9 Landfill Gas Hazards

9.1 Legislation, Standards and Guidelines

9.1.1 General

9.1.1.1 The relevant legislation, standards and guidelines applicable to the present study for the assessment of landfill gas (LFG) hazards include:

- Section 1.1 (f) in Annex 7 of Technical Memorandum on Environmental Impact Assessment Process (TM-EIAO);
- Section 3.3 in Annex 19 of TM-EIAO;
- Landfill Gas Hazard Assessment Guidance Note (1997) (EPD/TR8/97); and
- Landfill Gas Hazard Assessment for Developments adjacent to Landfills (ProPECC PN3/96).

9.1.1.2 These legislation and guidelines recommended that in general, a qualitative assessment of the risk posed by LFG is required for a development which is proposed within a 250m "Consultation Zone" around any landfill site, to ensure appropriate precautionary measures would be designed and implemented to safeguard the development.

9.1.2 Potential Hazard and Properties of LFG

9.1.2.1 Methane is odourless and colourless, and typically associated with numerous highly odoriferous compounds in LFG which will give some warning of its presence. However, the absence of odour should not be taken to mean that no methane gas is present – this can only be confirmed by using appropriately calibrated methane detectors. Methane is a flammable gas and will burn when mixed with air between approximately 5% and 15% by volume, the Lower Explosive Limit (LEL) and Upper Explosive Limit (UEL) respectively. A mixture of methane and air with a composition between the LEL and UEL ignited in a confined space could lead to an explosion. Methane is also an asphyxiant.

9.1.2.2 Carbon dioxide, which is another major component of LFG, could induce asphyxia and adverse health effects. The long-term eight-hour Occupational Exposure Limit (OEL) is 0.5% by volume. Similar to methane, it is also odourless and colourless, and can only be detected by using appropriately calibrated detectors.

9.1.2.3 Gas buoyancy: Methane is lighter than air whereas carbon dioxide is heavier than air. Typical mixtures of LFG are likely to have a density

close to or equal to that of air. However, site conditions may result in a ratio of methane to carbon dioxide which may make the gas mixture lighter or heavier than air. As a result, LFG may be concentrated in the bottoms of the trenches or excavations, or may rise up and accumulate beneath structures and foundations.

9.1.3 Assessment Criteria

9.1.3.1 In accordance with Environmental Protection Department (EPD)'s LFG Hazard Assessment Guidance Note, the risk due to LFG shall be evaluated based upon the following three criteria, each of which is further described as follows:

Source: the location, nature and likely quantities/concentrations of LFG which has the potential to affect the Project Site;

Pathway: the nature and length of potential pathways through which LFG must pass to reach the Project Site; and

Target: the elements of the development which are sensitive to the effects of LFG.

Source

9.1.3.2 The classification of the Source (i.e. the landfill) is determined as follows:

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.

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.

Minor: Landfill sites at which gas control 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, is less than 5% by volume (v/v).

Pathway

9.1.3.3 Generally, three types of pathways are considered for the transmission of LFG. They are:

- Man-made pathways e.g. utility connections, stormwater channels, etc.;
- Natural pathways such as rock jointing planes, fissures, and other naturally occurring phenomena which may promote or give rise to the transmission of gas over distances; and
- A combination of the previous categories. An example of the latter may be, for instance, where a specific geological feature promotes gas transmission but which stops short of directly linking the landfill and target. A man-made connection, however, may also co-exist near the edge of the geological feature, in combination with the former, may act to link the two sites. In this instance, careful assessment of the likelihood of the mechanism acting to link the two pathways needs to be undertaken before assigning an appropriate pathway classification.

9.1.3.4 The board classification of the pathway is as follows:

Very short/direct: Path length of less than 50m for unsaturated permeable strata and fissures rock or less than 100m for man-made conduits.

Moderately short/direct: Path length of 50 to 100m for unsaturated permeable soil or fissured rock or 100 to 250m for man-made conduits.

Long/indirect: Path length of 100 to 250m for unsaturated permeable soil and fissured rock.

9.1.3.5 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.

Target

9.1.3.6 Different types of targets may be broadly classified as follows:

Highly 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 structure 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 which are accessed only by authorised, well-trained personnel, such as the staff of utility companies, who have been briefed on the potential hazards relating to LFG and the specific safety procedures to be followed.

Deep excavations.

Low Sensitivity: Buildings and 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.

9.1.3.7 The above categories should be used as a general guide only and particular aspects of a building or development may render it more or less sensitive than indicated. Account should be taken of any particular circumstances when assigning a target to one of the three indicated categories.

9.1.3.8 Following the determination of the categories of source, pathway and target in which the combination of landfill, pathway and development fall, a qualitative assessment of the overall risk is undertaken with reference to **Table 9.1**. The potential implications associated with the various qualitative risk categories are summarised in **Table 9.2**.

Table 9.1 Classification of risk categories

Source	Pathway	Target	Risk Category
Major	Very short/direct	High	Very high
		Medium	High
		Low	Medium
	Moderate 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
	Moderate 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
	Moderate short/direct	High	Medium
		Medium	Low
		Low	Very low
	Long/indirect	High	Medium
		Medium	Low
		Low	Very low

Table 9.2 General categorisations of risks

Category	Level of Risk	Implication
A	Very high (undesirable)	The type of development being proposed is very undesirable and 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.

9.1.3.9 Five generic forms of protection will be used in mitigating the hazards to developments. These generic forms corresponding to the five risk levels are set out in **Table 9.3**. The terms used in **Table 9.3** are defined in **Table 9.4**.

Table 9.3 Generic protection measures for planning stage categorisation

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 Category A risk development will need to be more extensive than those for a Category B risk development.

Table 9.4 Definitions 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.

Term	Definition
Detection systems	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.

9.2 Description of the Environment

9.2.1.1 The Project Site is approximately 53ha (**Figure 1.1**). It is bounded by Ting Kok Road to the north, Fortune Garden to the northeast, Tai Po Industrial Estate (TPIE) to the west and Tolo Harbour to the east and south.

9.2.1.2 The Project Site was once part of the Tolo Harbour before 1970s. In the early 1970s, the Project Site was progressively reclaimed for the subsequent landfilling activities. The Shuen Wan Landfill commenced its operation in Year 1973 and ceased operation in Year 1995. Subsequent to the closure of the landfill site, restoration works were implemented. The 250m Consultation Zone of Shuen Wan Restored Landfill is shown in **Figure 9.1**.

9.2.1.3 Part of the Shuen Wan Restored Landfill has been serving as a 145-bay golf driving range for public use since Year 1999. EPD's Landfill Operator continues the monitoring of LFG and leachate, and maintenance of the existing landfill facilities until Year 2027.

