

Final draft awaiting HSE endorsement

**WASTE MANAGEMENT INDUSTRY**  
**DRILLING INTO LANDFILL WASTE**  
**INDUSTRY CODE OF PRACTICE**

ESA ICoP 4 (drilling), Edition 1, October 2006

	 <p><b>DRAGON DRILLING LTD</b></p>	<p><b>Envirodrilling UK Limited</b> Landfill, Foundation &amp; Geo Technical Drilling Tel: 01257 472 399 <a href="http://www.envirodrillinguk.com">www.envirodrillinguk.com</a></p>	
	<p><small>ORIGINAL PICKUP FORMAT</small></p>  <p><b>Magpie Environmental Drilling Services Limited</b> Telephone 0191 2368129 <a href="http://www.maggiedrilling.co.uk">www.maggiedrilling.co.uk</a></p>		
			

'final draft awaiting HSE endorsement'

This work was commissioned by ESA and funded by:  
Biffa Waste Services  
British Drilling Association  
Dragon Drilling,  
Envirodrilling UK  
Environmental Services Training and Education Trust  
Fugro Engineering Services  
Magpie Environmental Drilling Services  
SITA UK  
South Tyne Drilling  
Viridor Waste Management and  
Veolia Environmental Services

**Sira Certification** was contracted to produce this document for  
ESA Members and we acknowledge their technical contribution and  
assistance in the preparation of this document.

October 2006

Published by  
ESA  
154 Buckingham Palace Road  
London  
SW1W 9TR  
Tel: 0207 824 8882

Available for download from ESA's web site:  
[http://www.esauk.org/publications/reports/DSEAR\\_guidance.asp](http://www.esauk.org/publications/reports/DSEAR_guidance.asp)

**CONTENTS**

<b>1</b>	<b>Introduction and scope</b>	<b>5</b>
1.1	Terms of reference	5
1.2	Scope	5
1.3	Executive summary	6
<b>2</b>	<b>Glossary of terms</b>	<b>6</b>
<b>3</b>	<b>Properties of landfill gas</b>	<b>9</b>
<b>4</b>	<b>General principles of landfill drilling operations</b>	<b>10</b>
<b>5</b>	<b>Accident history of drilling operations</b>	<b>11</b>
<b>6</b>	<b>Hazard identification and risk reduction</b>	<b>12</b>
6.1	Methane concentration monitoring data	12
6.2	Types of borehole	12
6.2.1	'Type 1' boreholes	12
6.2.2	'Type 2' boreholes	12
6.2.3	'Type 3' boreholes	13
6.2.4	'Type 4' boreholes	14
6.3	Potential ignition sources	15
6.4	Control measures	16
6.5	Risk assessment for the use of uncertified micro-switches and E-stops in zone 2	18
6.6	Specification and use of fixed flammable gas monitors	19
6.6.1	Specification	19
6.6.2	Manufacturers of flammable gas detectors	19
6.6.3	Procedure for use	20
6.7	Anti-static clothing	21
6.8	Training	21
<b>7</b>	<b>Conclusion</b>	<b>21</b>
	<b>Appendix 1: Typical landfill gas analysis data</b>	<b>22</b>
	<b>Appendix 2: Methane concentration monitoring data</b>	<b>23</b>
	<b>Appendix 3: Symbol and letter sizes for signs:</b>	<b>26</b>
	<b>Appendix 4: References</b>	<b>26</b>

**LIST OF FIGURES**

Figure 1:	Principal landfill drilling methods	10
Figure 2:	Typical zoning around a 'Type 2' borehole	13
Figure 3:	Typical zoning around a 'Type 3' borehole	14
Figure 4:	Typical zoning around a 'Type 4' borehole	15

**LIST OF TABLES**

Table 1:	Glossary of terms	6
Table 2:	Properties of 60% methane landfill gas	9
Table 3:	Control measures for drilling into landfill waste	16
Table 4:	Flammable gas detectors – manufacturers' web-sites	20
Table 5:	Use of flammable gas detectors	20
Table 6:	Typical landfill gas analysis data	22
Table 7:	Methane concentration data – Site A (Type 3)	23
Table 8:	Methane concentration data – Site B (Type 3)	23
Table 9:	Methane concentration data – Site C (Type 3)	23
Table 10:	Methane concentration data – Site D (Type 3)	25
Table 11:	Methane concentration data – Site E (Type 3)	25
Table 12:	Recommended symbol and letter sizes for signs	26

## **FOREWORD**

This code has been prepared by the Environmental Services Association and British Drilling Association in consultation with the Health and Safety Executive and has been endorsed by the Waste Industry Safety and Health (WISH) Forum, which represents the interests of the industry.

This Code should not be regarded as an authoritative interpretation of the law, but if you follow the advice set out in it you will normally be doing enough to comply with health and safety law in respect of those specific issues on which the Code gives advice. Similarly, Health and Safety Inspectors seeking to secure compliance with the law may refer to this Guidance as illustrating good practice.

## **ACKNOWLEDGEMENTS**

This Waste management Industry Code of Practice was prepared by the following members of the Working Group representing the drilling industry, the waste management industry and external consultants:

David Holton	Sira Certification
Mark McCrindle	South Tyne Drilling Limited
Ben Rigg	Biffa Waste Services Limited
Paul Rogers	Biffa Waste Services Limited
Brian Stringer	British Drilling Association
Vic Walsh	Viridor Waste Management

Contributions from the following persons/bodies are gratefully acknowledged:

-	Environmental Services Association Executive Committee
-	Waste Industry Safety and Health (WISH) Forum
Ray Lewis Dalton	Biffa Waste Services Limited, ESA Steering Group
Geoff Ellison	Dragon Drilling Limited
Stuart Hayward-Higham	Sita UK Limited; Chair of ESA Steering Group
Marian Kelly	Environmental Services Association Steering Group
Donald Lamont	Health and Safety Executive
Iain Macfarlane	Fugro Engineering Services Limited, ESA Steering Group
Chris Parry	Biffa Waste Services Limited; ESA Steering Group
Gary Raffle	Magpie Environmental Drilling Services Limited, ESA Steering Group
John Shrigley	Envirodrilling UK Limited, ESA Steering Group
Michael Shrigley	Envirodrilling UK Limited, ESA Steering Group
Diane Young	Environmental Services Association

## 1 INTRODUCTION AND SCOPE

### 1.1 Terms of reference

This document (ESA ICoP 4) is one of a number called up by the primary document (ESA ICoP 1) that, together, advise on how to fulfil the requirements of the Dangerous Substances Explosive Atmospheres Regulations:2002 ('DSEAR')<sup>1</sup> for the waste management industry. This ICoP deals with the drilling and piling activities necessary to construct boreholes<sup>a</sup> in and around landfill waste. Throughout this ICoP, drilling and piling are usually referred to generically as 'drilling' for simplicity.

ICoP 4 is the reference document for the waste industry but is not intended to be the primary reference document for the drilling industry. The British Drilling Association (BDA) document "Guidance for safe intrusive activities on contaminated or potentially contaminated land<sup>2</sup>" will be published late 2006 and will include all risks associated with drilling operations, including risks associated with the flammable nature of landfill gas; ICoP 4 provides the rationale, which will only be provided in summary form in the BDA guidance.

ICoP 4 comprises a set of recommendations only and is not mandatory, but is intended to represent good practice. Alternative practices may be employed provided the level of safety is maintained. Site-specific factors should always be considered when applying this ICoP and, where site rules impose additional or more onerous requirements, these should be followed. Throughout ICoP 4, there are situations covered that may require additional verification of the validity of the assumptions. On a particular site, it is the Site/Facility Manager<sup>b</sup> who holds the final responsibility to ensure DSEAR compliance and contractors undertaking drilling operations must report to this person and must use agreed techniques that have due regard to the safety issues under DSEAR. The intention is that this ICoP will allow drilling to be performed in a consistently safe manner across the industry by suitably qualified persons.

It is envisaged that this Edition will be reviewed and re-issued during 2007. Comments from the industry are welcomed and should be sent to ESA ([info@esauk.org](mailto:info@esauk.org)) before 31 March 2007.

### 1.2 Scope

This ICoP should be applied to all landfill drilling operations<sup>c</sup>. Within this ICoP, a 'hazardous area' is one in which a potentially explosive atmosphere<sup>d</sup> is, or could be, present. Other risks not relating to the risk of fire or explosion (e.g. toxic risks, risks from moving machinery, etc.) are not specifically covered, although they may be mentioned.

