MAUNSELL | AECOM

Advanced Waste Treatment Facility - Elizabeth Drive
Supplementary Report

Preferred Project Report

SITA Environmental Solutions

20 December 2007

Supplementary Report

Prepared for

SITA Environmental Solutions

Prepared by

Maunsell Australia Pty Ltd
Level 11, 44 Market Street, Sydney NSW 2000, PO Box Q410, QVB Post Office NSW 1230, Australia
T +61 2 8295 3600 F +61 2 9262 5060 www.maunsell.com
ABN 20 093 846 925

20 December 2007

60010008/20014604.07

Quality Information

Document Supplementary Report

Ref 60010008/20014604.07

Date 20 December 2007

Prepared by Lee Sellick

Reviewed by Craig Niles / Geoff Hudson

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
A	13/12/2007	For submission to Department of Planning	Lee Sellick Project Manager	Previous signed
B	20/12/2007	For submission to Department of Planning	Lee Sellick Project Manager	

Table of Contents

1.0 Introduction

1.1 Purpose

This document has been prepared on behalf of SITA Environmental Solutions (SITA) by Maunsell Australia (Maunsell) to address submissions made by Badgerys Creek Consortium (BCC) in respect of the proposed Advance Waste Treatment Facility, Elizabeth Drive, Kemps Creek. Four submissions have been received by the Department of Planning from BCC, which are dated 21 November 2007, 26 November 2007, 10 December 2007 and 11 December 2007.

This document constitutes a Supplementary Report to the *Advanced Waste Treatment Facility – Elizabeth Drive Preferred Project Report* (October 2007) (Preferred Project Report). Reponses to other submissions are provided in Appendix A of the Preferred Project Report.

The Preferred Project Report should be read in conjunction with *Advanced Waste Treatment Facility – Elizabeth Drive Environmental Assessment* (June 2007) (Environmental Assessment).

1.2 BCC Submission No.1

The first submission by BCC, dated 21 November 2007 (BCC Submission No.1), is based on a review of the Environmental Assessment. This submission contains comment with respect to the following matters:

- Air Quality – Odour
- Noise
- Transport
- Water Quality

The submission contains suggested conditions of consent relating to:

- Air Quality – Odour
- Noise (and Vibration)
- Water Quality

1.3 BCC Submission No.2

The second submission by BCC, dated 26 November 2007 (BCC Submission No.2), is based on a review of the Preferred Project Report of October 2007. This submission contains comment with respect to only Air Quality – Odour, and questions the accuracy of the odour modelling completed for the Preferred Project Report.

BCC Submission No.2 also requests that the suggested conditions of consent, as contained in BCC Submission No.1, be retained.

1.4 BCC Submissions Nos. 3 and 4

The third submission by BCC, dated 10 December 2007, continues the comments made on Air Quality – Odour as made in BCC Submission No.1.

The fourth submission by BCC, dated 11 December 2007, constitutes legal opinion from Minter Ellison.

Issues raised in BCC Submissions Nos.3 and 4 are covered in this document as part of issues raised in BCC Submissions Nos. 1 and 2.

1.5 Summary of issues raised

The BCC submissions raise a number of issues which are collectively summarised in the following sections.

1.5.1 Air Quality – Odour

Comments are provided within BCC submissions based on a technical review of the Air Quality – Odour modelling completed by Holmes Air Sciences on behalf of SITA, specifically:

- the potential for impacts on future sensitive receptors specifically in the employment land adjacent to the SAWT Facility ;
- the validity of assumed odour emissions from the facility and existing landfill;
- the validity of the meteorological data used;
- the risks posed by upset conditions; and
- the potential for cumulative impacts with other industries in the area.

1.5.2 Noise

Comments are provided in BCC Submission No 1 and are in addition to those previously raised by NSW Department of Environment and Climate Change (DECC) in their response to the exhibition of the Environmental Assessment and include:

- noise should be considered cumulatively from SAWT facility and from the landfill;
- impact of potential future receivers; and
- potential noise mitigation.

1.5.3 Transport

BCC Submission No.1 comments that the Environmental Assessment does not adequately address transport. BCC Submission No.2 makes no further comment on this issue.

1.5.4 Water Quality

BCC Submission No.1 comments that the Environmental Assessment does not adequately address water quality. BCC Submission No.2 makes no further comment on this issue.

2.0 Response to BCC Submissions

2.1 Contact with BCC

SITA has met with members of BCC since the exhibition of the EA, and before the submission of the Preferred Project Report.

Section 2.3.2, Table 2 of the Preferred Project Report notes that SITA met with Mr Roy Medich and Mr Joe Damjanovic on 3 August 2007, and that both Mr Medich and Mr Damjanovic indicated they supported the SAWT proposal.

2.2 Air Quality – Odour

Since the production of the Environmental Assessment, there has been much discussion with Department of Planning and DECC regarding odour. The model used to predict odour emissions for the Preferred Project Report has been submitted to DECC for review. DECC have confirmed the model is acceptable, and SITA have continued on that basis.

The main issues raised by BCC submissions are:

- The potential for impacts on future sensitive receptors specifically in the employment land adjacent to the SITA site
- The validity of assumed odour emissions from the facility and existing landfill
- The validity of the meteorological data used
- The risks posed by upset conditions
- The potential for cumulative impacts with other industries in the area

These matters are addressed in the following sections and incorporate comment made by SITA's Air Quality Consultants, Holmes Air Sciences (HAS). HAS completed the air quality modeling for the Preferred Project Report, and their report, *Air Quality Assessment: Proposed SITA Advanced Waste Treatment Facility, Elizabeth Drive, Kemps Creek* (11 October 2007) (HAS PPR) is Appendix B to the Preferred Project Report.

2.2.1 Future sensitive receptors

BCC Submission No.1 quotes the following statement from the DECC Technical Framework:

*"The NSW DEC (2005) requires that the odour impact assessment criteria be applied at the nearest **existing or likely future** off-site sensitive receptor (subsection 7.5.2). 'Sensitive receptor' is defined as a 'location where people are **likely to work** or reside; this may include a dwelling, school, hospital, office or public recreational area'. Furthermore, 'an air quality impact assessment should also consider the location of known or **likely future sensitive receptors**.*

"NSW DEC (2006a) states 'As a minimum, in order for the odour impact to be predicted adequately, and for the approval authority to make a decision regarding the proposal and the likely acceptability of odour impacts, the parameters listed below need to be determined in any odour impact assessment.'"

At this stage there are no details available on any proposed land uses and so it is impossible to explicitly assess the extent of the impact at a particular location.

