12a. LANDFILL GAS HAZARDS ASSESSMENT (TTAL SITE)

12a.1 Introduction

12a.1.1.1 This chapter presents the risk assessment of landfill gas (LFG) hazards arising from the construction and operation phases of the IWMF at the Tsang Tsui Ash Lagoon (TTAL) site. Appropriate protective and precautionary measures will be implemented during various phases of the Project to control the LFG hazards to a minimum and acceptable level. No adverse impact is anticipated.

12a.1.1.2 The landfill gas hazard assessment has been conducted in accordance with the requirements in the *Landfill Gas Hazard Assessment Guidance Note*, and Clause 3.4.9 of the EIA Study Brief for the Project.

12a.2 Environmental Legislation, Policies, Plans, Standards and Criteria

12a.2.1.1 Relevant legislation and associated guidance notes applicable to the assessment of the LFG hazards include:

- Section 1.1(f) in Annex 7 of the Technical Memorandum on EIAO (TM-EIAO);
- Section 3.3 in Annex 19 of the TM-EIAO;
- Landfill Gas Hazard Assessment for Development Adjacent to Landfills (*ProPECC PN 3/96*); and
- Landfill Gas Hazard Assessment Guidance Note (1997) (*EPD/TR8/97*).

12a.2.1.2 These guidance notes set out the conditions under which a landfill gas hazard assessment should be carried out and provide guidance on undertaking a landfill gas hazard assessment. The guidance notes recommended that in general, assessment of landfill gas hazard is required for proposed developments that lie within the 250m Consultation Zone around a landfill.

12a.2.1.3 The IWMF at the TTAL site is located outside of the 250m consultation zone of existing WENT Landfill. However, it would be located within the 250m consultation zone of the future WENT Landfill Extensions, and therefore a qualitative landfill gas hazard assessment addressing the landfill gas hazards arising from the WENT Landfill Extensions and recommending the mitigation measures is undertaken for the Project. **Figure 12a.1** shows the details of the planned facilities of the IWMF.

12a.3 General Description of the IWMF and the WENT Landfill Extensions

12a.3.1.1 The IWMF comprises: (a) an advanced thermal incineration plant with design capacity of 3,000 tonnes per day (tpd) and (b) a mechanical sorting and recycling plant with design capacity of 200 tpd. The non-recyclables sorted from the mechanical plant will be sent to the thermal incineration plant for further treatment. Under any conditions, the total MSW feeding to the thermal incineration plant and the mechanical plant will not exceed 3,000 tpd.

12a.3.1.2 According to the approved Environmental Impact Assessment (EIA) study for West New Territories (WENT) Landfill Extensions, the extension works will be divided into 6 phases covering total tipping volume of 81Mm^3 (refer to **Figure 12a.2** for location of the WENT Landfill Extensions phases). Based on the tentative time line of WENT Landfill Extensions works, the construction of the first phase of the WENT Landfill Extensions

would be in 2016, and would start operation in 2018, while the final phase of the WENT Landfill Extension would tentatively operate in 2024.

12a.4 Potential Landfill Gas Hazards

12a.4.1.1 The typical composition of landfill gas is about 60% volume of methane and 40% volume of carbon dioxide, although these percentages can vary widely depending on the site conditions. Also present are trace quantities of hydrogen sulphide, nitrogen and gaseous hydrocarbons such as hexane, octane and heptane.

12a.4.1.2 Landfill gas migration can be a dangerous hazard because of its combustible and in some cases explosive nature of methane; and the asphyxiant nature of carbon dioxide.

12a.4.1.3 Landfill gas has the potential to cause fire, explosion or asphyxiation if it migrates into and accumulates in confined space such as building basements, underground car parks, lift shafts, pumping stations, and maintenance chambers. For the same reasons, temporary structures such as site huts and any other unventilated enclosures erected during construction stage are also exposed to landfill gas hazards. Underground services, such as sewer drains, storm drains and service ducts, may also be susceptible to the potential hazards as they act as pathways for landfill gas. Besides, any faults present in geological formation also act as pathways for landfill gas.

12a.4.1.4 As shown in **Figure 12a.2**, the IWMF site would fall within the 250m Consultation Zone of the WENT Landfill Extensions and would be affected by the WENT Landfill Extensions. The overall risk level of landfill gas hazard posed by WENT Landfill Extensions to the IWMF site is assessed and demonstrated below as recommended in *EPD/TR8/97 – Landfill Gas Hazard Assessment Guidance Note*.

12a.5 Landfill Gas Assessment Criteria and Methodology

12a.5.1 Landfill Gas Assessment Criteria

12a.5.1.1 In accordance with the *Landfill Gas Hazard Assessment Guidance Note*, the risk due to landfill gas may be evaluated based upon the following three criteria:

- Source – location, nature and likely quantities/ concentrations of landfill gas which has the potential to affect the development;
- Pathway – the ground and groundwater conditions, through which landfill gas must pass in order to reach the development; and
- Target – elements of the development that are sensitive to the effects of landfill gas.