9.3 Qualitative Risk Assessment in Construction Phase

9.3.1 Assessment Methodology

9.3.1.1 In accordance with the procedures recommended in LFG Hazard Assessment Guidance Note and the EIA Study Brief (ESB-303/2017), the following tasks have been undertaken to allow a full consideration of the potential risk of LFG from the Shuen Wan Restored Landfill to the proposed Shuen Wan Golf Course:

- Review of background information (including LFG monitoring data, if any) and studies related to the Shuen Wan Restored Landfill;
- Identification of the nature and extent of the sources, including the likely concentrations/amounts of hazardous emissions which might have the potential for causing impacts on the Project;
- Identification of possible pathways through the ground, underground cavities, utilities or groundwater, and the nature of these pathways through which hazardous emissions must traverse if they were to reach the facilities within the Project Site;

- Identification of the potential targets associated with the Project which are sensitive to the impacts of the hazardous emissions;
- Qualitative assessment on the degree of risk which the hazardous emissions may pose to the target for each of the source-pathway-target combinations;
- Design of suitable level of precautionary measures and types of protection measures and emergency procedures for the construction and operation of the development proposed under the Project; and
- Identification of monitoring requirements for assessing the adequacy and performance of the implemented protection measures.

9.3.2 Desktop Study

9.3.2.1 The information and documents which have been used as background materials for the preparation of this assessment include the following:

- Hong Kong Geological Survey Map (HGM20 series scale 1:20,000) (1986);
- Approved EIA report for the Proposed Submarine Gas Pipelines from Cheng Tou Jiao Liquefied Natural Gas Receiving Terminal, Shenzhen to Tai Po Gas Production Plant, Hong Kong (AEIAR-071/2003);
- Approved EIA report for Tai Po Sewage Treatment Works Stage V (AEIAR-081/2004);
- Geotechnical Review for Restored Shuen Wan Landfill - Final Geotechnical Assessment Report (2011) provided by EPD; and
- LFG monitoring data for the Shuen Wan Landfill - Annual Environmental Audit Reports (from 2012 to 2016) provided by EPD.

History of Shuen Wan Restored Landfill

9.3.2.2 The Shuen Wan Restored Landfill was opened for the reception of waste in 1973 and closed in 1995. The restoration works for Shuen Wan Landfill commenced in December 1996 and was completed in December 1997. Since then, monthly environmental monitoring (e.g. LFG, groundwater, leachate, surface water, etc.) and annually environmental audit have been conducted.

9.3.2.3 The Defect Correction Period commenced in January 1998 and ended in December 1998. The Aftercare Period commenced in December 1998 and will end in December 2027. EPD's Landfill Operator has been maintaining the management systems for LFG and leachate, and will continue the environmental monitoring on landfill restoration works during construction and operational phases of the Project.

9.3.2.4 At present, part of the landfill is used as a temporary golf driving range.

Restoration Facilities

9.3.2.5 The restoration facilities for Shuen Wan Landfill mainly consist of landfill capping layer, LFG management system and leachate management system as described below:

i) Landfill Capping Layer

9.3.2.6 According to the as-built drawings of Shuen Wan Restored Landfill, the components of the landfill capping layer include the following (from top to bottom):

- An approximately 800mm – 850mm thick soil layer of general cover, hydroseeded to act as the growing medium;
- A geocomposite drainage layer consists of filtration geotextile, high density polyethylene (HDPE) geonet, very flexible polyethylene (VFPE) geomembrane and cushion geotextile; and
- A 500mm think final intermediate soil cover.

ii) LFG Management System

9.3.2.7 According to the as-built drawings of Shuen Wan Restored Landfill, the LFG management system consists of active gas extraction wells, LFG utilisation plant, flaring system for LFG, passive vent trenches/pipes and monitoring of LFG both on site and off site.

9.3.2.8 Active gas extraction from the waste is used to relieve the pressure build-up in the waste to prevent LFG from migrating off site laterally or vertically. The extracted LFG is delivered to the Hong Kong and China Gas Company through the LFG utilisation plant for town gas production. However, when LFG utilisation plant is under maintenance, flaring system will be switched from standby mode to active mode for LFG treatment. Meanwhile, passive vent trenches and pipes use existing variations in landfill pressures and gas concentrations to vent LFG. In addition, methane and carbon dioxide are monitored by the Gas Monitoring Probes (GMPs) on a monthly basis.

iii) Leachate Management System

9.3.2.9 The leachate management system consists of the active leachate extraction system, leachate collection chambers and the Leachate Pre-treatment Works.

9.3.2.10 The active leachate extraction system is used to pump the leachate from the platform and slopes to the leachate collection chambers. Three leachate collection chambers are located on the perimeter of the site.

They collect the leachate intercepted by both peripheral drains beneath part of the capping layers at 30mPD, 40mPD and 38mPD platforms and side slope, followed by a series of horizontal sub-drains. The leachate collected in the chambers is pumped to the Leachate Pre-treatment Works and subsequently conveyed to the Tai Po Sewage Treatment Works for treatment.

9.3.3 Source

9.3.3.1 As part of the Shuen Wan Landfill Restoration Contract, a comprehensive monitoring programme commenced in December 1996 and is still being implemented on a monthly basis until Year 2027 when the restoration contract ends.

9.3.3.2 According to the Annual Environmental Audit Report (i.e. from 2012 to 2016), a LFG monitoring system, including 22 multiple-level and 28 single-level GMPs, has been installed and monitoring the levels of methane (CH_4) and carbon dioxide (CO_2) within and along the boundary of Shuen Wan Restored Landfill. Monitoring data during the course of January 2012 and December 2016 obtained from EPD have been reviewed. Monitoring locations and data are tabulated in **Appendix 9.4** and summarised in **Table 9.5**.

Table 9.5 Summary of LFG monitoring data for Shuen Wan Restored Landfill (2012-2016)

Monitoring Year	CH_4 (% v/v)		CO_2 (% v/v)	
	Range	Average	Range	Average
2012	0.0 – 0.0	0.0	0.0 – 7.4	0.45
2013	0.0 – 0.0	0.0	0.0 – 3.4	0.44
2014	0.0 – 0.0	0.0	0.0 – 3.0	0.42
2015	0.0 – 0.0	0.0	0.0 – 2.8	0.39
2016	0.0 – 0.0	0.0	0.0 – 6.9	0.23
Standard Compliance Level[1]	1.0% v/v (i.e. 1.0% v/v above natural background[2])		8.6% v/v (i.e. 1.5% v/v above natural background[2])	
Level indicating significant migration[1]	5.0% v/v (i.e. 5.0% v/v above natural background[2])		12.1% v/v (5.0% v/v above natural background[2])	

Notes:

[1] Standard Compliance Level of methane is taken to be 1% v/v and that of carbon dioxide is 1.5% v/v above natural background level. As stated in EPD's LFG Hazard Assessment Guidance Note, concentration of greater than 1% v/v methane or 1.5% v/v carbon dioxide (above the natural background levels in each case) indicates less than adequate control of the gas at source. In addition, any concentration of methane or carbon dioxide greater than 5% v/v above the natural background levels in any monitoring well outside the landfill's boundary indicates significant migration.