The HAS PPR assessed the potential impacts associated with a substantial decrease in odour emissions from the SAWT compared to the EA. This reduction was largely due to a revised SAWT design which included alterations in the way in which the material is composted and odour is controlled. These changes are detailed in Section 4 of the Preferred Project Report.

Contour plots in Figure 10 of the HAS PPR demonstrate the extent of the potential odour impacts, including the land immediately adjacent to the SAWT. The revised SAWT design as detailed in the Preferred Project

Report meets DECC's odour assessment criteria for Rural Single Residence, 7 odour units (ou) immediately beyond its boundary. Across the BCC land, odour levels for the SAWT and Landfill combined fall to 2ou, which is equivalent to DECC's odour assessment criteria for Urban areas.

The EA and the Preferred Project Report both note that the impact assessment is conservative. No account has been taken of the nature of the biofilter odour which is likely to be indistinguishable from natural odours in the environment. Therefore the odour predictions provided present a worst-case scenario under normal operating conditions.

It is the experience of HAS that it is extremely rare for all odour impacts from odorous industries to be contained within the subject land. It is much more common for a reasonable balance to be reached allowing some excursion beyond the property boundary of odour impacts contours in rural/residential areas. In the area of BCC land there are many chicken farms that, according to the information provided in BCC Submission No.1, already make significant excursions into the BCC land. It is often appropriate land use planning to allow development of odorous or other air emitting industries within the buffer zone of other air emitting industries, provided the air issues are amenity rather than health.

It should also be noted that currently DECC have no specific odour criteria for employment land and some account is usually taken of the hours of exposure which would be potentially less for workplaces. A reasonable starting point would be 7 odour units (ou). Figures 8-10 in the HAS PPR shows that the 7ou contour extends into an area where it is extremely unlikely that there would be any significant development, given that it overlays Badgerys Creek.

With respect to dust, Figure 11 of HAS PPR shows that all the long-term air quality criteria would not be exceeded at any location outside the SITA site. Short-term (24-hour) levels of PM_{10} are not predicted to be exceeded due to the operation alone and, given the steep concentration gradient, it is extremely unlikely that there would be any off-site impact. The main dust sources are emissions from the haul road. However the haul road will be sealed to minimise this emission.

The potential for dust emissions from stockpiles was also discussed in HAS PPR, which noted that there are no reliable emission factors available for this type of dust source. Management and operational procedures will be developed to minimise the potential for off-site impacts. This is noted in Section 8 of the Environmental Assessment.

2.2.2 Odour emissions from the facility

BCC Submission No.1 notes that the Bedminster measurements and the biofilter measurements made in France were not included. The Bedminster report by The Odour Unit Pty Ltd is attached as **Appendix A** to this report and the measurements made in France were included as Appendix C to the HAS PPR.

The BCC submissions consider as weak the grounds given for reducing emissions by 50% due to modern landfills being assessed as less odorous than past landfills, and further refinements of such rates to 10%. This comment was not included in the HAS PPR. The emission rates in HAS PPR were reduced to 5% of that previously used based on odour emission rates reported by **Bowly** (**2003**), and this is attached as **Appendix B** to this report.

2.2.3 Meteorological data

BCC note that there are other meteorological data available in the area apart from the Fleurs data which were used for the assessment by HAS. BCC specifically note that the Badgerys Creek station which was commissioned in 1995 is approximately 4.1 km southwest of the SITA landfill. BCC submissions refer to DECC's automatic weather station in the text although the supporting Figure refers to a Bureau of Meteorology station. DECC do operate a weather station at Bringelly which is approximately 7 km to the south of the subject site. Our interpretation of BCC submissions is that the data referred to were collected by the Bureau of Meteorology.

An examination of the windrose shows a more southwesterly prevalence of winds than at the Fleurs site. It was also noted in the BCC submissions that the Badgerys Creek monitoring station has a high incidence of calm wind conditions although this is inconsistent with the windrose where the percentage of calms was 3.1% compared to Fleurs data which had 3.9%. It also appears that most of the south-westerly winds are in the range greater than 1.5 m/s while the southerly winds at Fleurs are less strong.

Data is also available from Badgerys Creek as collected by Dr Robert Hyde of Macquarie University (who collected the Fleurs data) and a windrose compiled from this data is attached as **Appendix C**. It shows a similar pattern to that collected by the Bureau of Meteorology with predominant southwesterlies.

A consideration of the sites where the data were recollected is useful in determining their relevance to the SITA site. In general, the drainage flow patterns in the wind data, that is low wind speed, stable conditions (where odour impacts from ground-based sources are usually most significant) follow the drainage flow patterns of the water bodies. The Badgerys Creek data were collected along the section of Badgerys Creek running in a southwest/northeast direction. This is consistent with the windrose in Appendix C. The SITA site is where both South Creek and Badgerys Creek meet and both creeks are in a more north/south orientation. The Fleurs data reflect this. It should be noted that the Fleurs data was collected for the Sydney Oxidant Study and the station was specifically located to provide data on air drainage flows in the area.

The Fleurs data site is approximately three kilometres to the north northeast of the SITA site and immediately east of the Twin Creeks development. Please note the HAS PPR referred to the Fleurs Radio Observatory which is to the east of the SITA site, however the data was collected further to the north of the Fleurs Radio Observatory. The Fleurs data site is directly on the South Creek drainage flow which is a north/south flow at that point and is the most appropriate existing data for the SITA site.

The terrain was considered in the modelling in the HAS PPR. The final height (AHD) of the landform on the landfill will be approximately 68 metres compared to 65 metres for the current temporary stockpile. Both landforms will exert some local influence on the drainage flows but it is likely to be reasonably minor compared to the larger scale flows in the region.

The larger scale flows will have a stronger effect on the overall pattern of dispersion, particularly for the receptors at some distance from the site.

In summary the influence on dispersion of the change in landform is likely to be a second order effect

2.2.4 Risk posed by upset conditions

BCC Submission No.1 noted that the probability and impact potential of upset conditions was not evaluated. It is submitted that the probability of upset conditions occurring is difficult to estimate and has not been included in the modelling. This is consistent with impact assessments of this type and is addressed by air quality management plans.

2.2.5 Potential for cumulative impacts

It is important to include cumulative impacts in this type of assessment and to this end, the DECC note the following:

"The potential for cumulative odour impacts in relatively sparsely populated areas can be more easily defined and assessed than in highly populated urban areas. It is often not possible or practical to determine and assess the cumulative odour impacts of all odour sources that may impact on a receptor in an urban environment. Therefore, these odour assessment criteria allow for community expectations of amenity, for population density, cumulative impacts and anticipated odour levels during adverse meteorological conditions.

