



Veolia Australia & New Zealand

Woodlawn Bioreactor Expansion Project

Independent Odour Audit #4

December 2015

Final Report

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APPENDIX C: TECHNICAL DOCUMENTATION RELEVANT TO THE AUDIT

APPENDIX D: LIQUID ODOUR MEASUREMENT METHODOLOGY

APPENDIX E: ODOUR DIARY ENTRIES SUMMARY TABLES

LIST OF DEFINITIONS & UNITS

AS4323.3:2001	Australian Standard 4323.3: 2001: Determination of odour concentration by dynamic olfactometry
AS4323.4:2009	Australian Standard 4323.4:2009. Stationary source emissions - Area source sampling - Flux chamber technique.
BWMS	Bioreactor Waste Management System
C & D	Construction & Demolition
DPI	Department of Planning & Infrastructure
EA 2010	Environmental Assessment Woodlawn Expansion Report (August 2010)
ED3N	Evaporation Dam 3 North
EPL	Environment Protection License
FAOA	Field Ambient Odour Assessment
GC-FID	Gas Chromatography-Flame Ionisation Detector
GC-MS	Gas Chromatography-Mass Spectrometry
GC-SCD	Gas Chromatography-Sulphur Chemiluminescence
ha	hectare
HRT	hydraulic retention time
IFH	Isolation Flux Hood
IMF	Crisps Creek Intermodal Facility
IOA	Independent Odour Audit
Jerome	Jerome ® 631-X H ₂ S Analyser
IOA	Independent Odour Audit
L	litres
L/day	litres per day
L/sec	litres per second
LAD	Leachate Aeration Dam
LMS	Leachate Management System
LOM	Liquid Odour Method
lpm	litres per minute
m²	square metre
m³	cubic metres
mm	millimetres
MSW	Municipal Solid Waste
MWh	Megawatt hours
NATA	National Association of Testing Authorities
NGERS	National Greenhouse Emissions Reporting Scheme
OER	odour emission rate
ou	odour concentration
ou.m³/m²/s	specific odour emission rate
ou.m³/s	odour emission rate

ppm	parts per million, by volume
PTFE	polytetrafluoroethylene
RH	relative humidity
SOER	specific odour emission rate
the Audit	2015 Independent Odour Audit
the Site	Woodlawn Bioreactor Facility, Collector Road, Tarago, NSW
TOU	The Odour Unit Pty Ltd
tpa	tonnes per annum
US EPA	United States Environment Protection Agency
Veolia	Veolia Australia & New Zealand
VOC	Volatile Organic Compounds
WALTER	Woodlawn Aerated Leachate Treated Effluent Refiner
WIP 2012	Woodlawn Infrastructure Plan (WIP) Phase 1 - April 2012
WIP post-2014	Woodlawn Infrastructure Plan (WIP) 2015-2017

1 INTRODUCTION

In September 2015, Veolia Australia & New Zealand (Veolia) engaged The Odour Unit Pty Ltd (TOU) to carry out the fourth Independent Odour Audit (the Audit) of the Woodlawn Bioreactor Facility located at Collector Road, Tarago, NSW (the Site).

The specific scope of works for the Audit is detailed in *Condition 7 of Schedule 4* in the *Specific Environmental Conditions - Landfill site* and enforced by *Section 75J* of the *Environmental Planning and Assessment Act 1979* as part of the project approval for the Woodlawn Waste Expansion Project.

1.1 WOODLAWN WASTE EXPANSION PROJECT BACKGROUND

In March 2010, Veolia issued an application to the Department of Planning & Infrastructure (DPI) seeking approval to increase the maximum throughput rate of the Woodlawn Bioreactor from 500,000 to 1.13 million tonnes per annum (tpa). Simultaneously, Veolia was also seeking to increase the maximum throughput rate of the nearby Crisps Creek Intermodal Facility (IMF) to 1.18 million tpa.

In addition to the above, the proposal application entailed:

- Installing additional lighting at the Site;
- Extending the approved hours of operation at the Bioreactor and the IMF;
- Increasing the number of truck movements transporting waste to the Bioreactor from the IMF; and
- Increasing the amount of waste transported to the Site by road from regional councils from 50,000 to 130,000 tpa.

Veolia received approval for the Woodlawn Waste Expansion Project on 16 March 2012.

1.2 OBJECTIVES

In accordance with the project approval requirements of *Condition 7 of Schedule 4* in the *Specific Environmental Conditions - Landfill sites* (DA 10_0012), Veolia is required to carry out an Independent Odour Audit three months from the date of project approval and annually thereafter, unless otherwise agreed by the Director-General. The Audit must:

- a. *Consult with OEH and the Department;*
- b. *Audit the effectiveness of the odour controls on-site in regard to protecting receivers against offensive odour;*
- c. *Review the proponents' production data (that are relevant to the odour Audit) and complaint records;*

- d. *Review the relevant odour sections of the Air Quality and Greenhouse Gas Management Plan for the project and assess the effectiveness of odour control;*
- e. *Measure all key odour sources on-site including:*
 - i. *consideration of wet weather conditions providing all raw data used in this analysis;*
 - ii. *consideration of (but not limited to) all liquid storage area, active tipping faces, waste cover area, aged waste areas and recirculation of leachate onto waste in the Void;*
 - iii. *a comparison of the results of these measurements against the predictions in the EA*
- f. *Determine whether the project is complying with the requirements in this approval to protect receivers against offensive odour*
- g. *Outline all reasonable and feasible measures (including cost/benefit analysis, if required) that may be required to improve odour control at the site and; and*
- h. *Recommend and prioritise (mandatory and non-mandatory) recommendations for their implementations.*

This is the fourth Independent Odour Audit (IOA) commissioned since the Woodlawn Waste Expansion project approval was granted.

1.3 COMPLIANCE WITH AUDIT OBJECTIVES

The Audit has been undertaken by TOU and endorsed by the Director-General of the DPI, and consists of the following:

- *Fieldwork:* collection of odour samples from key sources (as per *Condition 7 (e)*), recording of relevant field observations and measurements, and discussions with Veolia Woodlawn staff in regards to the operations of the Bioreactor and IMF. The odour emissions inventory developed in the previous IOAs was used by the audit team as a basis for the sampling program in the Audit;
- *Reviewing:* a comprehensive review of all new relevant assessments undertaken and documentation since the 2014 IOA. In the Audit, this included:
 - Review of landfill gas capture since the previous audit;
 - Leachate quality data;
 - Odour complaints register and responses by Veolia;
 - Stack emission survey for Generator No. 3;
 - Olfactometry testing for Generator No. 3;
 - Gas speciation analysis of landfill gas emissions; and
 - Sulphur balance investigation.
- *Reporting:* a comprehensive summary of all aspects of the Audit, complying with the Audit objectives specified in **Section 1.2**.

1.3.1 Additional work to Audit requirements

In May 2014 Veolia, in collaboration with TOU, published and distributed odour diaries to participating community members. In addition to the requirements specified in **Section 1.2**, the Audit scope was extended to include a review and analysis of the odour diary entries that have been logged by participating residents from the period of October 2014 to October 2015 (see **Section 7.4.2**).

This report summarises the Audit carried out by the auditors at the Site.

2 THE SITE

2.1 WOODLAWN BIOREACTOR FACILITY BACKGROUND

The Site is located 250 km south of Sydney, within the 6,000 hectare (ha) Woodlawn Eco-Precinct, in the Southern Tablelands near Goulburn in New South Wales. An aerial view of the Site, highlighting the key areas as they currently stand, is shown in **Figure 2.1**.

Prior to waste operations, Woodlawn operated as a base metals open-cut mine site during the 1970s and 1990s, processing copper, lead and zinc. Since September 2004, the mine void has been operated as an in-situ Bioreactor, historically receiving putrescible waste solely from the Sydney metropolitan area via the Clyde Transfer Terminal Facility. Since early 2012, receipt of waste from local regional areas had commenced.

Waste received and contained within the Bioreactor undergoes anaerobic decomposition, which is supplemented by leachate recirculation, resulting in the production of landfill gas. The landfill gas, predominately rich in methane (CH₄) and carbon dioxide (CO₂), is continuously extracted from the Bioreactor and directly consumed via purpose built landfill gas-fired engines that form the Site's power plant. Each landfill gas-fired engine is capable of generating up to 1.065 Megawatt hours (MWh) of 'green' electricity. All electricity generated is exported to the main grid. The Bioreactor process is described in further detail in the **Section 2.2**.

Aside from generating electricity from waste at the Site, Veolia is also undertaking mine rehabilitation works and has established innovative wind farm, aquaculture and horticulture projects within the Eco-Precinct. Veolia has also commenced construction of a mechanical biological treatment facility at the Site, which falls under a separate development consent and environment protection licence. These undertakings are not relevant to the Audit and thus have been excluded.

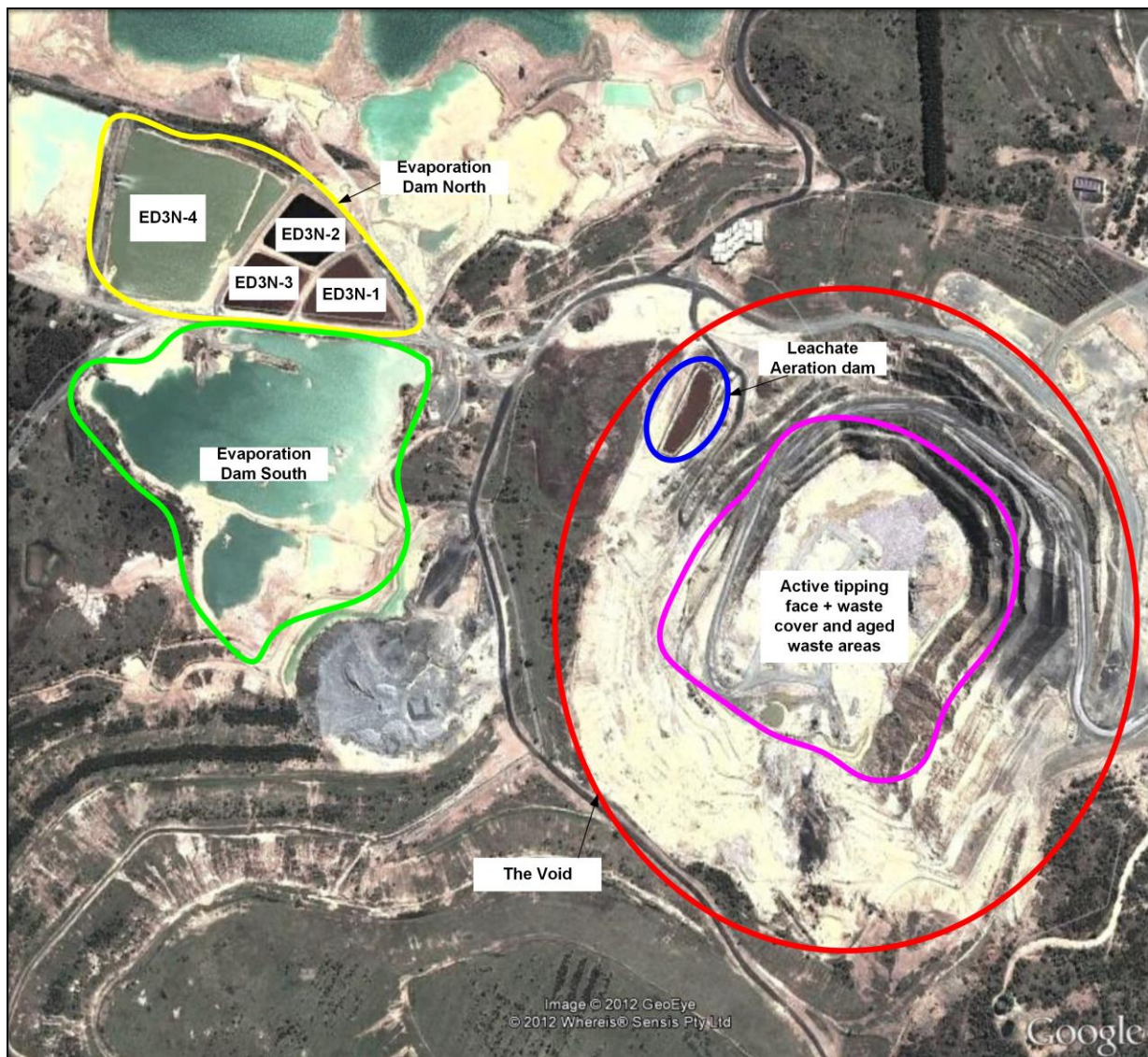


Figure 2.1 – An aerial view of the Site (Source: Google Earth ®)

2.2 PROCESS OVERVIEW

The Site has approval to operate between 0600hrs to 2200hrs on Mondays to Saturdays, with no activities on Sundays, Good Friday or Christmas Day. For the purpose of the Audit, the operational processes at the Site have been categorised under two primary management systems, namely:

1. The Bioreactor Waste Management System (BWMS); and
2. The Leachate Management System (LMS).

The above management systems are described in concise detail in **Section 2.3 & Section 2.4**, respectively. Further details in regards to these systems are contained in the *Environmental Assessment Woodlawn Expansion Report* dated August 2010 (EA 2010).

2.3 BIOREACTOR WASTE MANAGEMENT SYSTEM

At first glance, the Bioreactor surface layout appears to be a simple landfilling operation, consisting of the following:

- An active tipping face;
- Waste covered areas;
- Aged waste areas;
- A mobile tipping platform;
- A leachate recirculation system; and
- A gas extraction system.

On closer inspection, however, it is clear that there are complex operating procedures for the Bioreactor that result in a dynamic site layout that is able to vary with time and operational demands such as the requirement of covering areas of waste, setup of a gas extraction system at specified locations and the need for a leachate extraction/recirculation systems.

The Void layout and operations at the time of the Audit is shown in **Figure 2.2**.

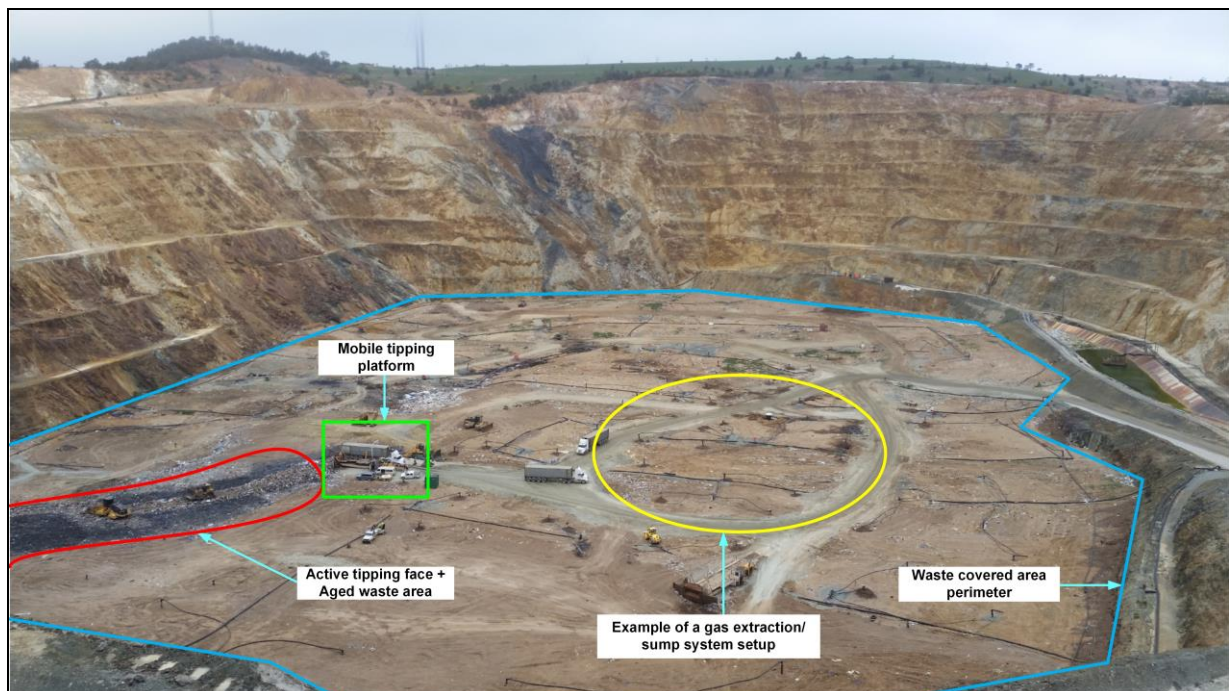


Figure 2.2 – Void Layout and operations as found on 7 October 2015

The current procedure for operating the Bioreactor consists of the receipt of putrescible waste transported to Woodlawn by rail from Sydney, after being containerised at the Veolia Transfer Terminal situated in Clyde, NSW. The fully sealed containerised waste is received by the IMF and transported by a series of trucks to the Bioreactor, where

waste is unloaded via a mobile tipping platform and subsequently transported by a dozer prior to compaction at the active tipping face area. The active tipping face area is progressively covered on a daily basis. As advised by Veolia in previous audits, covering of the active tipping face is an on-going operational process, although the area of exposed waste on a daily basis will vary depending on positioning in the Void, gas infrastructure and weather conditions. It was evident in the Audit that the size of the active tipping face was still well below the area size specified in the EA, discussed in further detail in **Section 7.2.1.7**.

It is understood by the Audit that the tipping process is supplemented by a hydrogen sulphide (H₂S) emission control measure which involves periodic in-situ addition of metal oxide (haematite and/or magnetite) to the waste as placed. Once a waste area is covered, leachate recirculation is promoted to optimise degradation rates and, in turn, encouraging the generation of landfill gas which is continuously extracted by the landfill gas infrastructure within the waste. The landfill gas collection system is constantly expanded to promote better gas capture as waste filling progresses around the Void. In addition to this emission control measure, Veolia is investigating the effectiveness of a sprayable polymer slurry, as a means of odour emission control. The potential use (and effectiveness) of this odour control measure is discussed in **Section 7.2.1.10**.

2.3.1 Leachate recirculation

The main principle of leachate recirculation within the Void is to move leachate from aged waste areas, especially those that are in a more advanced stage of anaerobic decomposition, to new waste areas in order to increase retained moisture levels and biological activity to enhance the waste decomposition process. This process has the effect of promoting higher and faster volumes of landfill gas generation within the Bioreactor.

The current recirculation method is by direct injection into the upper layers of waste.

2.3.2 Landfill gas extraction

The operational management and instalment of landfill gas extraction infrastructure in the Void has been extensively described in *the Woodlawn Infrastructure Plan (WIP) Phase 1 - April 2012* (WIP 2012). The configuration during placement of waste on the surface of the Void and during waste lift is designed to ensure streamlined gas (and leachate) extraction. Landfill gas that is extracted is directed to the on-site power station, with moisture removal undertaken via a series of knock out pots along landfill gas flow lines and the main header line.

2.4 LEACHATE MANAGEMENT SYSTEM

The key features of the LMS include: the Evaporation Dam 3 North; and Leachate Aeration Dam. Each of these features are described in **Section 2.4.1** to **Section 2.4.3**, respectively. Storage Pond 7, a previous feature of the LMS, no longer exists (see

Section 2.4.4 for details). Further details on the LMS can be found in *Chapter 8* of the *EA 2010*.

It is a condition of the Site's Environmental Protection Licence (EPL) that no leachate (treated or untreated) is allowed to be directly discharged from the Site. The only means of volume reduction is through mechanical and/or natural evaporation processes, although Veolia has advised the Audit that no mechanical evaporation had occurred since the previous audit.

2.4.1 Evaporation Dam 3 North (ED3N)

ED3N pond system covers a total area of 3.6 hectares (ha) and is divided into four discrete lagoons, namely:

- **ED3N-1:** contains treated leachate from the leachate aeration dam (LAD). The pond surface area, as of the Audit, is approximately 0.6 ha;
- **ED3N-2:** receives treated leachate from the LAD. The pond surface area, as of the Audit, is approximately 0.55 ha;
- **ED3N-3:** receives treated leachate from the LAD. On-site mechanical evaporators are available to promote evaporation but have not been used since the 2013 IOA. The pond surface area, as of the Audit, is approximately 0.55 ha. Any overflow from this pond is directed to ED3N-1; and
- **ED3N-4:** receives treated leachate overflow from ED3N-2, ED3N-3 and treated leachate direct from the LAD. The pond surface area, as of the Audit, is approximately 2.5 ha. Evaporators are available to promote evaporation which are controlled by wind direction and humidity.

2.4.1.1 Mechanical evaporation system

The mechanical evaporation system at the Site consists of five Turbomist® evaporation pump units, three active and two spare, each capable of spraying 350 L/min of liquid into the air. These evaporator units are intended to only be operated under favourable wind directions (i.e. when wind direction favours air movement back over the dam) and when ambient relative humidity (RH) levels are less than 75%. Information provided by Veolia indicates that approximately 20% to 30% of the pumped water is evaporated, depending upon ambient temperature and RH conditions. The evaporator units can be relocated to different areas within ED3N.

Veolia has indicated that they now intend on using the evaporator units as there is a growing need for volume reduction in the ponds to retrieve storage capacity. As cited in previous audits, the use of the evaporator units is an important part of volume reduction at the Site. This activity will be mainly undertaken in warmer months to maximise the evaporation potential. This is provided that the quality of the treated

leachate stored in ED3N is assessed to be of suitable quality (discussed further in **Section 7.2.1.5**).

2.4.2 Evaporation Dam 3 South (ED3S)

ED3S contains stormwater runoff which is managed as acid mine drainage. The pond surface area, as documented by LandTeam in August 2015, is 11.8 ha. This represents a revised surface area from the previous value of 6.7 ha.

2.4.3 Leachate Aeration Dam (LAD)

The LAD is located in the upper north-western edge of the Void and is an integral part of the LMS at the Site. Leachate from the Void is pumped directly to the LAD as required. Since the 2012 IOA, the LAD was upgraded from a batch-based wastewater treatment system to a continuous configuration. The upgraded system was commissioned in April 2013. Following this upgrade, the LAD process was modified since the previous audit to consist of aeration and anoxic zones and a reduction to the dam level as a means to increase the efficiency of the leachate treatment process. **Figure 2.3** illustrates the current continuous treatment configuration for the LAD.

The LAD has a hydraulic retention time (HRT) of 33 days and is capable of the continuous treatment of approximately 259,000 L/day of untreated leachate, equivalent to a current maximum treatment capacity of 3 L/s. The effluent from the LAD is dosed in-situ with a polymer before passing through a settling tank (known as the Woodlawn Aerated Leachate Treated Effluent Refiner or WALTER). The sludge from the settling tank is returned to the LAD and when required can be transported to the Void. Under this treatment configuration, the LAD requires desludging approximately every 2 - 5 months (as advised by Veolia Water). The sludge from the desludging process (and any excess sludge that is generated) is returned to the waste in the Bioreactor where it is buried and covered.

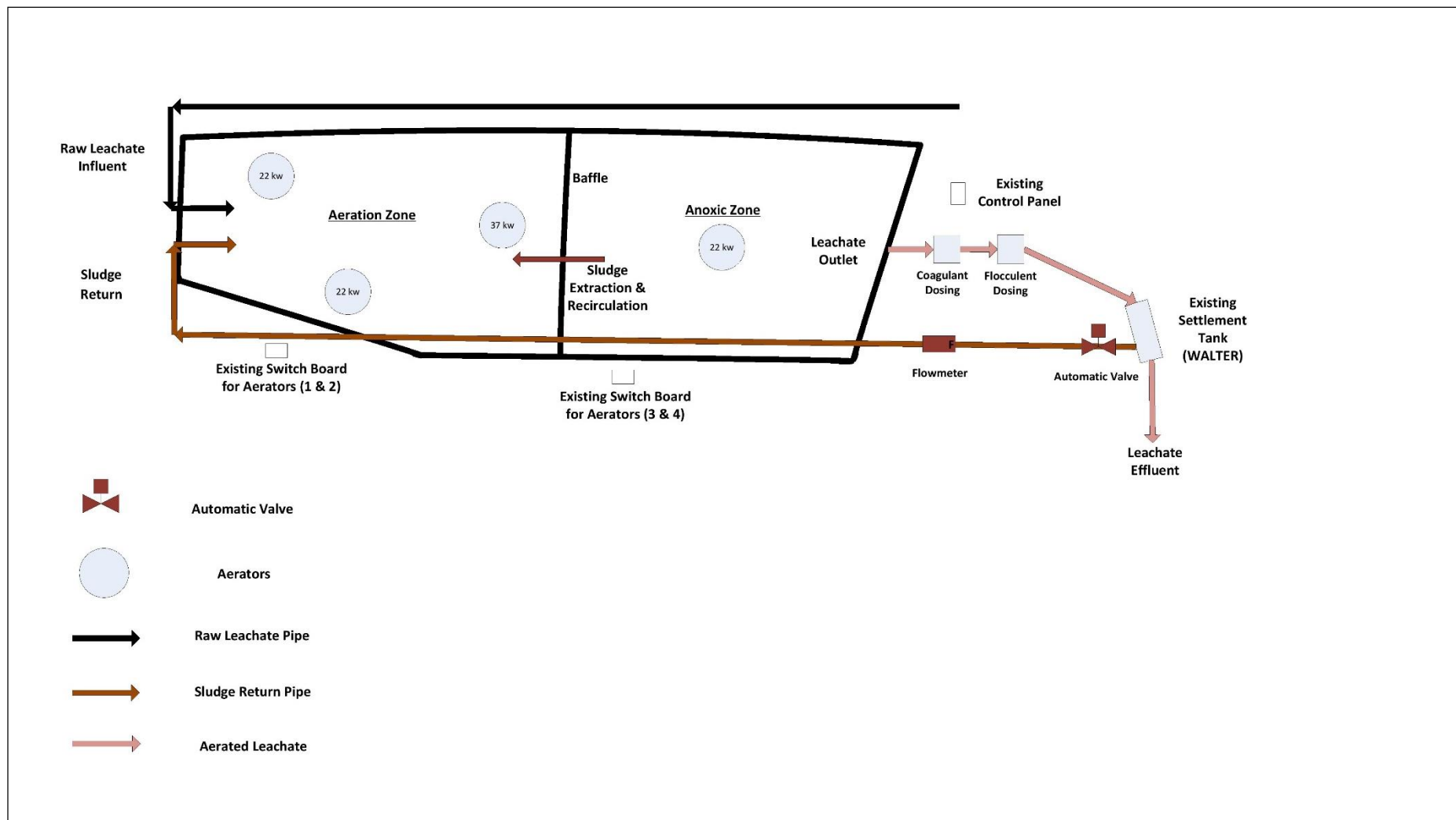


Figure 2.3 – A flow schematic of the current continuous treatment configuration for the LAD at the Site (Source: Veolia)

2.4.4 Storage Pond 7 (inside the Void)

At the time of the Audit, Storage Pond 7 remains decommissioned (previously located in the Void). As a result, it has been excluded as a valid odour emission source for the purposes of the Audit.

There are no stored leachate sources on the waste surface of the Void.

3 SAMPLING PROGRAM

As per *Condition 7 (e) of Schedule 4 in the Specific Environmental Conditions - Landfill site*, this Audit measured all current and key sources at the Site. As previously highlighted in **Section 1.3**, the odour emissions inventory developed in the 2014 IOA by the audit team was used as a basis for the sampling program in the Audit.

3.1 SCOPE

A total collection of twenty six samples were collected in the Audit, namely: twenty three gas samples for odour concentration measurement and gas speciation analysis (where applicable); and three liquid samples for odour concentration measurement testing using an in-house NATA-accredited Liquid Odour Concentration Determination Method (see **Section 4.3 & Appendix D** for details). The liquid samples, whilst not being a requirement for the purposes of the Audit, were collected from ED3N-1, ED3N-2 and ED3N-3 to quantify the odour emissions caused by the natural or forced evaporation of lagoons liquid contents (see **Section 7.2.1.5** for further details and results).

3.2 SCHEDULE

The sampling program schedule for the Audit is summarised in **Table 3.1**. As shown in **Table 3.1**, there are several key sampling locations at the Site. This includes:

- The Bioreactor;
- ED3N System;
- The Landfill Gas System; and
- Other sources in the Void.

The sampling program schedule includes all key sources requested in *Condition 7 (e) of Schedule 4 in the Specific Environmental Conditions - Landfill site* with the following exceptions:

- *Consideration of wet weather conditions:* No rainfall was experienced during sampling. As a result, the Audit was unable to collect representative odour samples under wet weather conditions but considered the effects of wet weather in terms of the need to handle increased levels of leachate under wet weather conditions; and
- *Leachate recirculation:* Similarly to the 2012 IOA, the Audit was unable to observe and thus collect representative samples for this scenario. Since the completion of the *EA 2010* was undertaken, Veolia has developed a leachate recirculation system that involves direct injection of leachate into the waste which eliminates the need for spraying over the surface (see **Section 2.3.1**). The audit team understands this will continue to remain normal practice, both for the Audit

and future IOAs. Therefore, no suitable access points for the collection of odour samples from this source is, and will continue to be, possible.

No samples were collected from the IMF as waste transportation is a fully contained process until displacement of the waste contents into the Void. Similarly to the previous audit, it has been determined by the Audit team that there are no odour emission sources from this operation that can be practically measured. As will be discussed in **Section 7.2.1.9**, and noted in previous audits, the IMF is not considered to be a significant contributor to the Site's overall odour emissions profile.

Table 3.1 - Woodlawn Bioreactor Facility sampling program schedule: 6 October 2015 – 8 October 2015		
Location	Source Type	No. of samples collected
The Bioreactor		
Active Tipping Face	Area source	8
Waste Covered Area		7
Leachate Aeration Dam		
Leachate Aeration Dam	Area source	1
ED3N Pond System		
ED3N - 1	Area Source (1) + Liquid odour measurement (1)	2
ED3N - 2	Area source (1) + Liquid odour measurement (1)	2
ED3N - 3	Area source (1) + Liquid odour measurement (1)	2
ED3N - 4	Area source	1
Landfill Gas System		
Gas engine inlet (i.e. landfill gas)	Point source	1
Construction and Demolition Area		
Active Tipping Face	Area source	2
TOTAL		26

4 SAMPLING METHODOLOGY

The following sampling methodologies refers to the source type description presented in **Section 3 - Table 3.1** source type description.

4.1 POINT SOURCE SAMPLING

The method used for collecting samples from the landfill gas inlet duct involved drawing the sample air through a polytetrafluoroethylene (PTFE), commercially known as Teflon®, sampling tube into a single use, Nalophan sample bag. The air samples collated using this technique only involved the positive pressure on the discharge side of the landfill gas inlet duct where the sample was collected from an existing tap point.

4.2 AREA SOURCE SAMPLING METHOD

The objective of the area source sampling was to collect representative odour samples from the settling pond and wastewater dam surface area. This was undertaken using an isolation flux hood (IFH). All sampling using the IFH was carried out according to the method described in the United States Environment Protection Agency (US EPA) technical report 'EPA/600/8-86/008', from which Australian Standard 4323.4:2009 (AS4323.4:2009) is based upon and is considered an '*Other Approved Method (OM-8)*' by EPA (DEC, 2007). TOU's IFH adheres to the design specifications, materials of construction and supporting equipment that the US EPA report 'EPA/600/8-86/008' defines. The IFH has a diameter of 0.406 metres (m), a chamber surface area of 0.126 square metres (m²) and a chamber volume of 30 litres (L), equivalent to 0.03 cubic metres (m³), when the skirt of the hood is inserted into the liquid or solid surface by the specified 25 millimetres (mm). Dry nitrogen is then introduced to the IFH at a sweep rate of 5 litres per minute (lpm).

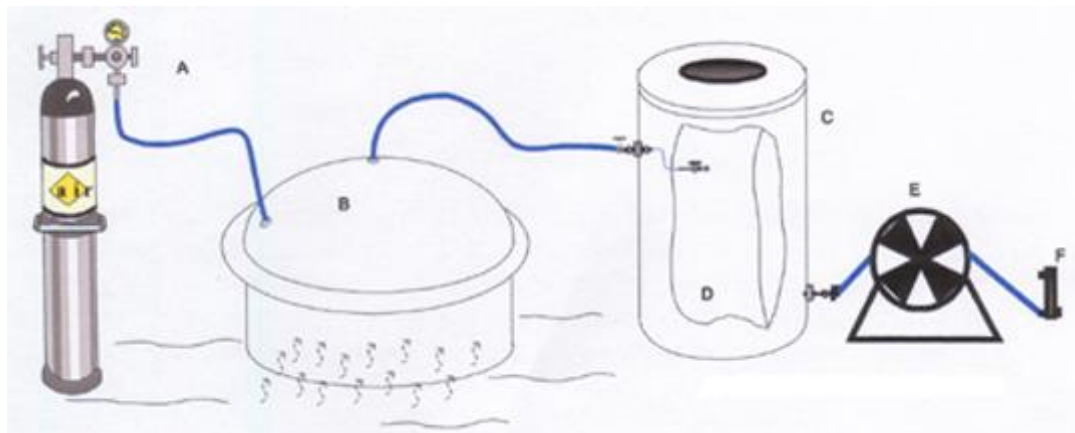
As these area sources are open to the atmosphere, wind is a major factor in the release of odorous pollutants from the surface and conveying the pollutant from the source to areas beyond the boundary. The IFH system is designed to simulate the transfer of odorous pollutants by the wind, resulting in a controlled and consistent sampling environment. This is achieved by the flux of near pure nitrogen gas into the IFH that is positioned on the liquid or solid surface. On a liquid surface this is achieved by floating the IFH within an inflated tyre inner tube. The nitrogen gas then transports the odour from the surface in the same way the wind does, albeit at a very low sweep velocity. This odorous air is then collected for odour and/or chemical analysis. As the IFH has a constant 5 lpm inflow of nitrogen gas to it, the sampling chamber remains under positive pressure and produces a net outflow through the vent on top of the IFH, therefore eliminating any chance of contamination of external air from the atmosphere. The IFH's volume of 30 L and the 5 lpm nitrogen sweep rate results in a gas residence time of six minutes. The US EPA method prescribes a minimum of four air changes in order to achieve optimum purging and equilibrium in the hood, and therefore a total of 24 mins

is allowed before sampling commences. The sample is then collected over a 10-minute period to obtain a 20 L sample for odour and/or chemical analysis.

The US EPA method followed by TOU may be summarised as follows, and as described in the schematic of the sampling equipment shown in **Figure 4.1**

- Dry nitrogen is directed into the IFH via odour free PTFE tubing until it has reached equilibrium. The nitrogen is channelled to a manifold fitted with small outlets above the surface, which direct the air towards the centre of the surface;
- The nitrogen flow (5 lpm) purges the flux hood with a residence time of four times the chamber volume occurring before sampling begins; and
- The odorous sample is drawn through a Teflon tube, into a single use, odour-free Nalophan sample bag secured inside a drum that is under vacuum. The balance of the gas flow is vented to atmosphere.

The IFH is manufactured from acrylic resin to ensure it does not contribute to the odour sample. All other surfaces in contact with the sample are made from PTFE or stainless steel.



Source: Odotech - Odoflux Isolation Flux Hood Manual

Key

- A Cylinder of medical air, nitrogen or any neutral gas.
- B Isolation Flux Hood (a detailed diagram is shown in **Figure 4.2**)
- C Lung chamber (sampling drum)
- D Nalophan sampling bag
- E Sampling pump
- F Air flow meter

Figure 4.1 - Isolation Flux Hood Setup Schematic

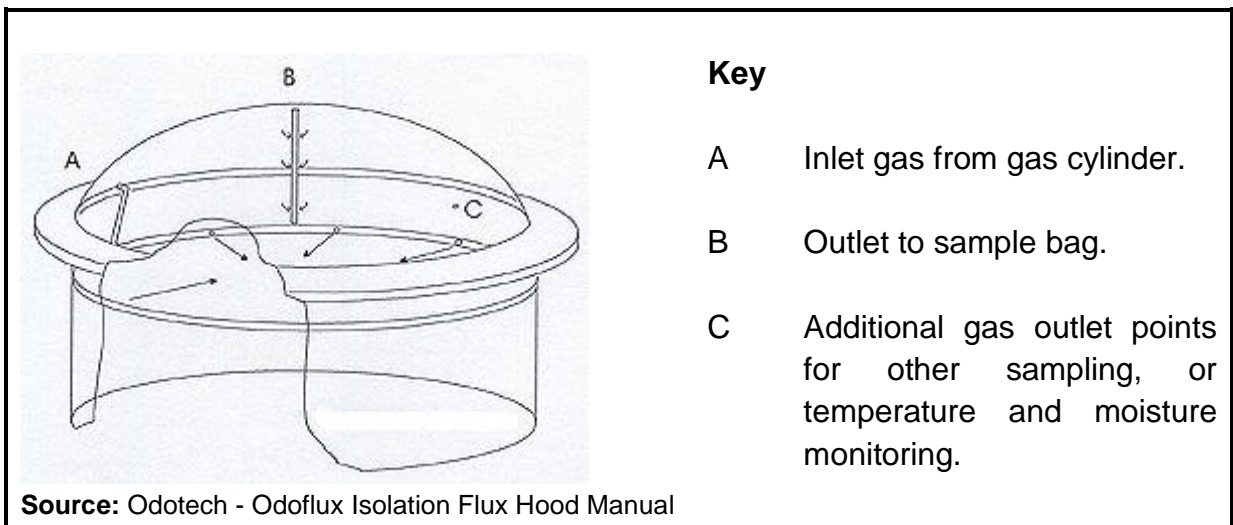


Figure 4.2 - Isolation Flux Hood Chamber Details

An example of IFH sampling on a compost cell stockpile at the VPA is shown in **Photo 4.1**.

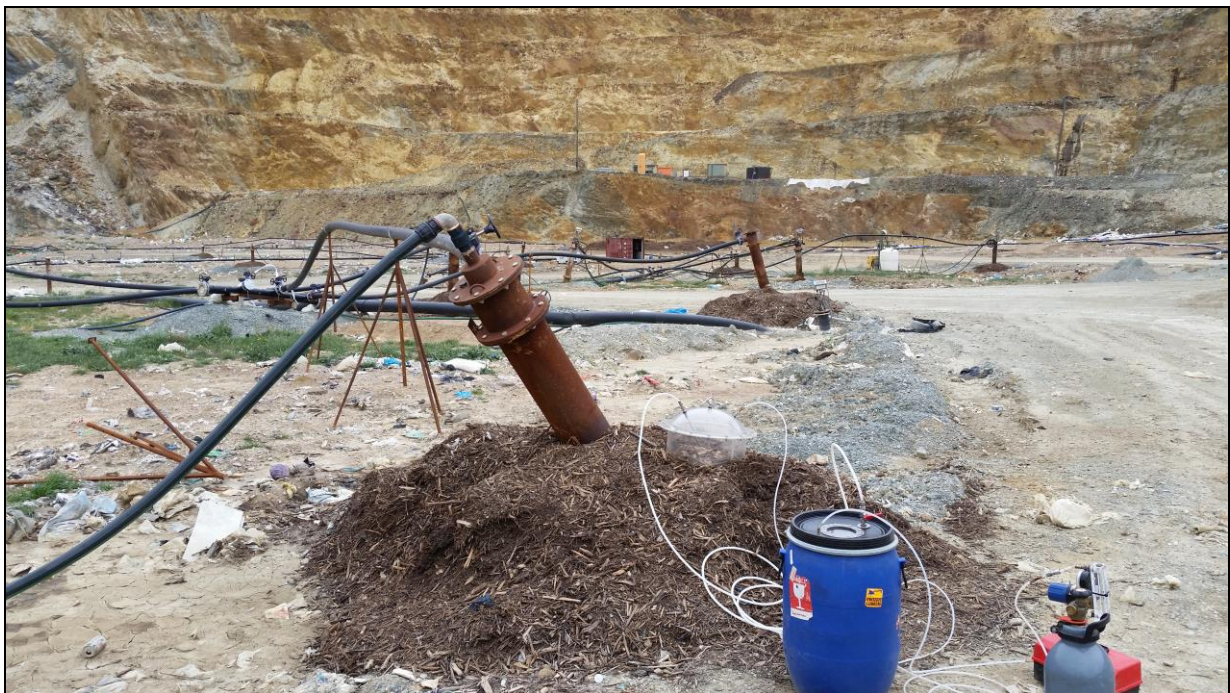


Photo 4.1 – An example of IFH sampling in the Void

4.3 LIQUID ODOUR METHOD

4.3.1 Overview

The Liquid Odour Method (LOM) was developed by TOU for measurement of the odour release potential from process liquors, which is universally applicable to aqueous solutions containing odorous substances. In simple terms, it measures the odour released when an odorous liquid evaporates. It is directly relevant to the mechanical evaporation units in use at the Site and natural evaporation processes for volume reduction of treated leachate (see **Appendix D** for details on methodology).

5 ODOUR & CHEMICAL MEASUREMENT METHODS

5.1 ODOUR MEASUREMENT LABORATORY

All samples collected for the project were tested at TOU's NATA Accredited Sydney Odour Laboratory.

5.1.1 Odour Concentration Measurement

TOU's odour laboratory operates to the Australian Standard for odour measurement '*Determination of odour concentration by dynamic olfactometry*' (AS4323.3:2001) which prescribes a method for sample analysis that provides quality assurance/quality control and ensures a high degree of confidence in the accuracy, repeatability and reproducibility of results.

The concentration of the gaseous odour samples were measured using a technique known as dynamic olfactometry. Dynamic olfactometry involves the repeated presentation of both a diluted gaseous odour sample and an odour-free air stream to a panel of qualified assessors through two adjacent ports on the olfactometer (known as the Odormat™). TOU utilises four to six trained assessors (or panellists) for sample analysis, with the results from four qualified panellists being the minimum allowed under the Australian Standard AS4323.3:2001. For the Audit, four panelists were used.

The method for odour concentration analysis involves the odorous gas sample initially being diluted to the point where it cannot be detected by any member of the panel. The assessor's step- up to the olfactometer in turn, takes a sniff from each port, then choose which port contains the odour and enter their response. At each stage of the testing process, the concentration of the odorous gas is systematically increased (doubled) and re-presented to the panellist's. A round is completed when all assessors have correctly detected the presence of the odour with certainty. The odour is presented to the panel for three rounds and results taken from the latter two rounds, as stated in AS4323.3:2001.

The results obtained give an odour measurement measured in terms of odour units (ou). One (1) ou is the concentration of odorous air that can be detected by 50% of members of an odour panel (persons chosen as representative of the average population sensitivity to odour). It is effectively the concentration of an odour at detection threshold level. The odour concentration of a sample expressed in odour units is the number of times the sample must be diluted to elicit a physiological response (the detection threshold level) from a panel. For example, twenty (20) odour units would mean that the odour sample will need to be diluted 20 times for the concentration to be at detection threshold level. This process is defined within AS/NZS 4323.3:2001. This process is defined within AS4323.3:2001. The odour units can be subsequently multiplied by an

emission rate or volumetric flow to obtain an Odour Emission Rate ($\text{ou.m}^3/\text{s}$) or a SOER ($\text{ou.m}^3/\text{m}^2/\text{s}$) for area source samples collected using the IFH method (see **Section 4.2** & **Section 5.1.2**).

5.1.2 Specific Odour Emission Rate

For area source samples collected using the IFH method, the results from odour concentration testing, derived in odour units (see **Section 4.2** for details), are multiplied by an emission rate to obtain a specific odour emission rate (SOER). SOER is a measure of odour released from a representative point at a source. The SOER is multiplied by the area of the source to obtain the odour emission rate (OER), or the total odour released from each source, that is:

- $\text{SOER } (\text{ou.m}^3 \text{m}^{-2} \text{s}^{-1}) = \text{OC} \times \text{Q} / \text{A}; \text{ and}$
- $\text{OER } (\text{ou.m}^3 \text{s}^{-1}) = \text{SOER} \times \text{area of source } (\text{m}^2)$

where:

- OC = odour concentration of compound from air in the chamber (ou)
- Q = sweep gas volumetric flow rate into chamber ($\text{m}^3 \text{s}^{-1}$)
- A = sample source total surface area (m^2)

The SOER is presented in the units $\text{ou.m}^3/\text{m}^2/\text{s}$ as per convention, and as referred to in the document – Klenbusch, M.R., 1986. USEPA Report No. EPA/600/8-86/008 ‘*Measurement of gaseous emission rates from land surfaces using an emission isolation flux chamber, - Users Guide*’. The OER is presented in the units’ $\text{ou.m}^3/\text{s}$ as referenced in the AS4323.3:2001.

5.1.3 Odour Measurement Accuracy

The repeatability and odour measurement accuracy of the Odormat™ is determined by its deviation from statistically reference values specified in AS4323.3:2001. This includes calculation of instrumental repeatability (r), where r must be less than 0.477 to comply with the standard criterion for repeatability. Its accuracy (A) is also tested against the 95th percentile confidence interval, where A must be less than 0.217 to comply with the accuracy criterion as mentioned in the Standard.

The Odormat™ V04 was last calibrated in March - May 2015 and complied with all requirements set out in the AS4323.3:2001 (see **Appendix A** – Result sheets: *Repeatability and Accuracy*). The calibration gas used was 51.5 parts per million, by volume, n-butanol in nitrogen gas (N_2).

5.2 GAS SPECIATION LABORATORY TESTING

Gas speciation samples were transported to SGS Laboratory in Alexandria, NSW. All gas speciation samples were analysed by a SGS Senior Chemist less than 24 hours after sample collection.

5.2.1 VOC analysis method

Volatile Organic Compounds (VOC) gases were determined by analysis on a Gas Chromatography-Mass Spectrometry (GC-MS). The analysis method involved trapping the gas sample onto a clean thermal desorption tube using a syringe, and thermally desorbed, using method US EPA TO-17.

5.2.2 Sulphur gases analysis method

Sulphur gases were determined by analysis on a GC with Sulphur Chemiluminescence (GC-SC) detection and carried out according to SGS in-house method complying with NIOSH standard. 250 micro-litre of gas was sampled directly to the GC-SCD using a gas-tight syringe.

5.2.3 Methane and hydrocarbon analysis method

For methane and hydrocarbon gases from C2 – C8, 250 microlitre of gas was sampled directly to a GC-Flame Ionisation Detector (FID) using a sample loop.

5.3 IN-SITU H₂S TESTING USING JEROME 631-X H₂S ANALYSER

The Jerome ® 631-X H₂S Analyser (Jerome) is a portable ambient air analyser with a range of 0.003 ppm to 50 ppm. All samples were measured on-site using the Jerome (see **Photo 5.1**), except where H₂S concentrations of greater than 50 ppm were encountered which necessitated the use of colorimetric tubes were used).



Photo 5.1– TOU's portable Jerome 631-X H₂S Analyser

5.3.1 Principle of Operation

A thin gold film, in the presence of H₂S, undergoes an increase in electrical resistance proportional to the mass of H₂S in the sample.

When the SAMPLE button is pressed, an internal pump pulls ambient air over the gold film sensor for a precise period. The sensor absorbs the H₂S. The instrument determines the amount absorbed and displays the measured concentration of H₂S in ppm. During normal sampling, the ambient air sample is diluted in the flow system at a ratio of 100:1. When sampling in Range 0 (where low levels of H₂S is expected) undiluted air samples are drawn across the gold film sensor.

The instrument's microprocessor automatically re-zeros the digital meter at the start of each sample cycle and freezes the meter reading until the next sample cycle is activated, thus eliminating drift between samples.

During the sample mode cycle, bars on the LCD represent the percentage of sensor saturation. Depending on the concentrations, 50 to 500 samples may be taken before the sensor reaches saturation. At that point, a 10-minute heat cycle must be initiated to remove the accumulated H₂S from the sensor. During the sensor regeneration cycle, both solenoids are closed to cause air to pass through a scrubber filter and provide clean air for the regeneration process. The flow system's final scrubber prevents contamination of the environment.

5.3.2 Sample Mode Accuracy

The length of the sample cycle depends on the concentration of H₂S and this determines the level of accuracy in the readings. There are four ranges which have been summarised in **Table 5.1**.

Table 5.1 – Jerome 631-X H₂S analyser: Sample mode

Range	Concentration	Response Time	Accuracy at Mid-range
0	0.001 to 0.099 ppm	30 seconds	± 0.003 ppm at 0.050 ppm
1	0.10 to 0.99 ppm	25 seconds	± 0.03 ppm at 0.5 ppm
2	1.0 to 9.9 ppm	16 seconds	± 0.3 ppm at 5.0 ppm
3	10 to 50 ppm	13 seconds	± 2 ppm at 25 ppm

5.3.3 Zeroing

Prior to testing air samples, the Jerome was zeroed and a blank sample taken using a zero air filter. For each zeroing event in the Audit, the Jerome indicated a nil reading (i.e. 0.000 ppm), indicating that the Jerome was free from any H₂S contamination.

5.4 IN-SITU AMMONIA TESTING

In-situ ammonia testing was only undertaken for gas samples collected at the LAD through the use of colorimetric tubes.

5.5 ODALOGGER MONITORING SURVEY TESTING

The ambient H₂S levels at the boundary of the Void was measured using low-range Odaloggers. These instruments are capable of detecting H₂S levels within a measurement range of 0.1 – 2.0 ppm and log continuously.