12a.5.2 Source

12a.5.2.1 The classification of the Source (i.e., WENT Landfill Extensions) should be undertaken as follows:

Minor Landfill sites at which gas controls have been installed and proven to be effective by comprehensive monitoring which has demonstrated that there is no migration of gas beyond the landfill boundary (or any specific control measures) **and** at which control of gas does not rely solely on an active gas extraction system or any other single control measure which is vulnerable to failure; or
Old landfill sites where the maximum concentration of methane within the waste, as measured at several locations across the landfill and on at least four occasions over a period of at least 3 months (preferably longer), is less than 5% by volume (v/v).

Medium Landfill site at which some form of gas control has been installed (e.g. lined site or one where vents or barriers have been retrospectively installed) but where there are only limited monitoring data to demonstrate its efficacy to prevent migration of gas; or
Landfill site where comprehensive monitoring has demonstrated that there is no migration of gas beyond the landfill boundary but where the control of gas relies solely on an active gas extraction system or any other single control system which is vulnerable to failure.

Major Recently filled landfill site at which there is little or no control to prevent migration of gas or at which the efficacy of the gas control measures has not been assessed; or
Any landfill site at which monitoring has demonstrated that there is significant migration of gas beyond the site boundary.

12a.5.2.2 The “significance” of migration should be assessed by reference to the concentration, frequency and location at which gas is detected. For guidance, it should be assumed that any concentration of methane or carbon dioxide greater than 5% v/v above background levels in any monitoring well outside the landfill's boundary indicates significant migration. Lower concentrations may still be “significant” if they are observed in more than one monitoring well, on several occasions or in monitoring wells located some distance from the site boundary. In general, concentrations of greater than 1% v/v methane or 1.5% v/v carbon dioxide (above background levels in each case) indicate less than adequate control of the gas at source.

12a.5.2.3 In classifying the source term, account needs to be taken of the likelihood and probable effect of a failure of the gas controls. Thus, if it has been demonstrated that there is no migration of gas and there is little danger of the gas controls failing (e.g., if these comprise solely of passive measures such as a liner) it can be assumed that the site represents a "Minor" Source. Where there is no gas migration but this may be as a result of a single, "vulnerable" control measure (e.g., an active extraction system with no warning of failure), the site should be regarded as a "Medium" or even a "Major" Source depending on the other factors (e.g., size of site and age of waste).

12a.5.2.4 Where the effectiveness of the gas controls has not been proven by off-site monitoring or if there is some doubt as to the adequacy of the monitoring, this should be taken into account when considering the impact of the control measures on the Source term. Assessments should always err on the side of caution and, in general, if the effectiveness cannot be demonstrated, the assessment should be undertaken on the same basis as if the controls were not in place.

12a.5.2.5 The reliability of the monitoring, for determining the efficacy of the gas controls, needs to take account of the design, number and location of the monitoring points together with the frequency and duration over which monitoring has been undertaken. Monitoring should have been undertaken under different weather conditions including, in particular, periods of low or falling atmospheric pressure.

12a.5.3 Pathway

12a.5.3.1 The broad classification of the Pathway should be undertaken as follows:

Very short / direct	Path length of less than 50m for unsaturated permeable strata and fissured rock or less than 100m for man-made conduits
Moderately short / direct	Path length of 50-100m for unsaturated permeable soil or fissured rock or 100-250m for man-made conduits
Long / indirect	Path length of 100-250m for unsaturated permeable soils and fissured rock

12a.5.3.2 In classifying the pathway, however, adjustment to the above general guidelines will often be required to take account of other factors which will affect the extent of gas migration including the following:

- particular permeability of the soils;
- spacing, tightness and direction of the fissures/joints;
- topography;
- depth and thickness of the medium through which the gas may migrate (which may be affected by groundwater level);
- the nature of the strata over the potential pathway;
- the number of different media involved; and
- depth to groundwater table and flow patterns.

12a.5.3.3 Thus, although there may be permeable soil between the landfill site and a proposed development, say 80m from the edge of the site, if the soil layer is very shallow and thin with its upper surface exposed to the atmosphere, then it will be appropriate to consider this as a long/indirect pathway. This could of course alter if the land between the landfill site and the development was paved over or altered in some other way which reduced the potential for gas release. Similarly, if the land is flat, the surface may be prone to waterlogging which will also effectively seal it at times of heavy rain. In general, a conservative approach should be adopted and it should be assumed that any such permeable surface soils may become less permeable in the future.

12a.5.3.4 If it is known that a conduit (man-made or natural feature such as a fault plane) leads directly from the landfill to the development area, it should be regarded as a "direct/short" pathway even if it is longer than 100m.