To ensure that offensive odour impacts are maintained within acceptable levels, the ***incremental increase*** *in ambient odours due to emissions resulting from a facility's operations should be assessed against the odour assessment criteria. Where it is likely that two or more facilities with similar odour character will result in cumulative odour impacts, the combined odours due to emissions resulting from all nearby facilities should also be assessed against the odour assessment criteria."*

The cumulative impact with the existing landfill was included in the modelling. The odour from the landfill and the SAWT will have common elements. While there are potential odours from the various poultry operations in the area, it would be inappropriate to include this in the assessment of the SAWT as the nature of the odour is different.

2.2.6 Summary

The revised modelling contained in HAS PPR incorporates more-detailed assessment of potential air quality impacts than in the Environmental Assessment.

A general statement is made in BCC Submission No.2 that the revised odour assessment was not conducted in accordance with the DECC's Approved Methods and that there are persistent shortcomings primarily due to questionable meteorological data used and cumulative impacts not being adequately addressed.

We submit that this is not the case. It is generally acknowledged that there are uncertainties in modelling, however in this instance modelling has been undertaken with the best meteorological and emission information available and in accordance with the DECC Approved Methods.

The model used to predict odour emissions for the Preferred Project Report has been submitted to DECC for review and DECC have confirmed the model is acceptable.

2.3 Noise

Since the exhibition of the Environmental Assessment, further discussions have taken place between SITA and DECC relating to noise. The main points raised by BCC are:

- Contribution of existing noise levels
- Noise should be considered cumulatively from SAWT facility and from the landfill
- Impact of potential future receivers
- Potential noise mitigation.

These matters are addressed in the following sections and incorporate comment from SITA's noise consultants, Wilkinson Murray. Wilkinson Murray have been conducting compliance measurements over the last 13 years, totalling 42 full day surveys, initially quarterly and reducing to biannually. It is from this vast amount of data that conclusions have been drawn about the contribution of landfill noise to both existing background noise and future intrusive noise.

The revised layout of the SAWT as shown in the Preferred Project Report notes that shredding will now take place inside.

2.3.1 Contribution of existing noise levels

BCC Submission No.1 raises concern about the unattended measurement locations and whether existing noise from the current landfill would have affected the noise criteria. This point was discussed in Section 3.2 of Appendix E to the Environmental Assessment. Whilst there may be some contribution on some days, it does not alter the Rating Background Levels used and therefore the intrusive criteria set.

2.3.2 Cumulative Impacts

The initial report considered that the noise from the new facility, which would be mostly indoors, would be significantly less than the existing landfill operations. Noise limits were selected for that part of the operation, taking into account the noise already generated by the landfill and the noise condition limits already imposed for the site.

However, since that report, Department of Planning have indicated that whilst they are comfortable with the level of noise emission, further work is required to predict future emissions over the life of the landfill for the whole site. In consultation with Department of Planning and DECC, predictions are currently being undertaken to represent cumulative noise for future operations. This will inform as to the mitigation measures required for the landfill component in order that noise levels from the whole facility can be reduced to those suggested by Department of Planning.

2.3.3 Potential Future Receivers

At this stage there are no details available on any proposed land uses and so it is impossible to explicitly assess the extent of the impact at a particular location. Therefore the current level of assessment is appropriate. If at this stage information is required to compare predicted noise levels to the boundary limits, this information is available in the noise contours for neutral weather conditions. No contours for adverse conditions are presented, although as noted within BCC Submissions, the difference in noise levels between neutral and adverse conditions is likely to be small due to the smaller distances involved from source to boundary, rather than source to existing receivers.

2.3.4 Potential Noise Mitigation

At this stage there are no details available on any proposed land uses and so it is impossible to explicitly assess the extent of the impact at a particular location. The mitigation measures suggested by BCC may or may not be appropriate.

2.3.5 Summary

Noise has been discussed at length with Department of Planning and DECC since the exhibition of the Environmental Assessment. SITA have commissioned further modelling to demonstrate that the cumulative noise of the SAWT and Landfill will meet noise conditions suggested by DECC. Any noise limits will be regulated by DECC as part of a DECC Licence for the SAWT operations.

2.4 Transport

Whilst no specific comments were made by BCC in either submission, further analysis of the intersection of Elizabeth Drive with the Site Access Road was completed at the request of Department of Planning and has been included in Section 3 of the Preferred Project Report. The purpose of this analysis was to confirm that the intersection is capable of managing the additional traffic that will be entering SITA's Elizabeth Drive Facilities.

The intersection assessment was undertaken using SIDRA Intersection 3.0, a computer based modelling package which calculates isolated intersection performance, and was based on the most recent data available from both RTA and SITA.

The results of the analysis show that the intersection is capable of accommodating the maximum permitted number of movements to the landfill and the proposed SAWT facility.

Furthermore the RTA has been consulted in respect to this project and advised that they do not have any concerns regarding the proposal.

2.5 Water Quality

Whilst no specific comments were made by BCC in either Submission, further discussion has taken place between SITA and DECC regarding water use and storage of run-off on the SAWT facility.

A series of ponds have been designed to hold stormwater leachate in accordance with DECC Guidelines for Composting Facilities. These Guidelines consider a 1-in-10 year, 24-hour rainfall event. Water flow around the ponds will be managed to ensure that water is reused within the SAWT process as much as possible, such that there is no discharge of leachate to Badgerys Creek.

Rainfall falling on the maturation pads will be kept separate from that falling on the buildings or roads. The rainfall from the pads will be kept in a series of ponds and managed as leachate, according to DECC Guidelines. Rainfall from the buildings will be managed as clean stormwater and be directed into the existing stormwater pond to the west of the SAWT Facility, as used by the Landfill. This discharges to Badgerys Creek and is currently subject to water quality conditions within the DECC Licence for the Landfill.

Full water balance modelling has been completed and submitted to DECC for their consideration. We have been informed by DECC that this modelling is acceptable and takes into account all relevant factors.

A DECC Licence is required for the Facility prior to construction and will include water quality as compliance criteria.

2.6 Suggested Consent Conditions

BCC suggest several consent conditions relating to the SAWT Facility. Department of Planning is the Consent Authority and at this time there has yet to be any discussion with Department of Planning regarding any consent conditions. SITA will discuss relevant consent conditions with Department of Planning after consent conditions have been drafted.