Many aspects of waste industry activities that relate to DSEAR compliance are covered by other ICoPs in the series:

- ◆ Top-level document (ESA ICoP 1) – Edition 1 published November 2005
- ◆ Area classification for landfill gas (ESA ICoP 2) – Edition 2 (final draft) published July 2006
- ◆ Leachate storage, treatment and disposal (ESA ICoP 3) – Edition 1 published April 2006
- ◆ Operations (production) (ESA ICoP 5) dealing with all aspects of the day-to-day running of a landfill site as well as the development of new sites – final draft published July 2006
- ◆ Operations (treatment) (ESA ICoP 6) including liquid treatments/solidification, advanced conversion technologies, aerosol destruction facilities – under discussion

ICoP 5 (Operations on landfill sites) can be referenced for further information, particularly Appendix 3 (hazardous area terminology) and Appendix 4 (equipment marking and ATEX categories).

---

<sup>a</sup> Where the word 'borehole' is used, this includes holes drilled to any depth for both landfill gas and leachate extraction.

<sup>b</sup> Wherever this term is used, it should be understood that the Site/Facility Manager can appoint another person for certain duties, but the Site/Facility Manager holds overall responsibility for ensuring that the duties are carried out.

<sup>c</sup> This includes the retro-drilling of leachate chambers.

<sup>d</sup> A 'potentially explosive atmosphere' in this context is limited to a mixture of landfill gas and air within the flammable range, i.e. between 4.4% and 16.5% methane by volume.

### 1.3 Executive summary

Drilling into landfill waste is likely to liberate landfill gas, which will mix with air and form a potentially explosive atmosphere. It is not possible to eliminate all potential ignition sources since the drilling process itself can produce sparks and hot surfaces. However, this ICoP identifies industry best practice and, by introducing control measures appropriate to the operations being performed, reduces the risk to workers to a level that is as low as reasonably practicable.

## 2 GLOSSARY OF TERMS

Only those terms relevant to this ICoP are given here. A fuller list of terms, including guidance on equipment marking and the various types of protection, is given in ICoP 5.

<b>Table 1: Glossary of terms</b>	
<b>Term</b>	<b>Explanation</b>
Apparatus group	This is the part of the certification code (IIA, IIB, IIC or II) that indicates the range of gases and vapours for which the equipment is suitable. Equipment marked IIC or II is suitable for all gases and vapours (provided the temperature class is appropriate). IIB equipment is suitable for IIA and IIB gases. IIA equipment is suitable only for IIA gases.
Area classification	The process of zoning the site to delineate between hazardous areas and non-hazardous areas
Arisings	The material cut out of the borehole by the drilling bit – also known as ‘cuttings’ or ‘returns’
Augers	
barrel drilling	The auger is pushed/rotated into the ground, withdrawn, emptied, and then re-inserted.
continuous flight	This auger is in the form of a continuous spiral
hollow stem	Tubes (threaded, keyed, etc.) with external continuous spiral flights
Auto-ignition temperature	The minimum temperature at which a potentially explosive atmosphere can spontaneously ignite; ignition usually occurs when it comes into contact with a hot surface above the AIT
Basal seal	Mineral liner, plastic membrane, combination liner or other impermeable material underneath the waste, primarily engineered to prevent leachate from seeping into the ground below the landfill.
Borehole	A hole made by drilling, piling or other techniques. This term is used to include ‘wells’.
Cable percussion drilling	Cable percussion drilling rigs lift and drop a string of heavy tools into the borehole. The falling tool breaks up the material allowing for its removal.
Categories of equipment	ATEX-marked equipment <sup>e</sup> is assigned a ‘category’ to indicate its level of protection. For mining equipment, the two categories are M1 and M2, with M1 being the higher level. For non-mining equipment, there are three categories: 1, 2 and 3, which indicate that the equipment is suitable for use in zones 0, 1 and 2 respectively <sup>f</sup> .
Cuttings	The material cut out of the borehole by the drilling bit – also known as ‘arisings’ or ‘returns’
Driller	Person who assists and supports the Lead Driller
Drill rig	Mechanical/hydraulic machine used to make a borehole
Driven pile (percussive) drilling	A technique in which a weight is dropped onto a steel pile and thereby forced into the ground. It could also be used to describe a steel pile being driven into the ground with a pneumatic hammer.

<sup>e</sup> Refer to ICoP 5 Appendix 4 for a full treatment of marking.

<sup>f</sup> Dust zones are ignored for the purposes of this ICoP, which deals only with flammable gases.

**Table 1: Glossary of terms**

<b>Term</b>	<b>Explanation</b>
DTH (down-the-hole) hammer drilling	A technique using a hammer bit down the borehole, which operates as the drill rods are rotating. The hammer-bit is driven by compressed air. Usually hammer drilling utilises a rotary air flush technique to remove arisings from the borehole as drilling progresses.
Flammable atmosphere	A mixture of gas and air that is within the flammable range, i.e. between the LEL and UEL – also known as a 'potentially flammable atmosphere' or a 'potentially explosive atmosphere'. The term 'potentially explosive atmosphere' will be used throughout the document.
Flight auger drilling	Material that is loosened by the auger tip is conveyed to the surface by the flight of augers. The borehole is also supported by the auger as it rotates
Gas detector	This is a device that usually detects a range of gases, one or more of which may be flammable. A device that measures methane only is sometimes referred to as a 'methanometer'. Where concentrations approaching the LEL are expected, such devices should be certified: normally they are intrinsically safe ('ia' or 'ib') with flameproof ('d') sensing heads.
Hazardous area	An area where there is a reasonable probability of finding a potentially explosive atmosphere. In this ICoP, the term 'hazardous' refers only to the fire or explosion hazard associated with landfill gas. The selection of equipment for use in hazardous areas is covered in ICoP 5.
<b>Ignition sources</b>	<i>The following are used for the purposes of this ICoP only and are not definitions that are in general circulation in the literature.</i>
High ignition potential	A high ignition potential source is one that is highly likely to ignite a potentially explosive atmosphere virtually instantaneously, e.g. a lighted cigarette, flare, grinder, welder, vehicle starter motor, metal-on-metal hammering.
Medium ignition potential	A medium ignition potential source is between a 'high' and a 'low'. Typical examples are: uncertified high-voltage electrical equipment (e.g. fixed luminaires); torches; other light sources; generators; compressors; impacts such as the drill string on the casing; static from water jets; static from V-belts; static discharge from the removal of clothing.
Low ignition potential	A low ignition potential source is one that is unlikely to ignite a potentially explosive atmosphere. Uncertified electrical equipment without obvious sparks and hot surfaces are considered low ignition potential sources: typically instrumentation, mobile phones and other low-power devices. Some types of switches may also be classed as 'low' if they are infrequently operated, e.g. emergency stops. Sparks and hot surfaces from most mechanical sources may also be regarded as 'low' (if not 'negligible'). (This does not imply, however, that low ignition potential equipment can be used in a hazardous areas, particularly electrical equipment – most cannot be used, but a risk assessment may allow certain items into a zone 2 – see section 6.5).
Negligible ignition potential	A negligible ignition potential source is one that need not be considered as a credible mechanism for igniting a potentially explosive atmosphere. Appropriately certified (pre-ATEX or post-ATEX) electrical and non-electrical equipment is in this category, in addition to equipment that has been assessed by the manufacturer or end user as being suitable for the zone, as will be the case with many pumps and motors in zone 2 for example.
Leachate	A water-based liquid that collects in a landfill site, containing numerous contaminants depending on the constituents leached from the landfill mass
Lead driller	The person who operates the drill rig
Lower explosive limit (LEL)	The minimum amount of flammable gas that, mixed with air, will produce a potentially explosive atmosphere; it is usually expressed as a percentage by volume (%v/v)

