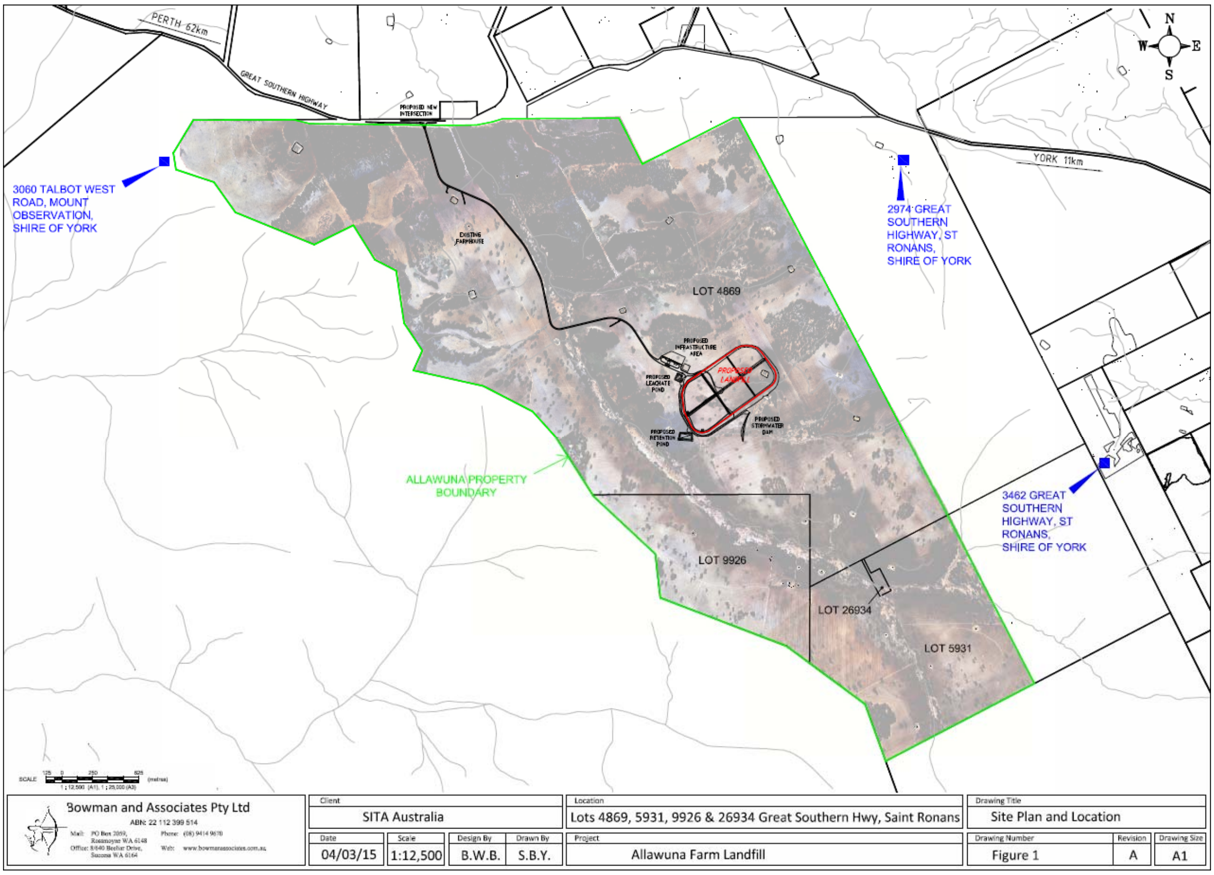

Figure 1 Location of proposed Allawuna Landfill

2. NEAREST RESIDENTS AND SENSITIVE LAND USES

The EPA Guidance Note 3 – "Separation Distances between Industrial and Sensitive Land Uses" lists minimum separation distances between industry and sensitive land uses. The Guidance Note 3 states that a putrescible landfill site (class II or III) must have a buffer distance of at least 500 m to the nearest sensitive land use such as subdivision(s), a 150 m buffer for single residences and an internal 35 m from the facility's own boundary.

There are very few residences within the immediate vicinity of the site – the nearest being approximately 1.8 km north-east of the proposed landfill footprint. The Mount Observation Picnic Area at is approximately 8 kms west-south-west of the site.

Therefore the minimum separation distance to sensitive land uses specified by the EPA's Guidance Note is easily met for the proposal.

3. PROPOSED LAYOUT

The proposed layout of the operation is shown in Figure 2. Also shown on the figure is:

- a leachate collection pond just outside the north-west corner of the landfill footprint toe, used for the collection of water that comes into contact with the waste;
- a retention pond outside the south-west corner of the landfill footprint toe, used for the collection of water from subsurface drainage and clean water outside the working area of the landfill; and
- a stormwater dam for the collection of stormwater diversion run-off on the south side of the footprint.

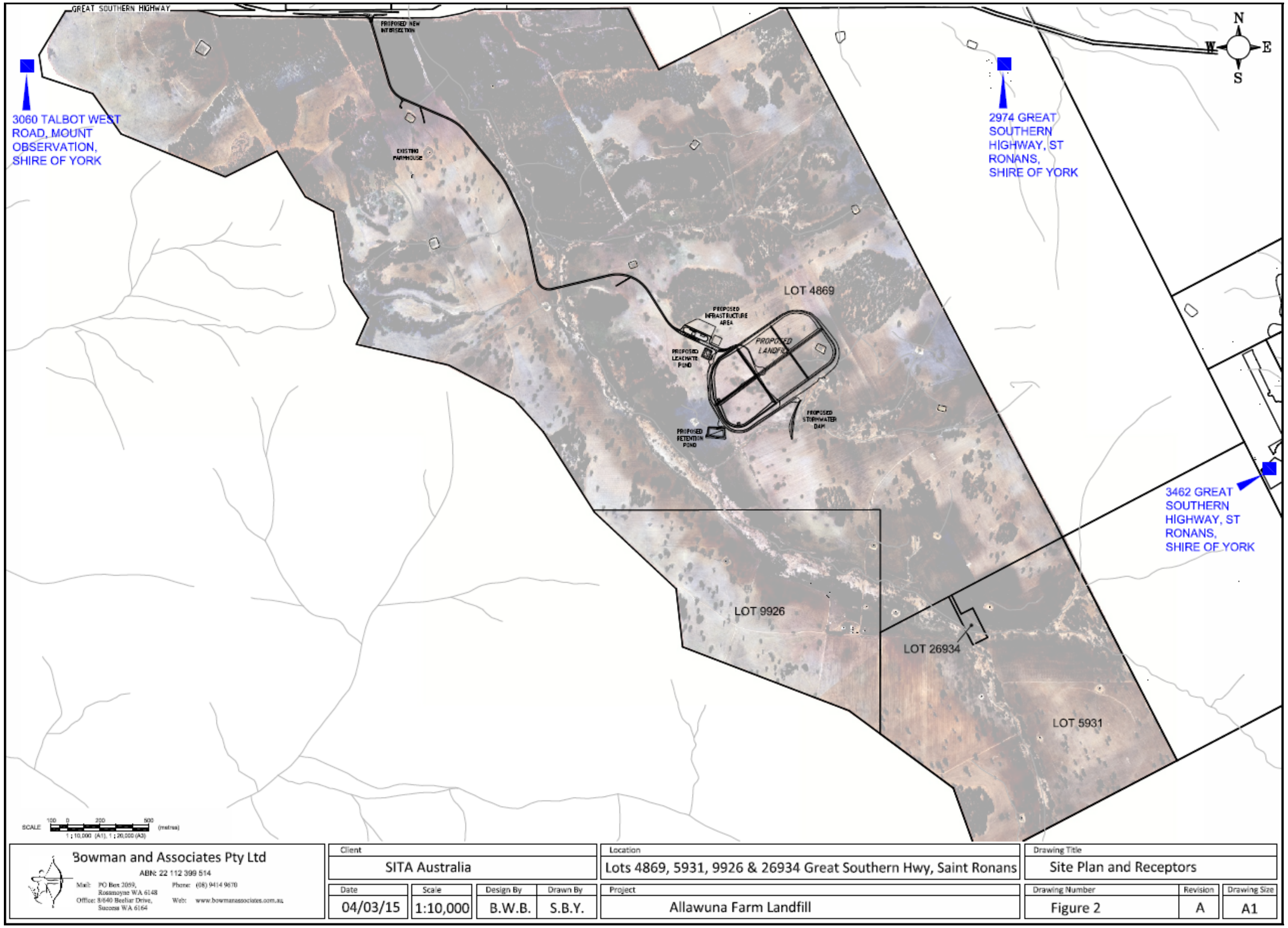

Figure 2 Landfill site layout

Note: Nearest residence at 2974 Great Southern Highway.

4. OPERATION

Details of the proposed Allawuna Landfill’s operation are described in other documentation.

The landfill will be required to be conducted and operated in accordance with current practices and specifications approved by the Department of Environmental Regulation (DER).

The following aspects are relevant from an odour management perspective.

Landfill Cover

An essential part of landfilling operations is the placement of cover over wastes. The purpose of cover is to mitigate against environmental or health impacts including:

- minimising landfill odours;
- controlling litter;
- preventing the spread of fire;
- controlling disease vectors such as birds, flies, mosquitoes and rodents;
- ensuring that the landfill is trafficable;
- limiting infiltration of water; and
- minimising emission of landfill gas.

Cover material

- The cover material will typically be soil or biodegradable sheeting.
- At least two weeks cover material will be available at the waste facility under all weather conditions.

Cover stockpile

- A cover stockpile will be maintained adjacent to the tip face at all times.
- There will be enough cover material in the stockpile to cover waste in accordance with the above-mentioned requirements.

Management of tipping area during waste receival

- The tipping area will be restricted to a maximum linear length of 30 m.
- The tipping area will not be greater than 2 m in height.
- Waste will be progressively covered to maintain the length of the active tipping area at less than 30 m.
- If odorous loads are received, these are buried amongst existing waste as soon as possible.

Note that “covering” means that the waste is totally covered with cover material so that no waste is left exposed.

Daily covering

- Waste will be covered at the end of every day to a minimum cover thickness of 300 mm.
- The daily cover may be scraped back before additional waste is placed on top and if this occurs, the daily cover will then be stored for reuse.

Intermediate Cover

- Intermediate cover material will be applied to a depth of 300 mm over surfaces that will be exposed for more than 90 days.
- To promote water runoff while the intermediate cover is exposed (and also when buried), the cover will be graded at a minimum slope of 2% away from the void face. This will also limit the potential for build up of leachate against the void face.
- When active landfilling is to be recommenced over an area previously capped with intermediate cover, the intermediate cover will be stripped off to the degree practicable or ripped in order to minimise the potential for a perched leachate level to subsequently develop over the intermediate cover. Where intermediate cover is not fully stripped back, the edge of the cell along the void face will be ripped to allow free drainage of leachate. Additional windows will be cut in the intermediate cover also to allow through flow of water.
- Wherever cover has been shifted due to strong winds, a reapplication of cover is required in order to maintain appropriate waste coverage.

4.1 WASTE TRANSPORT

For a design maximum operation rate of 250,000 tonnes/year, the majority of waste received at the landfill will be transported from the Welshpool transfer station at its maximum capacity using approximately 30 road trains per day. These will be purpose-built fully enclosed waste transport vehicles designed to minimise odour.

There will also be a small number of collection trucks from the local area received - likely 1-4 per day.

4.2 OPERATING HOURS

The facility will be operated from 7 am to 5 pm Monday to Friday and from 7 am to 4 pm on Saturdays. The Saturday schedule will be followed for public holidays but will remain closed for Christmas Day and Good Friday.

4.3 ODOUR SOURCES

The key odour-emitting sources are considered to be:

- the working tip face; and
- the Leachate Pond, used primarily for the collection of sub-surface leachate from the working area.

The retention pond will contain only clean water - with any contamination being removed to the Leachate Pond, and hence was considered to be a negligible odour source.

The stormwater dam is used for the collection of stormwater runoff from outside the landfill footprint and hence was similarly considered not to be an odour source.

5. ODOUR IMPACT ASSESSMENT

5.1 ODOUR MEASUREMENT

The basis for quantifying odour concentrations is “dynamic olfactometry”.

Dynamic olfactometry is the term used to describe the measurement of odour by presenting a sample of odorous gas to a panel in a range of dilutions and seeking a response from the panellists on whether they can detect the odour. The correlations between the known dilution ratios and the panellists’ responses are used to calculate the number of dilutions of the original sample required to achieve the odour detection threshold. The odour concentration of the sample is expressed in "odour units" (ou) - being the ratio of the volume which the sample would occupy when diluted to the odour threshold, to the volume of the sample.

An Australian Standard reflecting these procedures was published in 2001 (Standards Australia 2001).

5.2 ODOUR IMPACT ASSESSMENT METHODOLOGY

The approach recommended by the Department of Environmental Regulation (DER) to assess air quality impacts from industrial proposals is modelling the dispersion of air emissions as described of "Air Quality Modelling Guidance Notes" (DEP 2006) and comparing the predictions to criteria for acceptable impacts. With respect to odour more specifically, the DER has published an "Odour Methodology Guideline" (DEP 2002). The general approach for determining unacceptable odour impacts is:

1. estimating odour emissions rates from all odour-generating sources;
2. using a dispersion model to predict ambient odour levels over the course of a year; and
3. comparing predicted odour levels to criteria for acceptable impacts at residential areas.

In this document,

- the odour criteria are described in Section 6;
- the odour emissions rates for the proposed Allawuna Landfill's odour-generating sources are described in Section 7; these were primarily obtained from a sampling program of odours from the City of Cockburn's Henderson Landfill which is considered comparable in terms of capacity, waste and management practices to the Allawuna proposal site - the details of this are described in Appendix 1;
- the dispersion modelling and local meteorological data is described in Section 8; and
- the results from the dispersion modelling using the derived odour emissions rates compared to criteria for acceptable odour impacts at residential areas is described in Section 9.