Photo 5.2 – An example of an Odalogger unit

6 RESULTS

6.1 ODOUR TESTING AND H₂S CONCENTRATION MEASUREMENT RESULTS

This chapter is dedicated to addressing the following Audit requirement as outlined in **Section 1.2**, namely:

- e. *Measure all key odour sources on-site including:*
- i. *consideration of wet weather conditions providing all raw data used in this analysis;*
 - ii. *consideration of (but not limited to) all liquid storage area, active tipping faces, waste cover area, aged waste areas and recirculation of leachate onto waste in the Void;*
 - iii. *a comparison of the results of these measurements against the predictions in the EA.*

All key odour sources at the Site were measured in the Audit. This section has several tables presented, as follows:

- **Table 6.1** summarises the odour emission results obtained from the Audit and compares the results against the EA predictions;
- **Table 6.2** summarises the odour emission results obtained from the Audit in relation to the efficacy of applying a sprayable polymer slurry mixture to the waste surface;
- **Table 6.3** summarises the global mean SOER results derived in the Audit and compares these results to those derived in the previous IOAs (i.e. 2012 – 2014);
- **Table 6.4** summarises in-situ H₂S concentration measurement results undertaken on all collected samples in the Audit using a calibrated Jerome. The concentration results in this table have been presented in ppm; and
- **Table 6.5** summarises liquid odour measurement results.

In **Section 7.5**, **Table 7.9** summarises the odour emission rates from emission sources amenable to quantitative measurements. These sources have been ranked in descending order. The results in **Table 7.9** do not include potential gas pathways and other fugitive emission sources from the waste surface, due to the difficulty in assigning an appropriate emission area for these sources in order to calculate an OER derived from the SOER and the area. This was a similar constraint in the previous IOAs.

Table 6.1 - The Audit vs. EA 2010: Odour emissions testing results 6 October 2015 – 8 October 2015

Source	The Audit				EA	
Sample Location	Sample Number	Odour Concentration (ou)	SOER (ou.m ³ /m ² /s)	Odour Character	SOER Range (ou.m ³ /m ² /s)	SOER Model Input (ou.m ³ /m ² /s)
Bioreactor (The Void)						
Active Tipping Area						
Sample #18 - Active Tipping Face Area: Fresh Waste (< 1 day old, Point #1)	SC15511	17,900	11.8	garbage	1.0 – 7.3*	7.3 (wet fresh waste emission adopted)
Sample #19 - Active Tipping Face Area: Fresh Waste (< 1 day old, Point #2)	SC15512	15,000	9.15	garbage		
Aged Waste	n/m**				0.5	

* includes dry and wet waste

** unable to be sampled in the Audit due to access and safety concerns prevailing at the time

n/m = not measured

Table 6.1 continued - The Audit vs. EA 2010: Odour emissions testing results 6 October 2015 – 8 October 2015

Source	The Audit				EA	
Sample Location	Sample Number	Odour Concentration (ou)	SOER (ou.m ³ /m ² /s)	Odour Character	SOER Range (ou.m ³ /m ² /s)	SOER Model Input (ou.m ³ /m ² /s)
Bioreactor (The Void)						
Waste Covered Area						
Sample #6 - Waste Covered Area: Normal Capping (Zone A between LE85 & SM13)	SC15499	181	0.127	sweet, fermented	0.1 - 0.2* (covered)	0.2
Sample #7 - Waste Covered Area: Normal Capping (Zone A and parallel to LE99)	SC15500	558	0.388	sweet, fermented, pineapple, rotten egg, landfill gas		
Sample #10 - Waste Covered Area: Normal capping + Biocover material (LE41)	SC15503	256	0.176	garbage, dirt, ammonical	7.5 – 23.9**	23.9**
Sample #11 - Waste Covered Area: Normal capping + Biocover material (LE57)***	SC15504	2,520,000	1,692.9	landfill gas, rotten egg		
Sample #20 - Waste Covered Area: Normal Capping (Zone D - LE65)	SC15513	101,000	58.4	garbage, landfill gas, rotten, pineapple		
Sample #21 - Waste Covered Area: Normal capping + Biocover Material (Zone D - LE65)	SC15514	3,120,000	1765.4	landfill gas, rotten egg, pineapple, garbage		

* includes dry and wet covered waste

** represents potential gas pathways

*** estimated at 3,000 ou per 1 ppm of H₂S (i.e. mean of 2,000 - 4,000 ou per 1 ppm of H₂S)

n/m = not measured

Table 6.1 continued - The Audit vs. EA 2010: Odour Emissions Testing Results 6 October 2015 – 8 October 2015

Source	The Audit				EA	
Sample Location	Sample Number	Odour Concentration (ou)	SOER (ou.m³/m²/s)	Odour Character	SOER Range (ou.m³/m²/s)	SOER Model Input (ou.m³/m²/s)
Bioreactor (The Void)						
Construction and Demolition Area						
Sample #8 - Construction and Demolition Area: Active Tipping Face (Point #1)	SC15501	431	0.299	sweet, fermented, pineapple, rotten egg, landfill gas	n/a	
Sample #9 - Construction and Demolition Area: Active Tipping Face (Point #2)	SC15502	512	0.353	garbage, pineapple		
Leachate Aeration Dam						
Sample #5 - Leachate Aeration Dam	SC15498	362	0.276	ammonical, dirt, soil	0.1 - 7.4*	3.6
Leachate recirculation system						
Leachate recirculation system	n/m				1.6 – 2.5	2.5
Landfill Gas Extraction System						
Landfill gas inlet	n/m				n/a	
Catchment Pond (leachate)						
Storage Pond 7	n/m				2.1 – 8.8	8.8

* includes partially / fully treated leachate (dependent on the treatment stage of the process at the time samples were collected)

n/m = not measured

n/a = not applicable

Table 6.1 continued - The Audit vs. EA 2010: Odour emissions testing results 6 October 2015 – 8 October 2015

Source	The Audit				EA	
Sample Location	Sample Number	Odour Concentration (ou)	SOER (ou.m³/m²/s)	Odour character	SOER Range (ou.m³/m²/s)	SOER Model Input (ou.m³/m²/s)
Evaporation Dams						
Evaporation Dam 3 North (ED3N) Pond System						
Sample #3 - ED3N-1	SC15496	181	0.132	muddy, dirt	2.1 – 8.8	8.8
Sample #2 - ED3N-2	SC15495	197	0.145	ammonical, dirt, soil	0.1 – 7.4	0.2*
Sample #4 - ED3N-3	SC15497	118	0.091	muddy, dirt		
Sample #1 - ED3N-4	SC15494	362	0.269	ammonical, dirt, soil	0.1 – 0.7	0.7**
Sample #LOM1 - ED3N-1	SC15553	118	n/a	musty	n/a	
Sample #LOM2 - ED3N-2	SC15554	470	n/a	ammonia, dirty socks		
Sample #LOM3 - ED3N-3	SC15555	197	n/a	musty, dusty, dirty		
Evaporation Dam 3 South (ED3S) Pond System						
ED3S (Stormwater)	n/m				0.0 - 0.5	0.5

* partially / fully treated leachate

** includes groundwater and fully treated leachate

n/a = not applicable

n/m = not measured

Table 6.2 - Efficacy testing of the polymer slurry mixture odour emissions testing results: 8 October 2015

Source	The Audit				EA	
Sample Location	Sample Number	Odour Concentration (ou)	SOER (ou.m ³ /m ² /s)	Odour character	SOER Range (ou.m ³ /m ² /s)	SOER Model Input (ou.m ³ /m ² /s)
Active tipping face (polymer slurry efficacy testing)						
Sample #12 - Active Tipping Face Area: Soil Cover + Polymer Slurry (Point #1A)	SC15505	256	0.192	dirt, garbage	0.1 - 0.2* (covered)	0.2
Sample #14 - Active Tipping Face Area: Soil Cover + Polymer Slurry (Point #2A)	SC15507	724	0.502	vanilla, gassy		
Sample #13 - Active Tipping Face Area: Polymer Slurry applied (Point #1B)	SC15506	6,320	4.45	ammonical, garbage		
Sample #15 - Active Tipping Face Area: Polymer Slurry applied (Point #2B)	SC15508	4,470	2.83	dirt, garbage		
Sample #16 - Active Tipping Face Area: No cover (Point #3A)	SC15509	23,200	14.0	lime, sour, ammonical, garbage		
Sample #17 - Active Tipping Face Area: No cover (Point #3B)	SC15510	27,600	17.1	ammonical, garbage		

* includes dry and wet covered waste

n/a = not applicable

Table 6.3 – Global mean SOER results: Comparison between The Audit and previous IOAs

Source	The Audit	2014 IOA	2013 IOA	2012 IOA
Location	TOU SOER (ou.m ³ /m ² /s)			
ED3N-1	0.132	0.017	0.30	394
ED3N-2 & 3^	0.118	0.049	11.6 ^^^	0.29
ED3N-2	0.145	0.066	20.1 ^^	0.21
ED3N-3	0.091	0.032	0.2	0.37
ED3N-4	0.269	0.023	0.0604	0.41
Active Tipping Face	7.51^^^^	4.28	3.04	8.36
Leachate Aeration Dam	0.276	0.026	0.323	0.46
Construction and Demolition Tip Face	0.326		0.293	n/a
Storage Pond 7	n/m^^	n/a#		85

^ as specified in EA 2010

^^ no longer exists - see **Section 2.4.4** for details

^^^ represents the sub-optimal pond contents that has now been treated (see **IOA 2013 Report** for details)

^^^^ bulk of emissions originating from ED3N-2 (see **IOA 2013 Report** for details)

^^^^ includes testing results reflecting sampled areas with the polymer slurry applied

There was no designated area for this location (see **IOA 2014 Report** for details)

n/a = not applicable

n/m = not measured

Table 6.4 – Global Jerome H₂S measurement results: 6 October 2015 – 8 October 2015

Sample Location	TOU Sample Number	Jerome H ₂ S concentration reading in bag (ppm)
Evaporation Dam 3 North (ED3N) System		
Sample #1 - ED3N-4	SC15494	0.000
Sample #2 - ED3N-2	SC15495	0.000
Sample #3 - ED3N-1	SC15496	0.000
Sample #4 - ED3N-3	SC15497	0.000
Leachate Aeration Dam		
Sample #5 - Leachate Aeration Dam	SC15498	0.000
Active Tipping Area		
Sample #18 - Active Tipping Face Area: Freshly Waste (< 1 day old, Point #1)	SC15511	0.140
Sample #19 - Active Tipping Face Area: Freshly Waste (< 1 day old, Point #2)	SC15512	0.020
Waste Covered Area		
Sample #6 - Waste Covered Area: Normal Capping (Zone A between LE85 & SM13)	SC15499	0.000
Sample #7 - Waste Covered Area: Normal Capping (Zone A and parallel to LE99)	SC15500	0.01
Sample #10 - Waste Covered Area: Biocovered Material Area (LE41)	SC15503	0.004
Sample #11 - Waste Covered Area: Biocovered Material Area (LE57)^	SC15504	840
Sample #20 - Waste Covered Area: Normal Capping (Zone D - LE65)	SC15513	n/m
Sample #21 - Waste Covered Area: Biocovered Material Area (Zone D - LE65)	SC15514	180
Construction and Demolition Area		
Sample #8 - Construction and Demolition Area: Active Tipping Face (Point #1)	SC15501	0.025
Sample #9 - Construction and Demolition Area: Active Tipping Face (Point #2)	SC15502	n/m
Active Tipping Area (Polymer slurry efficacy testing)		
Sample #12 - Active Tipping Face Area: Soil Covered Final Layer (Point #1A)	SC15505	0.011
Sample #13 - Active Tipping Face Area: Polymer Slurry Secondary Layer (Point #1B)	SC15506	0.026
Sample #14 - Active Tipping Face Area: Soil Covered (Point #2A)	SC15507	0.000
Sample #15 - Active Tipping Face Area: Polymer Slurry (Point #2B)	SC15508	0.045
Sample #16 - Active Tipping Face Area: No cover (Point #3A)	SC15509	0.60
Sample #17 - Active Tipping Face Area: No cover (Point #3B)	SC15510	0.11

Table 6.5 – LOM derived odour emission rates for mechanical and natural evaporation methods: 6 October 2015 - 8 October 2015

Sample Location	TOU Sample Number	Odour Concentration (ou)	Calculated Liquid Odour Potential (ou/mL)	Mechanical Evaporation Rate (L/min) per evaporator^ η = 20% / 30%	Mechanical Evaporation Odour Emission Rate (ou.m³/s) per evaporator η = 20% / 30%	Mechanical Evaporation Odour Emission Rate (ou.m³/s) ALL evaporators^^^ η = 20% / 30%
Evaporation method: Mechanical						
ED3N-1	SC15553	118	0.413	70 / 105	8,330 / 12,500	25,000 / 37,500
ED3N-2	SC15554	470			33,300 / 49,800	99,900 / 149,000
ED3N-3	SC15555	197			13,900 / 20,800	41,700 / 62,400
Evaporation method: Natural						
Sample Location	TOU Sample Number	Odour Concentration (ou)	Calculated Liquid Odour Potential (ou/mL)	Current Area (m²)	Natural Evaporation rate (L/s) ^^	Natural Evaporation Odour Emission Rate (ou.m³/s)
ED3N-1	SC15553	118	7.14	6,000	0.212	1,510
ED3N-2	SC15554	470	28.5	5,500	0.194	5,530
ED3N-3	SC15555	197	11.9	5,500	0.194	2,310

[^] Mechanical evaporation rate is based on 20% / 30% evaporation efficiency per evaporator

^{^^} The natural evaporation rate is based on the mean evaporation rate recorded between May 2007 to June 2012, equivalent to 92.67 mm/month

^{^^^} Based on three active and identical evaporators

6.2 COMMENTS ON RESULTS

The following sections comment on the results presented in **Table 6.1** to **Table 6.4** in **Section 6.1**.

6.2.1 The Void Samples

- The sampling locations inside the Void have been nominally shown in **Figure 6.1**. The sample numbers presented in **Figure 6.1** correspond with those in the sampling location column in **Table 6.1**. The conditions prevailing in the Void at the time of the Audit is visually presented in **Photo 6.1**;
- The SOER results for the Active Tipping Area (SC15511-SC15512 & SC15505-SC15510) within the Void were much higher than all previous IOA and above the *EA 2010* model value of $7.3 \text{ ou.m}^3/\text{m}^2/\text{s}$. This value appears to be consistent with the field ambient odour assessment survey and odour diary results findings where a garbage odour was detectable downwind of the Void and;
- The Waste Covered Area samples (SC15503-C15504 & SC15513-SC15514) were collected from areas within the Void identified by the audit team as potential gas pathways (i.e. areas identified in this Audit as potentially having a higher fugitive emission level than other areas around the Void and/or were covered with biofilter material) and other strategic locations designed to quantify the general emissions emanating from the Void (SC15499-SC15500);
- In the Audit, there were three types of waste cover materials sampled in this Audit, including:
 1. Areas covered with normal cover material used in the Bioreactor; and
 2. Areas covered with biofilter material over the normal cover. The biofilter material is applied in known problematical areas; and
 3. Areas covered with a sprayable polymer slurry for the purpose of assessing odour suppression.
- The results for the Waste Covered Areas component of this Audit indicate odour emissions are close to the target SOER model value of $0.2 \text{ ou.m}^3/\text{m}^2/\text{s}$ for a covered area with no fugitive emission release measured. The areas where fugitive gas emission release was measured exceeded the SOER model value of $23.9 \text{ ou.m}^3/\text{m}^2/\text{s}$ including samples #11, #20 & #21. Sample #10 was a covered area with biofilter material and this returned a result well below $23.9 \text{ ou.m}^3/\text{m}^2/\text{s}$ ($0.176 \text{ ou.m}^3/\text{m}^2/\text{s}$), suggesting the application of biofilter material in this area is effective. The other areas covered with biofilter material indicate that there is still fugitive gas emission release from the surface of the Void; and
- The polymer slurry mixture efficacy testing results suggest that it is effective at attenuating odour emissions from the waste surface, if used as daily cover. With the polymer slurry applied, emissions from the active tipping face waste layer reduced by more than 85% to $2.3 \text{ ou.m}^3/\text{m}^2/\text{s}$. Notwithstanding this outcome,

this SOER is higher than the *EA 2010* model input of $0.2 \text{ ou.m}^3/\text{m}^2/\text{s}$ for a Waste Covered Area.

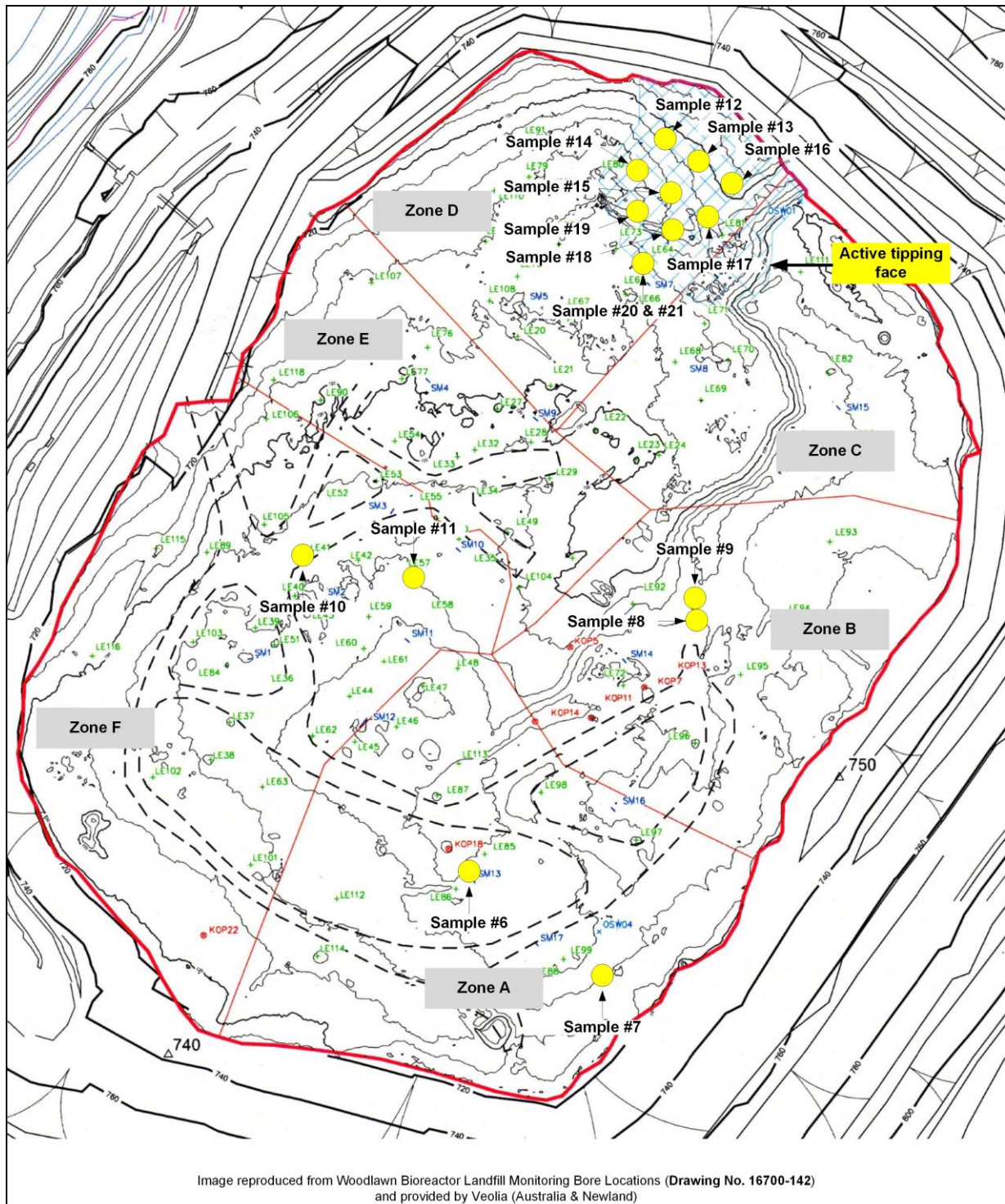


Figure 6.1 - Nominal sampling locations within the Void: 6 October 2015 – 8 October 2015



Photo 6.1 – Conditions prevailing in the Void during the Audit

6.2.2 Leachate Samples

- The leachate recirculation system continues to operate as a direct injection system that does not have suitable access points for sampling;
- All samples from the ED3N system were collected from the bank of the dams;
- All samples collected and tested from the ED3N Pond system (i.e. SC15496 – SC15497) were found to be below the EA SOER model input. The very low SOER values for all ponds (between 0.091 - 0.269 ou.m³/m²/s) indicate that the leachate treatment quality is high and that the leachate management system (i.e. the LAD & WALTER settling tank processes – see **Section 2.4**) is performing at a high performance efficiency from an odour emissions viewpoint; and
- Dam ED3S was not considered to emit any odour at the time of the Audit and was not sampled.

6.2.3 Leachate Aeration Dam Samples

- The LAD was found to be operating under normal operating conditions at the time of the Audit;
- The SOER results suggest that the LAD is not a significant odour emission source. This implies that the LAD was operating in optimum conditions at the time of the Audit, suggesting that adequate wastewater treatment conditions and breakdown of organic containments are prevailing;
- It appears the slight modification to the treatment configuration of the LAD (see **Section 2.4.3** for details) has had minimal effect to odour emissions from this source. This is a good result;

- The SOER found in the Audit ($0.276 \text{ ou.m}^3/\text{m}^2/\text{s}$) is well below the EA SOER range values ($3.6 \text{ ou.m}^3/\text{m}^2/\text{s}$); and
- In-situ ammonia testing by colorimetric tube indicate a reading of greater than 60 ppm. Four aerators were present at the time of the Audit with two online and two offline at the time of sampling. This is not considered to be an issue given the odour emission results found in the Audit.

6.2.4 Landfill Gas Samples

- A gas sample was collected from the extracted landfill gas en-route to Site's power plant for gas speciation analysis (see **Appendix C**), despite not being an audit requirement. The speciation analysis was conducted to compare the quality of the fugitive gas emission release from the Void and the extracted landfill gas to the power plant. The analysis indicated that the extracted landfill gas to the power plant primarily composed of methane (50.7%), carbon dioxide (47.2%) and hydrogen sulphide (< 1%). Other analytes were detectable at trace concentrations, although most of the reduced sulphides and terpene-based compounds (such as alpha pinene, beta pinene, camphene and limonene) were detected at above threshold levels. Further investigation into the composition of fugitive gas (and active tipping face) emissions should be undertaken as part of the next audit (see **Section 8.3.4**);
- The previous IOAs in 2012 & 2013 clearly indicate that landfill gas has a high potential to be odorous if it were released directly to atmosphere in an untreated state. This is supported by the emission results from fugitive gas pathways in the Audit;
- The global mean odour concentration for all previous audits for landfill gas en-route to the power plant is likely to be in the order 9,000,000 ou; and
- Fugitive landfill gas emissions from the Void are discussed further in **Section 7.5.2**).

6.2.5 Liquid Odour Measurement Samples

- The Liquid Odour Measurement results represent the odour that would be released if the sample were evaporated, either by natural or mechanical means. For the purposes of this Audit the mechanical and natural evaporation has been used in calculations;
- The natural evaporation rate shown is based on the mean rate at the Site between May 2007 to June 2012;
- The liquid odour sample results (SC15553– SC15555), tested using the LOM, indicate that the leachate is very low in odour. This result is consistent with the results from the collected gas samples from the ED3N Pond System (see **Section 6.2.2**). The implication of this result is discussed in **Section 7.2.1.5**; and
- The collected liquid samples are a grab sample from ED3N-1, ED3N-2 & ED3N-3.

6.2.6 Chemical Measurement Results

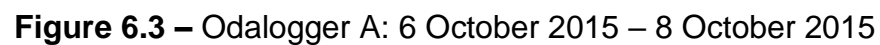
- Measurements were taken directly from the gas sample bags following the completion of sample collection; and
- All gas samples were analysed for H₂S using a calibrated Jerome, with the exception of two samples, as indicated in **Table 6.4**.

6.2.7 Odallogger measurements

- Odaloggers were setup at locations downwind of the Void;
- The prevailing wind direction during the Audit was north-easterly and easterly winds;
- No ambient levels of H₂S greater than 0.01 ppm was detectable by the Odallogger. This was the lowest detection limit of the Odallogger; and
- The results suggest that, using H₂S as a marker for landfill gas, no fugitive landfill gas emissions were detectable at the measured downwind locations during the Audit (i.e. Locations A, B1 & B2). This is a good result.



Figure 6.2 – Odallogger monitoring survey locations



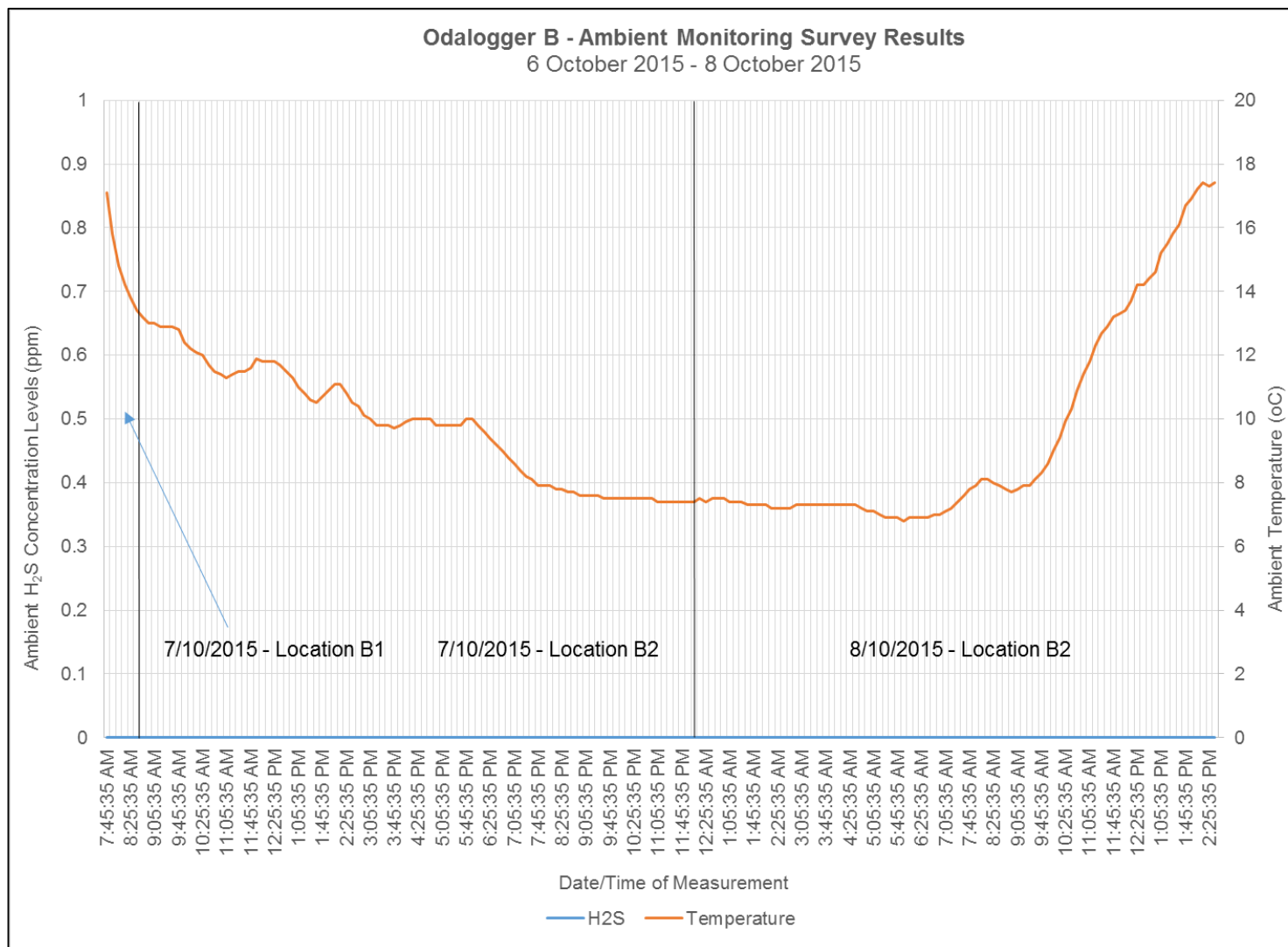


Figure 6.4 – Odallogger B: 6 October 2015 – 8 October 2015

6.3 FIELD AMBIENT ODOUR ASSESSMENT SURVEY & SPOT CHECKS

The methodology used for the undertaking the Field Ambient Odour Assessment (FAOA) survey in the Audit has been reported in previous IOAs and is therefore not reproduced in the Audit report.

A FAOA survey was conducted by a member of the audit team on 6 October 2015. The survey was aimed at identifying downwind odour impact from the Site. The results from the survey have been illustrated on a visual aerial map shown in **Figure 6.5**. The survey field logsheet can be found in **Appendix C**. In addition to this, the audit team carried out spot odour survey checks at the Site and noted the observations made throughout the course of the audit fieldwork.

The results from the odour surveys conducted during the Audit are as follows:

- A garbage character was intermittently detectable downwind of the Void. At the time, the audit team was located within the ED3N pond system area (not recorded in the downwind survey map plot);
- No odour was detectable beyond the boundary of the Site at the time of the FAOA survey conducted on 6 October 2015 between 1440 hrs and 1533 hrs (see **Figure 6.5**); and
- No landfill gas was readily detectable outside the Void perimeter over the course of the audit fieldwork at the Site.

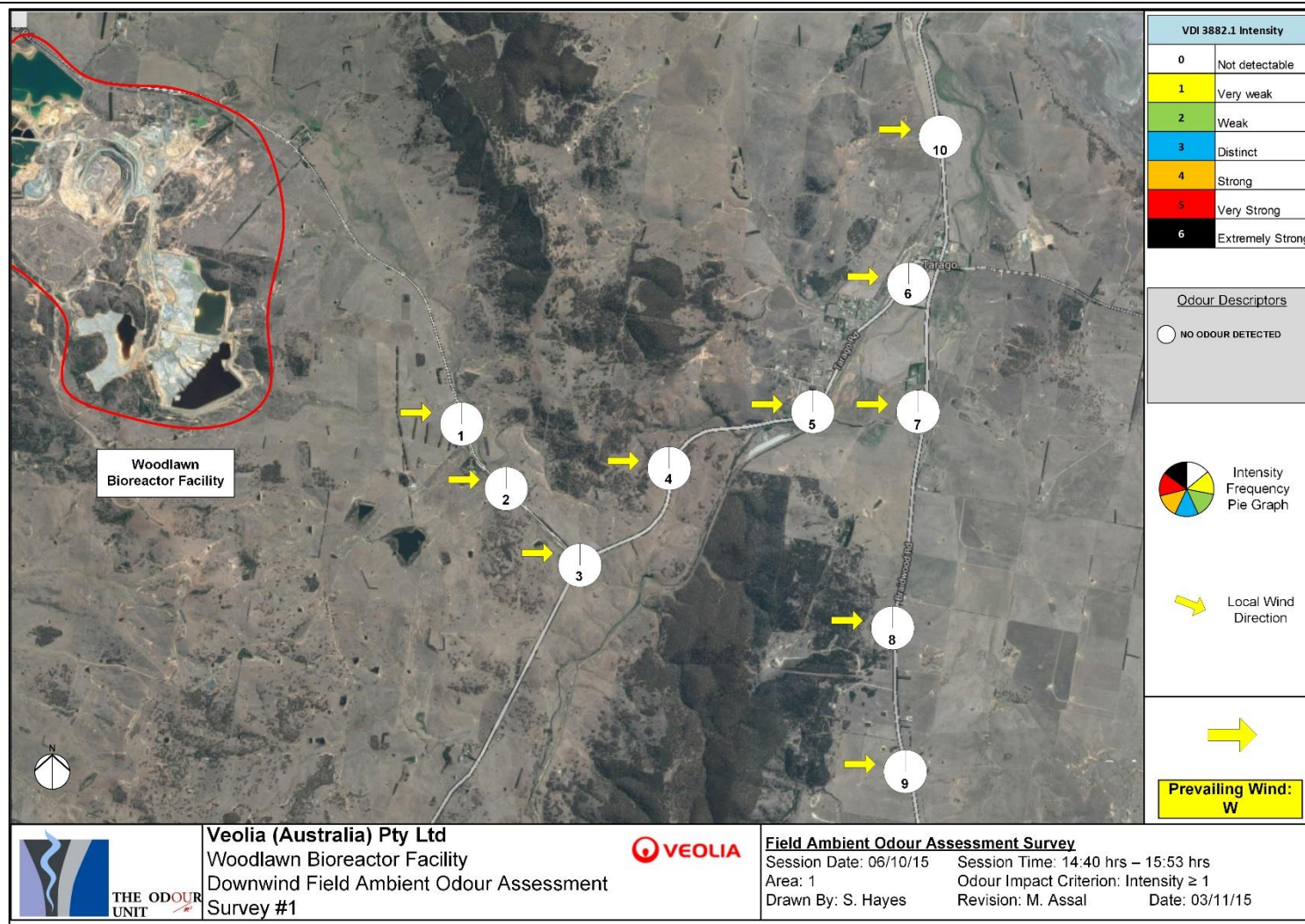


Figure 6.5 - Field Ambient Odour Assessment Survey: 6 October 2015 between 1440 hrs – 1553 hrs

7 DISCUSSION

7.1 PREVIOUS AUDIT RECOMMENDATIONS

The following **Tables 7.1 & 7.2** outline the mandatory and non-mandatory recommendations documented in the 2014 IOA respectively and Veolia's response to those recommendations since that time.

It is important to note that some of these recommendations are and will continue to remain an integral part of the on-going process operations at the Site. These on-going process operations include, but are not limited to:

- Planned infrastructure instalments within each waste lift;
- Continuous monitoring of leachate and gas extraction;
- The implementation of operational management programs including:
 - Leachate management;
 - Pumps and pumping solutions;
 - The expansion of wells in the Void for improved leachate recirculation and landfill gas extraction; and
 - De-sludging the LAD.

The above on-going process operations (and others) have been comprehensively documented in the WIP, with relevant sections reviewed by the Audit in the previous 2013 IOA. The Audit notes that the WIP is a 'live' document that is constantly updated as the volume of waste into the Void increases over time.

Veolia submitted an updated WIP post-2014 as part of the Audit process for review, with key aspects addressed as part of this discussion section.

7.1.1 Mandatory recommendations

The mandatory recommendations from the 2014 IOA are summarised in **Table 7.1**, and include Veolia's response since that time.

7.1.2 Non-mandatory recommendations

The non-mandatory recommendations from the 2014 IOA are summarised in **Table 7.2**, and include Veolia's response since that time.

Table 7.1 – 2014 IOA Mandatory Recommendations

No.	2014 Independent Audit Recommendations	Veolia Response
1	<p><u>Leachate management system</u></p> <p><i>Continue to adequately maintain and manage the upgraded leachate management system to ensure it is operating in an optimum state and meeting the leachate quality monitoring targets as outlined in the Leachate Treatment Operation Manual and recommended by Veolia Water. This manual should be considered as a 'live' document to reflect any variation in quality and operational demands and identifications of new constraints and/or issues. This will significantly attenuate the potential for odour generation from the leachate stored in ED3N both now and in the future.</i></p>	<p>Veolia continues to work with Veolia Water to optimise the leachate treatment process. This is evident in the recent modifications made to the LAD (see Section 2.4.3) & WIP post-2014. Veolia are planning a major upgrade to the treatment system in the coming years.</p>
2	<p><u>Odour mitigation from the Void: Improve Gas Capture within the Void</u></p> <p><i>Veolia has a WIP 2012 which outlines a comprehensive plan that is being implemented to increase gas capture. The continued implementation of this plan will more than likely reduce fugitive odour emissions/gas from the Void. The Audit endorses this strategy as the primary measure to reduce odour emissions from the Void and recommends that Veolia continue the implementation of the gas systems detailed in the WIP 2012, including the proposed perimeter gas collection infrastructure systems. The gas capture efficiency should be continuously monitored and recorded and the surface of the Void monitored to determine effectiveness of capture within specific areas of the Void. It appears that the WIP 2012 will require update post-2014 and this will be reviewed in the next Audit.</i></p>	<p>The improvement in gas capture from within the Void is an on-going planning and operational exercise that Veolia will continue to be implemented. An addendum to the WIP post-2014 has been provided to the Audit for review.</p> <p>The WIP post-2014 outlines the operational issues and plans to: improve leachate flow/recirculation, improve gas capture, reduce fugitive gas emission; optimise tipping strategy, and the proposal to connect more wells/trenches. The document is 'live' and designed around both a proactive and reactive approach to addressing operational issues.</p>

Table 7.1 continued - 2014 IOA Mandatory recommendations

No.	2014 IOA Mandatory Recommendation	Veolia Response
3	<p><u><i>Mechanical Evaporation Plan of stored effluent in ED3N</i></u> <i>Given the high quality of treated leachate now stored in ED3N, the Audit finds that mechanical evaporation can now be recommenced for the purposes of volume reduction. A mechanical evaporation protocol/procedure should be developed that provides advice on the conditions under which treated leachate can be mechanically evaporated. Important items that would need to be address included:</i></p> <ul style="list-style-type: none"> ▪ <i>Is the leachate treatment process meeting the set monitoring targets;</i> ▪ <i>Wind direction and speed;</i> ▪ <i>Number of evaporators used at any given time; and</i> ▪ <i>The conditions under which to commence/terminate mechanical evaporation.</i> 	<p>Veolia has developed a suitable operational protocol for the mechanical evaporation of treated leachate. Veolia's internal reference document for this is <i>PRO-NSW-218-090-1 NSW Woodlawn Bio Reactor Mechanical Evaporator Operation Protocol</i>.</p> <p>Due to civil and geology work being conducted near ED3N and evaporation stations, Veolia has decided not to mechanically evaporate treated leachate from ED3N Pond System since the previous 2014 IOA, although this is planned to recommence shortly.</p> <p>Veolia is also in the process of seeking approval to utilise the ED3S Pond System to increase storage capacity of treated leachate on-site.</p>

Table 7.2 - 2014 IOA Non-mandatory recommendations

No.	2014 IOA Non-Mandatory Recommendation	Veolia Response
1	<p><u>Biofiltration</u></p> <p><i>The Audit recommends expansion and continuation of the biofiltration medium trial to be used in areas where there is an identified risk of fugitive odour emissions from the Void surface. While biofiltration-type cover material is not commonly used for this particular application, the presence of the ester-like compounds in the observed gas emissions in the Void indicates that biological oxidation of the landfill gas odours is already occurring and biofiltration could be trailed in known problematical areas in the Void.</i></p>	<p>The biofilter medium cover has shown that it can be effective at attenuating odour from fugitive emission pathways, however, proper management of the biofilter medium is necessary. This includes the regularly watering and topping-up of biofilter medium as required. It is understood that regularly watering has been practically difficult to implement and will require more time to streamline. Nevertheless, the use of biocover material has reduced odorous gas emissions from potential gas pathways. It was noted by Veolia in the WIP 2015 that the biocover material does not contribute to any significant degree in improving gas capture and as such focus should continue to be on capturing the landfill gas. The Audit agrees and notes that the biocover materials intent is to reduce odorous gas emissions.</p> <p>The Audit also notes that the use of biocover material around the Void walls has been effective at mitigating odorous emissions (see Section 7.2.1.6). Therefore, Veolia will continue to implement the use of biocover material and develop an action strategy to streamline the management of this material.</p>

Table 7.2 continued - 2014 IOA Non-mandatory recommendations

No.	2014 IOA Non-Mandatory Recommendation	Veolia Response
2	<p><u>Pilot-scale biofilter system</u></p> <p>The development of a pilot-scale biofilter system to evaluate the effect of medium depth on landfill gas emissions is also recommended. A pilot-scale biofilter unit could be setup in an appropriate location (possibly in the Void) where safe and easy flow diversion of landfill gas is possible. Only small and continuous gas volumes would be required for this exercise. The conditions should address the effect on landfill gas odour at varying medium depths. A suitable medium depth range to trial would be between 0.5 – 1.0 m given the outcomes from the Audit. The medium would need to be kept adequately moist and possibly inoculated with sludge/leachate to assist with the acclimatisation of suitable microorganisms in the biofilter bed. Veolia has already indicated that it intends on undertaking this trial and is in consultation with TOU.</p>	<p>It was not possible to carry out the pilot-scale biofilter system in time for the Audit. Veolia will work with TOU to implement this trial, if deemed necessary. There is a case that this trial may not be necessary given the successful use of the biocover material with the current operations since the previous 2014 IOA.</p>
2	<p><u>Seepage of landfill gas in the air pressure relief vent</u></p> <p>The cause and extent of this landfill gas seepage into the air pump pressure relief streams should be investigated by Veolia. All possible mitigation improvements that could be practically implemented to maintain and improve pump performance and reduce potential odour emissions from this source should be undertaken. This source will be further investigated by the audit team in the next Audit.</p>	<p>The seepage of landfill gas in the air pressure relief vent is attenuated by the management of pump performance. Pump performance can be affected by wells, the physical nature of the waste area, and configuration of pipes in the Bioreactor. Veolia regularly service and replace the pumps on a required basis. This operational management activity will continue to occur and reviewed in the next Audit.</p>

Table 7.2 continued - 2014 IOA Non-mandatory recommendations		
No.	2014 IOA Non-Mandatory Recommendation	Veolia Response
4	<p><u>Odour Monitoring of Generator Exhaust Stacks</u></p> <p>Consideration should be given to repeating the odour monitoring of the generator exhaust stacks during the next stack emission survey in 2015. While it is still expected to not be a significant odour source, odour sampling results will enable the Audit to assess the significance of engine exhaust emissions to the overall Site's odour emission profile and use the results for modelling purposes if need be.</p>	<p>This was completed by Stephenson Environmental on 23 March 2015. See Section 7.2.1.4 for details.</p>
5	<p><u>Site Sulphur Loading Investigation</u></p> <p>Veolia should begin to investigate the Site sulphur loading and develop a protocol to optimise dosing of iron (or other metal based compounds) into waste to bond with available sulphur. The intention of this recommendation is to minimise the potential for hydrogen sulphide generation and emission.</p>	<p>This was carried out by URS and a finalised report was issued to Veolia on 28 October 2015 (see Section 7.2.1.11). A copy of this report is appended in Appendix C.</p>

7.2 DISCUSSION OF AUDIT FINDINGS

The following discussion examines the results of the Audit against each of the conditions of consent.

7.2.1 Condition 7 (B & D)

Condition 7 (B & D) of the Audit requirements stipulates that the following will be carried out in the IOA:

- *Audit the effectiveness of the odour controls on-site in regard to protecting receivers against offensive odour; and*
- *Review the relevant odour sections of the Air Quality and Greenhouse Gas Management Plan for the project and assess the effectiveness of odour control.*

As mentioned in the previous IOAs, and complemented by the Audit's on-site experience and discussions with Veolia personnel, it is clear that there continues to be a range of current and on-going odour controls implemented at the Site designed to mitigate off-site impacts arising from its waste management operations. These revolve around:

1. The leachate recirculation method (see **Section 7.2.1.1**);
2. Optimisation and continuous treatment of excess leachate from the Void (see **Section 7.2.1.2**);
3. Improvement of landfill gas extraction from the Bioreactor (see **Section 7.2.1.3**);
4. Adequate combustion of landfill gas (see **Section 7.2.1.4**);
5. Improve evaporation capability (see **Section 7.2.1.5**);
6. The implementation of alternative capping material in the form of a biofilter medium (see **Section 7.2.1.6**);
7. Using the minimal active tipping face as practically possible (see **Section 7.2.1.7**);
8. Water cart to control dust (see **Section 7.2.1.8**);
9. Transportation of waste in sealed containers until unloading at the Bioreactor (see **Section 7.2.1.9**);
10. The assessment of the application of polymer slurry material as part of the cover and capping of the active tipping face area operations (**Section 7.2.1.10**); and
11. Sulphur balance investigation (see **Section 7.2.1.11**)

7.2.1.1 Leachate recirculation method

In order to maximise the recirculation potential of the waste, leachate generated within the Bioreactor is removed when it becomes excess to the field capacity or interferes with gas extraction infrastructure. Any excess leachate that is extracted from the Void flows directly to the LAD for primary leachate treatment (see **Section 2.4** for further details).

The leachate recirculation method currently practiced within the Void continues to be via direct injection techniques (see **Section 2.3.1**). As explained in previous IOAs, this has the effect of minimising the potential exposure of leachate partitioning from the liquid phase to the gas phase, through aerosol generation and/or evaporation pathways, and subsequently leading to the generation of odorous emissions. The 2012 IOA indicated that Veolia's adoption of this recirculation technique is more effective at minimising odours than previously utilised techniques. The previous 2013 IOA concurred with this finding. The Audit notes that this continues to be the technique employed for leachate recirculation.

On this above basis, no further action by Veolia is required on this matter.

7.2.1.2 Optimisation and continuous treatment of excess leachate from the Void

The Audit understands that there is no longer a need to store untreated leachate in the evaporation dams following the upgrade improvements made to the LAD system since April 2013 (see **Section 2.4.3** for background details) and the growing waste volumes in the Bioreactor. Moreover, since the 2014 IOA, Veolia has further modified the leachate treatment process by dividing the LAD into two treatment zones, namely, an anoxic zone and an aerobic zone. The splitting into these zones appear to suggest that the Site is converting the LAD into an activated sludge treatment process, which is generally aimed at optimising BOD reduction and/or nitrification/denitrification processes through the increasing of sludge age in the process. This modification is considered to be a reflection of Veolia's on-going efforts in optimising the treatment process. From an odour emissions viewpoint, this has had a minimal effect on the Site's odour emissions profile from this source. On this basis, the Audit supports this modification from a leachate treatment perspective, provided that optimum conditions in the LAD are sustained and continue to result in good quality treated leachate that contains none of the original odour characteristics of untreated leachate.

It is understood that Veolia continues to regularly monitor the treated leachate quality and performance.

Based on the above analysis, no further action is required by Veolia on this matter. If however there are future operational issues with the LMS, Veolia should take the precautionary measures of notifying the EPA (and any other relevant stakeholders), until the issue is rectified.

7.2.1.3 Improvement of landfill gas extraction from the Bioreactor

Landfill gas extraction at this Site is an ongoing operational process. The WIP 2012 has clearly indicated that there is a comprehensive plan by Veolia to increase gas capture by undertaking the following key items:

1. Continuous expansion of the new drainage systems to promote gas collection; and

2. Management of Leachate – including recirculation and continuous treatment.

Further information regarding the design and operation of the Landfill Gas Extraction System has been previously documented in extensive detail in the 2012 IOA Report. As such, it has not been documented in the Audit report.

As outlined in the previous IOAs, it is difficult to calculate a representative odour emission rate from the Void given the dynamic virtue of the surface layout. Therefore, an alternative approach has been taken where improvement in landfill gas capture efficiency is used as an indicator of reduced potential for fugitive gas emissions from the Void surface. This appears to have been effective in that no fugitive landfill gas emissions were detectable during the audit fieldwork (see **Section 6.3**).

Table 7.3 summarises the results in landfill gas capture over the period between October 2014 and October 2015 and compares the results with those obtained in the 2014 IOA. **Figure 7.1** visually plots the landfill gas capture trend since monitoring commence in January 2009 till October 2015. As can be derived from the results **Table 7.3**, the monthly averaged landfill gas extraction over the period between October 2014 and October 2015 was approximately 1,990,000 m³. In comparison to the gas extraction result obtained from the previous period in the 2014 IOA (i.e. 1,555,000 m³), this represents a relative increase of approximately 29% in gas extraction volume (equivalent to an increase landfill gas volume of 448,000 m³) over this period. This is favourable result for Veolia.

It should be noted that the odour emission rates at each gas extraction efficiency presented in **Table 7.3** should be considered a conservative, worst-case scenario estimate, which represent potential emissions from the Void surface only. In reality, the extent of odour emission rates is likely to be much lower than that estimated, based on field observations and the previous IOAs and the Audit. This viewpoint is supported by the general upward trend in gas capture (as illustrated in **Figure 7.1**).

As noted in the previous 2014 IOA, the Audit understands that gas capture is measured against a calculated emissions model issued by the Australian Government – Clean Energy Regulator. This aspect is outside the scope of the Audit and is therefore not discussed further. Nevertheless, it remains clear that fugitive landfill gas emissions emitted from the Void surface have a very high odour emission potential, between 594,000 ou.m³/s to 2,960,000 ou.m³/s as found in the previous 2014 IOA and the Audit at varying gas extraction efficiencies. Therefore, the Audit continues to endorse Veolia's plan to actively improve gas extraction capability from the Bioreactor and the items addressed in the WIP post-2014 to achieve this.

