Report

Landfill Gas Risk Assessment

Grange Avenue Reserve, Schofields, NSW

Environmental Resources Management

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Environmental Resources Management (ERM) commissioned Biogas Systems Australia (Biogas Systems) to undertake a Landfill Gas Risk Assessment (LFGRA) for the proposed Northern portion of the West Schofields Precinct development area located at Schofields, NSW. The former landfill located at Grange Avenue Reserve (the Site) is located inside the proposed development area.

Between 1971 and 1975 Blacktown City Council operated the Site as a landfill for the disposal of putrescible and other wastes. The Site is located within the West Schofields precinct that is included within the North West Growth Area whereby it is anticipated that land adjacent the Site is likely to be subdivided and redeveloped for combined commercial, open space and residential land uses. Based on this proposed future use the objectives of the LFGRA were to assess the risk of sub-surface migration of LFG and to assess the safe proximity for houses to be constructed around the outside of the Site.

Landfill Gas (LFG) generation modelling, LFG well installation and monitoring undertaken as part of this and previous assessments has confirmed LFG as a potential hazard to current and proposed development of land near the Site. Whilst assessment of the data has indicated there is likely to be negligible gas production from the existing waste mass, peak concentrations of methane and carbon dioxide has been detected within the perimeter monitoring network at concentrations exceeding relevant NSW EPA criteria.

Based on review of the Site's setting and assessment of key parameters including LFG pressure and composition, the associated major transport mechanisms for the LFG constituents are considered most likely by leachate or buoyance (gravity) driven pathways rather than by pressure or diffusion drivers. As such, potential mechanisms are likely to include dissolution of dissolved gases derived from the landfill leachate or because of carbon dioxide sinking under the influencing of gravity from the landfill into the surrounding strata.

A Level 2 risk analysis and assessment undertaken in general accordance with the NSW EPA **Guidelines for the Assessment and Management of Sites Impacted by Hazardous Ground Gases** (2012) indicates a Characteristic Situation (CS) rating of 2 whereby it is possible to develop the area around the Site for sensitive uses including residential, public buildings and commercial. As this assessment was conducted on the landfills perimeter monitoring network this should be considered a conservative assessment. This assessment has however been undertaken in consideration of some limitations. In general, these limitations are associated with the limited period monitoring was undertaken. As such we recommend the following actions are implemented to enable to achieve the objectives:

- Extend the monitoring period in accordance with NSW EPA (2012) **Guidelines for the Assessment and Management of Sites Impacted by Hazardous Ground Gases**. Where this may impact the development program a high-frequency in-situ gas analyser can be used to expedite period of collecting representative data and capturing worst case conditions. Previous experience on similar sites with NSW accredited Auditors indicates six weeks to be sufficient.
- Trace gas analysis on selected wells to confirm source of ground gas.
- Nitrogen injection and recharge tests to estimate gas permeability of sub-surface and possible zone of LFG accumulation.
- Undertake an assessment of groundwater as a potential source of the observed ground gases.
- Install at least one background monitoring well in an area known to be natural ground away from potential influences from the landfill to assess the potential for natural sources of the gases identified (establish the background carbon dioxide).
- Establish presence of residual methane in the soil on the around the Site by installation and monitoring of monitoring wells spaced at about 50 m apart.
- Refine landfill gas risk assessment with final recommendations for remediation of Site based on data collected and the safe distance for houses on the proposed development.

List of Abbreviations and definitions	
Bore	Drilled borehole (where the monitoring well is installed)
BS	British Standard
Biogas Systems	Biogas Systems Australia (*and sub-contractors as authors/reviewers of this report)*
C&D	Construction and Demolition
C&I	Commercial and Industrial
CIRIA	Construction Industry Research and Information Association
CH_4	Methane
CLR	Contaminated Land Register
CO_2	Carbon Dioxide
CO_2-e	Carbon Dioxide Equivalent
CO	Carbon Monoxide
CSM	Conceptual Site Model
GCS	Gas Collection System
GC/MS	Gas Chromatography and Mass Spectrophotometry
GSV	Gas Screening Value
HGG	Hazardous Ground Gas (*sometimes used in this document interchangeably with LFG, the important distinction being that methane, or other gases, present in the mixture could be derived from a source or sources other than waste decomposition in the landfill*)
HGGRA	Hazardous Ground Gas Risk Assessment
HSE	Health & Safety Executive (UK)
HSEP	Health, Safety and Environment Plan
H_2S	Hydrogen Sulphide
JSA	Job Safety Analysis
KOP	Knock Out Pot
kPa	Kilopascal
LEL	Lower Explosive Limit (*of methane*)
LFG	Landfill Gas
Mb	Millibar
mBGL	Metres Below Ground Level
MSW	Municipal Solid Waste
NATA	National Association of Testing Authorities (UK)
NHBC	National House Building Council (UK)
NSWEPA	New South Wales Environmental Protection Agency
Pa	Pascal
PPB	Parts Per Billion
PPM	Parts Per Million
QA	Quality Assurance
QC	Quality Control
RA	Risk Assessment
T	Tonne (metric)
UEL	Upper Explosive Limit (*of CH_4*)
VOC	Volatile Organic Compound
v/v	Volume/Volume (in atmospheric air)
Well	Monitoring well (as part of the perimeter system)

1 INTRODUCTION

Environmental Resources Management (ERM) commissioned Biogas Systems Australia (Biogas Systems) to undertake a Landfill Gas Risk Assessment (LFGRA) for the proposed Northern portion of the West Schofields Precinct development area located at Schofields, NSW. The former landfill located at Grange Avenue Reserve (the Site) is located inside the proposed development area. The focus of the LFGRA is on the Site itself in relation to the assessing the potential risks associated with LFG migration from the Site onto the development area around the Site on all sides.

1.1 Background

Between 1971 and 1975 Blacktown City (BCC) operated the Site as a landfill for the disposal of putrescible and other wastes. The Site is currently utilised as a local recreation reserve within an area of low density residential (rural living) with several residential dwellings located adjacent the Site boundary. The landfill is located within the West Schofields precinct that is included within the North West Growth Area, whereby it is anticipated that the area around the Site is likely to be subdivided and redeveloped for combined commercial, open space and residential land use.

A previous LFGRA for the landfill and immediate surrounding area (GHD, 2015) found that although LFG generation rates were relatively low the existing perimeter monitoring network for LFG on the landfill was insufficient. As such there where uncertainties in relation to rates of LFG generated/emitted from the landfill with several potentially pathways to both on and off-site receptors.

1.2 Objective

The objectives of this LFGRA are to:

- To assess the risk of sub-surface migration and the acute effects related to accumulation of LFG from the former landfill waste mass located at the Site to the surrounding development area.
- To assess the safe the safe proximity of residential premises to the Site.
- To provide recommendations for further works required to ensure the risks associated with LFG emissions to the proposed development from the Site are at acceptable levels.

1.3 Scope and approach

To meet the project objectives of the project the following tasks were undertaken:

- Limited desk-based study to locate monitoring well locations and configurations.
- Installation of LFG monitoring wells.
- Weekly monitoring of LFG wells for over one month.

1.4 Guidance

This LFGRA was undertaken in general accordance with the following NSW regulatory guidance:

- NSW EPA (2012) Guidelines for the Assessment and Management of Sites Impacted by Hazardous Ground Gases.
- NSW EPA (2016) Environmental Guidelines Solid waste landfills.

In addition, where appropriate, the following national or international guidance was also considered:

- British Standard BS8576: 2013 Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs)
- British Standard BS8485:2015 Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings
- CIRIA 1995, R152 – Risk assessment for methane and other gases from the ground, Construction Industry Research and Information Association, London, UK.

- CIRIA 2007, C665 - Assessing risks posed by hazardous ground gases to buildings, Construction Industry Research and Information Association, London, UK.
- EPA Victoria 2011, Landfill licensing guidelines (EPA publication 1323).
- EPA Victoria 2015, Best Practice Environmental Management, Siting, Design, Operation and Rehabilitation of Landfill (EPA publication 788)
- National Environment Protection (Assessment of Site Contamination) Measure 1999.
- UK Environment Agency, (2004) LFTGN03 Guidance on the Management of Landfill Gas.

2 SITE DESCRIPTION

2.1 Site identification

The Site details are summarised in Table 1.

Table 1 – Site identification summary

Name	Grange Avenue Reserve
Address	181-191 Grange Avenue, Schofields
Owner	Blacktown City Council
Local Government Authority	Blacktown City Council
Land use zoning	RE1 Public Recreation[b]
Allotment size	15.3 hectares (ha)
Current land use	Recreational Reserve (Former landfill)
Future (proposed) land use	Unknown on landfill site but proposed residential subdivisions surrounding the site and commercial land to the south

2.2 Site setting

The roughly rectangular Site is in the BCC precinct of West Schofields between Grange Avenue and South Street. The Site's boundary is defined by a single span post a rail fence along both road frontages with mixed fencing including post a wire and chain mesh fencing separating the site from properties to the east and west.

The Site is relatively flat rising to approximately 10 m (40 m AHD) above local ground level across (batter) slopes of between approximately 10 and 20 %. The batter slopes start at ground level from between 5 and 10 m inside of perimeter fence. Atop of the batter slopes is a slightly mounded plateau that occupies a surface area of approximately 3 ha. The Site is largely covered with grass along with established native trees of up to 20 m in height around the perimeter. Four (leachate) dams are located near the perimeter at the north-eastern, north-west, south-eastern and southern-western corners.

2.3 Site authorisations

According to GHD (2015a) no formal approval documents for landfilling are known. As such this is not considered as a Site likely to be classified as a recently closed landfill pursuant to the Protection of the Environment Operations Act 1997 (POEO Act)). Therefore, in accordance with Contaminated Land Management Act 1997 (CLM Act) and subordinate guidance, the most relevant legislative document guiding assessment and management of the site is the NSW EPA (2012) *Guidelines for the Assessment and Management of Sites Impacted by Hazardous Ground Gases.*

2.4 Surrounding land uses

According the BCC zoning plans the area immediately surrounding the Site are currently zoned RU4 rural holdings. The Blacktown Local Environmental Plan 2015 defines classification RU4 as *Primary Production Small Lots.* Current surrounding land uses around the Site are as presented in Table 2.

[b] BCC maps http://maps.blacktown.nsw.gov.au/ accessed April 2018

Table 2 – Site surrounding land uses

North	Grange Avenue is located immediately north of the Site, across which are number of residential/commercial properties located on large allotments consistent with the RU4 zoning. From the Site's perimeter to the perimeter of the allotments is approximately 35 m.
South	South Street is located immediately south of the Site, across which are number of residential/commercial properties located on large allotments consistent with the RU4 zoning. From the Site's perimeter to the northern edge of these allotments is approximately 20 m.
East	Rural farm holding properties adjoin the Site's eastern boundary. Recent aerial photography[c] indicates there are two structure (sheds) located immediately adjoining the eastern boundary. The nearest potentially occupied residential structure is located approximately 50 m from the Site's boundary.
West	Rural farm holding properties adjoin the Site's western boundary. The nearest potentially occupied residential structure is located immediately adjoining the landfill boundary.

It is noted however as the Site is located within the North West Growth Area whereby higher density land uses are anticipated.

The Site location and planned development and zoning changes are shown in **Figures 1 and 2 Appendix A.**

2.5 Geology

According to GHD (2015a) the landfill is located within Blacktown Soil Landscape Group that is characterised by hard setting mottled texture contrast soils and red and brown podzolic soils on crests grading to yellow podzolic soils on lower slopes and in drainage lines. Underlying bedrock is expected to be composed of Wianamatta Group shales (usually Ashfield Shale) with steeply inclined bedding plans and small discontinuous sandstone or siltstone lenses.

2.6 Hydrogeology

According the GHD (2015b) standing water level indicated that the groundwater table around the Site is located within the shale/siltstone deposits between approximately 17 m AHD and 25 m AHD (approximately 1.5 to 10 metres below ground level (mBGL). This data also suggests that the groundwater levels around the perimeter of the Site appear to fall to the east and west of a north-south divide represented by bores MW11 and MW12 (refer to **Appendix A Figure 2**).

Based on the depth to groundwater and local geology groundwater in the area most likely occurs as an unconfined aquifer in fractures and joints with the shale and sandstone (i.e., a fracture rock aquifer).

2.7 Subsurface services

A Dial Before You Dig (DBYD) search undertaken for the Site in April 2018 identified the following services were present on or near the Site:

- Endeavor Energy service identified running to the north of the Site within Grange Road and south of the Site parallel to South Street in the portion of the easement between the landfill and South Street

[c] Googlearth image dated (May 2017)

and to the south of South Street. Services are also recording crossing south potentially linking both service channels.

- Optus fibre services are identified on the south side of South Street.
- Sydney Water services are identified within Grange Road and South Street.

All services identified run within and the identified road easements and do not cross the Site. No services were identified within the Site. Plans did not show potential future services to be installed to service the development outside of the Site.

2.8 Contaminant source

2.8.1 Landfill gas

The deposition of putrescible waste in landfill produces methane and carbon dioxide through anaerobic biodegradation to form the major constituents LFG. These gases are formed in mature anaerobic respiration that produces methane and carbon dioxide in approximately equal portions (%v/v). In practice, the proportions observed within landfills can differ from this ratio due to a multitude of factors including the composition of waste, the age of the landfill, moisture content and temperature. In addition, LFG will contain a mixture of other trace gases that may include hydrogen, hydrogen sulphide and a range of organic compounds, sometimes referred to as non-methane organics, or simply as NMVOCs. Over 500 substances have been reported in landfill gas (Environment Agency UK 2002) are will be dependent on the nature of the waste deposited (i.e., chemicals, solvent, glues).

The typical stages of landfill gas generation are illustrated in **Figure 1**. Phases 1 to 3 typically last from 3 to 12 months from initial deposition, a timeframe dependent on the landfill practises employed. Modern managed landfills that employ processes of compaction and daily covering significantly limiting the Phase 1 period where aerobic decay deposition occurs to as little as days or weeks. Older or less well managed landfills can extend the period of aerobic degradation and consequently limit the quantity of putrescible material available during the period of anaerobic decay.

The main stage of LFG generation, Phase 4, is when methane and carbon dioxide production stabilises, this period can last for decades with the rate of production reducing from landfill closure in a manner that is typically explained by an exponential decay curve. The half-life of this decay is dependent on the nature of the degradable waste as well as moisture content, temperature and availability of micronutrients. Typically, half-lives for LFG production can be measured periods of 5 to 20 years.

As the landfill ages the quantum of LFG production will reduce to negligible levels. Phase 5 in Figure 1 illustrate a period when containment system will degrade because of which oxygen (air) can renter the waste-mass, reintroducing a final period of aerobic decay whereby methane production is no longer favoured.

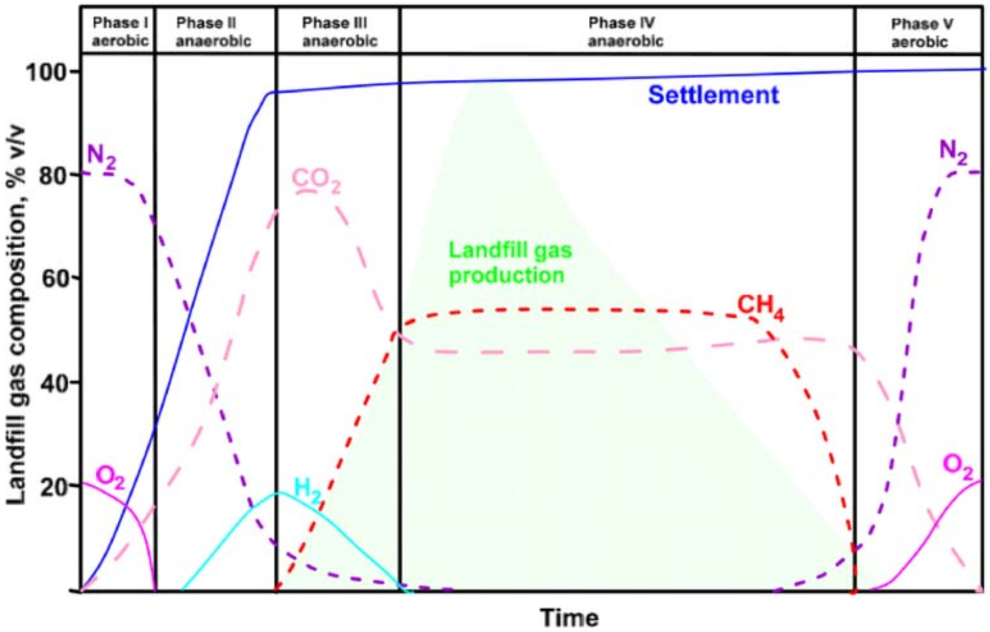


Figure 1. Stages of LFG maturation (source NSW EPA, 2012 – redrawn from Pohland et al., 1986)

2.8.2 Landfill gas hazards

LFG can cause health, safety, amenity and environmental impacts. Primary hazards associated with LFG to human health include:

- Flammable and explosive hazards caused predominantly by methane (explosive range of methane is 5 – 15% v/v).
- Asphyxiation (suffocation) hazard caused by bulk gases reducing oxygen availability (e.g., less than 19.5% v/v oxygen or greater than 6% carbon dioxide).
- Toxicity hazard from trace gases such as carbon monoxide, hydrogen sulphide or other trace gases.

In addition, the following environmental/amenity hazards are associated with LFG:

- Toxicity to flora and fauna
- Odour associated with trace gases
- Corrosion
- Greenhouse gas emissions
- Photochemical smog

Due to its potential hazardous nature LFG must be appropriately monitored and managed at landfill sites.

2.8.3 LFG Potential exposure

There are four major pathways by which landfill gas have been known to present to cause hazards that should be considered

- Sub-surface migration through the unsaturated zone
- Sub-surface migration via the saturated zone (leachate & groundwater)
- Through sub-surface services
- Emission to atmosphere from landfill surface and penetrations in the landfill capping layer.

Of the four major pathways listed, through their ability to transmit gas for some distance at potentially hazardous concentrations, the first three present the most significant risk to potential off-site receptors.

3 PREVIOUS INVESTIGATIONS

3.1 Background assessments

Previous relevant assessments for the Site reviewed in the preparation of this LFGRA include:

- GHD (2015a) Blacktown City Council Reserve 478 Landfill Gas Risk Assessment (Draft report dated July 2015)
- GHD (2015b) Blacktown City Council Reserve 478 Annual Environmental Monitoring Report (Draft report dated August 2015)
- Biogas Systems (2018) Installation of gas monitoring wells Grange Avenue Reserve, Schofields, NSW (Draft report dated March 2018)

3.1.1 GHD (2015a) Landfill Gas Risk Assessment

- Landfill gas generation rates during FYE 2015 where estimated in accordance with the Australian Government Clean Energy Regulator's Solid Waste Calculator. As of 2018 the rate of LFG production was predicted to bet 40 m^3/hr and declining. This modelling relied on a series of assumptions of waste volume and composition based on previous investigations and was noted to have assumed a conservative "*worst-case scenario*" for the landfill (i.e. to provide modelling figures that are likely maximum figures for landfill gas being generated and emitted by the landfill). This modelling provided a current estimate of LFG generation for the Site at approximately 30 to 40 m^3/hr.
- There is no existing engineered landfill gas collection and treatment system at the landfill nor is there an engineered containment system (no engineered liner or cap).
- Elevated concentration of methane had been detected within the waste mass consistent with it having been a putrescible waste landfill.
- Methane has been observed in perimeter monitoring bores at concentrations exceeding the nominated assessment criteria of 1.25% v/vd were periodically detected in four of the monitored bores (bores GW2, GW5, GW8 and MW12). Two of these bores (GW2 and MW12) were within five of the inferred waste footprint.
- Peak carbon dioxide concentrations exceeding the nominated assessment criteria of 1.5% v/v were detected in six of the monitored bores on at least one occasion (bores GW6, GW8, MW11, MW12, MW13 and MW14).
- All monitoring wells identified were within about 20 m outside the landfill waste mass
- Surface emissions were generally below the nominated assessment criteria of 500 ppm methane during 2013, except for four isolated locations along the north-western batter.

The risk classifications from the LFGRA identified the following (potentially) unacceptable risks:

- Surface LFG emissions potentially impacting upon landfill workers and visitors
- Sub-surface migration from the landfill potentially impacting upon workers, residents/visitors, buildings and structures and sub surface services close to the landfill.

Because of the findings the LFGRA made some key recommendations:

- Design, install and monitor an appropriately designed and located landfill gas monitoring bore network at the landfill's perimeter.

[d] historic criteria superseded by NSW EPA (2016) to be 1 %v/v.

Other potentially relevant matters identified within this report:

- Landfill operated for the disposal of putrescible and other wastes between approximately 1971 and 1975 prior to landfilling site appeared to have been uncleared bushland.
- The landfill was unlikely to have been excavated prior to waste disposal and as such, waste landfilled was likely placed above the natural prevailing ground levels of the site
- Following completion of putrescible waste disposal operations in circa 1975 that the waste was covered with a layer of fill materials.
- Illegal dumping is likely to have occurred on the site prior to 1993.
- Additional earthen fill materials are understood to have been imported and placed on the landfill between 1993 and 2010 (no engineered cap with thicknesses of overlying soil between 0.2 and 6m).
- No buried services were identified on the landfill.

3.1.2 GHD (2015b) Annual Environmental Monitoring Report

The Annual Environmental Monitoring Report (AEMR) was limited to monitoring of leachate and groundwater at the landfill. Key potentially relevant findings from this report included:

- Groundwater generally appears to be flowing away from a theoretical line running in a north - south orientation between groundwater monitoring wells MW11 and MW12.
- No significant leachate impacts upon groundwater.