[2] According to Annual Environmental Audit Reports for Shuen Wan Restored Landfill, the natural background levels for methane and carbon dioxide are 0.0% v/v and 7.1% v/v respectively.

9.3.3.3 **Table 9.5** and **Appendix 9.4** show that no methane gas was detected from January 2012 to December 2016. The carbon dioxide levels ranged from 0 to 7.4% v/v from Year 2012 to Year 2016 with a 5-year average of 0.39% v/v. The annual average carbon dioxide level dropped steadily from 0.45% v/v in Year 2012 to 0.39% v/v in Year 2015, and significantly dropped to 0.23% v/v in Year 2016.

9.3.3.4 No methane was detected at any multiple-level or single-level monitoring well from 2012 to 2016. All measured levels of carbon dioxide were below 8.6% v/v (i.e. 1.5% v/v above the natural background of 7.1% v/v) in these five years. According to the Annual Environmental Audit Reports in the respective reporting years, the occasionally high levels of carbon dioxide measured were unlikely caused by migration of LFG from the Shuen Wan Restored Landfill. Instead, it is more likely generated by other means such as plant roots or calcium oxide beneath the ground.

9.3.3.5 Surface methane has also been monitored quarterly for the entire Shuen Wan Restored Landfill. According to the Annual Environmental Audit Reports, the methane concentrations fluctuated within the range of 1.0 to 9.8ppm, which are much lower than the target limit of 10,000ppm (1% v/v), from Year 2012 to Year 2016. The methane monitoring results are summarised in **Table 9.6**.

Table 9.6 Surface gas emission results of Shuen Wan Restored Landfill (2012-2016)

Year	CH_4 conc., ppm
2012	1.0 – 9.8
2013	5.6 – 8.6
2014	6.0 – 8.7
2015	7.0 – 8.4
2016	6.4 – 9.8

9.3.3.6 Furthermore, multiple LFG control measures, including landfill capping layer, passive vent trenches/pipes and active LFG extraction system, have been installed in Shuen Wan Restored Landfill to prevent any unintended migration of LFG and are regarded as fail safe. Comprehensive monitoring has been undertaken by EPD's Landfill Operator for the Shuen Wan Restored Landfill.

9.3.3.7 In summary, no methane was detected at any GMP of Shuen Wan Restored Landfill, whilst carbon dioxide levels at all LFG monitoring locations were in compliance with the Standard Compliance Level in the past 5 years. Meanwhile, multiple LFG control measures, such as landfill capping layer, passive vent trenches/pipes and active LFG extraction system, have been installed in Shuen Wan Restored Landfill.

9.3.3.8 However, according to Landfill Gas Hazard Assessment Guidance Note, the monitoring criterion for carbon dioxide is 1.5% v/v, at which the historical monitoring data in past 5 years would occasionally exceed. As a conservative assessment, the Shuen Wan Restored Landfill is classified as **Medium**.

9.3.4 Pathway

Natural Pathway

9.3.4.1 In accordance with Geotechnical Review for Restored Shuen Wan Landfill (2011), the geological formation beneath Shuen Wan Landfill mainly comprises reclamation fill, underlain by Quaternary superficial deposits of fine and medium marine sands, debris flow deposits, alluvium and fill. Further, no major fault lines or fissures have been identified across the Shuen Wan Restored Landfill for migration of LFG.

9.3.4.2 As the Project is located right above the Shuen Wan Restored Landfill, the potential natural pathway for LFG migration is categorised as **Very Short/Direct**.

Man-made Pathway

9.3.4.3 Existing utilities and services directly linking Shuen Wan Restored Landfills and the Project Site were reviewed based on the utility layout plans provided by Hong Kong and China Gas Company Limited, Water Supplies Department, HGC Global Communications Limited, Hong Kong Telecommunications Limited and Hong Kong Broadband Network. Utility pipelines within Shuen Wan Restored Landfill are also reviewed from the as-built drawings of Shuen Wan Restored Landfill.

9.3.4.4 According to the information provided by various utility companies and EPD, existing underground utilities, including power cables, water pipelines and utility pipelines can be found within and around the boundary of the Project Site. It is therefore concluded that the Shuen Wan Restored Landfill, the potential man-made pathway for LFG migration is categorised as **Very Short/Direct**.

Combination of Natural and Man-made Pathways

9.3.4.5 The potential pathway of LFG migration from the source to the targets of the Project can be a combination of natural strata (i.e. the natural pathways) and subsequently through man-made facilities such as utilities connections (i.e. the man-made pathways).

9.3.4.6 This mode of transmission generally requires a series of events to occur in order for gas to potentially affect the Project. The path length for the migration of LFG by a combination of natural and man-made pathways is generally much longer than the direct distance between the source and the target. However, the target is located right atop or adjacent to

the Shuen Wan Restored Landfill. The potential combination of natural and man-made pathway for LFG migration is therefore categorised as **Very Short/Direct.**

9.3.5 Target

9.3.5.1 As the Project Site is located atop the Shuen Wan Restored Landfill, construction works will be undertaken within the Consultation Zone. The construction works associated with the Project include:

- tree felling;
- site formation (including excavation and filling);
- modification of existing LFG and leachate collection system;
- relocation/modification of the leachate pumphouses #1 & #2;
- relocation of passive vents and groundwater monitoring wells;
- road works and utilities installation;
- civil and E&M works for buildings (including car park) and ancillary facilities (e.g. plant rooms and water storage tanks); and
- temporary site office.

9.3.5.2 During construction phase, excavation may be required and the areas of confined spaces and trenches are especially at a higher risk to the exposure of LFG. In addition, indoor construction workers working in buildings and ancillary facilities such as plant rooms and water storage tanks may also at risk to the exposure of LFG.

9.3.5.3 Nevertheless, during the construction phase, the Project Site would only be accessible by authorised, well-trained personnel who would have been briefed on the potential hazards relating to LFG and the specific safety procedures to be followed. As such, the sensitivity of construction workforce is considered as **Medium Sensitive**.

9.3.6 Evaluation of Potential Impacts on Targets

9.3.6.1 With all the information regarding the sources, pathways and receivers identified in the previous sections, a qualitative risk assessment of LFG hazards during the construction phase is summarised in **Table 9.7**.

Table 9.7 Qualitative risk assessment of LFG hazards in the construction phase

Source	Pathway	Target	Risk
Shuen Wan Restored Landfill as LFG source: **Medium Source**	Natural: **Very Short/Direct** Man-made: **Very Short/Direct** Combined natural and man-made pathway: **Very Short/Direct**	Project Site: **Medium**	**Medium**

9.3.7 Recommended Precautionary and Protective Measures on Targets

9.3.7.1 The source-pathway-target analysis as summarised in **Table 9.7** has concluded that the overall risk level is **Medium** for the Project Site. With reference to **Table 9.3** and **Table 9.4**, for medium risk targets, engineering measures would be required to protect the Project Site which includes the use of "semi-active", enhanced passive gas controls and/or detection systems in some situations.