**Table 1: Glossary of terms**

<b>Term</b>	<b>Explanation</b>
Methanometer	A device for measuring methane concentrations. It usually gives the methane concentration <i>either</i> in parts per million (ppm) <i>or</i> as a percentage of the lower explosive limit (%LEL). The LEL of landfill gas is usually taken as 4.4% by volume, which equates to 44 000 ppm. Most operators do not use a device that detects methane only – see ' <i>Gas detector</i> '. Where concentrations approaching the LEL are expected, such devices should be certified: normally they are intrinsically safe ('ia' or 'ib') with flameproof ('d') sensing heads.
Monitoring	In the context of drilling into landfill waste, monitoring is the process of recording concentrations of any gases that might be evolved, particularly methane, but also, possibly hydrogen sulphide, hydrogen and other gases or vapours.
Negligible extent	Where the estimated volume of a potentially explosive atmosphere is small (less than 0.1 m <sup>3</sup> , equivalent to a sphere of radius 0.3 m) <sup>9</sup> , it is defined as having 'negligible extent' and no zoning applies.
Non-hazardous area	An area where there is zero or a negligible probability of a potentially explosive atmosphere being present; explosion-protected ('Ex') equipment is not required.
Perched leachate	This occurs where leachate is prevented from running to the bottom of the cell because it becomes trapped by an impermeable layer within the waste. The leachate itself tends to trap landfill gas and drilling through and below the leachate may release the gas.
Perimeter borehole	A borehole sunk outside the perimeter of the deposited waste but which may, nevertheless, suffer from landfill gas migration.
Potentially explosive atmosphere	A mixture of gas and air that is within the flammable range, i.e. between the LEL and UEL.
Purging	A process for replacing one gas with another, usually landfill gas with air (or sometimes nitrogen).
Returns	The material cut out of the borehole by the drilling bit – also known as 'arising' or 'cuttings'.
Simultaneous casing and drilling systems	This is a method in which a temporary casing is inserted into the borehole as drilling progresses; it is not generally used in landfill applications. This method is more suitable for unstable ground conditions, running sands, etc.
Site/Facility Manager	The person holding overall responsibility for ensuring that all duties relating to compliance with the various regulations are carried out. Wherever this term is used, it should be understood that the Site/Facility Manager could appoint another person for certain duties.
Sonic drilling	This is under investigation as a possible drilling method.
Temperature class	Equipment is designated with a temperature class, T1 to T6, to indicate the maximum temperature reached by the equipment under worst-case conditions. T6 equipment is the coolest (below 85°C), whereas T1 equipment is the hottest (below 450°C). Gases and vapours are also assigned temperature classes T1 to T6 to allow suitable equipment to be chosen
Upper explosive limit (UEL)	The maximum amount of flammable gas that, mixed with air, will produce a potentially explosive atmosphere; it is usually expressed as a percentage by volume (%v/v). Landfill gas within the landfill mass is usually above its UEL.
Vibrating displacement piling	This is a variant of a driven pile, where the pile vibrates to allow easier passage into the waste. One example of a commercially available version is the 'Vibropile'.
Working area	The exclusion area that unauthorised persons (i.e. those not involved with the drilling) should not enter; the hazardous area zone lies within the working area. Working areas are often designated with tape or another physical barrier.

<sup>9</sup> Strictly speaking, a 'hypothetical volume' (V<sub>2</sub>) of less than 0.1 m<sup>3</sup> rather than a zone volume is the criterion for being "of negligible extent". EN 60079-10:2003 calculation 4 (conclusion) states that a V<sub>2</sub> < 0.1 m<sup>3</sup> allows the ventilation to be assessed as degree 'high'. From the definition of degree 'high' in clause B.3.1, a zone of negligible extent results.

<b>Table 1: Glossary of terms</b>	
<b>Term</b>	<b>Explanation</b>
Zone 0	A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is present continuously or for long periods or frequently.
Zone 1	A place in which an explosive atmosphere consisting of a mixture with air or flammable substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally. The inside of gas wells are normally classified as zone 1
Zone 2	A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only. Examples include the area around gas wells, sample points and some manifolds.

### 3 PROPERTIES OF LANDFILL GAS

<b>Table 2: Properties of 60%<sup>h</sup> methane landfill gas</b>	
<b>Property</b>	<b>Value</b>
Main constituents	Methane (CH <sub>4</sub> ) – up to 60% v/v, the remainder being mainly carbon dioxide and nitrogen
Explosive limits <sup>3</sup>	4.4 – 16.5% v/v <sup>i</sup>
Density compared to air	Approximately the same as air – it may rise or fall in air, since its actual density compared to air depends on temperature and composition
Apparatus group	IIA
Auto-ignition temperature	537°C
Temperature class	T1

Since landfill gas has the least onerous apparatus group and temperature class, all hazardous area equipment<sup>l</sup> is suitable for use with landfill gas provided it has been correctly selected against other criteria, notably the zone.

Numerous other flammable materials may be present in landfill gas, but these are at very low concentrations compared to methane and no data exists to indicate that their concentration approaches their lower explosive limits<sup>k</sup>. Hydrogen is a potential concern, since it is highly sensitive to spark ignition and is a IIC/T1 gas. However, monitoring of 31 borehole sites<sup>l</sup> detected hydrogen concentrations ranging from <20 ppm to 1770 ppm, with an average of 276 ppm (see Appendix 1). The peak value of 1770 ppm equates to 0.177%v/v, or 4.4% of the LEL, so, even at this concentration, the effect of the hydrogen on the overall properties of landfill gas can be ignored. If hydrogen levels approaching the LEL are suspected, further measures may be necessary – this is outside the scope of ICoP 4.

Refer to LFTGN 04<sup>4</sup>, which addresses the health and environmental aspects of the constituents of landfill gas, but not primarily the flammable risk.

<sup>h</sup> The value of 60% is taken from Environment Agency guidance; LFTGN 03 quotes up to 63.7%

<sup>i</sup> BS EN 61779-1:2000 quotes 4.4 – 17% for methane.

<sup>j</sup> Explosion protected equipment is categorised into mining or non-mining applications (see glossary). HSE has been advised that the definition of mining should be taken as in S180 of the Mines and Quarries Act 1954. Therefore all tunnelling and underground construction is considered a *non*-mining application. However the selection of work equipment should primarily be on zonal suitability and not necessarily on whether the equipment is for the correct mining/non-mining application. In many cases only mining equipment will be available and may be used.

<sup>k</sup> Such materials may, however, present a toxic risk

<sup>l</sup> Monitoring carried out by Biffa between 1993 and 2005 at 207 locations, of which 31 were analysed for hydrogen. The data is summarised in Appendix 1

## 4 GENERAL PRINCIPLES OF LANDFILL DRILLING OPERATIONS

The general approach should be to ensure that, **wherever reasonably practicable, a potentially explosive atmosphere should be absent** when drilling activities are being performed. This is clearly not always possible due to the very nature of drilling, but current practices should always be assessed to attempt to find the safest way of working.

Landfill drilling is always carried out outdoors and the assumption has historically been made within the industry that any flammable gas released will be rapidly dispersed to a safe level, so that the extent of any potentially explosive atmosphere is too small to require specific protective measures. While this may be true, there is relatively little data in the form of gas concentration measurements to back up the assertion. Incidents involving injury and death can happen when rare events that are independent of each other occur simultaneously and unexpectedly. An example of one unusual (but predictable) event might be a very large release of landfill gas when the drilling bit breaks into a reservoir of landfill gas under pressure, causing a short-term but high-volume release. If this occurs in conjunction with an ignition source being present and effective, a situation could develop that is dangerous to workers. This ICoP attempts to assess the risks and determine whether further control or mitigation measures are required above those already employed.

The following is extracted from BS EN 791:1995, Drill rigs – Safety

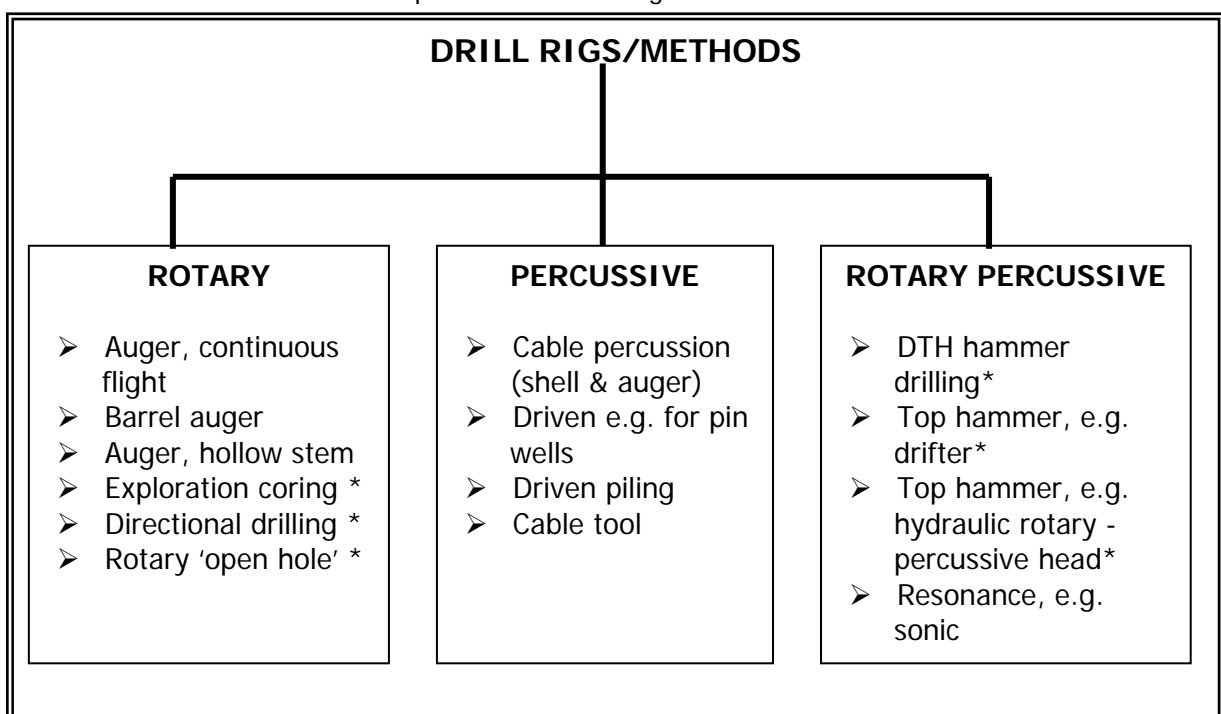
*"The methods used for drilling can be basically differentiated in percussive and rotary drilling principles.*