3.0 Conclusion

BCC consider that there are four issues that have not been adequately addressed by the Environmental Assessment:

- Noise
- Air Quality-Odour
- Transport; and
- Water Quality.

All four of these issues were addressed by the Preferred Project Report, and have been discussed at length with Department of Planning and DECC and agreement reached as to how these issues were to be addressed.

At this time we are not aware of any further requirement by either Department of Planning, DECC or any other Government organisation to carry out further studies or monitoring works, or that any response to these bodies has been in any way inadequate and submit that the submissions by BCC should not prevent the Environmental Assessment being approved by the Minister.

Appendix A Data from The Odour Unit

THE ODOUR UNIT PTY LIMITED

THE ODOUR UNIT

Suite G03 Bay 16
Australian Technology Park
Locomotive Street
Eveleigh
NSW 1430

Phone: +61 2 9209 4420
Facsimile: +61 2 9209 4421
Email:tschulz@odourunit.com.au
Internet: www.odourunit.com.au
ABN: 53 091 165 061

Form 06 - Sydney Laboratory
Odour Concentration Measurement Results

The measurement was commissioned by:

Organisation	EWT Bedminster	Telephone	(02) 4983 1520
Contact	R. Wark	Facsimile	(02) 4983 1980
Sampling Site	Raymond Terrace	Email	rebeccawark@ewtwaste.com
Sampling Method	Drum and pump	Sampling Team	TOU

Order details:

Order requested by	R. Wark	Order accepted by	T. Schulz
Date of order	See email confirmation	TOU Project #	1252
Order number	See email confirmation	Project Manager	T. Schulz
Signed by	See email confirmation	Testing operator	S. Hayes

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, this assessment is not covered by AS4323.3:2001.
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 $2^2 \leq \chi \leq 2^{18}$ ou. If the measuring range was insufficient the odour samples will have been pre-diluted. The machine is not calibrated beyond dilution setting 2^{17}. This is specifically mentioned with the results.
Environment	The measurements were performed in an air- and odour-conditioned room. The room temperature is maintained between 22°C and 25°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 V02
Instrumental Precision	The precision of this instrument (expressed as repeatability) for a sensory calibration must be $r \leq 0.477$ in accordance with the Australian Standard AS/NZS4323.3:2001. ODORMAT SERIES V02: $r = 0.2015$ (9/10 August, 2006) Compliance – Yes
Instrumental Accuracy	The accuracy of this instrument for a sensory calibration must be $A \leq 0.217$ in accordance with the Australian Standard AS/NZS4323.3:2001. ODORMAT SERIES V02: $A = 0.1882$ (9/10 August, 2006) 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.

Date: Wednesday, 16 August 2006

Report Number / Panel Roster Number: SYD20060815_071

T. Schulz
Managing Director

Steven Hayes
S. Hayes
Authorised Signatory

THE ODOUR UNIT PTY LIMITED

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
Tipping floor biofilter	SC60371	14/08/2006 1530hrs	15/8/2006 1633hrs	4	8	-	-	181	181	Bark, earthy.
Aeration biofilter - Cell 1	SC60372	14/08/2006 1520hrs	15/08/2006 1710hrs	4	8	-	-	430	430	Bark, leaves.

Odour Panel Calibration Results

Reference Odorant	Reference Odorant Panel Roster Number	Concentration of Reference gas (ppb)	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	SYD20060815_071	49,600	$20 \leq \chi \leq 80$	1,024	48	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.

Note This report shall not be reproduced, except in full, without written approval of The Odour Unit Pty Limited.

END OF DOCUMENT

Appendix B Bowly Report

AN ASSESSMENT OF CURRENT METHODS FOR QUANTIFYING LANDFILL ODOURS

S.W.BOWLY

Macquarie University, Department of Physical Geography, Division of Life and Environmental Sciences, Balaclava Road, North Ryde, New South Wales 2109 Australia.

SUMMARY: Three municipal solid waste landfills in NSW, Australia were investigated to assess landfill odour emissions. The objectives of the investigation were to estimate landfill odour source emission rates, chemically "fingerprint" the odorants of landfill odour, and predict odour concentrations based on measured chemical composition. The tools used in this investigation are tools currently used in odour impact assessment, namely forced-choice dynamic olfactometry, gas chromatograph - mass spectrometry (GC-MS) and artificial neural networking (ANN). Odorous emission rates were found to be 0.335 ou.m3/m2/s for landfill tipfaces and less than 0.002 ou.m3/m2/s for the covered landfill surfaces and it was found that landfill gas odour and tipface odour had a “distinct” odour intensity (based on the German VDI 3882 Standard) at an odour concentration of 1.4 ou and 1.0 ou, respectively. Methylmercaptan, ethylbenzene, hydrogen sulfide and dimethyl sulphide were found to be the primary odorants. Artificial neural networks were also used to predict odour concentrations based on 79 VOC concentrations. Odour concentrations were predicted within 50% of the input odour concentration.

1 INTRODUCTION

Landfill odours can adversely impact on the areas surrounding the landfills, especially residential areas. As the buffer zones between landfills and residential areas diminish due to increasing population, more accurate methods of landfill odour measurement and impact assessment are required. This investigation used a variety of current and new methods to suggest new techniques for landfill odour impact assessment (OIA).

A prediction or at least, an understanding of the likely impacts of landfill odour would be useful planning information. This information could also be used to better manage the landfill odour and minimise adverse impacts on nearby residences.

The understanding of landfill odour emissions, which have difficult sources to measure compared with other industrial odours, requires assessment using appropriate techniques and procedures. The techniques chosen in this project and the reason for the choice are shown in Table 1.

Proceedings Sardinia 2003, Ninth International Waste Management and Landfill Symposium
S. Margherita di Pula, Cagliari, Italy; 6 - 10 October 2003

Table 1 : Assessment Tool and Reason for use

Tool	Reason
Olfactometry	To determine emission rates and obtain odour intensity data
Chemical analysis	To identify the chemicals responsible for the odours by comparing the chemicals to their individual odour threshold
Artificial neural networking	To provide a predictive tool for assessing odour concentrations based on chemical concentrations

The project researched the current methods available for odour impact assessment (OIA) and the potential to interrelate and address the issues with odour impact assessment. One issue of OIA is the relationship between chemicals and odours. This current project investigated assessing odours using chemical concentration and Artificial Neural Networks (ANN) and their application to validation of low odour concentrations. A receptor, for example a resident near an industrial odour source, may complain of a low concentration odour. Current validation of the low concentration odour received by the complainant is usually by subjective assessment of a single authorised government representative eg. a representative of the Environment Protection Authority. This validation technique may be considered inconsistent and/or imprecise, depending on the representative(s) involved. The project researched an alternative method for validating odour complaints using ANN. Several methods for odour measurement / assessment have been mentioned, and this project will use these methods to establish whether all the methods can be combined to provide a scientifically sound, repeatable and consistent approach to odour impact assessment.