6. ODOUR CRITERIA

The criteria currently used by the DER to assess acceptable odour impacts from new proposals is[1]:

- for sources other than wake-free stacks: C99.9,1hr=8ou[2] and C99.5,1hr=2.5ou; and
- for wake-free stacks: C99.9,1hr = 1.6 ou and C99.5=0.5ou.

The criteria applies at "odour-sensitive premises" which includes "residential, hospitals, hotels, caravan parks, schools, aged care facilities, child care facilities, shopping centres, play grounds, recreational centres etc" (DEP 2002).

[1] D Griffiths *pers com* 19/10/2012.

[2] Also used by EPA.

Since the odour emissions for this proposal are from fugitive sources (i.e. "other than wake-free, point source"), the relevant odour criteria are:

- C99.9,1hr=8ou; and
- C99.5,1hr=2.5ou.

As described previously, the nearest residence to the proposal is to the north-east of the facility, approximately1.8 km away.

7. ODOUR EMISSION RATES

7.1 EMISSIONS FROM WORKING FACE

The odour emissions from the proposed Allawuna Landfill's working face were derived from measurements made at the Henderson Landfill as described in Appendix 1.

The nature of the waste currently being received at Henderson is similar to that expected for Allawuna[3]. The Henderson Landfill's current operating capacity is 200,000 tonnes/year. For the maximum 250,000 tonnes per year capacity at Allawuna, the results from the Henderson sampling were scaled by 1.25.

The derived operational emission rate includes odour from waste receival and tipping, and site compaction which occur continuously while the site is receiving waste. For subsequent modelling of odours from the proposed Allawuna Landfill, the odour emissions from the working face were assumed to occur during the periods of waste receival as described in Section 4.2.

A background "site odour" was also determined from the Henderson sampling. For subsequent modelling of odours from the proposed Allawuna Landfill, this was applied outside the proposed landfill's waste receival hours.

7.2 LEACHATE POND

As described in Section 4.3, the proposed Allawuna Landfill includes a Leachate Pond to be used primarily for the collection of sub-surface leachate from the landfill.

It is not known with certainty whether this will be a significant odour source. It was considered by ENVALL that a reasonable assumption would be that an odour character similar to "stale water" may develop from this storage. An odour source with this characteristic is the tertiary treatment ponds from a waste water treatment facility. Sampling data from these at the Subiaco Waste Water Treatment facility was reported in CH2MHill (1997). The result from the sampling was $SOER_{0.1m,0.05m/s}$ = 1.6 ou.m^3/m^2/s. It was assumed that this would be appropriate for the Leachate Pond.

For modelling the dispersion of odour emissions, the surface area of the Leachate Pond was assumed to be the full extent of the capacity. Given that it is likely that the pond will rarely, if ever, be this full, the emissions will be over-estimated and therefore contribute to a "conservative" (i.e. over-estimation) of odour impacts from the proposal.

The hourly odour emission rate was adjusted for prevailing wind speeds as described in Appendix 1.

[3] B. Bowman, pers com.

7.3 SUMMARY OF EMISSIONS

The annual average odour emission rates from the sources modelled are shown in Table 1.

Table 1 Estimated annual average odour emission rates for proposed Allawuna Landfill odour sources

Source	Annual odour emission rate based on 2011 meteorology and waste receival times ($ou.m^3/s$)
Working face area[(a)]	80,574
Leachate Pond	16,682

(a) Includes all odours during waste receival and tipping, and site compaction.

An example time series profile of the total odour emission from the proposal is given in Figure 3. This illustrates the variation in odour emissions from prevailing winds as well as due to the periods of waste receival.

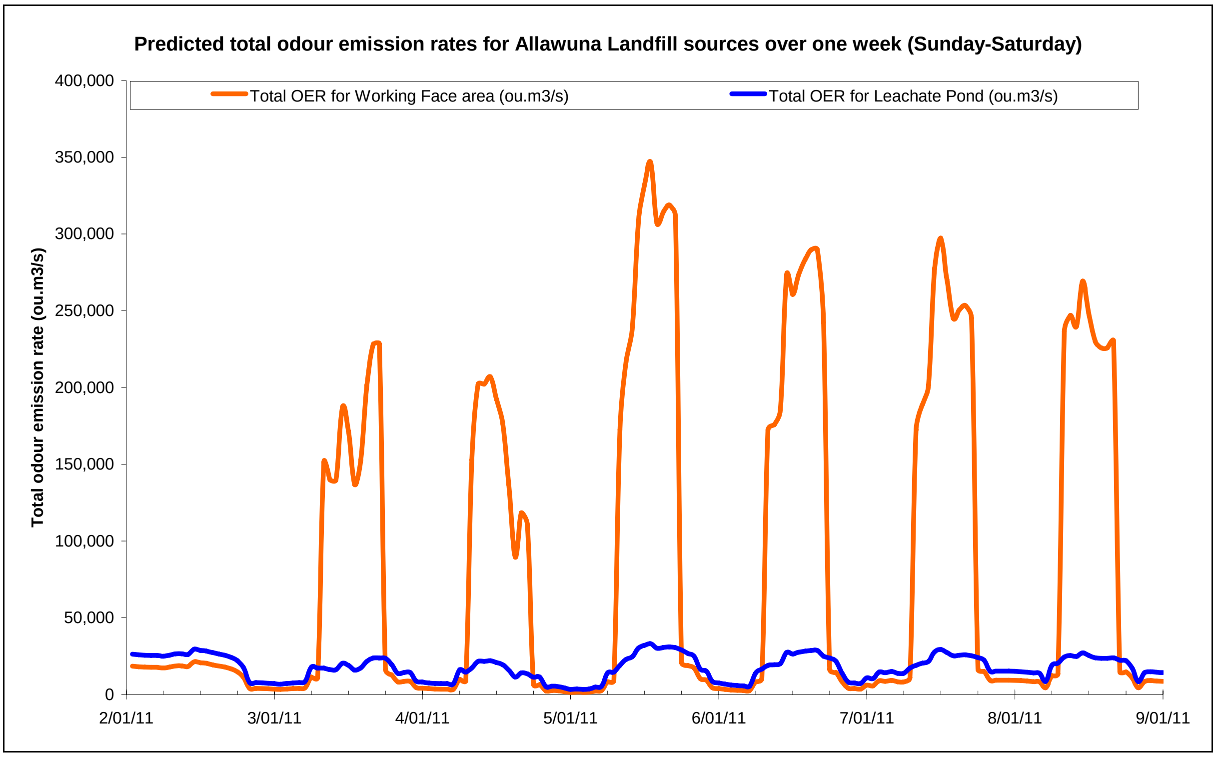

Figure 3 Example illustration of predicted total odour emission rates for Allawuna Landfill sources over one week

8. DISPERSION MODELLING METHODOLOGY

8.1 MODEL

The CALPUFF model (CALMET Version 6.3.3.3 and CALPUFF Version 6.4.2) was used for the dispersion modelling of odours from the proposed landfill.

This model has been adopted by the U.S. Environmental Protection Agency (USEPA) in its "Guideline of Air Quality Models" as the preferred model for assessing long range transport of pollutants and their impacts on Federal Class I areas and on a case-by-case basis for certain near-field applications involving complex meteorological conditions.

More specifically to this study, the Guideline (amongst other reasons) provides for the use of CALPUFF on a case-by-case basis for air quality estimates involving complex meteorological flow conditions, where steady-state straight-line transport assumptions are inappropriate.

Odour dispersion from a constantly-emitting ground level source is lowest and hence downwind odour concentrations highest, during stable, light wind conditions, which alternative gaussian dispersion models such as AUSPLUME handle poorly.

There are also significant topographical changes in the vicinity of the proposed landfill, which would lead to complex wind flows.

The CALPUFF modelling system consists of three main components; CALMET - a diagnostic 3-dimensional meteorological model, CALPUFF - an air quality dispersion model, and CALPOST - a post-processing package. Full details are described in the model's documentation (see http://www.src.com/calpuff/calpuff1.htm).

8.2 GRID DOMAIN

The meteorological grid defined for modelling odour from the proposed landfill comprised 56 x 56 cells with a 100 m resolution. This gave a domain size of approximately 5.5 km east-west by 5.5 km north-south.

8.3 GENERAL SETTINGS

Key assumptions used for modelling included:

- dispersion coefficients calculated from micrometeorological parameters;
- minimum sigma-v (over-land) set to 0.4 m/s to be consistent with recent recommendations for the AERMOD model (AECOM Environment, 2010) - this slightly increases predicted concentrations compared to the default sigma-v of 0.5 m/s; and
- terrain effects on dispersion included.

Details of other CALPUFF settings used for modelling odours from the proposal are shown in Appendix 2.

8.4 ANNUAL METEOROLOGICAL DATA

Surface meteorological data for annual modelling of odour emissions was derived primarily from the TAPM model with slight modifications based on a comparison with measured winds at Muresk, as described in Appendix 2. A wind frequency occurrence rose and matrix for the 2011 year from these data is shown in Figure 4. Seasonal and time-of-day roses are also shown in Appendix 2.

In brief, the main prevailing winds are from the east to south-east, with winds more frequent from the south-west and north-west in the afternoons and in winter respectively.

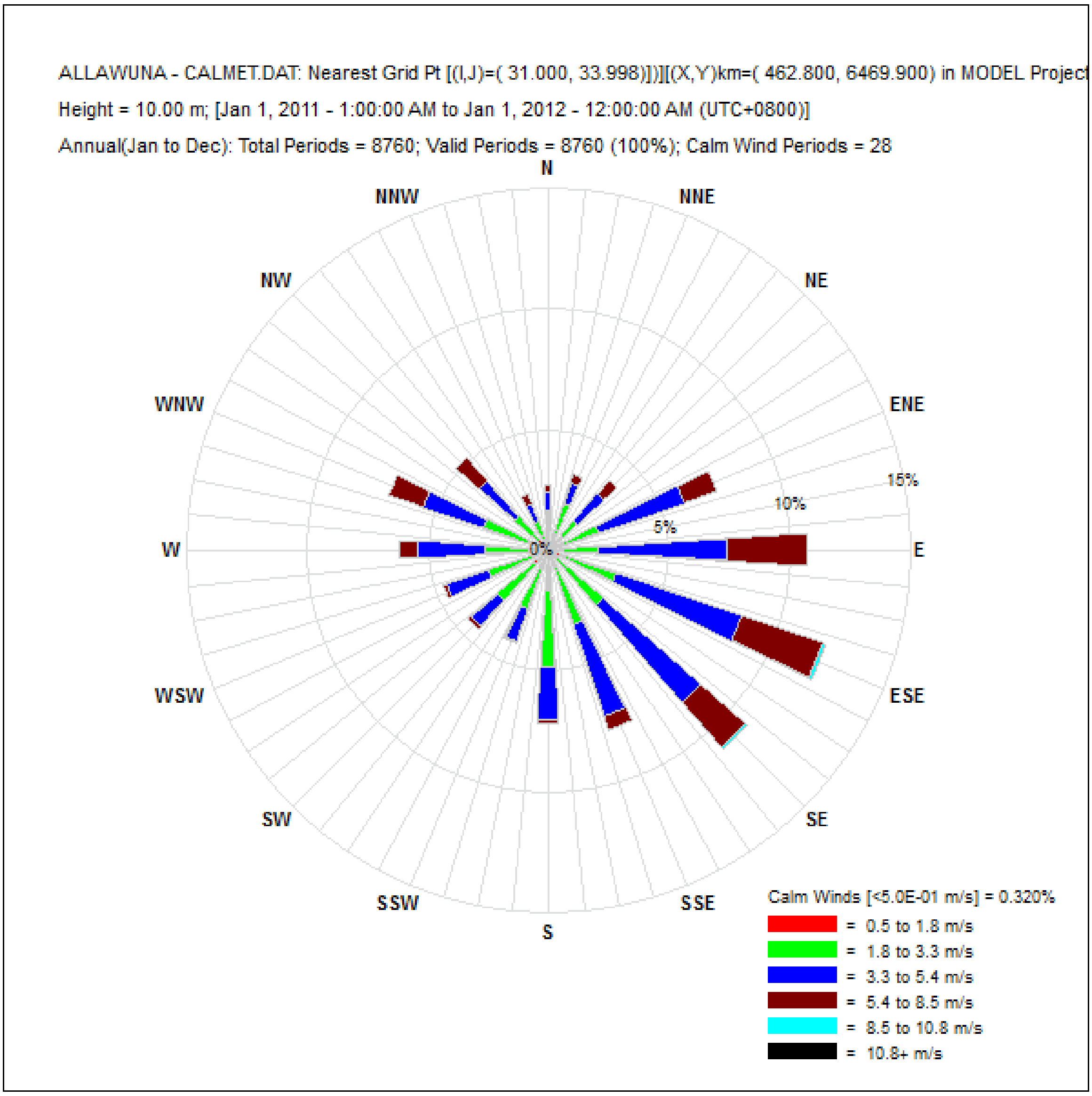

Figure 4 Predicted wind frequency occurrence rose at 10 metres for Allawuna site 2011

8.5 STABILITY DISTRIBUTIONS

Stability is a useful indicator of the turbulence characteristics of meteorological data use for modelling. The annual CALMET predicted stability distributions (based on two classification schemes) are shown in Table 2. The PG scheme is used by CALPUFF for the option of predicting dispersion using the Pasquil Gifford estimates of plume spread. The Golder (1972) relationship is more indicative of the dispersion calculated within CALPUFF if the micrometeorology scheme for determining dispersion (based on turbulence parameters), is selected.