*Percussive drilling is a method by which the hole is produced by crushing the ground or rock at the bottom of the borehole by striking it with the drilling tool and removing the cuttings out of the borehole.*

*Rotary drilling is a method in which the drilling tool at the bottom of the borehole is rotated and at the same time a feed force is applied by a feed system or drill collar. The ground or rock at the bottom of the borehole is crushed or cut by pressure, shear or tensile stress produced by the different drilling tools. The cuttings are periodically or continuously removed out of the borehole.*

*Rotary percussive drilling is performed by a piston striking directly on the bit (down the hole hammer drills) or by percussive energy transmitted via a drill string to the bit. The piston is powered by either hydraulic fluid or compressed air."*

This ICoP will use the word 'drilling' to also cover percussive piling methods and wherein no cuttings are generated but a hole is formed by driven displacement of the ground. Figure 1 shows the principal drilling methods used within landfill sites or for perimeter monitoring boreholes



Some of the above rotary and rotary percussive methods in Figure 1 (marked with \*) employ the use of a flushing medium to remove the cuttings (returns, arisings) from the borehole. The flushing can be air flush, water flush, foam flush or mud flush.

The various types of drill rig may be mounted on different types of carrier:

1. Wheeled vehicle (truck, tractor etc.)
2. Tracked carrier (crawler etc.)
3. Trailer (or integral trailer e.g. cable percussion rig)
4. Skid mounted, primarily dragged in by another vehicle but some have wheels.

Almost all landfill drill rigs are powered by a diesel engine other than some percussion (driven) and top hammer (drifter) rigs, which are pneumatically powered. Diesel engines drive a hydraulic power pack, which provides oil for the various rig functions. A cable percussion rig is diesel-powered with mechanical transmission. Petrol-driven rigs are very rare and will not be considered – it is recommended that they be excluded from landfill drilling operations.

The control system may be electro-hydraulic, mechanical or electrical. Some control systems are fixed close to the drilling area, while others are mounted remotely. Even where the control system is mounted remotely, it is likely that there is some electrical equipment in the vicinity of the drilling area for safety purposes. One example is emergency stop switches. Another example is micro switches associated with interlocked rotary guards or other protective devices, e.g. trip wires, which are fitted to the drill rig to comply with Regulation 11 of the Provision and Use of Work Equipment Regulations (PUWER). If in a zoned area, these switches should be appropriate for use (see section 6.5).

Most landfill drilling is associated with methane extraction and drilled vertically down. Some landfill drilling is investigative and for monitoring purposes but again mainly vertically down. Occasionally, and for specific applications, directionally or angled drilling could be employed with the drill rig situated outside the boundaries of the infill waste but drilling into the waste where it could encounter landfill gas. The control measures in this ICoP would apply in such cases.

## **5 ACCIDENT HISTORY OF DRILLING OPERATIONS**

HSE document TD5/030<sup>5</sup> summarises all recorded incidents on landfill sites in the period 1987-1995 and is the most recent collated version available. This document is primarily concerned with accumulations of landfill gas and/or geological methane in buildings, but also includes other incidents, some of which involve injury and/or death. Many incidents logged relate to measured concentrations of landfill gas that gave rise to concern and required suitable mitigation measures but did not result in an ignition.

The BDA has collected incident statistics for the 3 years ending March 2006, March 2005 and March 2004. No detailed breakdown of the causes is available, but anecdotal evidence indicates that none of the incidents involving injury or death was a result of a methane ignition or explosion.

In the USA, there have been instances where drilling rigs were burnt out as a result of methane explosions in landfills<sup>6</sup>. It is not recorded whether there were any injuries or the cause of the ignition.

The above data is incomplete and the more recent data does not clearly discriminate between the various causes of injury or death. None of the data apparently points to fires and explosions from drilling operations. This in itself is insufficient grounds for continuing with all current practices but it adds weight to the argument that, although there is an identified hazard, the actual risk from landfill gas fires and explosions is slight. The next section details how the risks may be made as low as reasonably practicable.

## 6 HAZARD IDENTIFICATION AND RISK REDUCTION

### 6.1 Methane concentration monitoring data

Appendix 2 gives methane monitoring data from a number of sites at varying borehole depths and varying horizontal distances from the borehole. The data is not sufficiently wide-ranging but is typical and applies to drilling activities on sites containing newly deposited mixed domestic waste (defined in section 6.2 as 'Type 3'). Different instruments were used and it is likely that the resolution of the instruments is not better than  $\pm 0.1\%$  methane.

There is a need to accumulate further data on all types of well. This will be added to the next edition of ICoP 4.

### 6.2 Types of borehole

For the purpose of this ICoP, boreholes will be divided into one of four types, which may be summarised as follows:

- 1 Boreholes that produce negligible landfill gas
- 2 Boreholes that may produce small amounts of landfill gas
- 3 Boreholes that produce significant quantities of landfill gas
- 4 Boreholes that have the potential to release large quantities of landfill gas

These type designations are not currently used by the industry but are introduced for use in this ICoP. The classification of a borehole may need to be changed as drilling commences. If a larger-than-expected release of landfill gas occurs, then drilling should stop and the risk re-assessed.

#### 6.2.1 'Type 1' boreholes

Type 1 boreholes are those sunk into material other than waste that does not generate landfill gas, although it is possible that small amounts may have migrated from the landfill mass or be present from natural sources. Perimeter monitoring boreholes are likely to be Type 1, since methane concentrations within the flammable range are not expected. Emissions, if any, will be small and will not reach the LEL, so a zone of negligible extent<sup>m</sup> occurs - this is not considered to pose a significant flammable risk.

#### 6.2.2 'Type 2' boreholes

Type 2 boreholes are those sunk into inert waste or landfill from industrial sources of relatively known composition that are not expected to contain appreciable amounts of material capable of generating landfill gas. Type 2 also includes off-site monitoring boreholes where there is known migration of methane from landfill gas or other sources but where explosive concentrations are unlikely to occur in significant quantities. Re-drilled perimeter boreholes are likely to be Type 2 or Type 3

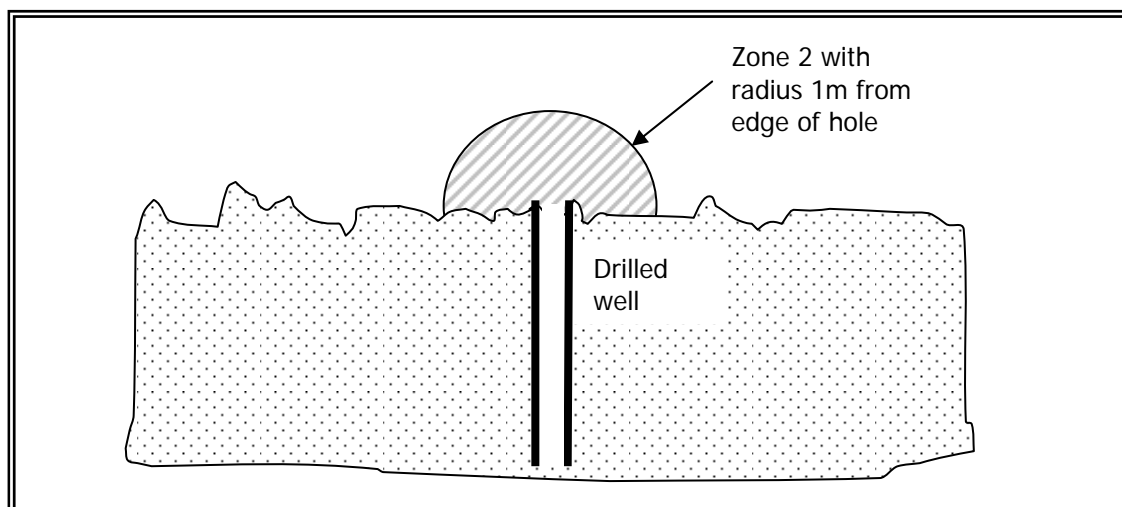
---

<sup>m</sup> 'Negligible extent' – see glossary of terms

### 'final draft awaiting HSE endorsement'

With Type 2 boreholes, it is not expected that there will be a measurable amount of gas within the flammable range at the surface, but, for prudence, a small zone 2 with a nominal radius of 1m is assigned, as shown in Figure 2 below.

Figure 2: Typical zoning around a 'Type 2' borehole



### 6.2.3 'Type 3' boreholes

Type 3 boreholes are drilled into freshly deposited mixed domestic waste which has, nevertheless, been resident long enough for landfill gas generation to be underway, particularly at greater depths. Landfill gas will be released by the drilling process and the formation of a significant potentially explosive atmosphere is to be expected in some cases.