9.3.7.2 The following sections provide general advice and recommendations for the avoidance of environmental impacts related to LFG during the construction phase. Where applicable, specific measures for handling the hazards identified during the construction phase will also be addressed to further reduce the likelihood of incidents and increase the level of the safety to the workers.

General Hazards which may be Encountered

9.3.7.3 The Project Proponent (PP) should be aware of, and should inform the Contractors accordingly, that methane and carbon dioxide are always likely to be present in soil voids. In addition, the PP should be aware of the hazards and other properties of LFG.

Outline of Safety Requirements

9.3.7.4 During construction, safety procedures should be implemented to minimise the risk of:

- fires and explosions;
- asphyxiation of workers; and
- toxicity effects.

9.3.7.5 Precautions should be clearly laid down and rigidly adhered to with respect to:

- trenching and excavation; and
- creation of confined spaces at, near to or below ground level.

9.3.7.6 In addition to normal site safety procedures, gas detection equipment and appropriate breathing apparatus should be available and used when entering confined spaces or trenches deeper than 1 metre.

Additional General Requirements

i) Appointment of Safety Officer

9.3.7.7 A Safety Officer trained in the use of gas detection equipment and LFG related hazards should be present on site throughout the ground works

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%

ii) Safety Measures

9.3.7.8 All personnel who work on site and all visitors to the site should be made aware of the possibility of ignition of gas in the vicinity of the excavations. Safety notices should be posted warning of the potential hazards.

9.3.7.9 Those staff who work in, or have responsibility for "at risk" areas, including all excavation workers, supervisors and engineers working within the Consultation Zone, should receive appropriate training on working in areas susceptible to LFG, fire and explosion hazards.

9.3.7.10 An excavation procedure or code of practice to minimise LFG related risk should be devised and carried out by the Safety Officer.

9.3.7.11 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.

9.3.7.12 Smoking, naked flames and other sources of ignition should be prohibited within 15m of any excavation or ground-level confined space. "No Smoking", "No Naked Flame" and "Potential Hazard of Landfill Gas" notices in Chinese and English should be posted prominently around the Project Site.

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

9.3.7.14 Welding, flame-cutting or other hot works may only be carried out in trenches or confined spaces when controlled by a "permit to work" procedure, properly authorised by Safety Officer.

9.3.7.15 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 the Safety Officer, in attendance outside the confined area, who shall be responsible for reviewing the gas measurements as they are made, and who shall 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.

9.3.7.16 Ground level construction plant should be fitted with vertical exhausts at least 0.6m above ground level and with spark arrestors.

9.3.7.17 Any electrical equipment, such as motors and extension cords, should be intrinsically safe.

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

9.3.7.19 Temporary facilities such as mobile site offices, equipment stores, mess rooms etc. should be raised clear of the ground. If buildings are raised clear of the ground, a minimum, clear separation distance (as measured from the highest point on the ground surface to the underside of the lowest floor joist) should be 500mm.

9.3.7.20 During construction, adequate fire extinguishing equipment, fire-resistant clothing and breathing apparatus sets should be made available on site and appropriate training given in their use.

9.3.7.21 Fire drills should be organised at not less than six months intervals.

9.3.7.22 The PP should formulate a health and safety policy standards and instructions for site personnel to follow.

iii) Monitoring

9.3.7.23 LFG should be closely monitored, particularly at which the ground-works are to be conducted. Monitoring details during the construction phase are specified in the EM&A Manual.

iv) Emergency Management

9.3.7.24 To ensure that excavation procedures are implemented in the event of the trigger levels specified in **Table 9.8** being exceeded, the Safety Officer is responsible for dealing with any emergency which may occur due to LFG.

Table 9.8 Actions in the event of LFG being detected in excavations

Parameter	Monitoring Results	Actions
Methane	>10% LEL (i.e. >0.5% v/v)	Prohibit hot works; Ventilate to restore methane to <10%LEL.
	>20% LEL (i.e. >1.0% v/v)	Stop works; Inform EPD and Landfill Operator; Evacuate all personnel/prohibit entry;

Parameter	Monitoring Results	Actions
		Increase ventilation to restore methane to <10% LEL.
Carbon dioxide	>0.5% v/v	Ventilate to restore carbon dioxide to <0.5% v/v.
	>1.5% v/v	Stop works; Inform EPD and Landfill Operator; Evacuate all personnel/prohibit entry; Increase ventilation to restore carbon dioxide to <0.5% v/v.
Oxygen	<19%	Ventilation trench/void to restore oxygen to >19%
	<18%	Stop works; Inform EPD and Landfill Operator; Evacuate personnel/prohibit entry; Increase ventilation to restore oxygen to >19%

9.3.7.25 In any emergency situation, the Safety Officer, or his deputies, shall have the necessary authority and shall ensure that the confined space is evacuated and the necessary works implemented for reducing the concentrations of gas. The following organizations should also be contacted as appropriate:

- Hong Kong Police Force;
- Fire Services Department;
- Environmental Protection Department; and
- Landfill Operator.

9.3.8 Evaluation of Potential Impacts on Landfill Restoration Facilities

9.3.8.1 The proposed Shuen Wan Golf Course is located atop the existing Shuen Wan Restored Landfill. The existing restoration facilities installed mainly include:

- Landfill capping layer;
- LFG management system; and
- Leachate management system.

9.3.8.2 As discussed in **Section 9.3.5.1**, during the construction phase, the construction works associated with the Project include:

- tree felling;
- site formation (including excavation and filling);

- modification of existing LFG and leachate collection system;
- relocation/modification of leachate pumphouses #1 & #2;
- relocation of passive vents and groundwater monitoring wells;
- road works and utilities installation;
- civil and E&M works for buildings (including car park) and ancillary facilities (e.g. plant rooms and water storage tanks); and
- temporary site office.

Tree Felling

9.3.8.3 The Project would involve tree felling and removal of existing vegetation on top of the landfill capping layer. Trees would be transplanted/felled, whereas vegetation would be removed for turf paving. Protective and precautionary measures would be required to avoid any potential soil erosion.

Site Formation

9.3.8.4 Excavation may be required within the Project Site as well. However, buildings, ancillary facilities, access road and water storage tanks etc. would be placed outside the waste boundary where the landfill capping layer has been installed. Thus, this avoids deep excavation and heavy construction atop the waste boundary. For any inevitable excavation on the existing landfill capping layer, a method statement should be submitted to EPD for approval before the works commence. The method statement should assess the risk of excavation based upon the excavation depth, equipment, extent and types of landfill capping system underneath. Excavation works on the existing landfill capping layer will only be performed in accordance with the approved method statement by Specialist Contractor. In addition, only machinery with allowable weight would be placed atop the waste boundary to avoid any potential settlement and damage of capping layer.