Table 7.3 – Gas capture volumes and estimated odour remission rate from Void surface: The Audit vs. 2014 IOA

Landfill gas capture efficiency (%)	Mean landfill gas capture/month (m ³ /month)		Landfill gas from surface (m ³ /month)		Landfill gas from Void Surface (m ³ /s)		Landfill gas Odour Concentration (ou) [^]	Landfill gas OER from surface (ou.m ³ /s)	
	Oct 2014 – Oct 2015	Nov 2013 – Sep 2014	Oct 2014 – Oct 2015	Nov 2013 – Sep 2014	Oct 2014 – Oct 2015	Nov 2013 – Sep 2014		Oct 2014 – Oct 2015	Nov 2013 – Sep 2014
90	1,990,455	1,542,829	221,000	171,000	0.09	0.07	9,000,000	767,000	594,000
80	1,990,455	1,542,829	498,000	386,000	0.19	0.15	9,000,000	1,730,000	1,340,000
70	1,990,455	1,542,829	853,000	661,000	0.33	0.26	9,000,000	2,960,000	2,300,000

[^] mean of 2012 & 2013 IOA

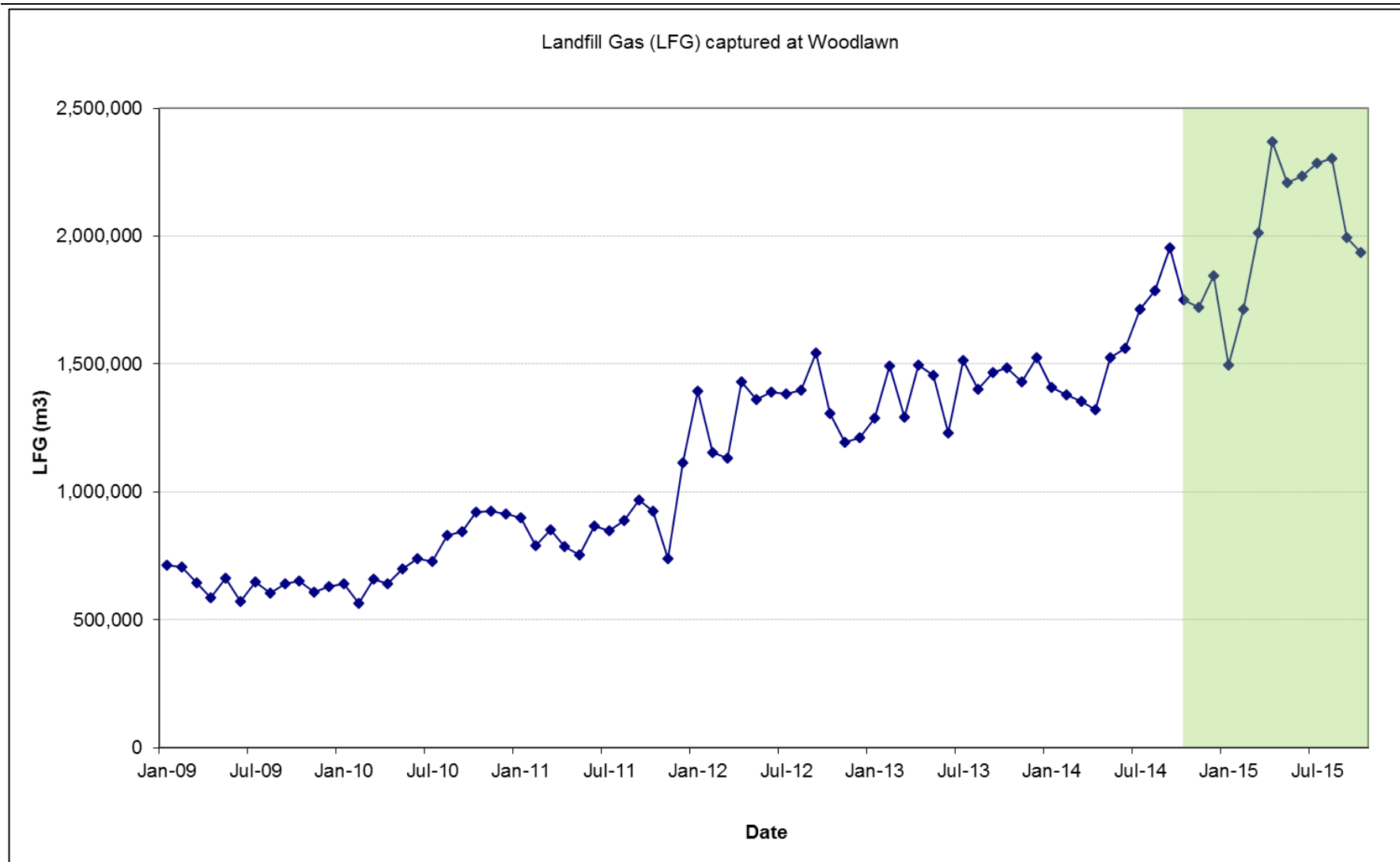


Figure 7.1 - Landfill gas capture since January 2009 to October 2015

7.2.1.4 Landfill gas combustion exhaust quality

According to the recent Stephenson Stack Emission Survey on Generator No. 3 carried out in March 2015, all combusted gas emissions from this generator comply with the EPL Limits for NO_x, SO₃/H₂SO₄ and H₂S.

As per the non-mandatory recommendation in the previous 2014 IOA (see **Table 7.2**), Veolia undertook odour monitoring simultaneously with the Stack Emission Survey in March 2015. A gas sample was collected at Generator Exhaust Stack #3 for testing at Stephenson Environmental Odour Laboratory. A total of three gas samples were collected during this sampling exercise from the same generator stack location over three intervals - spaced by an hour. The odour testing results from this sampling are summarised in **Table 7.4**.

Table 7.4 - Generator exhaust stack #3 odour testing results: 23 March 2015

Sampling location	ORLA Sample ID	Odour concentration (ou)	Volumetric Flow (Nm ³ /s)*	Odour emission rate (ou.m ³ /s)	
				2015	2014
Engine 3 Stack – R1	4194	1,721	1.5	2,580	2,900
Engine 3 Stack – R2	4195	1,314		1,970	
Engine 3 Stack – R3	4196	1,901		2,850	

*as measured by Stephenson Environmental on 23 March 2015

The above odour emission results are relatively low and comparable to the results obtained for Generator #3 Stack in the previous 2014 IOA. On this basis, and provided the landfill gas engines continue to operate under optimal conditions, and there is no significant deterioration in combustion performance and operating temperature, the landfill gas engine exhaust stacks are not considered to be significant odour emission sources at the Site. These results are consistent with the judgements made in the previous IOAs in that the engine stacks are considered to be a very minor source of odour (given the operating combustion temperatures) and highly unlikely to result in adverse odour impact beyond the Site boundary. This finding continues to remain valid in the Audit.

7.2.1.5 Improve evaporation capability

Veolia has only recently had the capacity to recommence mechanical evaporation, since this activity was ceased following the 2012 IOA finding of the odorous quality of the leachate previously stored in ED3N lagoons. The background for this has been well documented in the previous IOAs. The Audit understands that Veolia intends on using the mechanical evaporators given the sustained improvement in leachate quality, however, Veolia has indicated that this has been hindered by current geological and civil works occurring within the vicinity of the ED3N lagoons at ED3S.

Moreover, the Audit finds that the quality of the treated leachate currently stored in ED3N pond system is relatively comparably to that found in the previous 2014 IOA, where it was odour-free with no evidence of untreated leachate character present in any of the samples collected. This finding is broadly valid in the Audit however a slight 'ammonical' character was present in the samples collected from ED3N-2 & 4 (see SC15495 & SC15494 in **Table 6.1**). Notwithstanding this result, since 2014, any detectable odour from the ED3N ponds continues to be minimal and localised to the ED3N area only. The derived SOERs for the ED3N pond system support this, ranging between $0.091 \text{ ou.m}^3/\text{m}^2/\text{s}$ – $0.269 \text{ ou.m}^3/\text{m}^2/\text{s}$. These values are very low and well within the *EA 2010* target values. This finding is also consistent with the liquid test results which provides an indication on the liquid odour potential if the liquid was to partition to gas phase either by natural or mechanical evaporation processes. This is discussed below.

The results derived using the LOM testing is summarised in **Table 7.5**. The odour testing results found in the Audit via conventional area source sampling and the liquid odour measurement potential techniques indicate very low SOERs and odour concentration values respectively. In addition, the evaporation liquid odour character as determined by the panelists during laboratory testing indicated a 'muddy, dirty' character suggesting that there is no original untreated leachate character and favourable treatment of the stored effluent in the ED3N pond system. The exceptions are ED3N-2 & ED3N-4 which indicated a slight 'ammonical' character in both the conventional area source samples and LOM testing samples. As previously mentioned, this is not considered problematical given the very low odour emission rates.

Overall, the odour testing results for ED3N Pond System indicate the following:

- The ED3N contents are very low in odour (almost odour-free), with the exception of ED3N-2 & ED3N-4 which indicated a slight ammonical character. This is not considered to be a problem from an odour emissions viewpoint however Veolia should investigate the cause behind this as it is likely related to the leachate treatment process conditions (possibly pH);
- The observed highly coloured water in ED3N-1, 2 & 3 (an example of ED3N-2 is shown in **Photo 7.1**) appears to have no correlation with odour emission potential. The colour is likely due to other leachate quality factors such as tannins;
- From **Table 6.4**, there was virtually no H_2S detectable in the gas samples collected; and
- ED3N continues to be considered a very minor source of odour at the Site and unlikely to cause adverse odour impacts beyond the boundary.

Table 7.5 - ED3N Pond System stored liquid quality: Odour testing results 21 October 2015

Sampling technique:	Area source sampling	Liquid odour measurement potential			
Pond location	TOU SOER (ou.m ³ /m ² /s)	Odour concentration (ou)	Mechanical Evaporation Odour Emission Rate (ou.m ³ /s) per evaporator (η = 20% / 30%)	Mechanical Evaporation Odour Emission Rate (ou.m ³ /s) ALL evaporators ^{^^^} (η = 20% / 30%)	Evaporated liquid odour character
ED3N-1	0.132	181	8,330 / 12,500	25,000 / 37,500	musty
ED3N-2	0.145	197	33,300 / 49,800	99,900 / 149,000	ammonical, dirty socks
ED3N-3	0.091	118	13,900 / 20,800	41,700 / 62,400	musty, dusty, dirty
ED3N-4	0.269	362	n/m		

^ inaccessible safely for liquid sample collection

η = evaporation efficiency

n/m = not measured



Photo 7.1 - A view of ED3N-2 looking south-east at the Void on 7 October 2015

The leachate testing data supplied by Veolia appears to be consistent with the odour testing results observed. All key target parameters appear to be within ranges that result in a high quality treated effluent that is very low in odour (discussed further in **Section 7.5.1**). The leachate quality results (i.e. for treated leachate) provided by Veolia to the Audit are presented in **Appendix C**.

As part of the mandatory recommendations from the 2014 IOA, Veolia has developed a suitable operational protocol for the mechanical evaporation of treated leachate. Veolia's internal reference document for this is *PRO-NSW-218-090-1 NSW Woodlawn Bio Reactor Mechanical Evaporator Operation Protocol* (as previously highlighted in **Table 7.1**).

Based on the above analysis the current stored quality contents in ED3N-1, ED3N-2, ED3N-3 and ED3N-4 are suitable for mechanical evaporation and is unlikely to result in adverse odour impact, provided the effluent quality continues to remain of high quality as found in the Audit. The adequate management of the LMS continues to be in the Audit as a mandatory recommendation (see **Section 8.2.2**).

7.2.1.6 The implementation of improved capping material in the form of a biofilter trial program

The efficacy of the biofilter capping material trial was undertaken in the 2014 IOA and is well documented. Odour testing indicated that a reduction in emissions of 88% can be achieved with biofilter medium cover at 0.5 m. The key factors that affected the performance were found to be moisture and medium depth. Moisture is a key parameter as it provides the mass transfer interface necessary for the gas emissions to partition into the aqueous phase to enable biodegradation by microorganisms. The medium depth is another key parameter that influences the residence time of the gas which effectively determines the time duration that the gas has contact with the medium and in effect enhance the potential of mass transfer between the gas and aqueous phase before exiting the medium surface. A review undertaken by TOU on 2 March 2015 on *Trial for the use of a Biocover for Odour Management at Woodlawn Bioreactor (February 2015)* provided advice regarding Veolia odour management protocol for the use of a biocover at the Site. The report is appended to the Audit report as **Appendix C**.

The Audit found that some biocovered areas were emitting partially treated/untreated fugitive gas emissions into the Void area. This appeared to be related to a less than desirable moisture condition in the biocover material at some areas. Veolia advised the Audit that regularly watering of these areas have been practically difficult to implement and will require more time to streamline. Therefore Veolia will continue to work on this matter.

It is recommended that a pilot scale biofilter trial be undertaken to evaluate the effect to landfill gas containment/treatment with varying medium depths (and possibly moisture) under more controlled conditions. This has therefore been adopted as a non-mandatory recommendation, similar to the 2013 & 2014 IOAs (see **Section 8.3**).

7.2.1.7 Using the minimal active tipping face as practically possible

As identified in the previous IOAs, the active tipping face can vary depending on the tonnage input and how the waste is managed. Since the 2014 Audit, the exposed active tipping face was revised to reflect more realistic conditions that are prevalent in the Void (discussed further below). In addition to this, minimising the active tipping face continues to be one of the key performance indicators at the Site for the following reasons (as outlined in previous IOAs):

1. Reduces surface area of potential odour source;
2. Minimises temporary decommissioning of gas extraction infrastructure;
3. Minimises fuel usage, particularly in dozer and compactor; and
4. To meet EPA benchmark techniques.

Veolia continues to actively and practically maintain a minimal active tipping face area in the Void. The active tipping face was visually observed in the Audit and was considered to be roughly similar in working size to the 2014 IOA. **Photo 7.2** provides a visual indication of the active tipping face area size at the time of the Audit field visit. The original value adopted in the *EA 2010* for the active tipping face was 40,000 m². This was later revised to between 4,000 - 6,000 m² in the 2013 IOA to reflect realistic and current operating conditions. This continues to be the case and will therefore remain revised for the purposes of the Audit until such time where operational circumstances are modified.



Photo 7.2 - A visual indication of the active tipping face area size as found on 7 October 2015

The mean SOER value determined during this Audit was approximately $7.5 \text{ ou.m}^3/\text{m}^2/\text{s}$. Without factoring in the error margins from odour laboratory testing, this represents marginal exceedance of the SOER value used in the EA modelling ($7.3 \text{ ou.m}^3/\text{m}^2/\text{s}$). On the basis of these results, it appears that the active tipping face is likely at times to be a contributing source to downwind odour emissions from the Void under the appropriate meteorological conditions. This finding is consistent with the spot odour survey checks conducted by TOU as part of the Audit (see **Section 6.3**). Notwithstanding this, it should be noted here that fugitive landfill gas emissions are still judged to be the major contributor to odour emissions from the Void, as previously highlighted in **Section 7.2.1.3** & **Table 7.3**.

7.2.1.8 Water cart to control dust

Use of the water cart is an ongoing operational activity, which is effective at minimising dust generation. This was visually evident during the fieldwork component of the Audit. The Audit observed that the operating practice of using a water cart to control dust will be a continued practice at the Site.

On the above basis, no further action is required by Veolia for this component of the Site's operations.

7.2.1.9 Transportation of waste in sealed containers until unloading at the Bioreactor

Similar to the previous IOAs, the Audit has found that the current measures used for the waste transport operations are very effective at mitigating any odour emissions. The Audit team inspected the IMF and conducted a brief downwind olfactometry assessment to determine any presence of waste-based odour. The inspection did not find any evidence of any waste-based odour being emitted at the IMF. On this basis, the Audit determines that there is still no need to sample the IMF as it is very unlikely to generate problematical odour emissions. This is provided that the waste containers used in the process continue to be adequately maintained and remain fully sealed during waste transportation. As such, current practices should be continued and monitored. A photo of the IMF as found during the Audit on 8 October 2015 is shown in **Photo 7.3**.

No additional actions are required by Veolia for this component of the Site's operations.



Photo 7.3 - The IMF as found during the Audit inspection visit on 8 October 2015

7.2.1.10 The assessment of the application of polymer slurry material as part of the cover and capping of the active tipping face area operations

The Audit was advised that Veolia has previously trialled the use of a sprayable polymer slurry as an additional means of odour emission control from the active tipping face and Void. The efficacy of using this polymer slurry on the basis of odour emissions reduction was tested by using the following sampling methodology:

- Sampling of two different locations that are representative of:

- A soil covered area with the polymer slurry;
- An exposed area with only the polymer slurry (i.e. no soil cover); and
- An area without the polymer slurry.

The odour & H₂S testing results and statistics are summarised in **Table 7.7**. The results indicate that the application of the polymer slurry reduced odour emissions by an average of 86% when soil covered and 90% when only the polymer slurry mixture (and magnetite) is applied to the waste. The reason for the observed odour emission increase during Sampling Event A with the soil covered final layer is unknown, however this could be due to the need in shifting the sampling location to enable an accessible and safe sampling surface area at the time. Notwithstanding this, the results indicate that there is some merit in the application of the polymer slurry on the waste surface as an odour emission control measure. It is understood that haematite and/or magnetite can be blended with the polymer slurry. The Audit endorses the potential adoption of this odour mitigation strategy, if Veolia wish to pursue this further, particularly if it is effectively blended with other odour suppressing agents.

Table 7.7 – Efficacy testing of the polymer slurry mixture odour & H₂S testing results: 8 October 2015

Sample Location	SOER (ou.m ³ /m ² /s)	Jerome H ₂ S concentration reading in bag (ppm)	Odour character
Sampling Event A			
Sample #12 - Active Tipping Face Area: Soil Covered Final Layer (Point #1A)	0.19	0.011	dirt, garbage
Sample #14 - Active Tipping Face Area: Soil Covered (Point #2A)	0.50	0.000	vanilla, gassy
Sample #16 - Active Tipping Face Area: No cover (Point #3A)	14.1	0.60	lime, sour, ammonical, garbage
Sampling Event B			
Sample #13 - Active Tipping Face Area: Polymer Slurry Secondary Layer (Point #1B)	4.5	0.026	ammonical, garbage
Sample #15 - Active Tipping Face Area: Polymer Slurry Secondary Layer (Point #2B)	2.8	0.045	dirt, garbage
Sample #17 - Active Tipping Face Area: No cover (Point #3B)	17.1	0.11	ammonical, garbage

Table 7.6 – Efficacy testing of the polymer slurry mixture odour & H₂S statistics: 8 October 2015

Testing Results Statistics	Mean SOER (ou.m ³ /m ² /s)	Units
Sample waste with no cover (Points #3A & #3B)	15.6	ou.m ³ /m ² /s
Sample waste with the polymer slurry (Points #2A & #2B)	1.67	
Sample waste soil covered with the polymer slurry (Points #1A & #1B)	2.32	
Average odour removal efficiency (polymer slurry only)	90	%
Average odour removal efficiency (final layer)	86	

7.2.1.11 Sulphur balance investigation

The sulphur balance investigation was carried out by URS and submitted in a report dated 28 October 2015, attached to the Audit report under **Appendix C**. The balance investigation was conducted extensively. For the purposes of the Audit, the following key findings are noted from the investigation:

- The source of sulphur that could contribute to the production of H₂S include:
 - Municipal Solid Waste (MSW);
 - Construction and Demolition (C&D) waste, particularly material with gypsum (CaSO₄);
 - Fines; and
 - Groundwater inflows (seepage through waste rock and fresh rock i.e. acid mine drainage) estimated to flow into Bioreactor at a flow rate of 0.5 – 1 L/sec.
- The study attributes the bulk increase in H₂S, since 2011, to sulphate in the concrete fines;
- The study attempted to calculate fugitive gas emissions by comparing the estimated landfill gas production rate and the measured produced rate, with the difference assumed to be the non-collected gas i.e. the emissions from the landfill surface. The estimate surface H₂S emissions, based on an average H₂S of 330 ppm and 77% gas efficiency, is 0.05 g/m²/day, less than the calculated via the NGERS and LANDGEM model;
- The study assumes a gas capture efficiency of 77% is reasonable. Based on this efficiency and integrating the Audit's own estimation on fugitive landfill gas emissions (see **Table 7.3**), this would suggest an odour emission rate 1,730,000 ou.m³/s (at 80% capture); and
- The study indicates that there is a surplus of 3,800 tonnes of sulphur in the balance calculation, suggesting that there an accumulation of sulphur and an increase in sulphur mass in the landfill. The balance calculation further suggest that the outflow of sulphur from surface emissions (based on the NGERS model) is 10.8 tonnes, equivalent to approximately 6% of sulphur outflow from the Bioreactor.

The findings from the sulphur study will be used by Veolia to refine and improve on-going management of the Bioreactor, in conjunction with other relevant studies.

7.3 CONDITION 7 (C)

Condition 7 (C) of the Audit requirements stipulates that the following will be carried out in the IOA:

- *Review the proponents' production data (that are relevant to the odour audit) and complaint records*

The production data that is relevant to the Audit includes:

- Waste throughput to the Bioreactor;
- On-site evaporation data (from the 2012 IOA); and
- Landfill gas consumption in the generators and flare system.

This Audit obtained recent production data, complaint records and evaporation data from Veolia for the Site since the previous 2014 IOA. These were reviewed and used by the Audit and have been presented in **Appendix C**. Complaint log records indicate that the necessary fields required by the *EPL Condition M4 Recording of pollution complaints* are being documented by Veolia.

On the above basis, the Audit is satisfied that all relevant record-keeping duties continue to be adequately maintained.

7.4 CONDITION 7 (F)

Condition (F) of the Audit requirements stipulates that the following will be carried out in the IOA:

- *Determine whether the project is complying with the requirements in this approval to protect receivers against offensive odour*

This Audit has examined compliance or otherwise with *Condition 7(F)* from three perspectives, namely:

- Odour complaints data review and analysis and associated response letters from Veolia (discussed in **Section 7.4.1**);
- Odour diary entries analysis (discussed in **Section 7.4.2**); and
- Compliance with the modelling-based, project-specific odour performance goal of 6 ou (discussed in **Section 7.4.3**).

The above points have been discussed in the following sections.

7.4.1 Odour complaints analysis and response letters from Veolia

The odour complaints data logged by Veolia and associated response letters were reviewed and analysed in the Audit. **Figure 7.2** illustrates the odour complaints between 8 October 2010 and 11 October 2014 and the seasonal variations in the number of odour complaints logged over that period.

The odour complaints analysis indicated the following:

- Since the previous 2014 IOA, over the period of 12 October 2014 to 25 October 2015, there were 68 logged odour complaints, equivalent to a 57% increase in complaints. On face value, this suggests that there could possibly be an increase in odour levels present in the community. As such, this should be addressed via Veolia's established community liaison program (see **Section 8** for details);
- The bulk of complaints continue to occur in the winter and autumns periods, as illustrated in **Figure 7.2**; and
- The logged odour complaints data continue to not assist in identifying the nature or likely source of the problematic odours. This matter has been addressed however with the use of Odour Diaries that were distributed to participating community members in May/June 2014 (discussed further in **Section 7.4.2**).

Given the number of logged complaints since the previous audit, Veolia should consider refining its investigation of odour issues in the community, particularly surrounding the most common complainants, as to assess the extent to which odour is present in the community. This could assist the Site with its on-going odour mitigation strategies. As such, this has been put in as a non-mandatory recommendation in the Audit (see **Section 8.3.3** for more details).

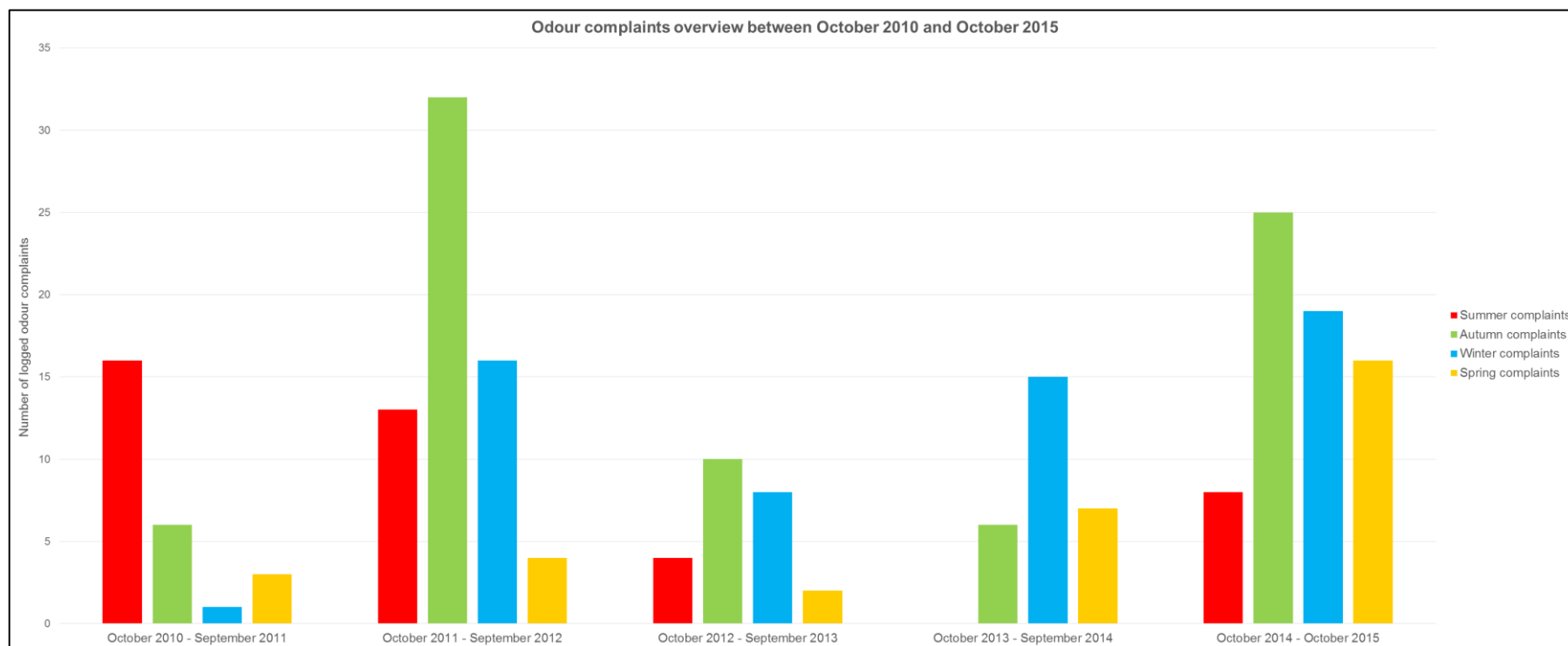


Figure 7.2 – Number of logged odour complaints between October 2010 and October 2015

7.4.2 Odour diary entries analysis

The Odour Diary project is a joint initiative between TOU and Veolia in early-2014 and was complete and issued to the community in May/June 2014. The purpose of the Odour Diary is to collect real-time data on ambient odour levels at residential properties. Whilst not being an Audit requirement, the odour diaries are relevant to the discussion of the Audit as it provides a better understanding on the nature and likely source of odours that are emitted beyond the Site boundary and experienced by the community. The Odour Diary will also open another direct communication channel between Veolia and the community in a standardised feedback format. This information will be assessed and a formal response provided to the community. To date, twelve odour diaries have been distributed to the surrounding community. The locations of these odour diaries are shown in **Figure 7.3**.

The Audit received and analysed a total of twelve odour diaries. During the analysis, two types of entries were identified and categorised as follows:

- *A positive entry*: odour was detected by the entrant at their residential premises and recorded; and
- *A negative entry*: odour was not detected by the entrant at their residential premises and recorded.

A summary of logged entries is shown in **Table 7.8**, with the electronic odour diary entries presented in **Appendix E**. The results are summarised in pie graphs, as follows:

- **Figure 7.4** – summaries the positive entry results according to time of day selected;
- **Figure 7.5** – summaries the positive entry results according to odour character selected;
- **Figure 7.6** - summaries the positive entry results according to odour intensity selected. The odour intensity rank scale is similar to that used in the FAOA survey by the Audit
- **Figure 7.7** – summaries the positive entry results according to wind direction; and
- **Figure 7.8** – summaries the positive entry results according to wind speed.

Table 7.8 – Odour diary entries statistics summary

Parameter	No. of entries	%
Total entries	292	100
Entries with negative smell	158	54.1
Entries with positive smell	134	45.9

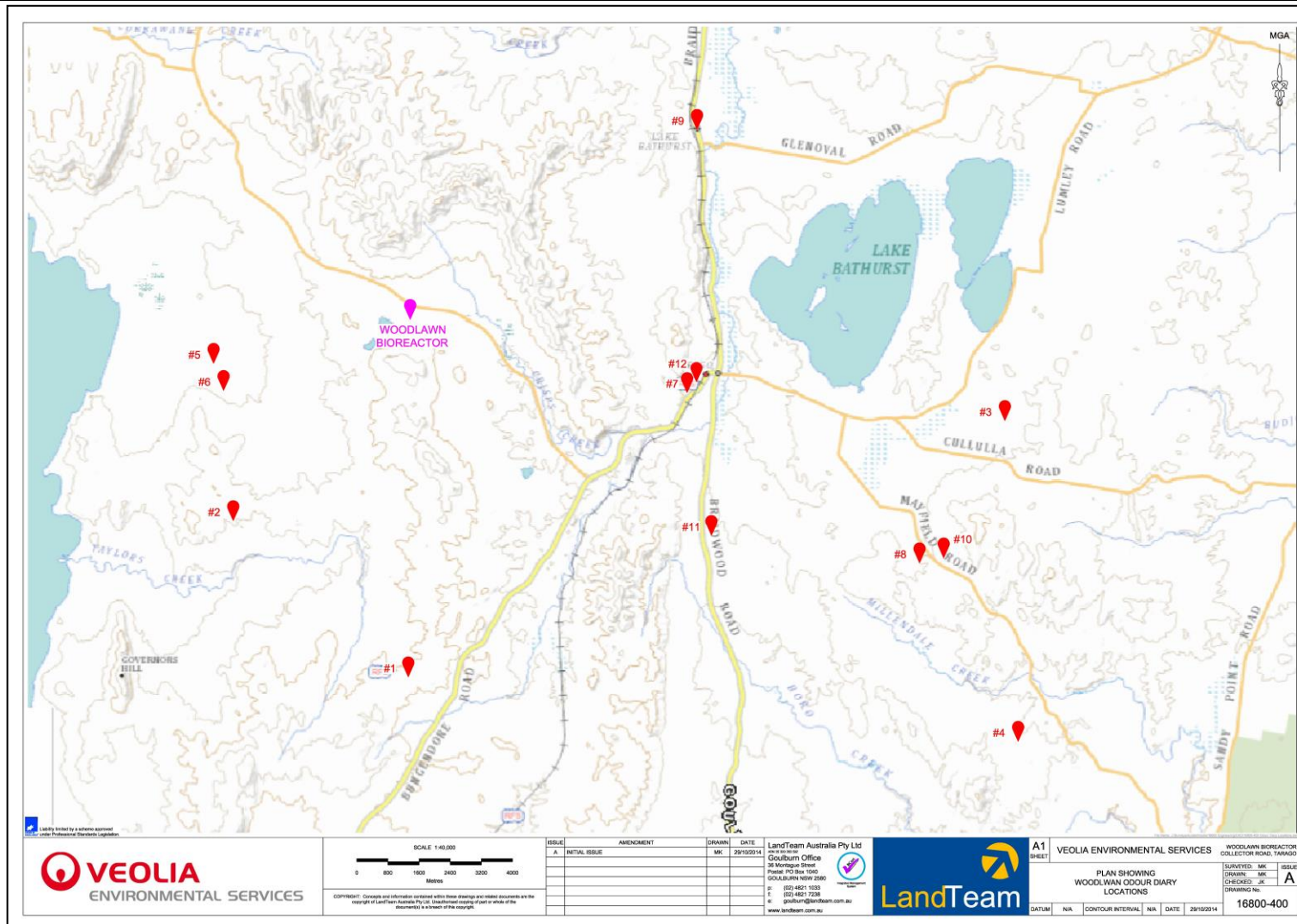


Figure 7.3 – Odour diary locations as of November 2015

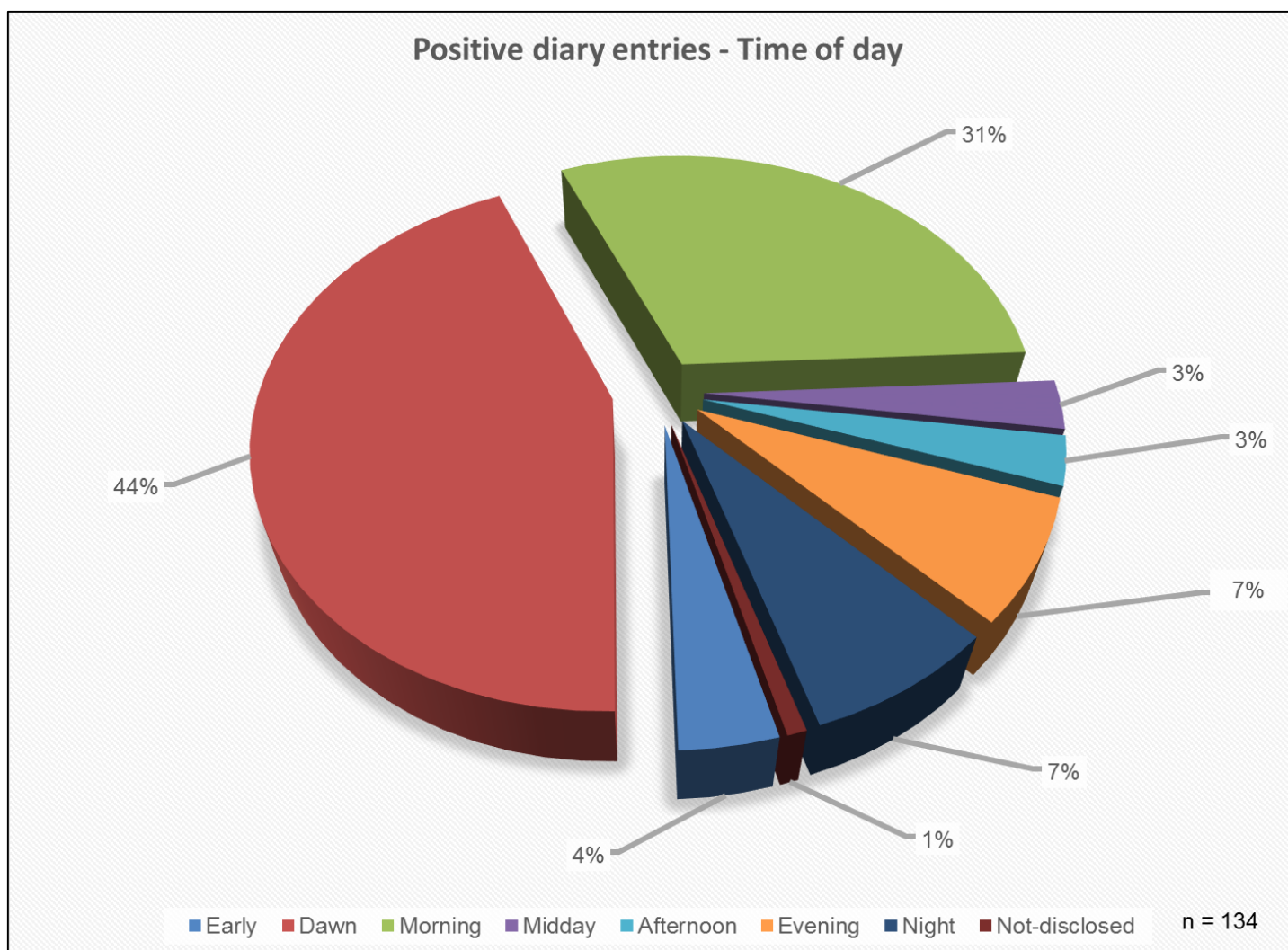


Figure 7.4 – Odour diary analysis: Time of day with positive entries

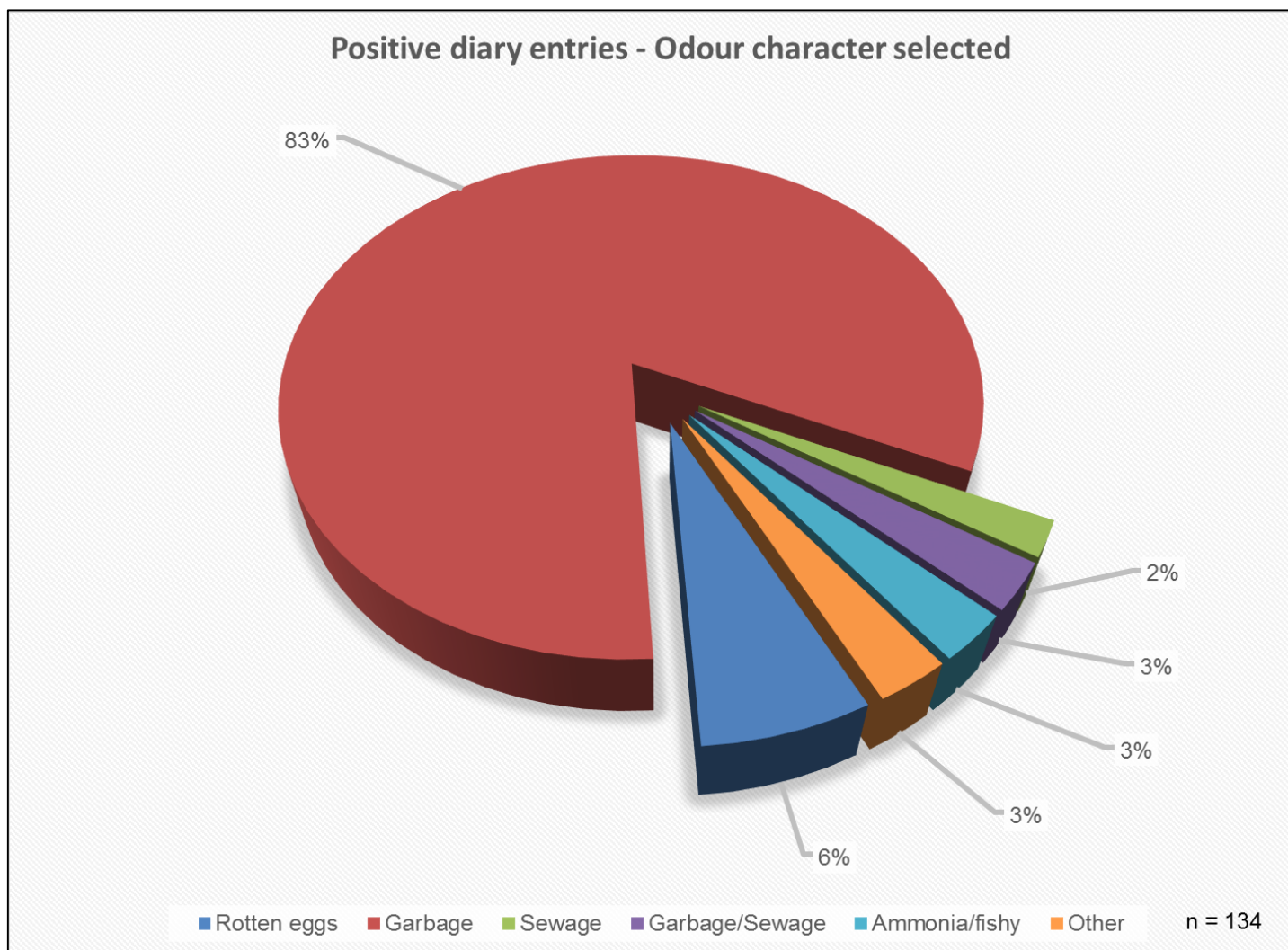


Figure 7.5 – Odour diary analysis: Odour character selected with positive entries

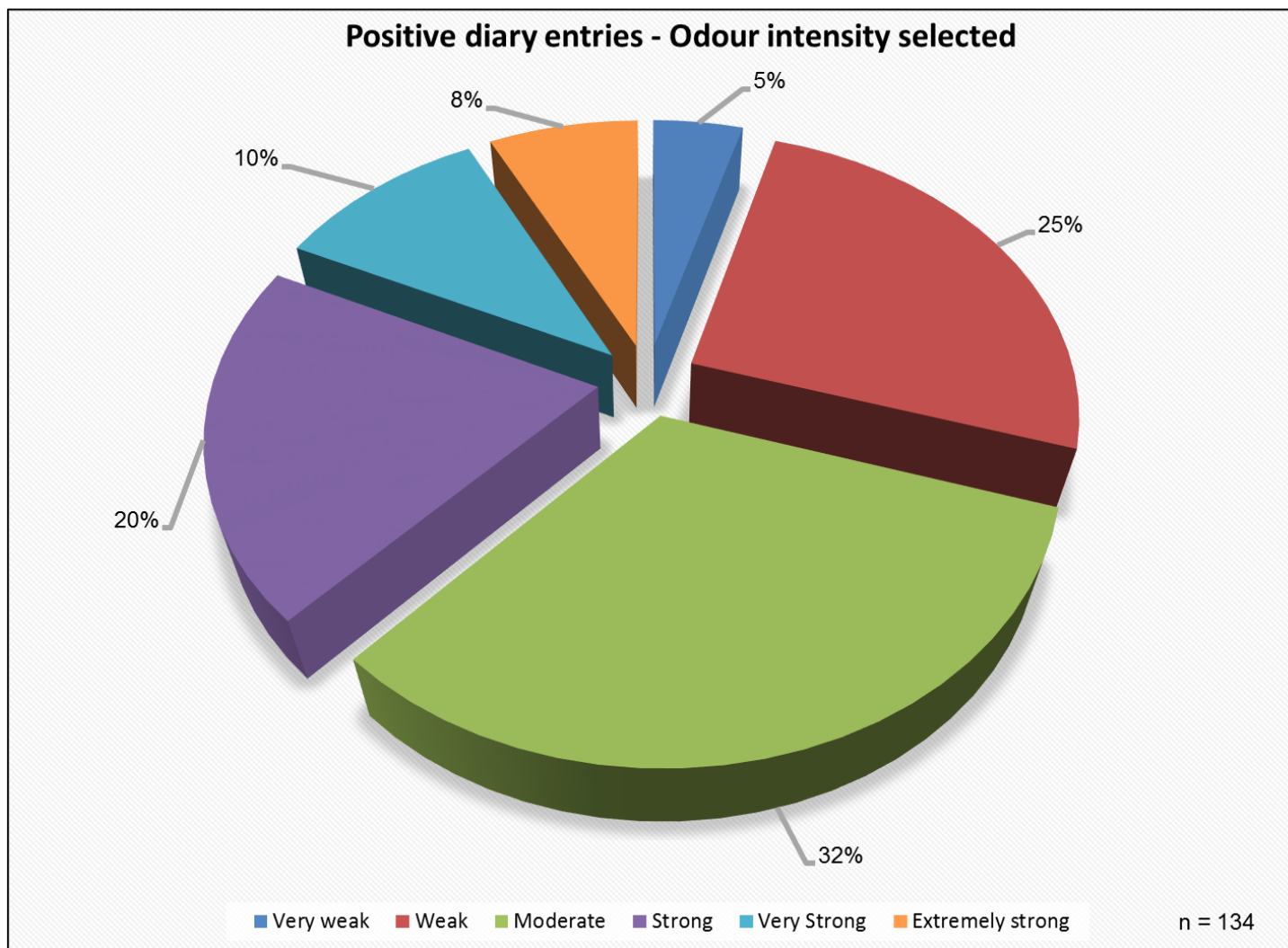


Figure 7.6 – Odour diary analysis: Odour intensity selected with positive entries

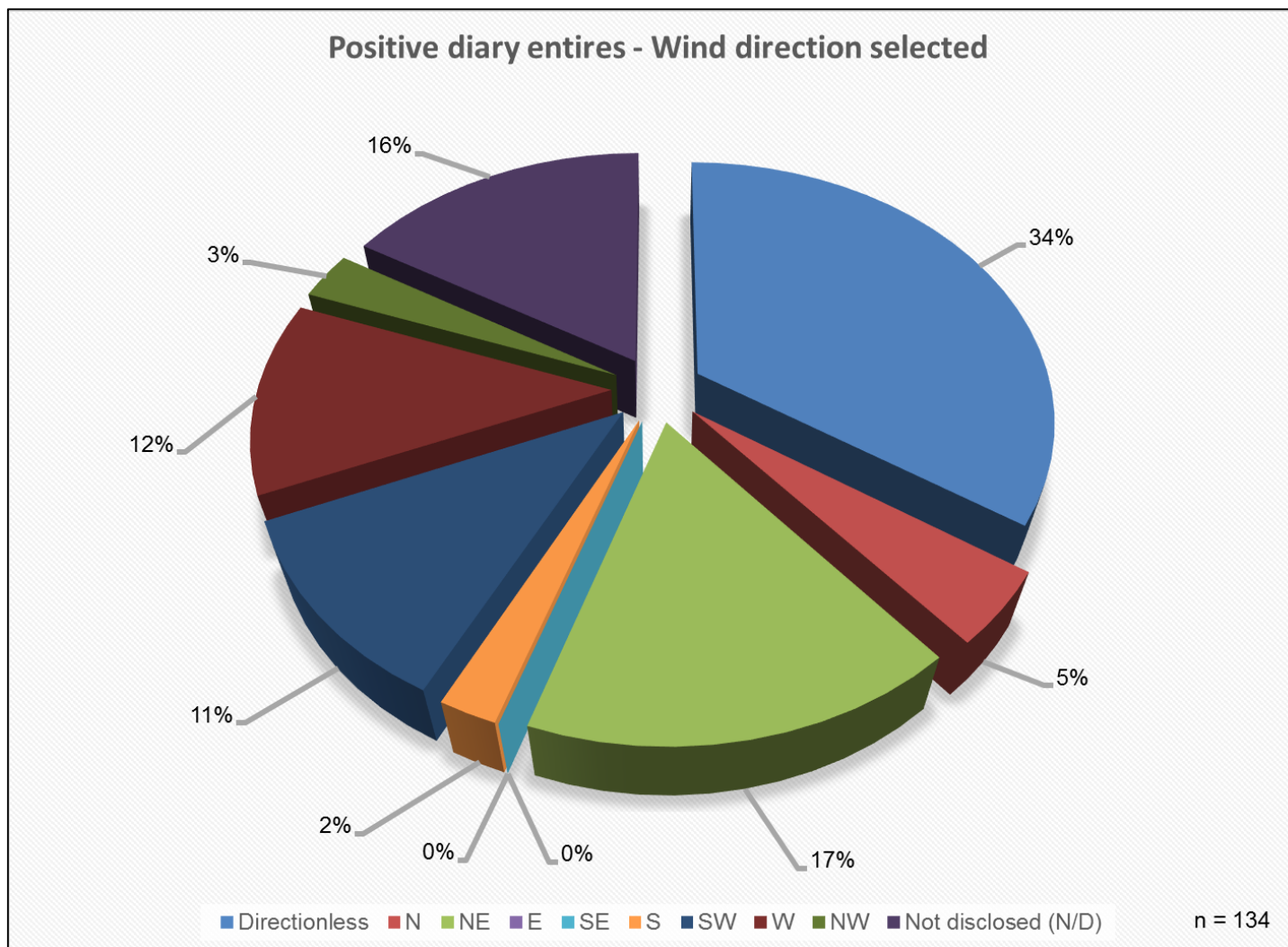


Figure 7.7 – Odour diary analysis: Wind direction selected with positive entries

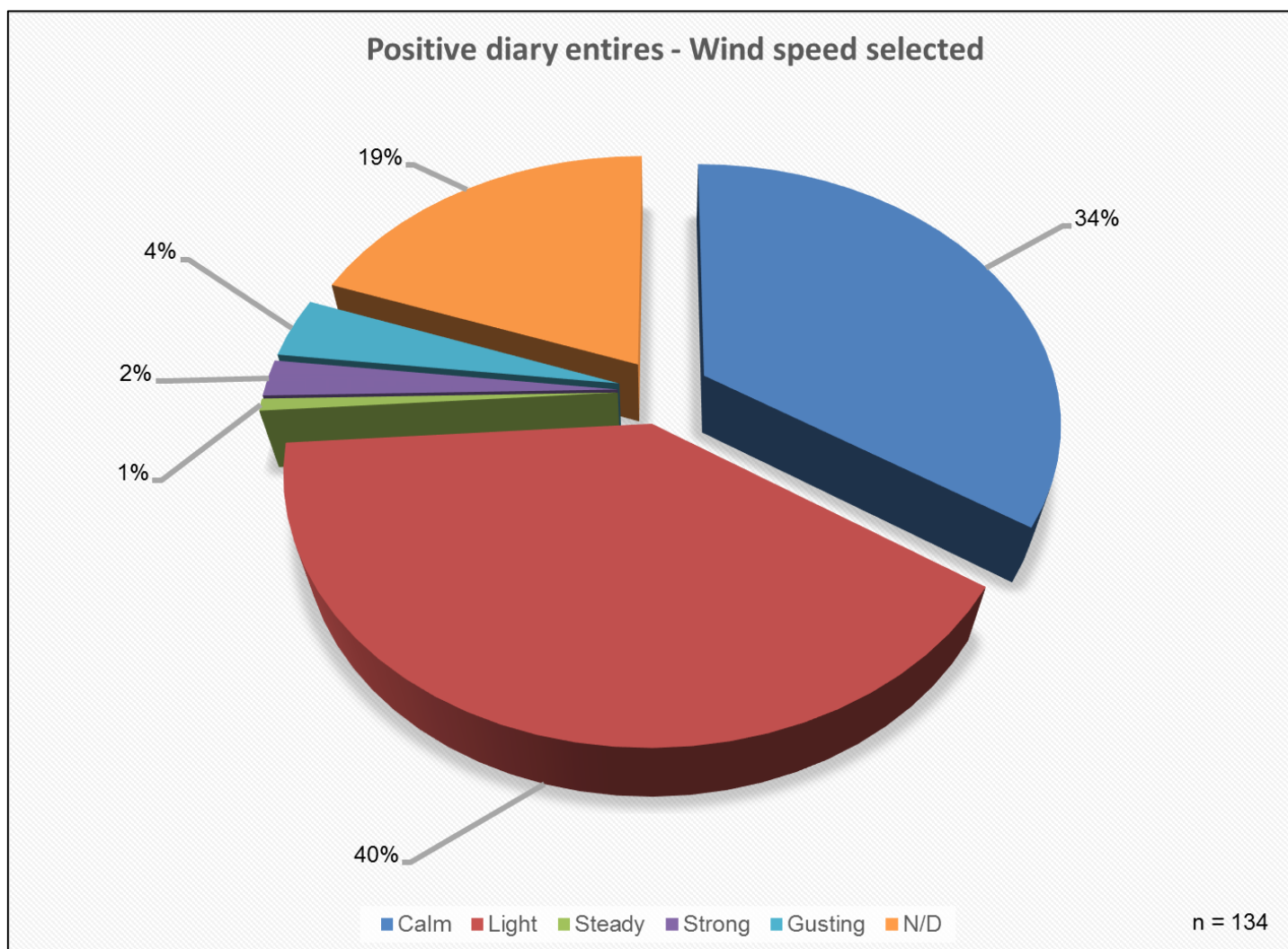


Figure 7.8 – Odour diary analysis: Wind speed selected with positive entries

The following comments can be based on the outcome of the odour diary analysis:

- A majority of positive entries were logged during calm to light winds;
- The major odour characters recorded for all positive entries was 'Garbage' (83%) followed by 'Rotten eggs' (6%);
- No odour characters were logged that could be directly related to the pond sources at the Site;
- Of all positive entries, 75% occurred in the dawn and morning periods (i.e. between 0500 hrs - 0759 hrs & 0800 hrs - 1059 hrs respectively); and
- Of all entries recorded, 54% were negative entries i.e. no odour was detected at the entrant's residential premises.