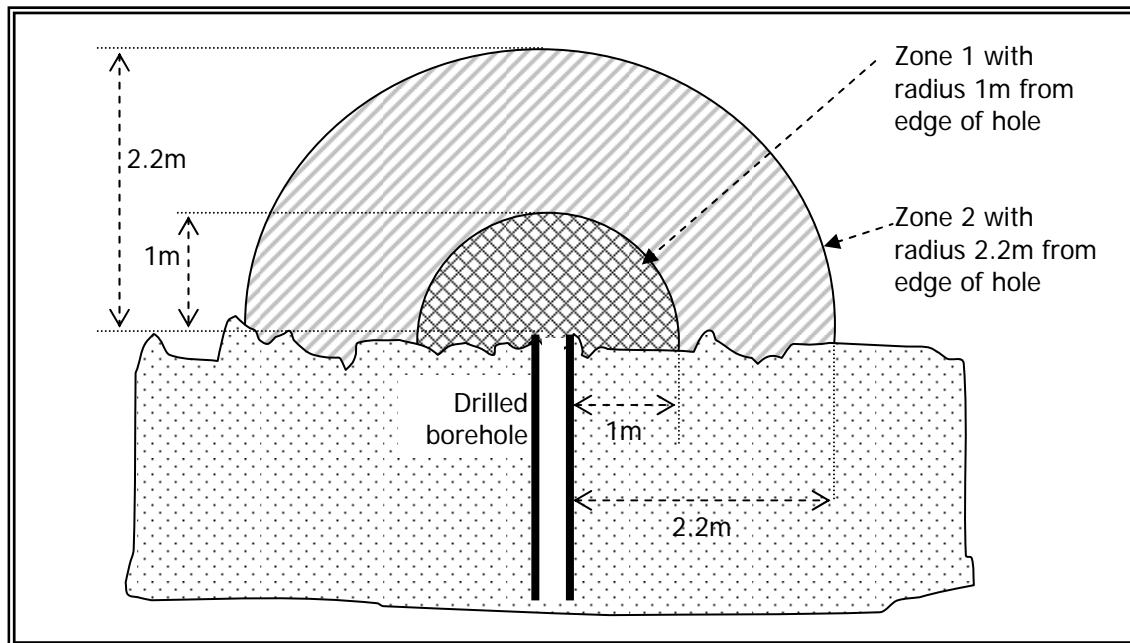
The rate of gas escape from the borehole is unlikely to be uniform during the drilling process, which makes the extent of the potentially explosive atmosphere difficult to estimate. Solid casing installed to depth during drilling is likely to reduce the gas flow rate. If the methane concentration is sampled in the borehole itself, it is likely to be within the flammable range, but on the surface the concentration falls very rapidly with distance from the borehole. There is some collated data (see section 6.1 and Appendix 2) that the methane concentration rarely exceeds 20% of its LEL at a distance of 1 m from the borehole. There is also anecdotal evidence based on gas monitoring without recorded data that supports the collated data. Until more data becomes available, the region around the hole will be classified as a zone 1 to a radius of 1m, since a potentially explosive atmosphere is expected relatively frequently.

With regard to larger but less frequent releases, leading to a zone 2, again it is not possible to accurately model this situation and calculate a zone extent with any certainty. In ICoP 2, a steady-state release rate of 30 m<sup>3</sup>/h was taken as a realistic upper limit that would apply to the vast majority of gas wells. This gives rise to a zone of radius 2.2m. This zone 2 radius will be used for drilling operations.

### 'final draft awaiting HSE endorsement'

The zoning around a typical Type 3 borehole is given in Figure 3 below.

Figure 3: Typical zoning around a 'Type 3' borehole



The zone radii must be kept under review and possibly modified in the light of more extensive sampling data, when this becomes available.

If, during drilling, a borehole classified as Type 3 does in fact give rise to a large release rate, drilling should stop; the risks and associated control measures should be reassessed. Indications of large release rates could be:

- ◆ gushing sound
- ◆ debris and leachate emitted from the hole

Other indicators that may not necessarily indicate a large release and may not therefore require a reassessment are:

- ◆ change in background smell;
- ◆ visible haze around the borehole (due to gas at a different temperature being emitted).

#### 6.2.4 'Type 4' boreholes

Type 4 boreholes are those that may produce very large release rates. Conditions that favour this are:

- 1 mature sites comprising mixed domestic waste that have not been subjected to extraction or where the extraction points are widely spaced
- 2 deeply-buried waste
- 3 where the site has a known history of 'perched' leachate.
- 4 high moisture content
- 5 highly biodegradable waste (usually household waste)

The specific risk relates to drilling into a 'reservoir' of trapped landfill gas that may not be under extraction and therefore could be at a modest pressure (80 mbarg is taken as the upper limit in ICoP 2, although this is for areas that are generally under extraction).

Data on such large-scale releases does not exist because the events are rare and have not been captured by routine monitoring. More work is needed to collate data from across the industry to try to quantify and define the risk more accurately. Such large-scale releases are very rare but a number have been identified by various operators. The pressurised release may audibly gush out of the drilled borehole for several minutes before slowly dying away; in some cases, the gas production remains very large and the borehole continues to release gas at a high rate.

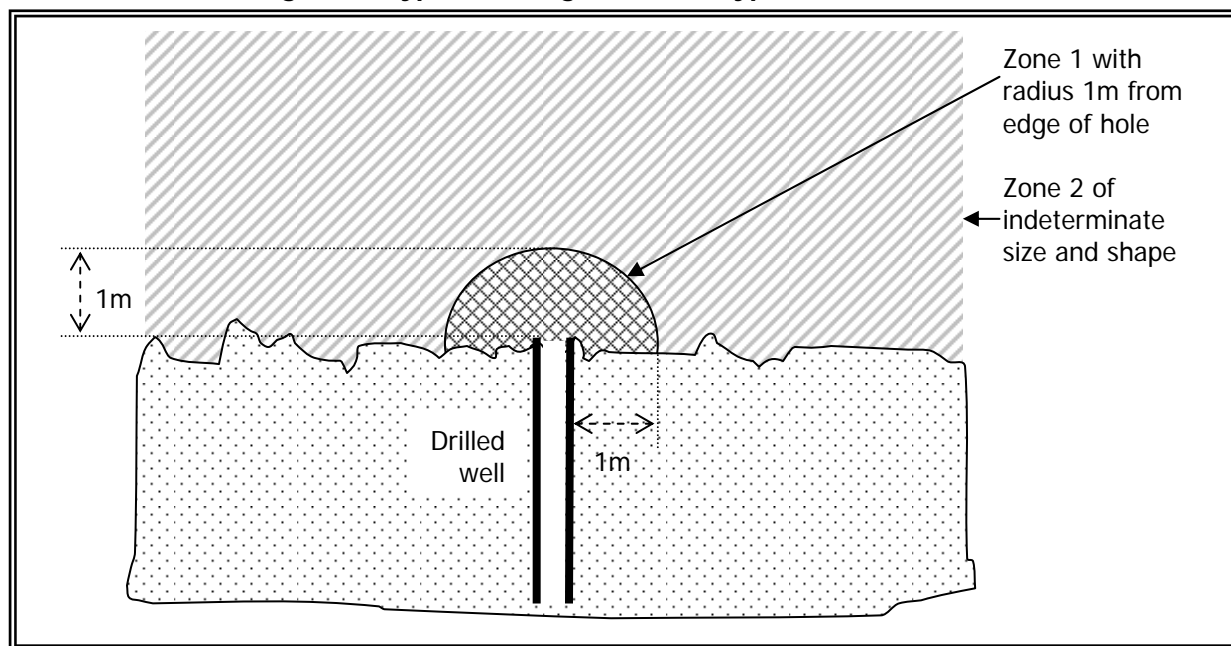
### 'final draft awaiting HSE endorsement'

A zone 2 is assigned, since such releases, although infrequent, are anticipated to occur from time to time and cannot be described as 'catastrophic' events<sup>n</sup>.

For very large release rates, a plume of gas results and dilution is mainly velocity-driven. However, the released gas will impinge on obstructions such as the drilling table and be diverted to the side and downwards. There is likely to be a methane concentration at ground level far in excess of the normal value and for a much larger radius. As the pressurised release dies away, a wind-dispersion mechanism takes over and the concentration at ground level will again be significantly higher than normal.

The zoning drawing for Type 4 boreholes is similar to that for Type 3, but the extent of the zone 2 is much larger, though indeterminate – see Figure 4.

Figure 4: Typical zoning around a 'Type 4' borehole



The potentially explosive atmosphere may well encompass numerous potential ignition sources associated with the rig. A fundamental problem with drilling is that the most likely ignition source is the drill bit itself. It is not proposed that all equipment in this zone will be suitable for use in zone 2 – some equipment will clearly not be suitable – but the implementation of further control measures, as outlined in Table 3 (section 6.4) reduce the risk to workers to an acceptably low level.