12a.5.4 Target

12a.5.4.1 Different types of target may be broadly classified as follows:

High sensitivity	Buildings and structures with ground level or below ground rooms/voids or into which services enter directly from the ground **and** to which members of the general public have unrestricted access or which contain sources of ignition. This would include any developments where there is a possibility of additional structures being erected directly on the ground on an ad hoc basis and thereby without due regard to the potential risks.
Medium sensitivity	Other buildings, structures or service voids where there is access only by authorized, well trained personnel, such as the staff of

utility companies, who have been briefed on the potential hazards relating to landfill gas and the specific safety procedures to be followed.
Deep excavations.

Low sensitivity Buildings/structures which are less prone to gas ingress by virtue of their design (such as those with a raised floor slab).
Shallow excavations.
Developments which involve essentially outdoor activities but where evolution of gas could pose potential problems.

12a.5.4.2 The classification of the above LFG sources, pathway and target are categorized. Having determined into which categories of source, pathway and target the combination of landfill and development fall, a preliminary assessment of the overall risk may be made by reference to **Table 12a.1**. The potential implications associated with the various qualitative risk categories are summarized in **Table 12a.2**.

Table 12a.1 Classification of Risk Category

Source	Pathway	Target Sensitivity	Risk Category
Major	Very short / direct	High	Very High
		Medium	High
		Low	Medium
	Moderately short / direct	High	High
		Medium	Medium
		Low	Low
	Long / indirect	High	High
		Medium	Medium
		Low	Low
Medium	Very short / direct	High	High
		Medium	Medium
		Low	Low
	Moderately short / direct	High	High
		Medium	Medium
		Low	Low
	Long / indirect	High	Medium
		Medium	Low
		Low	Very Low
Minor	Very short / direct	High	High
		Medium	Medium
		Low	Low
	Moderately short / direct	High	Medium
		Medium	Low
		Low	Very Low
	Long / indirect	High	Medium
		Medium	Low
		Low	Very Low

Table 12a.2 Summary of General Categorization of Risk

Category	Level of Risk	Implication
A	Very high	The type of development being proposed is very undesirable and a less sensitive form of development should be considered. At the very least, extensive engineering measures, alarm systems and emergency action plans are likely to be required.
B	High	Significant engineering measures will be required to protect the planned development.
C	Medium	Engineering measures will be required to protect the proposed development.
D	Low	Some precautionary measures will be required to ensure that the planned development is safe.
E	Very Low (insignificant)	The risk is so low that no precautionary measures are required.

12a.5.4.3 Five generic forms of protection will be used in mitigating the hazards to development. These generic forms corresponding to the five risk levels are set out in **Table 12a.3**. The terms used in **Table 12a.3** are defined in **Table 12a.4**.

Table 12a.3 Generic Protection Measures for Planning Stage Categorization

Category	Generic Protection Measures
A	For the planned development active control of gas, supported by barriers and detection systems. Another, less sensitive form of development should also be considered.
B	Active control of gas, including barriers and detection systems (1).
C	Use of "semi active" or enhanced passive controls. Detection systems in some situations.
D	Passive control of gas only.
E	No precautionary measures required.

Note:
(1) The gas protection measures required to allow the safe development of a Category A risk development will need to be more extensive than those for a Category B risk development.

Table 12a.4 Definition of Control Terms

Term	Definition
Active Control	Control of gas by mechanical means e.g. ventilation of spaces with air to dilute gas, or extraction of gas from the development site using fans or blowers.
"Semi active" Control	Use of wind driven cowls and other devices which assist in the ventilation of gas but do not rely on electrically powered fans.
Passive Control	Provision of barriers to the movement of gas e.g. membranes in floors or walls, or in trenches, coupled with high permeability vents such as no-fines gravel in trenches or voids/permeable layers below structures.
Detection System	Electronic systems based upon, for example, catalytic oxidation or infra-red measurement principles, which can detect low concentrations of gas in the atmosphere and can be linked to alarms and/or telemetry systems.

12a.6 Assessment of Potential Risk

12a.6.1 Source

12a.6.1.1 WENT Landfill Extensions is a source to generate LFG during the operation and aftercare phases. LFG hazards may be prone to front-line workers within the site especially where the LFG are extracted, transported and processed. With the proposed LFG control measures and utilization facilities in the WENT Landfill Extensions, the source of LFG will be properly controlled within the site similar to the operation in existing WENT Landfill.

12a.6.1.2 According to the WENT Landfill Extensions EIA Report, the WENT Landfill Extensions will be designed as a containment landfill incorporating multi-layer composite liner systems covering the entire surface area of the site with LFG collection and management systems to eliminate any off-site migration of LFG. Therefore, the source of LFG at the WENT Landfill Extensions will be categorised as **Medium**, considering the following reasons:

- Active gas extraction systems, similar to the existing WENT Landfill and will be installed in the WENT Landfill Extensions;
- Gas control systems will be installed and comprehensive monitoring will be conducted to ensure that no migration of gas beyond the landfill boundary; and
- Specific control measures (e.g., landfill gas cut-off trench barrier) will be applied if necessary.