9.3.8.5 As discussed in **Section 2**, filling of one to two metres would be conducted during the construction phase. A detailed geotechnical assessment and plate load test would be conducted in the detailed design stage to ensure the proposed golf course development would be safe. A preliminary plan for settlement monitoring is provided in **Appendix 9.5**. Further, settlement monitoring and precautionary measures shall be developed in the detailed design stage to control the potential settlement. The site formation plan containing detailed geotechnical assessment and associated proposal on settlement monitoring and precautionary measures will be submitted to Buildings Department under the Buildings Ordinance. Adverse impact on the landfill stability and the settlement of the Shuen Wan Restored Landfill are not anticipated.

9.3.8.6 In addition, the surface water drainage system will be re-provided for the entire golf course after the filling activities to facilitate effective collection of surface water. The surface water collected from the surface water drainage system will be conveyed to water storage tanks for storage and reuse. Thus, significant percolation of rainwater to the underneath waste layer is not anticipated. The residual agrochemicals seeped into the covering soil will be degraded through various environmental fate processes. The residual agrochemicals seeped into the waste mass would be in tiny amount and would not significantly change the pollution characteristics of leachate. Interference of agrochemicals in the leachate management system would be insignificant. The potential impacts of agrochemicals on surface water and leachate are discussed in detail in **Section 6.5.2**.

Modification of Existing LFG and Leachate Collection System

9.3.8.7 Due to extensive coverage of existing LFG and leachate extraction wells in the Project Site and consideration of safety of golfers, it is unavoidable that some of the extraction wells will be relocated to avoid conflict with the teeing ground and fairway. New extraction wells will be drilled into the waste mass and the new horizontal header pipes will be installed to convey the LFG and leachate to the nearby existing network. In the subsequent detailed design stage for the golf course, the existing locations of extraction wells would be further reviewed to minimise the number of wells to be relocated.

9.3.8.8 During the modification works for LFG and leachate monitoring wells, the capping layer or liner would require some relatively minor works. Any affected liner will be properly sealed with new liner and sufficient overlapping will be provided between the old and new liners. Capping layout will be reinstated after the completion of the modification of wells.

9.3.8.9 Subject to detailed design to be conducted at subsequent stages, the modifications would likely include the following 3 types:

- Vertical extension of the extraction wells; or
- Horizontal extension of the extraction wells; or
- Relocation of the extraction wells.

9.3.8.10 In order to minimize any impacts on the existing operation of the landfill system, the subsequent detailed design will aim to optimize the use of vertical or horizontal extension and relocation of the extraction wells, in which vertical / horizontal extension of the extraction wells would be given a higher priority.

9.3.8.11 Vertical extension of the extraction wells would involve extension of vertical shafts and header pipes to suit the final finishes level. Hence, it can be seen that vertical extension of the extraction wells would not

adversely affect the current operation of the landfill sites and would not generate any secondary environmental impacts such as significant gaseous emission to the environment.

9.3.8.12 Horizontal extension of the extraction wells would involve extension of shafts by inserting a 90-degree bend. The bended shaft would be connected to horizontal header pipe, which will be buried in soil without affecting the proposed teeing ground and fairway of the future golf course. Similar to the vertical extension, the horizontal extraction would not adversely affect the existing operation and would not generate any secondary environmental impacts such as significant gaseous emission to the environment.

9.3.8.13 In comparison, relocation of the extraction wells would involve installation of new wells and header pipes. While the details of the Design Plan/Works Plan will be provided by the Specialist Contractor/Landfill Consultant, in order to minimize any impacts on the LFG system, it is proposed that the relocation of the extraction wells should be conducted in phases as the site formation developed. For example, a maximum of 10 numbers of new shafts will be installed at once occasion. Since the existing 87 numbers of gas extraction wells remain in function during the modification process, both the LFG system and leachate system would remain in slightly negative pressure status. This would help to ensure insignificant release of both gaseous emission and liquid during the modification works. The impact of new well installation is also isolated and local, with well shaft diameter ranging 75mm to 300mm compares to the entire waste mass of 50ha. The existing wells being affected will only be demolished after the commissioning of the new wells. A detailed assessment on LFG hazard on the modification works and the associated impact on the existing restoration facilities will also be included in the future Design Plan.

Relocation/Modification of Leachate Pumphouses #1 & #2

9.3.8.14 Further, the location of the leachate pumphouse #1 will conflict with the ancillary facilities of the Project. It is thus proposed to relocate the pumphouse #1 as well as the associated leachate extraction wells and horizontal header pipes. New extraction wells will be drilled into the waste mass and new horizontal header pipes will be installed to convey the leachate from the waste mass to the new pumphouse. Modification to the capping layer will be required and sufficient overlapping will be provided for both existing and new capping to avoid adverse odour impact.

9.3.8.15 As the new leachate pumphouse #1 will be located outside the waste mass, excavation of the new pumphouse will not adversely affect the current operation of the landfill. To minimize the impact to the landfill operation, new valves and tee-off will also be provided for the existing pipework for future switch over. A new leachate pumphouse and associated pipework will be constructed. The existing pumphouse and

affected pipework will be decommissioned after the commissioning of the new pumphouse and associated pipeworks.

9.3.8.16 Similar to other utilities installation, the reprovisioned pipework will also be laid on top of the capping layer as far as practicable. As a result, release of both gaseous emission and leachate is unlikely and the proposed relocation of pumphouse and pipework and will not cause adverse environmental impact to the surrounding.

9.3.8.17 Subject to the future design of the pumphouse, if excavation to the waste mass is unavoidable, a Design Plan/Works plan will be provided by the Specialist Contractor/Landfill Consultant for submission to EPD for approval.

9.3.8.18 Besides, the access road of the Project will run over the existing leachate pumphouse #2. The existing control panel of the pumphouse and the manhole access shafts will be relocated and modified to suit the future road layout. It is envisaged that gaseous emission and leakage of leachate is unlikely for the panel relocation and manhole shafts extension.

Relocation of Passive Vents and Groundwater Monitoring Wells

9.3.8.19 In addition, there are existing LFG passive vents along the boundary of the Project close to the Fortune Garden. As there will be a new internal road running along the site boundary to the ancillary facilities, the existing LFG passive vents will be abandoned and new passive vents will be installed along the access road.

9.3.8.20 Likewise, for the existing groundwater monitoring wells near the seawall conflicting with the access road and ancillary facilities, new groundwater monitoring wells will be installed and the existing wells will be abandoned.

9.3.8.21 As both passive vents and groundwater monitoring wells are located outside the waste mass, there should be no adverse impact due to the relocation works.

Road Works and Utilities Installation

9.3.8.22 Roadworks and utilities installation are only 1m below the finished ground level and will not affect the capping layer of the restored landfill, there should be no adverse impact due to the roadworks and utilities installation.

Civil and E&M Works for Buildings and Ancillary Facilities

9.3.8.23 The buildings and ancillary facilities such as carpark, plant rooms and water storage tanks are all outside the waste boundary without

excavating the waste mass, and no adverse impact on gaseous emission and leakage of leachate is anticipated. Nevertheless, protection measures including gas detection system and gas barriers will be provided during construction stage and for long term operation stage.