### 6.3 Potential ignition sources

The following potential ignition sources have been identified:

- ◆ drill bit (thermal and sparking)
- ◆ other in-the-hole equipment (thermal and sparking)
- ◆ uncertified electrical equipment on the rig e.g. emergency stop switch, micro-switches on trip-wires, lights, horns, etc. (all equipment on the rig is likely to be uncertified)
- ◆ uncertified electrical equipment carried on the person e.g. mobile phones, cameras, torches
- ◆ smoking and other naked lights
- ◆ hammering (to free the auger or other in-the-hole equipment)
- ◆ 'barring' (cleaning out auger)
- ◆ hot works

<sup>n</sup> Area classification only deals with reasonably foreseeable events and does not consider highly improbable ('catastrophic') events. EN 60079-10 section 1.1(d) defines 'catastrophic' failures as "beyond the concept of abnormality dealt with in the standard" and lists "the rupture of a process vessel or pipeline and events that are not predictable" as examples. Thus, a 'catastrophic' failure may cause an explosive atmosphere to be present in an area defined by area classification as 'non-hazardous' and such situations are subject to a risk assessment by the operator under other legislation. The subject is dealt with in more detail in ICoP 2 section 4.

**'final draft awaiting HSE endorsement'**

- ◆ maintenance welding
- ◆ fusion welding of plastic pipes
- ◆ diesel generator
- ◆ hot engine exhaust
- ◆ mechanical impacts, e.g. from hydraulic clamp, chain clamp
- ◆ static sparks, e.g. from clothing, plastic pipes

Clearly, some of these hazards can be easily removed, e.g. a ban on smoking on the site, which is already in place. Others, such as ignition sources associated with the drilling process itself, are not so easily dealt with. The following sub-section deals with controlling risks.

## 6.4 Control measures

Even where the probability of a significant release of landfill gas is assessed as low or even negligible, it is good practice to adhere to control measures as a matter of course. If a uniform approach is adopted wherever practical, it is less likely that control measures will be omitted when the risk is higher or when a site is unexpectedly active. Liaison between the Site/Facility Manager and the drilling company should precede drilling activity and relevant site requirements followed (e.g. issue of a permit-to-work). Conditions on the landfill site may change from day to day, or even during the day, and it is the responsibility of the Site/Facility Manager to alert the drilling company of changes that may affect safety.

The following control measures, aimed at reducing the risk of ignition of a potentially explosive atmosphere, are recommended for all drilling operations on landfill sites.

<b>Table 3: Control measures for drilling into landfill waste</b>					
Key: * = mandatory; 'consider' = rig operator's risk assessment should decide whether control is required					
<b>Control measures</b>		<b>Borehole type</b>			
<b>Note</b>		Type 1	Type 2	Type 3	Type 4
1	Drilling contactor to be advised on borehole type at tender stage	*	*	*	*
2	Site/Facility Manager to issue permit to drill, the frequency as agreed by the parties involved	*	*	*	*
3	Only NVQ-qualified and BDA-audited lead drillers and drillers to operate rig	*	*	*	*
4	Drill crew given list of names/telephone numbers of site manager (or deputy) and those required in the event of an emergency	*	*	*	*
5	Drill crew advised on borehole type immediately prior to commencement of drilling	*	*	*	*
6	Removal of temporary borehole seal <sup>o</sup> to be under the supervision of the lead driller	Not required	*	*	*
7	No smoking unless in designated areas; if permitted, at least 15 m from drill rig	*	*	*	*
8	No smoking materials (cigarettes, etc.), lighters and matches within 15 m of drill rig	*	*	*	*
9	Working area, as designated by the lead driller, to be marked out, e.g. with tape, barriers.	*	*	*	*
10	Entry of persons or equipment into working area to be authorised by lead driller	*	*	*	*

<sup>o</sup> Such seals are typically put in overnight to limit gas release, e.g. for odour control.

**Table 3: Control measures for drilling into landfill waste**

Key: \* = mandatory; 'consider' = rig operator's risk assessment should decide whether control is required

<b>Control measures</b>		<b>Borehole type</b>			
<b>Note</b>		Type 1	Type 2	Type 3	Type 4
11	Warning notices (no entry, no smoking, no naked flames) to be visible from all directions and large enough to be read from the edge of the working area (see note 4 below this table).	*	*	*	*
12	Hazardous area warning signs to be visible from all directions and large enough to be read from the edge of the working area.	consider	*	*	*
13	No welding, grinding and other ignition sources without a permit-to-work issued by the site manager.	*	*	*	*
14	No flammable liquid or gases (apart from necessary lubricant/hydraulic oils and diesel)	*	*	*	*
15	Mobile phone to be available (outside the zoned area unless certified) in case of emergency	*	*	*	*
16	Fixed electrical equipment within a zone 1 (e.g. emergency stops, micro-switches on trip wires) to be suitably-certified (typically flameproof or supplied via an intrinsically safe galvanic isolator)	not required	not required	*	*
17	Fixed electrical equipment within a zone 2 (e.g. emergency stops, micro-switches on trip wires) to be suitably-certified or covered by a risk assessment – see section 6.5)	not required	consider	*	*
18	Ban on unauthorised electrical equipment e.g. personal stereo, etc. in the working area	consider	*	*	*
19	Daily check and record – correctly-certified fire extinguishing equipment on drill rig including fire blanket and appropriate fire extinguisher	*	*	*	*
20	Daily visual check of exposed electrical wiring, plus record by lead driller	*	*	*	*
21	Regular inspection of all potential sources of ignition which could arise through deterioration or damage, to include electrical systems <sup>p</sup> .	*	*	*	*
22	Pre drilling check and record – rig emergency stop(s), rig safety interlocks, trip wires, etc.	*	*	*	*
23	Written drilling log by lead driller (depths, changes, alarms, etc.) to be completed	*	*	*	*
24	Anti static footwear for all personnel within working area	not required	*	*	*
25	No petrol-driven machinery within the working area	consider	*	*	*
26	No lone working of the drill rig	*	*	*	*
27	No light metal alloy (e.g. aluminium alloy) drill strings	not required	*	*	*
28	Exhaust spark arrestor on exhaust outlet (if within zoned area)	not required	consider	consider	*

<sup>p</sup> Based on the requirements of PUWER Regulation 6

<b>Table 3: Control measures for drilling into landfill waste</b>					
Key: * = mandatory; 'consider' = rig operator's risk assessment should decide whether control is required					
<b>Control measures</b>		<b>Borehole type</b>			
<b>Note</b>		Type 1	Type 2	Type 3	Type 4
29	Air intake "Chalwyn-type" valve on drill rig engine (if within zoned area)	not required	consider	consider	*
30	Continuous methane monitoring, with a flammable gas detector at a designated location on the drill rig. The device may be permanently fixed to the rig or temporarily attached during drilling. See Table 5.	consider	*	*	*
31	Portable methane monitor available on site. If required, this should be available from the Site/Facility Manager and may also be operated by the Site/Facility Manager.	consider	consider	consider	*
32	Drill crew trained on their own company's gas detection equipment	*	*	*	*
33	Pre drilling methane gas detector reading at site of proposed borehole prior to set-up of drilling rig	consider	*	*	*
34	On set-up, drill table should be situated up wind where local conditions allow	not required	*	*	*
35	Ban on non-essential vehicles in the zoned areas. For essential vehicles (e.g. for delivering stones for back-filling), access is preceded by a gas check. If a level of $\geq 20\%$ LEL is detected more than 1m from the borehole, vehicles are not permitted.	consider	consider	*	*
36	Portable fans to enhance dilution of gas to be running during drilling (not to be situated in zone 2 unless suitable for hazardous area use)	not required	consider	consider	consider (see note 1)
37	Local exhaust ventilation (LEV) system fitted to borehole	not required	not required	consider	consider (see note 1)
38	Inert gas injection into borehole	not required	consider	consider	not required (see note 2)
39	Ban on rotary air flush drilling	not required	consider	*	*
40	Ban on percussive drilling without modifications being in place to minimise sparking	not required	consider	consider (see note 3)	*

Note 1: For Type 4 boreholes, one or the other of these two control measures should be used; the choice may be dictated by the site operator.

Note 2: For Type 4, the volume of nitrogen required for a large release would be excessive and impractical.

Note 3: The primary consideration is whether the percussion takes place within the zoned area and, if it does, the likelihood of a spark being generated.

## **6.5 Risk assessment for the use of uncertified micro-switches and E-stops in zone 2**

All drilling of Type 4 boreholes involves a potentially explosive atmosphere of indeterminate extent, which will almost certainly encompass a number of items of electrical equipment on the rig. Those items closest to the borehole are likely to be one or more emergency-stop switches (ESS) and micro-switches associated with the trip-wires and guards.

Depending on the design of the rig, these devices may also be within the zone 2 for type 3 boreholes; it is unlikely that they will be within the zone 1, as this would require them to be within 1m of the edge of the hole.