2 OBJECTIVES

The objectives of the investigation were to assess landfill odour by combining current tools in odour impact assessment i.e. olfactometry, chemical analysis, artificial neural networking and to:

- Determine specific odour emission rates for the various odour sources at a landfill;
- Develop a method to identify ie "fingerprint", the primary odorous compounds in landfill and landfill tipface gas (to be performed by GC-MS analysis of landfill gas (LFG));
- Develop a method to predict the concentration of landfill odours, focusing on low concentration odours, based on chemical concentrations (GC-MS analysis feeding into ANN to obtain odour concentration);

The above methods can be broadly classified into two groups, namely the prediction of odour and the validation of odour. The interrelationship of the above methods to predict and validate odours is shown in Figure 1.

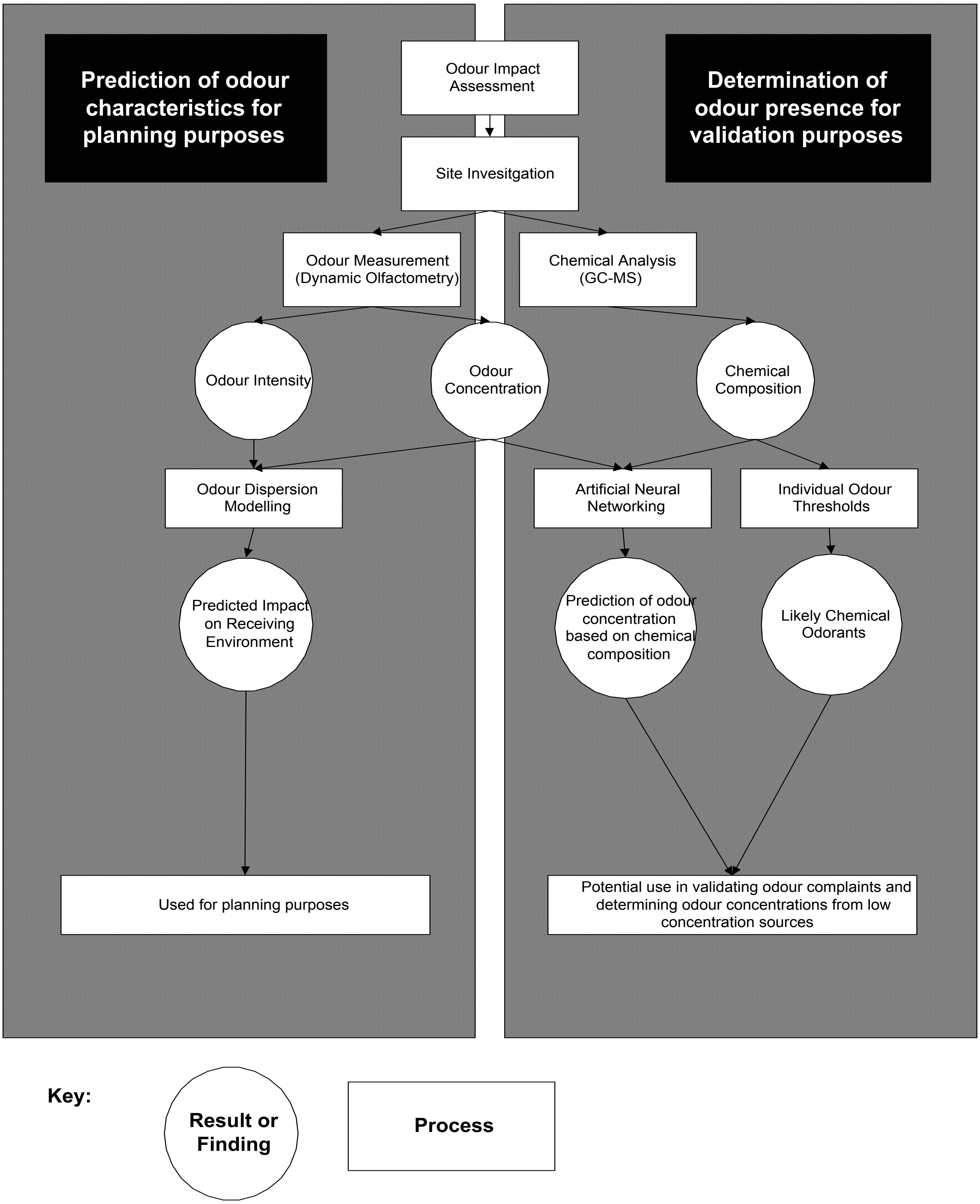


Figure 1 : Methods used to address key concerns in Odour Impact Assessment

3 METHODS

3.1 Odour Sampling

A technique for area source odour sampling is known as the isolation flux hood (IFH) method, and has been developed by the US EPA. The sampling equipment and method is described in Klenbusch (1986). The isolation flux hood comprises a perspex dome, and is supplied with a stream of neutral gas, usually nitrogen or air, which flows into the hood. Equilibrium is reached between the incoming odour free air stream and gas emission before samples can be taken. Four air changes are completed in the flux hood, by which time, the incoming neutral gas and emissions are believed to be at or near equilibrium. The odorous emission is then sampled at a rate lower than the incoming neutral gas to prevent ambient air being entrained in the sample. A diagram of the isolation flux hood is shown in Figure 2.