For low-buoyancy near-surface releases, the distribution of D to F is the most important issue for far-field dispersion. The CALMET PG and Golder stability distributions are very similar through these categories indicating the modelling predictions should be relatively insensitive to the choice of dispersion schemes.

Table 2 Estimated stability distribution at Allawuna for 2011

Stability Class	From CALMET using PG scheme	From CALMET using Golder (1972) scheme based on L and Z0
A	1.2	4.6
B	7.7	4.9
C	16.6	14.9
D	33.2	37.4
E	15.3	15.5
F	26.0	22.6

9. PREDICTED ANNUAL ODOUR LEVELS FOR COMPARISON TO CRITERIA

9.1 MODELLING RESULTS

In order to compare the modelling predictions to the DER's criteria (as in Section 6), the 8,760 1-hour average concentration values predicted by the CALPUFF model at each grid point over a year, are ranked from highest to lowest. The 99.5 percentile is the 44th highest ranked concentration. The 99.9 percentile is the 9th highest ranked concentration. The predicted 1-hour average concentrations at each gridded receptor for each percentile, may then be contoured using a computer software package to draw continuous lines of equal concentrations. The software interpolates the concentrations required for the contours as selected by the user between the values predicted at each discrete grid point. The 2.5 ou or 8 ou contour shows the extent from the source within which the DER's criterion is exceeded. Areas outside these contours have odour levels less than the criterion.

The process is the same as determining contours for other air quality criteria except that the percentiles and concentrations are varied accordingly.

The extent of the predicted odour concentrations against the criteria are shown in Figure 5. It is clear that the odour impact predicted for the proposed Allawuna Landfill easily meets both forms of the DER's criteria.

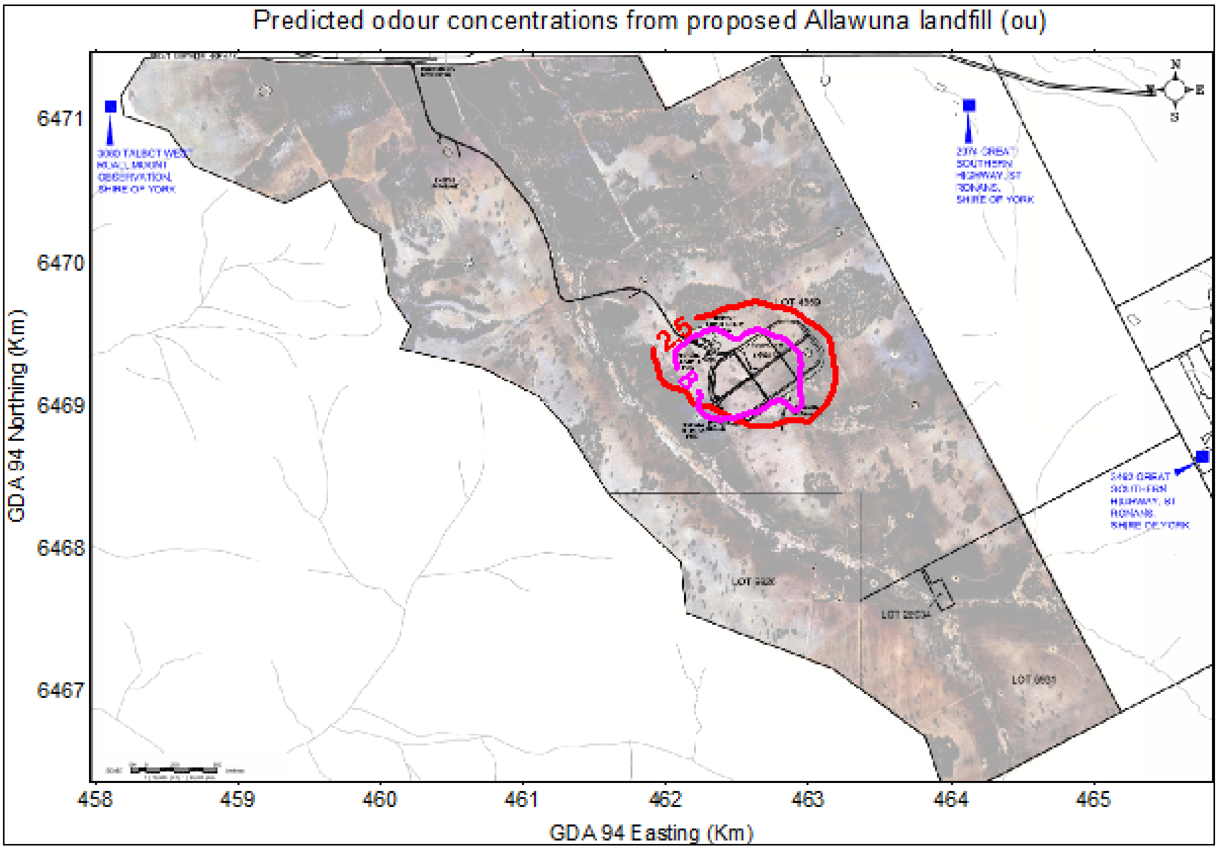

Figure 5 Extents of odour impacts using various criteria from proposed Allawuna Landfill

Notes:

Landfill footprint, cells and infrastructure outlines shown as black lines.

Odour criteria: 2.5 ou, 1- hour average, 99.5 percentile shown in red; 8 ou, 1- hour average, 99.9 percentile shown in pink.

Nearest residence is at 2974 Great Southern Highway (blue square).

9.2 QUALIFICATIONS AND UNCERTAINTIES

The largest uncertainty is considered to be the odour emission rates. These were determined from odour emissions at the Henderson landfill, which is similar in capacity to the final capacity at Allawuna, and in terms of waste being received.

It is considered that the odour emissions rates used for modelling odour impacts from the proposed Allawuna Landfill should be conservative because:

- the odour emissions sampled from Henderson were after a prolonged period of hot weather in Perth, therefore the putrescible waste being received was in a more advanced state of decomposition – and more odorous, than for average temperatures. The use of a “summer-time” odour emissions rate year-round at Allawuna should be an over-estimate;
- comparisons with the odour emission rates derived with those from other sites in Perth and from values derived overseas indicates that the odour emission rate used for Allawuna is at the high end of these values; and
- the Leachate Pond is assumed to be at its continuous maximum capacity.

Uncertainties that could result in the criterion odour contour being larger than predicted include:

- management practices deteriorating from those assumed; and
- poor integrity of the landfill gas capture system to be installed.

These matters are, however, subject to regulatory controls.

Given there is a wide margin between the most stringent of the predicted extent of the unacceptable odour impacts and the location of odour-sensitive premises (i.e. nearly 2 kms), there should be considerable confidence that the proposed Allawuna Landfill, if operated according to the assumed management practices, will not cause unacceptable odour impacts.

10. GLOSSARY OF TERMS

"BoM" means Bureau of Meteorology.

"DER" means Department of Environmental Regulation (WA).

"EPA" means Environmental Protection Authority (WA).

"hr" means hour.

"Kg" means kilograms.

"km" means kilometres.

"m/s" means metres per second.

"m" means metres.

"m^2" means square metres.

"m^3/s" means cubic metres per second.

"m^3" means cubic metres.

"min" means minute.

"°C" means degrees Celsius.

"OER" means odour emission rate with units of ou/s.

"ou" means odour units. An odour unit is a dimensionless ratio defined as the volume which an odorous sample would occupy when diluted to the odour detection threshold, divided by the volume of the odorous sample.

"$ou.m^3$" means odour units multiplied by the associated volumetric flow with units of m^3. When used as the emissions term in a dispersion model, the predicted ambient concentrations per cubic metre cause the volume units to cancel out to give odour units (the dimensionless ratio of the odour concentration to the odour threshold concentration).

"ou/s" means odour units per second.

"Percentile" means the division of a distribution into 100 groups having equal frequencies.

"s" means seconds.

"SOER" means odour emission rate (SOER) being the unit area odour emission rate from a surface for the prevailing wind or sweep air conditions, and having units of $ou.m^3/m^2/s$.

"t/hr" means tonnes per hour.

"t" means tonnes.

"tpa" means tonnes per annum.

"USEPA" means United States Environmental Protection Agency.

"°C" means degrees Celsius.

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Appendix 1 Estimation of odour emission rates from Henderson Landfill

The measurement of odour emissions from any landfill is not a straight-forward exercise. Unlike air emissions from chimney stacks which are "contained" before release and therefore easily sampled, odour emissions from a landfill are "fugitive" in nature. This means that they are released from open, uncontained sources such as garbage prior to burial, decomposing garbage that has been buried and liquid effluent ponds. The odour emissions rates may differ at various locations from the same general source and the physical extent of such sources is poorly defined.

The only available technique for estimating emissions from such sources is to measure and/or estimate odours downwind from a source during specific wind and meteorological conditions, then using a computer dispersion model to "back-calculate" what the emissions from the source must have been at that time in order to disperse.

The client has advised that the Henderson Landfill is similar to that proposed for Allawuna.

A field odour sampling program was consequently undertaken around the Henderson Landfill on 28 March 2011 for the purpose of determining odour emissions from the Landfill.

The program including taking five samples of ambient air for odour measurement using dynamic olfactometry following the Australian Standard. From previous experience, odour measurements from samples of ambient air often return ambiguous results because the bags used to collect the sample return a low "background" odour and the source odour is too low to give a meaningful measurement above the background odour – even though the source odour may be easily perceived while the sample was being taken. Therefore one sample was taken upwind to determine the "background" level of odour in a sampling bag.

Field odour assessments were also undertaken since a large number of assessments can be easily made at the most relevant locations (ie downwind of the source(s) following wind direction changes).

1.0 FIELD ODOUR SURVEY OF LANDFILL SITE

1.1 METHODOLOGY

The approach used for field odour assessments is derived from the German Standard "Determination of Odorants in Ambient Air by Field Inspections" (VDI 1993).

In brief, this technique involves one or more assessors sniffing the air and rating the odour strength downwind of a source according to a scale that correlates with the odour concentrations for that type of odour and recording the results. This is repeated each 10 seconds for three minutes at the same location. The process is then repeated for different locations downwind of the source to, as far as possible, obtain data both laterally and downwind through the "odour plume".

1.2 FIELD ODOUR ASSESSOR CHARACTERISTICS

The key characteristics of suitable field odour assessors are:

- aged between 18 and 55 years old;
- are in good health and not suffer from any illnesses or allergies which impairs olfactometry sense;
- maintain an appropriate level of personal hygiene including being a non-smoker;
- are independent of subjective bias and diligent in their approach; and
- have a normal olfactometry response as confirmed by a suitable test.

Two assessors meeting the criteria above were used in this study. A summary of their odour test results is given in Appendix 1A. Both assessors are within the range of normal sensitivity to butanol (used as a test odorant), albeit at the high end of the range (ie. towards high sensitivity).

1.3 AMBIENT CONDITIONS FOR FIELD ODOUR SURVEYS

For constant emissions from a ground-level source, ambient odour concentrations should be greatest during the night and early morning. This is because these periods are usually have light winds and stable atmospheric conditions which cause the dispersion of low-level emissions to be poor, and hence concentrations to be high.

The Landfill's odour emissions are, however, not constant since the rubbish is covered at the end of each day. The emissions arise primarily following the start of each day as waste is delivered then vary according to activity at the working face – trucks delivering waste, dozing and compaction.

The early morning was selected as being most appropriate time period.

The field odour survey was therefore undertaken between about 0630 hours to 1100 hours on 28 March 2008 when predicted winds were in a direction to enable access to locations suitable for safely sampling the downwind odour plume.

The Landfill was receiving waste from trucks after about 0700 hours.

1.4 SELECTION OF LOCATIONS FOR FIELD ASSESSMENTS

Assessment locations were mostly about 50 to 200 m downwind of the working face. The locations were changed as necessary in response to changes in wind direction.

1.5 ODOUR RATING TECHNIQUE

At each assessment location, the odour "intensity" ranking was recorded every 10 seconds over a 3-minute (typically) period. Preferably, a 10 minute period is used but this would have prevented adequate coverage of sufficient downwind locations within a reasonable time period encompassing similar wind conditions.

Intensity levels are qualitative descriptions of an odour sensation and are defined numerically in the German standard "Olfactometry – Determination of Odour Intensity" (VDI 1992), as indicated in Table A1-1.

Table A1-1 Odour intensity categories

Odour strength	Intensity level
Extremely strong	6
Very strong	5
Strong	4
Distinct	3
Weak	2
Very weak	1
Not perceptible	0

In the interpretation of odour strengths, the “distinct” level is that at which the odour character (eg rose, septage, coffee etc) is clearly recognisable. An odour must be at or above the distinct level if it is to recognised as an “offensive” odour and therefore possibly cause annoyance.

1.6 METHOD FOR CALCULATING ODOUR CONCENTRATIONS

Odour concentrations can be calculated for each intensity recorded over the assessment period using the Weber-Fechner relationship as described in DEP (2002):

$$I = m \, Log(C) + b \qquad \textbf{Equation 1}$$

Where-

I = Odour intensity;

C = Odour concentration;

m = Odourant-specific Weber-Fechner constant (slope); and

b = Intercept constant (the odour threshold, theoretically = 0.5),

which can be also be expressed as:

$$C = 10^{(I - b)/m} \qquad \textbf{Equation 2}$$

An estimated average odour concentration can be calculated from the arithmetic mean of the concentrations calculated from each intensity observation over the averaging period.

The distinct odour concentration (DOC) is the odour concentration corresponding to an intensity of 3 and is a useful parameter for interpreting the effect of Equation 1 for different odourants. For example, the EPA (2002) determined that the DOC for poultry odours was 7 ou.