12a.6.2 Pathway

12a.6.2.1 According to the Hong Kong Geological Survey Map (Scale 1:20,000) on the solid and superficial geology of Tsing Shan (Castle Peak), the superficial geology of the IWMF was mainly “undivided, mainly marine mud” with part of “marine sand”. It is also noted that no natural feature such as a fault plane leads directly from the landfill to the development area. The subsoil underneath the IWMF would mainly be ash, which is very compact with low porosity. Thus, it is anticipated that the chance for LFG migrating to the IWMF site would be very remote.

12a.6.2.2 However, the separation distances between the waste boundary of WENT Landfill Extensions and the potential site for the IWMF at the TTAL site are less than 50m, the pathway is therefore classified as **Very Short / Direct**.

12a.6.3 Target

12a.6.3.1 The earliest operation phase of the WENT Landfill Extensions will commence in Year 2018 tentatively while the construction of the IWMF would be completed by Year 2015/16. Nevertheless, there are uncertainties on the IWMF project that it may be delayed relative to the WENT Landfill Extensions project, LFG hazards during the construction of the IWMF shall be considered on conservative approach.

12a.6.3.2 During construction, the site would be occupied by construction workers who are well trained and with proper and safe construction methodology to be followed. Also, the construction would be mainly carried out in an outdoor environment. Therefore, in general the group is considered as **Low** sensitivity except for specific targets as below.

12a.6.3.3 The specific location of the site office is yet to confirm. Should the site office to be located within the WENT Landfill Extensions consultation zone, the construction workers and supporting staff would be working in an indoor environment with potential LFG hazards. However, they should be well informed of the situation and specific safety

procedures should be given to them to follow. Therefore, this group is considered as **Medium** sensitivity.

12a.6.3.4 During the operation stage of the IWMF, Mechanical Treatment (MT) Process Building, Administrative Building and Reception Hall are generally restricted to authorized personnel and the visitors to the Visitor Reception Building and the Environmental Education Centre will be guided by the operators of the IWMF. The risk level for this Target Sensitivity is therefore categorized as **MEDIUM**.

12a.6.3.5 As shown in **Figure 12a.2**, all parts of the IWMF such as the incineration & boiler, flue gas treatment unit and wastewater treatment system & demineralization system will fall within the consultation zone of the WENT Landfill Extensions. Moreover, as shown in **Figure 12a.3**, underground structures are anticipated. In view that access to the service voids will only allow authorized or well-trained personnel who have been briefed on the potential hazards relating to landfill gas and the specific safety procedures to be followed, the risk level for this Target Sensitivity is categorized as **MEDIUM** for ground level or below ground rooms/voids without sources of ignition. For ground level or below ground rooms/voids which contains sources of ignition, these targets should be categorised as **HIGH** sensitivity.

12a.6.3.6 Community facilities are planned, but the actual use and the design of the facilities have not yet finalized. Since the community facilities could be an indoor environment and would be opened to general public, on a conservative approach, the risk level for this Target Sensitivity is categorized as **HIGH**.

12a.6.3.7 Moreover, some ground or below ground level construction works may be carried out in case the WENT Landfill Extension project is in progress. As the works will be outside the boundary fence of the WENT Landfill Extensions, it is considered that stored waste as well as the LFG management facilities will not be affected. Detailed design of the construction works has not been carried out, and hence the depth of excavations cannot be confirmed. The Target is therefore classified as being of **Medium** Sensitivity.

12a.7 Summary of Qualitative Source-Pathway-Target Analysis

12a.7.1.1 Based on the information above, source-pathway-target analysis has been undertaken and the **Overall Risk Level** for construction phase and for operation phase associated with the WENT Landfill Extensions are **Medium** and **High** respectively, based on the highest level of risk for the potential impacts identified. Source-Pathway-Target analyses have been undertaken and are summarized in **Table12a.5**.

Table 12a.5 Qualitative Risk Assessment Matrix

Source	Pathway	Target Sensitivity	Risk
From WENT Landfill Extensions *(Medium Source)*	**During Construction**		
	Less than 50m from the WENT Landfill Extensions *(Very Short/ Direct Pathway)*	General* – Construction workers, well trained and follow specific safety procedures, mainly outdoor works *(Low Sensitivity Target)*	**Low**

Source	Pathway	Target Sensitivity	Risk
		Site Office* – Construction workers and support staff, well trained and follow specific safety procedures, indoor environment *(Medium Sensitivity Target)*	**Medium**
	During Operation		
	Less than 50m from the WENT Landfill Extensions *(Very Short/ Direct Pathway)*	MT Process Building, Administrative Building, Reception Hall, Visitor Reception Building and Environmental Education Centre *(Medium Sensitivity Target)*	**Medium**
		Operation & Maintenance of Incineration & Boiler, Flue Gas Treatment Unit and Wastewater Treatment System & Demineralization System *(High Sensitivity Targets for ground level or below ground rooms/voids with sources of ignition* and *Medium Sensitivity Targets for those without sources of ignition)*	**High / Medium**
		Community Facilities Building *(High Sensitivity Target)*	**High**
		Ground or Below Ground Level Construction Works *(Medium Sensitivity Target)*	**Medium**

Note: * As the works programmes of WENT Landfill Extension project and the IWMF projects are preliminary ones, LFG hazards during construction of the IWMF is taken into account in case the IWMF project is delayed relative to the WENT Landfill Extensions project.