3.1.3 Biogas systems (2018) well installation report

The installation report detailed installation of twelve (12) landfill gas monitoring wells (BH1-BH12) around the Site's perimeter. All wells were constructed of Class 18 PVC pipe perforated from 1 m below ground level to the total depth, nominally 12 m below ground level or to groundwater level. Subsurface lithology encountered during drilling generally comprised shale-based lithology including shale/ claystone/siltstone gravel and sand lenses identified in some boreholes. No municipal waste or refuse items were found indicating that all the boreholes are outside of the landfill waste mass area.

Groundwater was encountered in all monitoring wells apart from BH01, BH05 and BH09.

The combined well monitoring network included 16 perimeter monitoring bores with 12 recently installed validated wells. The well spacing of the network was about 100 m on the northern, 50 m on the southern boundaries and 75 to 150 m on the eastern and western boundaries.

A plan showing the monitoring well locations **Appendix A** and copy of the well installation report, included soil bore logs are provided in **Appendix B**.

4 CONCEPTUAL SITE MODEL

4.1 Potential contaminants

Based on the information summarised above, the primary contaminants of concern (COC) are methane and carbon dioxide. Other potential COCs include trace gases and Volatile Organic Compounds (VOCs) carbon monoxide and hydrogen sulphide.

In addition to the Site being a source of these COC through LFG it is also possible there is methane and/or carbon dioxide present that is derived from other potential sources of ground gas near the Site which include:

- Imported fill and man-made ground.
- Partitioning of methane dissolved in migrating groundwater.

- Reclaimed swamps/wetlands.
- Dissolution or chemical breakdown of carbonaceous strata (carbon dioxide) that may include calcareous claystone and/or coal units known to be present within the Ashfield Shale.

4.2 Release and transport mechanisms

Landfill gas contaminants generally migrate from a waste mass via a combination of sub-surface gas migration and groundwater migration mechanisms. The potential for contaminants to migrate is a combination of:

- The nature of the contaminants (mobility characteristics)
- The extent of the contaminants (isolated or widespread)
- The location of the contaminants (surface soils or at depth)
- The site topography, geology, hydrology and hydrogeology.

The driving force of LFG is affected by several variables and for LFG to migrate away from the waste mass a pathway must be available and for migration to be sustained the source of gas must be replenished. CIRIA C665 (2007) describe three main driving forces for LFG migration as:

- Pressure differential
- Diffusion along gas concentration gradients
- Flow, in dissolved form, within liquids.

The driving forces can then the further influenced by external conditions including barometric pressure changes, rainfall and anthropogenic influences.

4.2.1 Barometric pressure

Barometric pressure changes are documented as one of the most important factors in incidents of LFG explosions. The rate of fall of atmospheric pressure can be more significant than the actual pressure level in influencing LFG movement in the subsurface. Rapidly falling pressure can lead to a pressure differential between the waste mass and the external atmosphere in general, thus providing a motive force for LFG migration. Once equilibrium of pressure has been reached, even at low barometric pressure, the motive force is removed and the influence of barometric pressure on potential LFG migration is greatly reduced.

4.2.2 Rainfall

Precipitation can lead to a reduction in the permeability of the ground surface by sealing migration routes, again leading to a build-up of pressure within a gas body, and the potential for an increase in subsurface migration.

4.2.3 Anthropogenic influences

The potential also exists for LFG to preferentially migrate through subsurface structures such as buried utility lines, where more permeable sands and gravels may have been used during the construction of these services.

4.3 Exposure pathways

LFG can enter buildings and accumulate in confined spaces via the following routes listed below:

- Beneath suspended floors (cracks or gaps in both solid and suspended floors)
- Joins in walls
- Vertical structures such as foundation piles
- Cracks or gaps in walls and floors
- Settlement voids and joints formed during the construction process
- Around service pipes, ducts and drains.

4.4 Sensitive receptors

The potential sensitive receptors of environmental impacts present at the Site and its surrounds include:

- Subsurface migration from the Site, accumulation in structures including residential and commercial buildings on and around the Site.
- Present and future workers and users of the Site who may potentially be exposed to hazardous gases through direct contact with landfilled materials and/or inhalation of vapours.
- Future residents who live near the Site and may potentially be exposed to landfill gases through direct contact with impacted soils and/or inhalation of vapours associated with landfilled materials.

A summary of current potential sensitive off-site receptors immediately adjoining or near the landfill's boundaries is presented in Table 3:

Table 3 - Distances from the Site to the nearest receptors

Direction from the Site	Type of receptor	Address	Approximate distance from source to receptor*
North	Residential/commercial properties (structures)	180 Grange Road	50 m
		182 Grange Road	55 m
		184 Grange Road	60 m
		186 Grange Road	50 m
		190 Grange Road	60 m
South	Residential/commercial properties (structures)	39 South Street	140 m
		47 South Street	50 m
		53 South Street	50 m
		61 South Street	50 m
		Lot 106 South Street	110 m
		71 South Street	55 m
		79 South Street	65 m
		81 South Street	90 m
East	Shed/commercial	179 Grange Road	20 m
		Lot 106 South Street	20 m
West		193 Grange Road	20 m
		86 South Street	65 m

Note: *measured from inferred waste extent to nearest structure (as shown Google Earth, May 2017)

5 MONITORING AND MODELLING

5.1 Gas generation modelling

Biogas Systems has undertaken a review of the model assumptions used in gas production modelling for the previous LFGRA for the site (GHD, 2015a) and agree with the conclusion that the assumptions utilised are likely to provide a conservative estimation. This conclusion is made based on the following key assumptions of the GHD (2015a) model:

- The decay rates were based on temperate dry conditions (typical of desert climates).
- Waste composition across 1971 to 2003 equivalent to current NGER defaults.
- Putrescible waste density was assumed at 1 T/m^3.
- Waste inputs assumed 100 % of the 1971-1975 and of the illegal waste input was putrescible.
- Methane correction factor (MCF) assumed a well-managed landfill from 1971-1993 with 100 % of degradable carbon anaerobically decayed (methane correction factor of 1).

To assess the impact of the conservative assumptions Biogas Systems undertook modelling utilising the base case established in the GHD report with the following amendments to establish a probable (low) estimate of LFG production:

- Decay rates based on wet temperate climate (applicable to the Sydney region of NSW).
- MCF of 0.8 for the period 1971 to 1975 (equivalent to a moderately well operated landfill).
- Putrescible made up 90% of all 1971-1975, and of the illegal waste deposited
- Putrescible waste density was 0.9 T/m^3.

The revised modelling utilised an adapted version of Intergovernmental Panel on Climate Change (IPCC) Spreadsheet for estimating methane emissions from Solid Waste Disposal Sites[f]. The comparative results are shown in **Figure 2** that includes a calibrated model produced by Biogas System to replicate the same conservative output of the GHD (2015) model. Biogas Systems notes this calibrated model required higher waste quantity inputs to those used by GHD (2015), to produce what Biogas Systems considers a highly conservative estimation of gas generation rates. The comparison tables are presented in **Appendix F**.

Utilising the revised parameters described above within the same model calibrated to GHD (2015) outputs the Biogas Systems modelling predicted a current LFG gas production rate of 16 m^3/h, approximately 50 % of the GHD (2015) conservative estimation.

In consideration of both Biogas Systems and GHD (2015) modelling (or modelling of this nature in general) no result should be considered conclusive but combined these are likely to provide a reasonable assumption of range in gas generation. Importantly, the results of both modelling provide a similar conclusion, that the current LFG gas production for the site is likely to be low to negligible which is consistent with expectations for a landfill of this age and relative size.

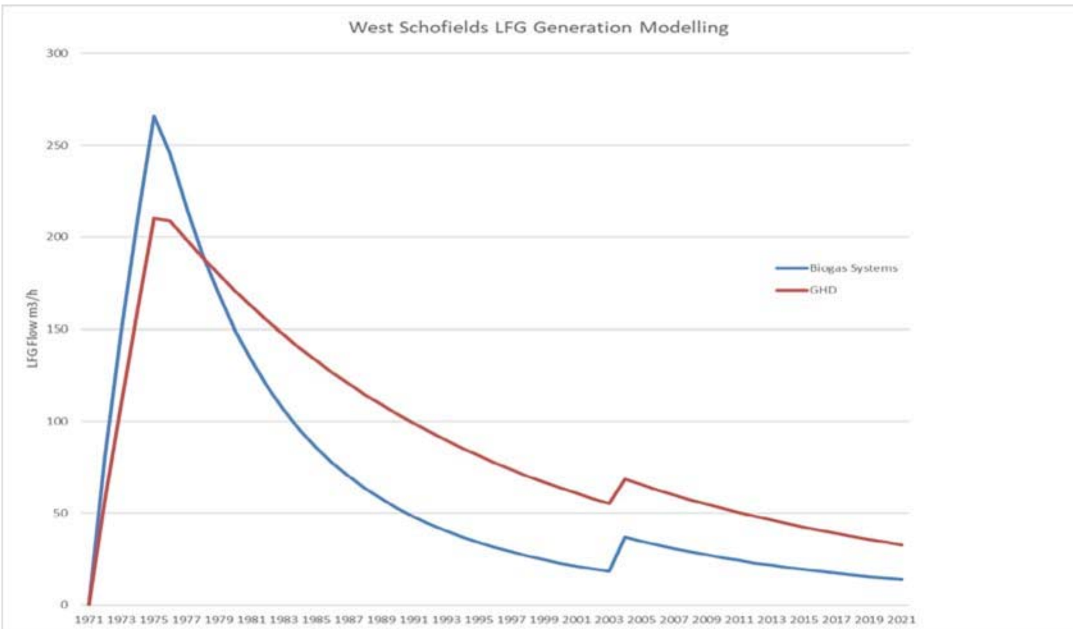


Figure 2. Landfill gas modelling results

[f] Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines for National Greenhouse Gas Inventories. This adapted first order decay model (FOD) used in the IPCC spreadsheet is consistent with the methodology utilised for the Clean Energy Regulator's Solid Waste Calculator.

5.2 2018 landfill gas monitoring

LFG monitoring was carried out by an experienced LFG practitioner using procedures described in the following sections.

5.2.1 Data quality objectives

The Data Quality Objective (DQO) process described in AS 4482.1-*2005 Guide to the Investigation and Sampling of Sites with Potentially Contaminated Soil Part 1: Non-Volatile and Semi-Volatile Compounds* outlines seven distinct steps to outline the project goals, decisions, constraints and an assessment of the project uncertainties and how to address these when they arise. The DQOs have been summarised in Table 4:

Table 4 - Data quality objectives for landfill gas monitoring

1	State the Problem	Sub-surface ground gas monitoring to establish if: ▪ Landfill gas is already present in the Soil at the Site or outside the Site. ▪ If there is lateral (sub-surface) migration of landfill gas outside the Site still occurring. The purpose to assess the suitability of the land adjacent the Site for future development, and informing a risk assessment and subsequent mitigation measures, if required.. The main problems are: ▪ Are existing monitoring wells suitable for the proposed monitoring program? ▪ Do additional monitoring wells need to be installed and, if so, how many and where? ▪ Do we understand the CSM adequately to design the sampling plan? ▪ What duration and frequency of monitoring should be adopted for the program? ▪ What parameters should be assessed?
2	Identify the Decisions	▪ Following implementation of sampling plan, and ground gas investigations if required, are measured gas concentrations sufficient to decide on whether the Site is suitable for the proposed development or are mitigation measures required to allow the proposed future development of the Site?
3	Identify Inputs to Decisions	▪ Results of ground gas sampling across the landfill ▪ Relevant legislation and regulatory guidance
4	Define Study Boundaries	Spatial boundaries: The investigation will focus on the area occupied by the landfill site located at Grange Avenue Reserve and the area around it to approximately 100 m from the Site boundary. Temporal boundaries: The investigation will include data gathered over the duration of the monitoring program lasting one month.

5	Develop Decision Rule	The decision rule for ground gas concentrations to assess the suitability of the Site will be as follows: ▪ QA/QC assessment indicates that the data is usable ▪ The data collected from the sampling plan is deemed sufficient without further investigation or assessment ▪ Where ground gas concentrations are less than the adopted investigation thresholds, then mitigation and management is not considered necessary ▪ Where ground gas concentrations exceed the adopted investigation thresholds, then further assessment may be required.
6	Specify Limits on Decision Errors	Two types of decision error are possible: ▪ Type 1 error (a or false negative), where the Site is assessed to be suitable for the proposed future land use when it is not. ▪ Type 2 error (β or false positive), when the Site is assessed to be not suitable for the proposed future land use when it is. The more severe consequence is with Type 1 errors (a) since the risk of jeopardising human or environmental health outweighs the consequences of additional mitigation costs. Field quality controls are implemented to avoid error and to ensure the action levels exceed the measurement detection limits.
7	Optimise Design for Obtaining Data	▪ Ensure access to all relevant and previous environmental data. ▪ Identify the most resource-effective sampling and analysis design for general data that are expected to satisfy the DQOs and avoid Type 1 and Type 2 errors.

5.2.2 Sampling plan

Sampling locations for ground gas investigations are based upon the following reference guidelines:

- *Guidelines for the assessment and management of sites affected by hazardous ground gases (NSW EPA, 2012)*
- *Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings* (British Standards 8485:2015)
- *Environmental Guidelines: Solid Waste Landfills Second Edition, 2016 (NSW EPA, 2016)*
- *Wilson, S., Oliver, S., Mallett, H., Hutchings, H., and Card, G (2007). Assessing risks posed by hazardous ground gases to buildings. CIRIA C665.*
- *Guidance on the management of landfill gas (UK Environment Agency, 2004)*.

Based upon the initial assessment the existing boundary monitoring borehole locations, an additional 12 perimeter wells were installed to provide a further assessment of Site conditions. Based on an initial assessment of risk it is considered that this density and spacing shall to be able to further characterise potential migration pathways on the Site. As a guide a 50 - 100 m borehole spacing (adjacent the areas of proposed higher density development) was established based on NSW EPA 2012 guidance for borehole spacing (refer to Table 5) and in consideration of the existing CSM that amongst other things indicates there is likely to be a low to negligible rates of gas generation providing a limited driving force for migration particularly given with the landfills above ground level setting.

Table 5 - Perimeter borehole spacing as described in LFTGN03 (EA [UK] 2004)

Site description	Monitoring borehole spacing (m)	
	Minimum	Maximum
Uniform low permeability strata (e.g. clay); no development within 250 m	50	150
Uniform low permeability strata (e.g. clay); development within 250 m	20	50
Uniform low permeability strata (e.g. clay); development within 150 metres	10	50
Uniform matrix dominated permeable strata (e.g. porous sandstone); no development within 250 metres	20	50
Uniform matrix dominated permeable strata (e.g. porous sandstone); development within 250 metres	10	20
Uniform matrix dominated permeable strata (e.g. porous sandstone); development within 150 metres	10	20
Fissure or fracture flow dominated permeable strata (e.g. blocky sandstone or igneous rock); no development within 250 metres	20	50
Fissure or fracture flow dominated permeable strata (e.g. blocky sandstone or igneous rock); development within 250 metres	10	50
Fissure or fracture flow dominated permeable strata (e.g. blocky sandstone or igneous rock); development within 150 metres	5	20

5.2.3 Methodology

In accordance with the agreed scope of works, monitoring of all gas wells was undertaken over a one-month period, across weekly monitoring events conducted on 2, 9, 14 and 23 March 2018.

The following LFG monitoring procedure was followed:

1. Verify equipment has been calibrated correctly.
2. Before starting monitoring, attach the insert sample tubing into landfill gas monitor (maximum 1 metre in length) and turn the instrument on in a location unlikely to be affected by landfill gas (or other air contaminants). Confirm that the instrument is reading gas concentrations that are indicative of the prevailing background conditions (generally <0.1% methane, <0.1% carbon dioxide, 21.0% oxygen, 79% balance (nitrogen)). Ensure the pressure transducers and flow cells are zeroed with the tube open to atmosphere.
3. Also note background information, including: site identification, bore location, start time of the monitoring round, date, barometric pressure and trend, prevailing weather and recent weather conditions, current ground conditions, instruments used and person completing the monitoring. Changes in any of the above should be noted as should the finish time.
4. Visually inspect the bore and, without breaking the gastight seal, note any issues or deficiencies that may prevent representative data being obtained (such as landfill gas odours, unsealed bores, screened sections of pipework above ground level, failed bentonite seal or an open gas tap).
5. Connect the sample tubing to the bore and connect HGG flow inlet tube to borehole, wait 60 seconds for flow to stabilise and record flow.
6. Record the differential pressure, including whether the pressure is positive (+) or negative (–). This must be done in a manner that prevents the pressure in the bore being released prior to measurement. If the bore is fitted with a gas sampling tap, connect the sample tubing to the instrument and the gas sampling tap prior to opening the tap. If the bore is fitted with a quick-connect coupling, connect the sample tubing to the instrument before being fitted to the bore

quick-connect fitting. Record the differential pressure be recorded before starting the instrument pump or measuring gas concentrations.

7. Turn on the pump and record the peak and stabilised concentrations of methane and carbon dioxide, and minimum concentration of oxygen.
8. If the monitored gas concentrations have not reached a stabilised concentration after three minutes of continuous sampling, record the final gas concentrations, along with the direction and rate of change in concentration (rapidly or slowly increasing or decreasing), and note them as non-stabilised final readings.
9. If very high landfill gas concentrations are recorded on the instrument (>30% v/v methane and/or 30% v/v carbon dioxide), then monitoring of the bore should be extended beyond three minutes to try to further determine the persistence of the gas detected within the bore.
10. Once the peak and stabilised concentrations have been recorded, fully close the gas sampling tap (if applicable) and disconnect the sample tubing from the gas tap. Keep the instrument pump turned on away from the bore and other sources of gas or contaminants until any residual gas present in the instrument has been purged from the instrument and sample tubing. The gas concentrations reported by the instrument should resemble those likely to be indicative of the prevailing background conditions (generally <0.1% methane, <0.1% carbon dioxide, ~21.0% oxygen, ~79% balance (nitrogen plus trace gases)).

Monitoring on the specified period was undertaken at the following locations:

- Newly installed (Biogas Systems) perimeter monitoring bores including BH1 to BH12.
- Existing combined groundwater and LFG perimeter monitoring wells MW11 to MW14.
- Existing combined leachate and LFG wells MW1 to MW5 (located within the inferred extent of the waste mass).

In addition, a stabilised gas reading was recorded on 23 February at BH1 to BH12, following the completion of well installation.

LFG monitoring was undertaken utilising a GA5000 (Geotechnical Instruments) landfill gas analyser that measured bulk ground gas concentrations (including methane, carbon dioxide, oxygen, hydrogen sulphide and carbon monoxide) as well as pressure, and borehole flow rates. During monitoring initial, maximum and steady bulk gas concentrations, pressure and flow rate were recorded. In addition, at the completion of gas monitoring on 2 March, the depth to standing water levels were recorded for each monitoring bore.

The GA5000 gas analyser specifications are summarised Table 6.

Table 6 - Sensitivity of gas analyser

Range	CH_4	0 - 70% to specification, 0-100% reading		
	CO_2	0 - 40% to specification, 0-100% reading		
	O_2	0 - 25%		
	CO	0 – 200 ppm		
	H_2S	0 – 200 ppm		
	Pressure	± 0.4 mb		
	Flow	± 0.3 l/hr		
Typical accuracy	**Gas**	**0-5 %v/v**	**5-15 %v/v**	**15 %- Full Scale (FS)**
	CH_4	±0.5%	±1.0%	±3.0%
	CO_2	±0.5%	±1.0%	±3.0%
	O_2	±1.0%	±1.0%	±1.0%
	Gas		**0-FS**	
	CO (0 – 500 ppm version)		±10.0% FS	
	CO (0 to 2000 ppm, H_2 compensated version)		±10.0% of reading or 15 ppm, whichever is greater	
	H_2S (0 - 200 ppm)		±10.0% FS	

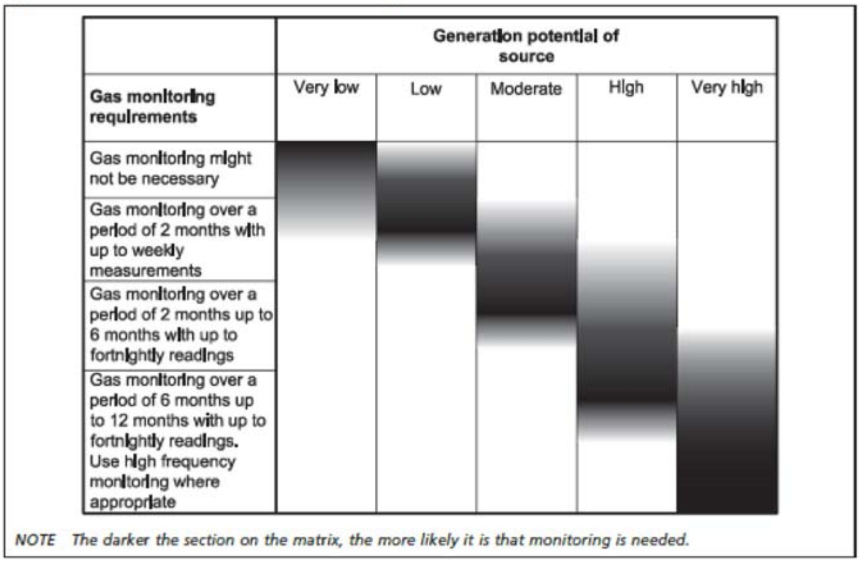
The GA5000 was independently calibrated by Airmet for all gas components analysed with the calibration certificates present in **Appendix D**.

Tabulated data for each monitoring event is presented in **Appendix C**.

5.2.4 Period and duration of monitoring for landfill gas

BS8576: 2013 provides guidance on minimum monitoring periods presented as a decision matrix to aid in deciding the appropriate level of gas monitoring on any site (refer to Figure 3). The extent of monitoring required is based on the type and distance of receptors, generation potential of the source, i.e. the risk that large volumes of gas can be generated and can credibly migrate to pose a credible hazard to the identified receptors. If the gas source is off-site and gas migration is being assessed, increasing the periods of monitoring to cover the range of critical influences indicated by the conceptual model should be considered, if such monitoring is likely to influence the outcome of the risk assessment.