2.0 RESULTS FROM FIELD ODOUR SURVEY

2.1 METEOROLOGICAL DATA

The prevailing weather conditions over the morning of 28 March 2011 were:

- essentially clear sky (very light high cloud); and
- light winds initially from the south east then from the south becoming variable before strengthening from the south-west.

Actual on-site winds were measured using a portable anemometer on a 4 metre mast. The 1-minute average data is illustrated in Figure A1-1.

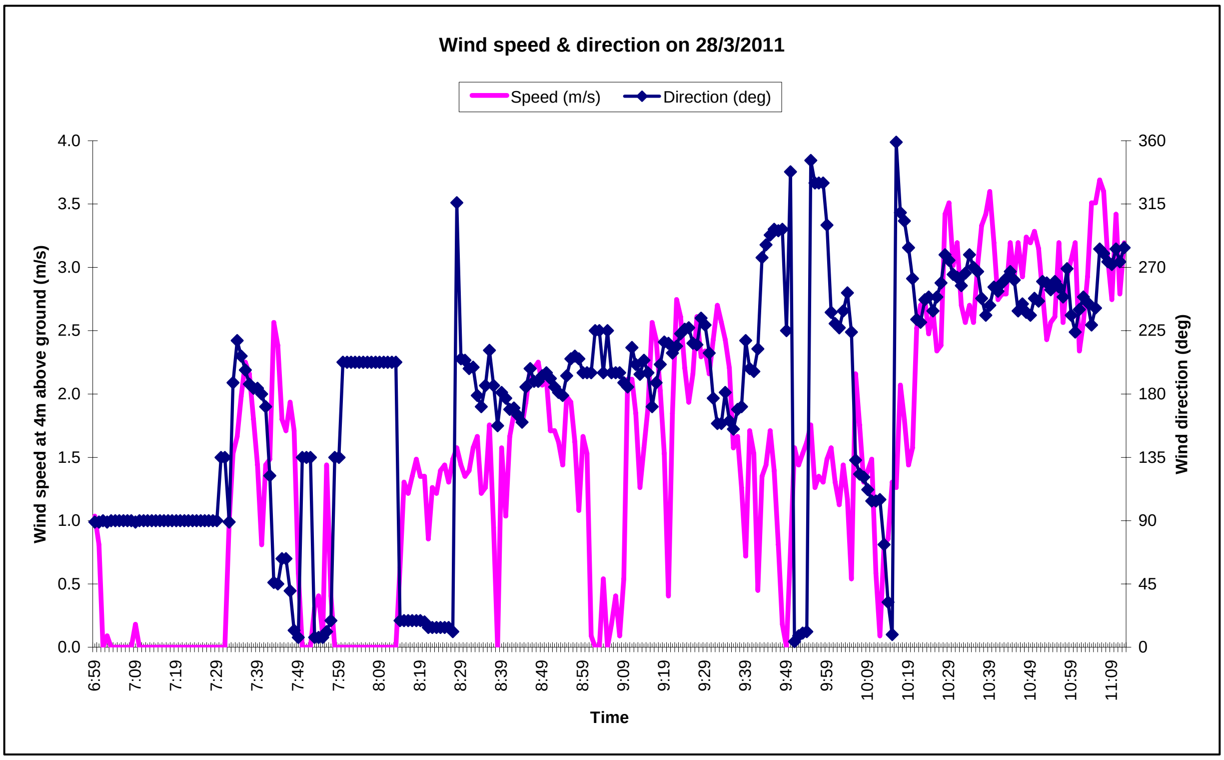

Figure A1-1 Wind speed and direction measured at Henderson Landfill during field survey period

2.2 ODOUR CHARACTERS

There were at times, numerous different types of odours from the Landfill area depending on the nature of waste being delivered at various times. The predominant odour character by far however, was garbage ("rubbish bin") odour from the site generally. Some minor, localised, landfill gas odours could be detected around some of the landfill gas recovery piping, however these areas were avoided for the purpose of the odour assessment.

Field observations of odour intensities need be converted odour concentrations - ultimately for the purpose of assessing off-site odour levels against criteria for acceptable odour impacts.

This can be done using Equation 1 together with assumptions of the slope ("m") for the relevant odour type in this case, garbage.

The DOC for municipal garbage odour has previously been estimated from a Perth waste sorting facility as 10 ou (EA 2006). This value was adopted for this study. The equation used to estimate odour concentrations from observed odours was, therefore:

$$C = 10^{(I - 0.5)/2.5}$$ **Equation 3**

2.3 CALCULATED FIELD ODOUR CONCENTRATIONS

The results of the field odour survey are shown in Table A1-2. The highest estimated 3-minute average concentrations were around 40 ou at about 100 m from the centre of the site. These tended to coincide with a substantial increased activity on the site in terms of truck waste deliveries and dozer compaction of the tipping area, around mid-to-late morning.

Table A1-2 Estimates of odour concentrations from field assessments on 28/3/2011

Distance from approx centre of working face (m)	Start time of assessment [a]	Assessment Location		"Garbage" odour					
				Cumulative percentage of observations in 3 minute period ≥ I (%)					Avg est. odour conc (ou)
		GDA94 (mE)	GDA94 (mN)	I≥1	I≥2	I≥3	I≥4	I≥5	
186	06:31	386327	6440850	78	44	11	0	0	3.5
155	06:35	386327	6440900	6	0	0	0	0	0.1
136	06:40	386327	6440950	0	0	0	0	0	0.0
134	06:44	386327	6441000	0	0	0	0	0	0.0
136	06:50	386327	6440950	0	0	0	0	0	0.0
155	06:55	386327	6440900	28	11	0	0	0	0.8
186	06:59	386327	6440850	44	0	0	0	0	0.9
155	07:03	386327	6440900	28	0	0	0	0	0.5
186	07:08	386327	6440850	0	0	0	0	0	0.0
155	07:13	386327	6440900	0	0	0	0	0	0.0
63	07:15	386400	6441000	67	61	22	0	0	4.0
136	07:20	386327	6440950	0	0	0	0	0	0.0
63	07:20	386400	6441000	44	17	6	0	0	1.4
60	07:23	386400	6440975	78	56	28	0	0	4.7
155	07:25	386327	6440900	44	11	0	0	0	1.0
186	07:30	386327	6440850	78	11	0	0	0	1.6
60	07:32	386400	6440975	100	83	50	11	0	8.3
224	07:35	386327	6440800	0	0	0	0	0	0.0
63	07:36	386400	6441000	100	83	39	0	0	5.9
186	07:40	386327	6440850	39	0	0	0	0	0.6
75	07:40	386400	6441025	100	94	83	39	0	17.2
75	07:43	386400	6441025	100	72	22	6	0	5.5
155	07:45	386327	6440900	83	56	39	0	0	5.6
63	07:47	386400	6441000	61	44	0	0	0	2.0
186	07:51	386327	6440850	50	11	6	0	0	1.4
224	07:55	386327	6440800	100	100	78	28	0	14.6
63	07:56	386400	6441000	100	100	78	22	0	13.8
186	08:00	386327	6440850	100	89	17	0	0	4.8
63	08:07	386400	6441000	78	50	28	0	0	5.1
63	08:10	386400	6441000	89	61	17	0	0	3.9
155	08:14	386327	6440900	11	0	0	0	0	0.2
63	08:16	386400	6441000	94	94	83	11	0	12.7
186	08:19	386327	6440850	0	0	0	0	0	0.0
224	08:23	386327	6440800	0	0	0	0	0	0.0
60	08:23	386400	6440975	94	89	72	17	0	12.1
60	08:27	386400	6440975	83	50	17	6	0	4.4
186	08:28	386327	6440850	0	0	0	0	0	0.0
155	08:33	386327	6440900	0	0	0	0	0	0.0
63	08:34	386400	6441000	61	61	22	0	0	3.8
136	08:38	386327	6440950	0	0	0	0	0	0.0
134	08:43	386327	6441000	0	0	0	0	0	0.0
75	08:44	386400	6441025	100	100	83	0	0	10.6
150	08:48	386327	6441050	0	0	0	0	0	0.0
92	08:53	386400	6441050	94	67	11	0	0	3.8
112	09:03	386400	6441075	67	33	0	0	0	1.9
96	09:07	386450	6441075	94	56	17	6	0	4.7
101	09:10	386425	6441075	100	83	78	11	0	11.9
112	09:12	386400	6441075	83	0	0	0	0	1.6
101	09:15	386425	6441075	100	100	78	78	11	28.9
112	09:17	386400	6441075	89	22	6	0	0	2.4
96	09:19	386450	6441075	100	100	83	67	11	26.1
101	09:23	386425	6441075	89	72	39	17	0	8.0

Distance from approx centre of working face (m)	Start time of assessment [(a)]	Assessment Location		"Garbage" odour					
				Cumulative percentage of observations in 3 minute period ≥ I (%)					Avg est. odour conc (ou)
		GDA94 (mE)	GDA94 (mN)	I≥1	I≥2	I≥3	I≥4	I≥5	
96	09:25	386475	6441075	100	100	100	83	33	41.0
115	09:27	386525	6441075	100	94	78	6	0	9.4
103	09:29	386500	6441075	100	100	100	65	24	32.7
131	09:31	386550	6441075	78	22	0	0	0	1.8
96	09:34	386475	6441075	100	100	72	11	0	12.3
96	09:38	386450	6441075	100	61	50	28	0	11.4
115	09:38	386525	6441075	83	39	11	0	0	3.1
115	09:41	386525	6441075	72	6	0	0	0	1.3
101	09:42	386425	6441075	100	61	22	6	0	5.7
103	09:45	386500	6441075	100	100	88	0	0	9.3
96	09:48	386450	6441075	78	33	22	6	0	4.5
115	10:41	386525	6441075	100	100	100	72	0	23.5
96	10:41	386525	6441050	100	83	78	33	0	14.5
79	10:44	386525	6441025	100	100	94	56	0	20.0
103	10:45	386500	6441075	100	100	78	28	6	17.2
72	10:48	386525	6440950	100	89	78	78	0	21.8
96	10:49	386475	6441075	100	100	56	28	0	13.4
103	10:52	386525	6440900	78	56	28	0	0	4.5
96	10:53	386450	6441075	17	0	0	0	0	0.3
123	10:55	386525	6440875	94	67	50	0	0	6.2
96	10:57	386475	6441075	89	78	56	39	0	13.8
85	10:59	386525	6440925	100	100	83	6	0	13.4
103	11:01	386500	6441075	100	100	100	67	28	35.6
68	11:02	386525	6441000	100	100	100	39	0	18.5
115	11:05	386525	6441075	100	100	89	56	0	21.7

[(a)] Note that the odour assessments were discontinued from about 0950 to 1030 when the wind direction became too variable to reliably determine appropriate locations for downwind assessments.

Figure A1-2 gives a general overview of the downwind odour assessments. The field assessment locations are shown as pink crosses. The locations for the collection of the odour samples with sample reference and times are shown as pink crosses. Also shown is the location of working face and an example downwind odour profile 0900-0940 hours when the wind was southerly. This shows for example an average[4] peak odour concentration of about 30 to 35 ou over that time period, about 100 m from the working face area.

[4] That is, where there were more than just a single 3-minute assessment at a particular location, these odour concentrations were then averaged for that location.

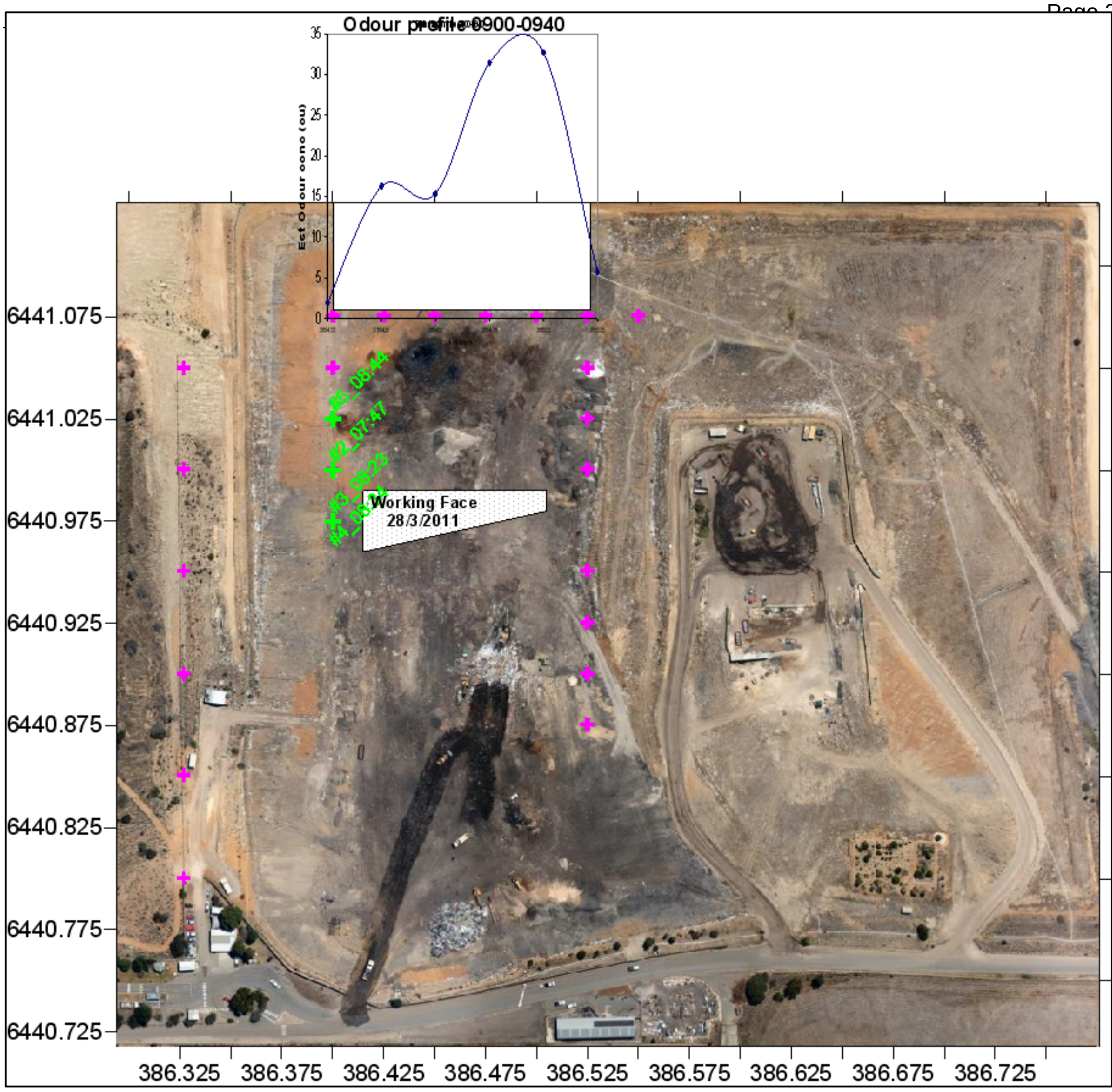

Figure A1-2 Location of working face, field odour assessments, odour sample collection and example downwind odour profile

Notes:

Pink crosses show locations of field odour assessments.