Based on the above odour diary entries analysis, it can be concluded that odour impact is predominately experienced by the participating entrants under calm to light wind conditions in the dawn and morning periods, a similar finding in the 2014 IOA. The major odour characters detected and recorded were garbage and rotten eggs, indicating that the Void is the likely source. This is consistent with field observations and experience gained by the audit team during the Audit.

The odour diary analysis suggests that there may be a need to validate the community's ability to characterise between the various odours detected. Notwithstanding this shortcoming, the results from the odour diaries appear consistent with findings from the downwind FAOA surveys that were conducted separately by the audit team where a garbage odour character was recorded during field observations over the course of the Audit period.

7.4.3 Compliance with the project-specific odour performance goal of 6 ou

Similar to previous IOAs, the Audit did not have access to the site-specific odour dispersion model used in the EA and did not carry out modelling, using the odour emission rates determined in the Audit. It is therefore unable to determine whether compliance with the 6 ou criterion is being achieved, based on the approach used in odour dispersion modelling, whereby the modelled emission rates prevail over an entire year. Following the substantial improvement in measured odour emissions for both pond and non-pond sources over previous audits, a re-run of the existing dispersion model to quantitatively check compliance should perhaps be undertaken. The Audit results suggest that compliance is likely to be achieved given that the majority of SOER results in this Audit are within the ranges used in the EA (see **Section 7.5** for further details), despite the marginal exceedance of the active tipping face (as this would be compensated by the significant reduction to the originally modelled area, see **Section 7.2.1.7** for details). It is unclear if there is a correlation with this increase and odour complaints.

Broadly speaking, the Audit finds that Veolia continues to actively undertake measures to minimise odour emissions from the Site, including participation in a community consultation process designed to provide the necessary odour impact feedback. This feedback will continue to be important given the recent increase in odour complaints. The Audit recommends that this continue in the future as a means of determining compliance or otherwise with the project-specific goal.

7.5 ODOUR EMISSIONS INVENTORY DISCUSSION

As per recommendation of the previous IOAs, the Audit recommends using an overall odour emissions inventory for the Site and examined it in order to place into context the emissions from any single source.

Table 7.9 details the odour emission inventory for the Site as determined by the testing carried out in this Audit, and compares these results with predictions of emissions contained in the EA. It also makes a comparison with the impact of the revised areas (where applicable) for each odour emission source as found in the Audit.

It is acknowledged that there are odour emissions not listed in this inventory, emanating mostly from sources where quantitative measurement or even estimates are difficult. These include the fugitive odour releases from the Void, previously described as potential gas pathways, arising from gas leakages from the covered areas and around the walls of the Void and leachate recirculation air pressure relief vent. Despite these omissions it is considered that the incomplete inventory remains to have real value and is discussed later (see **Section 7.5.2**).

Table 7.9 - Measureable odour emission rates for the Site ^

Parameters				The Audit		2014 IOA		2013 IOA			2012 IOA		EA		
Location	Current Area (m ²)	2014 Area (m ²) ^^	2012 Area (m ²)	SOER (ou.m ³ /m ² /s)	OER - Current Area (ou.m ³ /s)	SOER (ou.m ³ /m ² /s)	OER - Current Area (ou.m ³ /s)	SOER (ou.m ³ /m ² /s)	OER 2012 Area (ou.m ³ /s)	OER - Current Area (ou.m ³ /s)	SOER (ou.m ³ /m ² /s)	OER (ou.m ³ /s)	SOER (ou.m ³ /m ² /s)	OER (ou.m ³ /s)	OER - Current (ou.m ³ /s)
ED3N-1	6,000	6,000	7,000	0.132	794	0.017	104	0.30	2,100	1,800	394	2,760,000	8.8	61,600	52,800
ED3N-2 & 3 ^^^	11,000	11,000	13,000	0.118	1,300	0.049	543	11.6	150,000	127,000	0.29	3,800	7.4	96,200	81,400
ED3N-2	5,500	5,500	6,500	0.145	797	0.066	365	20.1	131,000	111,000	0.21	1,350	n/a^^^		
ED3N-3	5,500	5,500	6,500	0.091	500	0.032	178	0.2	1,010	852	0.37	2,430			
ED3N-4	25,000	25,000	16,000	0.269	6,720	0.023	575	0.0604	966	1,510	0.41	6,600	0.7	11,200	17,500
Active Tipping Face	6,000	6,000	40,000 *	7.51	45,100	4.28	25,700	3.04	122,000	18,200	8.36	334,000	7.3	292,000	43,800
Leachate Aeration Dam	5,000	5,000	2,000	0.276	1,380	0.026	129	0.323	647	1,620	0.46	920	3.6	7,200 #	18,000
Construction and Demolition Tip Face	900	500	900	0.326	294	n/a^	n/a	0.293	264	147	n/a	n/a	n/a	n/a	n/a
Storage Pond 7	n/a	n/a	1,200	n/a	n/a	n/m^^	n/a	n/m	n/m	n/m	85	102,000	n/m	n/m	n/m

^ All odour emission rates represent the mean derived SOER values for each location

^^ as advised by Veolia

^^^ n/a = reported in EA as a single emission source i.e. ED3N-2 & ED3N-3 as single area

represents mean result for different batches of leachate between 2007 to 2011

* as per AAQMP estimate

Based on the result in **Table 7.9**, the following comments are made:

- The total measureable odour emission rate from the Site found in the Audit was 56,900 ou.m³/s. This represents almost a 50% increase since the 2014 IOA, with the bulk of this increase stemming from the active tipping face area;
- The active tipping face is contributing to approximately 80% of the Site's total measureable odour emissions, without consideration of fugitive landfill gas emissions (see **Section 7.2.1.3**);
- The LMS continues to operate under very low odour emission conditions and is unlikely to be contributing to any significant odour impact beyond the Site boundary;
- From a comparative viewpoint, the SOER results show close agreement between the Audit results and the EA value for all emission sources (see **Table 6.1**). This is a significant result as it shows that the SOER predictions in the EA are suitable for current and future operations at the Site. As previously mentioned in **Section 7.4.3**, the exception is active tipping face where there is marginal exceedance of the *EA 2010* emissions; and
- Similarly to the previous 2012 IOA, ED3N-2 & ED3N-3 have been reported both as separate emission sources and a single source (as per the *EA 2010*) in order to determine the relative contribution of odour emission from each pond separately.

The following sections discuss the results from the odour emissions inventory and Audit in the context of pond and non-pond sources (see **Sections 7.5.1 & 7.5.2** respectively).

7.5.1 Pond sources

All pond sources at the Site sampled in the Audit are considered area sources, including:

- ED3N Pond System: this includes ED3N-1, 2, 3 and 4; and
- LAD.

The following sections discuss each of the above sources.

7.5.1.1 Storage Pond 7

Storage Pond 7 remains non-existent (previously located in the Void) and is therefore not a valid odour emission source in the Audit. The Audit understands that Veolia has no intention in recommissioning this pond system in the future. The WALTER system is a fully enclosed system with no exposed area. On this basis, it is not considered a significant odour emission source at the Site.

7.5.1.2 Leachate Aeration dam

The LAD was found to be very effective in treating the incoming leachate prior to storage in ED3N Pond System. The SOER derived in the Audit from this source is 0.276 ou.m³/m²/s, well below the EA 2010 value of 3.6 ou.m³/m²/s. On this basis, Veolia should continue to work with Veolia Water in optimising the treatment process. The Audit endorses this continuation.

7.5.1.3 ED3N Pond System

In the context of the odour emissions inventory for the Site, the Audit finds that at the current and above performance targets for leachate quality, leachate effluent stored in ED3N is almost odour-free and continues to represent very low SOERs since the IOAs began in 2011. The derived mean SOER's for ED3N-1, 2, 3 & 4 in the Audit is 0.132 ou.m³/m²/s, 0.145 ou.m³/m²/s, 0.091 ou.m³/m²/s & 0.269 ou.m³/m²/s. At these values, the stored contents of ED3N continue to be a minor odour emission source at the Site.

On the above basis, the Audit finds that the leachate performance targets set by Veolia are appropriate in attenuating odour emissions from pond-related sources. It can be considered that any significant deviation of the monitoring targets would be a reasonable indicator that the odour emission generation from pond sources would likely be impacted.

7.5.2 Non-pond sources

The activities within the Void were judged to be similar in terms of process operations to that found in the 2014 IOA. The Audit odour testing results indicate that the Void continues to remain as the major contributor to odour emissions at the Site, by virtue of the significant reduction in ED3N odour emissions in recent times. Based on discussions with Veolia and field observations, this appears to be related to gas capture capabilities within the Void and the need to meet the shortfalls with the currently applied cover material (previously discussed in **Section 7.2.1.6**) in areas where existing cover materials are not performing adequately. Despite this, it appears that fugitive landfill gas emissions is not the source of the increase in odour complaints observed since the 2014 IOA. The garbage character that was readily detectable in the collected odour samples, FAOA survey and odour diary entries appear to be the key cause behind odour emissions escaping from the Void and beyond the boundary. This could be related to a number of factors including, but not limited to:

- The physical and chemical characteristics of received waste;
- The physical and chemical characteristics of C & D waste. It is known that cement and plasterboard can have a significant influence on the degradation of waste and odour emissions. A key component would be plasterboard that contains calcium sulphate (CaSO₄). This can result in a drop to pH in the recirculated leachate causing accelerated degradation of waste before

adequately capping is possible of the active tipping face. This was identified in the sulphur balance study and the Audit concurs with this finding;

- Volumes of waste;
- Time of waste disposal in the Void; and
- The on-going landfill gas capture and implementation of biocover material has reduced the potential gas pathways leading to the active tipping face emissions to become more readily detectable. This can be attributed to the very low detection threshold of H₂S, contained in significant quantities in landfill gas from the Bioreactor, when compared to other chemical compounds found in active tipping face emissions.

The matter should be investigated and re-assessed in the next Audit.

7.5.2.1 Fugitive landfill gas emissions

The fugitive landfill gas emissions that arises due to wall effects and cracks in the capping of waste, particular near landfill gas extraction wells, are an on-going operational issue at the Site. Since the previous 2014 IOA, Veolia has adopted the use of biofiltration-based organic medium (a non-mandatory recommendation in the 2013 IOA and discussed in **Section 7.2.1.6**) in known problematically areas including the leachate extraction sump surface areas and Void perimeter. As can be shown in the Audit, this has proven to be successful when the medium material is maintained in an optimum manner such as the controlling of medium moisture and depth. Veolia should continue the implementation of the biocover material, alongside with improving gas capture, as a means of reducing fugitive gas emissions given that this is judged to be the major contributor to odour emissions from the Site (see **Section 7.2.1.3**).

8 AUDIT RECOMMENDATIONS

8.1 CONDITION 7 (G & H)

The following section is designed to address the following Audit requirement:

- *Outline all reasonable and feasible measures (including cost/benefit analysis, if required) that may be required to improve odour control at the site; and*
- *Recommend and prioritise (mandatory and non-mandatory) recommendations for their implementations.*

Based on the findings from this Audit, the following mandatory and non-mandatory measures have been recommended. In addition to these measures, Veolia should continue the current community liaison program (including the Woodlawn Community Liaison Committee and the Tarago and District Progress Association Inc.) to notify affected/nearby residents of works and address concerns. Veolia should also continue to log and monitor odour complaints in the current odour complaints register and odour diary project.

8.2 MANDATORY RECOMMENDATIONS

The mandatory recommendations in this Audit revolve around the leachate management system and the continuation of odour mitigation from the Void. These have been discussed in the following sections.

8.2.1 Odour mitigation from the Void

Fugitive landfill gas emissions

Veolia should continue to improve landfill gas capture from the Bioreactor. This continuation is already underway with Veolia completing an updated version of its WIP, which outlines a comprehensive plan that is being implemented to increase gas capture. It also seeks to address current areas of concern and the potential solution outcomes that can be implemented. This is considered to be an active (and effective) management approach that will result in a continual improvement in gas capture efficiency and ultimately reduce odour/landfill gas emissions from the Void. The Audit endorses this strategy as the primary measure to reduce odour emissions from the Void and recommends that Veolia continue the implementation of the gas systems detailed in the WIP post-2014, including the proposed leachate and gas extraction expansion around the Void. The landfill gas capture efficiency should continue to be monitored and recorded and the surface of the Void monitored to determine effectiveness of capture within specific areas of the Void.

It should be noted that the WIP is a live document that will be continual updated. Therefore, it will continue to remain a part of the IOA.

Active tipping face

Investigate emissions arising from the active tipping face operations. Given the positive outcomes from the preliminary trial testing, the efficacy of the sprayable polymer slurry mixture should be further investigated as a means of odour mitigation from the waste surface including the effect of blending other odour suppression products (such as haematite). This investigation should also take into consideration the potential effects that the applied mixture may have on landfill gas capture, if any.

8.2.2 Leachate management system

Continue to adequately maintain and manage the upgraded leachate management system to ensure it is operating in an optimum state and meeting the leachate quality monitoring targets as outlined in the *Leachate Treatment Operation Manual* and recommended by Veolia Water. This manual should be considered as a 'live' document to reflect any variation in quality and operational demands and identifications of new constraints and/or issues. This should continue to attenuate the potential for significant odour generation from the leachate stored in ED3N both now and in the future.

8.3 NON-MANDATORY RECOMMENDATIONS

The non-mandatory recommendations in this Audit revolve around odour mitigation strategies for the Void, odour complaints, and fugitive gas emissions from the Void. This has been discussed in the following sections.

8.3.1 Odour mitigation strategies for the Void

8.3.1.1 Biofilter cover material

The Audit recommends continuation and expansion of the biofilter cover material in areas where there is an identified risk of fugitive odour emissions from the Void surface. Moreover, development of an action strategy to streamline the application and management of this material is recommended.

8.3.2 Pilot-scale biofilter system

As per the previous 2014 IOA recommendation, the development of a pilot-scale biofilter system to evaluate the effect of medium depth on landfill gas emissions is also recommended. A pilot-scale biofilter unit could be setup in an appropriate location (possibly in the Void) where safe and easy flow diversion of landfill gas is possible. Only small and continuous gas volumes would be required for this exercise. The conditions should address the effect on landfill gas odour at varying medium depths. A suitable medium depth range to trial would be between 0.5 – 1.0 m given the outcomes from the previous audit and the Audit. The medium would need to be kept adequately moist and possibly inoculated with sludge/leachate to assist with the acclimatisation of suitable

microorganisms in the biofilter bed. Veolia has already indicated that it intends on undertaking this trial and is in consultation with TOU.

8.3.3 Refine investigation of odour issues in the community

Veolia should consider refining its investigation of odour issues in the community, particularly surrounding the most common complainants, as to assess the extent to which odour is present in the community. Such an investigation could include, potential odour transport pathways, undertaking of field ambient odour surveys, assess topography of surrounding land, analysis of climatic data and a detailed review of odour complaint data.

8.3.4 Gas speciation analysis of emissions from the Void

As part of the next audit, gas speciation analysis of fugitive landfill gas and active tipping face emissions should be conducted to identify the dominant gas compounds that are likely contributing to odour emissions from the Void. Collection of samples for gas speciation analysis may also assist in future planning of the odour audit at the Site.

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9 REPORT SIGNATURE PAGE

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Consultant



Steven Hayes
Senior Odour Consultant



Veolia Australia & New Zealand

Woodlawn Bioreactor Expansion Project

Independent Odour Audit #4

December 2015

Appendices



APPENDIX A:

ODOUR CONCENTRATION LABORATORY TESTING RESULT SHEETS

THE ODOUR UNIT PTY LTD



THE ODOUR
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Accreditation Number:
14974

Odour Concentration Measurement Results

The measurement was commissioned by:

Organisation	Veolia Australia & New Zealand	Telephone	(02) 9841 2932
Contact	Stephen Bernhart	Facsimile	--
Sampling Site	Woodlawn Bioreactor Facility	Email	stephen.bernhart@veolia.com
Sampling Method	AS4323.3 & AS4323.4	Sampling Team	TOU (M. Assal, S. Hayes)

Order details:

Order requested by	Stephen Bernhart	Order accepted by	M. Assal
Date of order	14.09.2015	TOU Project #	N1806L
Order number	4503279006	Project Manager	M. Assal
Signed by	Refer to correspondence	Testing operator	A. Schulz

Investigated Item	Odour concentration in odour units 'ou', determined by sensory odour concentration measurements, of an odour sample supplied in a sampling bag.
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. NATA accredited for compliance with ISO/IEC 17025. 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 V04
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 V04: $r = 0.1162$ (March - May 2015) 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 V04: $A = 0.2105$ (March - May 2015) Compliance – Yes
Lower Detection Limit (LDL)	The LDL for the olfactometer has been determined to be 16 ou (4 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: Thursday, 22 October 2015

Panel Roster Number: SYD20151008_071

J. Schulz
NSW Laboratory Coordinator

A. Schulz
Authorised Signatory

Odour Sample Measurement Results
Panel Roster Number: SYD20151008_071

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)	Specific Odour Emission Rate (ou.m ³ /m ² /s)
Sample #1 - ED3N-4	SC15494	07/10/2015 0848hrs	08/10/2015 1053hrs	4	8	--	--	362	362	0.269
Sample #2 - ED3N-2	SC15495	07/10/2015 0837hrs	08/10/2015 1129hrs	4	8	--	--	197	197	0.145
Sample #3 - ED3N-1	SC15496	07/10/2015 0946hrs	08/10/2015 1200hrs	4	8	--	--	181	181	0.132
Sample #4 - ED3N-3	SC15497	07/10/2015 0927hrs	08/10/2015 1325hrs	4	8	--	--	118	118	0.091
Sample #5 - Leachate Aeration Dam	SC15498	07/10/2015 1038hrs	08/10/2015 1351hrs	4	8	--	--	362	362	0.276

Note: The following are not covered by the NATA Accreditation issued to The Odour Unit Pty Ltd:

1. The collection of Isolation Flux Hood (IFH) samples and the calculation of the Specific Odour Emission Rate (SOER).
2. Final results that have been modified by the dilution factors where parties other than The Odour Unit Pty Ltd. have performed the dilution of samples.

Odour Sample Measurement Results
Panel Roster Number: SYD20151008_071

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)	Specific Odour Emission Rate (ou.m ³ /m ² /s)
Sample #6 - Waste Covered Area: Normal Capping (Zone A between LE85 & SM13)	SC15499	07/10/2015 1235hrs	08/10/2015 1415hrs	4	8	--	--	181	181	0.127
Sample #7 - Waste Covered Area: Normal Capping (Zone A and parallel to LE99)	SC15500	07/10/2015 1246hrs	08/10/2015 1458hrs	4	8	--	--	558	558	0.388
Sample #8 - Construction and Demolition Area: Active Tipping Face (Point #1)	SC15501	07/10/2015 1315hrs	08/10/2015 1534hrs	4	8	--	--	431	431	0.299

Note: The following are not covered by the NATA Accreditation issued to The Odour Unit Pty Ltd:

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Odour Sample Measurement Results
Panel Roster Number: SYD20151008_071

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)	Specific Odour Emission Rate (ou.m ³ /m ² /s)
Sample #9 - Construction and Demolition Area: Active Tipping Face (Point #2)	SC15502	07/10/2015 1330hrs	08/10/2015 1630hrs	4	8	--	--	512	512	0.353
Sample #10 - Waste Covered Area: Normal capping + biocover material (LE41)	SC15503	07/10/2015 1417hrs	08/10/2015 1705hrs	4	8	--	--	256	256	0.176
Sample #11 - Waste Covered Area: Normal capping + biocover material (LE57) *	SC15504	07/10/2015 1420hrs	--	--	--	--	--	2,520,000	2,520,000	1,692.9

Note: The following are not covered by the NATA Accreditation issued to The Odour Unit Pty Ltd:

1. The collection of Isolation Flux Hood (IFH) samples and the calculation of the Specific Odour Emission Rate (SOER).
2. Final results that have been modified by the dilution factors where parties other than The Odour Unit Pty Ltd. have performed the dilution of samples

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	SYD20151008_071	51,500	$20 \leq \chi \leq 80$	1,024	50	Yes

Comments Odour characters (non-NATA accredited) as determined by odour laboratory panel:

SC15494	ammonical, dirt, soil
SC15495	ammonical, dirt, soil
SC15496	muddy, dirt
SC15497	muddy, dirt
SC15498	ammonical, dirt, soil
SC15499	sweet, fermented
SC15500	sweet, fermented, pineapple, rotten egg, landfill gas
SC15501	sweet, fermented, pineapple, rotten egg, landfill gas
SC15502	garbage, pineapple
SC15503	garbage, dirt, ammonical
SC15504	landfill gas, rotten egg

* estimated at 3,000 ou per 1 ppm of H₂S (i.e. mean of 2,000 - 4,000 ou per 1 ppm of H₂S)

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 Ltd for the purpose of odour testing. The collection of odour samples by parties other than The Odour Unit Pty Ltd relinquishes The Odour Unit Pty Ltd 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 Ltd. Any attachments to this Report are not covered by the NATA Accreditation issued to The Odour Unit Pty Ltd.

END OF DOCUMENT

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ABN: 53 091 165 061



Accreditation Number:
14974

Odour Concentration Measurement Results

The measurement was commissioned by:

Organisation	Veolia Australia & New Zealand	Telephone	(02) 9841 2932
Contact	Stephen Bernhart	Facsimile	--
Sampling Site	Woodlawn Bioreactor Facility	Email	stephen.bernhart@veolia.com
Sampling Method	AS4323.3 & AS4323.4	Sampling Team	TOU (M. Assal, S. Hayes)

Order details:

Order requested by	Stephen Bernhart	Order accepted by	M. Assal
Date of order	14.09.2015	TOU Project #	N1806L
Order number	4503279006	Project Manager	M. Assal
Signed by	Refer to correspondence	Testing operator	A. Schulz

Investigated Item	Odour concentration in odour units 'ou', determined by sensory odour concentration measurements, of an odour sample supplied in a sampling bag.
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. NATA accredited for compliance with ISO/IEC 17025. 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 V04
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 V04: $r = 0.1162$ (March - May 2015) 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 V04: $A = 0.2105$ (March - May 2015) Compliance – Yes
Lower Detection Limit (LDL)	The LDL for the olfactometer has been determined to be 16 ou (4 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: Tuesday, 27 October 2015

Panel Roster Number: SYD20151009_072

J. Schulz
NSW Laboratory Coordinator

A. Schulz
Authorised Signatory

Odour Sample Measurement Results
Panel Roster Number: SYD20151009_072

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)	Specific Odour Emission Rate (ou.m ³ /m ² /s)
Sample #12 - Active Tipping Face Area: Soil Cover + Polymer Slurry (Point #1A)	SC15505	08/10/2015 0935hrs	09/10/2015 1029hrs	4	8	-	-	256	256	0.192
Sample #13 - Active Tipping Face Area: Polymer Slurry applied (Point #1B)	SC15506	08/10/2015 0940hrs	09/10/2015 1054hrs	4	8	-	-	6,320	6,320	4.45
Sample #14 - Active Tipping Face Area: Soil Cover + Polymer Slurry (Point #2A)	SC15507	08/10/2015 1018hrs	09/10/2015 1128hrs	4	8	-	-	724	724	0.502

Note: The following are not covered by the NATA Accreditation issued to The Odour Unit Pty Ltd:

1. The collection of Isolation Flux Hood (IFH) samples and the calculation of the Specific Odour Emission Rate (SOER).
2. Final results that have been modified by the dilution factors where parties other than The Odour Unit Pty Ltd. have performed the dilution of samples.

Odour Sample Measurement Results
Panel Roster Number: SYD20151009_072

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)	Specific Odour Emission Rate (ou.m ³ /m ² /s)
Sample #15 - Active Tipping Face Area: Polymer Slurry applied (Point #2B)	SC15508	08/10/2015 1021hrs	09/10/2015 1203hrs	4	8	-	-	4,470	4,470	2.83
Sample #16 - Active Tipping Face Area: No cover (Point #3A)	SC15509	08/10/2015 1118hrs	09/10/2015 1303hrs	4	8	-	-	23,200	23,200	14.0
Sample #17 - Active Tipping Face Area: No cover (Point #3B)	SC15510	08/10/2015 1119hrs	09/10/2015 1336hrs	4	8	-	-	27,600	27,600	17.1
Sample #18 - Active Tipping Face Area: Freshly Waste (< 1 day old, Point #1)	SC15511	08/10/2015 1225hrs	09/10/2015 1422hrs	4	8	-	-	17,900	17,900	11.8

Note: The following are not covered by the NATA Accreditation issued to The Odour Unit Pty Ltd:

1. The collection of Isolation Flux Hood (IFH) samples and the calculation of the Specific Odour Emission Rate (SOER).
2. Final results that have been modified by the dilution factors where parties other than The Odour Unit Pty Ltd. have performed the dilution of samples.

Odour Sample Measurement Results
Panel Roster Number: SYD20151009_072

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)	Specific Odour Emission Rate (ou.m ³ /m ² /s)
Sample #19 - Active Tipping Face Area: Freshly Waste (< 1 day old, Point #2)	SC15512	08/10/2015 1230hrs	09/10/2015 1453hrs	4	8	-	-	15,000	15,000	9.15
Sample #20 - Waste Covered Area: Normal Capping (Zone D - LE65)	SC15513	08/10/2015 1314hrs	09/10/2015 1520hrs	4	8	-	-	101,000	101,000	58.4
Sample #21 - Waste Covered Area: Normal capping + biocover material (Zone D - LE65)	SC15514	08/10/2015 1315hrs	09/10/2015 1547hrs	4	8	39:1	39:1	77,900	3,120,000	1765.4

Note: The following are not covered by the NATA Accreditation issued to The Odour Unit Pty Ltd:

1. The collection of Isolation Flux Hood (IFH) samples and the calculation of the Specific Odour Emission Rate (SOER).
2. Final results that have been modified by the dilution factors where parties other than The Odour Unit Pty Ltd. have performed the dilution of samples.

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	SYD20151009_072	51,500	$20 \leq \chi \leq 80$	861	60	Yes

Comments Odour characters (non-NATA accredited) as determined by odour laboratory panel:

SC15505 dirt, garbage
 SC15506 ammonical, garbage
 SC15507 vanilla, gassy
 SC15508 dirt, garbage
 SC15509 lime, sour, ammonical, garbage
 SC15510 ammonical, garbage
 SC15511 garbage
 SC15512 garbage
 SC15513 garbage, landfill gas, rotten, pineapple
 SC15514 landfill gas, rotten egg, pineapple, garbage

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 Ltd for the purpose of odour testing. The collection of odour samples by parties other than The Odour Unit Pty Ltd relinquishes The Odour Unit Pty Ltd 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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THE ODOUR UNIT PTY LTD



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Accreditation Number:
14974

Odour Concentration Measurement Results

The measurement was commissioned by:

Organisation	Veolia Australia & New Zealand	Telephone	(02) 9841 2932
Contact	Stephen Bernhart	Facsimile	--
Sampling Site	Woodlawn Bioreactor Facility	Email	stephen.bernhart@veolia.com
Sampling Method	Liquid Odour Method (LOM)	Sampling Team	TOU (M. Assal)

Order details:

Order requested by	Stephen Bernhart	Order accepted by	M. Assal
Date of order	14.09.2015	TOU Project #	N1806L
Order number	4503279006	Project Manager	M. Assal
Signed by	Refer to correspondence	Testing operator	A. Schulz

Investigated Item	Odour concentration in odour units 'ou', determined by sensory odour concentration measurements, of an odour sample supplied in a sampling bag.
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. NATA accredited for compliance with ISO/IEC 17025. 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 V04
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 V04: $r = 0.1162$ (March - May 2015) 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 V04: $A = 0.2105$ (March - May 2015) Compliance – Yes
Lower Detection Limit (LDL)	The LDL for the olfactometer has been determined to be 16 ou (4 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, 28 October 2015

Panel Roster Number: SYD20151021_076

J. Schulz
NSW Laboratory Coordinator

A. Schulz
Authorised Signatory

Odour Sample Measurement Results
Panel Roster Number: SYD20151021_076

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)	Specific Odour Emission Rate (ou.m ³ /m ² /s)
ED3N-1 (LOM)	SC15553	21/10/2015 0940hrs	21/10/2015 1437hrs	4	8	--	--	118	118	--
ED3N-2 (LOM)	SC15554	21/10/2015 0935hrs	21/10/2015 1510hrs	4	8	--	--	470	470	--
ED3N-3 (LOM)	SC15555	21/10/2015 0945hrs	21/10/2015 1543hrs	4	8	--	--	197	197	--

Note: The following are not covered by the NATA Accreditation issued to The Odour Unit Pty Ltd:

1. The collection of Isolation Flux Hood (IFH) samples and the calculation of the Specific Odour Emission Rate (SOER).
2. Final results that have been modified by the dilution factors where parties other than The Odour Unit Pty Ltd. have performed the dilution of samples.

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	SYD20151021_076	51,500	$20 \leq \chi \leq 80$	1,024	50	Yes

Comments Odour characters (non-NATA accredited) as determined by odour laboratory panel:

SC15553 musty
SC15554 ammonia, dirty socks
SC15555 musty, dusty, dirty

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 Ltd for the purpose of odour testing. The collection of odour samples by parties other than The Odour Unit Pty Ltd relinquishes The Odour Unit Pty Ltd 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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APPENDIX B:

ODOUR EMISSIONS WORKSHEET

THE ODOUR UNIT PTY LTD Surface Odour Emission Rate for Isolation Flux Hood Calculation Sheet Client: Veolia (Australia & New Zealand) Sampling Site: Woodlawn Bioreactor Facility Project Number: N1806L - Audit #4														
Sample Location	TOU Sample Number	Odour Concentration (ou)	Nominal Air Temperature (°C)	Measured Internal Flux Hood Odour Temperature (°C)	Emission Factor Nominal Air Temperature	Emission Factor measured air temperature	Temperature Correction Factor	Enclosed surface area (m ²)	Flux chamber sweep air flow rate - Q (L/min)	Flux chamber sweep air flow rate - Q (m ³ /min)	Odour Emission Rate at Source (Not corrected for temperature) (ou.m ³ /m ² /min)	Odour Emission Rate at Source (Corrected for temperature) (ou.m ³ /m ² /min)	Specific Odour Emission Rate (ou.m ³ /m ² /s)	Odour character
Sample #1 - ED3N-4	SC15494	362	25.0	16.1	1.384	1.233	1.123	0.126	5	0.005	14.37	16.13	0.269	ammonical, dirt, soil
Sample #2 - ED3N-2	SC15495	197	25.0	16.8	1.384	1.244	1.112	0.126	5	0.005	7.82	8.70	0.145	ammonical, dirt, soil
Sample #3 - ED3N-1	SC15496	181	25.0	17.3	1.384	1.252	1.105	0.126	5	0.005	7.18	7.94	0.132	muddy, dirt
Sample #4 - ED3N-3	SC15497	118	25.0	13.2	1.384	1.187	1.166	0.126	5	0.005	4.68	5.46	0.091	muddy, dirt
Sample #5 - Leachate Aeration Dam	SC15498	362	25.0	14.0	1.384	1.200	1.154	0.126	5	0.005	14.37	16.57	0.276	ammonical, dirt, soil
Sample #6 - Waste Covered Area: Normal Capping (Zone A between LE85 & SM13)	SC15499	181	25.0	20.5	1.384	1.305	1.060	0.126	5	0.005	7.18	7.62	0.127	sweet, fermented
Sample #7 - Waste Covered Area: Normal Capping (Zone A and parallel to LE99)	SC15500	558	25.0	21.1	1.384	1.316	1.052	0.126	5	0.005	22.14	23.29	0.388	sweet, fermented, pineapple, rotten egg, landfill gas
Sample #8 - Construction and Demolition Area: Active Tipping Face (Point #1)	SC15501	431	25.0	21.3	1.384	1.319	1.049	0.126	5	0.005	17.10	17.95	0.299	sweet, fermented, pineapple, rotten egg, landfill gas
Sample #9 - Construction and Demolition Area: Active Tipping Face (Point #2)	SC15502	512	25.0	21.7	1.384	1.326	1.044	0.126	5	0.005	20.32	21.21	0.353	garbage, pineapple
Sample #10 - Waste Covered Area: Normal capping + Biocover material (LE41)	SC15503	256	25.0	22.2	1.384	1.335	1.037	0.126	5	0.005	10.16	10.54	0.176	garbage, dirt, ammonical
Sample #11 - Waste Covered Area: Normal capping + Biocover material (LE57)^	SC15504	2,520,000	25.0	23.8	1.384	1.363	1.016	0.126	5	0.005	100000.00	101,572	1,692.9	landfill gas, rotten egg
Sample #12 - Active Tipping Face Area: Soil Cover + Polymer Slurry (Point #1A)	SC15505	256	25.0	15.2	1.384	1.218	1.136	0.126	5	0.005	10.16	11.54	0.192	dirt, garbage
Sample #13 - Active Tipping Face Area: Polymer Slurry applied (Point #1B)	SC15506	6,320	25.0	20.2	1.384	1.300	1.064	0.126	5	0.005	250.79	266.94	4.45	ammonical, garbage
Sample #14 - Active Tipping Face Area: Soil Cover + Polymer Slurry (Point #2A)	SC15507	724	25.0	21.4	1.384	1.321	1.048	0.126	5	0.005	28.73	30.11	0.502	vanilla, gassy
Sample #15 - Active Tipping Face Area: Polymer Slurry applied (Point #2B)	SC15508	4,470	25.0	28.3	1.384	1.445	0.958	0.126	5	0.005	177.38	169.93	2.83	dirt, garbage
Sample #16 - Active Tipping Face Area: No cover (Point #3A)	SC15509	23,200	25.0	31.8	1.384	1.512	0.915	0.126	5	0.005	920.63	842.74	14.0	lime, sour, ammonical, garbage
Sample #17 - Active Tipping Face Area: No cover (Point #3B)	SC15510	27,600	25.0	30.0	1.384	1.477	0.937	0.126	5	0.005	1095.24	1026.31	17.1	ammonical, garbage
Sample #18 - Active Tipping Face Area: Freshly Waste (< 1 day old, Point #1)	SC15511	17,900	25.0	25.3	1.384	1.389	0.996	0.126	5	0.005	710.32	707.55	11.8	garbage
Sample #19 - Active Tipping Face Area: Freshly Waste (< 1 day old, Point #2)	SC15512	15,000	25.0	31.2	1.384	1.500	0.923	0.126	5	0.005	595.24	549.14	9.15	garbage
Sample #20 - Waste Covered Area: Normal Capping (Zone D - LE65)	SC15513	101,000	25.0	35.3	1.384	1.582	0.875	0.126	5	0.005	4007.94	3505.65	58.4	garbage, landfill gas, rotten, pineapple
Sample #21 - Waste Covered Area: Normal capping + Biocover Material (Zone D - LE65)	SC15514	3,120,000	25.0	37.0	1.384	1.618	0.856	0.126	5	0.005	123809.52	105926.38	1765.4	landfill gas, rotten egg, pineapple, garbage

^ estimated at 3,000 ou per 1 ppm of H₂S (i.e. mean of 2,000 - 4,000 ou per 1 ppm of H₂S)



Liquid Odour Measurement Emission Results (Mechanical Evaporators)

Liquid Odour Measurement - Calculation (25L N ₂ with 413 µL sample)	TOU Sample Number	Odour Concentration (ou)	Volume of Liquid (mL)	Volume of dry N ₂ (L)	Odour Concentration (ou/m ³)	Calculated Liquid Odour Concentration (ou/mL)	Mechanical Evaporation Rate (L/min) @ 20% efficiency	Odour Emission Rate (ou.m ³ /min)	Odour Emission Rate (ou.m ³ /s)	Mechanical Evaporation Rate (L/min) @ 30% efficiency	Odour Emission Rate (ou.m ³ /min)	Odour Emission Rate (ou.m ³ /s)	Odour Character
ED3N-1	SC15553	118	0.413	25	118	7.14	70	500,000	8,330	105	750,000	12,500	musty
ED3N-2	SC15554	470	0.413	25	470	28.5	70	2,000,000	33,300	105	2,990,000	49,800	ammonical, dirty socks
ED3N-3	SC15555	197	0.413	25	197	11.9	70	833,000	13,900	105	1,250,000	20,800	musty, dusty, dirty

Mechanical evaporation rate is based on 20 % / 30% evaporation efficiency per evaporator

Evaporation efficiency	per evaporator		All evaporators	
	20%	30%	20%	30%
ED3N-1	8,330	12,500	25,000	37,500
ED3N-2	33,300	49,800	99,900	149,000
ED3N-3	13,900	20,800	41,700	62,400

Liquid Odour Measurement Emission Results (Natural Evaporation)

Liquid Odour Measurement - Calculation (25L N ₂ with 413 µL sample)	TOU Sample Number	Odour Concentration (ou)	Volume of Liquid (mL)	Volume of dry N ₂ (L)	Odour Concentration (ou/m ³)	Calculated Liquid Odour Concentration (ou/mL)	Area (m ²)	Natural evaporation rate (mm/month)	Natural evaporation rate (L/s)	Odour emission rate (ou.m ³ /s)
ED3N-1	SC15553	118	0.413	25	118	7.14	6,000	92.67	0.212	1,510
ED3N-2	SC15554	470	0.413	25	470	28.5	5,500	92.67	0.194	5,530
ED3N-3	SC15555	197	0.413	25	197	11.9	5,500	92.67	0.194	2,310

The natural evaporation rate is based on the mean evaporation rate recorded between May 2007 to June 2012 i.e. 92.67 mm/month



APPENDIX C:

TECHNICAL DOCUMENTATION RELEVANT TO THE AUDIT



ODOUR COMPLAINTS REGISTER:

12 OCTOBER 2014 – 25 OCTOBER 2015

[illegible]



URS SULPHUR BALANCE – WOODLAWN BIOREACTOR REPORT

28 OCTOBER 2015



Final Report

Sulphur Balance - Woodlawn Bioreactor

AUSTRALIA



Sulphur Balance




28 October 2015
43283820/R001/C

Prepared for:
Veolia

Prepared by URS Australia Pty Ltd



DOCUMENT PRODUCTION / APPROVAL RECORD

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Checked by	David Ife		28 Oct 2015	Senior Principal
Approved by	Harry Grynberg		28 Oct 2015	Director, Environment & Planning

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1 INTRODUCTION

1.1 Overview

URS was engaged by Veolia to undertake an assessment of factors that may be contributing to the generation of hydrogen sulphide in the bioreactor landfill at Woodlawn in NSW.

The Woodlawn Bioreactor is a specifically engineered facility with a particular range of design measures that relate to the development, maintenance and optimization of the waste disposal operations in a known sulphide rich and acidic environment, while also meeting the environmental and commercial objectives of the facility. Of particular concern has been the management of hydrogen sulphide emissions.

The scope of work comprised:

Stage 1 – Site visit and data acquisition.

Stage 2 – Establishment of a sulphur balance for the facility. The balance is based on a number of assumptions/estimates, including:

- The proportion of sulphate in the C&D cover materials;
- The inflow of sulphate waters into the waste mass from mine drainage;
- The rate of H₂S generation from MSW in the landfill before the application of the C&D cover (i.e. the background conditions); and
- The stoichiometry relationship that indicates one hundred tonnes of SO₄²⁻ has the potential to produce 35 tonnes of H₂S.

On this basis, the rate of H₂S generation from sulphate sources on the site over time was calculated and a comparison of the observed gas generation numbers and the gas generation rates predicted from models was conducted.

Stage 3 – Canvassing of mitigation measures. There are a number of ways to reduce H₂S emissions from the waste. These options will be reviewed although there will be insufficient budget to carry out an indicative cost estimate for comparative purposes. The options may include diversion of gypsum from the waste stream, identification of local Fe₂O₃ sources and the discussion of alternative amendment measures.

Based on the data provide by Veolia during the site visit and subsequently, the period considered was up until approximately November 2014.

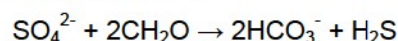
1.2 Observations and Previous Work

H₂S concentrations have been observed to be increasing in the landfill gas stream at the power station. Concentrations are now (2014) at around 1,200 ppm. There is also a rotten egg gas smell at the tip face and cover soils are observed to be locally blackened (the black material is most likely a result of reaction of H₂S in aqueous form and S²⁻ with dissolved iron and other metals to form precipitated FeS and other metal sulphides). Cover soils comprising concrete ("CCR") and construction and demolition waste ("C&D") have been applied across the waste for the last few years or so and these are considered to be contributing to the increasing H₂S concentrations that are being observed.

On the basis of work previously carried out at the site, and particularly the work of Stephen Hancock, it is considered that there are three sources that contribute to the production of H₂S in the Woodlawn Bioreactor:

1. The inflow of acid mine drainage into the open cut. Although drainage mitigation and interception works have been carried out on the mine face, there remains an inflow of water that comes into contact with the sulphide rock and emerges into the waste mass impacted by sulphate. The mine pit was a source of acid mine drainage resultant from surface water infiltration into waste rock piles and fractured bench areas around the pit as well as groundwater inflow to the pit. These processes have been long known to catalyse oxidation of the sulphidic minerals (pyrite FeS and FeS₂ and other metal sulphides) to form sulphuric acid (H₂SO₄). As a consequence the water flowing into the pit was both highly acid and highly contaminated with heavy metals in solution as sulphates.

Under anaerobic conditions, sulphate reducing bacteria (SRB) produce H₂S gas from the sulphate in AMD, gypsum (plasterboard) and the organic carbon waste materials through the following process:



2. The waste mass itself. Municipal Solid Waste (MSW) typically has the capacity to generate sulphides – through the reduction of sulphates from co-disposed organic wastes, plasterboard and other wastes. Surveys have been carried out in the US and are quoted in the USEPA Office of Research and Development (2014) Report. The studies quoted indicate a mean H₂S concentration in landfill gas, from a number of MSW landfills as being around 32 ppm. These are most likely not bioreactors but “dry” landfills with direct rainfall and potentially groundwater inflows..
3. The construction and demolition cover. C&D waste typically emits higher concentrations of H₂S because of the higher proportion of plasterboard (CaSO₄) than conventional MSW waste. Research quoted in the USEPA Office of Research and Development (2014) report indicated a mean concentration of 2,000 ppm from 10 C&D landfills and higher concentrations (between 9,000 and 18,000 ppm) at a C&D landfill in New York.

The work previously undertaken on H₂S management at Woodlawn has concentrated on the influence of inflows of high sulphate waters from the sulphide rock. Prior to the application of C&D waste as cover, this was considered the main cause of elevated H₂S emissions and at that stage it was considered that the extra buffering provided by the methanogenic leachate in the waste mass should counteract the high sulphate inflows. In addition, hematite and magnetite have been brought in and periodically applied on the waste to further facilitate adsorption of sulphides from the gas.

The CCR concrete fines and C&D wastes that are now being brought in and used for cover comprise significant gypsum components in the waste stream. The proportion of CaSO₄ in these materials has been tested at 10 – 20,000 mg/kg.(analyses provided by Veolia dated October/November 2014)

2 SITE OPERATIONS AND OBSERVATIONS

The Bioreactor was visited by Dr Harry Grynberg and David Ife on 2nd December 2014 and monitoring data was provided by site staff – Henry Gundry and Ben Quill. The following information was made available:

- Monthly analysis of CH₄, O₂ and H₂S from individual gas wells within extraction networks (referred to as spiders) for May, June, July, August and October 2013
- Location plan for wells and elevations of the wellheads
- Weekly gas capture rates (m³) – 1st Jan. 2012 to 11th Jan. 2015 with proportions of methane for each week
- Draeger tube analysis results for H₂S concentrations in landfill gas wells for 2011 and 2012
- H₂S concentrations in the landfill gas stream at the generator 7th Jan. 2006 – 28th Dec. 2014
- Mass of C&D fines deposited on a weekly basis between Aug 2012 and Nov 2014
- Hematite and magnetite use between 11th May 2005 and 13th Nov 2014
- Map of C&D deposition areas
- Leachate monitoring results – aeration pond, water effluent, evaporation ponds 1, 2 and 3 for Oct. and Nov. 2014
- Leachate extraction wells monitoring results – May and Dec. 2012 and May 2013
- Sulphur concentrations in soils, dolerite fines, CCR fines and clay in the void

Observations were made at the site and discussions with the site personnel indicated that:

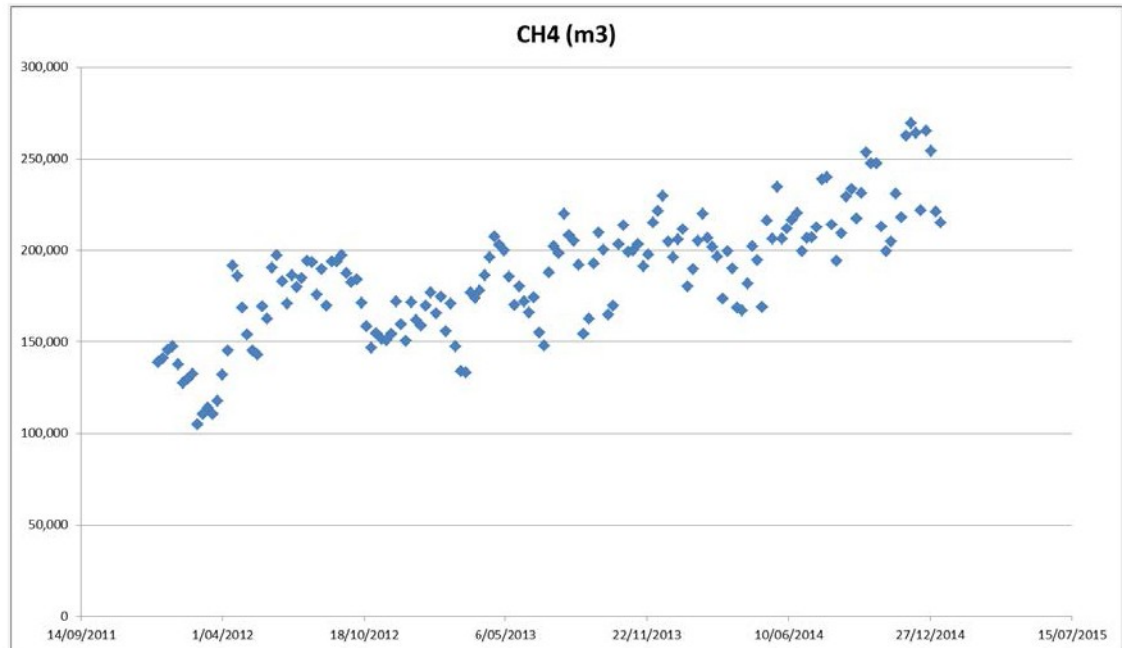
1. Disposal of construction and demolition (C&D) waste from Canberra Concrete Recycling (CCR) began in 2012.
2. Application of dolerite drainage began in 2011.
3. C&D fines began to be applied as cover in August 2012.
4. C&D was initially placed in a central location but elevated concentrations of H₂S were observed and so it was mixed with MSW. Elevated H₂S concentrations continued to occur.

The following summary of the information provided was used to develop the Sulphur balance presented in Chapter 4. It focuses on the biogas emissions from the landfill.

2.1 Gas Capture Rates

The methane capture rates are shown in **Figure 2-1** and observed H₂S concentrations in the gas stream at the power station are shown in **Figure 2-2**.