Figure 3 - Decision matrix for initial monitoring (BS8576:2013)



Using the matrix, the Site was classified as moderate risk, at least six months monitoring at fortnightly intervals would be required to obtain a representative understanding of LFG in the soil at the boundary of the Site.

A review of Bureau of Meteorological data from the nearest station (Richmond) indicated the events conducted during at least two monitoring events were undertaken during extended barometric pressure events that are considered potentially conducive to LFG migration:

- 14 March occurring after an extended period (4-5 days) of falling barometric pressure and
- 23 March during a period of falling barometric pressure that commenced at least 24 hours prior to monitoring.

The key requirement regarding Australian guidance is to capture the worst-case meteorological scenario, which is a 5th percentile three-hour pressure decrease rate, based on a two-year data set.

Based upon the last two years of with continuous barometric data obtained from the Bureau of Meteorology (BOM), the 5th percentile three-hour pressure decrease rate for the Site, based on a two-year data set, was calculated to be 1.2 millibar(mb). Three-hour pressure decrease rate data was assessed after one monitoring round to determine if during the monitoring event, a decrease rate of greater than 1.5 mb (thereby meeting worst case conditions) was achieved. This was confirmed on 23 March only.

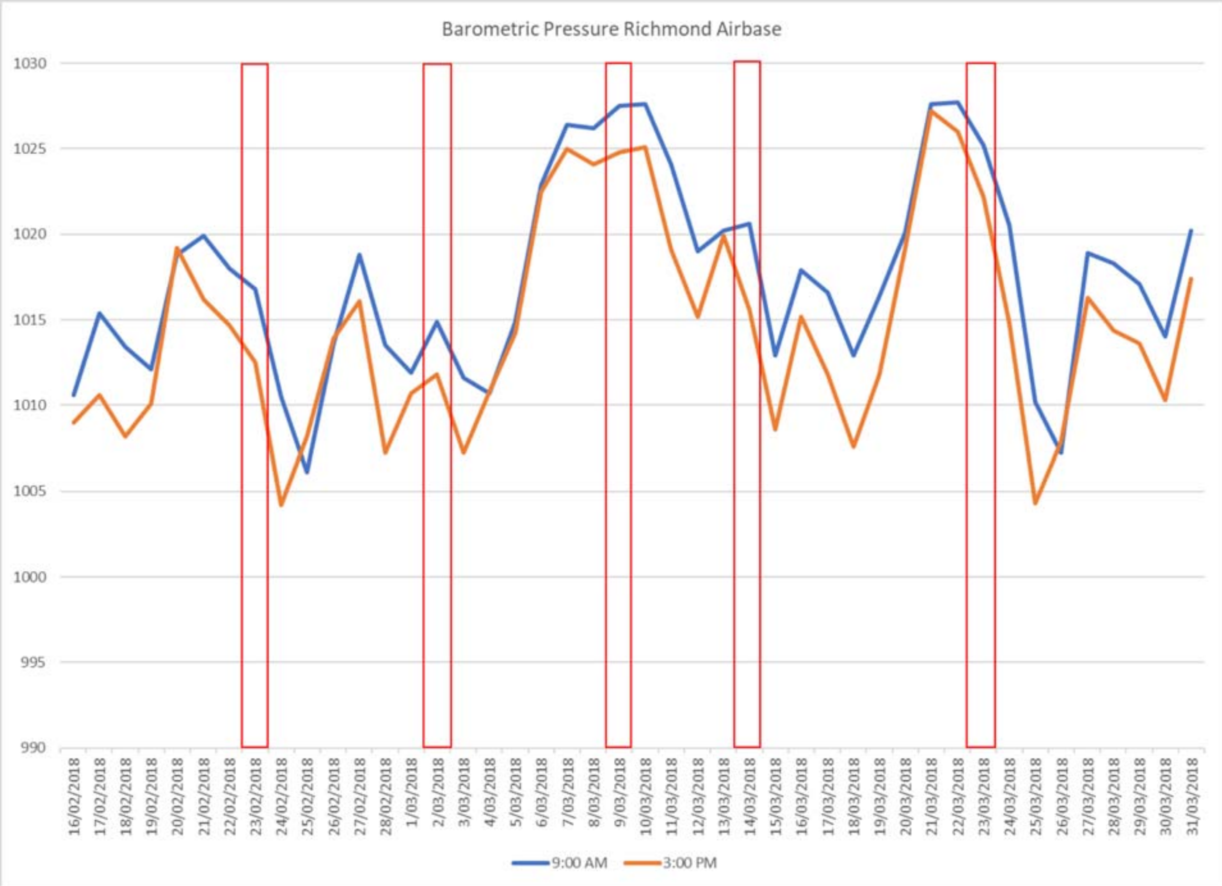


Figure 4 - Barometric trends across monitoring period (monitoring event highlighted in orange box)

5.3 Assessment criteria

The threshold levels for further investigation and corrective action are established from the Environmental Guidelines: Solid Waste Landfills (NSW EPA, 2016) which are also relevant to NSW EPA (2012). In accordance with NSW EPA 2016, the applicable criterion to perimeter monitoring bores are[g]:

- Methane at concentrations above 1 %v/v.
- Carbon dioxide at concentrations of 1.5 %v/v above established natural background levels.

5.3.1 Summary of perimeter monitoring results

A summary of the monitoring carried out by Biogas Systems over four visits is summarised in the following section.

<u>Methane</u>

The following bore holes reported peak results exceeding the adopted criteria for methane:

- BH6 during the monitoring event conducted on 2 and 23 March (maximum 1.7 %v/v on 2/3/18)
- BH8 during the monitoring event conducted on 9 March (maximum 1.6 %v/v on 2/3/18)
- BH9 during the monitoring event conducted on 9 March (maximum 1.2 %v/v on 2/3/18)

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[g] Criteria for hydrogen sulphide and carbon monoxide were not set as the purpose of this LFGRA was to assess the acute risks associated with methane and carbon dioxide.

- MW13 during the monitoring event conducted on 9 March (maximum 1.6 %v/v on 2/3/18)
- MW14 during the monitoring event conducted on 9 March (maximum 2.9 %v/v on 2/3/18)
- Steady state methane concentrations for all perimeter monitoring bores reported results of 0 %v/v.
- Maximum gas screening values (GSV) based on peak methane concentrations at BH4 during the 2 March monitoring event at 0.0034 L/h.

Carbon dioxide

Elevated carbon dioxide measurements exceeding 1.5 %v/v were recorded at all monitoring bores during one or more events across during the assessment period. The highest recorded carbon dioxide concentration was at BH7 at 24.4 %v/v recorded on 23 March. Although elevated concentrations of carbon dioxide across the monitoring network have been observed, a background concentration for the Site is yet to be established and therefore no conclusion to the likely extent of assessment criteria can be established at this time.

- Maximum gas screening values (GSV) based on peak carbon dioxide concentrations at BH7 during the 23 March monitoring event at 0.0488 L/h. This event also corresponded to a falling pressure event, where the maximum carbon dioxide and flow rate across all monitoring events and bore holes was recorded.

Hydrogen sulphide and carbon monoxide

- Maximum carbon monoxide concentrations were recorded at BH7 on 2 March at 22 ppm.
- Maximum concentration of hydrogen sulphide was 3 ppm, this was recorded at several monitoring rounds.

5.3.2 Summary of in-waste monitoring results

Gas monitoring within the extent of the waste mass indicted elevated methane concentrations ranging from 49.8 to 84.8 %v/v. The concentrations recorded at MW4 were consistently the lowest ranging between 49.8 and 54.4 %v/v, with concentrations at all other wells consistently exceeding 63% v/v.

The maximum recorded carbon dioxide concentration within the waste was recorded was 12.3% v/v.

LFG flow rates and gas pressures recorded across all in-waste monitoring bores was considered low:

- Maximum gas flow recorded at 0.5 L/h for MW2 with a corresponding methane GSV value of 0.42 L/h.
- Maximum recorded gas pressure for in-waste bores was recorded at MW3 (14 March) at 0.75 mb.

5.4 Discussion of monitoring results

The monitoring results confirm the results of LFG modelling indicating the current rate of LFG production is low to negligible as stable well flow or positive pressure greater than 1 mb was not recorded in wells installed inside the waste mass. Secondary lines of evidence include the relative concentrations of methane and carbon dioxide, that under active generation would be expected be in near equal proportions. The relatively high concentration of methane relatively to carbon dioxide suggests that as active gas generation has reduced or stagnated allowing a partitioning of gases, potentially due to both differential solubility and density differences.

The higher solubility of carbon dioxide will allow it to be preferentially stripped by downward migrating leachate, supported also by carbon dioxides higher relative density compared to methane. Combined, these mechanisms may allow methane to preferentially accumulate in the upper most portion of the waste mass and above ground level. These mechanisms would account for both the relatively high methane concentration in waste as well as the relatively high carbon dioxide proportion of ground gases detected in the surrounding soil strata.

The perimeter monitoring results provided evidence respect of the potential impact of barometric pressure events that are considered likely to favour migration of portioned carbon dioxide from LFG. Although the monitoring events were not undertaken across what would be considered worst case or significant barometric events, two of the events (on 14 and 23 March 2018) were recorded at periods considered potentially favourable. The highest peak and stabilised carbon dioxide concentrations (24.4 %v/v) were recorded during one of these events at BH7 (on 23 March 2018). Further, across both these monitoring events higher peak and stabilised carbon dioxide concentrations were recorded in most monitoring locations during both these events, when compared to those undertaken on 2 and 9 March. Notwithstanding the evidence provided by carbon dioxide trends, the highest peak methane concentrations were recorded during the monitoring events on 2 and 9 March. This also supporting the premise of gas portioning and indicating a low likelihood there is ongoing subsurface migration of methane from the landfill at levels likely to present a risk to off-site receptors

In respect of stabilised methane measurements within the perimeter monitoring network, methane concentrations reduced to 0 %v/v in all cases. Whilst the results have shown periodic accumulations of methane above the relevant criteria, the absence of detectable methane in stabilised measurements indicate that where it is present, the relative volumes are low. In addition, it is common for volatile organic compounds (VOCs) to confuse the infrared detection of methane (such as with the monitor used) and can as a result provide higher than actual results. In this respect exceedances of adopted criteria for (peak) methane are not considered significant. In contrast, similarities between peak and stablished carbon dioxide indicate this gas remains present in relatively higher volumes (than methane).

Overall the results support the premise that there is ongoing subsurface migration of carbon dioxide that may present a risk to subsurface receptors should a pathway be complete and a sensitive receptor present. Based on current monitoring data there would appear to be negligible risk from the methane component of LFG.

5.4.1 Assessment of sufficiency of data and monitoring period

The monitoring method employed was in accordance with the processes described in this section and methodologies described with in the ground gas guidelines (NSW EPA, 2012).

It is considered that this density and spacing of recently installed monitoring wells can further characterise potential migration pathways off-Site. The 12 new monitoring wells are considered valid for intercepting off Site migration of LFG, should it occur, for the following reasons:

- The have all been installed recently by a licensed and an experienced drilling contractor.
- The well construction details are appropriate i.e. the screens extend to the basement geology up to within one m of the ground surface.
- Whilst drilling the borehole ground water ingress was observed at the base of the boreholes. The final well installations were gauged for water depth and whilst there was recharge in most wells the water level was below the levels of the slots.
- The installation process has been independently observed and recorded by ERM and Biogas Systems field personnel
- They are less than 50 m apart so meet the spacing requirements of NSW EPA 2016.
- They are fitted with gas tight quick connect ‘excap’ type gas sample points.

The minimum requirements to assess a gas screening value and characteristic gas situation are measured flow rates and hazardous gas concentrations from an appropriate number of monitoring locations over an appropriate number of monitoring rounds, which should include measurements taken during falling atmospheric pressure (NSW EPA 2012).

For bulk ground gases and moderate-sensitivity development (equivalent to the residential use with minimal access to soil exposure setting), CIRIA C665 recommends "*6–12 monitoring events extending over 3–12 months (CIRIA 2007)*". However, the key requirement should be to capture the worst-case meteorological scenario.

Based upon the last two years of with continuous barometric data obtained from the Bureau of Meteorology (BOM), the 5th percentile three-hour pressure decrease rate for the Site, based on a two-year data set, was calculated to be 1.2 millibar(mb). However, only one event met this condition.

6 REVISED CSM

In consideration of the CSM providing by GHD (2015a) a revised CSM has been developed in consideration of recently collected monitoring data. This has indicated the primary (ground gas) contaminant of concern with respect to off-site receptors is carbon dioxide, with both peak steady state concentrations exceeding the adopted criteria indicating significant volumes of this gas are present in the underlying strata with the potential for an ongoing source. On the other hand, Methane, while present, was not detected in stabilised readings, indicating it is unlikely to be accumulate at volumes likely to create hazardous conditions.

A graphical presentation of this CSM is presented in the Figure 3 (**Appendix A**) with detailed discussion provided below.

6.1.1 Potential contaminant sources

The landfill is confirmed as a potential source of the LFG, include the constituent gases methane and carbon dioxide detected within the perimeter monitoring network at concentrations exceeding adopted criteria. The assessment results however cannot rule out other sources including:

- Natural sources including the shale strata underlying the landfill and the Site.

6.1.2 Release and transport mechanisms

Based on the monitoring data the dominant driving forces of observed migration are considered most likely to be:

- Downward flow of carbon dioxide due to buoyance effects (gravity).
- Flow, in dissolved form, within liquids.
- Low rate of diffusion considered to be the primary driving force of any methane migration (if occurring).

Due to the low to negligible gas generation predicted by LFG modelling and confirmed by observation of relative gas pressures and concentrations with the landfill, pressure driven flow is considered unlikely to provide sufficient force for migration. Further the Site being established above ground level and with an absence of potential preferential pathways indicates there would be limited connectivity of the waste with the surrounding strata. The limited connectively to subsurface strata may also be an inhibiting factor in diffusion although there is insufficient data to correlate.

6.2 Exposure pathways

Based on the properties the primary contaminant of concern of carbon dioxide (high density compared to air), the primary exposure pathway is likely to be in buried structures where dense gases have the potential to accumulate.

6.3 Sensitive receptors

The potential sensitive receptors of environmental impacts present at the Site include:

- Site workers and visitors who may potentially be exposed to hazardous gases through direct contact with landfilled materials and/or inhalation of vapours (due to the confirmed presence of methane and carbon dioxide within the waste mass).
- Risk to occupiers of subsurface structures (including residents and workers) both on and off-site.

6.3.1 Data limitations

The data presented in is based on limited monitoring that is not considered sufficient based on the number of sampling events in accordance with NSW EPA (2012) guidance. In addition, further assessment of groundwater as a source and/or migration pathway as well as the potential for vertical attenuation are data gaps in the existing CSM.

The data is however considered sufficient for a preliminary assessment of risk but should be revised with the availability of further data.

7 HAZARD IDENTIFICATION AND RISK SCREENING

7.1.1 Level 1 risk analysis and assessment

A Level 1 Risk Assessment has been undertaken in accordance with NSW EPA *Guidelines for the assessment and management of sites affected by hazardous ground gases* (NSW EPA 2012). This guideline presents qualitative measures of impact, likelihood and consequence that are appropriate for the Site.

A qualitative approach was adopted for the initial risk screening. A matrix was developed that combined hazard (or potential consequence) and probability (or likelihood of the potential consequence becoming a reality). The initial risk screening was undertaken in general accordance with the broad principles outlined in 'Australian Standard ISO/AS 31000, 2009 Risk Management – Principles and Guidelines'.

The LFGRA tables from this exercise are contained in **Appendix E**. It is noted this assessment of risk considers those identified by GHD (2015a) as unacceptable. The risk assessment has been undertaken by Biogas Systems personnel with extensive experience in landfill gas management who have applied a conservative in its approach where uncertainty exists.

Consequences and likelihood classifications are presented in Table 7, Table 8, Table 9:

Table 7 - Classification of consequence

Classification	Definition	Examples
Severe	Fatalities, including multiple fatalities Very serious injuries Catastrophic damage to buildings	Explosion causing building collapse
Medium	Long-term damage to human health Serious injuries Major damage to structures	Permanent injuries Structural damage requiring major repair or demolition and rebuild
Mild	More significant non-permanent injuries Significant damage to buildings, structures or services	Fractures, burns, gas inhalation or other injuries requiring medical treatment Severe cracking requiring closure of building and urgent repair
Minor	Minor non-permanent health effects. Harm that may result in financial loss, business disruption or reputational damage Minor property damage	Minor cuts, bruises requiring first-aid treatment Cosmetic damage to buildings or pavement Damage to landscaping Minor damage to vehicles

Table 8 - Classification of likelihood

Classification	Definition
High Likelihood	A credible linkage exists, and a trigger hazardous event is very likely to occur in the short term, and almost inevitable over the full timeframe of concern (Typically the effective life of a building or development). The likelihood of the stated consequence is also high.
Likely	A credible linkage exists, and all necessary elements required for a trigger hazardous event to occur are present. Occurrence is not inevitable, but it is possible in the short term, and probable over the full timeframe of concern. The stated consequence is likely
Low likelihood	A credible linkage exists and circumstances under which a trigger hazardous event could occur are possible. However, it is by no means certain that the event will occur within the timeframe of concern, and it is less likely in the short term. Thus, there is a low likelihood that the stated consequence will occur.
Unlikely	A credible linkage exists but circumstances are such that it is improbable that a trigger hazardous event would occur within the timeframe of concern, and therefore unlikely that the stated consequence will occur.

Table 9 - Qualitative Risk assessment matrix

		Consequence			
		Severe	Medium	Mild	Minor
Probability	Highly Likely	Very High Risk	High Risk	Moderate Risk	Moderate/low risk
	Likely	High Risk	Moderate Risk	Moderate/Low Risk	Low Risk
	Low Likelihood	Moderate Risk	Moderate/Low Risk	Low Risk	Very Low Risk
	Unlikely	Moderate/Low Risk	Low Risk	Very Low Risk	Very Low Risk

Based on this assessment the primary hazards identified are as follows:

- An accumulation of methane concentrations within the explosive range within enclosed spaces including excavations and or future potential on-site structures or subsurface utilities and/or service pits.
- Based on the absence of development on-site (currently no structures or service utilities) the probability of an explosive risk on-site is considered unlikely. A Level 1 Risk Analysis and Assessment therefore determined a be 'Moderate/Low Risk' due to the identified low likelihood and severe consequences from the incident occurring.
- An accumulation of gas, primarily carbon dioxide at concentrations leading to asphyxiation risks in either on or off-site structures, excavations, basements or subsurface utilities and/or service pits.
- Based on the existence of residential buildings within proximity to the landfill and without knowledge of the nature of construction the presence of subsurface structures, cellars or service pits associated with these (or future structures) should be assumed. Therefore, based on the current monitoring data the probability of gas accumulation to unacceptable levels is considered likely (i.e., in the absence of suitable building restrictions). A Level 1 Risk Analysis and Assessment therefore determined a be 'High Risk' due to the identified low likelihood and severe consequences from the incident occurring.

7.1.2 Level 2 Risk analysis and assessment

Given the determination of the Level 1 Risk analysis and Assessment that a high-risk level could exist, a Level 2 assessment has been undertaken. A maximum Gas Screening Value (GSV) and Characteristic Gas Situation (CS) for the site has been determined based upon Table 6 of the *NSW EPA Guidelines for the Assessment and Management of Sites Impacted by Hazardous Ground Gases (2012)*.

The method considers both gas concentrations and borehole flow rates to define a characteristic condition for a site using a calculation of the Gas Screening Value (GSV). The GSV is a multiple of the maximum gas flow rate (litres/hour) from a borehole and the maximum gas concentration (%v/v).

Table 10 - Wilson and Card Classification (modified from Table 6 NSW EPA 2012)

	Characteristic situation	Risk Classification	Gas Screening Value Threshold (GSV) (CH_4 or CO_2) (l/hr)	Additional Factors	Typical source of generation
	1	Very low risk	<0.07	Typically, methane 1.0 % v/v and/or carbon dioxide 5 % v/v. Otherwise consider increase to Situation 2	Natural soils with low organic content "Typical" fill
	2	Low risk	<0.7	Borehole air flow rate not to exceed 70l/hr. Otherwise consider increase to characteristic Situation 3	Natural soil, high peat/organic content. "Typical" made ground
	3	Moderate risk	<3.5		Old landfill, inert waste, mine-working flooded
	4	Moderate to high risk	<15	Quantitative risk assessment required to evaluate scope of protective measures.	Mine-working – susceptible to flooding, completed landfill WMP 26B criteria)
	5	High risk	<70	Level 3 risk assessment required	Mine-working Un-flooded inactive with shallow workings near surface
	6	Very high risk	>70		Recent putrescible landfill site

7.1.3 Calculated gas screening value using NSW 2012 Guidelines

Gas protection guidance values are calculated for perimeter wells only as no dwellings are proposed to be placed upon the landfill. GSVs have been calculated for each borehole under consideration (refer to section 5.3.4 and data tables provided in **Appendix C**). The risk calculation was carried out conservatively for methane and carbon dioxide by adding the error range of the GA5000 flow measuring device (± 0.3 l/hr) with the worst-case monitoring value adopted.

The characteristic gas situations (CS), risk and associated gas protection guidance values (based upon low density residential criteria) are selected using *Table 7: Guidance values for gas protection* and *Table 8a: Scores for Protection Measures* of the *NSW EPA Guidelines*.

The calculated GSV for worst-case monitoring was: 0.122 l/h for CO_2 with a calculated GSV the CS rating would be 2. This value was calculated based on increasing the actual observed flow by 0.3 l/h (the recording instruments accuracy range, refer Table 6 for instrument accuracy) to provide a conservative with a risk classification (RC) of very low risk.