Green crosses show locations where odour sample were taken, the sample # and time the sample was taken.

Example concentration profile over 0900 to 0940 hours is shown at the northern line of field odour assessment locations.

2.4 ODOUR SAMPLES

Five samples of ambient air were taken during the odour assessments for odour measurements following the Australian Standard 4323.3. The first sample was well upwind from the Landfill with no odours from the Landfill detectable at any time. The other four samples were taken downwind of the working face at times when the odour from the face were relatively high.

The results of these compared to the estimated odour from field assessments at the same time and location (for the downwind samples) are shown in Table A1-3 (Laboratory reports are shown in Appendix 1B).

Table A1-3 Comparison of odour measurement from sampling and field estimated concentration

Sample ref	Start time (Date 28/3/2011)	GDA94 (mE)	GDA94 (mN)	Results from field assessments (ou)	Odour Laboratory conc from sampling (ou)
EA#1 - Background upwind of Landfill (SE cnr Moylan/Russel Rds)	0600	386900	6441800	Nil	<16
EA#2	0747	386400	6441000	5.5, 2.0, 13.8 Avg=7.1	<16
EA#3	0823	386400	6440975	3.9, 12.7 Avg=8.3	<16
EA#4	0834	386400	6441000	3.8	<16
EA#5	0844	386400	6441025	12.7	<16

For all samples, the laboratory result was below the method detection limit of 16 ou. (It is noted that the comments on the laboratory's sampling sheets confirmed that the garbage odour was actually present in the downwind samples).

These results were consistent with the estimated concentrations from the field assessments which gave estimated downwind odour concentrations in the range from 3.8 to 12.7 ou.

The measurement uncertainty of the Australian Standard method is about –58% to + 73% (Standards Australia 2001), and from previous work, that of the field estimates of the same order.

The results confirm that the ambient odours adjacent to the working face, while fairly obvious to an observer, are of a low numerical concentration, and that the field-estimated results appear reasonable.

3.0 ESTIMATION OF ODOUR EMISSION RATES FROM LANDFILL

3.1 TRANSIENT NATURE OF EMISSIONS

Actual short-term odour emission rates also depend very much on the specific activities on the working face. It is has been shown in other work that odours increased substantially during tipping of municipal waste and subsequent agitation (eg dozing and compaction) of the waste. These transient high emissions tend to stabilise within 10 to 30 minutes as the waste is left stationary.

The only way to realistically deal with this effects whilst sampling from a working situation is to undertake numerous measurements and/or assessments so that effect on emissions transience can be averaged out.

3.2 WIND SPEED DEPENDENCE OF EMISSIONS

Notwithstanding the above, the rate of emission of odourants from area sources has been shown in wind tunnel studies to be dependent on wind speed and hence sweep velocity over the surface in accordance with Equation 5 (Pollock, 1997) below:

$$SOER_{h,Vh} = SOER_{m,Vm} (V_h/V_m)^{e}$$ **Equation 4**

Where: $SOER_{h,Vh}$ is the specific odour emission rate – that is the actual unit area emissions rate from the surface for prevailing ambient conditions (ou.$m^3/m^2/s$);

$SOER_{m,Vm}$ is the measured specific odour emission rate (ou.$m^3/m^2/s$) at height m and sweep velocity V_m;

V_h is the wind speed at height h above the surface (m/s);

V_m is the sweep velocity used to measure $SOER_{m,Vm}$ (m/s); and

e is an exponent of 0.5 for liquid surfaces and 0.63 for solid surfaces.

A review of values for the exponent in Equation 5 by Air Assessments (2005) stated that Galvin et al (2004, page 10) found that the exponent is a little uncertain, reporting values between 0.5 and in excess of 1.0 and that in chemical engineering, a value of around 0.76 to 0.78 is generally used (Cavanaugh et al, 1993) based on work by Sutton (1953). For this study however, 0.5 for liquids surfaces and 0.63 for solid surface was used on the basis that these are the most commonly referenced values used in Australian environmental assessments and are reasonably consistent with values reported internationally.

The wind speed at any given height above the surface can be estimated from the wind speeds at a reference height (normally assumed to be 10 m) using the profile law below:

$$V_h = (h/H)^p V_H$$ **Equation 5**

Where: V_h is the velocity at height h;

h is the height the 10m wind speeds are to be extrapolated to, (0.1 m is half the internal chamber height of a conventional wind tunnel) (m);

V_H is wind speed measured at height H (m/s); and

p is a stability and land use-dependent wind profile exponent – see Table A1-4.

Table A1-4 Rural wind speed exponents

Stability Class	p
A	0.07
B	0.07
C	0.1
D	0.15
E	0.35
F	0.55

.

In order to derive estimates of SOERs from the Landfill, the CALPUFF model was initially run over the field assessment period using a nominal (unitary) emission rate of 1 ou.m^3/m^2/s from the working face to give odour predictions at each field assessment location.

These were then ranked from highest to lowest and compared to ranked field concentrations from each source for the period from 0700 to 1108 hours when the landfill was receiving waste. This method of correlations is referred to as a quantile:quantile (Q:Q) plot, which is commonly used for comparing modelling prediction to observations because it relaxes the requirement for the model to predict the exact concentration at each location at the same time, which is difficult because the measured wind direction at a single location may not be representative of the wind direction everywhere at the same time.

The Q:Q correlation between model predictions using the unitary (1 ou.m^3/m^2/s) emission rate and adjusted for wind speed used for emission back-calculation, and the field-estimated concentrations, during the waste receival period is shown in Figure A1-3.

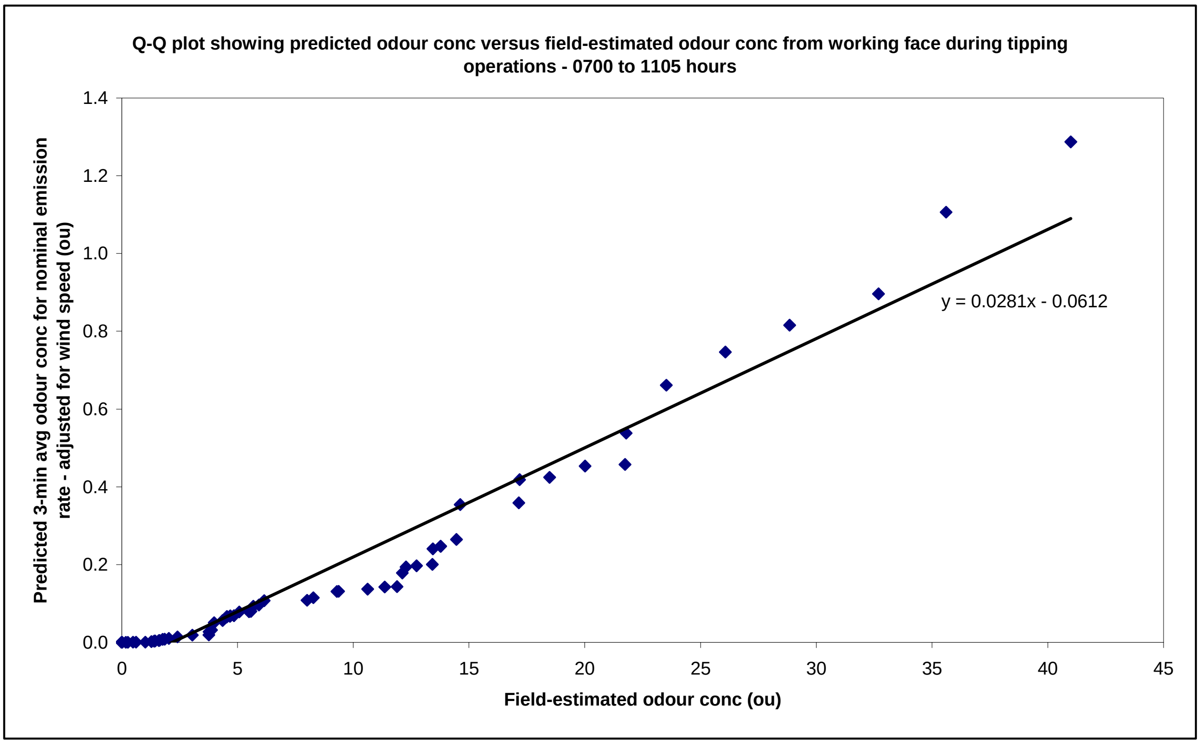

Figure A1-3 Q-Q plot of ranked predicted versus measured odour concentrations from Henderson working face during waste receival period

The inverse of the slope of the ranked line gives the required adjustment to the unitary SOER (ie the reciprocal of the slope is the factor required to multiply the unitary SOER by to give the actual SOER) to give the best fit between the predicted and field-estimated concentrations.

This gave a specific odour emission rate at reference conditions (ie $SOER_{m=0.1m,Vm=0.3m/s}$ in Equation 1) of 35.6 ou.m^3/m^2/s.

3.3 COMPARISONS WITH OTHER DATA

Other published odour emission rates for landfill working areas are shown in Table A1-5.

Table A1-5 Published odour emission rates for landfill working areas

Source/characteristics	SOER (ou.m^3/m^2/s)[(a)]	Location	Reference
Bridgetown Landfill	6.0 (at reference sampling conditions)	Bridgetown Landfill, WA	Environmental Alliances (2006)
Average emissions during operation of two sites	Between 8 and 30	Belgium	Nicolas et al (2006)
Uncovered waste during disposal Uncovered waste after disposal has ceased	Range of 60 Between 1 and 25	Various	Various other studies as reported in Nicolas et al (2006)
Old waste Mixed waste Truck waiting area	2.6 5.4 3.5	Canada	(Odotech, 2001), as reported in Nicolas et al (2006)

[(a)] Note that much lower are typically measured when using an isolation flux chamber to collect specific samples on the waste at rest, for example 0.3-0.5 ou.m3/m2/s in Bowly (2003) and 2 ou.m3/m2s for freshly tipped waste and 4.5 ou.m3/m2/s for freshly tipped sludge during summer in Sironi et al. (2003). The isolation flux chamber method creates an artificially low air sweep velocity of the sample and hence have not been used for comparisons here.

Unfortunately, except for the previous Environmental Alliances study of the Bridgetown Landfill, these are not referenced to a standardised sweep or wind velocity, so are probably indicative of average meteorological conditions rather than reference sampling conditions. In this case, a more meaningful comparison would be to compare the derived Henderson emission rate adjusted for "typical" meteorological conditions.

The specific odour emission rate at "typical" meteorological conditions (assuming D stability, 3 m/s@10m, rural wind profile) can be calculated from Equations 1 and 2 above yielding:

$V_h = (h/H)^p V_H = (0.1/10)^{0.15}\, 3 = 1.5$ m/s.

$SOER_{h,Vh} = SOER_{\mathbf{m,Vm}} (V_h/V_m)^{e} = 35.6\,(1.5/0.3)^{0.63} = 98.1$ ou.m^3/m^2/s.

Therefore, the above Table indicates that odour emissions rates per unit surface area at Henderson were:

- about six times higher than at Bridgetown (ie 35.6 versus 6 ou.m^3/m^2/s[5]); and
- at the high end of the range, from overseas studies (ie Henderson 98.1 compared to 6 – 60 ou.m^3/m^2/s overseas, based on "typical" meteorological conditions) - noting that while there are

[5] Both of these values are at reference sampling conditions of V_m=0.3 m/s.

many factors influencing odour generation from municipal waste, odours would generally expected to be less in colder climates (eg Belgium, Canada).

In summary, given the Henderson sampling was undertaken at the end of a prolonged period of daily maximum temperatures in Perth above 30ºC and would therefore be expected to be relatively high compared to other times of the year, the use of a reference odour emission rate of 35.6 ou.$m^3/m^2/s$ (equivalent to 98.1 ou.$m^3/m^2/s$ for "typical" meteorological conditions) as an all-year value for the Allawuna Landfill proposal appears to be justifiable and probably conservative.

3.4 AVERAGE TOTAL ODOUR EMISSION RATES

The estimated annual average operational total odour emission rates applied to the proposed Allawuna Landfill working face (excluding the Leachate Pond) using actual 2011 wind data is 80,574 ou.m^3/s.

As a comparison, the average operational total odour emissions from a large, semi-enclosed, municipal waste sorting facility in Perth determined from 8 years of sampling is 61,000 ou.m^3/s (EA 2006).

While again there are obvious differences in the types of facilities, this comparison also supports the view that the estimated odour emissions for the Allawuna Landfill should be conservative.