Figure 2-1 Methane Capture Rates - Woodlawn Bioreactor

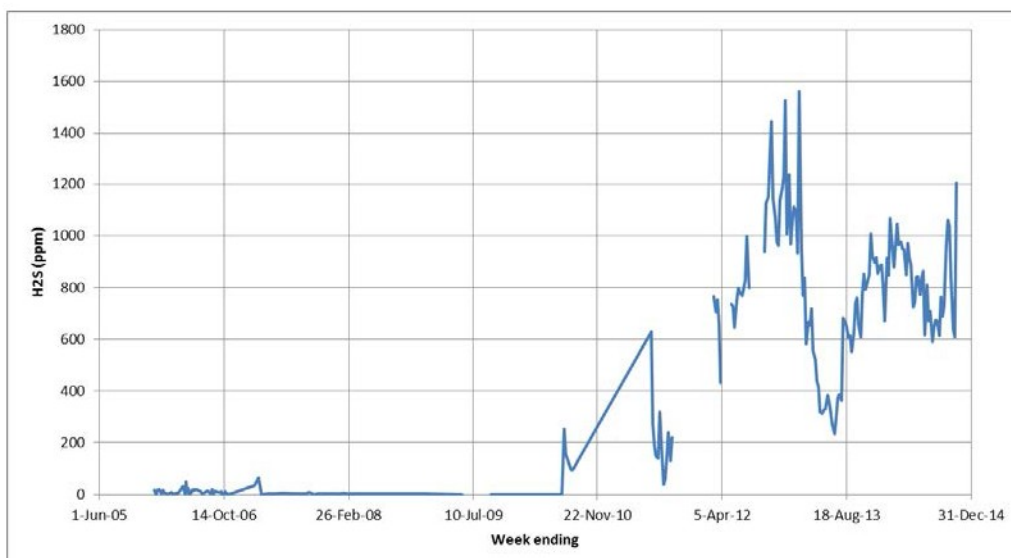


The data shows that the rate of gas production has been increasing steadily in line with the progressive filling of the void. It should be noted that as the void is being filled the surface area of the landfill has been increasing providing a greater area for surface emissions and requiring progressively larger areas requiring gas collection and cover. There appears to be some periodicity, highs and lows, possibly based on seasonal factors e.g. higher gas flows in summer and lower in winter.

Wastes delivered to site are likely to be at ambient temperature (or warmer in summer) and this could impact on rates of degradation and consequent landfill gas emissions. It may explain the periodicity in **Figure 2-1**.

2.2 Hydrogen Sulphide Concentrations in Gas Flow at Power Station

Figure 2-2 H₂S Concentrations Recorded at Power Station



The data demonstrates that compared to the period 2006 to 2009 there was a significant increase in sulphide concentrations in 2011 followed by periodicity (increases and decreases) through 2012 to 2014. The higher concentrations of H₂S in the landfill gas appear to be associated with the warmer summer months in 2013 and 2014. The data from 2010 to 2012 is based on Draeger tubes and samples taken for the gas line to the power station rather than the on line monitor. URS has been advised by Veolia that in late 2010 there was a significant “eruption” of leachate and gas, possibly due to the blocking of a gas blanket (at RL 650) and subsequent release. Veolia has commented that the wells in this area had high H₂S levels. This occurrence seems to broadly coincide with the increase in sulphide concentrations in the gas. Data provided later in the report for rainfall and the use of magnetite and hematite provides some analyses of the possible interactions (see **Section 5.1.4**).

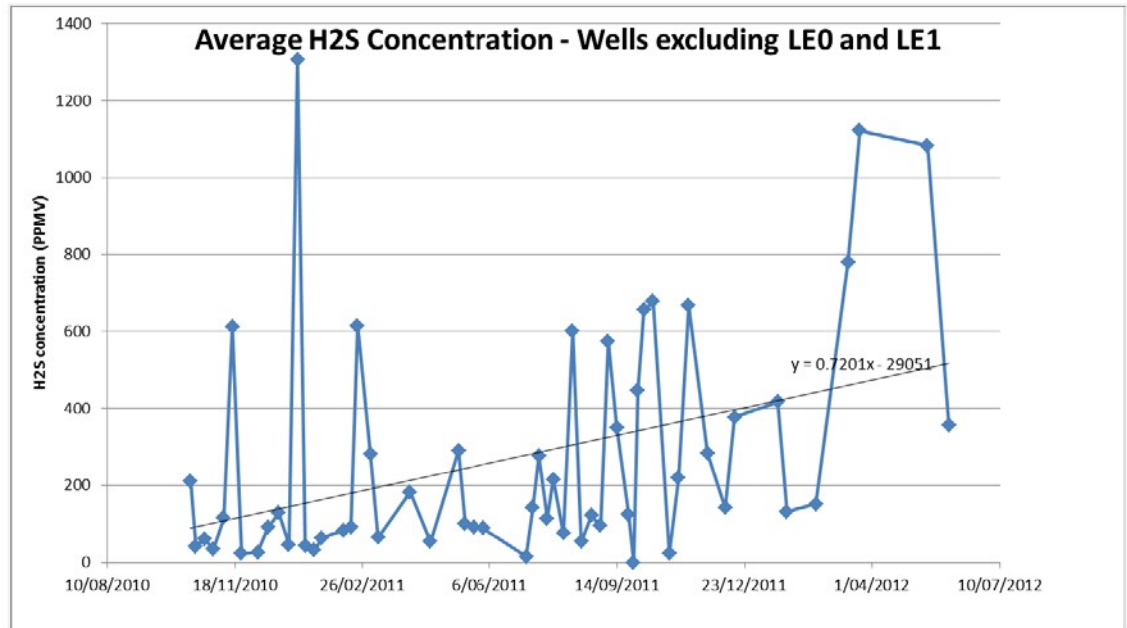
2.3 Gas Concentration in Wells

Given the absence of H₂S data on the gas fed to the power station (2009-2011), a review of the H₂S concentrations in the gas wells was conducted. The Bioreactor has a number of wells across the face from which gas samples have been taken. The Woodlawn data indicates that between October 2010 and May 2012, the average H₂S concentration in wells across the landfill was 300 ppmv, and the results were highly variable, as shown in **Figure 2-3**.

The highest average H₂S concentration was recorded in LE0 and LE1 (2,500 and 4,400 ppmv) which were located in the leachate sump on the eastern margin of the waste. These bores are in the area of the “eruption” that occurred in late 2010. Both of these bores have not been operational since October 2011.

The highest average concentration in the other wells was in LE63, which is located in the southwest area of the landfill. The average concentration at this site was found to be 2,000 ppmv H₂S. The results in **Figure 2-3** show high variability with increases and decreases in H₂S over 1-4 months periods. In this case the higher levels do not appear to be associated with the warmer months however these results are not flow weighted which may result in the data not being representative of the overall condition.

Figure 2-3 Average H2S Concentration in Wells



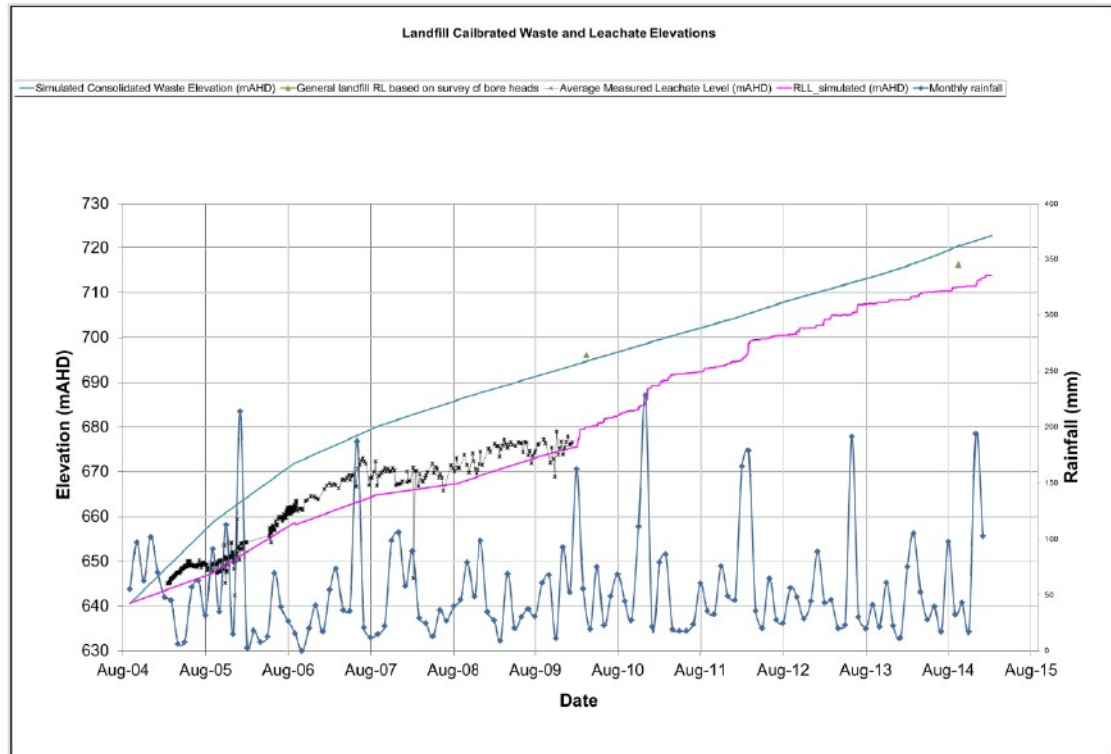
2.4

Moisture Levels

Leachate level in the waste has been simulated for a previous project and the results are presented in **Figure 2-4**. The plot also shows the simulated elevation of the waste mass as well as two points that represent averages of bore elevations in March 2010 and September 2014.

The plot shows that the average depth to leachate is 5 -10m below the surface of the waste. However it is understood that the recirculation of leachate over the freshly compacted waste occurs within weeks. On this basis the temperature effects noted previously could possibly occur within a few weeks. The data also shows that there are peak rainfall events (200 mm/month) occurring almost annually generally in January (2006, 2010,2011,2012, 2015) and occasionally July (2007, 2012). Rainfall of 200mm over the 10ha area generates approximately, 18 ML of infiltration assuming 90% infiltration. This provides for a significant saturation condition in cover material. The impact of rainfall on cover material effectiveness is discussed in **section 5.1.3** and **5.1.4**.

Figure 2-4 Leachate Levels - Woodlawn Bioreactor



2.5

Summary

The data on gas production and H₂S emission has been reviewed. Not all the data has been made available. The broad conclusions are:

- Collected landfill gas rates have been increasing as filling has continued
- The rates of gas production and H₂S concentrations show some seasonal impacts with higher rates in summer and lower in winter. This is most likely temperature related.
- The causes of increased sulphate levels in 2011 and onwards have not been identified; further discussion on sources of sulphur is provided in the next chapter.
- The area of the landfill has been progressively increasing and hence the surface emission rates are most likely increasing as well.

To assess whether cause-effect relationships can be developed for the H₂S emission rates and concentrations it would be necessary to:

- Define impacts of fines and C&D discharges ,
- Define impacts of hematite/ magnetite ,
- Develop a history of filling by location including the placement of fines, C&D and haematite/ magnetite, and
- Include the rate of increase in liquid level.
- Include rainfall impacts

This would take a significant amount of time and is beyond the scope/budget of this assessment.

3 SOURCES OF SULPHUR

The sources of sulphur related to inputs to the landfill are discussed in this section.

3.1 Municipal Solid Waste

Field measurements carried out by USEPA at five MSW landfills equipped with gas control systems (USEPA, 2007) are summarised in **Table 3-1**. These landfills are unlikely to be bioreactor type landfills given their age.

These numbers indicate that Woodlawn is producing at between 2 and 50 times the H₂S concentrations and hence significantly higher mass rates compared with other MSW sites in this study. Landfill B, with an equivalent waste mass and LFG extraction was found to have produced a fraction of the H₂S produced at Woodlawn.

Table 3-1 Comparison of LFG Measurements at 5 MSW Sites with Woodlawn

	LANDFILL A	LANDFILL B	LANDFILL C	LANDFILL D	LANDFILL E	WOODLAWN
Year landfilling began	1972	1967	1992	1991	1971	2004
Waste mass (t)	2,700,000	4,000,000	6,400,000	2,350,000	14,500,000	4,200,000
LFG extraction (m ³ /hour)	2,900	2,550	1,000	680	8,150	1,962
CH ₄ (%v/v)	48.8	39.2	56.0	58.6	49.5	56.6
H ₂ S (mg/m ³)	18.5	32.3	78.3	102.6	458	1,050
H ₂ S (ppmv)	13	22.9	55.5	72.7	322 (estimated)	741

(Source USEPA, 2007)

The USEPA compilation of air pollutant emission factors for MSW Landfills indicates an average H₂S concentration of 32 ppmv and a maximum recorded concentration of 330 ppmv (USEPA, 1998 and 2008).

3.2 Construction and Demolition Waste

The USEPA (2014) report quotes studies that indicate that passive vent wells at 10 C&D landfills showed highly variable concentrations of H₂S ranging from <0.03 ppmv to 12,000 ppmv. The USEPA Best Management Practices to Prevent and Control Hydrogen Sulphide and Reduced Sulphur Compound Emissions at Landfills that Dispose of Gypsum Drywall (USEPA, 2014) contains information on rates of H₂S emissions from C&D landfills and MSW landfills. The report attributes the generation of H₂S to the action of sulphate reducing bacteria (SRB) on gypsum from disposed plasterboard and based on stoichiometry one hundred tonnes of SO₄²⁻ have the potential to produce 35 tonnes of H₂S gas. The report concludes that gypsum is the significant source of H₂S in landfill gas. Plasterboard as either part of CCR fines or C&D waste is the source of gypsum at the Woodlawn facility.

3.3 Groundwater Inflow

Copper, lead and zinc sulphide mineralisation and the presence of significant pyritic material (FeS_2 and Fe_2S_3) has led to generation of acid drainage on the faces of the mine void when these minerals are exposed to the atmosphere and oxidised. Groundwater quality in MB16, adjacent to the waste rock dump, exhibited a sulphate concentration of 36,500 mg/L and a pH of 3.5 (Hancock et al, 2007). This is considered to be a worst case reading that would correlate with groundwater seeps that enter the void through the waste sulphide rock left in the void prior to landfilling.

Groundwater inflow to the mine pit has been estimated at around 1 L/sec and the water balance calculations carried out by URS in 2010 confirmed this as a reasonable approximation.

If it is assumed that a quarter of the pit wall is covered with sulphide-rich loose rock and the remainder is fresh rock, then the contributions to the sulphur load can be calculated as shown in **Table 3-2**.

Table 3-2 Sulphur Load from Groundwater Seepage

SEEPAGE INFLOW THROUGH SULPHIDE WASTE ROCK		SEEPAGE INFLOW THROUGH FRESH ROCK	
Flow	0.25 L/sec 21.6 m ³ /day	Flow	0.75 L/sec 64.8 m ³ /day
Sulphate	30,000 mg/L	Sulphate	2,200 mg/L
Sulphate load	648 kg/day	Sulphate load	143 kg/day
Sulphur load	216 kg/day	Sulphur load	48 kg/day
Duration of subject timeframe (Jun 2012 – Nov 2014) is 126 weeks or 883 days to align with the period from which C&D waste was deposited in the landfill.			
Therefore sulphur generated from groundwater inflow over the subject timeframe is 230 tonnes.			

Beyond the void, the background groundwater has a lower sulphate concentration. In monitoring wells that have been monitored since 2003 in some cases, the average sulphate concentration is 2,200 mg/L. The groundwater chemistry is presented in **Table 3-3**.

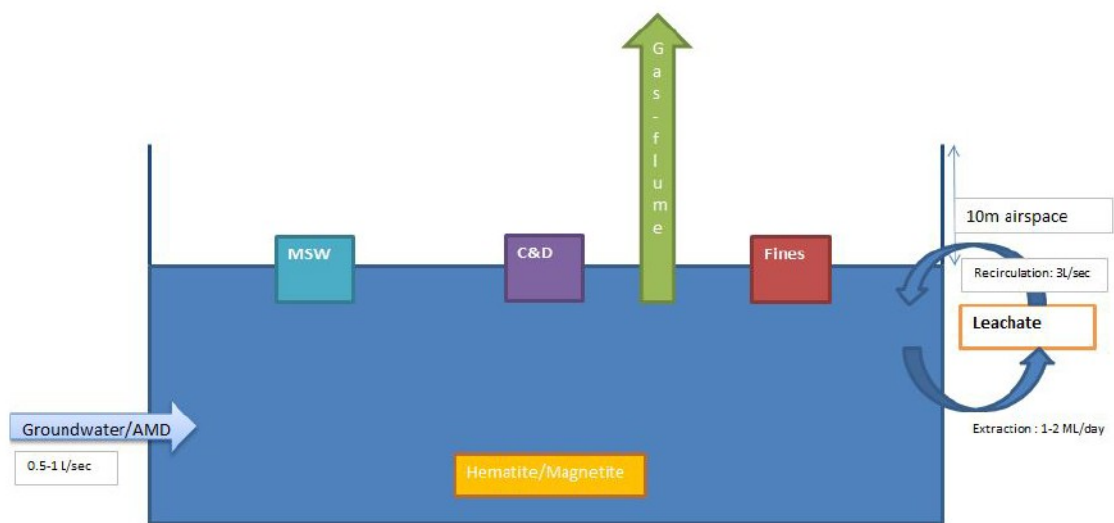
Table 3-3 Groundwater Chemistry

MW1 MW3 MW4 MW5 MW6 MW8S MW8D MW9S									
Bicarbonate	mg/L	204	<0.1	148	762	45	462	128	227
Carbonate	mg/L	0	<0.1	0	0	0	0	0	0
Alkalinity (as CaCO3)	mg/L	204	<1	628	762	46	462	128	227
Nitrogen (ammonia)	mg/L	0	2	0	0	0	0	0	0
Chloride	mg/L	185	64	46	2523	4838	3508	2063	2503
Conductivity	µS/cm	1912	3350	2059	6448	13238	12333	10367	10825
Dissolved Calcium	mg/L	226	210	210	89	103	267	347	355
Dissolved Magnesium	mg/L	104	215	33	269	432	927	1048	964
Dissolved Potassium	mg/L	5	12	2	2	3	5	6	3
Dissolved Sodium	mg/L	70	42	222	863	1845	1108	772	1135
pH	pH	7.2	4.2	6.7	7.4	6.3	6.8	6.2	6.7
Sulphate	mg/L	772	2600	984	159	370	2008	4018	6463
Total Dissolved Solids	mg/L	1650	4000	1548	4000	8570	9185	9030	9338

The sulphur balance has been carried out for the timeframe corresponding to the period from June 2012 to November 2014. Veolia (Ben Quill email of 17th Dec 2014) indicated that this is the period over which disposal of CCR fines and C&D waste was carried out. This period is equivalent to 126 weeks or 883 days.

The conceptual model for the sulphur balance is shown in **Figure 4-1**.

Figure 4-1 Conceptual Model of Sulphur Balance Components



Therefore the sources of sulphur that could contribute to the production of H_2S are: MSW, C&D waste, fines and groundwater inflows (seepage through waste rock and fresh rock i.e. acid mine drainage (AMD)).

Discharges of sulphur from the landfill are: collected landfill gas, surface emission from the landfill, and leachate.

These are discussed in more detail below.

4.1 Input Components of the Balance (sources of sulphur)

4.1.1 CCR Fines

CCR Fines material has been imported to the site for use as cover. The rate of disposal of fines was 674 t/week for the subject timeframe, this equates to a total mass of 85,000 tonnes of fines disposed in the landfill.

Analysis of the CCR fines cover material by Veolia indicated that the average total sulphur content is 13,167 mg/kg (October/ November 2014). Therefore over the subject timeframe the total sulphur mass disposed was 1,119 tonnes. The fines were used as cover and spread evenly across the landfill area of approximately 10 Ha. The total mass of fines would therefore have an even application rate of 0.85 t/m². If the fines have a density of 2 t/m³ then the total thickness of fines would be approximately 0.4m over the whole surface. The material has high pH. The high sulphate contents (compared to MSW) indicate contamination with plasterboard. The concrete itself would not have high sulphate levels.

On the basis that 100 tonnes of sulphate will produce 35 tonnes of H₂S, the sulphur balance suggests that the CCR fines have the potential to generate 1,200 tonnes of H₂S.

4.1.2 MSW

The average MSW waste disposal rate is 1,250 t/day, based on an annual rate of 460,000 t/year.

Data on sulphur content of conventional municipal solid waste is limited but some references suggest a sulphur concentration of 0.006-1.4 % wt/wt. of Sulphur in MSW (US Department of Energy, 2008).

In the most conservative case, where all of the sulphate converts to H₂S over time, and using an assumed sulphur concentration of 2000 mg/kg, the total sulphur mass in MSW over the subject timeframe is calculated to be 2226 tonnes.

The mass of sulphate within the waste mass will remain as a source of sulphur, although it will reduce to sulphides as the pH of the leachate increases and the sulphides are precipitated with various heavy metals in the leachate (Christensen et al, 1992).

4.1.3 C&D Waste

According to Veolia, over the subject timeframe a total of 22,300 tonnes of mixed C&D was disposed. The C&D waste was tipped into discrete stockpiles until Sep-Oct 2014 when C&D was integrated into main waste stream and disposed more evenly.

The USEPA (2014) report indicates that the C&D waste has about 10% plasterboard of which 90% is gypsum (CaSO₄). This equates to a concentration of 90,000 mg/kg of which sulphate is 63,500 mg/kg and sulphur is 21,350 mg/kg. Therefore the sulphur mass within the C&D waste in the landfill is calculated to be 472 tonnes.

4.1.4 Groundwater Inflow

Groundwater inflow to the pit is assumed to be 1 L/sec (see **section 3.3**). It is assumed that 25% of this inflow moves through the high sulphide rock in the pit and has an average sulphate concentration of 30,000 mg/L and 75% derives from groundwater flow through the host rock with an average sulphate concentration of 2,200 mg/L.

On the basis of these assumptions, sulphur contribution from groundwater inflow is calculated to be 230 tonnes over the subject timeframe.

4.2 Output Components of the Balance

4.2.1 Landfill Gas

There are two components to landfill gas, gas extracted and collected and surface emissions. Surface emissions have not been regularly monitored and the rate of emission has not been estimated or measured.

4.2.1.1 Gas Extraction (Power Station)

The average H₂S concentration for the gas stream as measured at the power station between June 2011 and November 2014 is 740 ppmv and the average gas extraction rate over that period was 1,962 m³/hour.

Converting the gas concentration in ppmv to mg/m³ is carried out using this equation:

$$\text{mg/m}^3 = (\text{ppmv}) \times 12.187 \times \text{MW} / (273.15 + ^\circ\text{C})$$

Where MW = molecular weight. For H₂S MW = 34.08 g/mol

Therefore, 740 ppmv of H₂S is equivalent to 1030 mg/m³ which equates to 2 kg/hour of sulphur.

Over the subject timeframe, the mass of sulphur extracted at the power station is therefore calculated to be 38 tonnes.

We have assumed that extracted gas includes flared gas. If this is not the case then it would be included in fugitive (surface) emissions estimates discussed in the next section..

4.2.1.2 Estimating Surface Emission Rates.

There are two components to landfill gas, gas extracted and collected and surface emissions. Surface emissions have not been regularly monitored and the rate of emission has not been estimated or measured.

In order to estimate the surface emissions (the difference between estimated gas production and the captured gas), two landfill gas production models were used: the NGERS model and the USEPA LandGem model. The outputs are compared in Table 4.1

The models, which predict different rates of gas production, differ by a factor of 2. The NGERS gas figure is more aligned with the measured gas collection rate and suggests a collection efficiency of 77% which seems reasonable.

The LandGem model predicts a much lower hydrogen sulphide emission rate than is measured in the landfill gas even with a greater landfill gas emission rate. This is because it uses a H₂S concentration of 36ppmv (similar to the USEPA figure). Comparing the estimated gas production rate and the measured production rate, the difference was assumed to be the non-collected gas i.e. the emissions from the landfill surface. Therefore the measured concentration of the landfill gas enables calculation of the surface emission flux rates.

The calculations based on the NGERS figures are used below. This information is discussed in the sections below.

Table 4-1 Comparison of LFG and Hydrogen Sulphide Emission Rates

	MEASURED	LANDGEM	NGER CALCULATOR
Daily gas Production(m ³ /d)	47,000	131,600	61,400
Daily gas Production(m ³ /hr)	1,962	5,480	2,560
Hydrogen Sulphide Concentration (ppmv)	740	36	not estimated
Gas Collection Efficiency (calculated based on measured gas)		35%	77%
Calculated Hydrogen Sulphide over the period(t)	38	5.6	not estimated in the model
Surface emissions at 741ppmv H ₂ S and estimated collection efficiency over the report period (t)	not estimated	73.8 (69.4 as S)	11.5 (10.8 as S)
Fugitive Emissions Flux Based on 10 ha(g/m ² /d)	not estimated	0.886	0.130

4.2.1.3 Surface Emissions

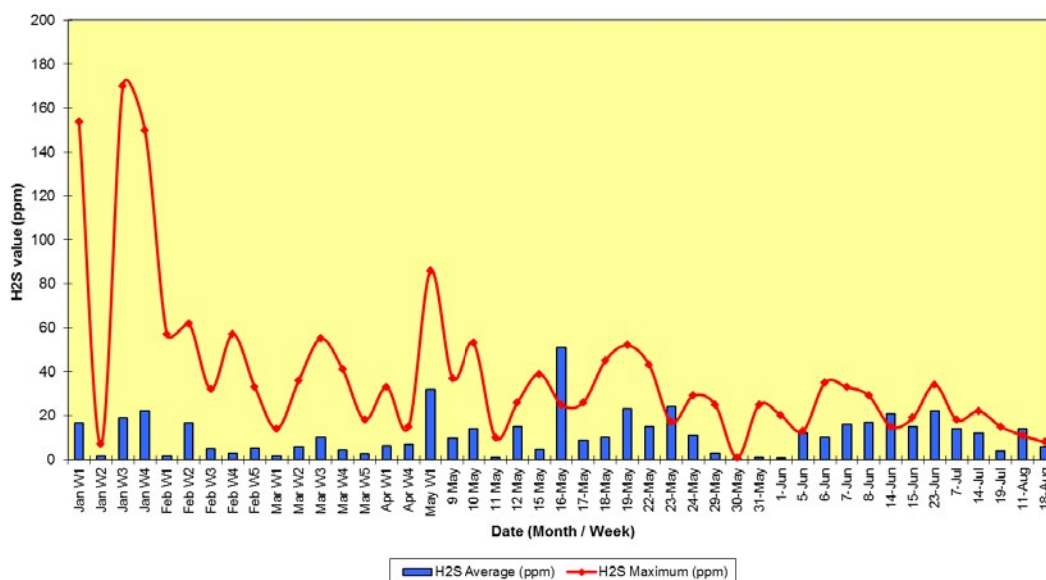
Monitoring was carried out at subsurface locations by Veolia in 2006. The results indicated an average H₂S concentration between January and August 2006 to be 11.5 ppmv, with a maximum recorded value of 170 ppmv recorded in January. The data are graphed in **Figure 4-2**.

Emissions of H₂S from the landfill surface are likely to be significant but there are no flux box results on which to base this estimate. Amini and Reinhart (2012) have carried out testing on MSW landfills and indicate a range of H₂S emission rates between 20 and 120 g/m²/day which are very high compared with another study by Eun et al (2007) which found H₂S flux rates of 0.192 to 1.76 mg/m²/day at a C&D landfills.

The estimated flux for the NGERS model presented in Table 4.1 is 0.130 g/m²/d and is toward the lower range of the fluxes quoted above. This figure is used in the balance below and is equivalent to 10.8t (as S) over the subject period.

Recently provided data indicated some surface measures ("top of void") in the range 0-550ppmv, with an average of approximately 300ppmv based on 77% gas collection efficiency. This is equivalent to 0.050 g/m²/d, less than the lower range discussed above.

Figure 4-2 H2S maximum and average weekly subsurface results 2006 (from Veolia, 2006)



4.2.2

Leachate Extraction

Leachate extraction is carried out at a rate of 1.5 ML/day. Most leachate is removed from the landfill but 3 L/sec is recirculated through the waste mass. Analysis of the leachate indicates three sulphur components:

Sulphate	40.4 mg/L
Sulphide	52.3 mg/L
Sulphite	154 mg/L

The total sulphur concentration is 127 mg/L as S; of this about 40% is sulphide.

These numbers contrast significantly with leachate monitoring carried out in the LE bores in 2006 where the average sulphur as sulphate concentration in the leachate was found to be 3000 mg/L which is 1000 mg/L sulphur.

The mass of sulphur exported with leachate from the landfill is therefore determined to be 140 tonnes over the subject timeframe.

4.3 Total Sulphur Balance

The total sulphur balance is presented in Error! Reference source not found..

COMPONENT	INFLOW (tonnes as S)	OUTFLOW (tonnes as S)
MSW	2,226	
CCR Fines	1,119	
C&D Waste	472	
Groundwater and AMD	230	
Gas Extraction (power station)		38
Surface emissions(Based on NGERS model)		10.8
Leachate Extraction		140
TOTAL	4,050	190

The balance indicates an accumulation of approximately 3800 tonnes of sulphur over the subject timeframe, and an increased sulphur mass in the landfill. This is confirmed by the observations in leachate wells and at the power station.

However in addition to the inflows and outflows there is sulphur stored in the MSW and leachate in the landfill.

Based on the stored volume of leachate of 2.8 Mm³ before June 2012 and a leachate concentration of 127 mg/L Total S, the mass of sulphur is 355 tonnes.

The balance demonstrates that there a significant store of sulphur in the MSW, based on the sulphate concentration of the waste mass. This has not mobilised in the landfill gas and is not reflected in the sulphur concentration in the leachate.

The question remains: why are there higher concentrations of H₂S in the Woodlawn landfill gas than the other landfills reported by USEPA? There are a number of potential causes:

1. *The operation of the landfill as a bioreactor*
 - The recirculation and flooding of the waste mass facilitates the enhanced rate of degradation, resulting in an increase in the rate of gas production. It could be expected that the rates of conversion of sulphur to H₂S could also be enhanced. One would expect that this could be commensurate.
2. *The forms of sulphur in the landfill are more readily available than in a traditional landfill*
 - Leachate recirculation in the bioreactor enhances the contact between leachate and CCR fines (and plaster sheeting).
 - The use of CCR fines with much smaller particle size as cover enhances the rate of degradation compared to plater board in C&D in sheets with paper cover.

5 SULPHIDE MANAGEMENT

5.1 Understanding Sulphur Sources and Interactions

As concluded in Section 4 the mass of sulphur ("sulphur store") in the landfill is significant and the quantities of sulphide emerging in the gas and sulphur compounds in the leachate are small relative to the sulphur store.

5.1.1 Availability of Sulphur

There are a number of potential causes either individually or in combination for the increased landfill gas sulphide concentration that appear to have started in mid-2011 but may have been earlier (see **Figure 2-2**).

In discussing the potential causes it is useful to discuss the potential sources of the hydrogen sulphide (through bacterial reduction of sulphur compounds). This is because the explanation may in part be in the availability of sulphur compounds for conversion to sulphide. The inputs are the MSW, groundwater and AMD, dolerite drains, CCR fines and C&D waste. Of these MSW and groundwater have been a "constant" over the life of the landfill while fines and C&D waste commenced in 2012, with dolerite drains in 2011. The relative bacterial availability of sulphate from the input elements is summarised as follows:

MSW-Dry (sulphur as organic S, sulphate and potentially other S compounds)	slowly available
MSW-wet (sulphur as organic S, sulphate and potentially other S compounds)	Less slowly available
Dolerite (sulphur bound as metal sulphate/sulphides)	very slowly available
Groundwater (dissolved sulphate after oxidation of pyrites)	readily available
C&D Wastes and CCR fines(Calcium Sulphate, high pH)	available

On this basis the (dissolved) sulphate from the AMD may be the most readily converted to H₂S. The CCR fines have smaller particle size and hence are more available than say C&D wastes and dolerite. The AMD and MSW inputs have been a constant over the life of the landfill. The wetting/flooding of the MSW results in an ever increasing mass of MSW with increased degradation rates and associated sulphide production.

5.1.2 Effect of pH

The higher the pH the greater the proportion of H₂S as dissolved sulphur compounds and not H₂S as dissolved gas. **Table 5-1** demonstrates that an increase in pH, from 7 to 8, reduces the proportion of H₂S by 41 %.

Table 5-1 Effect of pH on %H₂S as a dissolved gas in leachate

pH	%H ₂ S
6	90
7	50
7.5	24
8	9
8.5	3

During the initial stages of landfill development the acidogenic phase typically has a low pH and sulphide would mostly be as a dissolved gas. As the process stabilises in the methanogenic phase the pH is often in the 7-7.5 range with a much reduced fraction of sulphide as dissolved gas. The application of fines and C&D waste has had the impact of increasing the leachate pH and reducing the available H₂S as dissolved gas.

It would be useful to review the leachate pH, sulphur species concentration in the leachate and gaseous H₂S concentrations over say a 10 year period to identify any potential relationships.

5.1.3 The impact of the CCR fines and C&D waste whether wet or dry.

5.1.3.1 Dry

Once placed, the C&D waste and CCR fines having elevated pH should adsorb the gaseous phase H₂S as an acid. The fines would be much more effective than the C&D waste due to the smaller particle size and hence available area for reaction. The coating of plasterboard with paper will inhibit the adsorption for the C&D waste in particular. It is recognised that there is a small quantity of C&D waste compared to the CCR fines.

5.1.3.2 Wet

As part of the bioreactor operation, to enhance and increase degradation rates, the leachates are recirculated over the waste. This has the effect of wetting the fines and C&D waste and increasing the leachate pH.

There is published information supporting the enhanced sulphide emission rates from C&D wastes when they have been wet. Bergerson and Haarstad (2012) reported an increase of sulphide from 100 to 800 ppm for dry compared to wet plasterboard in landfill simulation columns.

It may be the case that because this is a bioreactor landfill the wetting of the plasterboard through leachate recirculation increases sulphate availability and rates of conversion to H₂S are enhanced. In addition the high rainfall events noted previously may have increased the sulphide production both from the CCR fines and the C&D waste.

The graph of leachate level and filled level (**Figure 2-4**). Indicates that there is a lag of about 2 years from filling to immersion. The large increases in H₂S emissions approximately coincide with use of C&D and CCR Fines, rather than lagging by 2 years. If immersion of C&D and Fines in leachate results in increased sulphides in the gas, the results in **Figure 2-3** would also indicate high concentrations of sulphides as early as the end of 2011. This does not appear to be the case; however the immersion of C&D and Fines could be a long term factor.

It is recommended that the data for H₂S in landfill wells be assessed for a longer period (pre 2010) to establish if there are any trends. The types of waste could also be reviewed to assess whether there were significant loads of C&D waste received that could provide an available sulphate store 2 years or more before the identification of increased landfill gas H₂S.

5.1.4 *Impacts of Heavy metals*

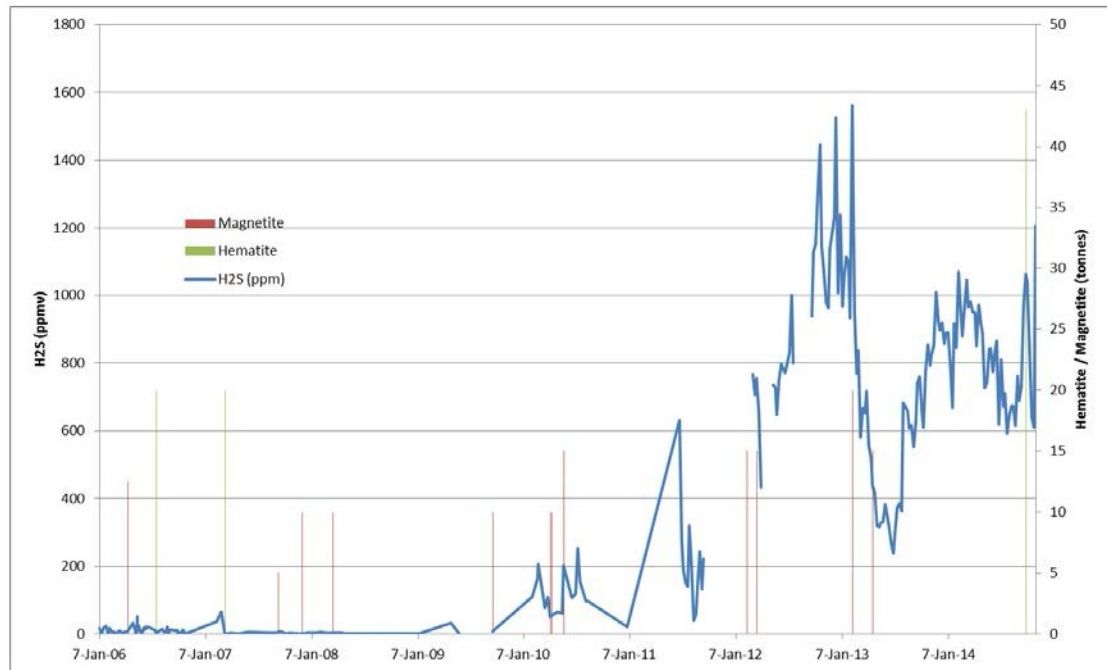
The MSW has a significant proportion of iron (750mg/kg according to US Department of Energy 2008). However on a stoichiometric basis this level of iron if it were to 100% precipitate sulphide would only remove about half its weight in sulphide (0.5 mg S /mg Fe) depending on whether it is Ferrous or Ferric Oxide (Fe₂O or Fe₂O₃). This is only a small proportion of the sulphur stored (375mgS /kg fixed compared to 2000mgS/kg in MSW). It is unlikely that all the iron would be available to precipitate as the sulphide.

Monitoring of groundwater inflows from the groundwater sump in 2005 indicated that the AMD waters had elevated iron concentrations (average 1150 mg/L) which are readily available to precipitate (refer **Table 5-2**). These could precipitate approximately 500 mg/L sulphide and hence could be significant. This however is insufficient to remove all the H₂S that could be generated from the sulphate in the AMD (670mg/L Sulphide based on 2000mg/L Sulphate).

It is recommended that data on heavy metals in the AMD be reviewed for the past 10 years to assess the sulphide removal capability.

The effectiveness of magnetite and hematite addition as cover material is illustrated in **Figure 5-1**. The capacity to adsorb is based on the mass of magnetite or haematite, its iron contribution, mass transfer rates and its stoichiometry. Published data indicates sulphide removal efficiency of 983 mg S /Kg of hematite (Bergersen, O. and Haarstad, K., 2008). This is much lower than stoichiometric based calculations. These will act slightly differently as the hematite is approximately 95% ferric oxide while the magnetite is 69.5% ferrous/ferric oxide. The hematite has a smaller particle size and would be more available

Figure 5-1 H₂S Concentration plotted against Hematite and Magnetite Application



We have assumed that the purchase date corresponds with the date the material was applied. The use of the iron in 2006-2008 appears to coincide with low sulphur emission and similarly iron application in May 2012 and May 2013 coincides with relatively low H₂S content. As noted previously there may also be a seasonality factor with higher H₂S in summer and lower in winter. Peak rainfall events in January 2012 July 2013 may have impacted on the effectiveness of the magnetite due to saturation. As discussed previously there may be a leachate immersion impact, which reduces the effectiveness of the iron materials due to lower mass transfer rates. . When the iron materials are dry they will be more reactive with the H₂S gas. Once the iron material has been flooded the pH is more neutral, the mass transfer rates may be much slower with associated over all lower reductions. This effect could be assessed in laboratory columns.

Table 5-2 AMD Chemistry in Sump (2005)

SAMPLE ID	SAMPLE_DATE	TDS	Na	K	Mg	Ca	NH4	Fe	Cl	SO4	HCO3	CO3
GW_2005-04-15	15/04/2005	32300	477	190	2210	574	94.4	1160	189	11700	1.22	0.6
GW_2005-08-01	1/08/2005	25400	452	291	1260	496	309	897	524	13000	1.22	0.6
GW_2005-08-04	4/08/2005	25800	450	284	1260	523	274	1250	598	13400	1.22	0.6
GW_2005-08-11	11/08/2005	25300	533	361	1140	500	193	1240	467	29800	1.22	0.6
GW_2005-08-15	15/08/2005	25500	1110	372	1370	528	335	1290	458	29800	1.22	0.6
GW_2005-08-19	19/08/2005	25100	233	355	497	161	335	1220	630	32800	1.22	0.6
GW_2005-08-24	24/08/2005	22300	554	395	1250	606	477	1160	861	11800	1.22	0.6
GW_2005-08-25	25/08/2005	23400	618	422	1190	638	363	990	719	19500	378.2	0.6
Average		25638	553	334	1272	503	298	1151	556	20225	48	1

5.2 The Need for Treatment

The sulphur balance shows that the CCR fines and the MSW are by far the largest source of sulphur which most likely contributes to generation of H₂S. The use of the fines as cover since June 2012 appears to have had a significant impact on generation of the gas, as **Figure 2-2** shows. The removal of CCR fines from the waste stream will remove a significant source of available sulphur and we recommend that this practice be stopped.

The cessation of disposal of CCR fines, however, will not address the issue of stored sulphur now in the landfill; which will continue to be emitted as H₂S.

There already is a significant store of sulphur in the landfill and it will continue to be operated as a bioreactor. Therefore to control/reduce the sulphide emissions it will be necessary to address the two emission pathways: via the surface and in the collected landfill gas. Both of these require some type of treatment to remove the sulphide.

The landfill gas flow can be treated with:

- Pre-treatment before the power station engines (e.g. Alkaline scrubbers); or
- Oxidation in the power station engines and or flare.(current operations)

If the corrosion of the landfill gas engines is an issue then alkaline scrubbers could be incorporated into the gas train if cost effective i.e. the scrubbing costs are less than the engine maintenance costs.

For the fugitive surface emissions from the landfill it will be necessary to provide in situ treatment or surface treatment. These are discussed in the next section.

5.3 Treatment Options

An effective way to manage the surface fugitive emissions of H₂S issue is through application of cover amendments that reduce the concentration through precipitation, adsorption or oxidation. These options are summarised in **Table 5-3**.

Table 5-3 H₂S Treatment Options

PROCESS	OPTIONS
Precipitation	Precipitation treatment can be effected using ion salts – ferric sulphate or ferric chloride.
	Ferric sulphate $\text{Fe}_2(\text{SO}_4)_3 + 3\text{H}_2\text{S} \leftrightarrow \text{Fe}_2\text{S}_3(\text{s}) + 3\text{H}_2\text{SO}_4$
	Ferric Chloride $2\text{FeCl}_3 + 3\text{H}_2\text{S} \leftrightarrow \text{Fe}_2\text{S}_3(\text{s}) + 6\text{HCl}$
	The use of ferric ions is efficient in that one mole of Fe ³⁺ (approx. 55 gm) precipitates 1.5 moles of H ₂ S (approx. 51 gm)

PROCESS	OPTIONS
Adsorption	<p>Control of the H₂S in the gas can be achieved by pH control – through adding a buffering agent to the fill to either maintain alkaline conditions (pH>9) or acidic conditions (pH<6). Contamination potential is increased under acidic conditions so alkaline buffering is preferred.</p> <p>Agents that may be used to increase the pH and facilitate adsorption include concrete fines (low sulphate), lime amended sandy soils, red muds or compost.</p>
	<p>Limestone (CaCO₃) and Lime</p> <p>Limestone acts as a sorbent for H₂S. Lime amended sandy soil, with a proportion of 1 – 3% lime – soil mixture has been found to be an effective control on C&D landfill surface (Xu et al, 2010).</p>
	<p>Coal ash</p> <p>This has been reported when mixed with recycled screen material (from a C&D waste recovery system) to have reduce the H₂S concentrations by an order of magnitude.</p> <p>Coal ash has a significant adsorptive capacity for H₂S (1 to 3% by mass)</p>
	<p>Red Mud</p> <p>Red muds are a waste material generated through aluminium hydroxide production from bauxite ore. Red muds are highly alkaline and contain high concentrations of Fe₂O₃ and CaO, both of which are beneficial in sequestering H₂S.</p>
	<p>Compost</p> <p>Compost has significant capacity to attenuate H₂S through adsorption and fixation by bacteria. However this is an aerobic process rather than an anaerobic process. Therefore the spreading of shallow layers of compost (say up to 0.5m) that would remain aerobic would reduce sulphide emission rates significantly. In aerobic soil/compost systems greater than 90% removal has been reported. However once these become anaerobic e.g. through covering by waste or immersion in leachate, sulphide fixation will cease.</p>
	<p>A number of treatments are possible using iron oxides to facilitate reaction with H₂S and conversion to iron sulphide and adsorption. The most practical methods involve the application of powdered iron oxides in the cover material. Hematite and magnetite have been employed at Woodlawn in the past, with 248 tonnes of magnetite and 430 tonnes of hematite being applied since 2005.</p> <p>Hematite (Fe₂O₃)</p> $\text{Fe}^{2+} + \text{H}_2\text{S} \rightarrow \text{FeS} + 2\text{H}^+$ <p>Magnetite (Fe₃O₄)</p> $\text{Fe}^{3+} + 2\text{H}_2\text{S} \rightarrow \text{FeS}_2 + 2\text{H}^+ + \text{H}_2\text{O}$

An assessment of the efficacy of the various treatment options is provided in **Table 5-3**.

Table 5-3 Cover Options for H₂S Removal

	HEMATITE (Fe ₂ O ₃)	MAGNETITE (Fe ₃ O ₄)	LIMESTONE/LIME	CONCRETE FINES (NO PLASTERBOARD)	COAL ASH / IRON OXIDE (3:1)	COMPOST (WOOD CHIPS)	RED MUD
Removal Efficiency	983 mg S/kg (Bergensen and Haarstad, 2008)		Ionisation of H ₂ S depends on pH. At pH 9 less than 1% of the sulphide is H ₂ S, at pH 7 48% is H ₂ S and at pH 6 90% is H ₂ S	90 – 99% (Plaza et al, 2007) removal efficiency for sandy soil amended with lime and fine concrete sand	3345 mg S/kg	387 mg S/kg (Bergensen and Haarstad, 2008) 99% removal	No data available
Logistics / Cost	Magnetite is a cheaper option available in NSW	Tallawang Superfine \$300/tonne delivered (min 30t)	Suppliers; West Lime, Sibelco and Boral. \$85/tonne for 100t delivered – (Westlime) \$30/t 1mm Aglime from Sibelco Galong – for pickup	If plasterboard can be removed from waste stream then CCR may be a good option	Has Veolia access to coal ash?	Localised application in high H ₂ S areas possible, but needs to be aerobic. The development of a compost facility on site could provide material. The price of compost is approximately \$3/T.	Transport from WA, NT or Queensland is expensive but red mud is a significant waste disposal problem for aluminium refineries

Note – costs do not include GST

6 CONCLUSIONS

6.1 Sulphur Balance

The sulphur balance is summarised in **Table 6-1**.

Table 6-1 Sulphur Balance - Woodlawn Bioreactor (June 2012 - November 2014)

COMPONENT	INFLOW (tonnes as S)	OUTFLOW (tonnes as S)
MSW	2,226	
CCR Fines	1,119	
C&D Waste	472	
Groundwater and AMD	230	
Gas Extraction (power station)		38
Surface emissions(Based on NGERS model)		10.8
Leachate Extraction		140
TOTAL	4,050	190

The balance indicates a surplus of 3800 tonnes of sulphur over the subject timeframe, which indicates an accumulation of sulphur and an increase in the sulphur mass in the landfill. This is confirmed by the observations in leachate wells and at the power station.

6.2 Impacts on Landfill Gas H₂S emission rates

The Woodlawn H₂S landfill gas concentration, at 741ppmv (average), is significantly higher than those typically reported (e.g. 36ppmv). This confirms what is already known that there appears to be either a range of conditions and or available source(s) of sulphur that cause the elevated sulphide emission rates. In terms of the increased H₂S since 2011, this is most likely due to the sulphate in the CCR fines.

While this review has taken a “big picture” approach it is recognised that there may be significant variability in fugitive emission rates (and H₂S concentrations) across the landfill surface. This could be due to a range of factors including the age of material, the location of fines, C&D wastes and magnetite/haematite, blockages in pipework, gas flow paths and application of leachate recirculation.

The sulphur balance demonstrates that there are large quantities of sulphur stored in the landfill that can contribute to H₂S emissions into the future. Elevating the pH of the leachate limits the quantities of H₂S as a dissolved gas. The use of CCR fines has elevated the pH however the high sulphate component due to plasterboard is counterproductive. The continued use of concrete fines is recommended only if plasterboard is not a contaminant. Otherwise it is recommended that the use cease and a continuing review of the leachate pH be conducted to observe any potential impacts such as pH reduction and H₂S landfill gas content increasing.

It is also recognised that the impact of the use of materials such as magnetite/hematite, compost, fines, etc., is likely to vary depending on whether it is in a “dry” state (e.g. above the leachate level in the landfill), saturated by rainfall or immersed (below the leachate level in the landfill).

For example, the magnetite/hematite in the dry state should be very effective in removing H₂S in the gas but may be less effective when immersed due to lower mass transfer rates and neutral conditions. On a stoichiometric basis iron only adsorbs/ removes approximately 35-25 of its mass as sulphide; however published results indicate a much lower adsorption rate (around 1 g/kg).