- Based on the CS rating of 2 it would be possible to develop land for sensitive uses including residential, public buildings and commercial. It should be noted however that the monitoring well network is generally within 20 m of the waste mass. Given there is a limited driving force there is likely to be a significant capacity for lateral attenuation from any site derived gases. Therefore, a CS rating of 2 is considered likely to be conservative in the context of the proposed development.

8 CONCLUSION AND RECOMMENDATIONS

This LFGRA for the former landfill located at Grange Avenue Reserve (the Site) was undertaken following the installation of twelve (12) additional perimeter gas monitoring wells on the perimeter of the Site. As a response to data gaps identified within the existing LFGRA (GHD, 2015a), the 12 new perimeter monitoring wells were installed, followed by four LFG monitoring events undertaken across a four-week period (from February 2018) that included the newly installed wells, together with four existing perimeter wells and five existing in-waste wells. The results of this recent monitoring in addition to revised LFG modelling have been considered in the development of this LFGRA.

The LFG modelling and monitoring undertaken as part of this and previous assessments have confirmed LFG as a potential hazard to current and proposed development of land near the Site. Whilst assessment of the data has indicated there is likely to be negligible gas production from the existing waste mass, the presence of both methane and carbon dioxide has been detected within the perimeter monitoring network at concentrations exceeding the adopted NSW EPA criteria. Notwithstanding these exceedances, the monitoring data shows the actual risk from methane is likely to be low, with stabilised readings in the perimeter monitoring network recorded at 0 %v/v across all wells. Carbon dioxide concentrations however, remained consistently above criteria with stable (consistent peak and stablished) concentrations exceeding hazardous (asphyxiation) levels, indicating it is present in potentially hazardous volumes with a likelihood of an active ongoing source.

The monitoring results also support a hypothesis that due to the landfill age, relatively low rate of gas generation and above ground level setting of the site LFG is likely able to partition into is main constituent gases, carbon dioxide and methane. This occurs as methane is both lighter and less (water) soluble than carbon dioxide allowing the methane component to accumulate within the waste mass (above ground), while carbon dioxide is more likely to move down into the underlying strata, driven by both buoyancy and dissolved in downward migrating leachate. The occurrence of relatively low volumes of methane in the perimeter network maybe a consequence of limited dissolution from leachate/groundwater (where it is sparingly soluble) and/or from anaerobic degradation of organic matter within the groundwater.

A Level 2 risk analysis and assessment undertaken in accordance with the NSW EPA *Guidelines for the Assessment and Management of Sites Impacted by Hazardous Ground Gases* (2012) indicates a CS rating of 2 whereby it is possible to develop land around the Site for sensitive uses including residential, public buildings and commercial. This is however likely to be a conservative rating for development as it was established from gas concentrations within the landfill's perimeter network, within 20 m of the waste mass. Lateral and vertical attenuation of ground gases over the distance to these potential receptors would likely result in a reduced rating.

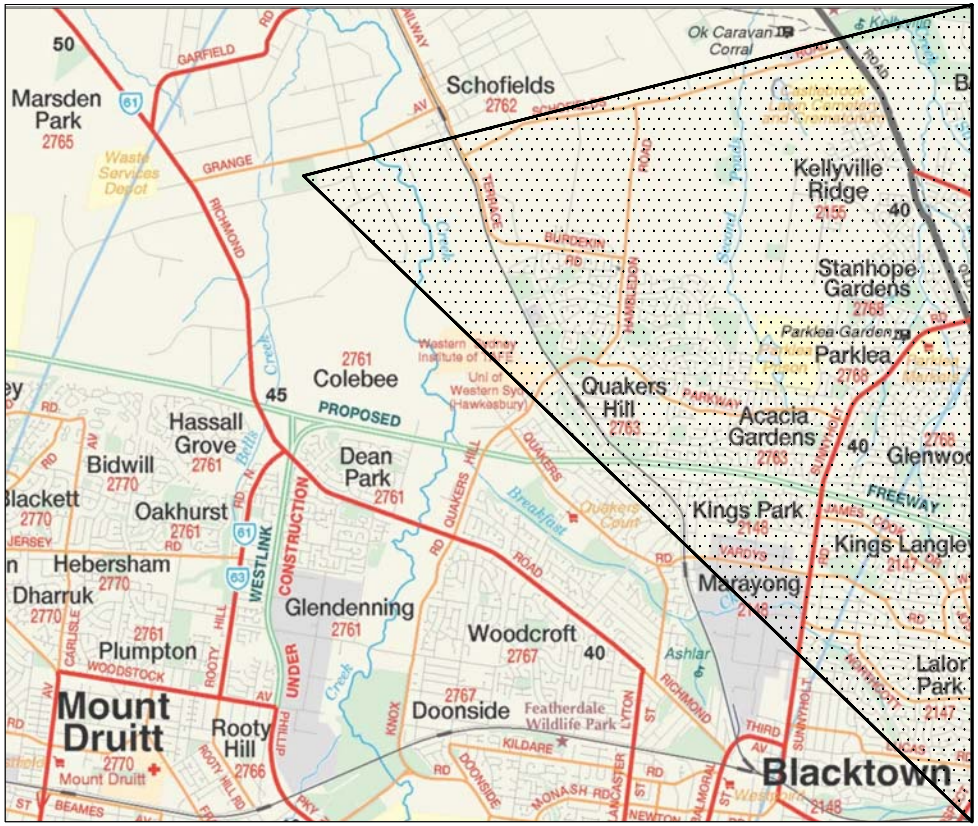
In general, we consider the landfill is not likely to present a significant ongoing risk to the proposed development at the Site, due to:

- Negligible, declining and non-replenishing gas production from the landfill (source), thereby providing limited driving force for lateral migration.
- The Site is constructed above ground level, thereby limiting direct connection to the subsurface strata and potential migration pathways.
- The relatively proximity of perimeter monitoring network to the Site in-situ landfill waste mass from which the LFGRA was based provides a conservative CS rating of 2. Further the CS rating was based on peak carbon dioxide concentrations, however actual flow rates were and GSV's were low and provided an initial CS rating of 1 (low risk). It is therefore considered likely with greater separation distance the risk presented from the landfill would be further reduced.

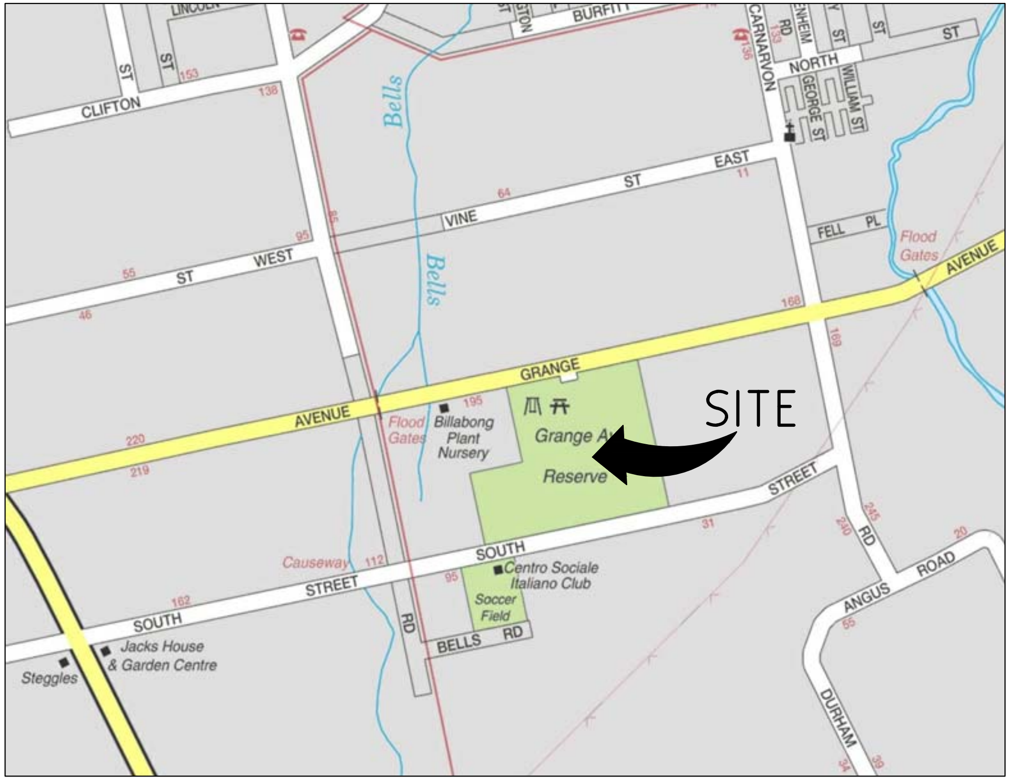
This assessment has been undertaken in consideration with number of limitations associated with the available monitoring data, as such we recommend the following actions are implemented to enable a less limiting assessment of risk:

- Extend the monitoring period in accordance with NSW EPA (2012) *Guidelines for the Assessment and Management of Sites Impacted by Hazardous Ground Gases*. Where this may impact the development program a high-frequency in-situ gas analyser can be used to expedite period of collecting representative data and capturing worst case conditions. Previous experience on similar sites with NSW accredited Auditors indicates six weeks to be sufficient.
- Trace gas analysis on selected wells to confirm source of ground gas
- Nitrogen injection and recharge tests to estimate gas permeability of sub-surface and possible zone of LFG accumulation.
- Undertake an assessment of groundwater as a potential source of the observed ground gases.
- Install at least one background monitoring well in an area known to be natural ground away from potential influences from the landfill to assess the potential for natural sources of the gases identified (establish the background carbon dioxide).
- Establish presence of residual methane in the soil on the around the Site by installation and monitoring of monitoring wells spaced at about 50 m apart.
- Refine landfill gas risk assessment with final recommendations for remediation of Site based on data collected and the safe distance for houses on the proposed development.

Appendix A : **FIGURES**



REGIONAL MAP
NOT TO SCALE



UBD MAP
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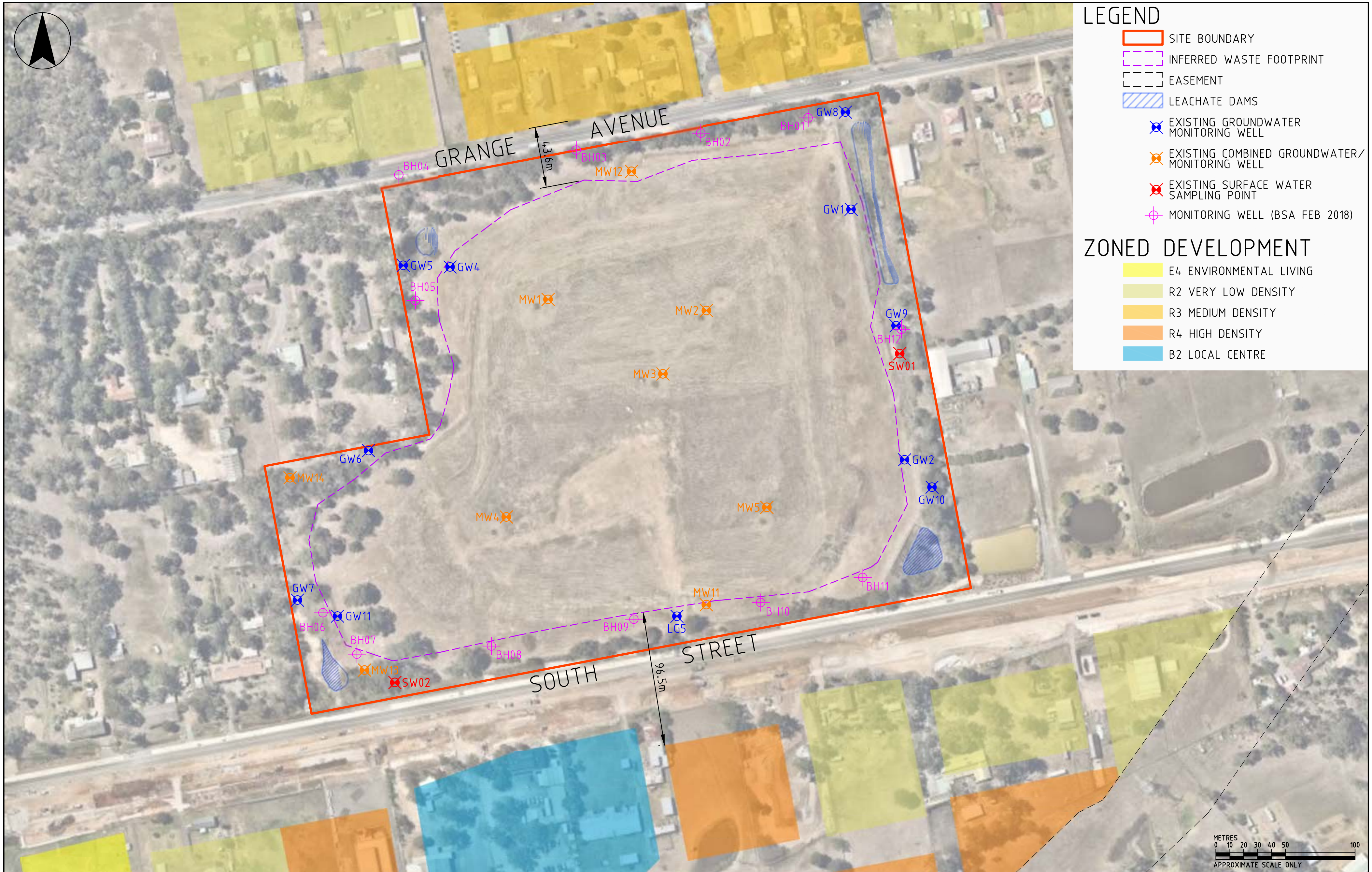
ISSUE	DATE	AMENDMENTS	DRN	CKD
01	09.04.18	ORIGINAL ISSUE	RM	JV

SITE LOCATION

LANDFILL GAS RISK ASSESSMENT
GRANGE AVENUE, SCHOFIELDS, NSW

SHEET SIZE: A3 | DRAWN: RM | REV: 01 | DATE: 09.04.18 | DWG NAME: 0040-F01 | CHECKED | APPROVED | FIG No: FIGURE 1



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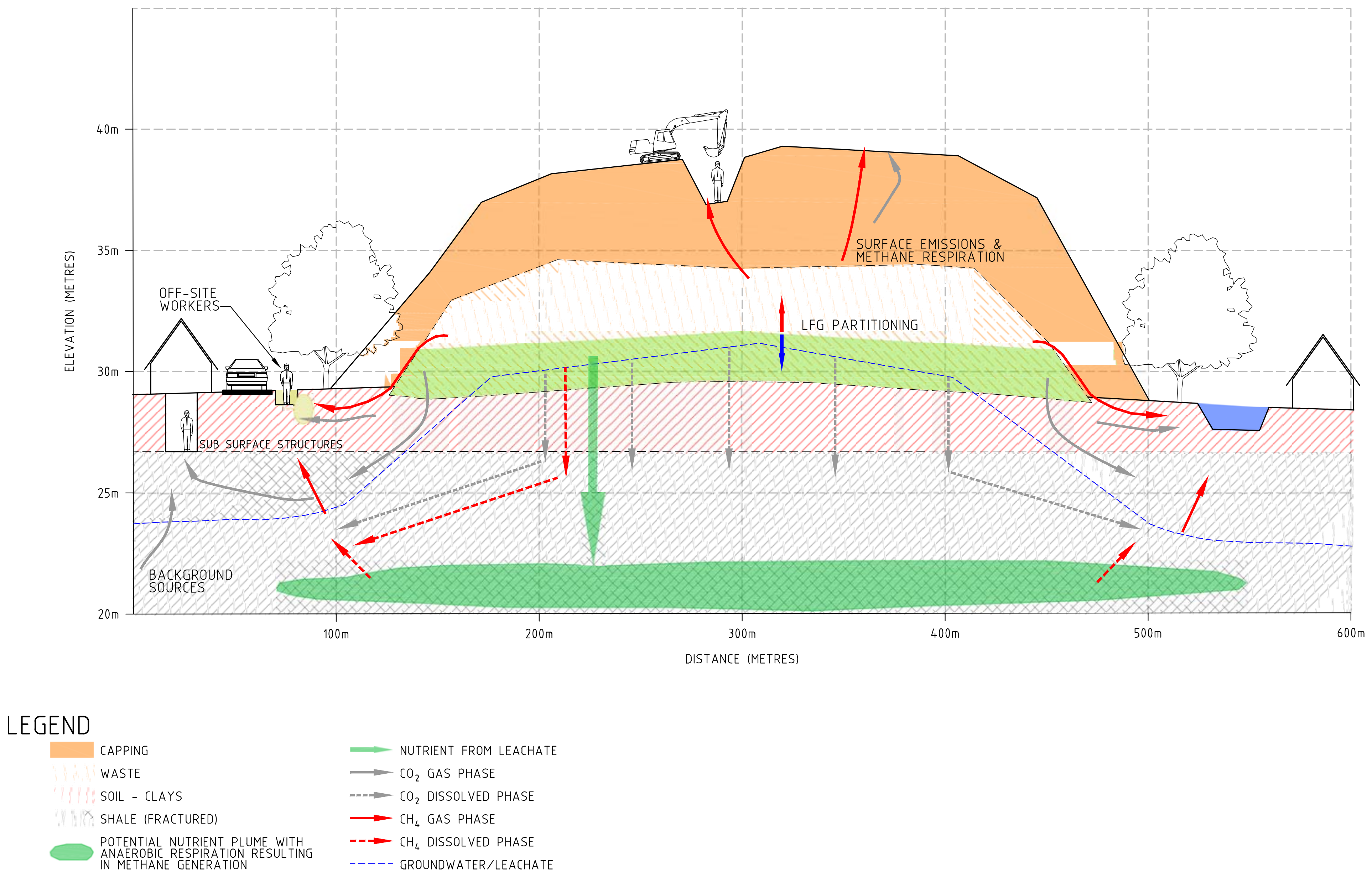
ISSUE	DATE	AMENDMENTS	DRN	CKD
01	03.01.17	ORIGINAL ISSUE	RM	JV

OVERALL SITE LAYOUT
LANDFILL GAS RISK ASSESSMENT
GRANGE AVENUE, SCHOFIELDS, NSW

SHEET SIZE	DRAWN: RM	DATE: 04.04.18	CHECKED	APPROVED	FIG No: FIGURE 2
A3	REV: 01	DWG NAME: 0040-F02			



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ISSUE	DATE	AMENDMENTS	DRN	CKD
01	09.04.18	ORIGINAL ISSUE	RM	JV

CONCEPTUAL SITE MODEL
LANDFILL GAS RISK ASSESSMENT
GRANGE AVENUE, SCHOFIELDS, NSW

SHEET SIZE	DRAWN: RM	DATE: 09.04.18	CHECKED	APPROVED	FIG No:
A3	REV: 01	DWG NAME: 0040-F03			FIGURE 3

Appendix B : **WELL INSTALLATION REPORT**

Report

Installation of gas monitoring wells

Grange Avenue Reserve, Schofields, NSW

Environmental Resources Management

Job ID. 040ERM

March 2018

PROJECT NAME:	Installation of gas monitoring wells – Grange Avenue Reserve, West Schofields
JOB ID:	040ERM
DOCUMENT CONTROL NUMBER	040ERM_RPT0001.A
PREPARED FOR:	Environmental Resources Management
APPROVED FOR RELEASE BY:	
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DOCUMENT CONTROL

VERSION	DATE	COMMENT	PREPARED BY	REVIEWED BY
A	10.03.2018	Draft for Client comments	Sam Willacy	Aidan Marsh

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CONTENTS

FIGURES

EXECUTIVE SUMMARY

This report documents installation of landfill gas monitoring wells at the Grange Avenue Reserve located at Grange Avenue, Schofields, NSW. The installation was undertaken by BG Drilling contractors engaged by Environmental Resources Management Pty Ltd. Biogas Systems Australia were engaged by Environmental Resources Management to supervise the drilling program.

Twelve (12) LFG monitoring wells (designated BH01 to BH12) were installed following solid auger drilling to a maximum depth of 13.3 m below ground level. Subsurface conditions encountered in the well boreholes generally comprised the following types:

Type 1: Natural soils
These consisted of mainly;

- Shale based deposits including shale / claystone / siltstone
- Gravel based deposits including gravel / clayey gravel
- Sand based deposits including gravelly sand / clayey sand / silty sand

Type 2: Capping Materials
Fill materials that appear to be acting as a capping layer were intersected in boreholes BH07-11 and generally included;

- High plasticity sandy clays
- High plasticity silty clays

Type 3: Uncontrolled fill
Uncontrolled fill was experienced in the minority of the boreholes and mainly consisted of;

- Gravelly sands/ sandy gravels
- Silty/Clayey sands

No municipal waste or refuse was recorded whilst installing the wells, indicating that all the boreholes are outside of the landfill area although some fill was observed.

Groundwater was encountered in all monitoring wells apart from BH01, BH05 and BH09.

1 INTRODUCTION

This report documents installation of LFG monitoring wells at Grange Avenue Reserve located on Grange Avenue, Schofields, NSW (the Site). The installations were undertaken by BG Drilling Contractors Biogas Systems Australia (Biogas Systems) were retained by Environmental Resources Management (ERM) for the purpose of supervision of the installation of the gas monitoring wells and a subsequent Landfill Gas Risk Assessment (LFGRA) based on monitoring from the new well locations.

Twelve (12) LFG monitoring wells (designated BH01 to BH12) were installed following solid auger drilling to a maximum depth of 13.3 m Below Ground Level (BGL).

2 SITE DESCRIPTION

The Site is about 15.3 hectares (ha) in area and is surrounded by sparsely spaced residential and commercial properties. The property is bound to the north by Grange Avenue, to the south by South Street with rural properties beyond both. To the east and west it is bordered by rural, residential properties.