3.5 SITE BACKGROUND ODOUR EMISSION RATE

A similar analysis of the field odour assessments at Henderson prior to waste being received (ie before 0700 hours) gave a "site background" emission rate of 2.5 ou.$m^3/m^2/s$ (at reference conditions) across the working face area. This is due to slight emissions from the covered burial area and possibly nearby various recyclable materials temporary stockpiles (ie steel etc). Whilst based on limited data, this is about 7% of the emission rate during waste receival activities and again appears to be a reasonable estimate.

Appendix 1A Procedure for testing individual odour sensitivity

Field assessors underwent an olfactory test prior to the surveys using a procedure recommended by St Croix Sensory Inc.

The “Sniffing Sticks” testing procedure assesses an individual's olfactory sensitivity by using odour pens, devices like felt tip pens that contain 1-butanol (n-butanol), a standard odourant. 1-butanol is a common odourant used in felt tip marker pens thus tested individuals are familiar with its odour.

The practice combines two statistical procedures. First, the ascending concentration procedure utilises 14 odour pens that contain an increasing concentration of 1-butanol in discrete steps (15=lowest and 2=highest). Second, the three-alternative forced choice procedure requires the individual to indicate which pen contains the odourant out of a triplet of pens, one of which is an odour pen and the other is an odourless pen, used twice as the blank pen. The individual will make three sniffing observations, one of each pen, and will be forced to make a choice, even if no difference is observed. When making a choice between pen one, two or three, the testing individual will indicate the selection as detect if a detectable odour difference is perceptible or will state guess if no difference is observed between the pens in the series. A response of detect is given even in the case that the odour is only observed in one of the two nostrils. A detection threshold is the concentration of the odourant that has a 0.5 probability of being detected under test conditions.

This test procedure requires a concentration series presentation pre-test, Test #1, to approximate the olfactory threshold of the individual. This is followed by Test #2 and Test #3, two more concentration series presentations. The second and third presentation results are averaged together to become the individual’s olfactory threshold estimate.

The results are compared to published population mean responses to the test as indicated in the Table below.

Subject	Score
Population average	8.5
Acceptable range (± 1 std dev); low-to-high sensitivity	6.5 – 10.5

The scores for the assessors used in this study were:

Subject	Score
Assessor #1	10
Assessor #2	10.5

References

Standard Procedure for Testing Individual Odour Sensitivity, St Croix Sensory, Inc., MN, USA ; Revision Date January 1, 2004.

Kobal G; Klimek L; Wolfensberger M; Gudziol H; Temmel A; Owen CM; Seeber H; Pauli E; Hummel T., 2000, “Multicenter investigation of 1,036 subjects using a standardized method for the assessment of olfactory function combining tests of odor identification, odor discrimination, and olfactory thresholds”, European Archives of Oto-Rhino-Laryngology. 257(4):205-11, 2000.

Appendix 1B Laboratory report of results from odour samples

THE ODOUR UNIT (WA) PTY LTD

THE ODOUR UNIT

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16 Hulme Court
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WA 6154

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Facsimile: +61 8 9330 1868
Email: tschulz@odourunit.com.au
Internet: www.odourunit.com.au
ABN: 70 126 439 076

NATA

Accreditation Number: 14974

Form 06 - Perth Laboratory
Odour Concentration Measurement Results

The measurement was commissioned by:

Organisation	Environmental Alliances	Telephone	(08) 9343 0554
Contact	David Pitt	Facsimile	(08) 9343 0079
Sampling Site	Garbage / Landfill	Email	David.pitt@ea.iinet.net.au
Sampling Method	Not specified	Sampling Team	D. Pitt

Order details:

Order requested by	David Pitt	Order accepted by	John Hurley
Date of order	28th March 2011	TOU Project #	1153
Order number	L1017	Project Manager	Clayton Hough
Signed by	D. Pitt	Testing operator	Clayton Hough

Investigated Item	Odour concentration in odour units 'ou', determined by sensory odour concentration measurements, of an odour sample supplied in a sampling bag. Odour character is also assessed, however, AS4323.3:2001 and NATA accreditation do not cover the performance of this service. Where parties other than The Odour Unit perform the dilution of samples, the result that has been modified by the dilution factor is not covered by The Odour Units NATA accreditation. The collection of IFH samples and calculation of the SOER is not covered by The Odour Units NATA accreditation.
Identification	The odour sample bags were labelled individually. Each label recorded the testing laboratory, sample number, sampling location (or Identification), sampling date and time, dilution ratio (if dilution was used) and whether further chemical analysis was required.
Method	The odour concentration measurements were performed using dynamic olfactometry according to the Australian Standard 'Determination of Odour Concentration by Dynamic Olfactometry AS/NZS4323.3:2001. The odour perception characteristics of the panel within the presentation series for the samples were analogous to that for butanol calibration. Any deviation from the Australian standard is recorded in the 'Comments' section of this report.
Measuring Range	The measuring range of the olfactometer is $2^2 \le \chi \le 2^{18}$ ou. If the measuring range was insufficient the odour samples will have been pre-diluted. This is specifically mentioned with the results.
Environment	The measurements were performed in an air- and odour-conditioned room. The room temperature is maintained at 25°C or less, with temperature fluctuations of less than ± 3°C.
Measuring Dates	The date of each measurement is specified with the results.
Instrument Used	The olfactometer used during this testing session was: ODORMAT SERIES V01
Instrumental Precision	The precision of this instrument (expressed as repeatability) for a sensory calibration must be $r \le 0.477$ in accordance with the Australian Standard AS/NZS4323.3:2001. ODORMAT SERIES V01: $r = 0.244$ (16th & 17th March, 2010) Compliance – Yes
Instrumental Accuracy	The accuracy of this instrument for a sensory calibration must be $A \le 0.217$ in accordance with the Australian Standard AS/NZS4323.3:2001. ODORMAT SERIES V01: $A = 0.197$ (16th & 17th March, 2010) Compliance – Yes
Lower Detection Limit (LDL)	The LDL for the olfactometer has been determined to be 16 ou (four times the lowest dilution setting)
Traceability	The measurements have been performed using standards for which the traceability to the national standard has been demonstrated. The assessors are individually selected to comply with fixed criteria and are monitored in time to keep within the limits of the standard. The results from the assessors are traceable to primary standards of n-butanol in nitrogen.

NATA

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Date: Friday, 1 April 2011

Report Number / Panel Roster Number: PER20110328

J. Hurley
State Manager

C. Hough
Authorised Signatory

- 1 -

The Odour Unit (WA) Pty Ltd
ACN 126 439 076
Form 06 – Odour Concentration Results Sheet (V04)

Issue Date: 13.11.2003
Issued By: SB
Odour Measurement Manual

Revision: 6
Revision Date: 20.09.2007
Approved By: TJS

THE ODOUR UNIT (WA) PTY LTD

NATA
Accreditation Number: 14974

Odour Sample Measurement Results

Sample Location	TOU Sample ID	Sampling Date & Time	Analysis Date & Time	Panel Size	Valid ITEs	Nominal Sample Dilution	Actual Sample Dilution (adjusted for Temperature)	Sample Odour Concentration (as received, in the bag) (ou)	Sample Odour Concentration (Final, allowing for dilution) (ou)	Odour Character
EA 1	PC11145	28/03/2011 @ 06:00hrs	28/03/2011 @ 14:09hrs	4	4	-	-	< 16	< 16	Negligible
EA 2	PC11146	28/03/2011 @ 07:50hrs	28/03/2011 @ 14:35hrs	4	6	-	-	< 16	< 16	Negligible – Slight Rubbish
EA 3	PC11147	28/03/2011 @ 08:15hrs	28/03/2011 @ 14:59hrs	4	4	-	-	< 16	< 16	Negligible – Musty
EA 4	PC11148	28/03/2011 @ 08:35hrs	28/03/2011 @ 15:19hrs	4	3	-	-	< 16	< 16	Negligible – Musty
EA 5	PC11149	28/03/2011 @ 08:45hrs	28/03/2011 @ 15:38hrs	4	6	-	-	< 16	< 16	Negligible – Musty

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Odour Panel Calibration Results

Reference Odorant	Reference Odorant Panel Roster Number	Concentration of Reference gas (ppm)	Panel Target Range for n-butanol (ppb)	Measured Concentration (ou)	Measured Panel Threshold (ppb)	Does this panel calibration measurement comply with AS/NZS4323.3:2001 (Yes / No)
n-butanol	PER2011.03.28	50.2	$20 \leq \chi \leq 80$	1,220	41	Yes

Comments: None.

Disclaimer: Parties, other than TOU, responsible for collecting odour samples hereby certify that they have voluntarily furnished these odour samples, appropriately collected and labelled, to The Odour Unit Pty Limited for the purpose of odour testing. The collection of odour samples by parties other than The Odour Unit Pty Limited relinquishes The Odour Unit Pty Limited from all responsibility for the sample collection and any effects or actions that the results from the test(s) may have.

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END OF DOCUMENT

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Appendix 2 Derivation and details of meteorological data used for modelling

TAPM Model

Prognostically derived surface and upper air meteorological data (from TAPM) are increasingly being used in dispersion modelling where no observational meteorological data exists or where the network is sparse. This method of coupling derived meteorological with observational data has been used in modelling the dispersion of pollutants for this study.

The Air Pollution Model, or TAPM, is a three dimensional meteorological and air pollution model produced by the CSIRO Division of Atmospheric Research. Briefly, TAPM solves the fundamental fluid dynamics and scalar transport equations to predict meteorology and pollutant concentrations. It consists of coupled prognostic meteorological and air pollution concentration components, eliminating the need to have site-specific meteorological observations. The model predicts airflow important to local scale air pollution, such as sea breezes and terrain induced flows, against a background of larger scale meteorology provided by synoptic analyses.

TAPM incorporates the following databases for input to its computations:

- Gridded database of terrain heights on a longitude/latitude grid of 30 second grid spacing, (approximately 1 km). This default dataset was supplemented by finer resolution data at 9 second spacing for this study.
- Australian vegetation and soil type data at 3 minute grid spacing, (approximately 5 km).
- Rand's global long term monthly mean sea-surface temperatures on a longitude/latitude grid at 1 degree grid spacing, (approximately 100 km).
- Six-hourly synoptic scale analyses on a longitude/latitude grid at 0.75-degree grid spacing, (approximately 75 km), derived from the LAPS analysis data from the Bureau of Meteorology.

In this study, the TAPM output was used to generate surface and upper wind data for CALMET as follows:

- Grid dimensions were 43 x 43 cells with nests at 10000 m, 3000 m and 1000 m.

It has widely been found that TAPM tend to over-predict low wind speeds (DEC 2006).

Therefore, the TAPM-predicted winds at the lowest grid nest (1000m resolution) were compared to data measured at Muresk – about 18km NNE of the proposed landfill site, by the Department of Agriculture[6].

The 10m wind speeds were correlated and an adjustment of 0.9 applied to the TAPM data.

A comparison of the adjusted TAPM wind speeds against measured at Muresk is shown in Figure 6 below. This shows a slightly higher frequency of the TAPM wind speeds below about 6 m/s and a slightly lower frequency above 6 m/s. The slight bias towards low wind speeds in the adjusted data will be conservative for modelling low-level releases of odour.

A comparison of the TAPM wind direction against measured at Muresk is shown in Figure 7 below. The correspondence is good with the TAPM frequencies lower than the measured around north and higher around south. This bias will lead to higher predicted concentrations to the north (due to more

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[6] See http://agspsrv34.agric.wa.gov.au/climate/clig/Climinfo/awsdata/MK.htm

southerly winds) which is towards the general direction of the nearest residence and hence also be conservative for the purposes of this assessment.

The CALMET input file surface meteorological data (with adjusted wind speeds) was also slightly modified by incorporating the 0900 and 1500 hours cloud cover observations from the BoM York station. These were then slightly smoothed with the existing TAPM-predicted cloud cover by assuming the rate of change between successive observations did not exceed 2 oktas per hour.

The upper air profile data required by CALMET was that produced by TAPM at the Allawuna site.