12a.8 Recommended Protection Measures

12a.8.1 Introduction

12a.8.1.1 According to **Table12a.2**, landfill gas risks would be "Medium" to "High" and significant engineering measures will be required to protect the IWMF from the WENT Landfill Extensions. According to Table 4.2 of the EPD's *Landfill Gas Hazard Assessment Guidance Note*, the generic protection measures required include "Active control of gas, including barriers and detection systems" for "High" risks targets and "Use of 'semi-active' or enhanced passive gas control. Detection systems in some situations" for "Medium" risk targets. The recommended preventive measures are presented in sections **12a.8.2** and **12a.8.3**.

12a.8.1.2 According to the tentative time line of the WENT Landfill Extensions (summarized in **Section 12a.3.1.2**), the IWMF would operate before commissioning of the WENT Landfill Extensions. However, there are uncertainties on the IWMF project that it may be delayed relative to the WENT Landfill Extensions project, LFG protection measures may be required during the construction stage of the IWMF. Moreover, during the operation stage of the IWMF, some ground or below ground level construction works may be carried out and if the WENT Landfill Extension project is in progress, proper LFG protection measures may be required.

12a.8.2 During Construction Phase, if the WENT Extension project is in operation

Appointment of Safety Officer

12a.8.2.1 A safety officer, trained in the use of gas detection equipment and landfill gas-related hazards, should be present on site throughout the groundworks phase. The Safety Officer should be provided with an intrinsically safe portable instrument, which is appropriately calibrated and able to measure the following gases in the ranges indicated below:

Methane	0-100% LEL and 0-100% v/v
Carbon dioxide	0-100%
Oxygen	0-21%

Safety Measures

12a.8.2.2 For staff who work in, or have responsibility for "at risk" area, such as all excavation workers, supervisors and engineers working within the Consultation Zone, should receive appropriate training on working in areas susceptible to landfill gas, fire and explosion hazards.

12a.8.2.3 An excavation procedure or code of practice to minimize landfill gas related risk should be devised and carried out.

12a.8.2.4 No worker should be allowed to work alone at any time in or near to any excavation. At least one other worker should be available to assist with a rescue if needed.

12a.8.2.5 Smoking, naked flames and all other sources of ignition should be prohibited within 15m of any excavation or ground-level confined space. "No smoking" and "No naked flame" notices should be posted prominently on the construction site and, if necessary, special areas should be designed for smoking.

12a.8.2.6 Welding, flame-cutting or other hot works should be confined to open areas at least 15m from any trench or excavation.

12a.8.2.7 Welding, flame-cutting or other hot works may be only be carried out in trenches or confined spaces when controlled by a "permit to work" procedure, properly authorized by the Safety Officer (or, in the case of small developments, other appropriately qualified person).

12a.8.2.8 The permit to work procedure should set down clearly the requirements for continuous monitoring for methane, carbon dioxide and oxygen throughout the period during which the hot works are in progress. The procedure should also require the presence of an appropriately qualified person, in attendance outside the 'confined area', who should be responsible for reviewing the gas measurements as they are made, and who should have executive responsibility for suspending the work in the event of unacceptable or hazardous conditions. Only those workers who are appropriately trained and fully aware of the potentially hazardous conditions which may arise should be permitted to carry out hot works in confined areas.

12a.8.2.9 Where there are any temporary site offices, or any other buildings located within the WENT Landfill Consultation Zone which have enclosed spaces with the capacity to accumulate landfill gas, then they should either be located in an area which has been proven to be free of landfill gas (by survey using portable gas detectors); or be raised clear of the ground by a minimum of 500mm. This aims to create a clear void under the structure which is ventilated by natural air movement such that emission of gas from the ground are mixed and diluted by air.

12a.8.2.10 Any electrical equipment, such as motors and extension cords, should be intrinsically safe.

12a.8.2.11 During piping assembly or conduiting construction, all valves/seals should be closed immediately after installation. As construction progresses, all valves/seals should be closed to prevent the migration of gases through the pipeline/conduit. All piping /conduiting should be capped at the end of each working day.

12a.8.2.12 During construction, adequate fire extinguishing equipment, fire-resistant clothing and breathing apparatus (BA) sets should be made available on site.

12a.8.2.13 Fire drills should be organized at not less than six monthly intervals.

12a.8.2.14 The contractor should formulate a health and safety policy, standards and instructions for site personnel to follow.