The Site has been owned by Council since 1916 and it operated as a landfill for the disposal of putrescible and other wastes between approximately 1971 and 1975. Prior to this (based on an aerial photograph from 1966) the site appears to have been uncleared bushland. It is understood that no quarrying or excavation was undertaken prior to waste disposal operations commencing. As such, it is understood that the putrescible waste landfilled was placed above the natural prevailing ground levels of the site. It is thought that following completion of putrescible waste disposal operations in circa 1975 that the waste was covered with a layer of fill materials.

Prior to 1993, it is understood that the site was subject to illegal waste dumping by unknown parties. Council suggests that this illegal waste was regularly removed from the site and disposed of at a licensed landfill. Additional earthen fill materials are understood to have been imported and placed on the site between 1993 and 2010 (GHD, 2015).

Figure 1. Location of Grange Avenue Reserve

Figure 2. Boundaries of the site

3 METHODOLOGY

Boreholes were drilled to a maximum depth of 13.3 m BGL at locations nominated by Biogas Systems and ERM. It was planned to hand augur to a depth of 1.5 mBGL to prevent disturbance of utilities or services below ground level. It became apparent upon hand auguring that this would not be possible because the surface layers of soil were too hard, and it was found that drilling below 0.2 m by hand would not be feasible. Boreholes were then drilled using a solid flight auger drill rig with a tungsten carbide drill bit (ADT method), owned and operated by BG Drilling. The target depth of all wells was to below the level of the waste in the landfill (approximately 12 m), to refusal on bedrock or to water level. All LFG monitoring well locations were recorded using a hand-held GPS.

Monitoring wells were installed at each of the twelve boreholes drilled, with gas well construction determined dependent on subsurface conditions encountered. All LFG wells installed to 12 mBGL comprised 1m of solid Class 18 PVC pipe, with the lower 11.0 m length being PVC slotted screen, and with a push on bottom cap. The annulus surrounding these wells was backfilled with coarse clean crushed silica gravel (up to 5 mm) to 0.8 m BGL (0.2 m above slotted section), then topped with a bentonite (pellet) plug to 0.2-0.3 m BGL. At the top of the well pipes were fitted with expanding rubber seal caps with a built in quick connect valve fittings, then covered with steel monuments set in 'rapid set' concrete.

Full borehole logs and gas monitoring well construction details are presented in **Appendix A**, together with explanatory notes. Well coordinates (latitude and longitude) are included in the borehole/well reports. Photographs illustrating the approximate location of each well, and the finished surface conditions, are presented with the borehole/well report **Appendix A**.

Supervision of the well installation was conducted by an experienced landfill technician from Biogas Systems who logged soil and groundwater conditions encountered and determined appropriate well construction details based upon the subsurface conditions encountered. Well installations were carried out between 21 and 23 February 2018.

Well locations are shown in **Figure 3** at the end of this report,

4 RESULTS

4.1 Geology

The 1:100,000 Soil Landscape Series Sheet 9030 – Penrith (Bannerman & Hazelton, 1990) maps the site as the Blacktown Soil Landscape Group. This Landscape Group is characterised by soils of residual origin comprising shallow to moderately deep (<0.1 m) hard setting mottled texture contrast soils and red and brown podzolic soils on crests grading to yellow podzolic soils on lower slopes and in drainage lines.

The 1:100,000 Geological Series Sheet 9030 – Penrith (New South Wales Government, 1991) maps the site as shallow Wianamatta Group shales (usually Ashfield Shale) with steeply inclined bedding plans and small discontinuous sandstone or siltstone lenses. Some locations have a thin remnant capping of Michinbury Sandstone.

4.2 Subsurface conditions

Subsurface conditions encountered in the well boreholes generally comprised the following types:

Type 1: Natural soils
These consisted of mainly;

- Shale based deposits including shale / claystone / siltstone
- Gravel based deposits including gravel / clayey gravel
- Sand based deposits including gravelly sand / clayey sand / silty sand.

Type 2: Capping materials
Fill materials that appear to be acting as a capping layer were intersected in boreholes BH07 to 11 and generally included;

- High plasticity sandy clays
- High plasticity silty clays.

Type 3: Uncontrolled fill
Uncontrolled fill was experienced in the minority of the boreholes and mainly consisted of;

- Gravelly sands/ sandy gravels
- Silty/Clayey sands.

No municipal waste or refuse items were found indicating that all the boreholes are outside of the landfill area.
Groundwater was encountered in all monitoring wells apart from BH01, BH05 and BH09. All wells will be monitored in the future for the presence of any groundwater.

5 CONCLUSION

The monitoring wells have been installed in virgin ground outside the waste mass and the process has been recorded in this report. The monitoring well locations are considered valid for intercepting sub-surface movement or accumulation of LFG, therefore data collected from these wells is considered valid for inclusion into the LFGRA.

Figure 3. Location of Boreholes

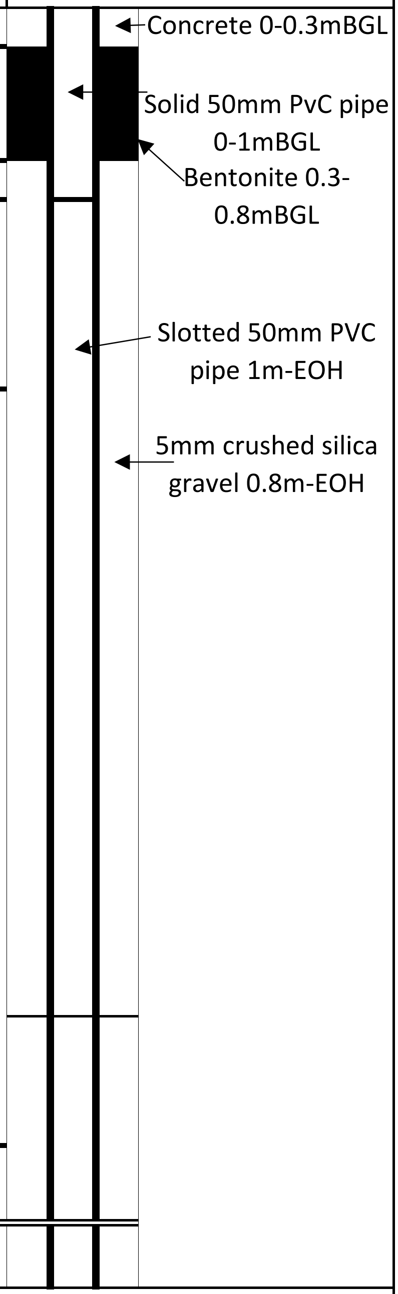
Appendix A : **BOREHOLE LOGS**

Engineering Borehole Log

Bore ID: BH01	**Project Name:** West Schofields	**Date Started:**	22/02/2018
Location Grange Avenue Reserve	**Client:** ERM	**Date Completed:**	22/02/2018
Co-ords 33°42'4.88"S 150°51'10.92"E	**Project Number:** 0040	**Logged by:**	Sam Willacy

Groundwater	Depth (mBGL)	USCS Classification – Letter	USCS Classification – Graphic Log	Description (Type, size, consistency/density, moisture content, colour where applicable)	Additional Observations
	0	CL		Hard, dry, clayey topsoil	
		CL		Red, clayey, gravel	
		CH		Hard grey, clay, highly plasticity	
	1	CL		Red, dry, clayey shale	
	2–7	CL		Grey, dry, clayey shale	
		CL		Very hard shale rock. Could be other hard rock. Drill was struggling to penetrate	
	8			End of Borehole 7.8m BGL	

Borehole Construction Details



DRILLER	BG Drilling
DRILLING METHOD	Solid Auger 125mm
GROUNDWATER	N/a ▼

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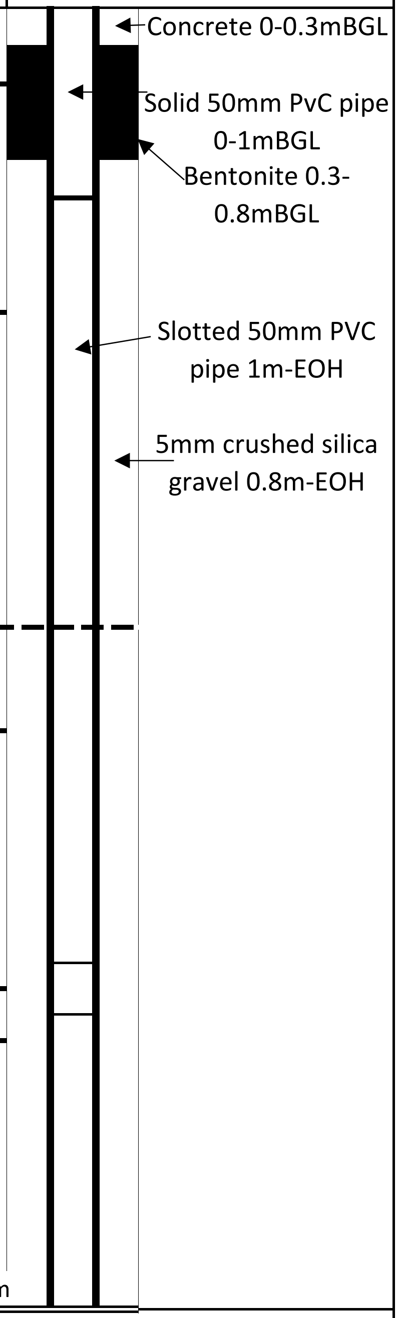
Engineering Borehole Log

Bore ID: BH02	**Project Name:** West Schofields		**Date Started:** 22/02/2018
Location Grange Avenue Reserve		**Client:** ERM	**Date Completed:** 22/02/2018
Co-ords 33°42'5.39"S 150°51'7.93"E		**Project Number:** 0040	**Logged by:** Sam Willacy

Groundwater	Depth (mBGL)	USCS Classification – Letter	USCS Classification – Graphic Log	Description (Type, size, consistency/density, moisture content, colour where applicable)	Additional Observations
	0	CL		Hard clayey top soil	
	1	CL		Dry graveley clay	
	2, 3, 7	CL		Red, dry clayey shale	
	8, 9	CL		Grey, dry clayey shale	
		CL		Hard layer of shale	
▼	10, 11	CL		Grey, dry clayey shale	Refusal at 11.6m
				End of Borehole 11.6m BGL	

Borehole Construction Details



DRILLER	BG Drilling
DRILLING METHOD	Solid Auger 125mm
GROUNDWATER	10.4m ▼

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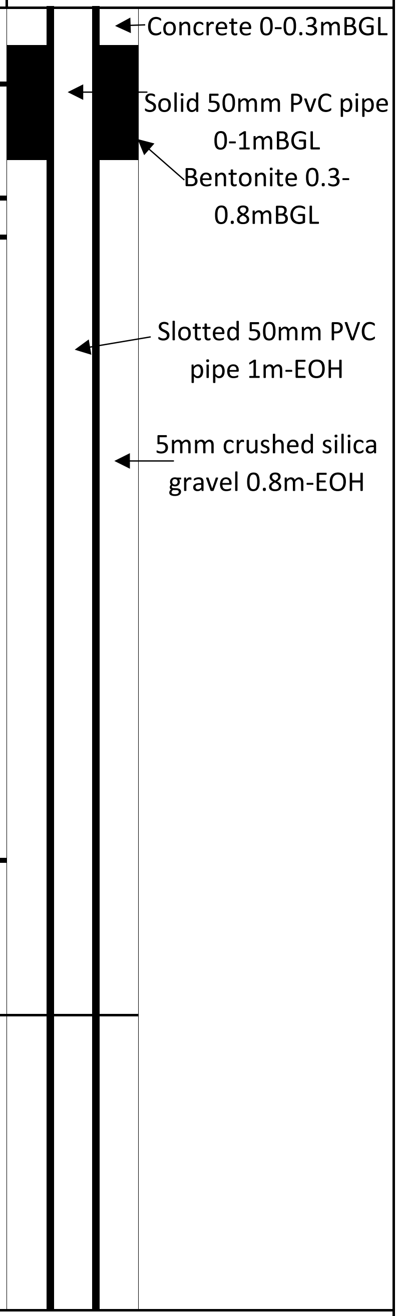
Engineering Borehole Log

Bore ID: BH03	**Project Name:** West Schofields	**Date Started:**	22/02/2018
Location Grange Avenue Reserve	**Client:** ERM	**Date Completed:**	22/02/2018
Co-ords 33°42'5.88"S 150°51'4.49"E	**Project Number:** 0040	**Logged by:**	Sam Willacy

Groundwater	Depth (mBGL)	USCS Classification – Letter	USCS Classification – Graphic Log	Description (Type, size, consistency/density, moisture content, colour where applicable)	Additional Observations
	0	CL		Hard, dry clayey top soil	
		CL			
	1	CH		High plasticity grey clay	
	2, 3, 4, 5	CL		Red coloured gravelly clayey shale	
	6			Grey coloured hard and dry shale	
▼	10, 11	CL		Grey coloured hard and dry shale	
				End of Borehole 11.6m BGL	

Borehole Construction Details



DRILLER	BG Drilling
DRILLING METHOD	Solid Auger 125mm
GROUNDWATER	10m ▼

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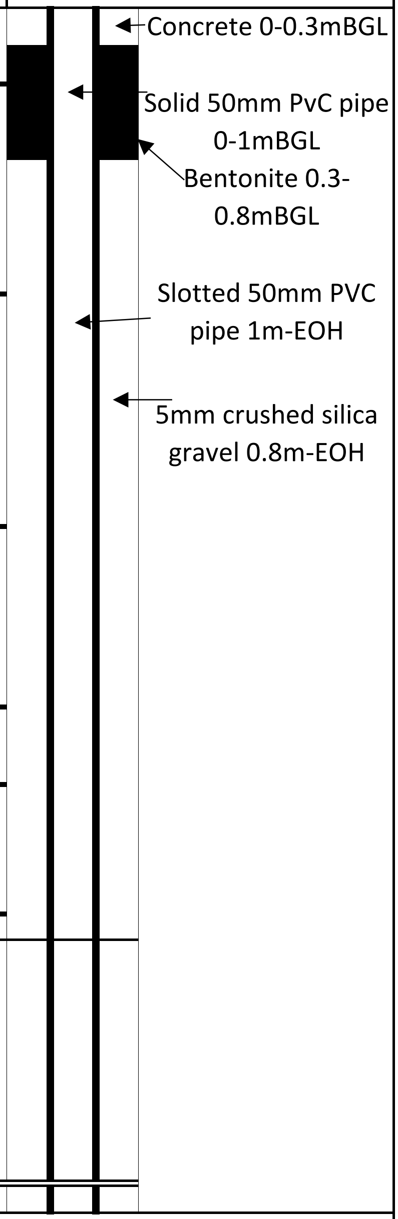
Engineering Borehole Log

Bore ID: BH04	**Project Name:** West Schofields	**Date Started:**	21/02/2018
Location Grange Avenue Reserve	**Client:** ERM	**Date Completed:**	21/02/2018
Co-ords 33°42'6.54"S 150°50'59.58"E	**Project Number:** 0040	**Logged by:**	Sam Willacy

Groundwater	Depth (mBGL)	USCS Classification: Letter	USCS Classification: Graphic Log	Description (Type, size, consistency/density, moisture content, colour where applicable)	Additional Observations
	0	CL		Topsoil, gravelly clay	
	1	CL		Grey, dry soil, clay	
	2–3	CL		Red clay band	
	4	CL		Dry becoming firm sandstone/shale	
	5	CL		Dry, grey shale	
	6				
▼	9–12	CL		Dry, grey, firm shale	
				End of Borehole 12.0m BGL	

Borehole Construction Details



DRILLER	BG Drilling
DRILLING METHOD	Solid Auger 125mm
GROUNDWATER	8.0m ▼

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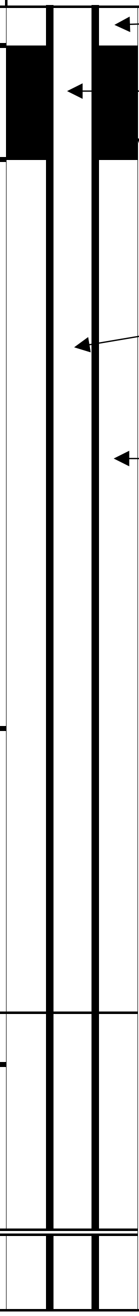
Engineering Borehole Log

Bore ID:	BH05	**Project Name:** West Schofields	**Date Started:**	23/02/2018
Location	Grange Avenue Reserve	**Client:** ERM	**Date Completed:**	23/02/2018
Co-ords	33°42'9.94"S 150°50'59.97"E	**Project Number:** 0040	**Logged by:**	Sam Willacy

Groundwater	Depth (mBGL)	USCS Classification – Letter	USCS Classification – Graphic Log	Description (Type, size, consistency/density, moisture content, colour where applicable)	Additional Observations
	0			Hard, dry topsoil	
		CL		Hard, gravely, clay	
	1–4	CL		Red, clayey, shale	
	5–6	CL		Soft, dry, grey shale	
	10–11	CL		Soft, grey shale	12.5m BGL. Well installed to 11.2 due to collapse
				End of Borehole 11.2m BGL	

Borehole Construction Details



DRILLER	BG Drilling
DRILLING METHOD	Solid Auger 125mm
GROUNDWATER	N/a ▼

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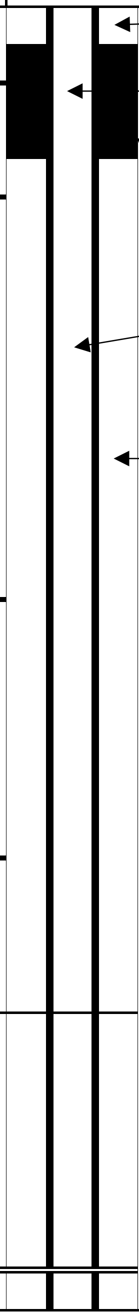
Engineering Borehole Log

Bore ID: BH06	**Project Name:** West Schofields	**Date Started:**	23/02/2018
Location Grange Avenue Reserve	**Client:** ERM	**Date Completed:**	23/02/2018
Co-ords 33°42'16.91"S 150°50'58.35"	**Project Number:** 0040	**Logged by:**	Sam Willacy

Groundwater	**Depth (mBGL)**	**USCS Classification – Letter**	**USCS Classification – Graphic Log**	**Description (Type, size, consistency/density, moisture content, colour where applicable)**	**Additional Observations**
	0	CL		Dry, soft topsoil	
		CL		Sandy, rocky, loose fill	
	1–3	CL		Red, gravelly, sand, soft	
	3–5	CL		brown, gravelly clay, harder	
	5–6				
▼	10–11	CL		Dry, grey shale	Drilled to 12m but well installed to 11.3m due to collapse
				End of Borehole 11.3m BGL	

Borehole Construction Details



Concrete 0-0.3mBGL

Solid 50mm PvC pipe 0-1mBGL

Bentonite 0.3-0.8mBGL

Slotted 50mm PVC pipe 1m-EOH

5mm crushed silica gravel 0.8m-EOH

DRILLER	BG Drilling
DRILLING METHOD	Solid Auger 125mm
GROUNDWATER	11.2m▼

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Engineering Borehole Log

Bore ID:	BH07	**Project Name:** West Schofields		**Date Started:**	21/02/2018
Location	Grange Avenue Reserve		**Client:** ERM	**Date Completed:**	21/02/2018
Co-ords	33°42'17.69"S 150°50'59.15"		**Project Number:** 0040	**Logged by:**	Sam Willacy

Groundwater	Depth (mBGL)	USCS Classification: Letter	USCS Classification: Graphic Log	Description (Type, size, consistency/density, moisture content, colour where applicable)	Additional Observations	Borehole Construction Details
	0			hard, dry topsoil		Concrete 0-0.3mBGL
				dry, red clayey sand		Solid 50mm PvC pipe 0-1mBGL; Bentonite 0.3-0.8mBGL
	1			hard grey clay layer		
	2, 3, 4			Red, gravelly, sand, soft clay		Slotted 50mm PVC pipe 1m-EOH; 5mm crushed silica gravel 0.8m-EOH
	5, 6			Light grey shale		
▼	10, 11					
				End of Borehole 11.6m BGL		

DRILLER	BG Drilling
DRILLING METHOD	Solid Auger 125mm
GROUNDWATER	10m ▼

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Engineering Borehole Log

Bore ID: BH08	**Project Name:** West Schofields	**Date Started:**	21/02/2018
Location Grange Avenue Reserve	**Client:** ERM	**Date Completed:**	21/02/2018
Co-ords 33°42'17.25"S 150°51'2.47"E	**Project Number:** 0040	**Logged by:**	Sam Willacy

Groundwater	Depth (mBGL)	USCS Classification – Letter	USCS Classification – Graphic Log	Description (Type, size, consistency/density, moisture content, colour where applicable)	Additional Observations
	0	CL		Hard, dry, topsoil	
		CL		grey, sandy clay	
	1	CH		Hard, grey clay layer	
	2–6	CL		Dry, grey shale Soft becoming firmer	
▼ (6.5)	11–12	CL		Grey, shaley clay, wet	
				End of Borehole 12.2m BGL	

Borehole Construction Details
- Concrete 0-0.3mBGL
- Solid 50mm PvC pipe 0-1mBGL
- Bentonite 0.3-0.8mBGL
- Slotted 50mm PVC pipe 1m-EOH
- 5mm crushed silica gravel 0.8m-EOH