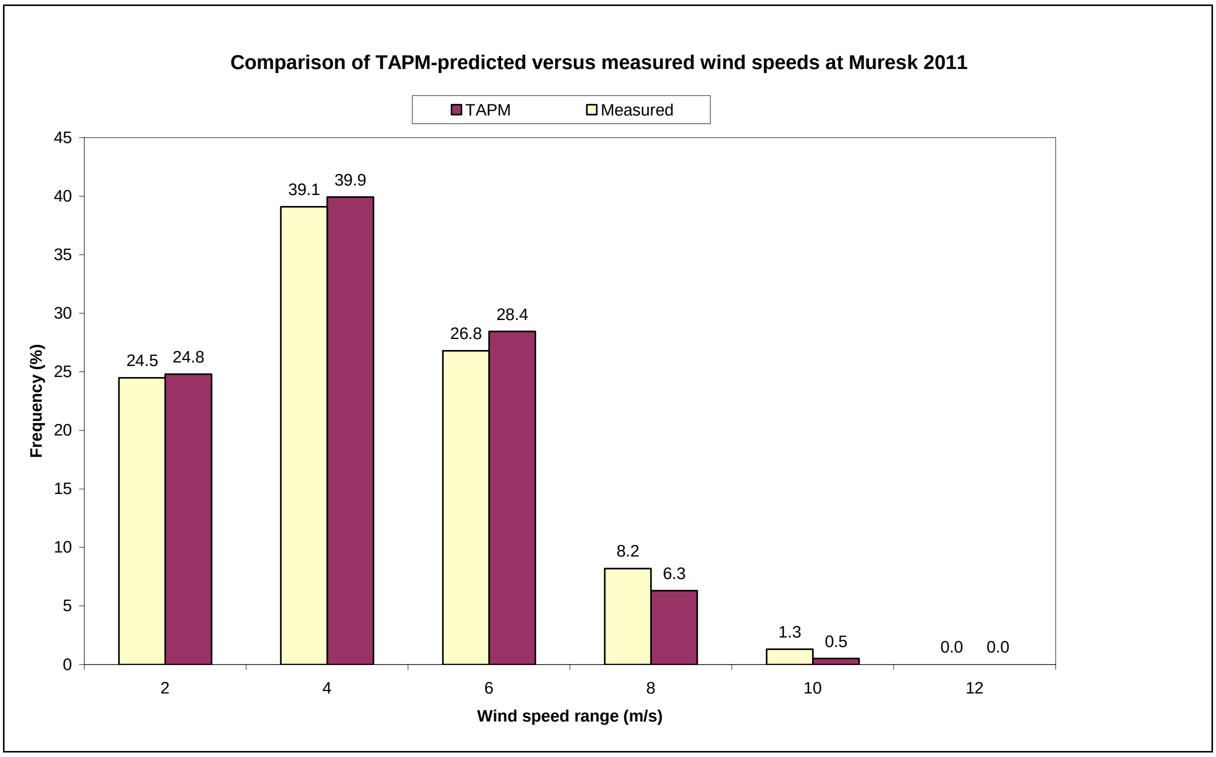

Figure 6 Comparison of adjusted TAPM versus measured wind speeds at Muresk 2011

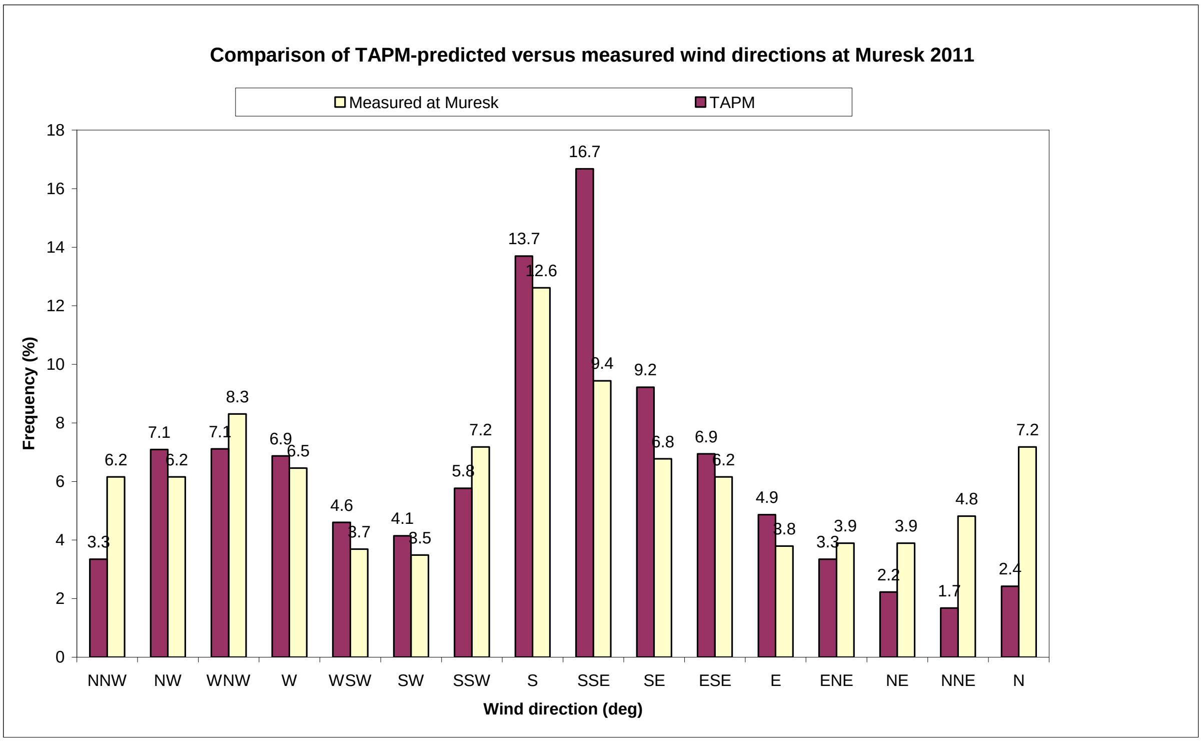

Figure 7 Comparison of TAPM-predicted versus measured wind directions at Muresk 2011

Land use characteristics

The land use within a 2.5 km radius of the site is mostly cleared pasture with intermittent strands of medium to tall trees.

For CALMET, the cleared pasture land use category of 20 was assumed to apply uniformly around the site. The geophysical parameters (such as roughness, leaf surface area, albedo and Bowen ratio) associated with each land use as specified for each grid cell comprising the modelling domain are shown in Table 3. For example, the land use category of 20 will apply a roughness length of 0.1 m, which will be conservative for the vegetated areas.

Table 3 Land use categories and associated geophysical parameters

CALMET application					
Land use description	**Land Use Category**	**Zo[(c)](m)**	**Albedo[(d)]**	**Bowen Ratio[(e)]**	**Leaf Area Index [(f)]**
Urban	10	0.4[(a)]	0.18	1.5	0.2
Agricultural land – unirrigated	20	0.25	0.15	Summer: 3 Autumn/Spring:1 Winter: 0.75	1[(b)]
Rangeland	30	0.2	0.25	Summer: 3 Autumn/Spring:1 Winter: 0.75	0.5
Bays and Estuaries	54	0.001	0.10	0.0	0.0
Large Water Body	55	0.001	0.10	0.0	0.0
Barren	70	0.05	0.3	Summer: 4 Autumn/Spring:1 Winter: 0.75	0.05

(a) Modified from CALMET default of 1.0 which is based on cities.
(b) Modified from CALMET default of 3.0 based on less vegetation coverage for this interpretation.
(c) Zo is the roughness length.
(d) Albedo is the ratio of the reflected outgoing radiation to incoming short wave radiation.
(e) Bowen ratio is the ratio of sensible to latent heat flux.
(f) Leaf Area Index is the ratio of leaf area to land area (eg a value of 2 would indicate that are 2 m^2 of leaf area per m^2 of land).

Diurnal and seasonal wind roses are shown below.

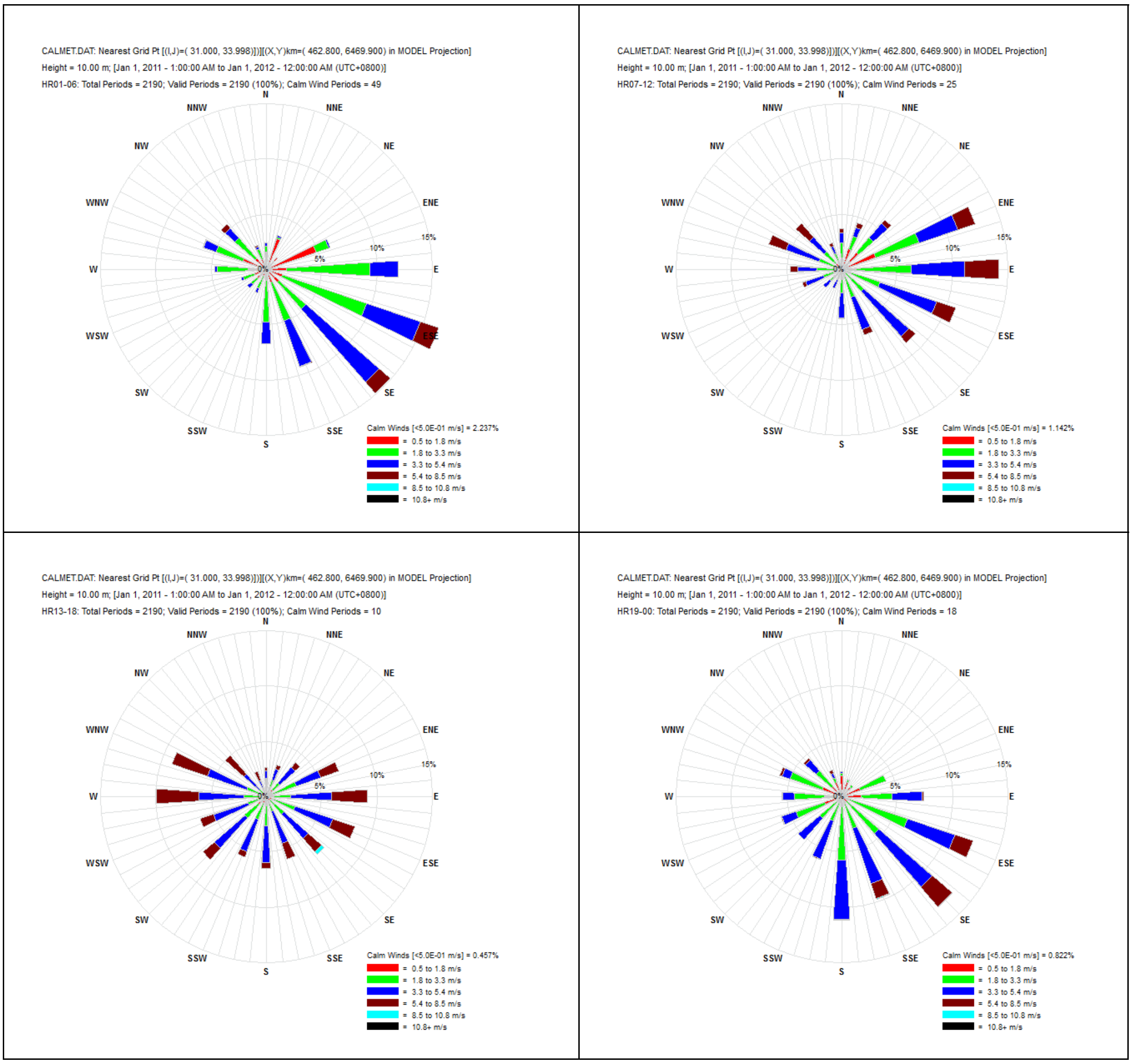

Figure 8 Diurnal wind roses for Allawuna

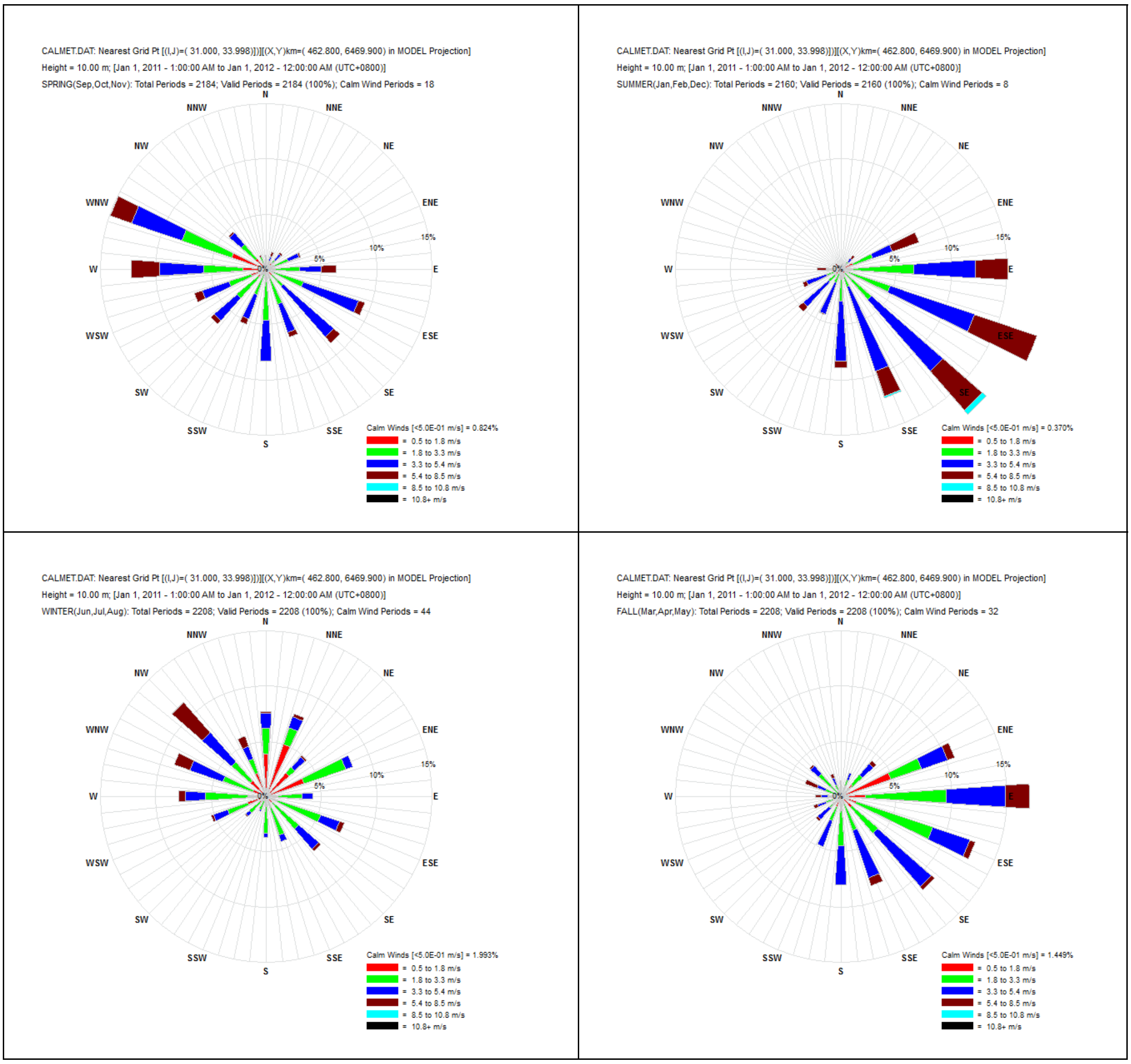

Figure 9 Seasonal wind roses for Allawuna

Terrain data

Terrain height data was sourced from the USGS SRTM archive (see http://dds.cr.usgs.gov/srtm/version2_1/SRTM3/). These data were obtained from the STS-99 mission of the Space Shuttle Endeavour during February 2000. For Australia, these data are available at a resolution of 3 arc-seconds (referred to as SRTM3) or approximately 90 m. This is a useful improvement over the Australian Surveying and Land Information Group (AUSLIG) 9 seconds (approximately 250 m resolution) data generally used previously for modelling.