Compost is a cheaper source of material. It can be used in the dry state as long as it remains aerobic. This can be achieved through the use of shallow layers e.g. 0.5m. The optimal depth could be developed by trial and error using flux hoods to measure emission rates for various depths.

6.3 Management Options

As there is already a significant store of sulphur in the landfill and that it will continued to be operated as bioreactor, to control/reduce the sulphide in the landfill gas will require management i.e. treatment.

Collected Landfill gas

The gas flow can be treated with:

- Pre-treatment before the power station engines (e.g. Alkaline scrubbers, activated carbon, etc.); or
- Oxidation in the power station engines and or flare (current operations).

Pre-treatment should be considered if the costs of scrubbing are less than the maintenance costs of the gas fired engines due to moisture, pH and sulphide related maintenance costs.

Increasing the Gas Collection systems

Increasing the effectiveness of gas collection will reduce the fugitive emissions and hence impact (e.g. odour).

Insitu/Surface treatments for surface emission (fugitive emissions)

The following ongoing treatment options are available:

- Magnetite/hematite: this should be effective in the dry phase with less impact in the immersed phase. The quantities required are very large from a stoichiometric basis. However if flux hood tests indicated specific areas of very high sulphide, magnetite/haematite could be used in the dry to address that area.
- Compost: This can be effective in the dry due to bacteria adsorbing the sulphur when aerobic. When the compost is immersed it is unlikely whether the process would continue, if it does it is likely to be at a lower rate. The use of compost on a trial basis could be implemented with associated monitoring.

- Coal Ash: Coal Ash (mixed with CCR fines or magnetite/haematite) could be trialled in a similar manner to magnetite/haematite as indicated above.
- Low sulphur concrete fines: These should be effective in elevating leachate pH and reducing the concentration of H₂S as a dissolved gas, and adsorbing H₂S in the dry phase particularly.
- Leachate recirculation: the sulphur balance indicates that the removal of leachate (to the Evaporation ponds) removes significant quantities of sulphur from the system. The balance indicates that more is removed with leachate than in the collected landfill gas. However this has been a constant over the years, although the rates and composition have not been reviewed.

Overall, due to the multi-faceted aspect of the issue and lack of assessed detailed information over time, it is recommended that the compost option be implemented with associated monitoring.

Low sulphate concrete fines could be used to manage leachate for the elevation of pH (both in the wet and dry) and adsorptive capacity (mostly in the dry).

6.4 Further Assessment

In order to better understand some of the processes and potential interrelationships, the following further data collection and assessment is recommended.

It is recommended that flux hood tests be conducted to estimate the fugitive emission rates of methane, carbon dioxide and H₂S in order to confirm or revise the estimates provided herein. In addition areas emitting high gas rates and or high H₂S concentrations should be identified.

It is recommended that the data for H₂S in landfill wells be assessed for a longer period (pre 2010) to establish if there are any trends relative to local landfill history. The types of waste could also be reviewed to assess whether there were significant loads of C&D waste received that could provide an available sulphate store 2 years or more before the identification of increased landfill gas H₂S.

It is recommended that data on heavy metals in the AMD be reviewed for the past 10 years to assess the sulphide removal capability through heavy metals.

When the iron materials are dry they will be more reactive with the H₂S gas. Once the iron material has been flooded the pH is more neutral and the mass transfer rates may be much slower with associated overall lower reductions. This effect could be assessed in laboratory columns.

It would be useful to review the leachate pH, sulphur species concentration in the leachate and gaseous H₂S concentrations over say a 10 year period to identify any potential relationships.

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GAS SPECIATION ANALYSIS LABORATORY REPORT:

8 OCTOBER 2015

ANALYTICAL REPORT

Customer: The Odour Unit Pty Ltd

Attention: Michael Assal, James Schulz

Your Reference: Investigation of landfill gases

SGS Report Number: ENV 22966A

Date of Receipt of Samples: 9th October, 2015

The work has been carried out in accordance with your instructions. The results and associated information are contained in the following pages of the report. Should you have any queries regarding this report please contact the undersigned.

Reported by: Dr David Stone

Report authorised by: Dr Paul Pui

A handwritten signature in black ink, appearing to read 'D Stone'.A handwritten signature in blue ink, appearing to read 'Pui'.

Date: ____15/10/2015____

Date: ____20/10/2015____

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1. Background

Two samples of process gas (in 20-litre Nalothane gas sample bags) were delivered to SGS by TOU. The list of samples appears below. The scope of this investigation is to determine the fixed gases composition, plus concentrations of VOCs, siloxane compounds and H₂S and the nature of any other sulphur-containing gases, common hydrocarbons and major hydrocarbons in the landfill gas.

2.1 Sample description

Sample	Description	Material Type
1	#22 LE 57 (landfill gas)	landfill gas
2	#23 Inlet to Power Station (landfill gas)	landfill gas

2.2 Sample preparation prior to analysis:

No preparation was required, the gases are sampled directly. Blank analyses were run between samples to avoid any possibility of contamination from one sample to affect the result for another.

For volatile organic compounds, and siloxanes the process gases were trapped onto a clean thermal desorption tube using a gas syringe, and thermally desorbed, using method US EPA TO-17.

For sulphur gases, 250 micro-litre of gas was sampled directly to a GC-SCD using a gas-tight syringe. For methane and hydrocarbons from C₂ – C₈ 250 microlitre of gas was sampled directly to a GC-FID using a sample loop. One of the samples was analysed in duplicate.

Fixed (major) gases were determined by GC-TCD, using a 550 micro-litre loop injection.

3. Preliminary laboratory examinations

Because of the reactive nature of the samples, the samples were analysed for all analytes including Volatile Organic Compounds (VOCs) within 24 hours of arrival.

4. Analytical Spectroscopic Results

4.1 Table 1. GC-TCD examination of landfill gases

analyte	LE 57	Inlet to Power Station
	Concentration (%)	
methane	13.8	50.7
carbon dioxide	12.9	47.2
oxygen	15.5	0.43
nitrogen	57.8	1.62
carbon monoxide	<0.01	<0.01
hydrogen	<0.001	<0.001
argon	0.07	0.03

4.2 Table 2. GC-SCD examination of landfill gases

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analyte	LE 57	Inlet to Power Station
	Concentration (ppm)	
hydrogen sulphide	705	625
carbonyl sulphide	0.05	0.05
methyl mercaptan	2.95	2.73
ethyl mercaptan	0.3	0.3
i-propyl mercaptan	1.60	1.55
propyl mercaptan	0.49	0.48
dimethyl sulphide	3.23	3.11
dimethyl disulphide	0.25	0.22
2-buthylmercaptan	5.03	4.86
carbon disulphide	0.48	0.46

4.3 Table 3. GC-MS examination of landfill gases

analyte	LE 57	Inlet to Power Station
	Concentration (ppm)	
acetone	15.2	14.3
2-butanone	29.2	28.4
ethanol	65.1	55.7
i-propanol	11.8	9.7
cis-1,2-dichloroethene	2.1	1.9
trichloroethene	0.21	0.20
hexane	1.8	1.6
heptane	3.2	2.8
benzene	1.5	1.4
toluene	13.6	13.2
ethylbenzene	4.5	4.4
m,p-xylenes	4.7	4.5
o-xylene	3.8	3.7
styrene	0.52	0.48
1-methyl-4-ethylbenzene	1.3	1.2
1,3,5-trimethylbenzene	0.54	0.54
1,2,3-trimethylbenzene	1.2	1.1
alpha pinene	2.55	2.40
beta pinene	1.15	1.10
camphene	0.08	0.07
limonene	16.8	15.6
SILOXANES	Concentration (ppm)	
hexamethyl cyclotrisiloxane	0.065	0.062
octamethyl cyclotetrasiloxane	0.63	0.60
decamethyl cyclopentasiloxane	0.47	0.45
dodecamethyl cyclohexasiloxane	0.0062	0.0060
tetradecamethyl cycloheptasiloxane	<0.0003	<0.0003
hexadecamethyl cyclooctasiloxane	<0.0003	<0.0003



EVAPORATION DATA SUPPLIED BY VEOLIA:

MAY 2007 TO JUNE 2012

Evaporation	2006								2006				2007					
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	5.60	6.80	5.00	3.00	1.50	1.41
2	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	2.20	2.60	4.80	3.60	2.40	1.04
3	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	2.60	5.00	3.80	3.80	3.19	1.16
4	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	5.00	6.40	7.60	2.80	4.52	1.30
5	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	6.80	7.40	6.60	3.00	2.68	0.69
6	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	7.20	8.20	3.60	4.60	2.52	1.00
7	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	8.60	7.00	5.00	2.40	2.43	0.67
8	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	5.80	4.60	3.60	1.40	1.87	0.83
9	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	6.60	6.80	5.00	2.40	1.37	0.48
10	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	7.40	5.20	4.80	2.00	1.41	0.73
11	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	8.60	3.60	5.40	3.20	1.48	1.24
12	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	11.40	2.20	7.00	3.60	1.74	0.77
13	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	13.40	3.80	3.60	2.60	2.19	1.23
14	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	8.40	4.40	2.80	3.00	1.51	1.02
15	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	7.80	5.80	4.80	3.60	2.03	0.43
16	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	8.40	6.20	6.20	4.00	2.09	0.64
17	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	8.80	3.80	4.60	2.80	1.47	0.84
18	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	7.20	5.60	2.40	3.40	1.49	0.75
19	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	6.00	1.60	2.00	3.80	0.72	0.63
20	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	7.60	3.60	0.20	2.20	1.53	0.43
21	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	11.00	6.80	2.20	2.60	2.14	1.13
22	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	8.40	7.40	3.40	2.60	2.21	1.12
23	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	7.60	5.60	4.40	2.60	1.69	1.35
24	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	9.40	5.20	4.80	1.80	1.59	1.11
25	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	7.20	4.60	4.00	0.60	1.81	1.16
26	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	8.00	4.20	2.60	1.20	1.75	0.57
27	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	12.40	3.60	2.80	2.40	1.56	0.27
28	6.40	5.40	4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	10.60	3.00	2.80	1.40	2.20	0.42
29	8.20		4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	8.80		4.20	1.40	1.75	0.79
30	8.20		4.10	2.60	1.70	1.10	1.20	1.90	2.80	3.90	5.00	6.20	8.00		3.00	1.80	2.65	1.27
31	8.20		4.10		1.70		1.20	1.90		3.90		6.20	10.00		3.40		1.24	
Total Month	203.8	151.2	127.1	78	52.7	33	37.2	58.9	84	120.9	150	192.2	246.8	141	126.4	79.6	60.68	26.47
Accumulated Year	204	355	482.1	560.1	612.8	645.8	683	741.9	825.9	946.8	1096.8	1289	246.8	387.8	514.2	593.8	654.48	681

Evaporation data recorded from the Goulburn Tafe W

						2008												2009	
Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1.21	1.13	4.17	4.49	2.73	2.82	7.058	4.079	4.42	3.876	2.082	1.889	2.563	2.158	1.339	3.822	8.25	5.487	6.915	7.353
0.82	1.27	2.87	5.04	4.66	2.286	7.126	2.908	4.566	3.485	1.918	0.485	1.146	0.953	2.667	4.838	2.408	7.579	8.11	6.754
1.21	2.29	3.26	5.41	4.31	5.675	7.446	4.000	4.257	5.316	1.977	0.828	1.139	1.469	2.828	6.486	3.711	6.729	6.339	6.712
1.75	0.94	2.94	8.39	1.49	4.147	2.006	4.788	4.536	2.663	2.314	0.46	1.32	1.967	1.616	6.588	3.963	6.955	5.254	5.055
1.18	1.59	2.46	5.05	3.30	4.956	7.4	1.496	4.274	3.13	2.225	0.771	0.847	1.659	1.006	1.318	5.035	5.046	6.369	4.618
0.72	1.67	1.44	5.48	2.40	1.109	6.6	1.512	4.457	3.239	2.423	0.76	1.387	1.263	1.288	2.328	3.928	5.442	8.86	6.982
1.06	1.65	1.87	5.68	4.5	4.2	6.883	4.498	5.111	2.656	2.177	1.026	1.22	1.656	1.162	3.205	6.31	7.507	8.46	7.344
1.02	1.71	1.38	3.90	2.097	3.395	6.251	3.381	3.829	2.231	2.323	1.351	1.312	1.147	2.65	3.387	3.199	6.765	8.21	8.81
0.70	2.11	1.61	3.89	2.106	4.31	6.6	2.689	4.053	1.712	2.209	0.5	1.227	1.663	2.508	4.196	3.801	6.172	3.146	8.3
0.90	2.39	2.04	3.91	2.929	6.974	5.175	2.861	4.623	1.81	2.056	1.211	0.51	1.35	3.038	4.017	5.71	6.895	4.802	2.73
1.19	3.15	2.55	4.12	4.648	3.645	6.945	4.415	4.768	2.685	2.026	0.588	0.875	0.664	2.896	4.264	5.541	3.662	4.78	1.038
1.44	3.09	1.69	4.89	5.543	1.426	7.747	4.853	4.954	3.052	1.296	0.865	1.079	1.452	3.56	3.963	5.464	1.874	4.981	4.292
1.09	2.27	2.29	3.87	5.421	5.00	5.179	3	4.862	2.614	1.532	1.672	1.215	1.511	4.341	4.769	6.244	0.951	4.415	1.801
1.02	1.69	3.53	4.15	6.033	4.40	7.447	1.161	4.992	2.11	1.757	1.089	1.621	1.801	5.149	4.463	6.274	4.303	6.69	3.05
0.86	1.02	4.08	4.78	6.794	5.362	1.344	3.54	4.861	2.854	1.874	1.572	2.064	1.693	2.177	1.793	6.243	3.726	9	2.4
1.06	1.08	3.46	6.31	6.455	5.385	6.369	5.299	5.892	2.901	1.997	1.141	1.281	1.726	4.05	3.63	6.192	5.567	9.69	2.225
1.04	1.87	3.82	7.67	5.901	0.933	4.194	5.042	4.894	2.611	1.468	0.794	1.247	1.834	2.663	4.097	4.685	6.225	7.435	3.11
1.34	0.82	2.25	4.52	6.297	4.659	4.4	4.186	4.841	1.902	1.245	1.042	1.28	2.186	2.098	4.755	5.378	3.919	6.079	2.313
1.30	0.95	3.21	4.95	5.31	4.40	2.054	4.73	5.056	2.09	1.432	1.056	1.051	1.361	3.326	4.845	3.55	4.689	6.418	3.187
1.52	0.78	4.30	5.30	6.444	2.116	1.72	4.48	2.672	1.27	1.881	0.842	1.652	2.009	4.809	5.672	2.603	5.48	7.43	5.529
1.49	0.94	1.92	5.45	6.425	1.79	3.779	5.237	4.843	1.596	1.602	0.297	1.258	2.209	5.661	4.572	3.418	4.656	7.28	3.265
1.15	1.14	3.13	7.20	6.425	5.306	2.357	2.445	1.335	2.494	1.74	1.192	1.394	2.44	4.423	3.561	5.702	5.765	7.637	4.303
0.78	0.88	3.23	6.92	0.573	2.921	4.681	5.397	1.763	1.229	1.673	1.271	1.551	1.138	4.422	3.28	2.389	6.683	5.991	3.535
1.51	1.16	3.62	4.15	1.268	4.309	5.547	6.058	3.212	2.211	1.193	1.118	1.17	1.594	2.527	3.602	2.16	3.337	6.481	4.391
1.60	1.70	4.87	1.97	2.786	4.859	6.208	5.649	1.777	1.685	1.456	1.126	1.146	2.284	2.461	4.178	5.332	1.37	7.481	6.763
1.99	2.03	4.68	1.29	5.691	5.20	4.636	4.078	0.872	1.569	1.499	1.623	1.547	2.553	3.68	5.96	4.286	6.181	4.449	5.653
1.86	2.98	3.07	2.36	4.37	6.216	6.022	5.26	2.734	3.338	1.253	1.242	1.2	2.669	4.221	5.949	3.299	7.006	6.364	5.124
1.30	3.73	3.92	4.32	6.6	3.844	6.413	3.85	3.058	2.642	1.484	1.607	0.866	2.212	5.675	8	5.683	4.365	4.688	4.802
1.73	4.86	5.73	4.75	5.35	6.515	5.972	0.894	2.139	1.338	1.37	1.198	1.235	1.744	6.15	5.297	3.178	5.461	6.868	
1.18	3.51	3.62	5.87	3.106	6.941	6.752		3.646	2.208	1.425	1.927	1.503	1.283	3.495	1.819	5.458	7.121	7.29	
1.56	3.98		5.56		7.736	6.868		3.861		1.726		1.703	2.13		5.019		6.405	7.182	
38.56	60.372	92.97	151.606	131.946	132.835	169.179	111.786	121.158	74.517	54.633	32.543	40.609	53.778	97.886	133.673	139.394	163.323	205.09	131.44
719.5	779.88	872.8	1024.45	1156.4	1289.23	169	280.965	402.123	476.64	531.273	563.816	604.425	658.203	756.089	889.762	1029.16	1192.48	205	336.533

Weather Station

										2010					
Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
6.917	2.423	1.755	1.077	1.847	1.551	1.984	4.057	4.662	2.028	3.998	5.099	3.148	2.332	1.695	0.878
4.472	1.71	2.372	0.801	1.384	1.814	2.912	6.426	5.645	5.513	6.6	6.074	1.88	3.354	1.916	1.125
3.878	1.453	1.88	0.787	1.089	1.202	2.841	1.895	5.112	5.577	4.735	5.207	2.762	2.975	2.831	1.087
3.498	3.908	2.072	0.56	1.165	2.058	1.365	0.766	7.929	7.173	4.158	3.146	3.891	2.655	1.683	0.855
5.725	2.928	2.129	0.701	1.104	1.529	2.454	1.152	5.29	6.583	4.044	3.664	4.055	2.152	2.958	0.907
4.923	3.621	1.981	1.211	1.493	1.623	3.174	2.186	1.641	6.23	5.176	2.508	1.321	3.063	1.433	1.303
4.612	2.546	2.117	1.313	0.921	1.996	3.339	2.677	2.032	6.638	7.148	2.434	3.007	1.81	2.05	1.055
4.945	2.97	2.058	0.786	1.202	2.192	1.115	1.318	4.208	7.695	3.889	1.551	1.534	1.5	1.903	1.346
2.91	3.12	1.763	1.105	0.611	2.206	2.108	3.38	5.156	7.358	5.272	1.77	3.112	3.291	1.955	1.332
3.338	3.284	2.182	0.895	0.771	1.865	1.68	2.502	6.205	4.17	7.378	5.177	3.092	2.66	1.906	0.827
3.617	1.841	1.215	1.285	0.927	1.887	2.787	2.709	6.607	6.303	7.771	4.201	2.743	3.463	2.485	1.431
4.376	2.073	1.848	1.049	0.982	1.502	3.644	2.501	6.865	6.729	7.485	6.063	3.919	3.058	3.087	1.381
3.763	2.514	1.946	0.691	2.192	1.643	5.067	1.654	6.934	7.03	9.3	4.934	2.812	3.207	1.911	1.201
1.961	0.469	2.119	1.578	1.559	2.055	6.87	3.239	4.736	6.693	5.012	0.81	3.277	2.865	2.033	1.074
3.811	1.969	1.581	1.521	0.818	1.996	2.964	2.22	6.605	3.489	2.788	0.918	2.577	3.386	1.734	1.141
4.779	4.187	1.602	1.015	1.049	2.365	3.78	2.346	5.514	6.185	3.759	3.496	3.634	2.66	1.728	1.179
4.66	3.699	1.789	0.784	1.013	3.062	3.287	3.11	7.546	8	3.442	4.03	4.26	2.696	1.379	1.443
4.282	2.983	1.842	1.059	1.434	2.581	3.727	3.306	5.807	11.73	6.841	5.162	4.197	2.758	0.917	0.864
4.783	2.608	1.432	1.027	1.474	2.222	2.763	3.298	5.604	1.331	4.313	4.24	4.181	2.507	1.724	1.379
3.871	1.738	1.076	1.456	1.814	2.725	3.061	4.18	6.838	6.966	6.507	3.96	3.73	2.511	1.701	0.776
4.548	1.094	1.284	1.107	2.203	2.918	3.498	5.517	8	3.649	7.994	4.726	4.999	2.921	0.885	1.32
4.535	1.638	1.287	0.589	2.459	1.673	3.687	5.776	4.833	7.337	7.766	6.52	4.999	2.688	1.165	1.185
4.201	1.488	0.719	1.161	2.013	2.523	2.501	4.272	6.697	6.719	9.95	6.017	3.975	2.918	1.664	0.491
5.067	1.991	1.288	0.863	0.761	2.127	1.283	5.039	0.884	7.524	9.65	5.734	4.213	3.392	1.157	1.154
6.118	1.73	1.478	0.824	1.547	1.984	3.13	5.359	1.841	8.85	4.516	4.929	3.705	1.498	0.839	0.983
5.434	1.438	1.413	1.087	1.784	2.257	4.556	1.522	6.292	0.754	6.134	4.726	4.034	2.387	0.64	1.076
3.611	1.52	0.777	0.838	0.859	2.071	1.988	1.903	5.591	0.895	7.369	4.487	4.923	2.272	0.491	0.995
2.982	1.68	1.037	1.244	1.546	3.473	1.579	2.641	4.326	3.024	6.039	4.945	4.015	1.531	0.891	1.21
3.861	1.917	0.689	0.798	1.562	4.048	2.576	4.087	8.2	4.501	3.961		4.129	2.867	1.166	1.24
4.352	1.667	0.843	0.898	1.621	1.767	3.663	2.571	3.657	6.765	6.124		1.592	2.643	0.628	1.417
2.855		0.777		1.283	2.321		5.037		6.318	3.125		0.785		0.27	
132.69	68.21	48.35	30.11	42.49	67.24	89.38	98.65	161.26	179.76	182.24	116.53	104.50	80.02	48.83	33.66
469.218	537.425	585.776	615.886	658.373	725.609	814.992	913.638	1074.895	1254.652	182	298.77	403.27	483.29	532.12	565.77

						2011							
Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1.268	1.296	2.57	3.375	4.13	1.186	7.051	7.012	2.274	1.106	1.672	0.987	1.048	1.254
1.044	1.432	3.342	2.595	1.913	1.338	7.866	9.26	4.678	3.107	1.878	1.056	0.911	2.284
0.452	1.033	0.811	2.4	2.259	3.215	3.502	5.421	3.477	3.304	0.655	1.016	1.027	1.942
1.215	1.468	1.109	1.091	4.22	2.258	0.963	3.908	5.296	3.294	1.914	1.53	1.616	3.34
1.111	1.031	0.862	2.602	1.355	3.228	2.593	2.614	5.187	3.215	2.064	0.861	1.293	3.226
1.077	1.714	1.645	4.097	1.948	4.476	5.333	6.545	3.419	1.963	2.11	1.51	1.004	3.188
0.573	1.737	1.99	3.927	2.165	3.351	3.727	1.692	3.268	1.802	1.676	1.527	0.864	1.604
1.348	1.679	2.243	3.864	4.228	5.486	3.458	4.228	4.416	2.223	2.087	1.093	1.247	1.912
1.326	1.577	2.275	3.793	4.414	4.11	4.247	3.948	4.142	3.183	2.375	0.862	1.228	0.946
0.814	1.94	1.779	2.713	3.68	1.728	2.307	3.324	3.978	3.395	1.6	1.092	1.16	1.769
0.855	0.94	2.288	2.238	3.89	4.773	2.736	4.659	1.385	1.308	2.051	1.078	1.079	1.23
0.7	0.917	1.423	2.36	5.513	5.854	1.677	2.874	1.6	2.148	1.193	1.34	1.41	0.462
1.493	0.976	1.389	3.446	5.371	5.957	4.233	2.073	3.28	1.747	1.684	0.956	1.458	1.427
0.631	2.024	1.307	1.812	6.154	5.745	3.408	1.502	4.49	1.923	1.434	0.744	0.815	1.582
1.03	1.39	0.437	3.58	3.953	4.113	3.981	4.138	0.749	2.724	1.743	0.804	1.333	1.771
1.381	1.588	1.027	1.264	1.957	6.395	5.885	3.005	2.157	2.568	1.959	0.557	1.19	1.495
1.225	1.2	3.789	2.281	4.89	3.684	6.391	1.15	2.357	2.236	1.344	0.813	0.589	1.994
1.302	1.883	2.998	3.349	4.525	5.331	7.255	3.479	1.534	2.029	1.467	1.074	1.178	0.561
1.433	1.683	2.743	3.847	6.084	3.731	5.497	2.893	0.69	2.608	1.735	1.222	0.831	0.867
0.826	1.684	2.645	3.02	2.109	3.686	4.004	3.746	1.547	2.338	1.71	1.208	0.475	0.819
1.377	1.882	2.91	3.964	5.642	2.636	4.759	4.729	1.814	1.341	1.56	1.517	1.369	0.957
1.379	1.539	3.202	4.17	6.288	5.074	6.263	4.947	0.758	2.355	1.738	0.914	0.853	1.532
1.336	2.092	2.737	4.903	5.996	5.285	4.855	4.657	3.055	2.246	1.803	0.864	0.721	1.235
1.201	1.533	2.271	3.476	4.515	6.343	6.291	4.763	2.44	2.209	0.854	1.412	1.208	1.695
1.573	1.865	3.718	2.227	5.96	2.143	5.118	4.651	2.026	2.329	1.129	1.207	0.621	2.437
1.431	1.816	2.922	2.794	5.9	5.442	6.436	4.057	3.047	1.251	1.797	1.25	0.674	3.024
1.326	1.186	4.061	4.945	4.33	3.951	7.204	5.033	2.824	1.474	1.694	1.653	1.431	3.163
1.452	1.803	3.858	4.318	5.672	3.478	6.509	2.284	2.365	1.764	1.191	1.369	1.506	2.636
0.515	2.243	3.876	3.221	1.734	5.219	5.086		3.328	1.206	1.303	0.969	2.089	2.91
0.838	2.186	3.174	4.233	1.189	6.065	5.724		2.678	1.313	1.275	0.918	2.003	2.894
0.86	1.966		4.17		6.422	6.781		3.709		0.946		2.083	1.518
34.39	49.30	71.40	100.08	121.98	131.70	151.14	112.592	87.968	65.709	49.641	33.403	36.314	57.674
600.17	649.47	720.87	820.94	942.93	1074.63	151.14	263.732	351.7	417.409	467.05	500.453	536.767	594.441

				2012									
Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
2.471	2.435	4.777	2.325	5.891	5.284	0.9	3.54	1.227	1.373	1.384			
2.241	1.588	4.316	4.913	6.209	2.501	1.154	2.845	2.177	0.793	0.822			
2.59	1.69	3.187	3.823	6.572	0.926	0.938	2.605	1.285	0.278	1.289			
3.132	3.258	2.896	5.667	7.179	1.351	0.919	3.164	2.134	0.594	1.277			
3.208	3.717	5.035	2.502	3.869	5.308	1.289	2.861	1.909	1.126				
2.879	2.781	6.021	4.276	5.369	6.111	4.487	2.241	1.845	0.44				
3.472	1.184	5.481	2.521	4.112	3.608	2.485	3.182	1.434	1.351				
2.624	1.667	4.105	4.129	6.458	1.226	1.009	3.775	1.077	1.279				
2.148	2.349	3.484	1.996	2.415	1.754	1.291	3.02	2.012	1.112				
1.354	2.354	4.679	5.002	6.068	2.106	3.155	2.901	2.752	1.18				
2.113	3.671	3.949	4.417	5.436	4.055	4.215	2.367	3.317	1.241				
1.992	2.976	4.623	3.436	3.858	2.691	3.676	2.476	2.556	0.629				
3.06	3.96	5.283	2.506	5.435	3.405	1.858	2.471	2.095	0.589				
2.947	3.783	4.932	2.187	6.049	3.371	3.285	2.797	1.384	1.253				
3.867	2.61	7.31	4.185	2.996	4.062	2.97	1.622	1.75	1.101				
3.495	3.47	6.555	5.44	2.083	4.704	4.013	2.658	1.504	1.735				
4.641	4.797	1.852	2.785	4.367	5.012	3.449	2.979	1.687	0.388				
4.808	4.456	4.183	5.786	5.552	3.774	2.386	1.349	1.343	1.027				
5.481	4.215	5.886	3.902	6.141	3.874	3.566	1.094	1.883	1.354				
5.343	4.925	7.084	1.302	6.487	4.644	2.513	2.241	1.763	1.264				
2.999	5.604	2.288	4.018	4.825	2.77	3.803	2.089	0.999	1.125				
3.491	5.794	4.966	2.69	4.856	4.255	4.005	1.749	1.613	1.895				
4.132	4.353	1.416	4.248	4.142	3.313	1.574	1.236	2.124	0.979				
5.552	5.458	2.959	5.868	3.036	4.821	3.37	2.224	2.66	1.068				
0.677	6.477	1.808	6.049	4.872	5.508	3.169	1.13	1.581	1.355				
1.441	0.997	0.889	6.216	2.176	5.785	2.475	0.934	1.061	1.264				
2.871	1.547	4.708	2.701	3.709	2.374	3.162	1.885	0.925	0.88				
3.301	2.761	4.889	4.081	2.485	2.673	1.564	1.73	1.416	0.587				
1.057	4.003	5.752	4.757	4.831	1.274	1.226	2.061	0.983	1.278				
1.649	2.008	5.654	6.255	5.77		3.304	1.868	1.428	1.283				
	4.498		3.977	2.548		3.262		1.146					
91.036	105.386	130.967	123.96	145.796	102.54	80.472	69.094	53.07	31.821	4.772	0	0	0
685.477	790.863	921.83	1045.79	145.796	248.336	328.808	397.902	450.972	482.793	487.565	487.565	487.565	487.565

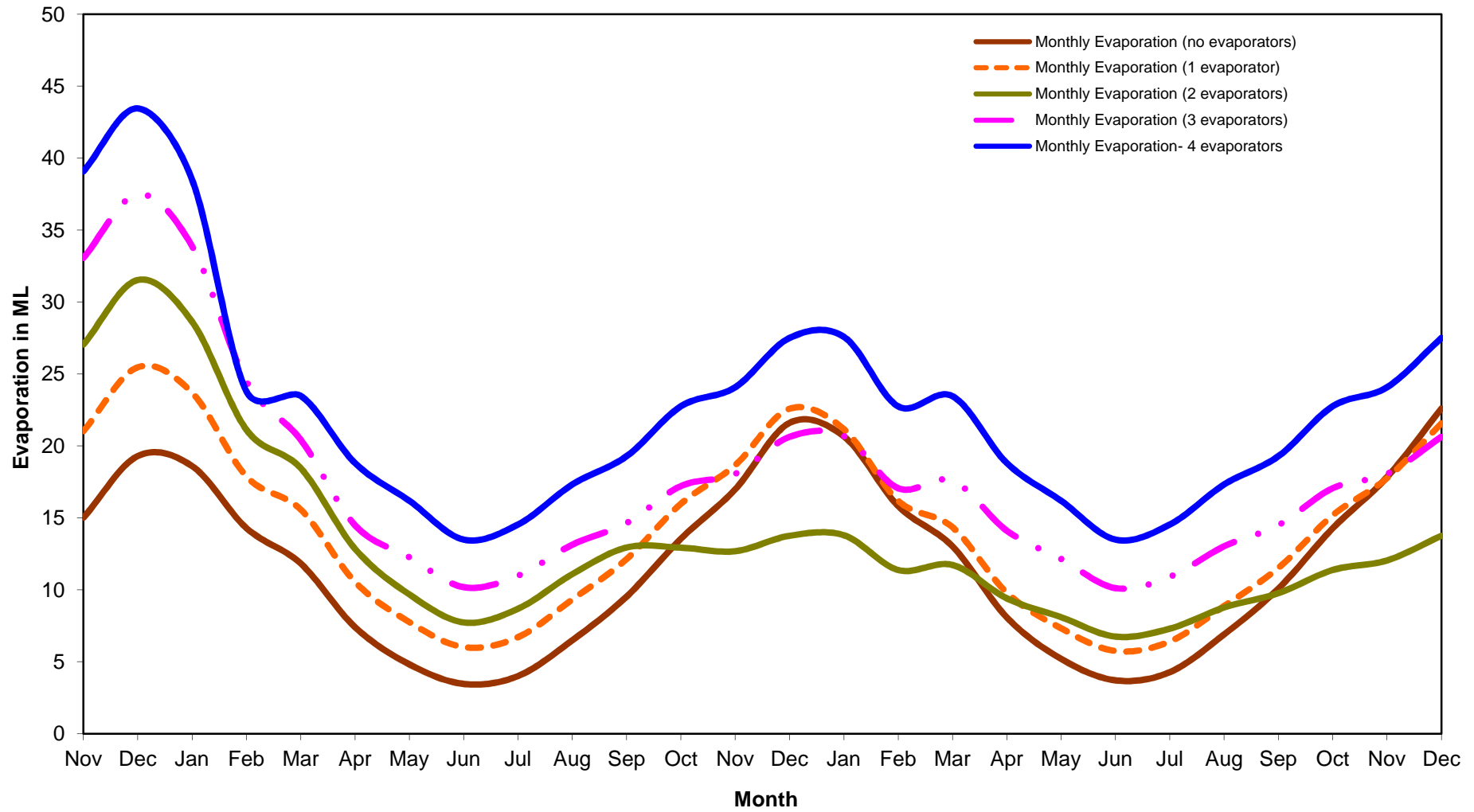
Nov

Dec

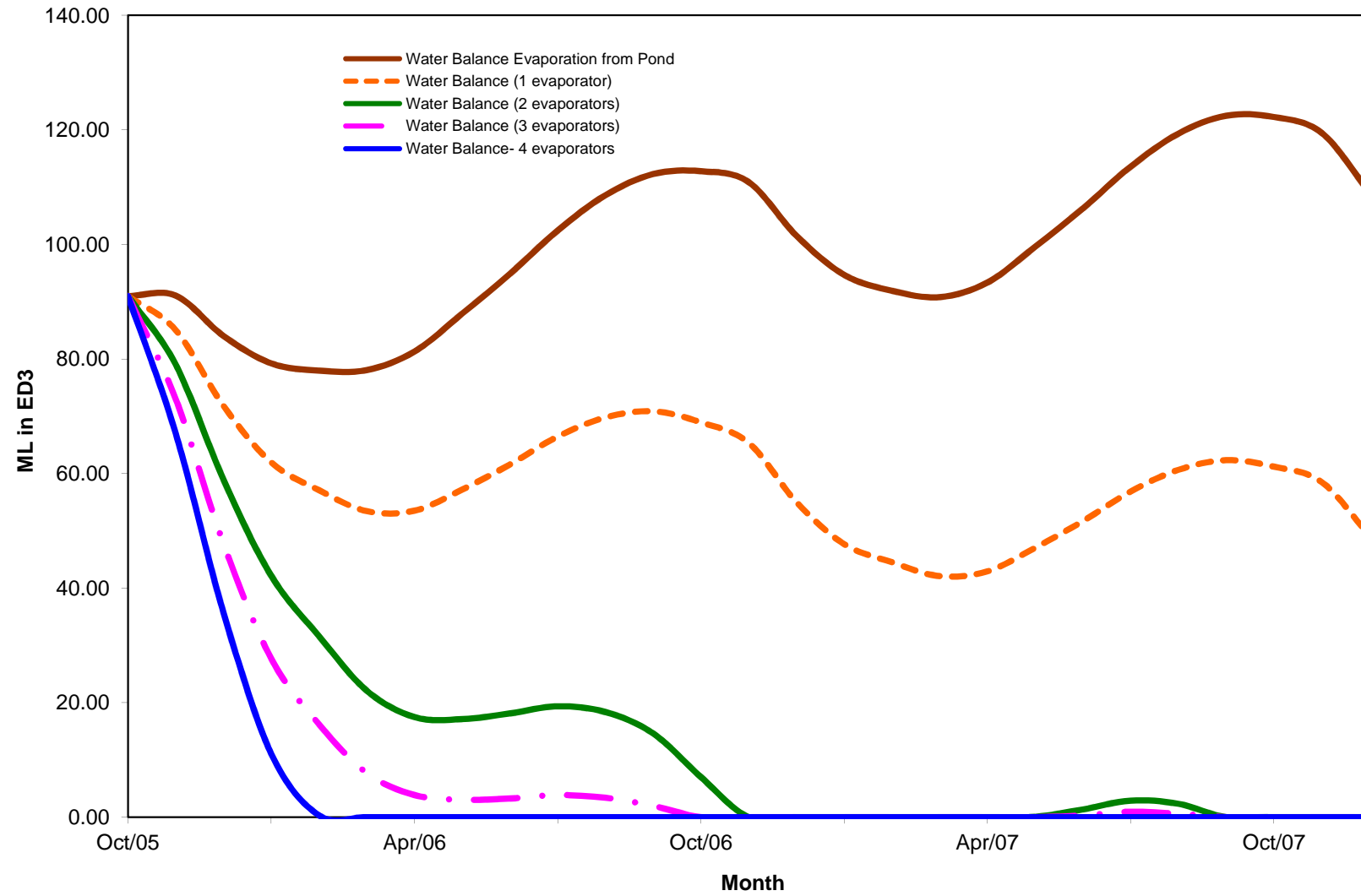


0	0
487.565	487.565

**Monthly
Evaporative loss from ED3**



Water balance ED3



	November	December	January	February	March	April	May	June	July	August	September	October	November	December	January	February	March	April	May	June	July	August	September	October	November	December
	30	30	31	28	31	30	31	30	31	31	30	29	30	30	31	28	31	30	31	30	31	31	30	29	30	31
	18.1	16.1	18.3	17.1	18.3	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	
	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	
Average Monthly Pan Evaporation (mm-total)	0.1725	0.22165	0.2232	0.1778	0.1488	0.093	0.0589	0.0405	0.04995	0.06975	0.099	0.13795	0.1725	0.22165	0.2232	0.1778	0.1488	0.093	0.0589	0.0405	0.04995	0.06975	0.099	0.13795	0.1725	0.22165
Estimated monthly evaporation (M3) attributed to 1 evaporator (350 l/min)	6019	6875	6895	5686	5862	4701	4046	3371	3632	4330	4820	5687	6019	6875	6895	5686	5862	4701	4046	3371	3632	4330	4820	5687	6019	6875
Estimated monthly evaporation (M3) attributed to 2 evaporators (350 l/min)	12037	13751	13789	11372	11725	9402	8093	6742	7264	8659	9640	11375	12037	13751	13789	11372	11725	9402	8093	6742	7264	8659	9640	11375	12037	13751
Estimated monthly evaporation (M3) attributed to 3 evaporators (350 l/min)	18056	20626	20684	17058	17587	14103	12139	10113	10895	12989	14460	17062	18056	20626	20684	17058	17587	14103	12139	10113	10895	12989	14460	17062	18056	20626
Estimated monthly evaporation (M3) attributed to 4 evaporator(s) (350 l/min)	24075	27502	27578	22744	23449	18804	16186	13484	14527	17118	19280	22750	24075	27502	27578	22744	23449	18804	16186	13484	14527	17118	19280	22750	24075	27502
Estimated Evaporation (M3) attributed to surface evaporation (no evaporator)	15006.3	15291.2	18596.0	14286.3	11827.1	7387.5	4816.0	3457.6	4001.0	6488.1	9529.3	13544.4	16882.3	21601.0	20657.1	15814.9	13016.6	8081.2	5197.2	3706.7	4272.1	6895.5	10083.4	14273.9	17829.0	22594.3
Estimated Evaporation (M3) attributed to surface evaporation (1 evaporator)	15006.3	16866.9	16798.5	12168.2	9715.6	5945.2	3705.0	2687.1	3070.1	4994.2	7313.1	10262.7	12643.3	15705.6	14263.7	10950.7	8482.3	5096.7	3274.3	2374.8	2773.1	4542.8	6698.9	9492.8	11738.3	14684.1
Estimated Evaporation (M3) attributed to surface evaporation (2 evaporator)	15006.3	17777.3	14847.0	9765.8	6725.4	3443.3	1581.8	988.8	1414.3	2427.2	3298.7	1550.3	843.3	0.0	0.0	0.0	0.0	0.0	0.0	1.5	32.2	107.1	123.8	0.0	0.0	0.0
Estimated Evaporation (M3) attributed to surface evaporation (3 evaporator)	15006.3	16861.3	13193.4	7424.1	2837.6	382.6	121.3	65.6	78.0	143.4	178.4	144.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.6	35.5	30.9	0.0	0.0	0.0
Estimated Evaporation (M3) attributed to surface evaporation (4 evaporator(s))	15006.3	15950.5	10922.7	1049.4	25.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Evaporator evaporation as % of Surface Evaporation (1 evaporator)	40.1%	35.6%	37.1%	39.8%	49.6%	63.9%	84.0%	87.5%	90.8%	66.7%	50.6%	42.0%	35.4%	31.8%	33.4%	36.0%	45.0%	58.2%	77.9%	90.9%	85.0%	62.8%	47.8%	39.8%	33.8%	30.4%
Evaporator evaporation as % of Surface Evaporation (2 evaporator)	80.2%	71.3%	74.2%	79.6%	99.1%	127.1%	168.0%	195.0%	181.5%	133.5%	101.2%	84.0%	70.9%	63.7%	66.8%	71.9%	80.1%	116.3%	155.7%	181.9%	170.0%	125.6%	95.6%	79.7%	67.5%	60.9%
Evaporator evaporation as % of Surface Evaporation (3 evaporator(s))	120.3%	106.9%	111.2%	119.4%	148.7%	190.6%	252.1%	292.5%	272.3%	200.2%	151.7%	126.0%	106.3%	85.5%	100.1%	107.9%	135.1%	174.5%	233.6%	272.8%	255.0%	188.4%	143.4%	119.5%	101.3%	91.3%
Evaporator evaporation as % of Surface Evaporation (4 evaporator(s))	160.4%	142.6%	148.3%	159.2%	198.3%	254.2%	336.1%	390.0%	363.0%	266.9%	202.3%	166.0%	141.8%	127.3%	133.5%	143.8%	180.1%	232.7%	311.4%	363.8%	340.0%	251.2%	191.2%	159.4%	135.0%	121.7%

Evaporation from Pond	15006.31158	15291.2246	18595.96903	14286.305	11827.0785	7387.5361	4815.98473	3457.57676	4001.9273	6488.09051	9529.31306	13544.40844	16882.28	21600.97867	20657.05538	15814.9363	13016.6113	8081.88995	5197.22556	3706.71156	4272.10208	6895.50571	10083.4006	14273.9441	17829.0205	22594.3205
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Incident Rainfall																											
Water Pumped In		10081.5	7243.5	8819.25	8027.25	6913.5	5926.5	6435	5395.5	6575.25	7656	8217	9050.25	10081.5	7243.5	8819.25	8027.25	6913.5	5926.5	6435	5395.5	6575.25	7656	8217	9050.25	10081.5	7243.5
	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000

Initial Volume stored in ED3																											
Progressive Water Balance (no evaporators)	91051	84003	79226	77967	78054	81283	87902	94840	102413	108581	112268	112774	110874	101516	94078	91891	90787	93333	99571	106259	113562	119323	122457	122233	119485	109135	
Progressive RL of dam	789.09	789.09	789.02	788.96	788.95	788.95	788.99	789.06	789.13	789.21	789.27	789.31	789.31	789.29	789.29	789.13	789.10	789.09	789.11	789.18	789.25	789.32	789.38	789.41	789.41	789.38	789.27
Progressive Water Balance (1 evaporator)	90976	85032	71813	61939	57093	53428	53509	57192	61569	66443	69775	70859	68929	65349	55011	47872	44513	42082	42911	47025	51674	56845	60628	62327	61197	58521	49205
Progressive RL of dam	789.09	789.03	788.87	788.73	788.67	788.62	788.62	788.67	788.73	788.79	788.84	788.85	788.83	788.78	788.64	788.55	788.50	788.46	788.48	788.54	788.60	788.67	788.72	788.74	788.73	788.69	788.57
Progressive Water Balance (2 evaporators)	90976	79013	59919	42151	31611	22091	17471	17108	18114	19355	18358	14622	7005	0	0	0	0	0	0	68	1346	2985	2339	0	0	0	0
Progressive RL of dam	789.09	788.96	788.70	788.46	788.26	788.07	787.81	787.75	787.93	788.02	787.98	787.28	785.83	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50
Progressive Water Balance (3 evaporators)	90976	72995	47751	27693	16238	7727	3868	3042	3259	3861	3385	1963	0	0	0	0	0	0	0	0	282	955	587	0	0	0	0
Progressive RL of dam	789.09	788.89	788.55	788.18	787.58	785.97	785.23	785.08	785.12	785.23	785.14	784.87	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50
Progressive Water Balance- 4 evaporators	90976	66976	35767	11085	320	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Progressive RL of dam	789.09	788.80	788.34	788.60	784.56	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50	784.50

Monthly Evaporation (no evaporators)	15.006	19.291	18.596	14.286	11.827	7.398	4.816	3.458	4.002	6.488	9.529	13.544	16.882	21.601	20.657	15.815	13.017	8.081	5.197	3.707	4.272	6.896	10.083	14.274	17.829	22.594
Monthly Evaporation (1 evaporator)	21.025	25.462	23.693	17.874	15.578	10.546	7.752	6.018	6.702	9.348	12.133	15.980	18.662	22.581	21.158	16.167	14.345	9.798	7.321	5.746	6.405	8.872	11.519	15.180	17.757	21.560
Monthly Evaporation (2 evaporators)	27.044	31.528	28.936	21.127	18.450	12.845	9.675	7.731	8.678	11.086	12.937	12.925	12.681	13.751	13.789	11.372	11.725	9.402	6.993	6.744	7.296	9.768	9.763	11.375	12.037	13.751
Monthly Evaporation (3 evaporators)	33.063	37.487	33.877	24.482	20.425	14.485	12.261	10.179	10.973	13.132	14.638	17.207	18.056	20.626	20.684	17.058	17.587	14.103	12.139	10.113	10.902	13.024	14.491	17.062	18.056	20.626
Monthly Evaporation- 4 evaporators	39.081	43.452	38.501	23.873	23.475	18.804	16.186	13.484	14.527	17.318	19.280	22.750	24.075	27.502	27.578	22.744	23.449	18.804	16.186	13.484	14.527	17.318	19.280	22.750	24.075	27.502

Net pan evaporation (mm/month)	Percentage of volume pumped by evaporator	Net pan evaporation (mm/month)	Percentage of volume pumped by evaporator
1.5	20	7.0	40
2.0	28	7.5	41
2.5	29	8.0	42
3.0	30	8.5	43
3.5	32	9.0	44
4.0	34	9.5	45
4.5	35	10	46
5.0	36	10.5	47
5.5	37	11	48
6.0	38	11.5	49
6.5	39	12	50
7.0	40	12+	up to 85

Net pan evaporation Percentage of volume pumped by evaporator (from manufacturer specifications)

1.5	20%	38.1	21.8%	21.8%
2	28%	50.8	24.4%	24.4%
2.5	29%	63.5	26.7%	26.7%
3	30%	76.2	28.7%	28.7%
3.5	32%	88.9	30.5%	30.5%
4	34%	101.6	32.2%	32.2%
4.5	36%	114.3	33.8%	33.8%
5	38%	127	35.2%	35.2%
5.5	37%	139.7	36.6%	36.6%
6	38%	152.4	37.9%	37.9%
6.5	39%	165.1	39.1%	39.1%
7	40%	177.8	40.3%	40.3%
7.5	41%	190.5	41.4%	41.4%
8	42%	203.2	42.5%	42.5%
8.5	43%	215.9	43.5%	43.5%
9	44%	228.6	44.6%	44.6%
9.5	45%	241.3	45.5%	45.5%
10	46%	254	46.5%	46.5%
10.5	47%	266.7	47.4%	47.4%
11	48%	279.4	48.3%	48.3%
11.5	49%	292.1	49.1%	49.1%
12	50%	304.8	50.0%	50.0%

12+

up to 86



WOODLAWN BIOREACTOR FACILITY – TOU COMMENTS RE
BIOCOVER TRIAL REPORT:

2 MARCH 2015



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2 March 2015

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WOODLAWN BIOREACTOR FACILITY – TOU COMMENTS RE BIOCOVER TRIAL

Dear Stephen,

As requested, The Odour Unit Pty Ltd (TOU) has undertaken a review of the Veolia Australia & New Zealand (Veolia) titled *Trial for the use of a Biocover for Odour Management at Woodlawn Bioreactor* dated February 2015 (the document). The following letter is intended to provide TOU's formal feedback on the document in a concise format.

Context of document

The biocover trial is a non-mandatory recommendation from the last Odour Audit conducted at Woodlawn. It is understood that in recent times Veolia decided to adopt the trial as a potential means of managing fugitive gas emissions emanating from the Void surface. The document was developed in order to *...outline the necessary requirements needed for successful implementation as well as ongoing measures that are required to ensure optimal use*. In general, TOU's review of the document is that it achieves these objectives.

Equipment and Resources for Biocover material

The general specifications outlined in the document for the biocover material is considered by TOU to be appropriate and addresses all key factors that generally

would promote effective biofiltration. The biocover material factors that have been addressed in the document include: nutrient levels, porosity and gas conductivity, water retention capacity; drainage; and consistency and structural properties of the medium. The medium selection outlined in the document takes into consideration these factors. The proposed selection of a range of organic-based materials (such as composted green waste fractions, pine chips, composted residual waste) of varying size fractions (20-100 mm) is considered essential to ensuring availability of medium all year round.