12a.8.2.15 All personnel who work on the site and all visitors to the site should be made aware of the possibility of ignition of gas in the vicinity of excavations. Safety notices (in Chinese and English) should be posted at prominent position around the site warning danger of the potential hazards.

12a.8.2.16 For staff who work in, or have responsibility for 'at risk' areas, such as all excavation workers, supervisors and engineers working within the WENT Landfill Consultation Zone should receive appropriate training on working in areas susceptible to landfill gas, fire and explosion hazards.

12a.8.2.17 Service runs within the Consultation Zone should be designated as "special routes"; utilities companies should be informed of this and precautionary measures should be implemented. Precautionary measures should include ensuring that staff members are aware of the potential hazards of working in confined spaces such as manholes and service chambers, and that appropriate monitoring procedures are in place to prevent hazards due to asphyxiating atmospheres in confined spaces. Detailed guidance on

entry into confined spaces is given in *Code of Practice on Safety and Health at Work in Confined Spaces* (Labour Department, Hong Kong).

12a.8.2.18 Periodically during ground-works construction within the 250m Consultation Zone, the works area should be monitored for methane, carbon dioxide and oxygen using appropriately calibrated portable gas detection equipment. The monitoring frequency and areas to be monitored should be set down prior to commencement of ground-works either by the Safety Officer or an approved and appropriately qualified person.

Monitoring

12a.8.2.19 Routine monitoring should be carried out in all excavations, manholes, chambers, relocation of monitoring wells and any other confined spaces that may have been created. All measurements in excavations should be made with the extended monitoring tube located not more than 10 mm from the exposed ground surface. Monitoring should be performed properly to make sure that the area is free of landfill gas before any man enters into the area.

12a.8.2.20 For excavations **deeper than 1m**, measurements should be carried out:

- at the ground surface before excavation commences;
- immediately before any worker enters the excavation;
- at the beginning of each working day for the entire period the excavation remains open; and
- periodically throughout the working day whilst workers are in the excavation.

12a.8.2.21 For excavations **between 300mm and 1m deep**, measurements should be carried out:

- directly after the excavation has been completed; and
- periodically whilst the excavation remains open.

12a.8.2.22 For excavations **less than 300mm deep**, monitoring may be omitted, at the discretion of the Safety Officer or other appropriately qualified person.

12a.8.2.23 Depending on the results of the measurements, actions required will vary and should be set down by the Safety Officer or other appropriately qualified person. As a minimum these should encompass those actions specified in **Table 12a.6**.

Table 12a.6 Actions in the Event of Landfill Gas Being Detected in Excavations/Confined Areas

Parameter	Measurement	Action
Oxygen	< 19 %	• Ventilate to restore oxygen to > 19 %
	< 18 %	• Stop works • Evacuate personnel/prohibit entry • Increase ventilation to restore oxygen to > 19 %
Methane	> 10 % LEL (i.e. > 0.5 % by volume)	• Prohibit hot works • Ventilate to restore methane to < 10% LEL
	> 20 % LEL (i.e. > 1 % by volume)	• Stop works • Evacuate personnel/prohibit entry • Increase ventilation to restore methane to < 10 % LEL
Carbon	> 0.5 %	• Ventilate to restore carbon dioxide to < 0.5%

Dioxide		
	> 1.5 %	• Stop works • Evacuate personnel/prohibit entry • Increase ventilation to restore carbon dioxide to <0.5%

12a.8.2.24 The hazards from landfill gas during the construction stage within the future WENT Landfill extensions Consultation Zone should be minimized by suitable precautionary measures recommended in Chapter 8 of the *Landfill Gas Hazard Assessment Guidance Note.* A copy of which is enclosed in **Appendix 12A.1**. In the operation phase, if it is necessary to carry out construction works, landfill gas precautionary measures same as those recommended for the construction stage above should be followed.

12a.8.3 Design of Landfill Gas Protection Measures and other Protection Measures during Operation Phase

Gas Barrier

12a.8.3.1 The most common way of preventing gas from entering an area of ground is to set a "gas barrier" into the ground which is either keyed into low permeability strata or extends at least 1m below the lowest groundwater level.

12a.8.3.2 The presence of a gas barrier to the movement of gas may lead to a gradual build up of gas on the landfill side of the barrier if the gas migration pathway is covered by low permeability materials. To relieve the potential build up of gas, it may be necessary to install additional measures for venting the gas such as trenches filled with no-fines, granular material, e.g. gravel, connected to venting pipes which will provide a preferential pathway for the release of gas to atmosphere. An outline of a landfill gas cut-off barrier is shown in **Figure 12a.4** and a more detailed typical design of it is shown in **Figure 12a.5**.