Temporary Site Office

9.3.8.24 Similarly, the temporary site office will be provided outside the waste boundary, no adverse impact on gaseous emission and leakage of leachate is anticipated. Protection measures including gas detection system and LFG barriers will be provided during construction stage.

Overall Mitigation Strategy

9.3.8.25 For any demolition, relocation, reprovision and modification works of the existing landfill facilities, including passive vents, leachate and LFG management systems and leachate pumphouses, etc., the Project Proponent or the future golf course operator shall hire a Specialist Contractor/Landfill Consultant who possesses experiences in local or overseas landfill restoration and/or aftercare projects. Before commencement of aforementioned works, both Design Plan and Works Plan should be submitted to EPD for approval after the certification of the independent Landfill Consultant. The LFG hazard assessment will also be updated to cover both construction and operational phase of the development during the detailed design stage.

9.3.8.26 On formulating the Design Plan and Works Plan, the following design considerations should be incorporated:

- Avoid adverse environmental impact;
- Minimise the disruption to the landfill operation and monitoring;
- Ensure proper access to the landfill facilities for subsequent monitoring and maintenance after the proposed demolition, relocation and modification; and
- Ensure safety of future golfers and site staff.

9.3.8.27 The Design Plan shall include a table identifying the affected landfill facilities, and detailing the proposed modification works and mitigation measures to be employed in order to minimise the operation of the existing landfill. The Works Plan shall include construction phasing, the construction method and sequence of the modification works including testing and commissioning of the reprovisioning works, and how to resolve the interfacing issues with the existing landfill operation.

9.3.8.28 In addition, all demolition, relocation, reprovision and modification works should be conducted by Specialist Contractors who have been involved in the construction of corresponding landfill facilities. The future designers would work closely with the existing landfill contractor and consultant to ensure the modification details would be

technically feasible and the impact on the LFG facilities would be minimal.

9.3.8.29 For the relocation of the LFG and leachate wells, the capping layer or liner would require some minor works. Any affected liner will be sealed with new liner. Sufficient overlapping will be provided between the old and new liners to maintain the integrity of the capping layer.

9.3.8.30 By employing a Landfill Consultant for the design of the modification works of the existing landfill facilities and a Specialist Contractor to perform modification works, adverse impact from modification of landfill facilities can be minimised, provided that precautionary and protective measures are in place. Relevant as-built drawings of landfill capping layer will be submitted to EPD after the construction phase.

9.3.9 Recommended Precautionary and Protective Measures on Landfill Restoration Facilities

General – Method Statement for Works

9.3.9.1 After the land exchange and prior to the commencement of the following works, including (1) excavation on the existing landfill capping layer; (2) drilling new extraction wells; (3) overlapping of the new and old liners; and/or (4) demolition, relocation, reprovision and modification works of the existing landfill facilities, within the Project Site, a Design Plan should be submitted to EPD for approval after the certification of an independent Landfill Consultant with the provision of following details:

- the objectives of the design and works;
- the landfill facilities affected by the design and works;
- the locations of affected facilities and drawings to shown the design of the new facilities proposed;
- a summary table detailing the affected facilities and the proposed modification works involved, and the mitigation measures to be employed;
- the potential environmental impacts of the design and works;
- any safety precaution and monitoring required.
- impact assessment on the waste excavated, if any, as well as its disposal.

9.3.9.2 After the approval of Design Plan by EPD, a Works Plan with method statement should be prepared by Specialist Contractor including the following details:

- works areas;
- construction phasing;

- number of operatives;
- experience and special skills of operatives;
- supervisors responsibilities;
- plant and equipment;
- method statement, procedures and sequencing of the works;
- measures to address the interfacing issues and to avoid any impact to the existing operations;
- emergency procedures, including firefighting;
- storage and use of safety equipment;
- proposed LFG monitoring requirements;
- safety precaution; and
- signs, barriers and guarding.

9.3.9.3 The Works Plan should also be certified by an independent Landfill Consultant and submitted to EPD for approval before the commencement of works. During the construction phase, the method statement should be strictly followed.

Precautionary Measures for Excavation

9.3.9.4 For the excavation works, depth of excavation should be closely monitored. As mentioned in **Section 9.3.7**, concentrations of LFG including methane, carbon dioxide and oxygen, should be closely monitored at the excavation works areas.

9.3.9.5 Any sudden rise of LFG concentration or leachate level indicates a potential loss of the integrity of the landfill capping layer. In case of any sign of damage of the landfill capping layer, the PP should notify EPD for detail inspection. Once damage of the impermeable layer is confirmed, rectification works should be undertaken by the PP the soonest for acceptance by EPD.

9.3.9.6 Excavation, felling of trees and removal of vegetation may result in erosion of topsoil on the landfill capping layer. The following good site practices should be implemented to avoid soil erosion of the site wherever practicable.

- Construction works should be programmed to minimise soil excavation works in rainy seasons (April to September). If excavation in soil could not be avoided in these months or at any time of year when rainstorms are likely, for the purpose of preventing soil erosion, temporarily exposed slope and all excavated surfaces should be covered e.g. by tarpaulin, and temporarily access roads should be protected by crushed stone or gravel, as excavation proceeds. Arrangements should always be in place to ensure that adequate surface protection measures can be safely carried out well before the arrival of a rainstorm. After excavation, soil should be backfilled as soon as possible.
- Surface protection should be carried out immediately after the final surfaces are formed to prevent erosion caused by rainstorms or wind. After the removal of vegetation from the site, pavement of turf should be implemented on the bared topsoil earliest possible to avoid soil erosion.
- To prevent the sediments and soil in the runoff from entering the monitoring wells, channels or earth bunds or sand bag barriers should be provided on site to properly direct stormwater to silt removal facilities for discharge.

Precautionary Measures for Demolition, Relocation, Reprovision and Modification of Landfill Facilities

9.3.9.7 Before any demolition, relocation, reprovision and modification of existing landfill facilities, including passive vents, leachate and LFG management systems and leachate pumphouses, etc., EPD's approval should be obtained.

9.3.9.8 The following strategy would be adopted to designing and implementing the modification works for the LFG and leachate extraction wells:

- The future golf course design shall avoid the impact on the existing landfill facilities as far as possible.
- Maximise the number of vertical extension and horizontal extension of extraction wells where practicable to suit the golf course design;
- Minimise the number of relocation of extraction wells where practicable to suit the golf course design;
- If unavoidable, relocation of extraction wells shall be carried out in phase and in small batch, to minimize any impacts on the operation of the landfill system;
- Implement all necessary precautionary measures during the implementation of the relocation of extraction wells to avoid and minimize any release of gaseous emission and liquid (e.g. ensure active pumping within the waste mass, sealing and overlapping of new and old liners, etc.)