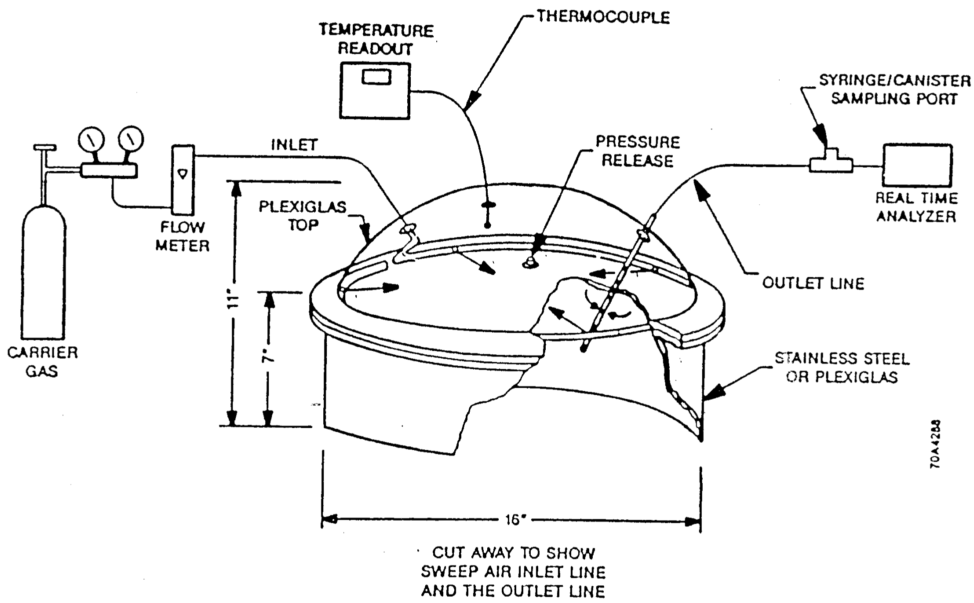


Figure 2 : Diagram of the isolation flux hood (Figure 3-1, Klenbusch, 1986)

The New South Wales Environment Protection Authority (2001), recommends the use of an IFH and back calculation IFH to determine landfill odour emission rates. The sampling that was performed during this study used the IFH to sample covered landfills and the tipface of landfills. Initially, a wind tunnel was used to collect odour samples, and a conversion factor was able to be established for specific odour emission rates (SOER). The wind tunnel SOER was found to be 3.7 times that of the IFH SOER for the same source. The areas surrounding the tipface were not collected using the IFH, but were collected using the wind tunnel, hence the IFH SOER value (shown in Table 2) was calculated based on wind tunnel SOER. For collection of odour samples the following method was employed: a Teflon tube was connected to the IFH. The teflon tube was connected to a single use, odour free Nalophan sample bag inside a portable drum. A vacuum was created in the drum by expelling air, thereby drawing sample gas into the sampling bag which was sealed with a metal valve.

3.2 Odour Analysis

Olfactometry is the method by which the gas samples are collected and presented to trained odour assessors for quantitative and qualitative odour assessment. The primary aims of olfactometry in this thesis were two fold; firstly, to obtain the *odour concentrations* for use in calculating odour emission rates, and secondly obtaining *odour intensity* information. Odour *concentration* is a measure of the strength of the odour, measured in terms of dilution to the threshold, whilst *odour intensity* relates to the subjective response of the assessors to the odour before and after their threshold is reached, and the relationship between odour concentration and odour intensity is non linear (Standards Australia, 2002). There is interest in assessing adverse odour impact based on odour intensity rather than odour concentration (Western Australia Department of Environment Protection, 2000). Odour intensity analysis was based on the the German VDI 3882 (1992) method for determining odour intensity. The use of odour intensity may be regarded as a fairer measure of odour impact, as it incorporates subjective human assessment of the odour, and it is reasonable to assume that subjective human assessment is the basis of odour complaints. The odour concentration data were used to calculate odour emission rates from the specific sources at the landfill and the odour intensity data were then ready to be applied in atmospheric dispersion modelling.

3.3 Chemical Analysis

Landfills generate a significant variety of odorous compounds. However, the majority of the odorous compounds are present in small concentrations. The two main gases in LFG, namely carbon dioxide and methane are odourless. To accurately assess the compounds responsible for the odours, a study into the relationship between the chemical composition and of LFG and olfactory characters of the gas needed to be performed.

Whilst the chemical composition and relative concentrations of the primary chemicals of LFG is well documented (Cooper 1990, Cooper *et al*. 1992, Arthur & Nelson 1994, El-Fadel *et al.* 1995), each landfill has a distinct set of chemicals due to the unique nature of the fill. Chemical analysis of odours is a highly specialised field of science using gas chromatograph / mass spectometry (GC-MS) to assess the VOCs present.

The objective of the chemical analysis component of the investigation was to provide a general chemical speciation of landfill odours. The information was then used in conjunction with the individual odour threshold data to assess the primary VOCs responsible for the odour and predict landfill odour concentrations based purely on the chemicals present Individual odour threshold data is the odour threshold for a chemical. The chemical concentration obtained by GC-MS was divided by the individual odour threshold data obtained from Devos *et al.* 1990, to obtain a chemical odour unit (COU) for each chemical. The chemicals were then able to be ranked in order of contribution to the total odour concentration. The GC-MS information was also required to provide input data for combination with odour concentration to be used in artificial neural networking.

3.4 Artificial Neural Networking

An Artificial Neural Network (ANN) is a predictive tool used in diverse contexts for forecasting and pattern recognition. ANN was used in this thesis to predict odour concentrations based on chemical concentrations. The ANN used in the study was a multi-layer perceptron (MLP) with back-propagation. This may be a valuable prediction tool, as odour quantification at low odour thresholds is not currently accurate, due to the reliance on subjective human assessment at or near the human threshold for odour detection. Chemical analysis is more accurate at low concentrations. By enabling prediction of odour concentrations at low thresholds based on chemical concentrations, one may be able to confirm the presence or absence of a certain odour at a location, where odour concentrations are purported to be present, without the expense and uncertainty of human olfactometry trials.

The training sets are the data with known input and output where the ANN learns the relationship between the variables, in this project, the relationship between odour concentration and VOC composition. The test set is used to provide the input data, but the ANN predicts the output. The predicted output can then be compared to the actual output to assess the predictive ability of ANN. In this investigation a similar amount (between 23 and 26) of samples was targeted. The training set and test sets were divided into three groups, namely, "Group 1 - low concentration odours", "Group 2 - LFG collected in the field" and "Group 3 - all samples".

The training set comprised Group 1 (23 samples), Group 2 (24 samples) and Group 3 (26 samples), and the test set comprised 4, 5 and 6 samples Group 1, Group 2 & Group 3 respectively. The training set incorporated that range of available odour concentrations, and the test set of three samples comprised diluted LFG, and surface tipface / LFG and synthesised gas. The test sets were chosen to have odour concentrations representative of the range of those found in the training set.

4 RESULTS

4.1 Landfill Odour Emission Rates

Specific Odour Emission Rates for landfill sources are shown in Table 2.