12a.8.3.3 Referencing WENT Landfill Extensions EIA Report, it is proposed that landfill gas cut-off trench barrier will be built along the boundary between the IWMF and the WENT Landfill Extensions under the WENT Landfill Extensions project. This will cut off any gas migration to the IWMF from the WENT Landfill Extensions. The indicative location of the proposed cut-off trench barrier is shown in **Figure 12a.6**. Since the works programmes of WENT Landfill Extension project and the IWMF project mentioned in **Section 12a.3.1.2** and **12a.6.3.1** are preliminary ones, the IWMF contractor will keep abreast of the works programme of the WENT Landfill Extensions project and liaise with the contractor of WENT Landfill Extension project as necessary to make sure that the landfill gas (LFG) cut-off trench barrier along the boundary will be completed in a timely manner.

12a.8.3.4 It is also recommended that several landfill gas monitoring wells be installed into the ground on the development side of the gas barrier. These are used to measure the concentrations of methane and carbon dioxide within the ground and hence determine the effectiveness of the measures in preventing LFG migration.

Building Protection Design Measures

Passive control

12a.8.3.5 Passive control measures for building structures with ground level or below ground rooms / voids including the following could be considered in the detailed design if necessary:

- Gas-resistant polymeric membranes which can be incorporated into the floor or wall construction as a continuous sealed layer. Membranes should be able to demonstrate low gas permeability and resistant to possible chemical attack and may incorporate aluminum wafers to improve performance;
- Other building materials, e.g. dense well-compacted concrete or steel shuttering which provide a measure of resistance to gas permeation;
- Creation of a clear void under the structure which is ventilated by natural structure and provides preferential pathways for release of gas (**Figure 12a.7** refers);
- Synthetic composite geotextile which provide a free-venting cellular structure and provide preferential pathways for release of gas; and
- Passive control measures may be used in low and medium risk situations where gas emissions are expected to be at relatively low rates and concentrations and venting to atmosphere is unlikely to cause a hazard or nuisance due to the low concentration or high dilution which will occur.

Active systems

12a.8.3.6 Active control measures should be employed where the rates of gas emission are too high to rely on passive ventilation or in particular circumstances where, for example, there is a sensitive target to protect. Active control measures include the following:

- A void under the structure like passive control, but it is continuously ventilated by a fan such that any emissions of gas from the ground are mixed and diluted in the air flow before discharge to atmosphere (**Figure 12a.7** refers). The rate of ventilation is usually expressed in terms of the volume of air changes (volume of void) per hour and is designed to ensure that, based on the estimated rate at which gas will enter the void; the LFG will be diluted to safe concentrations. Discharge to atmosphere usually takes place above eaves level of the building.
- Construction of a granular layer incorporating perforated collector pipes which is continually ventilated by a fan, such that any emissions of gas from the ground are drawn towards the end of the pipes and diluted in the air flow before discharge to atmosphere above the eaves level of the building.
- Creation of a positive pressure zone below the building structure by injection of air into the granular layer.
- Creation of positive air pressure zones within building structures to counteract possible LFG migration into the building from the ground.

12a.8.3.7 Active control measures should be used in conjunction with passive barriers, e.g. membranes in floors, in order that there is no migration of air / gas flow through a floor or wall into a structure. Gas detection systems should also be used to monitor gas in extracted air flow, and to monitor internal spaces inside buildings. Active systems are normally required for high risk sites (such as the rooms/voids with sources of ignition, community facilities - should it be designed as an indoor environment) where gas has been measured in the ground at or close to the development site, and buildings are close to the source of gas.

Gas detection system

12a.8.3.8 Gas detection systems include the following:

- A series of sensors located in appropriate positions within a structure where gas has the potential to accumulate, e.g. near service entries, inside ventilation basements, cupboards or ducts. The sensors detect flammable gas by catalytic oxidation or infra-

red principles, and pass data back to a control panel by electrical cabling. The control panel can be set to have two triggers activating alarms and may also be linked by wireless telemetry or internet off-site.

- A series of sampling tubes which are located in appropriate positions and run back to a single measurement station operating on infra-red measurement principles. A pump automatically draws samples of air/gas along each tube in a pre-set pattern such that measurements of flammable and/or other gases (e.g. CO_2) can be taken at regular and frequent intervals. Triggers, alarms, wireless telemetry and internet systems can be incorporated.
- Manual monitoring can be conducted using a range of portable instruments. Instruments used in areas where flammable gas may be present should be intrinsically safe.

12a.8.3.9 Gas detection system should only be proposed where there is an organisation involved in the long-term use of the development which can be relied upon to maintain and calibrate the system on a regular basis. Where a detection system is used as a final defence, it must be ensured that appropriate emergency action, to be taken in the event of the trigger levels being exceeded, are specified explicitly in an Emergency and Contingency Plan.

Maintenance of control measures

12a.8.3.10 Fundamental to the success of gas protection measures is the means by which they are monitored, managed and maintained, and thus all designs must be accompanied by a statement or set of procedures showing how the measures proposed can be confidently expected to operate satisfactorily for the duration of the potential gas-producing lifetime of the landfill.