## 'final draft awaiting HSE endorsement'

By their very nature, switches spark. They are supplied from the vehicle's nominally 24 V battery, which has a peak voltage of 28.2 V. At this voltage, a current in excess of 585 mA is required to ignite methane<sup>7</sup>.

The probability of the switches causing an ignition is very low because of the following factors:

- ◆ it is unlikely that a current larger than 585 mA will be flowing in the control circuit
- ◆ it requires a finite time for any surrounding flammable gas to diffuse into the switch mechanism
- ◆ the switches only spark rarely during drilling, as a result of a worker close to the auger activating a trip wire or the lead driller hitting the ESS
- ◆ the probability of there being a potentially explosive atmosphere in a zone 2 is low.

In addition, the severity of an ignition is low since a flash fire is the most likely consequence, rather than an explosion.

In conclusion, uncertified ESS and micro-switches on existing rigs need not be replaced if they are in a zone 2.

In the relatively unlikely event that they are located close enough to the borehole to be in a zone 1, then they should be replaced by certified flameproof switches or else supplied via a suitable intrinsically safe galvanic isolator.

The specification for new rigs intended for use in landfill drilling operations should require that they be fitted with protected switches<sup>9</sup>, whether the switches are in a zone 2 or 1.

## 6.6 Specification and use of fixed flammable gas monitors

### 6.6.1 Specification

This ICoP recommends the use of a fixed flammable gas detector, although other gases may also be detected depending on the model chosen. Only methane detection will be addressed in this section. There is an HSE guidance document<sup>8</sup> covering the choice and use of flammable gas detectors.

There are certain requirements for the flammable gas detector:

- 1 it should be in a fixed location on the rig;
- 2 IR detection may be preferable to the catalytic bead (pellistor) type, since the latter may burn out at concentrations above the LEL if such levels are frequently encountered;
- 3 the head should be of rugged construction;
- 4 the device should have a visible and/or audible indication of operation;
- 5 the device should have an alarm threshold set at 20%;
- 6 alarms should be audible and also visible, since the level of noise may make it impossible to hear an alarm;
- 7 as far as possible, the device should avoid false alarms caused by small volumes of high concentration gas that only persist transiently due to incomplete dilution – this may be a feature of the software in the controller
- 8 the device should be tamper-proof to prevent unauthorised personnel from changing the sensitivity

It is not a requirement for the gas detection to be linked to the control system such that there is automatic shutdown if the alarm threshold is reached, provided an emergency stop is within easy reach of the lead driller.

### 6.6.2 Manufacturers of flammable gas detectors

The following list is in alphabetical order by manufacturer and is not exhaustive. Inclusion in the list does not indicate a recommendation or endorsement. Other manufacturers are welcome to contact ESA at the address on page 2 of this ICoP and provide their web-site addresses for inclusion in the next edition of this ICoP.

---

<sup>9</sup> I.e. flameproof (Ex d) switches or standard switches supplied via an intrinsically safe galvanic isolator.

<b>Table 4: Flammable gas detectors – manufacturers' web-sites</b>	
<b>Manufacturer</b>	<b>Web-site</b>
Crowcon	<a href="http://www.crowcon.com/fixedgasdetectors.htm">http://www.crowcon.com/fixedgasdetectors.htm</a>
Draeger	<a href="http://www.draeger.com">http://www.draeger.com</a>
Geotechnical Instruments	<a href="http://keison.co.uk/geotechnical/geotechnical_instruments.htm">http://keison.co.uk/geotechnical/geotechnical_instruments.htm</a>
GMI	<a href="http://www.gmiuk.com/fixed.html">http://www.gmiuk.com/fixed.html</a>
MSA	<a href="http://www.msabritain.co.uk/index.php?id=51&amp;L=3">http://www.msabritain.co.uk/index.php?id=51&amp;L=3</a>
raeSystems	<a href="http://www.raesystems.com">http://www.raesystems.com</a>
Trox	<a href="http://www.trox.com/gas.html">http://www.trox.com/gas.html</a>

### 6.6.3 Procedure for use

Table 5 below outlines the procedure for using flammable gas (methane) detectors:

<b>Table 5: Use of flammable gas detectors</b>	
A	It is recommended that a suitable flammable gas detector <sup>r</sup> be attached to the rig structure in a location that is between the borehole and the most likely potential ignition source – usually this will be on the tractor side. If spurious alarms occur too frequently, this may lead to 'alarm fatigue' whereby alarms are no longer treated seriously. Under these circumstances, it may be necessary to relocate the head to avoid areas where gas may be trapped.
B	The methane concentration should be measured before drilling starts and continuously monitored during the drilling process. The drilling operator's Safe Operating Procedure should include the requirement for a reading to be taken before commencing drilling and that drilling is not started if the methane level is above the alarm threshold.
C	On hearing or seeing an alarm, the lead driller should shut the rig down in a controlled manner by appropriate means and the crew should ensure that the area is evacuated in an orderly manner to a distance of at least 15 m, preferably upwind. Even if not an explosion risk, it should be noted that landfill gas is highly toxic at these concentrations.
D	If the alarm threshold has been reached, the rig should not be approached without a portable methane monitor; this should be made available by the Site/Facility Manager and need not be carried by the drilling operator. Approaching an area with suspected high methane levels should be under the site's permit system.
E	The flammable gas detector must be calibrated and certificated according to the manufacturer's guidelines.

Reaching the alarm threshold should be an unusual event even in Type 4 boreholes and even more unusual in Type 3. If a very large-scale release occurs, the alarm threshold will be reached both at the initial high-velocity stage (due to deflection by the drilling floor) and at the latter stages, where wind dispersion takes over. The lead driller will therefore shut down the rig using an emergency stop or in an otherwise controlled manner.

<sup>r</sup> See section 6.6.1 for the specification

## **6.7 Anti-static clothing**

As stated in ICoP 5, a static discharge from clothing is a potential ignition source but, provided clothing is not removed when in a zoned area, anti-static footwear alone is generally sufficient for all activities.

Therefore, from a DSEAR perspective, the only PPE<sup>s</sup> required is anti-static footwear, but other PPE will be necessary for risks other than flammable ones. Minimum PPE will typically comprise:

- ◆ anti-static protective footwear
- ◆ hi-visibility jacket or vest
- ◆ hard hat
- ◆ eye protection
- ◆ ear protection
- ◆ gloves

The level of PPE actually required will derive from the risk assessment carried out by the lead driller prior to starting work, or could be prescribed by local site rules.

## **6.8 Training**

Training is one of the measures to reduce risk. All operators should be trained to NVQ level II in Land Drilling (the qualification subject to independent audit, e.g. from the BDA). This qualification goes well beyond the consideration of merely the flammable risks, but does include these.

Along with general hazardous area awareness, specific training in the use of flammable gas detectors is essential, with an understanding of the concept of the explosive limits of landfill gas.

## **7 CONCLUSION**

The risk of flash fire from landfill gas emissions during drilling is small and the risk of explosion (since there is no containment) is virtually zero. As a result, the majority of existing drilling practices are sufficiently safe for landfill activities if the listed control measures are applied, many of which are already incorporated into the existing industry guidance from the BDA.

A summary of ICoP 4 will be included in the next revision of the BDA guidance document such that this BDA document becomes the single source of reference for drilling operators.

---

<sup>s</sup> PPE = Personal Protective Equipment

## APPENDIX 1: TYPICAL LANDFILL GAS ANALYSIS DATA

The table below gives the analysis data for a total of 207 sites and provides a typical breakdown of the main constituents of landfill gas. It is for information only and should not be taken as definitive.