TOU comments for consideration

The document addresses quite comprehensively the application and management of the biocover material within the Void. To further improve the effectiveness of the biocover material trial however, TOU has the following comments:

- A key factor in achieving good performance from the biocover material will be the ability of operators to maintain adequate moisture content of the biocover material, given the shallow bed depths (300mm - 500mm). This will be especially important under dry/hot climatic conditions. The regular application and monitoring of moisture will be necessary to maintaining the health of the biocover material and the microbial population;
- It is recommended that treated leachate from the Leachate Aeration Dam be used as the source of inoculum (and moisture – if practical - in combination with the water cart services when needed) when applying the biocover material to a new area or for bed recovery after an upset event (such as the drying and/or sterilisation of the biocover material). The treated leachate would already contain sulphur-oxidising aerobic microorganisms that will accelerate the acclimatisation phase within the biocover bed;
- A bed depth of approximately 500 mm is favoured to provide more contact time between the gas emission and bed. This would also have the effect on maintain an moderate gas loading on the bed at any given time;
- The suggested frequency of replacement for the biocover material of 18 months appears to be reasonable. Based on TOU's experience, it is quite possible that the medium could have a longer working life than highlighted in the document. This would need to be evaluated over the trial period;
- The suggested monitoring parameters and frequency as specified in the document is adequate;

- It has been found from the Odour Audits that hydrogen sulphide (H_2S) and ester-based compounds are responsible for the bulk of odour that emanates from the Void. With this in mind, TOU suggests that hydrogen sulphide (H_2S) could be used as an indicator of bed performance. This in combination with the other suggested measures in the document would assist at effectively monitoring any adverse signs of bed performance. Alternatively, monitoring of the pH in the biocover material would indicate bio-oxidation of H_2S if acidic readings are achieved.

Overall, TOU's feedback on the document is that it provides the necessary management and operational practices for the effective trial application of the biocover material for odour management within the Void. It is suggested that the comments in this letter be taken into consideration during the finalisation of the document.

Please feel free to contact us if you have any further enquiries.



Terry Schulz
Managing Director



Michael Assal
Senior Engineer



FIELD AMBIENT ODOUR ASSESSMENT SURVEY: MAP PLOT AND
FIELD LOGSHEETS

6 OCTOBER 2015



Woodlawn
Bioreactor Facility

VDI 3882.1 Intensity	
0	Not detectable
1	Very weak
2	Weak
3	Distinct
4	Strong
5	Very Strong
6	Extremely Strong

Odour Descriptors

○ NO ODOUR DETECTED

Intensity
Frequency
Pie Graph

Local Wind
Direction

Prevailing Wind:
W



Veolia (Australia) Pty Ltd
Woodlawn Bioreactor Facility
Downwind Field Ambient Odour Assessment
Survey #1



Field Ambient Odour Assessment Survey
Session Date: 06/10/15 Session Time: 14:40 hrs – 15:53 hrs
Area: 1 Odour Impact Criterion: Intensity ≥ 1
Drawn By: S. Hayes Revision: M. Assal Date: 03/11/15

FAOA - Field Data Record Sheet (Odour Intensity & Quality)



Name: Terry Schulz Member ID: Date: 6/12/2015

Assessment Area: Woodlawn Bioreactor Facility Start Time: 1440 hrs End Time: 1553 hrs

Measurement Point: 1
Wind Speed and Direction 270
Start: 2:40 PM End: 2:45 PM

min-1	0	0	0	0	0	0
min-2	0	0	0	0	0	0
min-3	0	0	0	0	0	0
min-4	0	0	0	0	0	0
min-5	0	0	0	0	0	0

Descriptor(s):

A	B	C	D	E
F	G	H	I	J

Comment: None

Measurement Point: 2
Wind Speed and Direction 270
Start: 2:46 PM End: 2:51 PM

min-1	0	0	0	0	0	0
min-2	0	0	0	0	0	0
min-3	0	0	0	0	0	0
min-4	0	0	0	0	0	0
min-5	0	0	0	0	0	0

Descriptor(s):

A	B	C	D	E
F	G	H	I	J

Comment: None

Measurement Point: 3
Wind Speed and Direction 270
Start: 2:55 PM End: 3:00 PM

min-1	0	0	0	0	0	0
min-2	0	0	0	0	0	0
min-3	0	0	0	0	0	0
min-4	0	0	0	0	0	0
min-5	0	0	0	0	0	0

Descriptor(s):

A	B	C	D	E
F	G	H	I	J

Comment: None

Measurement Point: 4
Wind Speed and Direction 270
Start: 3:02 PM End: 3:07 PM

min-1	0	0	0	0	0	0
min-2	0	0	0	0	0	0
min-3	0	0	0	0	0	0
min-4	0	0	0	0	0	0
min-5	0	0	0	0	0	0

Descriptor(s):

A	B	C	D	E
F	G	H	I	J

Comment: None

Measurement Point: 5
Wind Speed and Direction 270
Start: 3:07 PM End: 3:12 PM

min-1	0	0	0	0	0	0
min-2	0	0	0	0	0	0
min-3	0	0	0	0	0	0
min-4	0	0	0	0	0	0
min-5	0	0	0	0	0	0

Descriptor(s):

A	B	C	D	E
F	G	H	I	J

Comment: Crisps Creek Intermodal Facility

Measurement Point: 6
Wind Speed and Direction
Start: 3:12 PM End: 3:17 PM

min-1	0	0	0	0	0	0
min-2	0	0	0	0	0	0
min-3	0	0	0	0	0	0
min-4	0	0	0	0	0	0
min-5	0	0	0	0	0	0

Descriptor(s):

A	B	C	D	E
F	G	H	I	J

Comment: Tarago

FAOA - Field Data Record Sheet (Odour Intensity & Quality)



Name: Terry Schulz Member ID: Date: 6/12/2015

Assessment Area: Woodlawn Bioreactor Facility Start Time: 1440 hrs End Time: 1553 hrs

Measurement Point: 7

Wind Speed and Direction 270

Start: 3:17 PM End: 3:22 PM

min-1	0	0	0	0	0	0
min-2	0	0	0	0	0	0
min-3	0	0	0	0	0	0
min-4	0	0	0	0	0	0
min-5	0	0	0	0	0	0

Descriptor(s):

A	B	C	D	E
F	G	H	I	J

Comment: None

Measurement Point: 8

Wind Speed and Direction 270

Start: 3:22 PM End: 3:27 PM

min-1	0	0	0	0	0	0
min-2	0	0	0	0	0	0
min-3	0	0	0	0	0	0
min-4	0	0	0	0	0	0
min-5	0	0	0	0	0	0

Descriptor(s):

A	B	C	D	E
F	G	H	I	J

Comment: None

Measurement Point: 9

Wind Speed and Direction 270

Start: 3:28 PM End: 3:33 PM

min-1	0	0	0	0	0	0
min-2	0	0	0	0	0	0
min-3	0	0	0	0	0	0
min-4	0	0	0	0	0	0
min-5	0	0	0	0	0	0

Descriptor(s):

A	B	C	D	E
F	G	H	I	J

Comment: None

Measurement Point: 8

Wind Speed and Direction 270

Start: 3:35 PM End: 3:40 PM

min-1	0	0	0	0	0	0
min-2	0	0	0	0	0	0
min-3	0	0	0	0	0	0
min-4	0	0	0	0	0	0
min-5	0	0	0	0	0	0

Descriptor(s):

A	B	C	D	E
F	G	H	I	J

Comment: None

Measurement Point: 7

Wind Speed and Direction

Start: 3:42 PM End: 3:47 PM

min-1	0	0	0	0	0	0
min-2	0	0	0	0	0	0
min-3	0	0	0	0	0	0
min-4	0	0	0	0	0	0
min-5	0	0	0	0	0	0

Descriptor(s):

A	B	C	D	E
F	G	H	I	J

Comment: None

Measurement Point: 10

Wind Speed and Direction

Start: 3:48 PM End: 3:53 PM

min-1	0	0	0	0	0	0
min-2	0	0	0	0	0	0
min-3	0	0	0	0	0	0
min-4	0	0	0	0	0	0
min-5	0	0	0	0	0	0

Descriptor(s):

A	B	C	D	E
F	G	H	I	J

Comment: None



STEPHENSON ENVIRONMENTAL STACK EMISSION SURVEY –
GENERATOR NO. 3 TESTING REPORTS:

MARCH 2015



Stephenson

Environmental Management Australia

STACK EMISSION SURVEY 2015 – GENERATOR NO.3

WOODLAWN LANDFILL

VEOLIA ENVIRONMENTAL SERVICES

TARAGO, NSW

PROJECT NO.: 5474/S23614A/15

DATE OF SURVEY: 23 MARCH 2015

DATE OF ISSUE: 10 APRIL 2015



Stephenson

Environmental Management Australia

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STACK EMISSION SURVEY 2015 – GENERATOR No.3

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P W STEPHENSON

J WEBER

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1 INTRODUCTION

Stephenson Environmental Management Australia (SEMA) was requested by Veolia Environmental Services (Veolia) to assess the emissions from one generator associated with the landfill gas power plant at their Woodlawn Landfill, Tarago, New South Wales (NSW). Generator No.3 was selected to be tested.

The objective of the tests was to determine compliance of the concentration of emissions to be reported to the Environment Protection Authority (EPA) as specified in their Environment Protection Licence (EPL) No.11436. The EPA is now part of the Office of Environment and Heritage (OEHL).

The exhaust stack serving Generator No.3 is referred to in the EPL as EPA Identification Point No.8.

The stack emission from the generator engine set No. 3 was assessed for the following components:

- Exhaust flow, velocity, temperature and moisture
- Dry gas density
- Molecular Weight of Stack Gases
- Oxygen (O₂)
- Carbon Monoxide (CO)
- Carbon Dioxide (CO₂)
- Hydrogen Sulphide (H₂S)
- Oxides of Nitrogen (NO_x) (as Nitrogen Dioxide (NO₂))
- Sulphur Dioxide (SO₂)
- Sulphur Trioxide/Sulphuric Acid Mist (SO₃/H₂SO₄)
- Volatile Organic Compounds (VOCs).

The emission tests were undertaken on the stack serving Generator No.3 during normal operations on 23 March, 2015.

2 LICENCE AND REGULATORY LIMITS

The facility at Woodlawn is licensed by the NSW OEH under EPL No. 11436. Condition L2.4 of the EPL specifies the concentration limits from the generator exhaust stack. Table 2-1 summarises the EPL concentration limits.

TABLE 2-1 EPL 100 PERCENTILE CONCENTRATION LIMITS (EPL POINT NO. 8)

Parameter	EPL Emission Limit
Nitrogen Oxides	450 mg/m ³
Hydrogen Sulphide	5 mg/m ³
Sulphuric Acid Mist and Sulphur Trioxide	100 mg/m ³

Key:

mg/m³ = milligrams per cubic metre @ reference conditions specified in Condition L3.5

Condition L3.5 specifies the reference conditions which are:

- For Nitrogen Oxides (NO_x): dry, 273 Kelvin (K), 101.3 kilopascals (kPa), 7% Oxygen (O₂).
- For Sulphuric Acid Mist (H₂SO₄) and Sulphur Trioxide (SO₃): dry, 273 K, 101.3 kPa.

Table 2-2 specifies the monitoring requirements under Condition M2.1 of EPL No.11436.

TABLE 2-2 MONITORING REQUIREMENTS AS PER EPL 11436

Pollutant	Units	Frequency	Test Method
Carbon Dioxide	%	Annual	TM-24
Carbon Monoxide	mg/m ³	Annual	TM-32
Dry Gas Density*	mg/m ³ (kg/m ³)	Annual	TM-23
Moisture content	%	Annual	TM-22
Molecular weight of stack gases	g/g mole	Annual	TM-23
Nitrogen Oxides	mg/m ³	Annual	TM-11
Oxygen	%	Annual	TM-25
Sulphur Trioxide/Sulphuric Acid Mist	mg/m ³	Annual	TM-3
Sulphur Dioxide	mg/m ³	Annual	TM-4
Temperature	°C	Annual	TM-2
Velocity	m/s	Annual	TM-2
Volatile Organic Compounds	mg/m ³	Annual	TM-34
Volumetric Flow Rate	m ³ /s	Annual	TM-2

Key:

%	=	percent
°C	=	degrees Celsius
g/g mole	=	grams per gram mole
kg/m ³	=	kilograms per cubic metre
m/s	=	metres per second
m ³ /s	=	cubic metres per second
mg/m ³	=	milligrams per cubic metre at 0°C and 1 atmosphere and reference conditions
TM	=	Test Method

* Note: The unit for Dry Gas Density is normally reported in kilograms per cubic metre (kg/m³) not milligrams per cubic metre (mg/m³) as specified in EPL 11436.

3 PRODUCTION CONDITIONS

Veolia Environmental Services personnel considered the landfill and the associated gas fired power plant to be operating under typical conditions on the days of testing.

Veolia Environmental Services provided the production records for the day of testing. A copy of these records is included in Appendix D.

4 EMISSION TEST RESULTS

4.1 INTRODUCTION

SEMA completed the sampling for all emission test parameters and the analysis of flow, temperature, moisture, velocity, dry gas density, molecular weight of stack gases, O₂, NO_x, SO₂, CO and CO₂. SEMA is NATA accredited for this sampling and analysis, Accreditation No. 15043.

Refer to SEMA's Emission Test Report No. 5474, Appendix C, which includes a summary of results and the associated certificates of analysis.

The VOC sample collected by SEMA was analysed by the NATA accredited (NATA No. 3726) TestSafe Laboratories, Report No 2015-1135. Analysis for SO₃/H₂SO₄ and H₂S samples were performed by the NATA accredited (NATA No. 825) ALS Environmental, Report No. EN 1510991.

The stack emission test results are summarised in Table 4-1 and presented in detail in Table A-1 of Appendix A. Appendix B presents a graphical logged record of SO₂ and NO_x continuous emission analysis. Appendix E details the most recent calibration of each instrument used to take measurements and the sample location is presented in Appendix F.

4.2 SULPHUR DIOXIDE (SO₂)

The measured SO₂ emission concentration averaged 161 milligrams per cubic metre (mg/m³) for the one-hour sampling period. Refer to Table 4-1 and Figure B-1 in Appendix B for detailed results.

4.3 OXIDES OF NITROGEN (NO_x)

The one-hour average NO_x (expressed as NO₂) emission concentration and corrected to 7% O₂ was 207 parts per million (ppm) (425 mg/m³) during the sampling period, which is *in compliance* with the EPL NO_x limit of 450 mg/m³. Refer to Table 4-1 and Figure B-2 in Appendix B for detailed results.

4.4 OXYGEN (O₂), CARBON DIOXIDE (CO₂) & CARBON MONOXIDE (CO)

During the monitoring period, the emission concentrations averaged 8.2% for O₂, 11.5% for CO₂ and 870 mg/m³ for CO.

4.5 SULPHUR TRIOXIDE/SULPHURIC ACID MIST (SO₃/H₂SO₄)

The SO₃/H₂SO₄ emission concentration measured was 11.5 mg/m³ which is *in compliance* with EPL SO₃/H₂SO₄ limit of 100 mg/m³. Refer to Table 4-1 and Appendix A, Table A-1 detailed results.

4.6 HYDROGEN SULPHIDE (H₂S)

The H₂S emission concentration measured was below the limit of detection for the analytical method, thus was *in compliance* with EPL H₂S limit of 5 mg/m³. Refer to Table 4-1 and Appendix A, Table A-1 for detailed results.

4.7 VOLATILE ORGANIC COMPOUNDS (VOCs)

The Protection of the Environment Operations (Clean Air) Regulation 2010 requires VOCs to be reported as n-propane equivalent. The total VOCs emission concentration (as n-propane equivalent) was 0.16 mg/m³. The only detected VOC emission from the generator tested was Benzene and all other VOC emissions were below the limit of detection for analytical method. Refer to Table 4-1 and Appendix C for Certificate of Analysis.

TABLE 4-1 AVERAGE EMISSION CONCENTRATIONS TEST RESULTS EPA POINT 8-3

Pollutant	Units	Generator No.3	EPL Emission Concentration Limit
Dry Gas Density	kg/m ³	1.35	--
Moisture content	%	6.3	--
Molecular weight of stack gases	g/g mole	30.17	--
Temperature	°C	451	--
Velocity	m/s	44.0	--
Volumetric Flow Rate	m ³ /s	1.50	--
Carbon Dioxide	%	11.5	--
Carbon Monoxide	mg/m ³	870	--
Hydrogen Sulphide	mg/m ³	<0.362	5
Nitrogen Oxides @ 7% O ₂	mg/m ³	425	450
Oxygen (O ₂)	%	8.2	--
Sulphur Trioxide / Sulphuric Acid Mist	mg/m ³	11.5	100
Sulphur Dioxide	mg/m ³	161	--
Volatile Organic Compounds - Benzene (as n-propane equivalent)	mg/m ³	0.16	--

Key:	<	=	less than
	g/g mole	=	grams per gram mole
	--	=	No limit
	kg/m ³	=	kilograms per cubic metre
	°C	=	degrees Celsius
	m/s	=	metres per second
	%	=	percent
	m ³ /s	=	cubic metres per second
	mg/m ³	=	milligrams per cubic metre at 0°C (273 K) and 1 atmosphere

5 CONCLUSIONS

From the data presented and compliance emission test work conducted during typical operational conditions of Generator No.3 at the Woodlawn Landfill gas fired power plant, the following conclusion can be drawn:

- The emissions from Generator No.3 complied with the EPL limits for NO_x , $\text{SO}_3/\text{H}_2\text{SO}_4$ and H_2S .

6 TEST METHODS

6.1 EXHAUST GAS VELOCITY AND TEMPERATURE

(OEH NSW TM-1 & 2)

Velocity profiles were obtained across the stack utilising an Airflow Developments Ltd. S-type pitot tube and digital manometer. The exhaust gas temperature was measured using a Digital thermometer (0-1200°C) connected to a chromel/alumel (K-type) thermocouple probe.

6.2 CONTINUOUS GASEOUS ANALYSIS

(OEH NSW TM- 4, 11, 24, 25 & 32)

Sampling and analysis of exhaust gas were performed using a SEMA mobile combustion and environmental monitoring laboratory. Emission gases were distributed to the analysers via a manifold. Flue gas from each stack was pumped continuously. The following components of the laboratory are relevant to this work:

Sulphur Dioxide, Oxides of Nitrogen Oxygen, Carbon Monoxide, Carbon Dioxide	Testo 350XL
---	-------------

Calibration	BOC Special Gas Mixtures relevant for each analyser. Instrument calibrations performed at start and finish of sampling at all locations.
-------------	--

QA/QC	Calibration (Zero/Span) checks Sample line integrity calibration check
-------	---

6.3 HYDROGEN SULPHIDE

(OEH NSW TM-5)

Samples were drawn through 3% H₂O₂ then CdSO₄ solution in midget impingers, per USEPA Method 11. Sample collection time was increased from 10 minutes to approximately 3 hours to increase the lower detection limit. Test method requires sample to be taken over at least a 10-minute duration. Samples, collected in solution, were analysed by NATA accredited ALS Environmental.

6.4 SULPHUR TRIOXIDE/SULPHURIC ACID MIST (SO₃/H₂SO₄)

(OEH NSW TM- 3)

SO₃/H₂SO₄ were sampled isokinetically and drawn through a glass probe into four Greenburg Smith impingers in series. The first and second impingers in the train contained 100 ml of 80% isopropanol, the third was empty and the fourth contained silica gel. The impinger train was mounted in an ice water bath. Analysis was performed by the NATA accredited laboratories of ALS Environmental.

6.5 VOLATILE ORGANIC COMPOUNDS (VOCs)

(OEH NSW TM-34)

A sample of stack air is drawn onto an activated carbon adsorption tube and analysed using Gas Chromatography/Mass Spectrometry (GC/MS) performed by the NATA accredited laboratory TestSafe Australia, accreditation number, 3726.

6.6 ACCURACY

All results are quoted on a dry basis. SEMA has adopted the following (Table 6-1) uncertainties for various stack testing methods.

TABLE 6-1 ESTIMATION OF MEASUREMENT UNCERTAINTY

Pollutant	Methods	Uncertainty
Carbon Monoxide	TM-32, USEPA 10	15%
Hydrogen Sulphide	TM-5 USEPA 11	25% +++++
Moisture	AS4323.2, TM-22, USEPA 4	25%
Nitrogen Oxides	TM-11, USEPA 7E	15%
Oxygen and Carbon Dioxide	TM-24, TM-25, USEPA 3A	1% actual
Sulphur Dioxide	TM-4, USEPA 6C	15%
Sulphur Trioxide/Sulphuric Acid Mist (SO ₃ /H ₂ SO ₄)	TM-3, USEPA 8	20%
Velocity	AS4323.1, TM-2, USEPA 2	5%
Volatile Organic Compounds (adsorption tube)	TM-34, USEPA 18	25%

Key:

Unless otherwise indicated the uncertainties quoted have been determined @ 95% level of Confidence level (i.e. by multiplying the repeatability standard deviation by a co-efficient equal to 1.96) (Source – Measurement Uncertainty)

+++++ = Similar to test method for Fluorine and SO₃/H₂SO₄ which is about 25%

Sources: *Measurement Uncertainty – implications for the enforcement of emission limits* by Maciek Lewandowski (Environment Agency) & Michael Woodfield (AEAT) UK

Technical Guidance Note (Monitoring) M2 Monitoring of stack emissions to air Environment Agency Version 3.1 June 2005.

APPENDIX A – EMISSION TEST RESULTS

Glossary:

%	=	percent
°C	=	Degrees Celsius
am ³ /min	=	cubic metre of gas at actual conditions per minute
Normal Volume (m ³)	=	cubic metre at 0°C and 760 mm pressure and 1 atmosphere
am ³	=	cubic metre of gas at actual conditions
g/g mole	=	grams per gram mole
g/s	=	grams per second
hrs	=	hours
kg/m ³	=	kilograms per cubic metre
kPa	=	kilo Pascals
m ²	=	square metre
m/s	=	metre per second
m ³ /sec	=	cubic metre per second at 0°C and 1 atmosphere
mg	=	milligrams
mg/ m ³	=	milligrams per cubic metre at 0°C and 1 atmosphere
O ₂	=	Oxygen

Abbreviations of Parameters

H ₂ S	=	Hydrogen Sulphide
SO ₃ /H ₂ SO ₄	=	Sulphur Trioxide/ Sulphuric Acid Mist

Abbreviations of Personnel

PWS	=	Peter Stephenson
JW	=	Jay Weber
AP	=	Alok Pradhan
AM	=	Argyll McGhie

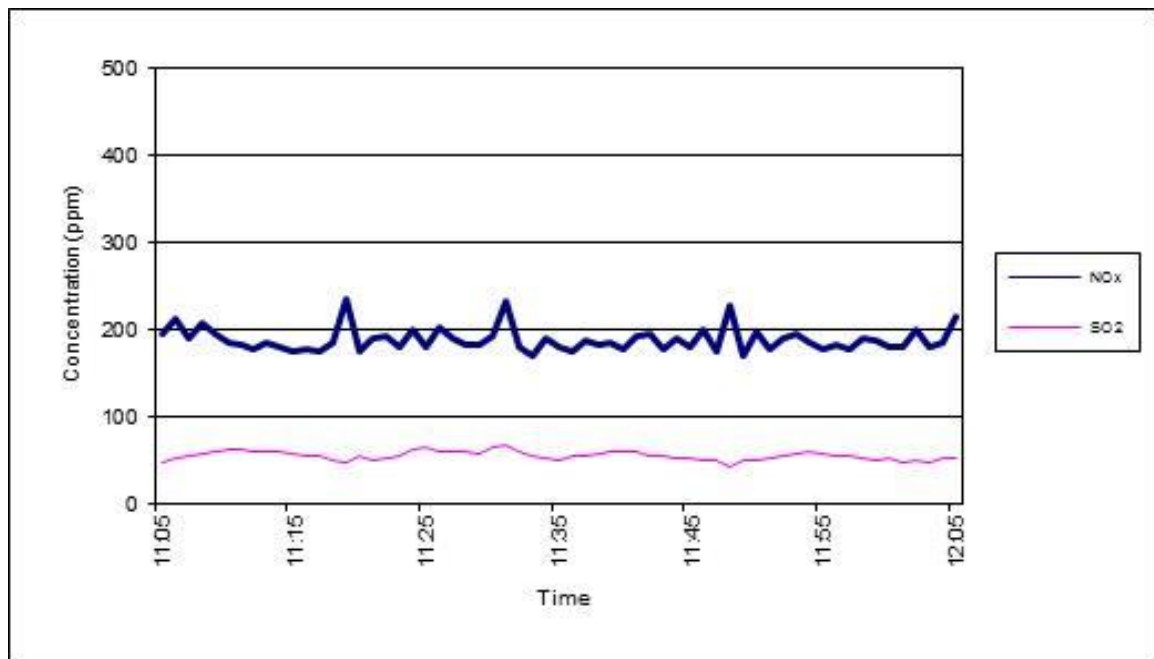
TABLE A-1 DETAILED EMISSION TEST RESULTS – GENERATOR NO. 3

Emission Test Results	SO₃/H₂SO₄	H₂S
Project Number	5474	5474
Project Name	Veolia Environmental Services	Veolia Environmental Services
Test Location	Generator No.3 EPA Point 8.3	Generator No.3 EPA Point 8.3
Date	23-Mar-2015	23-Mar-2015
RUN	1	1
Sample Start Time (hrs)	11:22	10:55
Sample Finish Time (hrs)	12:22	13:30
Sample Location (Inlet/Exhaust)	Exhaust	Exhaust
Stack Temperature (°C)	451.0	451.0
Stack Cross-Sectional area (m ²)	0.096	0.096
Average Stack Gas Velocity (m/s)	44.0	43.4
Actual Gas Flow Volume (am ³ /min)	254	251
Total Normal Gas Flow Volume (m ³ /min)	90	95
Total Normal Gas Flow Volume (m ³ /sec)	1.50	1.58
Total Stack Pressure (kPa)	101.31	101.31
Analysis	SO ₃ /H ₂ SO ₄	H ₂ S
Method	TM-3	USEPA M11
SEMA Lab Number	724633	724635
Mass In Sample (mg)	11.00	< 0.1
Air Volume Sampled (am ³)	1.04	0.30
Normal Sample Volume (m ³)	0.96	0.28
Concentration at Stack O₂ (mg/m³)	11.49	< 0.362
Mass Emission Rate (g/s)	0.02	< 0.0006
Moisture Content (% by volume)	6.3	NA
Molecular Weight Dry Stack Gas (g/g-mole)	30.168	30.168
Dry Gas Density (kg/m ³)	1.35	1.35
EPL Limit (mg/m³)	100	5
Isokinetic Sampling Rate (%)	96.5	NA
Sample Storage Period	Consumed in Analysis	Consumed in Analysis
Sampling Performed by	JW, AM	JW, AM
Sample Analysed by (Laboratory)	ALS	ALS
Calculations Entered by	JW	JW
Calculations Checked by	AN	AN

APPENDIX B – CONTINUOUS LOGS

**REPRESENTATIVE SECTION OF CHART SHOWING CONCENTRATIONS OF SULPHUR DIOXIDE AND
OXIDES OF NITROGEN**

FIGURE B-1 CONTINUOUS LOGGED RECORD OF SO₂ & NO_x – GENERATOR NO. 3 – 23 MARCH 2015



APPENDIX C – NATA EMISSION TEST REPORT INCLUDING CERTIFICATES OF ANALYSIS



Stephenson

Environmental Management Australia

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Emission Test Report No. 5474

The sampling and analysis was commissioned by:

Client

Organisation: Veolia Environmental Services
Contact: Amila Wijedasa
Address: 610 Collector Road, Tarago, NSW 2850
Telephone: 02 4844 6262
Email: Amila.Wijedasa@veolia.com

Project Number: 5474/S23614A/15
Test Date(s): 23 March 2015
Production Conditions: Normal operating conditions during testing

Analysis Requested: Flow, temperature, moisture, dry gas density, molecular weight of stack gases, Carbon Monoxide, Carbon Dioxide, Hydrogen Sulphide, Oxygen, Nitrogen Oxides, Sulphur Dioxide, Sulphur Trioxide/Sulphuric Acid Mist, and Volatile Organic Compounds

Sample Locations: Generator No.3 Stack
Sample ID Nos.: Refer to Attachment A



Accredited for Compliance with ISO/IEC 17025

Identification	The samples are labelled individually. Each label recorded the testing laboratory, sample number, sampling location (or Identification) sampling date and time and whether further analysis is required.	
Test	Test Method Number for Sampling and Analysis	NATA Laboratory Analysis By: NATA Accreditation No. & Report No.
Carbon Dioxide	TM-24, USEPA M3A	SEMA, Accreditation No. 15043, Emission Test Report 5474
Carbon Monoxide	TM-32, USEPA M10	SEMA, Accreditation No. 15043, Emission Test Report 5474
Dry Gas Density	NSW TM-23, USEPA M3	SEMA, Accreditation No. 15043, Emission Test Report 5474
Flow	NSW TM-2, USEPA M2	SEMA, Accreditation No. 15043, Emission Test Report 5474
Hydrogen Sulphide	NSW TM-5, USEPA M11	ALS Environmental, Accreditation No. 825, Report No. EN1510991
Moisture	NSW TM-22, USEPA M4	SEMA, Accreditation No. 15043, Emission Test Report 5474
Molecular Weight of Stack Gases	NSW TM-23, USEPA M3	SEMA, Accreditation No. 15043, Emission Test Report 5474
Oxides of Nitrogen	NSW TM-11, USEPA M7E	SEMA, Accreditation No. 15043, Emission Test Report 5474
Oxygen	NSW TM-25, USEPA M3A	SEMA, Accreditation No. 15043, Emission Test Report 5474
Stack Temperature	NSW TM-2, USEPA M2	SEMA, Accreditation No. 15043, Emission Test Report 5474
Sulphur Dioxide	NSW TM-4, USEPA M6C	SEMA, Accreditation No. 15043, Emission Test Report 5474

Sulphuric Acid Mist	NSW TM-3, USEPA M8	ALS Environmental, Accreditation No. 825, Report No. EN1510991
Velocity	NSW TM-2, USEPA M2	SEMA, Accreditation No. 15043, Emission Test Report 5474
Volatile Organic Compounds	NSW TM-34, USEPA M18	WorkCover, Accreditation No. 3726, Report No. 2015-1135
Deviations from Test Methods	Nil	
Sampling Times	NSW - As per Test Method requirements or if not specified in the Test Method then as per Protection of the Environment Operations (Clean Air) Regulations Part 2.	
Reference Conditions	NSW - As per (1) Environment Protection Licence conditions, or (2) Part 3 of the Protection of the Environment Operations (Clean Air) Regulations	

All associated NATA endorsed Test Reports/Certificates of Analysis are provided separately in Attachment A.

Issue Date
8 April 2015



P W Stephenson
Managing Director

SUMMARY OF THE AVERAGE EMISSION RESULTS – TEST REPORT NO. 5474

Pollutant	Units	Generator No. 3 EPL Point 8-3
		23/03/2015
Dry Gas Density	kg/m ³	1.35
Moisture content	%	6.3
Molecular weight of stack gases	g/g mole	30.17
Temperature	°C	451
Velocity	m/s	44.0
Volumetric Flow Rate	m ³ /s	1.50
Carbon Dioxide	%	11.5
Carbon Monoxide	mg/m ³	870
Hydrogen Sulphide	mg/m ³	<0.362
Nitrogen Oxides @ 7% O ₂	mg/m ³	425
Oxygen (O ₂)	%	8.2
Sulphur Trioxide / Sulphuric Acid Mist	mg/m ³	11.5
Sulphur Dioxide	mg/m ³	161
Volatile Organic Compounds as n-propane	mg/m ³	0.16

Key:

*	=	corrected to 7% O ₂ (oxygen)
°C	=	degrees Celsius
<	=	less than
%	=	percentage
kg/m ³	=	kilograms per cubic metre
g/g mole	=	grams per gram mole
m ³ /s	=	dry cubic metre per second 0°C and 101.3 kilopascals (kpa)
m/s	=	metres per second
mg/m ³	=	milligrams per cubic metre at 0°C and 101.3 kilopascals (kpa)

ESTIMATED UNCERTAINTY OF MEASUREMENT

Pollutant	Methods	Uncertainty
Carbon Monoxide	TM-32, USEPA M10	15%
Hydrogen Sulphide	TM-5, USEPA 11	25% ++++
Moisture	AS4323.2, TM-22, USEPA 4	25%
Nitrogen Oxides	TM-11, USEPA 7E	15%
Oxygen and Carbon Dioxide	TM-24, TM-25, USEPA 3A	1% actual
Sulphur Dioxide	TM-4, USEPA 6C	15%
Sulphur Trioxide/Sulphuric Acid Mist (SO ₃ /H ₂ SO ₄)	TM-3, USEPA 8	20%
Velocity	AS4323.1, TM-2, USEPA 2	5%
Volatile Organic Compounds (adsorption tube)	TM-34, USEPA 18	25%

Key:

Unless otherwise indicated the uncertainties quoted have been determined @ 95% level of Confidence level (i.e. by multiplying the repeatability standard deviation by a co-efficient equal to 1.96) (Source - Measurement Uncertainty)

++++ = Similar to test method for Fluorine and SO₃/H₂SO₄ which is about 25%

Sources: *Measurement Uncertainty - implications for the enforcement of emission limits* by Maciek Lewandowski (Environment Agency) & Michael Woodfield (AEAT) UK

Technical Guidance Note (Monitoring) M2 Monitoring of stack emissions to air Environment Agency Version 3.1 June 2005.

ATTACHMENT A – NATA CERTIFICATES OF ANALYSIS



CERTIFICATE OF ANALYSIS

Work Order	: EN1510991	Page	: 1 of 2
Client	: STEPHENSON ENVIRONMENTAL MANAGEMENT AUSTRALIA	Laboratory	: Environmental Division Newcastle
Contact	: MR PETER STEPHENSON	Contact	: Peter Keyte
Address	: UNIT 7/2 HOLKER STREET NEWINGTON NSW, AUSTRALIA 2127	Address	: 5595 Martland Road Mayfield West NSW Australia 2304
E-mail	: peter@stephensonnw.com.au	E-mail	: peter.keyte@alisglobal.com
Telephone	: +61 02 97379991	Telephone	: +61 2 4014 2500
Facsimile	: +61 02 97379993	Facsimile	: +61 2 4967 7382
Project	: 5474	QC Level	: NEPM 2013 Schedule B(3) and ALS OCS3 requirement
Order number	: 4353	Date Samples Received	: 25-Mar-2015 17:20
C-O-C number	: ---	Date Analysis Commenced	: 27-Mar-2015
Sampler	: ---	Issue Date	: 31-Mar-2015 20:59
Site	: ---	No. of samples received	: 4
Quote number	: ---	No. of samples analysed	: 4

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results



NATA Accredited Laboratory 825
Accredited for compliance with
ISO/IEC 17025.



Signatories

This document has been electronically signed by the authorized signatories indicated below. Electronic signing has been carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	Position	Accreditation Category
Merrin Avery	Supervisor - Inorganic	Newcastle - Inorganics



Page : 2 of 2
Work Order : EN1510991
Client : STEPHENSON ENVIRONMENTAL MANAGEMENT AUSTRALIA
Project : 5474

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key :

CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.

LOR = Limit of reporting

A = This result is computed from individual analyte detections at or above the level of reporting

g = ALS is not NATA accredited for these tests.

Analytical Results

Sub-Matrix: IMPINGER SOLUTION
(Matrix: AIR)

Sub-Matrix: IMPINGER SOLUTION (Matrix: AIR)		Client sample ID	
Compound	CAS Number	Client sampling date / time	
		LOR	Unit



CHEMICAL ANALYSIS BRANCH



Alok Pradhan
Stephenson Environmental Management Australia
PO Box 6398
SILVERWATER NSW 1811

Lab. Reference: 2015-1135

SAMPLE ORIGIN: Job No. 5474

DATE OF INVESTIGATION: 23/03/2015

DATE RECEIVED: 25/03/15

ANALYSIS REQUIRED: Volatile Organic Compounds

REPORT OF ANALYSIS

See attached sheet(s) for sample description and test results.

The results of this report have been approved by the signatory whose signature appears below.

For all administrative or account details please contact the Laboratory.

Martin Mazereeuw

Manager

Date: 1/04/15

WorkCover NSW Chemical Analysis Branch
ABN 77 682 742 966 L2, Bldg 1, 9-15 Chilvers Road Thornleigh NSW 2120 AUSTRALIA
T: +61 2 9473 4000 F: +61 2 9980 6849 E: lab@workcover.nsw.gov.au
WorkCover Assistance Service: 13 10 50 W: www.workcover.nsw.gov.au



Accreditation No. 3726

Accredited for compliance with ISO/IEC 17025



WorkCover



Analysis of Volatile Organic Compounds in Workplace Air by GC/MS

Client : Alok Pradhan

Sample ID : 724637

Sample : 2015-1135-1

No	Compounds	CAS No	Front	Back	No	Compounds	CAS No	Front	Back
			µg/section					µg/section	
Aliphatic hydrocarbons (LOD = 5µg/compound/section)					Aromatic hydrocarbons (LOD = 1µg/compound/section)				
1	2-Methylbutane	78-78-4	ND	ND	39	Benzene	71-43-2	2	ND
2	n-Pentane	109-66-0	ND	ND	40	Ethylbenzene	100-41-4	ND	ND
3	2-Methylpentane	107-83-5	ND	ND	41	Isopropylbenzene	98-82-8	ND	ND
4	3-Methylpentane	96-14-0	ND	ND	42	1,2,3-Trimethylbenzene	526-73-8	ND	ND
5	Cyclopentane	287-92-3	ND	ND	43	1,2,4-Trimethylbenzene	95-63-6	ND	ND
6	Methylcyclopentane	96-37-7	ND	ND	44	1,3,5-Trimethylbenzene	108-67-8	ND	ND
7	2,3-Dimethylpentane	565-59-3	ND	ND	45	Styrene	100-42-5	ND	ND
8	n-Hexane	110-54-3	ND	ND	46	Toluene	108-88-3	ND	ND
9	3-Methylhexane	589-34-4	ND	ND	47	p-Xylene &/or m-Xylene	106-21-2	ND	ND
10	Cyclohexane	110-82-7	ND	ND	48	o-Xylene	95-47-6	ND	ND
11	Methylcyclohexane	108-87-2	ND	ND	Ketones (LOD #49, #54 & #55 = 5µg/section, #48, #51, #52 & #53 = 25µg/section)				
12	2,2,4-Trimethylpentane	540-84-1	ND	ND	49	Acetone	67-64-1	ND	ND
13	n-Heptane	142-82-5	ND	ND	50	Acetoin	513-86-0	ND	ND
14	n-Octane	111-65-9	ND	ND	51	Diacetone alcohol	123-42-2	ND	ND
15	n-Nonane	111-84-2	ND	ND	52	Cyclohexanone	108-94-1	ND	ND
16	n-Decane	124-18-5	ND	ND	53	Isophorone	78-59-1	ND	ND
17	n-Undecane	1120-21-1	ND	ND	54	Methyl ethyl ketone (MEK)	78-93-3	ND	ND
18	n-Dodecane	112-10-3	ND	ND	55	Methyl isobutyl ketone (MIBK)	108-10-1	ND	ND
19	n-Tridecane	629-50-5	ND	ND	Alcohols (LOD = 25µg/compound/section)				
20	n-Tetradecane	629-50-1	ND	ND	56	Ethyl alcohol	64-17-5	ND	ND
21	α-Pinene	80-56-8	ND	ND	57	n-Butyl alcohol	71-36-3	ND	ND
22	β-Pinene	127-91-3	ND	ND	58	Isobutyl alcohol	78-83-1	ND	ND
23	D-Limonene	138-86-3	ND	ND	59	Isopropyl alcohol	67-63-0	ND	ND
Chlorinated hydrocarbons (LOD = 5µg/compound/section)					60	2-Ethyl hexanol	104-76-7	ND	ND
24	Dichloromethane	75-09-2	ND	ND	61	Cyclohexanol	108-93-0	ND	ND
25	1,1-Dichloroethane	75-34-3	ND	ND	Acetates (LOD = 25µg/compound/section)				
26	1,2-Dichloroethane	107-06-2	ND	ND	62	Ethyl acetate	141-78-6	ND	ND
27	Chloroform	67-66-3	ND	ND	63	n-Propyl acetate	109-60-4	ND	ND
28	1,1,1-Trichloroethane	71-55-6	ND	ND	64	n-Butyl acetate	123-86-4	ND	ND
29	1,1,2-Trichloroethane	79-00-5	ND	ND	65	Isobutyl acetate	110-19-0	ND	ND
30	Trichloroethylene	79-01-6	ND	ND	Ethers (LOD = 25µg/compound/section)				
31	Carbon tetrachloride	56-23-5	ND	ND	66	Ethyl ether	60-29-7	ND	ND
32	Perchloroethylene	127-18-4	ND	ND	67	tert-Butyl methyl ether oxmas	1634-04-4	ND	ND
33	1,1,2,2-Tetrachloroethane	79-34-5	ND	ND	68	Tetrahydrofuran (THF)	109-99-9	ND	ND
34	Chlorobenzene	108-90-7	ND	ND	Glycols (LOD = 25µg/compound/section)				
35	1,2-Dichlorobenzene	95-50-1	ND	ND	69	PGME	107-98-2	ND	ND
36	1,4-Dichlorobenzene	106-46-7	ND	ND	70	Ethylene glycol diethyl ether	629-14-1	ND	ND
Miscellaneous (LOD #37 = 5µg & #38 = 25µg/compound/section)					71	PGMEA	108-65-6	ND	ND
37	Acetonitrile	75-05-8	ND	ND	72	Cellosolve acetate	111-15-9	ND	ND
38	n-Vinyl-2-pyrrolidone	88-12-0	ND	ND	73	DGMEA	112-15-2	ND	ND
Total VOCs (LOD = 50µg/compound/section)					Worksheet check				
					YES YES				



WorkCover



Analysis of Volatile Organic Compounds in Workplace Air by GC/MS

Client : Alok Pradhan

Stephenson Environmental Management Australia

ND = Not Detected

VOCs = Volatile Organic Compounds

Method : Analysis of Volatile Organic Compounds in Workplace Air by Gas Chromatography/Mass Spectrometry

Method Number : WCA.207

Detection Limit : 5µg/section; 25µg/section for oxygenated hydrocarbons except acetone, MEK and MIBK at 5µg/section and aromatic hydrocarbon at 1µg/section

Brief Description : Volatile organic compounds are trapped from the workplace air onto charcoal tubes by the use of a personal air monitoring pump. The volatile organic compounds are then desorbed from the charcoal in the laboratory with CS₂. An aliquot of the desorbant is analysed by capillary gas chromatography with mass spectrometry detection.

The Total Volatile Organic Compounds (TVOC) test result in µg/section is calculated by combining the determined values of the 73 compounds with other VOCs that have been identified by mass spectrometry in the sample. These extra VOCs were individually estimated by the response of the nearest internal standard to that compound. Therefore, the TVOC test result should be interpreted as a semi-quantitative guide to the amount of VOCs present. If the TVOC test result is greater than the addition of all the compounds quantified then this can indicate that there are additional compounds present other than the 73 quantified compounds reported.

PGME : Propylene Glycol Monomethyl Ether

PGMEA : Propylene Glycol Monomethyl Ether Acetate

DGMEA : Diethylene Glycol Monoethyl Ether Acetate

Measurement Uncertainty

The measurement uncertainty is an estimate that characterises the range of values within which the true value is asserted to lie. The uncertainty estimate is an expanded uncertainty using a coverage factor of 2, which gives a level of confidence of approximately 95%. The estimate is compliant with the "ISO Guide to the Expression of Uncertainty in Measurement" and is a full estimate based on in-house method validation and quality control data.

Quality Assurance

In order to ensure the highest degree of accuracy and precision in our analytical results, we undertake extensive intra- and inter-laboratory quality assurance (QA) activities. Within our own laboratory, we analyse laboratory and field blanks and perform duplicate and repeat analysis of samples. Spiked QA samples are also included routinely in each run to ensure the accuracy of the analyses. WorkCover Laboratory Services has participated for many years in several national and international inter-laboratory comparison programs listed below:-

- Workplace Analysis Scheme for Proficiency (WASP) conducted by the Health & Safety Executive UK;
- Quality Management in Occupational and Environmental Medicine QA Program, conducted by the Institute for Occupational, Social and Environmental Medicine, University of Erlangen - Nuremberg, Germany;
- Quality Control Technologies QA Program, Australia;
- Royal College of Pathologists QA Program, Australia.