A check of the influence of terrain steering of winds is illustrated in Figure 10 below. The 10m wind speed at the site was 0.6 m/s, which is just above a "calm". The wind vectors entering the NW-SE gully on the west side of the site tend to be steered along the axis of the gully although this effect is complied by the hilly nature of the ridge lines either side of the gully.

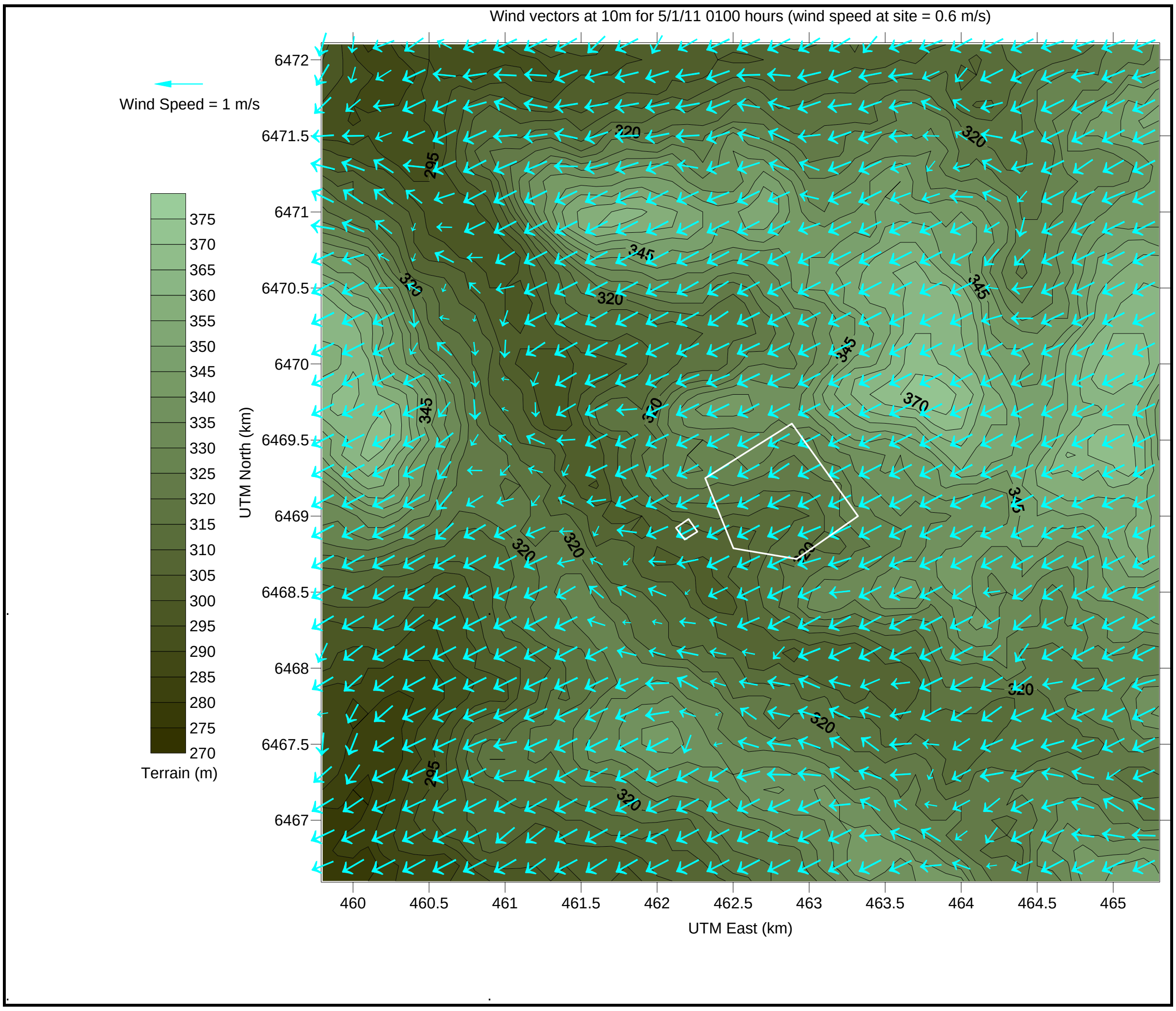

Figure 10 Example of terrain-induced wind steering

Appendix 3 CALPUFF detailed modelling parameters

CALPUFF Input file: ALLAWF.INP

```
CALPUFF.INP     2.0             File version record
Allawuna LandFill
Working Face
Rev March 2015 - sig v set to 0.4 m/s
---------------- Run title (3 lines) ----------------------------------------

                    CALPUFF MODEL CONTROL FILE
! PUFLST =M:\L2172\CALR\PUF\ALLAWF.LST  !
! CONDAT =M:\L2172\CALR\PUF\ALLAWF.CON     !
! ARDAT  =M:\L2172\CALR\EMIS\ALLAWF.SRC  !
! AUXEXT =AUX     !
! LCFILES = F !
! NMETDOM =   1   !
! NMETDAT =   5   !
! NPTDAT =   0   !
! NARDAT =   0   !
! NVOLDAT =   0   !
!END!
! METDAT1 = M:\L2172\CALR\META\MET1101.MET     !
! METDAT1 = M:\L2172\CALR\META\MET1103.MET     !
! METDAT1 = M:\L2172\CALR\META\MET1106.MET     !
! METDAT1 = M:\L2172\CALR\META\MET1109.MET     !
! METDAT1 = M:\L2172\CALR\META\MET1112.MET     !
! METRUN =   0  !
! IBYR  =  2011  !
! IBMO  =  1  !
! IBDY  =  1  !
! IBHR  =  0  !
! IBMIN =  0  !
! IBSEC =  0  !
! IEYR  =  2012  !
! IEMO  =  1  !
! IEDY  =  1  !
! IEHR  =  0  !
! IEMIN =  0  !
! IESEC =  0  !
! ABTZ= UTC+0800 !
! NSECDT =  3600  !
! NSPEC =  1   !
! NSE =  0   !
! ITEST =  2   !
! MRESTART =  0   !
! NRESPD =  0   !
! METFM =  1   !
! MPRFFM =  1   !
! AVET = 60. !
! PGTIME = 10. !
! IOUTU =  1   !
! IOVERS =  2   !
!END!
! MGAUSS =  1   !
! MCTADJ =  2   !
! MCTSG =  0   !
! MSLUG =  0   !
! MTRANS =  1   !
! MTIP =  1  !
! MRISE =  1  !
! MBDW =   1  !
! MSHEAR =  0  !
! MSPLIT =  0  !
! MCHEM =  0   !
! MAQCHEM =  0   !
! MLWC =  1   !
! MWET =  0   !
! MDRY =  0   !
! MTILT =  0   !
! MDISP =  2   !
! MTURBVW =  3  !
! MDISP2 =  3  !
! MTAULY =  0  !
```

```
! MTAUADV =  0  !
! MCTURB =  1  !
! MROUGH =  0  !
! MPARTL =  1  !
! MPARTLBA =  1  !
! MTINV =  0  !
! MPDF =  0  !
! MSGTIBL = 0  !
! MBCON = 0  !
! MSOURCE = 0  !
! MFOG =  0   !
! MREG =  0   !
!END!
! CSPEC =        ODOR !
!        ODOR  =        1,               0,           0,                  0   !
!END!
! PMAP = UTM  !
! FEAST  = 0.000  !
! FNORTH = 0.000  !
! IUTMZN =  50   !
! UTMHEM = S  !
! RLAT0 = 0N  !
! RLON0 = 0E  !
! XLAT1 = 0N  !
! XLAT2 = 0N  !
! DATUM = WGS-84  !
! NX =  56   !
! NY =  56   !
! NZ =  7   !
! DGRIDKM = .1 !
! ZFACE = .0, 20.0, 40.0, 80.0, 160.0, 320.0, 640.0, 1280.0 !
! XORIGKM = 459.75 !
! YORIGKM = 6466.55 !
! IBCOMP =  1   !
! JBCOMP =  1   !
! IECOMP =  56   !
! JECOMP =  56   !
! LSAMP = T !
! IBSAMP =  1   !
! JBSAMP =  1   !
! IESAMP =  56   !
! JESAMP =  56   !
! MESHDN =  1  !
!END!
!  ICON =  1   !
!  IDRY =  0   !
!  IWET =  0   !
!  IT2D =  0   !
!  IRHO =  0   !
!  IVIS =  0   !
! LCOMPRS = T !
!  IQAPLOT =  1   !
! IMFLX =  0  !
! IMBAL =  0  !
! INRISE =  0  !
! ICPRT =  1   !
! IDPRT =  0   !
! IWPRT =  0   !
! ICFRQ =  6   !
! IDFRQ =  1   !
! IWFRQ =  1   !
! IPRTU =  1   !
! IMESG =  2   !
!        ODOR =     1,           1,           0,           0,           0,           0,
0   !
! LDEBUG = F !
! IPFDEB =  1  !
! NPFDEB =  1  !
! NN1 =  1   !
! NN2 =  10  !
!END!
! NHILL =  0   !
! NCTREC =  0   !
! MHILL =  2   !
! XHILL2M = 1.0 !
! ZHILL2M = 1.0 !
```

```
! XCTDMKM = 0 !
! YCTDMKM = 0 !
! END !
!END!
!END!
!  RCUTR = 30.0 !
!    RGR = 10.0 !
! REACTR = 8.0 !
!   NINT =  9  !
!   IVEG =  1   !
!END!
!END!
! MOZ =  0   !
!  BCKO3 = 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00, 80.00
!
! MNH3 =  0   !
! MAVGNH3 =  1   !
!  BCKNH3 = 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00
!
! RNITE1 = .2 !
! RNITE2 = 2.0 !
! RNITE3 = 2.0 !
! MH2O2 =  1   !
!  BCKH2O2 = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00 !
!  BCKPMF = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00 !
!  OFRAC  = 0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.15 !
!  VCNX   = 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00
!
! NDECAY =  0   !
!END!
! SYTDEP = 5.5E02 !
! MHFTSZ =  0   !
! JSUP =  5   !
! CONK1 = .01 !
! CONK2 = .1 !
! TBD = .5 !
! IURB1 =  10  !
! IURB2 =  19  !
! ILANDUIN =  20  !
! Z0IN = .25 !
! XLAIIN = 3.0 !
! ELEVIN = .0 !
! XLATIN = -999.0 !
! XLONIN = -999.0 !
! ANEMHT = 10.0 !
! ISIGMAV =  1  !
! IMIXCTDM =  0  !
! XMXLEN = 1.0 !
! XSAMLEN = 1.0 !
! MXNEW =  99   !
! MXSAM =  99   !
! NCOUNT =  2   !
! SYMIN = 1.0  !
! SZMIN = 1.0  !
! SZCAP_M = 5.0E06 !
! SVMIN = 0.400, 0.400, 0.400, 0.400, 0.400, 0.400, 0.370, 0.370, 0.370, 0.370, 0.370, 0.370!
! SWMIN = 0.200, 0.120, 0.080, 0.060, 0.030, 0.016, 0.200, 0.120, 0.080, 0.060, 0.030, 0.016!
! CDIV = .0, .0 !
! NLUTIBL =  4  !
! WSCALM = .5 !
! XMAXZI = 3000.0 !
! XMINZI = 50.0 !
! WSCAT = 1.54, 3.09, 5.14, 8.23, 10.80 !
! PLX0 = 0.07, 0.07, 0.10, 0.15, 0.35, 0.55 !
! PTG0 = 0.020,   0.035 !
!  PPC = 0.50, 0.50, 0.50, 0.50, 0.35, 0.35 !
! SL2PF = 10.0 !
! NSPLIT =  3  !
!  IRESPLIT = 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0 !
! ZISPLIT = 100.0 !
! ROLDMAX = 0.25 !
! NSPLITH =  5  !
! SYSPLITH = 1.0 !
! SHSPLITH = 2.0 !
! CNSPLITH = 1.0E-07 !
! EPSSLUG = 1.0E-04 !
```

```
! EPSAREA = 1.0E-06 !
! DSRISE = 1.0 !
! HTMINBC = 500.0 !
! RSAMPBC = 10.0 !
! MDEPBC =  1  !
!END!
!  NPT1 =  0  !
!  IPTU =   1  !
!  NSPT1 =  0  !
!  NPT2 =  0  !
!END!
!  NAR1 =  0   !
!  IARU =   1  !
!  NSAR1 =  0  !
!  NAR2 =  1   !
!END!
!  NLN2 =  0   !
! NLINES =  0  !
!  ILNU =   1  !
!  NSLN1 =  0  !
! MXNSEG =  7  !
! NLRISE =  6  !
! XL = .0 !
! HBL = .0 !
! WBL = .0 !
! WML = .0 !
! DXL = .0 !
! FPRIMEL = .0 !
!END!
!  NVL1 =  0   !
!  IVLU =   1  !
!  NSVL1 =  0  !
!  NVL2 =   0   !
!END!
!  NREC =  1   !
!END!
! X =     464.038,   6471.117,     338.000,       2.000!
```