**Table 6: Typical landfill gas analysis data**

<b>Material (flammable gases in bold)</b>	<b>Units</b>	<b>Number of readings</b>	<b>Average</b>	<b>Max</b>	<b>Min</b>
Oxygen	%	207	1.89	14.9	<0.1
Nitrogen	%	207	20.4	59.1	<0.2
<b>Methane</b>	%	207	45.4	61.6	12.9
Carbon Dioxide	%	207	32.0	43.4	11.5
<b>Carbon Monoxide</b>	ppm	9	21.4	50	<10
<b>Hydrogen</b>	ppm	31	278	1770	<20
<b>Ethylene</b>	ppm	31	7.6	40	<5
<b>Ethane</b>	ppm	31	10.2	39	<5
<b>Acetylene</b>	ppm	31	5.0	5	<5
Toluene	mg/m <sup>3</sup>		62.9		
Freon 12	mg/m <sup>3</sup>		14.6		
Freon 22	mg/m <sup>3</sup>		4.6		
Freon 114	mg/m <sup>3</sup>		18.5		
Freon 21	mg/m <sup>3</sup>		22.6		
Freon x	mg/m <sup>3</sup>		5.6		
1:2 Dichloro 1:1:2	mg/m <sup>3</sup>		2.6		
Freon 113	mg/m <sup>3</sup>		5.0		
Vinyl Chloride	mg/m <sup>3</sup>	199	15.8		
Chloroethane	mg/m <sup>3</sup>	199	3.8		
1:1 Dichloroethane	mg/m <sup>3</sup>	199	9.6		
Dichloromethane	mg/m <sup>3</sup>	199	13.4		
Dichloroethane	mg/m <sup>3</sup>	199	2.1		
cis 1:2 Dichloroethene	mg/m <sup>3</sup>	199	15.7		
1:1:1 Trichloroethane	mg/m <sup>3</sup>	199	4.5		
1:2 Dichloroethane	mg/m <sup>3</sup>	199	3.2		
Trichloroethene	mg/m <sup>3</sup>	199	6.1		
Tetrachloroethene	mg/m <sup>3</sup>	199	9.5		
Chlorobenzene	mg/m <sup>3</sup>	199	5.2		
Hexamethyldisiloxane	mg/m <sup>3</sup>	9	9.1		
Hexamethylcyclotrisiloxan	mg/m <sup>3</sup>	9	2.0		
Octamethylcyclotetrasiloxan	mg/m <sup>3</sup>	9	27.3		
Decamethylcyclopentasiloxan	mg/m <sup>3</sup>	9	18.8		
Dodecamethylcyclohexasiloxan	mg/m <sup>3</sup>	9	9.9		
Methanethiol	mg/m <sup>3</sup>	9	5.3		
Ethanethiol	mg/m <sup>3</sup>	9	5.0		
Dimethylsulphide	mg/m <sup>3</sup>	9	6.2		
<b>Carbon disulphide</b>	mg/m <sup>3</sup>	9	<5	<5	<5
1-Propanethiol	mg/m <sup>3</sup>	9	5.0		
Methylethylsulphid	mg/m <sup>3</sup>	9	42.3		
Thiophen	mg/m <sup>3</sup>	9	8.3		
Ethylsulphide	mg/m <sup>3</sup>	9	5.0		
1-Butanethiol	mg/m <sup>3</sup>	9	5.0		
Dimethyldisulphide	mg/m <sup>3</sup>	9	5.2		
Diethyldisulphide	mg/m <sup>3</sup>	9	4.8		
<b>Hydrogen Sulphide</b>	mg/m <sup>3</sup>	62	291	2641	10
Fluorine Compounds	mg/m <sup>3</sup>		62.8		
Chlorine Compounds	mg/m <sup>3</sup>		80.9		
Silicon Compounds	mg/m <sup>3</sup>		123		
Organo Sulphur	mg/m <sup>3</sup>		80.3		
Organic Fluorine	mg/m <sup>3</sup>		11.4		
Organic Chlorine	mg/m <sup>3</sup>		13.0		
Organic Silicon	mg/m <sup>3</sup>		47.0		
Total Sulphur	mg/m <sup>3</sup>		110		

## APPENDIX 2: METHANE CONCENTRATION MONITORING DATA

In Table 7 and Table 8, the detection instrument was held downwind as close to the borehole as safely possible, but the actual distance was not recorded.

<b>Table 7: Methane concentration data – Site A (Type 3)</b>			
(data from 22 different boreholes on the same site)			
	Number of results showing detectable CH <sub>4</sub> levels at various stages	Average CH <sub>4</sub> concentration	
		%v/v	% of LEL
Start of well	0 out of 22	0	0
Through cap	0 out of 22	0	0
Barrel withdrawal depth			
2 m	0 out of 22	0	0
half drill depth	0 out of 22	0	0
full drill depth (15 m)	1 out of 22	0.27 <sup>t</sup>	6.1

<b>Table 8: Methane concentration data – Site B (Type 3)</b>			
(data from 37 different boreholes on the same site)			
	Number of results showing detectable CH <sub>4</sub> levels at various stages	Average CH <sub>4</sub> concentration	
		%v/v	% of LEL
Start of well	17 out of 37	0.02%	0.45
Through cap	37 out of 37	0.11%	2.5
Barrel withdrawal depth			
2 m	37 out of 37	0.13%	3.0
half drill depth	37 out of 37	0.10%	2.3
full drill depth (15 m)	35 out of 37	0.07%	1.6

Table 9 shows methane concentration at various drill depths in a limited number of wells. The position of the detection instrument is not specifically recorded but was downwind and close to the well.

<b>Table 9: Methane concentration data – Site C (Type 3)</b>			
(data from 7 new boreholes and 3 existing boreholes on the same site)			
	Number of results showing detectable CH <sub>4</sub> levels at various drill depths	Average CH <sub>4</sub> concentration	
		%v/v	% of LEL
New boreholes			
Less than 2 m depth	7 out of 7	0.03	0.6
2 – 4 m depth	7 out of 7	0.07	1.6
Existing boreholes, <2m depth			
Borehole 1	-	0.37	8.4
Borehole 2	-	0.53	12
Borehole 3	-	<b>15</b>	<b>340</b>

<sup>t</sup> 6% methane detected in one of the 22 tests, all other tests being zero

**'final draft awaiting HSE endorsement'**

**'final draft awaiting HSE endorsement'**

Table 10 shows methane concentration with the detection instrument 0.5 m downwind.

<b>Table 10: Methane concentration data – Site D (Type 3)</b>			
(data from 6 boreholes on the same site, monitor 0.5 m downwind)			
Borehole #	Number of readings	Average CH <sub>4</sub> concentration	
		%v/v	% of LEL
Borehole 1	5	0.04	0.91
Borehole 2	4	0.03	0.57
Borehole 3	3	0.53	12
Borehole 4	4	<b>1.4</b>	<b>31</b>
Borehole 5	4	0.10	2.3
Borehole 6	4	0.20	4.5

Table 11 shows methane concentration with the detection instrument various distances downwind.

<b>Table 11: Methane concentration data – Site E (Type 3)</b>							
(data from GA2000+ on 8 boreholes on the same site, monitoring varying distances downwind)							
Borehole #	Drill depth	CH <sub>4</sub> concentration (% v/v)					
		Ground level			1 m above ground		
Distance from hole:		0.5 m	1 m	2 m	0.5 m	1 m	2 m
Borehole 1	-	0.3	0.1	0.1	0.2	0.2	0.2
Borehole 2	18m	0.5	0.3	0.2	0.3	0.1	0.0
Borehole 3	16m	0.5	0.3	0.3	0.2	0.2	0.2
Borehole 4	18m	0.5	0.4	0.2	0.2	0.2	0.1
Borehole 5	11m	0.4	0.2	0.1	0.2	0.1	0.1
Borehole 6	18m	0.6	0.4	0.3	0.3	0.1	0.1
Borehole 7	-	0.4	0.4	0.4	0.3	0.3	0.3
Borehole 8	19m	0.6	0.4	0.3	0.4	0.2	0.2

**Summary of methane concentration data**

From the limited data available, the indication is that methane concentrations approaching the LEL close to the borehole are unusual but do occur from time to time. The data covers readings from 83 boreholes, of which one (borehole 4 in Table 10) exceeded 20% LEL at 0.5 m from the hole and one (borehole 3 in Table 9) exceeded the LEL.

## APPENDIX 3: SYMBOL AND LETTER SIZES FOR SIGNS:

Warning signs will be sufficiently visible<sup>u</sup> if they have the following symbol manufactured letter heights, depending on the anticipated distance from which they may be viewed:

Max. viewing distance (m)	Min. symbol height (mm)	Recommended letter height for supplementary text (mm)
7	60	5
9	80	7
14	120	10
21	180	15
28	240	20

## APPENDIX 4: REFERENCES

The following publications were referenced in compiling this document:

- <sup>1</sup> Dangerous Substances Explosive Atmospheres Regulations:2002 ('DSEAR') - Regulation 7 requires area classification to be undertaken
- <sup>2</sup> British Drilling Association document "Guidance for safe intrusive activities on contaminated or potentially contaminated land", 2006, obtainable from late 2006 from BDA Ltd, Wayside, London End, Upper Boddington, Daventry NN11 6DP (telephone 01327 264622)
- <sup>3</sup> Environment Agency publication LFTGN03: Guidance on the management of landfill gas, page 53, section 6.2.3, downloaded August 2005.
- <sup>4</sup> Guidance for monitoring trace components in landfill gas, document LFTGN 04, September 2004, Environment Agency
- <sup>5</sup> Review of landfill gas: incidents and guidance, TD5/030, E M Gregson, HSE, 2 October 2000
- <sup>6</sup> Background information to patent US5701963, United States Army
- <sup>7</sup> Ignition current data from EN 50020:2002 Table A1 for propane – methane has a higher ignition current.
- <sup>8</sup> The selection and use of flammable gas detectors, HSE, November 2004 - free download from <http://hse.gov.uk/pubns/gasdetector.pdf>

<sup>u</sup> <http://www.sign-language.co.uk/help-leg-bs.php?SignLanguage=cda5f5c8361483c590a4736870dadf8a>