DRILLER	BG Drilling
DRILLING METHOD	Solid Auger 125mm
GROUNDWATER	6.5m ▼

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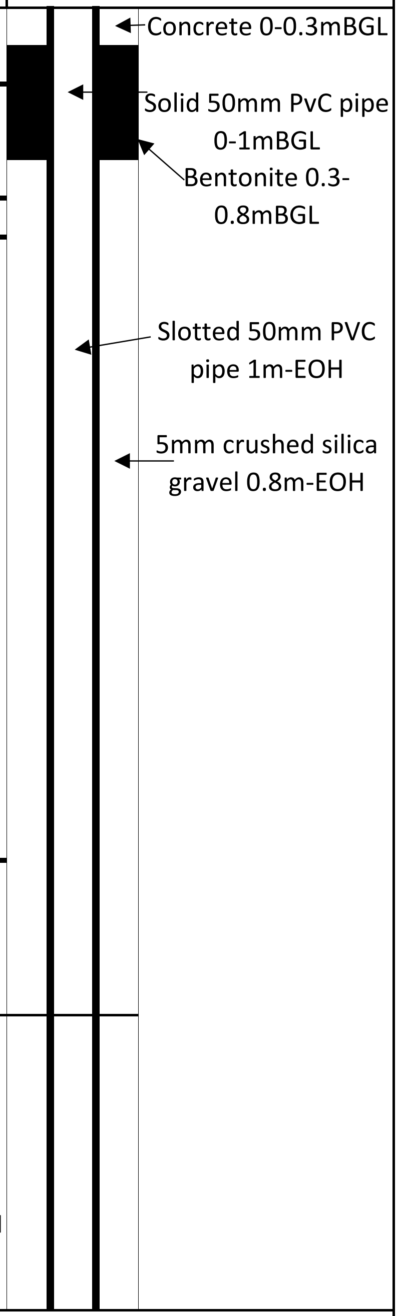
Engineering Borehole Log

Bore ID:	BH09	**Project Name:** West Schofields		**Date Started:**	21/02/2018
Location	Grange Avenue Reserve	**Client:** ERM		**Date Completed:**	21/02/2018
Co-ords	33°42'16.44"S 150°51'6.23"E	**Project Number:** 0040		**Logged by:**	Sam Willacy

Groundwater	Depth (mBGL)	USCS Classification: Letter	USCS Classification: Graphic Log	Description (Type, size, consistency/density, moisture content, colour where applicable)	Additional Observations
	0			Topsoil	
				Red, gravelly, clay	
	1			Hard grey clay layer	
	2, 3, 4, 5			soft grey, shale	
	6, 10, 11			Hard, dry, grey shale	Drilled to 13.3m. Installed well to 11.9m due to collapse
				End of Borehole 11.9m BGL	

Borehole Construction Details



DRILLER	BG Drilling
DRILLING METHOD	Solid Auger 125mm
GROUNDWATER	N/a ▼

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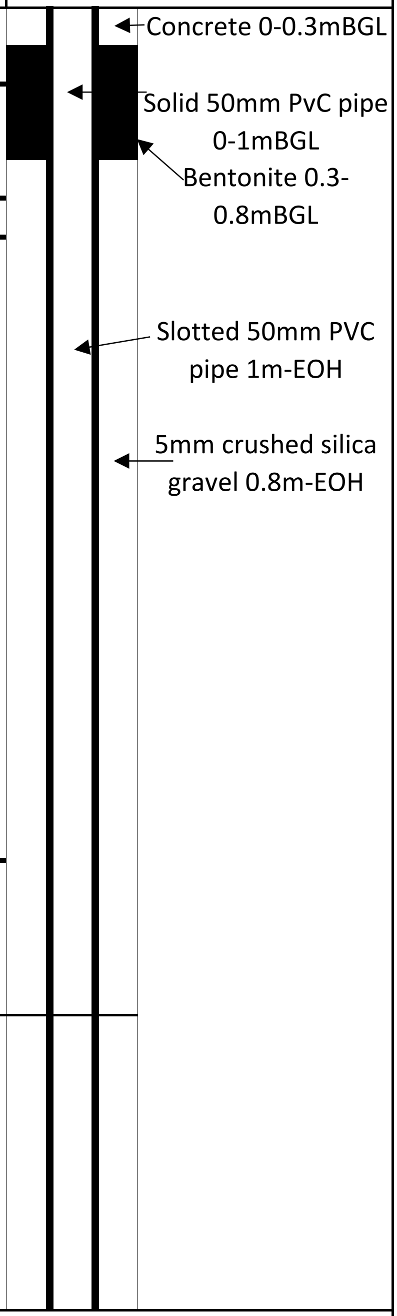
Engineering Borehole Log

Bore ID: BH10	**Project Name:** West Schofields		**Date Started:** 22/02/2018
Location Grange Avenue Reserve	**Client:** ERM		**Date Completed:** 22/02/2018
Co-ords 33°42'16.13"S 150°51'9.51"E	**Project Number:** 0040		**Logged by:** Sam Willacy

Groundwater	Depth (mBGL)	USCS Classification – Letter	USCS Classification – Graphic Log	Description (Type, size, consistency/density, moisture content, colour where applicable)	Additional Observations
	0	CL		Hard, clay, topsoil	
		CL		Hard, red, gravelly clayey	
	1	CH		Hard, grey clay layer	
	2			Dry, grey, clay and shale	
	3	CL			
	4				
	5			dry, grey shale	
▼	6				
	10				
	11	CL		dry grey shale	
				End of Borehole 12.3m BGL	



DRILLER	BG Drilling
DRILLING METHOD	Solid Auger 125mm
GROUNDWATER	9.5m ▼

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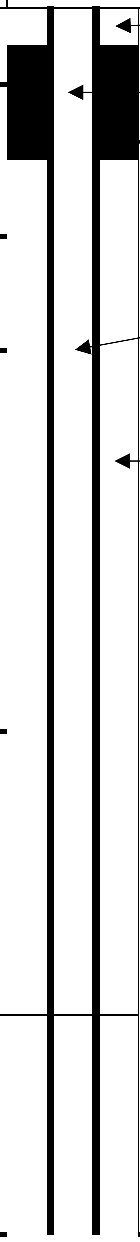
Engineering Borehole Log

Bore ID: BH11	**Project Name:** West Schofields	**Date Started:**	22/02/2018
Location Grange Avenue Reserve	**Client:** ERM	**Date Completed:**	22/02/2018
Co-ords 33°42'15.72"S 150°51'12.29"	**Project Number:** 0040	**Logged by:**	Sam Willacy

Groundwater	Depth (mBGL)	USCS Classification – Letter	USCS Classification – Graphic Log	Description (Type, size, consistency/density, moisture content, colour where applicable)	Additional Observations
	0	CL		Hard, dry topsoil	
	1	CL		Loose, dry sandy soil Some small rocks up to 50mm	
		CH		Hard grey, clay band	
	2, 3, 4	CL		Soft, dry, red shale	
▼	5, 6	CL		Dry, grey shale	
	8, 9	CL		Dry, grey shale	
				End of Borehole 9.2m BGL	

Borehole Construction Details



DRILLER	BG Drilling
DRILLING METHOD	Solid Auger 125mm
GROUNDWATER	7.5m ▼

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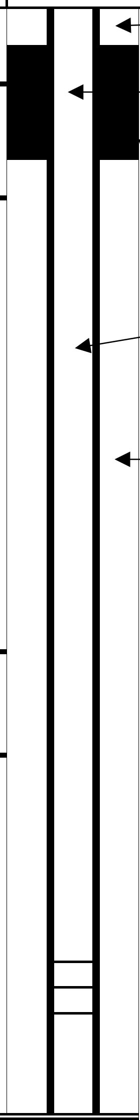
Engineering Borehole Log

Bore ID: BH12	**Project Name:** West Schofields	**Date Started:**	22/02/2018
Location Grange Avenue Reserve	**Client:** ERM	**Date Completed:**	22/02/2018
Co-ords 33°42'10.08"S 150°51'13.26"E	**Project Number:** 0040	**Logged by:**	Sam Willacy

Groundwater	Depth (mBGL)	USCS Classification – Letter	USCS Classification – Graphic Log	Description (Type, size, consistency/density, moisture content, colour where applicable)	Additional Observations
	0	CL		Hard, dry topsoil	
		CL		Soft, sandy, gravelly clay	
	1	CL			
	2, 3	CL		Brown, dry clayey shale	
▼	4, 7, 8, 9	CL		Dry, grey, clayey shale	Refusal at 9.6m BGL
	10			End of Borehole 9.6m BGL	

Borehole Construction Details



DRILLER	BG Drilling
DRILLING METHOD	Solid Auger 125mm
GROUNDWATER	7.0m ▼

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Appendix C : MONITORING DATA

Site: West Schofields	Occupier: Blacktown Council	Licence/notice number:	Date: 02/03/18	Start time: 1030	Finish time: 1400
Monitoring personnel: S Willacy		Monitoring equipment: GA5000	Date of last calibration:		
Atmospheric pressure at start (mb): 1009		Rising or falling: Rising	Weather and ground conditions: 24C, some clouds, dry		

Bore ID	Start time	Atmospheric pressure (mb)	Relative pressure (mb)	Peak (% v/v) CH4	Peak (% v/v) CO2	Min O2 (% v/v)	Stabilised (% v/v) CH4	Stabilised (% v/v) CO2	Stabilised (% v/v) O2	Stabilised (ppm) CO	Stabilised (ppm) H2S	Bal	Obs Flow (l/h)	Adj Flow (l/h) (+0.3*)	Depth to water (mBGL)	GSV Methane	GSV CO2
BH1	10:30:00 AM	1009	0.05	0.0	5.0	14.4	0.0	5.0	14.4	0.0	0.0	80.6	0.0	0.3	0	0	0.015
BH2	10:30:00 AM	1011	0.01	0.0	0.3	19.4	0.0	0.1	19.8	0.0	0.0	80.1	-0.1	0.2	8.5	0	0.0006
BH3	10:30:00 AM	1012	0.03	0.0	9.0	11.4	0.0	9.0	11.4	0.0	0.0	79.6	0.1	0.4	8.2	0	0.036
BH4	10:30:00 AM	1012	0.09	0.0	4.1	13.7	0.0	4.1	13.7	1.0	0.0	82.2	0.2	0.5	7.4	0	0.0205
BH5	10:30:00 AM	1012	0.07	1.0	11.3	12.2	0.0	16.3	12.2	4.0	0.0	71.6	0.1	0.4	6.9	0.004	
BH6	10:30:00 AM	1012	0.05	1.7	8.0	12.5	0.0	8.0	12.5	1.0	0.0	79.5	0.2	0.5	3	0.0085	0.04
BH7	10:30:00 AM	1012	0.02	0.5	16.5	10.8	0.0	16.5	10.8	22.0	1.0	72.7	0.1	0.4	2.8	0.002	0.066
BH8	10:30:00 AM	1012	0.05	0.4	8.6	15.7	0.0	8.6	15.6	4.0	0.0	75.6	0.0	0.3	3.6	0.0012	0.0258
BH9	10:30:00 AM	1012	0.07	0.1	6.5	13.9	0.0	6.5	13.9	4.0	1.0	79.6	0.1	0.4	7.9	0.0004	0.026
BH10	10:30:00 AM	1012	0.03	0.0	5.5	15.5	0.0	5.5	15.5	3.0	1.0	79.0	0.1	0.4	8.8	0	
BH11	10:30:00 AM	1012	0.05	0.0	9.8	11.6	0.0	9.8	11.6	2.0	1.0	78.6	0.1	0.4	5.2	0	0.0392
BH12	10:30:00 AM	1012	0.05	0.0	4.1	16.0	0.0	4.1	16.3	5.0	3.0	79.6	0.0	0.3	3.9	0	0.0123
MW1	10:30:00 AM	1013	0.18	63.1	9.1	0.0	63.1	9.1	0.0	1.0	1.0	27.8	0.2	0.5	8.7	0.3155	0.0455
MW2	10:30:00 AM	1013	0.14	76.5	7.2	0.1	76.5	7.2	0.1	0.0	1.0	16.2	0.3	0.6	9.9	0.459	0.0432
MW3	10:30:00 AM	1012	0.31	84.8	10.4	0.0	84.8	10.4	0.0	1.0	2.0	4.8	0.4	0.7	9.7	0.5936	0.0728
MW4	10:30:00 AM	1012	0.16	50.4	6.4	0.6	50.4	6.4	0.6	0.0	3.0	42.6	0.1	0.4	8.4	0.2016	0.0256
MW5	10:30:00 AM	1013	0.2	65.7	1.8	1.0	65.7	1.8	1.0	0.0	2.0	31.5	0.1	0.4	9.1	0.2628	0.0072
MW11	10:30:00 AM	1012	0.01	0.0	0.3	19.4	0.0	0.1	19.8	0.0	0.0	80.1	0.0	0.3	10	0	0.0009
MW12	10:30:00 AM	1012	0.03	0.0	3.2	16.5	0.0	3.2	16.5	0.0	0.0	80.3	0.1	0.4	8.5	0	0.0128
MW13	10:30:00 AM	1012	0.08	0.0	5.4	12.2	0.0	5.4	12.2	0.0	1.0	82.4	0.1	0.4	3.1	0	0.0216
MW14	10:30:00 AM	1012	0.03	0.0	4.0	15.8	0.0	4.0	15.8	0.0	0.0	80.2	0.1	0.4	3.3	0	0.016

* Instrument error

Site: West Schofields		Occupier: Blacktown Council				Licence/notice number:				Date: 09/03/18		Start time: 0930			Finish time: 1300		
Monitoring personnel: S Willacy						Monitoring equipment: GA5000				Date of last calibration:							
Atmospheric pressure at start (mb): 1024						Rising or falling: Stable				Weather and ground conditions: 24C, some clouds, dry							
				Peak (% v/v)			Stabilised (% v/v)			Stabilised (ppm)							
Bore ID	Start time	Atmospheric pressure (mb)	Relative pressure (mb)	CH4	CO2	Min O2 (% v/v)	CH4	CO2	O2	CO	H2S	Bal	Obs Flow (l/h)	Adj Flow (l/h) (+0.3*)	GSV Methane	GSV CO2	
BH1	9:30:00 AM	1024	0.02	0.0	3.8	14.1	0.0	3.8	14.1	0.0	0.0	82.1	0.0	0.3	0	0.0114	
BH2	9:30:00 AM	1024	0.01	0.0	0.3	19.6	0.0	0.3	19.6	0.0	0.0	80.1	0.1	0.4	0	0.0012	
BH3	9:30:00 AM	1024	0.03	0.0	7.6	13.4	0.0	7.6	13.4	0.0	0.0	79.0	0.1	0.4	0	0.0304	
BH4	9:30:00 AM	1024	0.01	0.0	3.0	15.0	0.0	3.0	15.0	0.0	0.0	82.0	0.0	0.3	0	0.009	
BH5	9:30:00 AM	1024	0.01	0.0	10.2	10.6	0.0	10.2	10.6	0.0	1.0	79.2	0.2	0.5	0	0.051	
BH6	9:30:00 AM	1024	0	0.0	6.7	15.4	0.0	6.7	15.4	0.0	0.0	77.9	0.0	0.3	0	0.0201	
BH7	9:30:00 AM	1024	0.03	0.0	12.4	9.8	0.0	12.4	9.8	0.0	0.0	77.8	0.0	0.3	0	0.0372	
BH8	9:30:00 AM	1025	0.12	1.6	5.6	15.4	0.0	5.6	15.4	0.0	1.0	79.0	0.0	0.3	0.0048	0.0168	
BH9	9:30:00 AM	1024	0.08	1.2	7.6	13.7	0.0	7.6	13.7	0.0	2.0	78.7	0.1	0.4	0.0048	0.0304	
BH10	9:30:00 AM	1025	0.03	0.0	4.4	17.5	0.0	4.4	17.5	0.0	0.0	78.1	0.1	0.4	0	0.0176	
BH11	9:30:00 AM	1024	0.04	0.0	7.4	14.3	0.0	7.4	14.3	0.0	0.0	78.3	-0.1	0.2	0	0.0148	
BH12	9:30:00 AM	1024	0.01	0.4	4.2	15.9	0.0	4.2	15.9	0.0	0.0	79.9	0.2	0.5	0.002	0.021	
MW1	9:30:00 AM	1025	0.24	65.2	8.4	0.0	65.1	8.4	0.0	0.0	1.0	26.5	0.2	0.5	0.326	0.042	
MW2	9:30:00 AM	1025	0.28	79.2	6.5	0.1	79.2	6.5	0.1	0.0	1.0	14.1	0.2	0.5	0.396	0.0325	
MW3	9:30:00 AM	1024	0.43	82.4	11.6	0.1	83.7	11.7	0.1	1.0	3.0	4.5	0.2	0.5	0.412	0.058	
MW4	9:30:00 AM	1025	0.19	49.8	6.6	0.5	49.8	6.6	0.5	0.0	3.0	43.0	0.1	0.4	0.1992	0.0264	
MW5	9:30:00 AM	1024	0.24	68.2	1.3	0.1	68.2	1.3	0.1	0.0	2.0	30.3	0.1	0.4	0.2728	0.0052	
MW11	9:30:00 AM	1024	0.01	0.0	0.1	20.9	0.0	0.1	20.9	0.0	0.0	79.1	0.0	0.3	0	0.0003	
MW12	9:30:00 AM	1025	0.02	0.0	4.7	11.6	0.0	4.7	11.6	0.0	0.0	82.0	0.1	0.4	0	0.0188	
MW13	9:30:00 AM	1026	0.08	1.6	6.6	11.9	0.0	6.6	11.9	0.0	1.0	81.5	0.0	0.3	0.0048	0.0198	
MW14	9:30:00 AM	1024	0.02	2.9	3.8	16.4	0.0	3.8	16.4	0.0	1.0	79.8	0.0	0.3	0.0087	0.0114	

* Instrument error

Site: West Schofields		Occupier: Blacktown Council		Licence/notice number:					Date: 14/03/18		Start time: 0930				Finish time: 1300		
Monitoring personnel: S Willacy				Monitoring equipment: GA5000					Date of last calibration:								
Atmospheric pressure at start (mb): 1017				Rising or falling:					Weather and ground conditions: 22C, overcast, damp underfoot								
				Peak (% v/v)			Stabilised (% v/v)			Stabilised (ppm)							
Bore ID	Start time	Atmospheric pressure (mb)	Relative pressure (mb)	CH4	CO2	Min O2 (% v/v)	CH4	CO2	O2	CO	H2S	Bal	Obs Flow (l/h)	Adj Flow (l/h) (+0.3*)	GSV Methane	GSV CO2	
BH1	10:00:00 AM	1017	0.03	0.7	4.6	15.7	0.0	4.6	15.7	0.0	0.0	79.7	0.0	0.3	0.0021	0.0138	
BH2	10:10:00 AM	1018	0.05	0.0	11.2	8.8	0.0	11.2	8.8	1.0	0.0	80.0	0.1	0.4	0	0.0448	
BH3	10:20:00 AM	1018	-0.01	0.0	9.2	12.5	0.0	9.2	12.5	0.0	0.0	78.3	0.0	0.3	0	0.0276	
BH4	10:30:00 AM	1018	0.01	0.0	5.1	15.8	0.0	5.1	15.8	1.0	1.0	79.1	0.0	0.3	0	0.0153	
BH5	10:40:00 AM	1018	0.02	0.1	22.0	9.6	0.0	22.0	9.6	2.0	1.0	68.4	0.1	0.4	0.0004	0.088	
BH6	10:50:00 AM	1019	0.02	0.7	9.8	10.6	0.0	9.8	10.6	1.0	0.0	79.6	0.1	0.4	0.0028	0.0392	
BH7	11:00:00 AM	1019	0.02	0.5	21.7	6.6	0.0	21.7	6.6	2.0	1.0	71.7	0.0	0.3	0.0015	0.0651	
BH8	11:10:00 AM	1019	0.05	0.4	14.0	12.5	0.0	14.0	12.5	3.0	1.0	73.5	0.1	0.4	0.0016	0.056	
BH9	11:20:00 AM	1018	0.03	0.3	9.0	13.5	0.0	9.0	13.5	1.0	1.0	77.5	0.0	0.3	0.0009	0.027	
BH10	11:30:00 AM	1017	0.01	0.2	9.3	13.4	0.0	9.3	13.4	0.0	1.0	77.3	0.0	0.3	0.0006	0.0279	
BH11	11:40:00 AM	1017	0.04	0.0	10.2	12.3	0.0	10.2	12.3	0.0	1.0	77.5	0.1	0.4	0	0.0408	
BH12	11:50:00 AM	1016	0.02	0.0	5.5	15.9	0.0	5.5	15.9	7.0	3.0	78.6	0.0	0.3	0	0.0165	
MW1	12:00:00 PM	1018	0.21	64.9	8.5	0.1	64.8	8.5	0.1	0.0	1.0	26.6	0.1	0.4	0.2596	0.034	
MW2	12:10:00 PM	1016	0.55	78.9	6.8	0.0	78.9	6.8	0.0	6.0	2.0	14.3	0.4	0.7	0.5523	0.0476	
MW3	12:20:00 PM	1016	0.75	84.5	11.9	0.1	84.2	11.9	0.1	4.0	2.0	3.8	0.3	0.6	0.507	0.0714	
MW4	12:30:00 PM	1018	0.14	54.4	7.0	0.1	54.4	7.0	0.1	0.0	4.0	38.5	0.1	0.4	0.2176	0.028	
MW5	12:40:00 PM	1018	0.48	69.7	1.3	0.2	69.7	1.3	0.2	1.0	3.0	28.8	0.3	0.6	0.4182	0.0078	
MW11	12:50:00 PM	1018	-0.02	0.1	10.8	9.0	0.0	10.8	9.0	1.0	1.0	80.2	0.0	0.3	0.0003	0.0324	
MW12	1:00:00 PM	1018	0.02	0.0	10.0	4.7	0.0	10.0	4.7	0.0	0.0	85.3	0.0	0.3	0	0.03	
MW13	1:10:00 PM	1018	0.01	0.3	7.0	12.8	0.0	7.0	12.8	1.0	0.0	80.2	0.0	0.3	0.0009	0.021	
MW14	1:20:00 PM	1017	0.01	0.0	3.4	16.0	0.0	3.4	16.0	1.0	0.0	80.6	0.0	0.3	0	0.0102	
* Instrument error																	