TestSafe Australia – WorkCover NSW Chemical Analysis Branch

WorkCover NSW ABN 77 682 742 966 L2, Building 1, 9-15 Chilvers Rd, Thornleigh, NSW 2120 Australia

Telephone: 61 2 9473 4000 Facsimile: 61 2 9980 6849 Email: lab@workcover.nsw.gov.au

Website: testsafe.com.au/chemical.asp WorkCover Assistance Service 13 10 50

WC03147NATA 0614

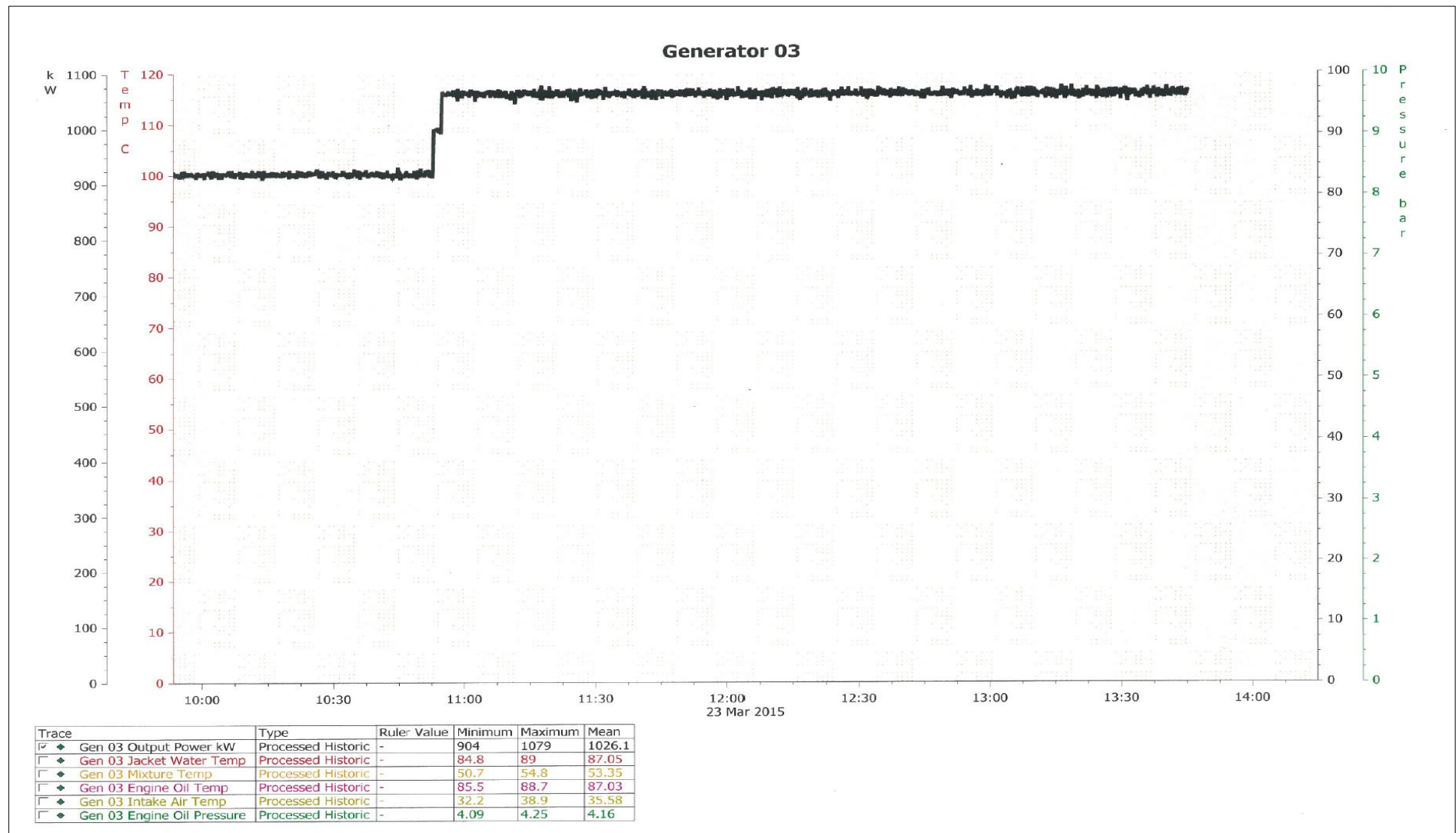


Accreditation No. 3726

Accredited for compliance with ISO/IEC 17025

APPENDIX D – PRODUCTION RECORDS

FIGURE D-1 GENERATOR NO.3 PRODUCTION DATA - 23 MARCH 2015



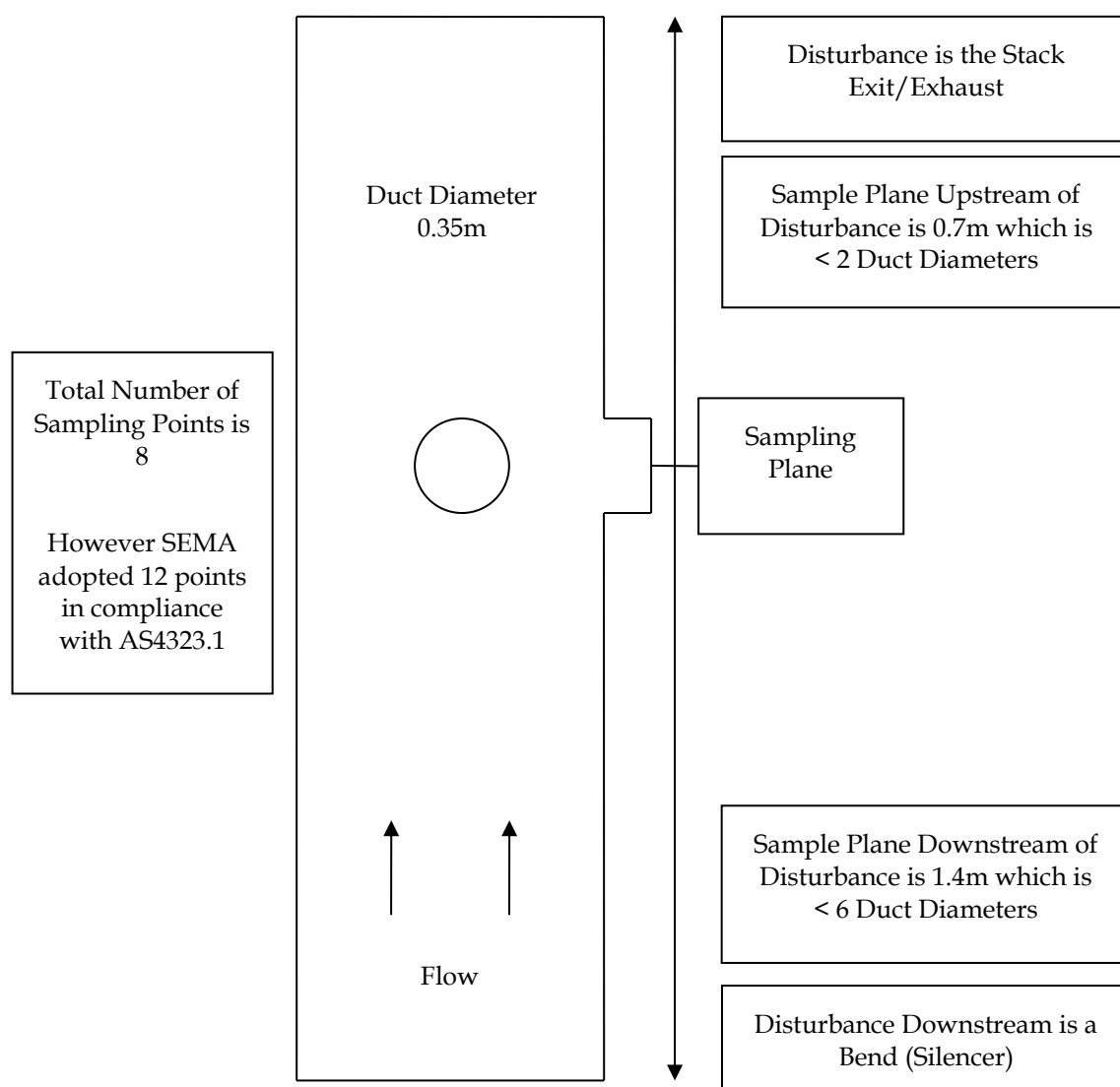
APPENDIX E – INSTRUMENT CALIBRATION INFORMATION

TABLE E-1 INSTRUMENT CALIBRATION DETAILS

SEMA Asset No.	Equipment Description	Date Last Calibrated	Calibration Due Date
910	Gas Meter	24-Apr-14	24-Apr-15
811	TESTO 350	03-Mar-15	03-Sep-15
905	Gas Meter	10-Jun-14	10-Jun-15
858	Digital Temperature Reader	27-Jan-15	27-Jul-15
720	Thermocouple	17-Nov-14	17-May-15
815	Digital Manometer	06-Mar-15	06-Mar-16
613	Barometer	02-Mar-15	02-Mar-16
695	Pitot	19-Jun-14	19-Jun-2015 Visually inspected On-Site before use
928	Balance		Response Check with SEMA Site Mass
633	Calibrated Site Mass	20-Aug-14	20-Aug-15
646	Stopwatch	02-Mar-15	02-Mar-16
754	Personal Sampler	30-Apr-14	30-Apr-15
Gas Mixtures used for Analyser Span Response			
Conc.	Mixture	Cylinder No.	Expiry Date
0.099% 9.8% 10.1%	Carbon Monoxide Carbon Dioxide Oxygen In Nitrogen	ALST 9799	19-Mar-19
243 ppm 247 ppm	Nitric Oxide Total Oxide Of Nitrogen In Nitrogen	ALTN1892	20-Aug-19
441 ppm 443 ppm	Nitric Oxide Total Oxide Of Nitrogen In Nitrogen	437883	04-Apr-17
385 ppm	Sulphur Dioxide In Nitrogen	ALTV4381	25-Oct-18
255 ppm	Sulphur Dioxide In Nitrogen	ALTM0020	11-Aug-19

APPENDIX F – SAMPLE LOCATION

FIGURE F-1 SAMPLE LOCATION – GENERATOR NO. 3



In the absence of cyclonic flow activity ideal sampling plane conditions will be found to exist at 6-8 duct diameters downstream and 2-3 duct diameters upstream from a flow disturbance. The sampling plane does not meet this criterion. Additional sample points were adopted in accordance with AS4323.1 to compensate for the non-ideal sampling plane.

However the sampling plane does meet the minimum requirements; sampling plane conditions will be found to exist at 2 duct diameters downstream and 0.5 duct diameters upstream from a flow disturbance.

The location of the sampling plane complies with AS4323.1 criteria for temperature, velocity and gas flow profile and therefore is satisfactory for gas flow sampling.



Odour Research Laboratories Australia

A Division of Peter W. Stephenson & Associates Pty Ltd
ACN 002 600 526 (Incorporated in NSW)

ABN 75 002 600 526

Newington Business Park
Unit 7/2 Holker Street
Newington NSW 2127 Australia
Tel: (02) 9737 9991
Fax: (02) 9737 9993
E-Mail: pstephenson@orla.com.au

Olfactometry Test Report

The measurement was commissioned by SEMA on behalf of:

Client	Organisation:	Veolia Environmental Services
	Address:	Woodlawn Bioreactor, 610 Collector Road Tarago NSW 2850
	Contact:	Stephen Bernhart
	Sampling Site:	Engine Genset #3
	Telephone:	(02) 9841 2932
	Email:	stephen.bernhart@veolia.com.au
Project	ORLA Report Number:	5487/ORLA/01
	Project Manager:	Peter Stephenson
	Testing operator:	Ali Naghizadeh
	ORLA Sample number(s):	4194, 4195, 4196
	SEMA Sample number(s):	724628, 724629, 724630
Order	Analysis Requested:	Odour Analysis
	Order requested by:	SEMA on behalf of Veolia Environmental Services
	Date of order:	24 March 2015
	Order number:	4352
	Telephone:	02 9737 9991
	Signed by:	Ali Naghizadeh
	Order accepted by:	Ali Naghizadeh
Report	Date of issue:	25 March 2015

NATA accredited laboratory number 15043.

Accredited for Compliance with ISO/IEC 17025.



Investigated Item	Odour concentration in odour units 'ou' determined by Sensory odour concentration measurements, of an odour sample supplied in a sampling bag. All samples were received in good condition.
Analysis Method	The samples were analysed in accordance with AS/NZS4323.3:2001.
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 n-butanol calibration. Any deviation from the Australian standard is recorded in the 'Comments' section of this report.
Instrument Used	The Olfactometer used during this testing session was: AC'SCENT International Olfactometer
Measuring Range	The measuring range of the AC'SCENT International olfactometer is $12 \leq \chi \leq 78,172$ ou. If the measuring range was insufficient the odour samples will have been pre-diluted.
Environment	The measurements were performed in an air- and odour-conditioned room. The room temperature is maintained between $\pm 3^{\circ}\text{C}$.
Measuring Dates	The date of each measurement is specified with the results.
Instrument Precision	The precision of this instrument (expressed as repeatability) for a sensory calibration must be $r \leq 0.05$ in accordance with the Australian Standard AS/NZS4323.3:2001. AC'SCENT International Olfactometer: $r = 0.0038$ (February 2015) Compliance - Yes
Instrumental Accuracy	The accuracy of this instrument for a sensory calibration must be $A \leq 0.20$ in accordance with the Australian Standard AS/NZS4323.3:2001. AC'SCENT International Olfactometer: $A = 0.097$ (February 2015) Compliance - Yes
Lower Detection Limit (LDL)	The LDL for the AC'SCENT International Olfactometer has been determined to be 12 ou
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 every session to keep within the limits of the standard. The results from the assessors are traceable to primary standards of n-butanol in nitrogen.

25 March 2015



Peter Stephenson
Managing Director



Odour Olfactometry Results - 5487/ORLA/01

Sample Location	Sample ID No.	Sampling Date & Time	ORLA Sample No.	Analysis Date & Time (Completed)	Panel Size	Valid ITEs	Sample Pre-Dilution	Sample Odour Concentration (ou) ¹	Sample Odour Concentration (ou) ²	Odour Character & Hedonic Tone ^{^ +}
Sample ID: Engine 3 - R1	724628	23/03/2015 1005-1015	4194	24/03/2015 1008-1030	4	8	Nil	1,721	1,721	Sharp, slight car exhaust odour, kerosene, sulphur, acid, vinegar, chemical, septic, cleaning fluid (-2.8) [^]
Sample ID: Engine 3 - R2	724629	23/03/2015 1120-1130	4195	24/03/2015 1033-1100	4	8	Nil	1,314	1,314	Car exhaust, kerosene, pool chlorine, acid, vinegar, sharp, chemical, septic, cleaning fluid (-2.8) [^]
Sample ID: Engine 3 - R3	724630	24/03/2015 1230-1240	4196	24/03/2015 1105-1130	4	8	Nil	1,901	1,901	Exhaust, slightly yeasty, pool chlorine, acid vinegar, sharp, chemical, septic, cleaning fluid (-2.5) [^]



Odour Panel Calibration Results – 5487/ORLA/01

Reference Odorant	ORLA Sample No.	Concentration of Reference Gas (ppm)	Reference Gas Measured Concentration (ou)	Panel Average Measured Concentration (ppb) ³	Does this panel calibration measurement comply with AS/NZS4323.3:P2001 (Yes/No) ⁴
n-butanol	4192	41	1,333	30.8	Yes

Comments: All samples were collected by Stephenson Environmental Management Australia and analysed by Odour Research Laboratories Australia at their Sydney Laboratory.

Notes from Odour Olfactometry Results:

¹ Sample Odour Concentration: as received in the bag

² Sample Odour Concentration: allowing for pre-dilution

³ Panel Average Measured Concentration: indicates the sensitivity of the panel for the session completed

⁴ Target Range for reference gas n-butanol is $20 \leq \chi \leq 80$ ppb and compliance with AS/NZ4323.3:2001 is based on the individuals rolling average and not on the panel average measured concentration. Panellist Rolling Average: PR = 44.7, DS = 32.7, TL = 37.5, AP = 26.6

[^] denotes the Average Hedonic Tone: describes the pleasantness of the odour being presented where (+5) represents Very Pleasant, (0) represents Neutral and (-5) represents Very Unpleasant and has been derived from the panellist responses at the recognition threshold.

+ This value is not part of our NATA Scope of Accreditation and AS4323.3

-----END OF TEST REPORT-----



LEACHATE TREATMENT QUALITY DATA

Raw Leachate	Units	Feb-14	Mar-14	Jul-14	Aug-14	Oct-14
Date		7/02/2014	25/03/2014	3/07/2014	12/08/2014	20/10/2014
Field Readings						
pH		8.3	8.34	7.84	8.06	
DO	mg/L	0.07		0.18	0.15	
Conductivity	uS/cm	32100	32300	N/A	34700	
Temperature	C	23.2	17.8	8.6	8.9	
Organics						
COD	mg/L	6726	5870	> Detection Limit	9650	
BOD	mg/L		755	515	478	
TOC	mg/L		1770			
VFA	mg/L	1193		210	4600	
Phosphorous						
Ortho Phosphorous	mg/L					
Total phosphorous	mg/L		20.8			
Sulphur Compounds						
Sulphate	mg/L	500		Below detection		
Sulphide	mg/L	17.4		10.94	4.8	
Sulphite	mg/L			83.2	122	
Nitrogen Compounds						
Ammonia	mg/L	2450	3090	3670	1580	
TKN	mg/L		3510	3770	3660	
Total Oxydised Nitrogen (Nitrate + Nitrite)	mg/L		0.399	0.74	0.63	
Total Nitrogen	mg/L		3510	3770	3660	
Nitrite	mg/L					
Nitrate	mg/L					
Others						
Total Alkalinity	mg/L		14200	16000	16700	
TSS	mg/L		467	162	74	
VSS	%			95	71	

Aeration Pond		Feb-13	Feb-13	Feb-13	Mar-13	Apr-13	Apr-13	Apr-13	May-13	May-13	May-13	Jun-13	Jun-13	Jun-14	Mar-14	Apr-14	May-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14
Date	Units	5/2/2013	14/2/2013	20/2/2013	1/3/2013	4/4/2013	9/4/2013	18/4/2013	9/5/2013	16/5/2013	30/5/2013	6/6/2013	13/6/2013	23/6/2014	30/3/2014	14/4/2014	27/5/2014	30/7/2014	12/8/2014		20-Oct		
Field Reading																							
pH		9.2	9.04	9.11	9.06	8.9	9.1	9.33	8.7	8.83	9.04	9.05				7.82							
DO	mg/L	8.8	3.04	7.78	8.51		9.1	9.12	8.35	-	-	9.76				6.96							
Conductivity	uS/cm	25009	25900	24800	23400		23800	25400	23800	23000	21610	21080				21580							
Temperature	C															16.6							
Organics																							
COD	mg/L	5500	5622	5400	5245	5100	4800	-	6000	4681	4934	5234	4619										6880
BOD								39		150	72	66	70				190	240					154
TOC	mg/L	-	-	2900	-	2600	2200	2600	2840				2180										
VFA	mg/L	641	397	480	389				900	419	368	350	397										980
Phosphorous																							
Ortho Phosphorous	mg/L													3.1	2.63	4.1	4.69	19.6	20	6.84			10.2
Total phosphorous	mg/L	7.3	-	7	-	8.7	8.1	15	2		11												
Sulphur Compounds																							
Sulphate	mg/L	3400	4400	3500	3800	3500	3400		2300	1300	1200	1400	1100			1100							342
Sulphide	mg/L	3	-	0.5	-	0.7	0.55	2.6	0.99	-	1.4	0.61	0.54			0.83							<0.02
Sulphite	mg/L	-	-	-	-	25	25	25		-	-	-	-				6.1	11					17.1
Nitrogen Compounds																							
Ammonia	mg/L	370	293	230	155	69	60		136	240	142	158	190										1180
TKN	mg/L					< 1	< 1	< 0.69		147							800	1160					1420
Total Oxidised Nitrogen (Nitrate + Nitrite)	mg/L					< 5	< 5	< 0.01	34.6	25.4							1520	1940					
Total Nitrogen																	2520	3100					2930
Others																							
Total Alkalinity	mg/L	6550	-	5720	-	4930	4940	6980		-	-						614	1819					2720
TSS	mg/L	690	-	410	-	1160	1600	1900		1300	580	660	250		603	138	3030	854	357	362			368
YSS	%	58	-	54	-	16	54	48		57	68		70				61	63	345	60			256

ED3N-1		Jan-14	Apr-14	May-14	Jul-14	Aug-14
Date	Units	23/01/2014	14/04/2014	27/05/2014	3/07/2014	12/08/2014
Field Readings						
pH		8.39	8.6		8.42	8.45
DO	mg/L	4.41	7.09		6.66	3.08
Conductivity	uS/cm	26900	23800		25000	25700
Temperature	C	15.8	16.4		8.6	7.8
Organics						
COD	mg/L	5656	6015		5946	5042
BOD	mg/L	58	41	33	14	32
VFA	mg/L	352	408		78	540
Sulphur Compounds						
Sulphate	mg/L	700	2700		3100	
Sulphide	mg/L	0.47	0.26		0.27	0.19
Sulphite	mg/L	49	34.2	13.4	13.4	12.2
Nitrogen Compounds						
Ammonia	mg/L	137	83.3		84.4	
TKN	mg/L	430	352	364	345	308
Total Oxidised Nitrogen (Nitrate + Nitrite)	mg/L	<0.5	76.4	126	177	176
Total Nitrogen	mg/L	430	428	490	522	484
Nitrite	mg/L					
Nitrate	mg/L					
Others						
Total Alkalinity	mg/L	6720	5700	5200	4990	4960
TSS	mg/L	80	80	92	203	43
VSS	%			46	103	77
TDS	mg/L	24800				

ED3N-2		Aug-14	Sep-14	Oct-14	Nov-14	Dec-14
Date		12/08/2014				
Field Readings						
pH		8.15				
DO	mg/L	2.92				
Conductivity	uS/cm	25900				
Temperature	C	7.8				
Organics						
COD	mg/L	6811				
BOD	mg/L	168				
VFA	mg/L	741				
Sulphur Compounds						
Sulphate	mg/L					
Sulphide	mg/L					
Sulphite	mg/L	12.2				
Nitrogen Compounds						
Ammonia	mg/L					
TKN	mg/L	1220				
Total Oxydised Nitrogen (Nitrate + Nitrite)	mg/L	1590				
Total Nitrogen		2810				
Nitrite	mg/L					
Nitrate	mg/L					
Others						
Total Alkalinity	mg/L	5340				
TSS	mg/L	152				
VSS	%	63				

ED3N-3		Apr-13	Jun-13	Jul-13	Aug-13	Sep-13	Nov-13	Jan-14	Apr-14	May-14	Jul-14	Aug-14		
Date	Units	18/04/2013	6/06/2013	11/07/2013	22/08/2013	12/09/2013	21/11/2013	23/01/2014	14/04/2014	27/05/2014	3/07/2014	12/08/2014		
Field Readings														
pH			8.77		9.06	8.9	8.74	8.42	8.65		8.25	8.17		
DO	mg/L		4.8		4.41	7.1	1.49	4.38	2.05		3.14	1.02		
Conductivity	uS/cm		32900		24300	23000	22600	23700	21470		N/A	23400		
Temperature	C				6.5		20	15.8	16.5		8.6	7		
Organics														
COD	mg/L	8407	7593			4212	4629	5326	5311		6946	5240		
BOD		120	110	18		33	46	53	100	56	49	18		
TOC	mg/L	3600	3600											
VFA	mg/L	301			249	403	384	471	419		138	656		
Sulphur Compounds														
Sulphate	mg/L	7600	6300		3400	3100	3000	700	2500		3000			
Sulphide	mg/L	0.6	0.6		0.32	0.28	0.69	0.53	0.22	11	0.36			
Sulphite	mg/L	25	25			25	88	39.2	44		12.2	9.8		
Nitrogen Compounds														
Ammonia	mg/L	80.9	51.3		86.2	87	354	303	185		222			
TKN	mg/L					360	630	544	425	467	416	405		
Total Oxydised Nitrogen (Nitrate + Nitrite)	mg/L					0.3	<0.5	<0.5	415	543	724	665		
Total Nitrogen	mg/L								840	1010	1140	1070		
Nitrite	mg/L	0.42												
Nitrate	mg/L	<0.01												
Others														
Total Alkalinity	mg/L	6480	6480	5130		5500	5760	6360	4160	3010	3480	2710		
TSS	mg/L	110	180	160		92	100	99	111	112	142	146		
VSS	%	56	62	56		72	83			64	86	48		
TDS	mg/L							20100						



LANDFILL GAS PRODUCTION DATA:

OCTOBER 2014 – OCTOBER 2015

Landfill gas production data

October 2014 - October 2015

Date	Generation		
	LFG m ³	CH4 %	CH4 m ³
Oct-14	1692300.00	56.36	953780.28
Nov-14	1615424.00	60.91	983954.76
Dec-14	1697520.00	60.04	1019191.01
Jan-15	1318888.00	62.17	819952.67
Feb-15	1649584.00	57.07	941417.59
Mar-15	1940816.00	52.16	1012329.63
Apr-15	2271800.00	49.60	1126812.80
May-15	2161536.00	47.61	1029107.29
Jun-15	2177680.00	46.91	1021549.69
Jul-15	2234096.00	48.56	1084877.02
Aug-15	2238960.00	51.15	1145228.04
Sep-15	1953216.00	51.70	1009812.67
Oct-15	1894016.00	50.39	954394.66

Date	Flared		
	LFG m ³	CH4 %	CH4 m ³
Oct-14	58785	56.36	33131.23
Nov-14	105065	60.91	63995.09
Dec-14	146973	60.04	88242.59
Jan-15	177145	62.17	110131.05
Feb-15	65095	57.07	37149.72
Mar-15	73028	52.16	38091.40
Apr-15	97607	49.6	48413.07
May-15	46482	47.61	22130.08
Jun-15	57830	46.91	27128.05
Jul-15	51760	48.56	25134.66
Aug-15	66123	51.15	33821.91
Sep-15	43291	51.7	22381.45
Oct-15	40891	50.39	20604.97

Date	TOTAL	
	LFG m ³	CH4 m ³
Oct-14	1751085.00	986911.51
Nov-14	1720489.00	1047949.85
Dec-14	1844493.00	1107433.60
Jan-15	1496033.00	930083.72
Feb-15	1714679.00	978567.31
Mar-15	2013844.00	1050421.03
Apr-15	2369407.00	1175225.87
May-15	2208018.00	1051237.37
Jun-15	2235510.00	1048677.74
Jul-15	2285856.00	1110011.67
Aug-15	2305083.00	1179049.95
Sep-15	1996507.00	1032194.12
Oct-15	1934907.00	974999.64



APPENDIX D:

LIQUID ODOUR MEASUREMENT METHODOLOGY

Methodology

The Liquid Odour Method (LOM) is comprised of the following components:

- Evaporation of a known amount of liquid in a known volume of dry nitrogen contained in a Nalophan odour sample bag;
- Determination of the odour concentration of the gaseous sample by Dynamic Dilution Olfactometry following AS/NZS 4323.3:2001; and
- Calculation of the odour concentration in the liquid from the gaseous odour concentration (ou/m^3) and the volume of liquid evaporated to produce the gaseous sample.

Procedure

Liquid Sample Storage

The liquid samples analysed from the Woodlawn Bioreactor Facility were collected from stored leachate in lagoons ED3N-1, ED3N-2 and ED3N-3. These were refrigerated prior to testing. A liquid sample was extracted immediately from the refrigerated sample bottle and not allowed to warm to room temperature. This is the general procedure when carrying out the liquid odour measurement method for aqueous samples.

Liquid Sample Size

The volume of liquid is determined by the requirement to produce a gaseous sample with relative humidity of less than 100%. This equates to less than 2.3% v/v water at 20° C, or for a 25 L sample, 413 μL of aqueous sample. The method development work carried out to date has shown that 413 μL of liquid sample in 25 L dry nitrogen will evaporate in approximately 30 mins. The nominal liquid sample size required for the Liquid Odour method can be specified as 340-413 μL , which provides a gaseous sample with 80-100% RH. For the liquids samples collected at the Woodlawn Bioreactor Facility, 413 μL of liquid sample was used in 25 L dry nitrogen.

Table D1 details a range of liquid volumes and approximate evaporation times observed from the method development work carried out to date.

Table D1 - Liquid sample volumes, evaporation and equilibration time		
Volume μL (% saturation)	Approximate evaporation time (in 25 L dry nitrogen)	Recommended equilibration time (in 25 L dry nitrogen)
280 μL (60%)	20-30 min	60 min
340 μL (80%)	30-40 min	60 min
413 μL (100%)	40-60 min	60 min

Sample Equilibration and Ageing

The development work to date has shown that condensate derived odour samples are not stable and degrade significantly over time. However, the degradation appears insignificant in the first 2-4 hours after preparation of the gaseous samples. Therefore, samples must be tested within that time period after preparation. For samples prepared at 100% saturation or below, the equilibration time can be standardised to 1 hour.

Sample Preparation and Odour Testing Procedure

The gaseous sample for odour testing is prepared as follows:

1. Dispense 25 L of dry nitrogen into a conditioned Nalophan bag.
2. Place a piece of clear packaging tape (approximately 100 mm long) onto the wall of the bag half way between the ends. Ensure that the a least a 1 cm² section of tape is completely adhered to the bag with no air bubbles trapped between the tape and bag that could allow a leak of gas to the edge of the tape
3. Remove the liquid sample from cold storage.
4. Rinse the microlitre syringe (5 x) with the liquid sample.
5. Draw up the required volume of liquid sample (see **Liquid Sample Size and Table D1**) and record the exact volume in the syringe.
6. Inject the liquid through the tape and wall of the bag at the point where the tape has completely adhered to the bag. Tap the syringe to displace residual drop that adheres to the needle and withdraw the syringe from the bag.
7. Place a second piece of packaging tape over the first piece such that the puncture hole is sealed. Ensure no air bubbles are trapped between the layers of tape such that a leak could occur.
8. Vigorously shake the bag to disperse the liquid droplets inside the bag (to aid in the evaporation rate).
9. Store the bag in the laboratory for the prescribed equilibration time (see **Sample Equilibration and Ageing and Table D1**) to allow all the liquid to evaporate.
10. At the completion of the equilibration time, carry out the measurement of odour concentration using AS/NZS 4323.3:2001.

Calculation of Liquid Odour Concentration

The odour concentration from a liquid (ou per mL) is calculated from the gaseous sample odour concentration, the volume of liquid used to prepare the gaseous sample and the volume of dry nitrogen:

$$[odour]_{liquid} = \frac{\left(\frac{OU}{m^3} \times \frac{\text{litres}_{Nitrogen}}{1000} \right)}{mL_{liquid}}$$

An example of the calculation is presented in **Table D2**.

Table D2 – Example calculation of liquid odour concentration for ED3N-1		
Parameter	Value	Unit
Volume of liquid from ED3N-1	0.413	mL
Volume of dry N₂	25	L
Measured odour concentration	118 [^]	ou
Calculated liquid odour concentration	$= (118 \times 25/1000)/0.413$ $= 7.14$	ou.m ³ /mL

[^] TOU Sample Number SC15553 – see **Table 6.5** in Main Report

Calculation of Odour Emission Rates from Evaporation of Liquids

A primary driver for development of a liquid odour measurement is the requirement to predict odour emission rates from liquids area sources (such as storage ponds) as well as condensates. In particular, evaporation of condensates or other odorous refinery waters in cooling towers has been implicated as a significant contributor to refinery odour. With a measurement of the odour from liquids now available, the estimation of emission rates can be considered.

An example is presented below for treated leachate stored in ED3N-1 which returned a measured odour concentration of 7.14 ou.m³/mL (see **Table D2**) with an evaporation rate of 0.212 L/sec (based on on-site evaporation data collected by Veolia between May 2007 and June 2012):

Odour concentration	= 7.14 ou.m ³ /mL
Ambient pond evaporation rate	= 0.212 L/sec
Odour emission rate	= 7.14 ou.m ³ /mL x 212 mL/sec
	= 1,510 ou.m ³ /sec (see Table 6.5 in Main Report)



APPENDIX E:

ODOUR DIARY ENTRIES SUMMARY TABLES

Document title: Summary table of odour diary entries										
Resident ID: A (Diary #2)										
Diary Entry No.	Date	Time	Wind direction	Wind speed	Odour character	Other odour character	Odour detected	Odour offensiveness	Odour intensity	Duration
1	Oct-14	Morning		Calm	Garbage		1		1	Constant
2	Oct-14	Morning		Calm			0			
3	Oct-14	Dawn	N/D	Light	Garbage		1		3	
4	Oct-14	Morning	W	Light			0			
5	Oct-14	Morning		Calm			0			
6	Nov-14	Morning	W	Strong			0			
8	Nov-14	Morning	S	Light			0			
9	Nov-14	Morning		Calm			0			
10	Nov-14	Morning	E	Light			0			
11	Dec-14	Morning		Calm			0			
12	Dec-14	Morning	E	Light			0			
13	Dec-14	Morning		Calm			0			
14	Dec-14	Morning	E	Light			0			
15	Dec-14	Morning		Calm			0			
16	Dec-14	Morning	NW	Light			0			
17	Dec-14	Afternoon	NE	Gusting	Garbage		1		2	Constant
18	Dec-14	Morning	NW	Light			0			
19	Dec-14	Morning	E	Light			0			
20	Dec-14	Dawn	N	Light	Garbage		1		2	
21	Jan-15	Morning		Calm			0			
22	Jan-15	Morning	NE	Light			0			
23	Jan-15	Dawn	W	Steady			0			
24	Jan-15	Morning		Calm			0			
25	Jan-15	Morning	SE	Strong			0			
26	Jan-15	Morning	S	Light			0			
27	Feb-15	Morning		Calm			0			
28	Feb-15	Morning	N/D	Light			0			
29	Mar-15	Morning		Calm			0			
30	Mar-15	Morning		Calm			0			
31	Mar-15	Morning	N/D	Light			0			
32	Mar-15	Morning		Calm			0			
33	Mar-15	Midday		Calm	Garbage		1	Yes	2	
34	Apr-15	Morning	W	N/D			0			
35	Apr-15	Morning		Calm			0			
36	Apr-15	Morning		Calm			0			
37	Apr-15	Morning	SE	Strong			0			
38	May-15	Morning	E	Light			0			
39	May-15	Morning	W	Light			0			
40	May-15	Morning		Calm			0			
41	May-15	Morning		Calm			0			
42	May-15	Morning	W	N/D			0			
43	May-15	Morning	W	Light			0			
44	Jun-15	Morning		Calm			0			
45	Jun-15	Morning	N/D	Light			0			
46	Jun-15	Morning		Calm			0			
47	Jun-15	Morning		Calm			0			
48	Jul-15	Morning		Calm			0			
49	Jul-15	Morning	W	Light			0			

Document title: Summary table of odour diary entries										
Resident ID: B (Diary #3)										
Diary Entry No.	Date	Time	Wind direction	Wind speed	Odour character	Other odour character	Odour detected	Odour offensiveness	Odour intensity	Duration
23	Oct-14	Morning		Calm			0			
24	Oct-14	Dawn		Calm	Garbage		1		3	Constant
25	Oct-14	Morning	W	Light			0			
26	Nov-14	Morning	S	Steady			0			
27	Nov-14	Morning	NW	Light			0			
28	Nov-14	Morning		Calm			0			
29	Nov-14	Morning	NE	Steady			0			
30	Nov-14	Morning	W	Light			0			
31	Dec-14	Dawn	W	Light	Garbage		1	Yes	3	Constant
32	Dec-14	Morning	E	Light			0			
33	Dec-14	Morning	E	Light			0			
34	Dec-14	Morning	NE	Light			0			
35	Dec-14	Morning	W	Strong	Sewage		1		3	Constant
36	Jan-15	Morning	W	Light			0			
37	Jan-15	Morning	NE	Light			0			
38	Jan-15	Morning	N	Light			0			
39	Jan-15	Morning	NW	Light			0			
40	Jan-15	Evening	S	Light	Ammonia/fishy		1	Yes	3	Constant
41	Jan-15	Morning	S	Light			0			
42	Feb-15	Morning		Calm			0			
43	Feb-15	Morning	NE	Light			0			
44	Feb-15	Morning	E	Light			0			
45	Feb-15	Morning	SE	Light			0			
46	Mar-15	Dawn		Calm	Garbage		1	Yes	3	Constant
47	Mar-15	Evening	W	Steady	Garbage		1		2	Constant
48	Mar-15	Morning	N/D	Calm			0			
49	Mar-15		W	Light			0			
50	Mar-15	Morning	SE	Steady			0			
51	Mar-15	Evening	S	Light	Garbage		1		3	Constant
52	Mar-15	Morning		Calm			0			
53	Apr-15	Morning	E	Light			0			
54	Apr-15	Morning		Calm			0			
55	Apr-15	Morning	SE	Light			0			
56	Apr-15	Dawn	SW	Light	Garbage		1		2	Constant
57	Apr-15	Morning		Calm			0			
58	Apr-15	Afternoon	SW	Light	Garbage/Sewage		1	Yes	4	Constant
59	May-15	Morning	NE	Light			0			
60	May-15	Morning	W	Steady			0			
61	May-15	Morning	N	Light			0			
62	May-15	Morning		Calm			0			
63	May-15	Morning	N	Light			0			
64	Jun-15	Dawn		Calm	Garbage		1	Yes	5	Constant
65	Jun-15	Evening		Calm	Garbage	Smoke	1		3	Constant
66	Jun-15	Morning		Calm			0			
67	Jun-15	Evening	N	Light	Sewage		1		3	Constant
68	Jun-15	Morning	S	Light	Garbage		1		2	Intermittent
69	Jun-15	Morning		Calm			0			
70	Jun-15	Night	N	Light	Garbage		1	Yes	3	Constant
71	Jun-15	Morning		Calm			0			
72	Jun-15	Morning	N	Light	Garbage		1	Yes	4	Constant
73	Jun-15	Dawn	N	Light	Garbage		1	Yes	4	Constant
74	Jul-15	Morning	N	Light			0			
75	Jul-15	Morning	N	Light	Garbage		1	Yes	4	Constant

Document title: Summary table of odour diary entries										
Resident ID: C (Diary #4)										
Diary Entry No.	Date	Time	Wind direction	Wind speed	Odour character	Other odour character	Odour detected	Odour offensiveness	Odour intensity	Duration
21	Oct-14	Morning	W	Light			0			
22	Oct-14	Dawn	NW	Light	Garbage/Sewage		1	Yes	3	Constant
23	Oct-14	Dawn	SW	Light	Garbage		1	Yes	2	
24	Nov-14	Morning	NW	Light			0			
25	Nov-14	Morning		Calm			0			
26	Nov-14	Morning	NE	Steady			0			
27	Dec-14	Morning	NE	Light			0			
28	Dec-14	Morning	NE	Light			0			
29	Dec-14	Morning	NE	Light			0			
30	Dec-14	Morning	NE	Light			0			
31	Jan-15	Morning	NW	Light			0			
32	Jan-15	Morning	NE	Light			0			
33	Jan-15	Morning	NW	Light			0			
34	Jan-15	Morning	W	Light			0			
35	Jan-15	Morning		Calm			0			
36	Feb-15	Morning	N	Light			0			
37	Feb-15	Morning	NE	Light			0			
38	Feb-15	Morning	W	Light			0			
39	Feb-15	Morning	NE	Light			0			
40	Mar-15	Morning	NW	Light			0			
41	Mar-15	Morning	SW	Light			0			
42	Mar-15	Morning	SE	Steady			0			
43	Mar-15	Morning	W	Light			0			
44	Apr-15	Morning	SE	Light			0			
45	Apr-15	Morning	NE	Light			0			
46	Apr-15	Dawn		Calm	Garbage		1		3	Constant
47	Apr-15	Morning	W	Steady			0			
48	Apr-15	Morning	NE	Light			0			
49	May-15	Morning	NE	Light			0			
50	May-15	Morning	W	Steady			0			
51	May-15	Morning	SE	Light			0			
52	May-15	Morning	SW	Light			0			
53	May-15	Dawn	SW	Light	Garbage		1	Yes	2	Constant
54	May-15	Morning	NE	Light			0			
55	Jun-15	Night	W	Light	Other	Putrid	1	Yes	6	Constant
56	Jun-15	Dawn		Calm	Garbage		1	Yes	5	Constant
57	Jun-15	Dawn	W	Light	Garbage		1	Yes	2	Constant
58	Jun-15	Dawn	W	Light	Garbage		1	Yes	2	Constant
59	Jun-15	Morning	W	Light	Garbage		1	Yes	1	Constant
60	Jun-15	Morning		Calm	Garbage		1	Yes	3	Constant
61	Jun-15	Morning		Calm			0			
62	Jun-15	Dawn	W	Light	Garbage		1	Yes	1	Constant
63	Jun-15	Dawn	NW	Light	Garbage		1	Yes	2	Constant
64	Jun-15	Morning	NW	Light			0			
65	Jun-15	Dawn		Calm	Garbage		1	Yes	2	Constant
66	Jul-15	Morning	SW	Light			0			

Document title: Summary table of odour diary entries										
Resident ID: D (Diary #6)										
Diary Entry No.	Date	Time	Wind direction	Wind speed	Odour character	Other odour character	Odour detected	Odour offensiveness	Odour intensity	Duration
1	Oct-14	Morning	NE	N/D	Garbage		1	Yes	2	Constant
2	Nov-14	Morning	NE	Light	Garbage		1	Yes	3	Constant
3	Nov-14	Dawn	NE	N/D	Garbage		1	Yes	3	Constant
4	Nov-14	Night	NE	N/D	Garbage		1	Yes	6	Constant
5	Dec-14	Morning	NE	N/D	Garbage		1	Yes	3	Constant
6	Dec-14	Morning	NE	Light	Garbage		1	Yes	2	Constant
7	Dec-14	Dawn	NE	Light	Garbage		1	Yes	3	Constant
8	Dec-14	Morning	NE	Light	Garbage		1	Yes	4	Constant
9	Dec-14	Early	NE	Light	Garbage		1	Yes	4	Constant
10	Dec-14	Dawn	NE	Light	Garbage		1	Yes	4	Constant
11	Dec-14	Night	NE	Light	Garbage		1	Yes	2	Constant
12	Dec-14	Dawn	NE	Light	Garbage		1	Yes	3	Constant
13	Jan-15	Morning	NE	Light	Garbage		1	Yes	3	Constant
14	Jan-15	Night	NE	Light	Garbage		1	Yes	6	Constant
15	Jan-15	Dawn	NE	N/D	Garbage		1	Yes	6	Constant
16	Jan-15	Dawn	NE	N/D	Garbage		1	Yes	3	Constant
17	Jan-15	Midday	NE	N/D	Garbage		1	Yes	2	Intermittent
18	Jan-15	Afternoon	NE	N/D	Garbage		1	Yes	2	Intermittent
19	Jan-15	Evening	NE	N/D	Garbage		1		3	Constant
20	Feb-15	Midday	N/D	N/D	Garbage		1		2	
21	Feb-15	Early	N/D	N/D	Garbage		1	Yes	6	
22	Feb-15	Morning	N/D	N/D	Garbage		1	Yes	2	
23	Feb-15	Early	N/D	N/D	Garbage		1	Yes	6	
24	Feb-15	Morning	N/D	N/D	Garbage		1	Yes	4	
25	Mar-15	Night	N/D	N/D	Garbage		1	Yes	6	
26	Jun-15	Morning	N/D	N/D	Garbage		1	Yes	3	
27	Jun-15	Evening	N/D	N/D	Garbage		1	Yes	5	
28	Jun-15	Morning	NE	Light	Garbage		1	Yes	4	

Document title: Summary table of odour diary entries										
Resident ID: E (Diary #8)										
Diary Entry No.	Date	Time	Wind direction	Wind speed	Odour character	Other odour character	Odour detected	Odour offensiveness	Odour intensity	Duration
23	Oct-14	Dawn		Calm	Rotten eggs		1	Yes	2	Constant
24	Oct-14	Morning		Calm			0			
25	Oct-14	Morning		Calm			0			
26	Nov-14	Morning	NW	Strong			0			
27	Nov-14	Morning	NW	Light			0			
28	Nov-14	Morning	NW	Light			0			
29	Nov-14	Morning	W	Steady			0			
30	Nov-14	Morning	W	Light			0			
31	Dec-14	Dawn	NW	Light	Rotten eggs		1	Yes	3	Constant
32	Dec-14	Morning		Calm			0			
33	Dec-14	Morning		Calm			0			
34	Dec-14	Morning	E	Steady			0			
35	Dec-14	Morning	SE	Light			0			
36	Jan-15	Morning	W	Steady			0			
37	Jan-15	Morning		Calm			0			
38	Jan-15	Morning	W	Gusting			0			
39	Jan-15	Morning	NE	Light			0			
40	Jan-15	Morning	NE	Light	Ammonia/fishy		1	Yes	2	Constant
41	Feb-15	Morning	W	Light			0			
42	Feb-15	Morning		Calm			0			
43	Feb-15	Morning		Calm			0			
44	Mar-15	Morning		Calm			0			
45	Mar-15	Morning		Calm			0			
46	Mar-15	Morning	W	Light			0			
47	Mar-15	Morning		Calm			0			
48	Apr-15	Morning		Calm			0			
49	Apr-15	Dawn		Calm	Rotten eggs		1	Yes	2	Intermittent
50	Apr-15	Morning		Calm			0			
51	Apr-15	Morning	W	Light			0			
52	Apr-15	Morning	SE	Light			0			
53	May-15	Morning		Calm			0			
54	May-15	Afternoon	W	Strong	Garbage/Sewage		1	Yes	3	Intermittent
55	May-15	Morning	W	Strong			0			
56	May-15	Morning	W	Light			0			
57	May-15	Dawn		Calm	Sewage		1	Yes	3	Intermittent
58	May-15	Dawn	W	Light	Rotten eggs		1	Yes	3	Constant
59	Jun-15	Morning		Calm	Garbage/Sewage		1	Yes	2	Intermittent
60	Jun-15	Morning	W	Light	Garbage		1	Yes	2	Intermittent
61	Jun-15	Morning		Calm			0			
62	Jun-15	Morning	W	Light			0			
63	Jul-15	Morning	W	Light			0			

Document title:		Summary table of odour diary entries								
Resident ID:		F (Diary #9)								
Diary Entry No.	#NAME?	Time	Wind direction	Wind speed	Odour character	Other odour character	Odour detected	Odour offensiveness	Odour intensity	Duration
10	Nov-14	Morning	NW	Light			0			
11	Nov-14	Morning	NW	Calm			0			

Document title: Summary table of odour diary entries										
Resident ID: G (Diary #10)										
Diary Entry No.	Date	Time	Wind direction	Wind speed	Odour character	Other odour character	Odour detected	Odour offensiveness	Odour intensity	Duration
6	Apr-15	Dawn		Calm	Garbage		1	Yes	4	Intermittent
7	Apr-15	Dawn		Calm	Garbage		1	Yes	5	Constant
8	May-15	Evening	SW	Gusting	Garbage		1	Yes	4	Constant
9	May-15	Morning		Calm	Garbage		1	Yes	4	Constant
10	May-15	Dawn		Calm	Garbage		1	Yes	3	Constant
11	May-15	Early		Calm	Garbage		1	Yes	5	Constant
12	Jun-15	Dawn		Calm	Garbage		1	Yes	4	Constant
13	Jun-15		SW	Light	Garbage		1	Yes	6	Constant
14	Jun-15	Dawn	SW	Light	Garbage		1	Yes	5	Constant
15	Jul-15	Morning	SW	Light	Garbage		1		5	Constant
16	Jul-15	Morning		Calm	Garbage		1		3	Constant
17	Jul-15	Midday		Calm	Garbage		1		4	Constant

Document title: Summary table of odour diary entries										
Resident ID: H (Diary #10g)										
Diary Entry No.	Date	Time	Wind direction	Wind speed	Odour character	Other odour character	Odour detected	Odour offensiveness	Odour intensity	Duration
10	Oct-14	Dawn		Calm	Garbage		1	Yes	4	Constant
11	Oct-14	Dawn		Calm	Garbage		1	Yes	1	Constant
12	Nov-14	Dawn		Calm	Garbage		1	Yes	1	Constant
13	Dec-14	Dawn		Calm	Garbage		1	Yes	1	Constant
14	Dec-14	Dawn	N/D	Light	Garbage		1	Yes	2	Constant
15	Dec-14	Dawn		Calm	Garbage		1	Yes	3	Constant
16	Jan-15	Morning		Calm	Garbage		1	Yes	3	Constant
17	Feb-15	Dawn		Calm	Garbage		1	Yes	3	Constant
18	Mar-15	Morning		Calm	Garbage		1	Yes	4	Constant
19	Apr-15	Dawn		Calm	Garbage		1	Yes	3	Constant
20	Jun-15	Dawn	W	Light	Garbage		1	Yes	5	Constant
21	Jun-15	Morning		Calm	Garbage		1	Yes	2	Constant
22	Jun-15	Morning		Calm	Garbage		1	Yes	2	Constant
23	Jun-15	Morning	N/D	Light	Garbage		1		4	Constant
24	Jul-15	Dawn		Calm	Garbage		1	Yes	3	Constant
25	Jul-15	Morning		Calm	Garbage		1	Yes	3	Constant
26	Jul-15	Morning	N/D	Light	Garbage		1	Yes	2	Constant

Document title: Summary table of odour diary entries										
Resident ID: I (Diary #17)										
Diary Entry No.	Date	Time	Wind direction	Wind speed	Odour character	Other odour character	Odour detected	Odour offensiveness	Odour intensity	Duration
1	Jul-15	Evening	W	Strong	Garbage		1	Yes	3	Intermittent
2	Jul-15	Morning	W	Strong			0			
3	Jul-15	Morning		Calm			0			
4	Jul-15	Dawn	N/D	N/D	Rotten eggs		1	Yes	2	Intermittent
5	Jul-15	Morning	W	Light	Rotten eggs	Putrid	1	Yes	4	Constant
6	Jul-15	Morning	SW	Strong			0			
7	Aug-15	Morning	N/D	Steady			0			
8	Aug-15	Dawn		Calm	Rotten eggs	Fishy	1	Yes	2	Intermittent
9	Aug-15	Morning	W	Light			0			
10	Aug-15	Morning	W	Light			0			
11	Aug-15	Morning	W	Light	Rotten eggs		1	Yes	2	Intermittent
12	Sep-15	Morning		Calm	Rotten eggs		1	Yes	2	Intermittent
13	Sep-15	Morning	W	Light	Garbage		1	Yes	2	Intermittent
14	Sep-15	Morning	N/D	N/D	Garbage		1	Yes	3	Constant
15	Sep-15	Morning	SE	Light			0			
16	Sep-15	Morning	SE	Light			0			
17	Oct-15	Morning	SE	Light			0			
18	Oct-15	Morning		Calm			0			
19	Oct-15	Morning	N/D	N/D			0			
20	Oct-15	Morning	N/D	N/D			0			

Document title: Summary table of odour diary entries Resident ID: J (Diary #20)										
Diary Entry No.	Date	Time	Wind direction	Wind speed	Odour character	Other odour character	Odour detected	Odour offensiveness	Odour intensity	Duration
1	Jul-15	Dawn	N/D	N/D	Garbage		1	Yes	5	Constant
2	Jul-15	Dawn	N/D	N/D	Garbage		1	Yes	5	Constant
3	Jul-15	Dawn	N/D	N/D	Garbage		1	Yes	6	Constant
4	Jul-15	Early	N/D	N/D	Garbage		1	Yes	4	Constant
5	Jul-15	Morning	N/D	N/D	Garbage		1	Yes	4	Constant
6	Oct-15	Morning	N/D	N/D	Garbage		1	Yes	2	Intermittent
7	Oct-15	Dawn	NW	Gusting	Garbage		1	Yes	3	Constant

Document title: Summary table of odour diary entries Resident ID: K (Diary #22)										
Diary Entry No.	#NAME?	Time	Wind direction	Wind speed	Odour character	Other odour character	Odour detected	Odour offensiveness	Odour intensity	Duration
2	Aug-15	Morning		Calm	Garbage		1	Yes	4	
3	Aug-15	Morning		Calm	Garbage		1		3	Constant
4	Sep-15	Morning		Calm	Garbage		1	Yes	3	Constant
5	Sep-15	Dawn		Calm	Garbage		1	Yes	3	Constant
6	Oct-15	Dawn	N/D	Light	Garbage		1	Yes	3	Intermittent

Document title: Summary table of odour diary entries										
Resident ID: L (Diary #24)										
Diary Entry No.	Date	Time	Wind direction	Wind speed	Odour character	Other odour character	Odour detected	Odour offensiveness	Odour intensity	Duration
1	Jul-15	Dawn		Calm	Garbage		1	Yes	5	Constant
2	Jul-15	Dawn	SW	Light	Garbage		1	Yes	4	Intermittent
3	Aug-15	Dawn		Calm	Garbage		1	Yes	4	Intermittent
4	Aug-15	Night	N/D	N/D	Garbage		1	Yes	6	Constant
5	Aug-15	Dawn	SW	Light	Garbage		1	Yes	4	Constant
6	Aug-15	Night	SW	Light	Garbage		1	Yes	5	Constant
7	Sep-15	Night	SW	Gusting	Garbage		1	Yes	5	Constant
8	Sep-15	Morning		Calm	Garbage		1	Yes	4	Intermittent
9	Sep-15	Evening	SW	Gusting	Garbage		1	Yes	3	Constant
10	Oct-15	Night		Calm	Garbage		1	Yes	5	Constant
11	Oct-15	Dawn		Calm	Garbage		1	Yes	4	Intermittent
12	Oct-15	Dawn	SW	Light	Garbage		1	Yes	3	Constant
13	Oct-15	Dawn	SW	Light	Garbage		1	Yes	4	Constant