Table 2 : Primary Odour Emission Rates for Major Landfill Sources Using IFH

Source	Specific Odour Emission Rate ($ou/m^2/s$) [B,C]	Comment
	Buttonderry Landfill	
Tipface	0.335	
Surrounding Tipface	(0.529) Based on Wind Tunnel	IFH value taken to be proportional to Wind Tunnel SOER of Tipface and surrounding tipface
Covered Landfill	0.002	-
Leachate Pond	(0.833) Based on Wind Tunnel	IFH value taken to be proportional to Wind Tunnel SOER of Tipface and surrounding tipface
	Kincumber Landfill [A]	
Tipface	0.146	
Surrounding Tipface	(0.231) Based on Wind Tunnel	IFH value taken to be proportional to Wind Tunnel SOER of Tipface and surrounding tipface.
	Woy Woy Landfill [A]	
Tipface	0.110	-
Surrounding Tipface	(0.174) Based on Wind Tunnel	IFH value taken to be proportional to Wind Tunnel SOER of Tipface and surrounding tipface.

[A]:Leachate Ponds and covered landfills were not considered to be significant sources at either the Kincumber of Woy Woy Landfills
[B]: ou/m2/s = measurement of specific odour emission rate (SOER) measured in odour units per square metre per second ($ou/m^2/s$). See Klenbusch (1986)
[C]: "Based on Wind Tunnel" values are derived from the SOER relationship between wind tunnel and isolation flux hood found during this investigation.

4.2 Landfill Odour Characteristics

The odour analysis performed consisted of odour concentration and odour intensity analysis. Odour concentration results were used to develop odour emission rates and odour intensity curves were used to develop odour intensity versus concentration plots. The odour intensity results are shown in Table 3. The top 10 landfill odorants, based on individual odour threshold estimates, for 33 samples are shown in Table 4. Table 4 also separates the tipface and the LFG samples to show the difference in odorous chemicals from each source.

Table 3: Odour concentrations corresponding to perceived distinct intensity value

	Landfill Gas	Tipface	Downwind of tipface	Average value
Odour Concentration (ou) where odour is "distinct"	1.4	1.0	0.8	1.1

Table 4 : Contribution of top 10 chemical odorants based on individual odour thresholds (All samples)

All	Percentage odour contribution	Tipface	Percentage odour contribution	LFG	Percentage odour contribution
Ethylbenzene	24.3%	2,3-butanedione	31.6%	Ethylbenzene	40.8%
2,3-butanedione	21.6%	Methyl-mercaptan	24.7%	Methyl-mercaptan	20.5%
Methyl-mercaptan	20.0%	Hydrogen sulphide	22.5%	Hydrogen sulphide	18.9%
Hydrogen sulphide	18.5%	Ethylbenzene	11.3%	Dimethyl-sulphide	7.5%
Dimethyl-sulphide	5.3%	Dimethyl-sulphide	3.4%	Sulphur dioxide	4.7%
Sulphur dioxide	2.0%	2-methylpropanal	1.2%	Carbon-disulphide	2.8%
Dimethyl-disulphide	1.9%	i-propyl-mercaptan	1.2%	Benzene	1.8%
Carbon-disulphide	1.8%	Dimethyl-disulphide	0.7%	2,3-Butanedione	0.6%
Benzene	0.8%	Ethylmercaptan	0.7%	M,p-xylenes	0.6%
i-propyl-mercaptan	0.6%	Ethanol	0.5%	2-methylpentane	0.3%

4.3 Predicting Landfill Odour Concentration based on chemical composition

The ANN prediction results are shown in Table 5.

Table 5: Summary of the best predicted odour concentrations using artificial neural networks

Categories predicted using ANN							
Neurons and epochs used	N/A	40 neurons, 40 epochs	40 neurons, 25 epochs	40 neurons, 15 epochs	60 neurons, 60 epochs	60 neurons, 60 epochs	40 neurons, 40 epochs
Observed Values (Odour Test Set) (ou)	Low concentration odours (ou)	Landfill gas samples (ou)	Landfill gas samples (ou)	Landfill gas samples (ou)	Landfill gas samples (ou)	Landfill gas samples (ou)	All Samples (ou)
35	N/A	19	22	24	32	30	20
6	N/A	317	304	218	413	222	840
101000	N/A	50435	48505	36547	35804	55215	106720
724	N/A	535	452	534	1032	483	870
23170	N/A	25910	26364	32478	24181	25812	21410
50535	N/A	N/A	N/A	N/A	N/A	N/A	234470

5 DISCUSSION

The intensity results shown in Table 3 indicates both the landfill and tipface odours are perceived as having an intensity of distinct (intensity level of 3) at approximately the odour threshold i.e. 1 ou by definition. The odour concentration where the population determines the value to be distinct is shown in Table 3. There is little difference between the LFG, tipface and downwind of tipface values suggesting that the population is able to perceive the odour at a distinct level between 0.8 ou and 1.4 ou for all these sources. This indicates that the basis chemical composition and the perceived odour is similar. These values also suggest that the odour is distinct close to the odour threshold.

Based on the investigation into predicting odour concentrations based on LFG VOC concentration, it was concluded that Artificial Neural Network (ANN) can be a useful tool at predicting odour concentrations. The sample and test sets used in this investigation were considered to be too small for prediction purposes. A minimum training sample size should ideally be 50-100, while a test size may be in the order of 10-20. ANN also appears to provide more accurate results if the input and output ranges are narrow. For example, if looking to predict low odour concentrations of between 20 ou and 100 ou, the bulk of the input should also be in that range. If the application of ANN is predicting low odour concentrations in the community, the majority of the data should have odour concentrations of between 0-100 ou, as this concentration range is where most of the population would complain. As much of the input data must be measured at the lower end of measurable odour thresholds i.e., around 5-10 ou, the odour concentrations must be calculated as accurately as possible. ANN appears to work best in the middle range eg. 200 ou to 50,000 ou, but drops off in accuracy in the extremities of the range being measured eg. 10 ou.

ANN may be used to predict odour concentrations based on VOC data to within approximately 50-100% for low odour concentrations, with higher prediction accuracy for odour concentrations in the middle to higher concentrations i.e. greater than 200 ou. A greater training and test set for low odour concentrations is likely to significantly increase the predictive accuracy

The odour sample in the test set with an odour concentration of 6 ou was not successfully predicted. This could potentially be due to a higher than normal concentration of a non odorous chemical that distorted the results. The poor correlation between actual and synthesised odours in the e-nose analysis also suggested that the synthesised samples did not add useful data to the predictive ability of artificial neural networking.