Site: West Schofields | Occupier: Blacktown Council | Licence/notice number: | Date: 23/03/18 | Start time: 1130 | Finish time: 1430

Monitoring personnel: S Willacy | Monitoring equipment: GA5000 | Date of last calibration: 23/02/18

Atmospheric pressure at start (mb): 1026 | Rising or falling: Stable/Falling | Weather and ground conditions: 22C, overcast, some rain, ground wet

				Peak (% v/v)			Stabilised (% v/v)			Stabilised (ppm)						
Bore ID	Start time	Atmospheric pressure (mb)	Relative pressure (mb)	CH4	CO2	Min O2 (% v/v)	CH4	CO2	O2	CO	H2S	Bal	Obs Flow (l/h)	Adj Flow (l/h) (+0.3*)	GSV Methane	GSV CO2
BH1	11:30:00 AM	1026	0.01	0.1	5.1	15.1	0.0	5.1	15.1	0.0	1.0	79.8	0.1	0.4	0.0004	0.0204
BH2	11:40:00 AM	1027	0.02	0.0	11.1	11.8	0.0	11.1	11.8	1.0	0.0	77.1	0.2	0.5	0	0.0555
BH3	11:50:00 AM	1027	0.02	0.0	11.8	6.1	0.0	11.8	6.1	1.0	0.0	82.1	0.1	0.4	0	0.0472
BH4	12:00:00 PM	1027	0.01	0.0	5.5	15.5	0.0	5.5	15.5	1.0	0.0	79.0	0.0	0.3	0	0.0165
BH5	12:10:00 PM	1027	0.05	0.0	20.0	9.9	0.0	20.0	9.9	2.0	1.0	70.1	0.2	0.5	0	0.1
BH6	12:20:00 PM	1027	-0.01	1.2	10.0	12.2	0.0	10.0	12.2	1.0	0.0	77.8	0.1	0.4	0.0048	0.04
BH7	12:30:00 PM	1027	0.05	0.6	24.4	5.7	0.0	24.4	5.7	2.0	1.0	69.9	0.2	0.5	0.003	0.122
BH8	12:40:00 PM	1027	-0.14	0.2	14.1	12.1	0.0	14.1	12.1	2.0	2.0	73.8	-0.4	-0.1	-0.0002	-0.0141
BH9	12:50:00 PM	1026	0.02	0.3	9.9	13.3	0.0	9.9	13.3	1.0	1.0	76.8	0.0	0.3	0.0009	0.0297
BH10	1:00:00 PM	1026	0.02	0.1	10.6	12.2	0.0	10.6	12.2	1.0	2.0	77.2	0.2	0.5	0.0005	0.053
BH11	1:10:00 PM	1026	0.02	0.1	9.4	12.8	0.0	9.4	12.8	1.0	1.0	77.8	0.1	0.4	0.0004	0.0376
BH12	1:20:00 PM	1026	0.01	0.2	5.9	16.2	0.0	5.9	16.2	2.0	3.0	77.9	0.0	0.3	0.0006	0.0177
MW1	1:30:00 PM	1026	0.17	65.7	8.6	0.1	65.4	8.6	0.1	0.0	1.0	25.9	0.3	0.6	0.3942	0.0516
MW2	1:40:00 PM	1026	0.73	84.7	12.3	0.1	84.7	12.3	0.1	1.0	1.0	2.9	0.5	0.8	0.6776	0.0984
MW3	1:50:00 PM	1025	0.5	80.0	6.8	0.1	80.0	6.8	0.1	1.0	2.0	13.1	0.4	0.7	0.56	0.0476
MW4	2:00:00 PM	1025	0.19	52.2	7.0	0.0	52.2	7.0	0.0	1.0	5.0	40.8	0.3	0.6	0.3132	0.042
MW5	2:10:00 PM	1025	0.43	69.0	1.5	0.1	69.0	1.5	0.1	0.0	3.0	29.4	0.3	0.6	0.414	0.009
MW11	2:20:00 PM	1026	0.02	0.1	10.7	10.7	0.0	10.7	10.7	1.0	1.0	78.6	0.2	0.5	0.0005	0.0535
MW12	2:30:00 PM	1027	0.03	0.0	9.2	12.1	0.0	9.2	12.1	1.0	0.0	78.7	0.1	0.4	0	0.0368
MW13	2:40:00 PM	1027	-0.01	0.3	7.3	13.6	0.0	7.3	13.6	0.0	1.0	79.1	0.1	0.4	0.0012	0.0292
MW14	2:50:00 PM	1027	0.01	0.5	4.5	15.8	0.0	4.5	15.8	0.0	1.0	79.7	0.1	0.4	0.002	0.018

* Instrument error

Appendix D : CALIBRATION CERTIFICATE

Gas Calibration Certificate

Instrument GA5000
Serial No. G502021
Sensors CH4, CO2, O2, CO, H2S

airmet

Air-Met Scientific Pty Ltd
1300 137 067

Item	Test	Pass	Comments
Battery	Charge Condition	✓	
	Fuses	✓	
	Capacity	✓	
	Recharge OK?	✓	
Switch/keypad	Operation	✓	
Display	Intensity	✓	
	Operation (segments)	✓	
Grill Filter	Condition	✓	
	Seal	✓	
Pump	Operation	✓	
	Filter	✓	
	Flow	✓	
	Valves, Diaphragm	✓	
PCB	Condition	✓	
Connectors	Condition	✓	
Sensor	O2	✓	
	CH4	✓	
	CO2	✓	
	CO	✓	
	H2S	✓	
Alarms	Beeper	✓	
	Settings	✓	
Software	Version		
Datalogger	Operation		
Download	Operation		
Other tests:			

Certificate of Calibration

This is to certify that the above instrument has been calibrated to the following specifications:

Diffusion mode Aspirated mode

Sensor	Serial no	Calibration gas and concentration	Certified	Gas bottle No	Instrument Reading
O2		20.9% Vol O2		Fresh Air	20.9% O2
CH4		60%.CH4	NATA	SY136	59.7% CH4
CO2		40% CO2	NATA	SY136	39.2% CO2
CO		100ppm CO	NATA	SY174	102ppm CO
H2S		25ppm H2S	NATA	SY174	24ppm H2S

Calibrated by: Michelle C Wagner **Michelle Wagner**

Calibration date: **8/03/2018**

Next calibration due: **4/09/2018**

Appendix E : **RISK MATRICES**

Site	Grange Avenue Reserve, NSW	**Author**	Dr Jon Varcoe
Client	ERM	**Reviewer**	Aidan Marsh
Project	LFGRA	Date	8/04/2018

Risk Number	Receptor	Impact	Current Information	Likelihood	Consequence	Initial Risk Rating	Recommendations/Controls	Likelihood	Consequence	Reviewed risk rating
On-site risks										
1	On-site workers (non-penetrative works e.g. monitoring, walking across site surface, grass cutting etc.) working in the leachate pond area	Human health (e.g. toxic exposure, fire, explosion, asphyxiation etc.)	The rate of gas generation has declined at the landfill to negligible levels (confirmed by both monitoring results and theoretical modelling). In addition the site is understood to have a substantial earthen cap that provides the potential to both retard and oxidise fugitive methane. As such there is not considered to be a significant driving force to direct LFG constituent gases at concentrations likely to impact human health via this exposure pathway. In addition there are no structures on site, so limited opportunity exists for gases to accumulate to harmful levels, further mitigating both explosive and asphyxiation risks.	Unlikely	Minor	very low	Continue to monitor and maintain landfill cap in order to provide sufficient restriction to driving forces and provide sufficient oxidative attenuation capacity to mitigate risks.	na	na	na
2	On-site workers (penetrative works, hot works)	Human health (e.g. toxic exposure, fire, explosion, asphyxiation etc.)	Although gas production levels have declined to negligible levels, methane still remains present within the landfill mass. Thereby, penetrative work has the potential to establish a connection to the landfill permitting methane to accumulate at potentially explosive levels. In addition there is the potential for bulk LFG gases to accumulate within any confined space at potentially harmful levels	Likely	Severe	high risk	Council should implement procedures in relation to ensure that workers on the site are made aware of and adequately manage the ground gas risks potentially present.	low likelihood	Severe	moderate risk
3	On-site workers (penetrative works, hot works)	Human health (e.g. toxic exposure, fire, explosion, asphyxiation etc.)	As for 2	low likelihood	Severe	moderate risk	Ensure access to all penetrations is restricted and the potential hazards are sufficiently identified.	Unlikely	Severe	moderate /low risk
Off-site risks										
4	Off-site workers (including intrusive works)	Human health (e.g. toxic exposure, fire, explosion, asphyxiation etc.)	The rate of gas generation has declined at the landfill to negligible levels (confirmed by both monitoring results and theoretical modelling), however monitoring results indicate there is a potential for carbon dioxide to migrate from the site under the influence of gravity or by groundwater transport where it may accumulated at hazardous levels in the perimeter monitoring wells. It is not currently known to what level this risk may extend off-site. Given the density characteristics of carbon dioxide there is a potential for it to accumulate in subsurface structures, including uncovered ones. Based on limited driving forces methane migration on the other hand appears to be less likely to cause hazardous conditions off-site.	Low likelihood	Severe	moderate risk	Undertake background investigations, including for basement structures and excavation in close proximity to the site (accounting for the settlement of carbon dioxide toward the bottom of any such space). Install a background bore to determine background concentrations and associated risks.	Unlikely	Severe	moderate /low risk
5	Off-site residents / visitors	Human health (e.g. toxic exposure, fire, explosion, asphyxiation etc.)	As for 4.	Low likelihood	Severe	moderate risk	As for 4	low likelihood	Severe	moderate /low risk

Appendix F : GAS FLOW ESTIMATES

Gas Flow Estimation (Model Calibration)

biogas systems

LFG Gas Flow: GHD (2015) calibrated Model
West Schofields, NSW

Yr	Tonne Methane from IPCC model	m3 CH4 /hr TCH4 x F1	m3 LFG/hr TCH4 x F2
1971	0	0	0
1972	169	28	57
1973	328	55	110
1974	476	80	160
1975	626	105	210
1976	622	104	209
1977	591	99	198
1978	562	94	189
1979	535	90	179
1980	508	85	171
1981	484	81	162
1982	460	77	154
1983	438	73	147
1984	416	70	140
1985	396	67	133
1986	377	63	127
1987	359	60	120
1988	341	57	115
1989	325	55	109
1990	309	52	104
1991	295	49	99
1992	280	47	94
1993	267	45	90
1994	254	43	85
1995	242	41	81
1996	231	39	77
1997	220	37	74
1998	209	35	70
1999	199	33	67
2000	190	32	64
2001	181	30	61
2002	172	29	58
2003	164	28	55
2004	204	34	68
2005	195	33	65
2006	186	31	63
2007	178	30	60
2008	171	29	57
2009	163	27	55
2010	156	26	52
2011	150	25	50
2012	143	24	48
2013	137	23	46
2014	131	22	44
2015	126	21	42
2016	121	20	40
2017	116	19	39
2018	111	19	37
2019	106	18	36
2020	102	17	34
2021	98	16	33

Conversion Assumptions		
Gas Density	0.68	kg/SCM
Hours/ yr	8760	hr
Conversion T CH4 to SCM CH4/h	0.1678754	F1
CH4 as % of landfill gas (LFG)	50%	
Conversion T CH4 to SCM LFG/h	0.3357507	F2

Estimated Waste Input

	Annual T Waste	% MSW	MSW	Food	P	Garden	Wood	textile	nappies	% C&I	C&I	Food	P (R&L)	Garden	Wood	textile	nappies	Sludge	%C&D	C&D	Paper	Garden	Wood
				0.35	0.14	0.165	0.01	0.015	0.04			0.215	0.19	0.04	0.125	0.04	0	0.015			0.03	0.02	0.06
1971	67000	1	67000	23450	9380	11055	670	1005	2680	0	0	0	0	0	0	0	0	0		0	0	0	0
1972	66500	1	66500	23275	9310	10973	665	998	2660	0	0	0	0	0	0	0	0	0		0	0	0	0
1973	65000	1	65000	22750	9100	10725	650	975	2600	0	0	0	0	0	0	0	0	0		0	0	0	0
1974	69000	1	69000	24150	9660	11385	690	1035	2760	0	0	0	0	0	0	0	0	0		0	0	0	0
1975	10500	1	10500	3675	1470	1733	105	158	420	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1976			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0
1977			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1978			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1979			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1980			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1981			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1982			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1983			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1984			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1985			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1986			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1987			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1988			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1989			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1990			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1991			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1992			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1993			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1994			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1995			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1996			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1997			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1998			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1999			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
2000			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
2001			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
2002			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
2003	120000		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	1	120000	3600	2400	7200
2004			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
2005			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
2006			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
2007			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
2008			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
2009			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0

Input into IPCC Model

	Food	Garden	Paper	Wood	Textile	Nappies	Sludge
1971	23450	11055	9380	670	1005	2680	0
1972	23275	10972.5	9310	665	997.5	2660	0
1973	22750	10725	9100	650	975	2600	0
1974	24150	11385	9660	690	1035	2760	0
1975	3675	1732.5	1470	105	157.5	420	0
2003	0	2400	3600	7200	0	0	0

IPCC Spreadsheet for Estimating Methane emissions from Solid Waste Disposal Sites

Bulk waste and waste composition options.

Theory and equations

The basic equation for the first order decay model is:

(1) $DDOCm = DDOCm(0) * e^{-kt}$

where DDOCm(0) is the mass of decomposable degradable organic carbon (DOC) at the start of the reaction, when t=0 and e^-kt=1, k is the reaction constant and t is the time in years. DDOCm is the mass of DDOC at any time.

From equation (I) it is easy to see that at the end of year 1 (going from point 0 to point 1 on the time axis) the mass of DDOC left not decomposed in the SWDS is:

(2) $DDOCm(1) = DDOCm(0) * e^{-k}$

and the mass of DDOC decomposed into CH_4 and CO_2 will be:

(3) $DDOCmdecomp(1) = DDOCm(0) * (1 - e^{-k})$

In a first order reaction, the amount of product (here decomposed DDOCm) is always proportional to the amount of reactant (here DDOCm). This means that it does not matter when the DDOCm was deposited. This also means that when the amount of DDOCm accumulated in the SWDS, plus last year's deposit, is known, CH_4 production can be calculated as if every year is year number one in the time series. Then all calculations can be done by equations (2) and (3) in a simple spreadsheet.

The default assumption is that CH_4 generation from all the waste deposited each year begins on the 1st of January in the year after deposition. This is the same as an average six month delay until substantial CH_4 generation begins (the time it takes for anaerobic conditions to become well established). However, the worksheet includes the possibility of an earlier start to the reaction, in the year of deposition of the waste. This requires separate calculations for the deposition year. For longer delay times than 6 months, DDOCmd in the columns F and G cells in the CH_4 calculating sheets, have to be readdressed one cell down, and the number 13 in exp2 has to be changed to 25 (7 to 18 months delay time).

The equations used in these spreadsheets are: (As the mathematics of every waste fraction/category is the same, indexing for fraction/category is omitted for equations 4-9.)

To calculate mass of decomposable DOC (DDOCm) from amount of waste material (W):

(4) $DDOCmd(T), = W(T) \cdot DOC * DOCf \cdot MCF$

The amount of deposited DDOCm remaining not decomposed at the end of deposition year T:

(5) $DDOCmrem(T) = DDOCmd(T) \cdot e^{(-k \cdot ((13-M)/12)}$

The amount of deposited DDOCm decomposed during deposition year T:

(6) $DDOCmdec(T) = DDOCmd(T) \cdot (1 – e^{(-k \cdot ((13-M)/12))})$

The amount of DDOCm accumulated in the SWDS at the end of year T

(7) $DDOCma(T) = DDOCmrem(T) + (DDOCma(T-1) \cdot e^{-k})$

The total amount of DDOCm decomposed in year T

(8) $DDOCmdecomp(T) = DDOCmdec(T) + (DDOCma(T-1) \cdot (1 - e^{-k}))$

The amount of CH_4 generated from DOC decomposed

(9) CH_4 generated(T) = DDOCmdecomp(T) • F • 16/12

The amount of CH_4 emitted

(10) CH_4 emitted in year T = ($\Sigma_x CH_4$ generated (x,T) – R(T)) • (1- OX(T))

Where:

- T = the year of inventory
- x = material fraction/waste category
- W(T) = amount deposited in year T
- MCF = Methane Correction Factor
- DOC = Degradable organic carbon (under aerobic conditions)
- DOCf = Fraction of DOC decomposing under anaerobic conditions
- DDOC = Decomposable Degradable Organic Carbon (under anaerobic conditions)

IPCC Spreadsheet for Estimating Methane emissions from Solid Waste Diposal Sites

Parameters

Country Australia

Region

Please enter parameters in the yellow cells. If no national data are available, copy the IPCC default value.
Help on parameter selection can be found in the 2006 IPCC guidelines

	IPCC default value		Country-specific parameters	
			Value	Reference and remarks
Starting year		1971	1971	
DOC (Degradable organic carbon)				
(weight fraction, wet basis)	Range	Default		
Food waste	0.08-0.20	0.15	0.15	
Garden	0.18-0.22	0.2	0.2	
Paper	0.36-0.45	0.4	0.4	
Wood and straw	0.39-0.46	0.43	0.43	
Textiles	0.20-0.40	0.24	0.24	
Disposable nappies	0.18-0.32	0.24	0.24	
Sewage sludge	0.04-0.05	0.05	0.05	
Industrial waste	0-0.54	0.15	0.15	
DOCf (fraction of DOC dissimilated)		0.5	0.5	
Methane generation rate constant (k)				
(years^{-1})	Range	Default		
Food waste	0.05–0.08	0.06	0.06	
Garden	0.04–0.06	0.05	0.05	
Paper	0.03–0.05	0.04	0.04	
Wood and straw	0.01–0.03	0.02	0.02	
Textiles	0.03–0.05	0.04	0.04	
Disposable nappies	0.04–0.06	0.05	0.05	
Sewage sludge	0.05–0.08	0.06	0.06	
Industrial waste	0.04–0.06	0.05	0.05	
Delay time (months)		6	6	
Fraction of methane (F) in developed gas		0.5	0.5	
Conversion factor, C to CH_4		1.33	1.33	
Oxidation factor (OX)		0	0	
Parameters for carbon storage				
% paper in industrial waste		0%	0%	
% wood in industrial waste		0%	0%	
For Harwested Wood Products calculations for Bulk waste option only:				

IPCC Spreadsheet for Estimating Methane emissions from Solid Waste Diposal Sites

Amount deposited data **Country** **Australia**

Countries with good inventory data:
Enter those data onto this sheet.