9.3.9.9 During the detailed design stage, the Project Proponent shall employ a Specialist Contractor/Landfill Consultant who shall prepare and provide a Design Plan/Works Plan to EPD for approval regarding the proposed modifications works and associated mitigation measures, with the aim to minimise the disruption to the landfill operation and to avoid adverse environmental impact. (NB the Project Proponent has committed to employ the existing landfill operator of restored Shuen Wan Landfill to carry out the subsequent design work to ensure the modification works can be seamlessly integrated with the existing LFG and leachate system.).

9.3.9.10 During the construction phase, the Project Proponent shall employ a Specialist Contractor to implement the Design Plan/Works Plan established during the detailed design stage. The Project Proponent/Specialist Contractor/Landfill Consultant shall coordinate with the EPD and the landfill operator and prepare a method statement as mentioned in **Section 9.3.9.2** prior to any demolition, relocation, reprovision and modification works to avoid any disturbance to the existing aftercare works. The method statement should be approved by EPD prior to the commencement of these works.

9.3.9.11 The Specialist Contractor should provide regular and effective training to construction workers/landfill personnel. During the modification works, Specialist Contractor should provide proper personal protective equipment (PPE) to the construction workers. The following safety equipment shall also be provided by Specialist Contractor at all times during the drilling works:

- no smoking signs, to be placed prominently adjacent to the drilling area;
- portable fire extinguisher;
- high visibility clothing to be worn by all drilling operatives; and
- additional protective clothing should include stout industrial boots (with steel toe cap and insole), plastic hard hats, heavy duty waterproof industrial groves.

9.3.9.12 Upon drilling on landfill sites for well installation, the following mitigation measures and safety precaution should also be followed by the Specialist Contractor:

- Portable methane meter should be available at all times.
- On arrival at site, the drilling rig should be set-up up-wind of the borehole location, ‘No smoking’ signs set out and the working area should be roped or coned-off.

- When drilling on landfill sites, all spoil obtained from the borehole should be stockpiled alongside the borehole and disposed of (to an appropriately licensed disposal site) at the end of the working day. At the end of the working day, all vehicles, the drilling rig and any hand tools should be hosed-down with clean water to remove deposits of excavated spoil. Suitable guards or barriers should be placed around the excavation or borehole to prevent access by unauthorised persons.
- One person should be present at all times during drilling operations, with the sole responsibility of assuring the observance of all safety procedures. This person should be trained in the use of all recommended safety equipment.
- Smoking should be prohibited anywhere on a landfill site and within 15 metres of a boring or excavation at any locations within the Consultation Zone.
- For large diameter boreholes, a working platform should be placed over the hole which will prevent accidental entry into the hole by operatives.
- No worker should be allowed to work alone at any time near the edge of the well under construction. Another worker should always be present, beyond the area considered to be subject to the possible effects of LFG or cave-in.
- Periodically during the well construction, the work areas should be monitored for levels of methane.
- If the well construction is not completed by the end of the working day, the hole should be covered with a plate of sufficient overlap to prevent access to the hole and sufficient structural strength to support expected loads. The plate should be weighted down to discourage removal and, on landfill sites, the edges of the plate should be covered with sufficient depth of wet soil to prevent escape of gas.
- All pipes or casings should be capped at the end of each working day.
- Engine-driven rigs should have vertical exhaust stacks discharging not less than 1.5m above ground level and should have speed limits to prevent engine run away on ingested gas.
- Diesel engine air-intakes should also be located not less than 1.5m above ground level.
- Any electrical equipment should be intrinsically safe.
- Additional safety advice and guidance may be found in “Investigation into Establishing an Effective Practical Safe Working Practice When Drilling in Landfill Sites and Adjacent Areas and Contaminated Ground and Adjacent Areas” compiled by the British Drilling Association (1993).

9.3.9.13 During the installation of vertical wells, the following mitigation measures and safety precaution should be followed by the Specialist Contractor:

- To prevent uncontrolled gas release and to protect personnel from the risk of falling into the borehole, the open borehole should be covered with a sheet or plate strong enough to support personnel and having an overlap all round the borehole.
- The drilling rig, boring machine or excavator should remain in place over the borehole and could be used as a support to assist placement of the casing.
- The upper end of the well casing should be sealed, preferably with a fused or screwed end cap or alternatively with an inflatable bag type flow stopper, until the permanent headworks/monitoring tap is fitted. LFG must not be allowed to vent freely at the site surface.

Precautionary Measures for Working in Confined Spaces

9.3.9.14 When working in manhole, leachate pumphouse or any other confined space, workers should always follow the regulations and guidelines on confined spaces and occupational safety. Workers entering the confined spaces should be equipped with breathing masks. Methane, carbon dioxide and oxygen should be continuously monitored.

9.3.9.15 With the implementation of above precautionary and protective measures, residual impacts on the existing restoration facilities of Shuen Wan Restored Landfill is insignificant.

9.4 Qualitative Risk Assessment in Operational Phase

9.4.1 Assessment Methodology

9.4.1.1 The assessment methodology on operational phase follows that on the construction phase as discussed in **Section 9.3.1.1**.

9.4.2 Source

9.4.2.1 The risk level of the source has been assessed in detail in **Section 9.3.3**. The LFG source of Shuen Wan Restored Landfill is classified as **Medium.**

9.4.3 Pathway

Natural Pathway

9.4.3.1 As the Project Site is located right above the Shuen Wan Restored

Landfill, the potential natural pathways for LFG migration is categorised as **Very Short/Direct**.

Man-made Pathway

9.4.3.2 Upon completion of the Project, new underground utilities and irrigation system will have been installed in the Project Site. The underground utilities include but not limited to the power cables, water pipelines, and drainage pipelines. In view of the short distance between the source and targets, the potential man-made pathway for LFG migration is categorised as **Very Short/Direct**.

Combination of Natural and Man-made Pathways

9.4.3.3 The consideration of this potential pathway allows for a combination of LFG migration through natural strata and subsequently through man-made facilities such as utilities connections as the potential means to affect the existing and potential developments.

9.4.3.4 This mode of transmission generally requires a series of events to occur in order for gas to potentially affect the developments. The path length for the migration of LFG by a combination of natural and man-made pathways is generally much longer than the direct distance between the source and the target. However, the Project Site is located right atop the Shuen Wan Restored Landfill. The potential combination of natural and man-made pathway for LFG migration is still categorised as **Very Short/Direct.**

9.4.4 Target

9.4.4.1 As the Project Site will be located within the Shuen Wan Restored Landfill, operation will be undertaken within the Consultation Zone. Users associated with the operation of the Project under Scenario 1 are identified as follows:

- visitors (indoor);
- general staff (working indoor at offices, repair workshops, catering facilities, car park etc.) and maintenance staff (working at E&M plant rooms, water storage tanks, manholes etc.); and
- visitors and staff (outdoor).

9.4.4.2 As discussed in **Section 2.4.9**, the provision of staff quarters and overnight accommodations has been proposed under Scenario 2 for more flexible uses of the Project and development of the Project to suit contemporary circumstances and operational requirements. Targets in connection have also been included for comprehensive assessment.