Design Measures for Sub-Surface Building Services

12a.8.3.11 As shown in **Figure 12a.4** to **Figure 12a.5** and **Figure 12a.8** to **Figure 12a.10**, generic protection measures for the sub-surface building services including the following are recommended:

- A gas barrier used to prevent movement of gas through services may form part of a more extensive barrier to prevent general mitigation towards the development. The gas barrier may be made of clay (or clay-rich soils), bentonite or polymeric membranes (e.g. HDPE). In the case of water pipes and sewers which are not always fully filled, water traps e.g. U-bends, should be provided to effectively seal off the conduit and prevent gas-phase transport; and
- Vent pipes or gridded manhole covers may be used to avoid build-up of gas in underground utilities manholes. Venting stacks may be built into inspection chambers or connected to collection pipes in high permeability drainage layers adjacent to gas barriers. Under all circumstances, care should be taken when accessing any manhole chambers especially those which are not fitted with vents and necessary safety procedures must be followed.

Guidance for Entry into Service Rooms / Voids, Manholes and Chambers

12a.8.3.12 During the operation phase, any service voids, manholes, chambers or culvert within the proposed site, which is large enough to permit access to personnel should be subject to entry safety procedures. Works in confined spaces are controlled by the *Factories and Industrial Undertakings (Confined Spaces) Regulation* of the *Factories and Industrial Undertakings Ordinance* and the *Safety Guide to Working in Confined Spaces* should be followed to ensure compliance with the Regulation.

12a.8.3.13 In general, when work is being undertaken in confined spaces, sufficient approved resuscitation equipment, breathing apparatus and safety torches should be made available. Persons involved in or supervising such work should be trained and practiced in the use of such equipment. A permit-to-work system for entry into confined spaces should be developed by an appropriately qualified person and the system should be consistently employed. The safety measures recommended in Chapter 8 of the *Landfill Gas Hazard Assessment Guidance Note* should also be strictly followed.

12a.8.3.14 All the access to confined spaces should be restricted only to authorized personnel who are aware of the landfill gas hazard. No general public should be permitted or allowed to access the service voids, manholes, chambers or wells.

Landfill Gas Monitoring

12a.8.3.15 Regular Monitoring of landfill gas should be done at the monitoring wells mentioned in **Section 12a.8.3.4** as well as at the underground service voids and manholes by the IWMF contractor. Monitoring would be required to verify the effectiveness and to ensure the continued performance of the implemented protection measures. As mentioned in **Section 12a.8.3.16-17**, a detailed LFG monitoring programme will be prepared by the contractor at the detailed design stage and it will be submitted to EPD for vetting.

Design of LFG Protection Measures

12a.8.3.16 As this Project is at the Preliminary Design Stage, a detailed design is not available yet and the above qualitative landfill gas hazard assessment is just a preliminary one based on limited available information. When the detailed design of the IWMF is available, the Design-Build-Operate (DBO) contractor of the IWMF is required to undertake further landfill gas hazard assessment to take account of the more readily available detailed information to finalize the design of the landfill gas protection measures recommended in this report. During the detailed design stage, a review of this preliminary qualitative risk assessment should be carried out and a detailed qualitative landfill gas risk assessment as described in Section 1.15 and Chapter 6 of the Landfill Gas Hazard Assessment Guidance Note should be prepared. The detailed qualitative landfill gas risk assessment together with the detailed design of gas protection measures and a landfill gas monitoring programme should be submitted to EPD for vetting.

12a.8.3.17 The design of the landfill gas precautionary measures to be adopted on-site should be performed by a competent professional person who has knowledge on LFG protection measures appointed by the DBO contractor of the IWMF. The design should also be checked and certified by a qualified independent consultant. The DBO contractor should ensure that the required protection measures are implemented and constructed in accordance with the design and a maintenance and monitoring programme should be established to ensure the continued performance of the implemented protection measures. The above requirements should be included in the tender documents of the IWMF.

12a.9 Conclusion

12a.9.1.1 The landfill gas hazard assessment shows that the overall level of landfill gas risk posed by the WENT Landfill Extensions onto the IWMF would be categorised as "**Medium**" to "**High**". Appropriate protective measures have been proposed to minimize the landfill gas risk for the Project site during construction and operation phase. In particular, it is noted that landfill gas cut-off trench barrier will be built along the boundary between the IWMF and the WENT Landfill Extensions under the WENT Landfill Extensions project to cut off any landfill gas migration from WENT Landfill extensions. Monitoring wells are recommended to be installed into the ground for verifying the effectiveness of the above measures. Moreover, necessary landfill gas protection measures such as passive and/or

active control measures and detection systems will be incorporated in the buildings in the project and the measures will be designed by a competent professional person during the detailed design stage.

12a.9.1.2 Provided that all the recommended protection measures are implemented properly, the safety of all personnel and general public (i.e. visitors) presence at the proposed Project site would be safeguarded and there would be no adverse impact anticipated on the feasibility of the proposed Project.

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