6 CONCLUSION

This investigation provided a way of combining current and emergent technologies of odour assessment to address a variety of planning and management issues in the landfill industry. For low concentration odours collected from area source surveys or residents who complain about odour from landfills, information may be gathered and analysed to assess the likely odour concentration and odorants present. If the main odorants present match the main odorants in LFG, it may be possible to assess the presence of odour at the site in question, however an assessment should be performed to determine the source of the odour and rule out sub-surface LFG migration. The methods used in this study to assess landfill odour and predict its movement and impact can be combined to form a powerful tool for landfill odour impact assessment. Artificial neural networking and electronic nose analysis, while still in developmental stages hold particular promise for accurately assessing ambient or low concentration odours in the future, however the current techniques of odour impact assessment, namely dynamic olfactometry, GC-MS and atmospheric dispersion modelling will continue, at least in the near future to be the dominant methods used due to the reliability and robustness.

7 REFERENCES

Arthur, KR and Nelson PE 1994 Investigation into the air contaminants from landfills. in *Odour Measurement EIA & Regulatory Control Workshop, 12-13 July 1994, Lincoln University New Zealand*

Cooper, C, (1990) *Landfill Gas Emissions.* Florida Center for Solid and Hazardous Waste Management. Gainesville Florida, 59 pp.

Cooper DC, Reinhardt DR, Rash F, Seligman D, Keely D 1992 *Landfill Gas Emissions* Florida Center for Solid and Hazardous Waste Management. Gainesville Florida, 136 pp.

Devos, M Patte, F Rouault J Laffort, P Van Gemert, LJ 1990 *Standardized Human Odour Thresholds*. Oxford University Press. Oxford.

El-Fadel M, Findikakis AN, Leckie JO, Environmental Impacts of Solid Waste Landfilling in *Journal of Environmental Management* (1997) Volume 50. Pages 1-25. Academic Press Limited.

Klenbusch, MR 1986 *Measurement of Gaseous Emission Rates from Land Surfaces using an Emission Isolation Flux Chamber : User's Guide. Report EPA/600/8-86/008*. United States Environment Protection Agency. Las Vegas. 60 pp.

New South Wales Environment Protection Authority (2001) *Technical Notes, Draft Policy: Assessment and Management of Odour from Stationary Sources in NSW*. Environment Protection Authority, Sydney. 109 pp.

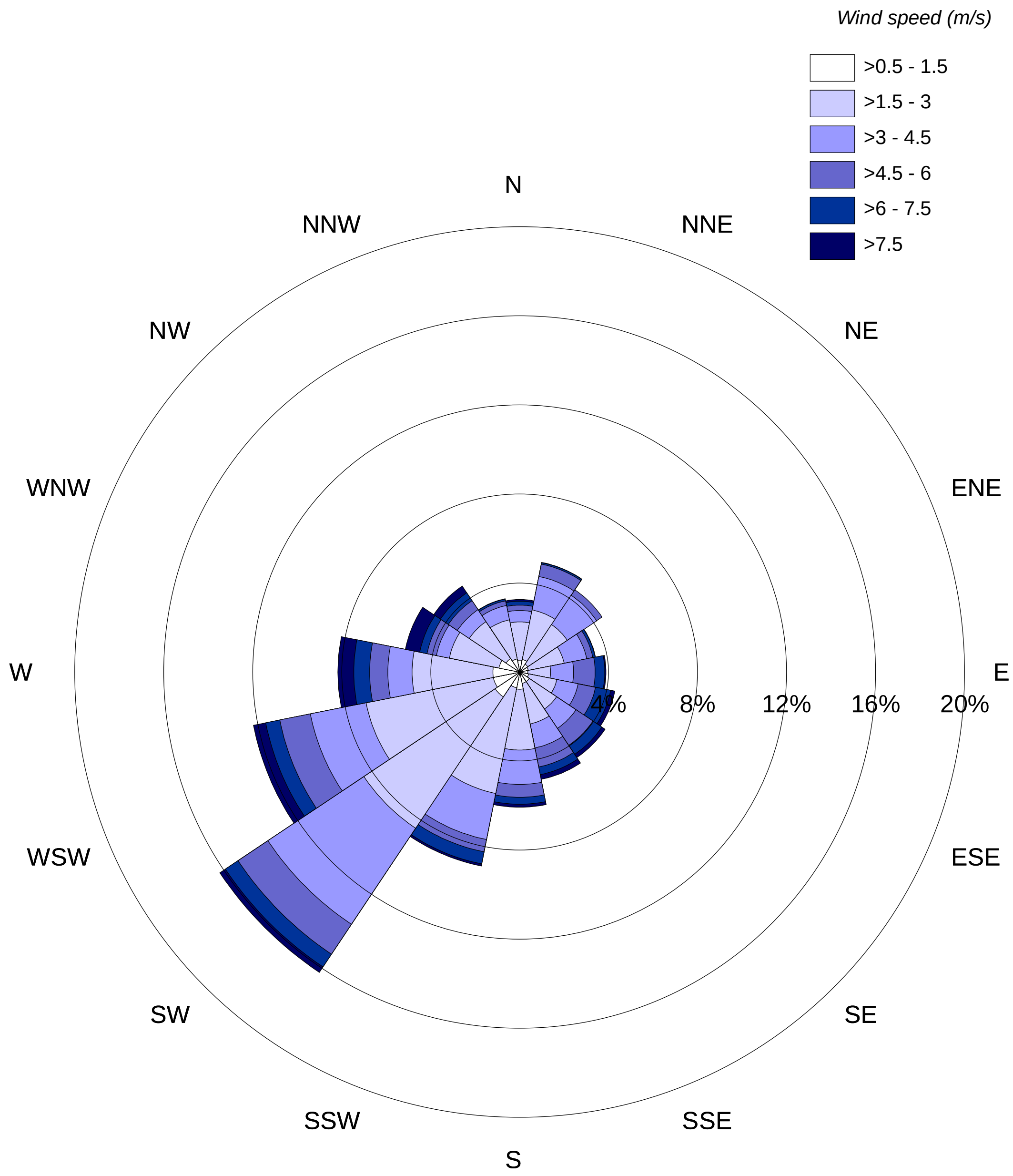
Standards Australia / Standards New Zealand 2001 *Stationary source emissions: Part 3: Determination of odour concentration by dynamic olfactometry*. AS/NZS 4323.3:2001

Verein Deutscher Ingenieure (1992) *VDI 3882 Part1. Olfactometry: Determination of Odour Intensity*. Dusseldorf. 27 pp.

Western Australia Department of Environment Protection, 2000 *Guidance for the assessment of environmental Factors (in accordance with the Environmental Protection Act 1986) Assessment of Odour Impacts* No.47 Draft April 2000.

Appendix C Windrose

Windrose for Badgerys Creek
1990/1991



Calms = 1.3%