	Amounts deposited in SWDS									
Year	**Food**	**Garden**	**Paper**	**Wood**	**Textile**	**Nappies**	**Sludge**	**Deposited MSW**	**Inert**	**Industrial**
	T	T	T	T	T	T	T	T	T	T
1971	23,450	11,055	9,380	670	1,005	2,680	0			
1972	23,275	10,973	9,310	665	998	2,660	0			
1973	22,750	10,725	9,100	650	975	2,600	0			
1974	24,150	11,385	9,660	690	1,035	2,760	0			
1975	3,675	1,733	1,470	105	158	420	0			
1976	0	0	0	0	0	0	0			
1977	0	0	0	0	0	0	0			
1978	0	0	0	0	0	0	0			
1979	0	0	0	0	0	0	0			
1980	0	0	0	0	0	0	0			
1981	0	0	0	0	0	0	0			
1982	0	0	0	0	0	0	0			
1983	0	0	0	0	0	0	0			
1984	0	0	0	0	0	0	0			
1985	0	0	0	0	0	0	0			
1986	0	0	0	0	0	0	0			
1987	0	0	0	0	0	0	0			
1988	0	0	0	0	0	0	0			
1989	0	0	0	0	0	0	0			
1990	0	0	0	0	0	0	0			
1991	0	0	0	0	0	0	0			
1992	0	0	0	0	0	0	0			
1993	0	0	0	0	0	0	0			
1994	0	0	0	0	0	0	0			
1995	0	0	0	0	0	0	0			
1996	0	0	0	0	0	0	0			
1997	0	0	0	0	0	0	0			
1998	0	0	0	0	0	0	0			
1999	0	0	0	0	0	0	0			
2000	0	0	0	0	0	0	0			
2001	0	0	0	0	0	0	0			
2002	0	0	0	0	0	0	0			
2003	0	2,400	3,600	7,200	0	0	0			
2004	0	0	0	0	0	0	0			
2005	0	0	0	0	0	0	0			
2006	0	0	0	0	0	0	0			
2007	0	0	0	0	0	0	0			
2008	0	0	0	0	0	0	0			
2009	0	0	0	0	0	0	0			

IPCC Spreadsheet for Estimating Methane emissions from Solid Waste Diposal Sites

Results

Country

Australia

Enter starting year, industrial waste disposal data and methane recovery into the yellow cells.
MSW activity data is entered on MSW sheet

	Methane generated											
Year	**Food**	**Garden**	**Paper**	**Wood**	**Textile**	**Nappies**	**Sludge**	**MSW**	**Industrial**	**Total**	**Methane recovery**	**Methane emission**
	A	B	C	D	E	F	G	H	J	K	L	M = (K-L) (1-OX)
	T	T	T	T	T	T	T	T	T	T	T	T
1971	0	0	0	0	0	0	0		0	0	0	0
1972	68	36	49	2	3	10	0		0	169	0	169
1973	132	70	96	4	6	20	0		0	328	0	328
1974	191	101	140	6	9	29	0		0	476	0	476
1975	250	133	185	7	12	39	0		0	626	0	626
1976	246	133	185	8	12	39	0		0	622	0	622
1977	232	126	178	7	11	37	0		0	591	0	591
1978	218	120	171	7	11	35	0		0	562	0	562
1979	205	114	164	7	11	33	0		0	535	0	535
1980	194	109	158	7	10	32	0		0	508	0	508
1981	182	103	152	7	10	30	0		0	484	0	484
1982	172	98	146	7	9	29	0		0	460	0	460
1983	162	93	140	7	9	27	0		0	438	0	438
1984	152	89	134	6	9	26	0		0	416	0	416
1985	143	85	129	6	8	25	0		0	396	0	396
1986	135	80	124	6	8	23	0		0	377	0	377
1987	127	76	119	6	8	22	0		0	359	0	359
1988	120	73	115	6	7	21	0		0	341	0	341
1989	113	69	110	6	7	20	0		0	325	0	325
1990	106	66	106	6	7	19	0		0	309	0	309
1991	100	63	102	6	7	18	0		0	295	0	295
1992	94	60	98	5	6	17	0		0	280	0	280
1993	89	57	94	5	6	16	0		0	267	0	267
1994	84	54	90	5	6	16	0		0	254	0	254
1995	79	51	87	5	6	15	0		0	242	0	242
1996	74	49	83	5	5	14	0		0	231	0	231
1997	70	46	80	5	5	13	0		0	220	0	220
1998	66	44	77	5	5	13	0		0	209	0	209
1999	62	42	74	5	5	12	0		0	199	0	199
2000	58	40	71	5	5	12	0		0	190	0	190
2001	55	38	68	5	4	11	0		0	181	0	181
2002	52	36	65	4	4	11	0		0	172	0	172
2003	49	34	63	4	4	10	0		0	164	0	164
2004	46	40	79	25	4	10	0		0	204	0	204
2005	43	39	76	24	4	9	0		0	195	0	195
2006	41	37	73	24	4	9	0		0	186	0	186
2007	38	35	70	23	3	8	0		0	178	0	178
2008	36	33	67	23	3	8	0		0	171	0	171
2009	34	32	65	22	3	7	0		0	163	0	163
2010	32	30	62	22	3	7	0		0	156	0	156
2011	30	29	60	22	3	7	0		0	150	0	150
2012	28	27	58	21	3	6	0		0	143	0	143
2013	27	26	55	21	3	6	0		0	137	0	137
2014	25	25	53	20	3	6	0		0	131	0	131
2015	24	23	51	20	3	5	0		0	126	0	126
2016	22	22	49	19	2	5	0		0	121	0	121
2017	21	21	47	19	2	5	0		0	116	0	116
2018	20	20	45	19	2	5	0		0	111	0	111
2019	19	19	43	18	2	4	0		0	106	0	106
2020	18	18	42	18	2	4	0		0	102	0	102
2021	17	17	40	18	2	4	0		0	98	10	88

Methane Correction Factor (MCF)

This worksheet calculates a weighted average MCF from the estimated distribution of site types
Enter either IPCC default values or national values into the yellow MCF cells in row 12
Then enter the approximate distribution of waste disposals (by mass) between site types in the columns below.
Totals on each row must add up to 100% (see "distribution check" values)

	MSW						Industrial						
	Un-managed, shallow	Un-managed, deep	Managed	Managed, semi-aerobic	Uncate-gorised	Distri-bution Check	Un-managed, shallow	Un-managed, deep	Managed	Managed, semi-aerobic	Uncate-gorised	Distri-bution Check	References / remarks
	MCF	MCF	MCF	MCF	MCF		MCF	MCF	MCF	MCF	MCF		
IPCC default	0.4	0.8	1	0.5	0.6		0.4	0.8	1	0.5	0.6		
Country-specific value	0.4	0.8	1	0.5	0.6		0.4	0.8	1	0.5	0.6		
	Pre 1980	85-95	1995-				Distribution of Waste by Waste Management Type						
"Fixed" Country-specifc value	100%	100%	100%	0%	0%	Total	20%	30%	25%	5%	20%	Total	
Year	%	%	%	%	%	(100%)	%	%	%	%	%	(100%)	
1971			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1972			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1973			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1974			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1975			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1976			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1977			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1978			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1979			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1980			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1981			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1982			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1983			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1984			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1985			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1986			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1987			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1988			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1989			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1990			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1991			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1992			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1993			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1994			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1995			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1996			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1997			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1998			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
1999			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2000			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2001			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2002			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2003			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2004			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2005			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2006			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2007			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2008			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2009			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2010			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2011			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2012			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2013			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2014			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2015			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2016			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2017			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2018			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2019			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2020			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	
2021			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%	

Gas Flow Estimation (BGS revised)

biogas systems

LFG Gas Flow: GHD (2015) calibrated Model "Low Estimate"
West Schofields, NSW

Yr	Tonne Methane from IPCC model	m3 CH4 /hr TCH4 x F1	m3 LFG/hr TCH4 x F2
1971	0	0	0
1972	239	40	80
1973	446	75	150
1974	622	104	209
1975	791	133	266
1976	731	123	246
1977	643	108	216
1978	567	95	190
1979	502	84	168
1980	445	75	149
1981	396	66	133
1982	354	59	119
1983	316	53	106
1984	284	48	95
1985	256	43	86
1986	231	39	77
1987	209	35	70
1988	189	32	64
1989	172	29	58
1990	157	26	53
1991	143	24	48
1992	131	22	44
1993	120	20	40
1994	110	18	37
1995	101	17	34
1996	93	16	31
1997	86	14	29
1998	79	13	27
1999	73	12	25
2000	68	11	23
2001	63	11	21
2002	58	10	20
2003	54	9	18
2004	110	18	37
2005	103	17	35
2006	97	16	33
2007	91	15	31
2008	86	14	29
2009	81	14	27
2010	76	13	26
2011	72	12	24
2012	68	11	23
2013	64	11	22
2014	61	10	20
2015	57	10	19
2016	54	9	18
2017	51	9	17
2018	49	8	16
2019	46	8	15
2020	44	7	15
2021	41	7	14

Conversion Assumptions		
Gas Density	0.68	kg/SCM
Hours/ yr	8760	hr
Conversion T CH4 to SCM CH4/h	0.1678754	F1
CH4 as % of landfill gas (LFG)	50%	
Conversion T CH4 to SCM LFG/h	0.3357507	F2

Estimated Waste Input

	Annual T Waste	% MSW	MSW	Food	P	Garden	Wood	textile	nappies	% C&I	C&I	Food	P (R&L)	Garden	Wood	textile	nappies	Sludge	%C&D	C&D	Paper	Garden	Wood
				0.35	0.14	0.165	0.01	0.015	0.04			0.215	0.19	0.04	0.125	0.04	0	0.015			0.03	0.02	0.06
1971	54270	1	54270	18994.5	7598	8955	543	814	2171	0	0	0	0	0	0	0	0	0		0	0	0	0
1972	53865	1	53865	18852.75	7541	8888	539	808	2155	0	0	0	0	0	0	0	0	0		0	0	0	0
1973	52650	1	52650	18427.5	7371	8687	527	790	2106	0	0	0	0	0	0	0	0	0		0	0	0	0
1974	55890	1	55890	19561.5	7825	9222	559	838	2236	0	0	0	0	0	0	0	0	0		0	0	0	0
1975	8505	1	8505	2976.75	1191	1403	85	128	340	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1976	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0
1977	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1978	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1979	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1980	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1981	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1982	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1983	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1984	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1985	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1986	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1987	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1988	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1989	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1990	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1991	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1992	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1993	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1994	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1995	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1996	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1997	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1998	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
1999	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
2000	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
2001	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
2002	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
2003	97200		0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	1	97200	2916	1944	5832
2004			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
2005			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
2006			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
2007			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
2008			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0
2009			0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0

Input into IPCC Model

	Food	Garden	Paper	Wood	Textile	Nappies	Sludge
1971	18994.5	8954.55	7597.8	542.7	814.05	2170.8	0
1972	18852.75	8887.725	7541.1	538.65	807.98	2154.6	0
1973	18427.5	8687.25	7371	526.5	789.75	2106	0
1974	19561.5	9221.85	7824.6	558.9	838.35	2235.6	0
1975	2976.75	1403.325	1190.7	85.05	127.58	340.2	0
1976	0	0	0	0	0	0	0
2003	0	1944	2916	5832	0	0	0
2004	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0

IPCC Spreadsheet for Estimating Methane emissions from Solid Waste Disposal Sites

Bulk waste and waste composition options.

Theory and equations

The basic equation for the first order decay model is:

(1) DDOCm = DDOCm(0) * e^-kt

where DDOCm(0) is the mass of decomposable degradable organic carbon (DOC) at the start of the reaction, when t=0 and e^-kt=1, k is the reaction constant and t is the time in years. DDOCm is the mass of DDOC at any time.

From equation (I) it is easy to see that at the end of year 1 (going from point 0 to point 1 on the time axis) the mass of DDOC left not decomposed in the SWDS is:

(2) DDOCm(1) = DDOCm(0) * e^-k

and the mass of DDOC decomposed into CH_4 and CO_2 will be:

(3) DDOCmdecomp(1) = DDOCm(0) * (1 - e^-k)

In a first order reaction, the amount of product (here decomposed DDOCm) is always proportional to the amount of reactant (here DDOCm). This means that it does not matter when the DDOCm was deposited. This also means that when the amount of DDOCm accumulated in the SWDS, plus last year's deposit, is known, CH_4 production can be calculated as if every year is year number one in the time series. Then all calculations can be done by equations (2) and (3) in a simple spreadsheet.

The default assumption is that CH_4 generation from all the waste deposited each year begins on the 1st of January in the year after deposition. This is the same as an average six month delay until substantial CH_4 generation begins (the time it takes for anaerobic conditions to become well established). However, the worksheet includes the possibility of an earlier start to the reaction, in the year of deposition of the waste. This requires separate calculations for the deposition year. For longer delay times than 6 months, DDOCmd in the columns F and G cells in the CH_4 calculating sheets, have to be readdressed one cell down, and the number 13 in exp2 has to be changed to 25 (7 to 18 months delay time).

The equations used in these spreadsheets are: (As the mathematics of every waste fraction/category is the same, indexing for fraction/category is omitted for equations 4-9.)

To calculate mass of decomposable DOC (DDOCm) from amount of waste material (W):

(4) DDOCmd(T), = W(T) • DOC * DOCf • MCF

The amount of deposited DDOCm remaining not decomposed at the end of deposition year T:

(5) DDOCmrem(T) = DDOCmd(T) • e^(-k • ((13-M)/12)

The amount of deposited DDOCm decomposed during deposition year T:

(6) DDOCmdec(T) = DDOCmd(T) • (1 – e^(-k • ((13-M)/12)))

The amount of DDOCm accumulated in the SWDS at the end of year T

(7) DDOCma(T) = DDOCmrem(T) + (DDOCma(T-1) • e^-k)

The total amount of DDOCm decomposed in year T

(8) DDOCmdecomp(T) = DDOCmdec(T) + (DDOCma(T-1) • (1 - e^-k))

The amount of CH_4 generated from DOC decomposed

(9) CH_4 generated(T) = DDOCmdecomp(T) • F • 16/12

The amount of CH_4 emitted

(10) CH_4 emitted in year T = (ΣxCH_4 generated (x,T) – R(T)) • (1- OX(T))

Where:

- T = the year of inventory
- x = material fraction/waste category
- W(T) = amount deposited in year T
- MCF = Methane Correction Factor
- DOC = Degradable organic carbon (under aerobic conditions)
- DOCf = Fraction of DOC decomposing under anaerobic conditions
- DDOC = Decomposable Degradable Organic Carbon (under anaerobic conditions)
- DDOCmd(T) = mass of DDOC deposited year T
- DDOCmrem(T) = mass of DDOC deposited in inventory year T, remaining not decomposed at the end of year.
- DDOCmdec(T) = mass of DDOC deposited in inventory year T, decomposed during the year.
- DDOCma(T) = total mass of DDOC left not decomposed at end of year T.
- DDOCma(T-1) = total mass of DDOC left not decomposed at end of year T-1.
- DDOCmdecomp(T) = total mass of DDOC decomposed in year T.
- CH_4 generated(T) = CH_4 generated in year T
- F = Fraction of CH_4 by volume in generated landfill gas
- 16/12 = Molecular weight ratio CH4/C

IPCC Spreadsheet for Estimating emiisions from Solid Waste Disposal Sites

Parameters

Country Australia

Region

Please enter parameters in the yellow cells. If no national data are available, copy the IPCC default value.
Help on parameter selection can be found in the 2006 IPCC guidelines

	IPCC default value		**Country-specific parameters**	
			Value	**Reference and remarks**
Starting year		1971	1971	
DOC (Degradable organic carbon)				
(weight fraction, wet basis)	**Range**	**Default**		
Food waste	0.08-0.20	0.15	0.15	
Garden	0.18-0.22	0.2	0.2	
Paper	0.36-0.45	0.4	0.4	
Wood and straw	0.39-0.46	0.43	0.43	
Textiles	0.20-0.40	0.24	0.24	
Disposable nappies	0.18-0.32	0.24	0.24	
Sewage sludge	0.04-0.05	0.05	0.05	
Industrial waste	0-0.54	0.15	0.15	
DOCf (fraction of DOC dissimilated)		0.5	0.5	
Methane generation rate constant (k)				
(years^{-1})	**Range**	**Default**		
Food waste	0.1–0.2	0.185	0.185	
Garden	0.06–0.1	0.1	0.1	
Paper	0.05–0.07	0.06	0.06	
Wood and straw	0.02–0.04	0.03	0.03	
Textiles	0.05–0.07	0.06	0.06	
Disposable nappies	0.06–0.1	0.1	0.1	
Sewage sludge	0.1–0.2	0.185	0.185	
Industrial waste	0.08–0.1	0.09	0.09	
Delay time (months)		6	6	
Fraction of methane (F) in developed gas		0.5	0.5	
Conversion factor, C to CH_4		1.33	1.33	
Oxidation factor (OX)		0	0	
Parameters for carbon storage				
% paper in industrial waste		0%	0%	
% wood in industrial waste		0%	0%	
For Harwested Wood Products calculations for Bulk waste option only:				

IPCC Spreadsheet for Estimating emiisions from Solid Waste Disposal Sites

Amount deposited data

Country **Australia**

Countries with good inventory data:
Enter those data onto this sheet.

	Amounts deposited in SWDS									
Year	**Food**	**Garden**	**Paper**	**Wood**	**Textile**	**Nappies**	**Sludge**	**Deposited MSW**	**Inert**	**Industrial**
	T	T	T	T	T	T	T	T	T	T
1971	18,995	8,955	7,598	543	814	2,171	0			
1972	18,853	8,888	7,541	539	808	2,155	0			
1973	18,428	8,687	7,371	527	790	2,106	0			
1974	19,562	9,222	7,825	559	838	2,236	0			
1975	2,977	1,403	1,191	85	128	340	0			
1976	0	0	0	0	0	0	0			
1977	0	0	0	0	0	0	0			
1978	0	0	0	0	0	0	0			
1979	0	0	0	0	0	0	0			
1980	0	0	0	0	0	0	0			
1981	0	0	0	0	0	0	0			
1982	0	0	0	0	0	0	0			
1983	0	0	0	0	0	0	0			
1984	0	0	0	0	0	0	0			
1985	0	0	0	0	0	0	0			
1986	0	0	0	0	0	0	0			
1987	0	0	0	0	0	0	0			
1988	0	0	0	0	0	0	0			
1989	0	0	0	0	0	0	0			
1990	0	0	0	0	0	0	0			
1991	0	0	0	0	0	0	0			
1992	0	0	0	0	0	0	0			
1993	0	0	0	0	0	0	0			
1994	0	0	0	0	0	0	0			
1995	0	0	0	0	0	0	0			
1996	0	0	0	0	0	0	0			
1997	0	0	0	0	0	0	0			
1998	0	0	0	0	0	0	0			
1999	0	0	0	0	0	0	0			
2000	0	0	0	0	0	0	0			
2001	0	0	0	0	0	0	0			
2002	0	0	0	0	0	0	0			
2003	0	1,944	2,916	5,832	0	0	0			
2004	0	0	0	0	0	0	0			
2005	0	0	0	0	0	0	0			
2006	0	0	0	0	0	0	0			
2007	0	0	0	0	0	0	0			
2008	0	0	0	0	0	0	0			
2009	0	0	0	0	0	0	0			
2010	0	0	0	0	0	0	0			
2011	0	0	0	0	0	0	0			
2012	0	0	0	0	0	0	0			
2013	0	0	0	0	0	0	0			
2014	0	0	0	0	0	0	0			
2015	0	0	0	0	0	0	0			
2016	0	0	0	0	0	0	0			
2017	0	0	0	0	0	0	0			
2018	0	0	0	0	0	0	0			
2019	0	0	0	0	0	0	0			
2020	0	0	0	0	0	0	0			
2021	0	0	0	0	0	0	0			

IPCC Spreadsheet for Estimating emiisions from Solid Waste Disposal Sites

Results

Country

Australia

Enter starting year, industrial waste disposal data and methane recovery into the yellow cells.
MSW activity data is entered on MSW sheet

	Methane generated									
Year	Food	Garden	Paper	Wood	Textile	Nappies	Sludge	MSW	Industrial	Total
	A	B	C	D	E	F	G	H	J	K
	T	T	T	T	T	T	T	T	T	T
1971	0	0	0	0	0	0	0		0	0
1972	128	45	47	2	3	13	0		0	239
1973	234	86	91	4	6	25	0		0	446
1974	319	122	132	5	8	36	0		0	622
1975	397	157	173	7	11	46	0		0	791
1976	350	149	170	7	11	43	0		0	731
1977	291	135	160	7	10	39	0		0	643
1978	242	122	151	7	10	36	0		0	567
1979	201	111	142	6	9	32	0		0	502
1980	167	100	134	6	9	29	0		0	445
1981	139	91	126	6	8	26	0		0	396
1982	115	82	119	6	8	24	0		0	354
1983	96	74	112	6	7	22	0		0	316
1984	80	67	105	6	7	20	0		0	284
1985	66	61	99	5	6	18	0		0	256
1986	55	55	93	5	6	16	0		0	231
1987	46	50	88	5	6	14	0		0	209
1988	38	45	83	5	5	13	0		0	189
1989	32	41	78	5	5	12	0		0	172
1990	26	37	73	5	5	11	0		0	157
1991	22	33	69	5	4	10	0		0	143
1992	18	30	65	4	4	9	0		0	131
1993	15	27	61	4	4	8	0		0	120
1994	13	25	58	4	4	7	0		0	110
1995	10	22	54	4	3	7	0		0	101
1996	9	20	51	4	3	6	0		0	93
1997	7	18	48	4	3	5	0		0	86
1998	6	17	45	4	3	5	0		0	79
1999	5	15	43	4	3	4	0		0	73
2000	4	14	40	3	3	4	0		0	68
2001	3	12	38	3	2	4	0		0	63
2002	3	11	36	3	2	3	0		0	58
2003	2	10	34	3	2	3	0		0	54
2004	2	21	54	28	2	3	0		0	110
2005	2	19	51	27	2	2	0		0	103
2006	1	18	48	26	2	2	0		0	97
2007	1	16	45	25	2	2	0		0	91
2008	1	14	43	25	2	2	0		0	86
2009	1	13	40	24	2	2	0		0	81
2010	1	12	38	23	1	1	0		0	76
2011	1	11	36	23	1	1	0		0	72
2012	0	10	34	22	1	1	0		0	68
2013	0	9	32	21	1	1	0		0	64
2014	0	8	30	21	1	1	0		0	61
2015	0	7	28	20	1	1	0		0	57
2016	0	6	26	19	1	1	0		0	54
2017	0	6	25	19	1	1	0		0	51
2018	0	5	23	18	1	1	0		0	49
2019	0	5	22	18	1	1	0		0	46
2020	0	4	21	17	1	1	0		0	44
2021	0	4	20	17	1	0	0		0	41

IPCC Spreadsheet for Estimating emiisions from Solid Waste Disposal Sites

Methane Correction Factor (MCF)

This worksheet calculates a weighted average MCF from the estimated distribution of site types
Enter either IPCC default values or national values into the yellow MCF cells in row 12
Then enter the approximate distribution of waste disposals (by mass) between site types in the columns below.
Totals on each row must add up to 100% (see "distribution check" values)

	MSW						Industrial					
	Un-managed, shallow	Un-managed, deep	Managed	Managed, semi-aerobic	Uncate-gorised	Distri-bution Check	Un-managed, shallow	Un-managed, deep	Managed	Managed, semi-aerobic	Uncate-gorised	Distri-bution Check
	MCF	MCF	MCF	MCF	MCF		MCF	MCF	MCF	MCF	MCF	
IPCC default	0.4	0.8	1	0.5	0.6		0.4	0.8	1	0.5	0.6	
Country-specific value	0.4	0.8	1	0.5	0.6		0.4	0.8	1	0.5	0.6	
	Pre 1980	85-95	1995-				Distribution of Waste by Waste Management Type					
"Fixed" Country-specifc value	100%	100%	100%	0%	0%	Total (100%)	20%	30%	25%	5%	20%	Total (100%)
Year	%	%	%	%	%		%	%	%	%	%	
1971		100%		0%	0%	100%	20%	30%	25%	5%	20%	100%
1972		100%		0%	0%	100%	20%	30%	25%	5%	20%	100%
1973		100%		0%	0%	100%	20%	30%	25%	5%	20%	100%
1974		100%		0%	0%	100%	20%	30%	25%	5%	20%	100%
1975		100%		0%	0%	100%	20%	30%	25%	5%	20%	100%
1976			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1977			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1978			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1979			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1980			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1981			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1982			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1983			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1984			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1985			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1986			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1987			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1988			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1989			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1990			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1991			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1992			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1993			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1994			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1995			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1996			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1997			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1998			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
1999			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2000			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2001			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2002			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2003			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2004			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2005			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2006			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2007			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2008			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2009			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2010			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2011			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2012			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2013			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2014			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2015			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2016			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2017			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2018			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2019			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2020			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%
2021			100%	0%	0%	100%	20%	30%	25%	5%	20%	100%