9.4.4.3 Indoor areas where the public have unrestricted access include car park, lift and staircases, offices, lavatories, overnight accommodation etc.

Underground utilities may enter directly from the ground. The sensitivity of the target is categorised as **Highly Sensitive**.

9.4.4.4 For the E&M plant rooms, golf club repair workshops, staff quarters and confined spaces (e.g. water storage tanks) where underground utilities may entre directly, only the authorised, well-trained staff would be allowed to access. They will be briefed on the hazards relating to LFG and the specific safety procedures to be followed. Thus, the sensitivity of the target is categorised as **Medium Sensitive**.

9.4.4.5 For the outdoor open spaces of the Project, such as the teeing area, greens, fairway and driving range, release of LFG is possible and may pose potential problems to visitors and staff. As LFG is likely to be diluted in open area, the sensitivity of the target is categorised as **Low Sensitive**.

9.4.5 Evaluation of Potential Impacts on Targets

9.4.5.1 With all the information regarding the sources, pathways and receivers identified in the previous sections, a qualitative risk assessment of LFG hazards during the operational phase is summarised in **Table 9.9**.

Table 9.9 Qualitative risk assessment of LFG hazards in the operational phase

Source	Pathway	Target	Risk
Shuen Wan Restored Landfill as LFG source: **Medium Source**	Natural: **Very Short/Direct** Man-made: **Very Short/Direct** Combined natural and man-made pathway: **Very Short/Direct**	Indoor areas where the public have unrestricted access include car park, lift and staircases, offices, lavatories, overnight accommodation: **Highly Sensitive**	**High**
		Plant rooms, water storage tanks, workshop areas, staff quarters and confined spaces: **Medium Sensitive**	**Medium**
		Outdoor golf course: **Low Sensitive**	**Low**

9.4.6 Recommended Precautionary and Protective Measures on Targets

9.4.6.1 The source-pathway-target analysis as summarised in **Table 9.9** concluded that the overall risk level is **High** for the indoor areas of the Project Site where public have free access. With reference to **Table 9.3** and **Table 9.4**, significant engineering measures, comprising active gas control system, barriers and detection systems, would be required to protect the high-risk targets.

9.4.6.2 For the restricted areas, such as plant rooms, stored rooms and water storage tanks, where only the authorised personnel can access, the overall risk level is **Medium**. With reference to **Table 9.3** and **Table 9.4**, engineering measures will be required to protect the planned development. Either use of semi-active (e.g. use of wind driven cowls and other devices to assist in the ventilation of gas but do not rely on electrically powered fans) or enhanced passive controls (e.g. gas-proof membranes and high-density concrete in floor or wall) shall be applied wherever necessary.

9.4.6.3 The following protective and precautionary measures would be implemented for the indoor areas of the Project wherever practicable. Precautionary measures incorporated in the building design as shown in **Appendix 9.6** should be well documented in the building plans in the subsequent detailed design stage and submit to EPD for design check. The building protection design measures as stipulated in the LFG Hazard Assessment Guidance Note should be followed, to prevent gas build up within the ancillary facilities (including dwellings).

Active Gas Control

9.4.6.4 Active gas control mainly relies on the use of mechanical ventilation system. Mechanical ventilation system makes use of electrical energy to accelerate the dispersion of any accumulated LFG. The mechanical ventilation system may or may not integrate with the air conditioning system to control the air temperature.

9.4.6.5 According to the assessment conducted (see **Appendix 9.7**), with the implementation of gas-proof membrane, a ventilation rate of <0.5 air changes per hour would be required to content the risk associated with LFG in the proposed site. This could be achieved by either a separate ventilation system dedicated for mitigating the risk for LFG, and/or through the conventional mechanical ventilation system. Subject to detailed design, the system shall achieve at least 0.5 air changes per hour in any circumstances. In case any space or room is occupied by users such as staff and guests, the respective requirements such as those stipulated by Buildings Ordinance and suggested by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) would also need to be complied with. Typical requirements for office uses from those guidelines are ventilation rates of 4-6 air changes per hour, which would be much higher than that to content LFG risk. By using this approach, the energy consumption for the ventilation system in the long run could be better optimized. The ventilation requirements for other areas would be determined during the detailed design stage.

9.4.6.6 Such mechanical ventilation should be connected with emergency power supply so that ventilation should not be interrupted in case of power failure. The mechanical ventilation system will also be interlocked with the always-on gas detection system to regulate the air flow based upon the methane, carbon dioxide and oxygen gas concentrations. While at least 0.5 air changes per hour would be

maintained in any circumstances, in case the gas concentrations exceed the trigger levels (see **Table 9.10**), the mechanical ventilation system will be set to operate in full load to reduce the gas concentrations to safe concentrations as soon as possible. The mechanical ventilation system should also be spark-proofed.

9.4.6.7 To summarise, the provision of the above mechanical ventilation system with such air change rate, with details to be developed during detailed design stage, would be sufficient to avoid/minimise LFG accumulation. The blowers and vents of the mechanical ventilation system should be suitably located to facilitate air movement of the entire room/space and to carry away, if any, excessive residual LFG.

Semi-active Gas Control

9.4.6.8 Wind scoops would be installed to facilities where the air conditioners are not provided such as the car park to facilitate the ventilation. They will be installed on the roof of the ancillary facilities with pipes to extract air from the car park. When wind strikes the wind scoops, the fans of the scoops would move and create negative pressure to extract air in the car park. Electricity supply is not required for wind scoops. This acts as a semi-active control to extract, if any, LFG from the indoor facilities.

Passive Gas Control

9.4.6.9 Passive controls involve the use of gas-proof membranes, compacted high density concrete and ventilation by natural air movement.

i) Gas-proof Membranes

9.4.6.10 Gas-proof membrane could be incorporated into the floor and wall construction as a continuous sealed layer to prevent any gas ingression into the building facilities. The gas-proof membrane can be made of polymeric membranes such as high density polyethylene (HDPE) membrane liners. The material of the membrane should consist of a high strength woven fabric with an impermeable coating on both sides with equivalent materials. The permeability of the membrane should be less than 10^{-12} m/s as stated in the EPD's LFG Hazard Assessment Guidance Note. The membrane should possess a long-term stability with a lifetime of at least 30 years. They should be installed on the floors and/or the walls directly in contact with the ground and/or slope of the landfill. **Appendix 9.6a** shows the details of typical gas-proof membrane protection for buildings. **Appendix 9.8** shows the sectional diagram of the ancillary facilities where gas-proof membranes will be installed.

ii) Compacted High Density Concrete

9.4.6.11 To further increase the resistance to gas permeation to the building, compacted high density concrete should be used for the floors and/or

the walls directly in contact with the ground and/or slope of the landfill. **Appendix 9.7** shows the sectional diagrams of the ancillary facilities where compacted high density concrete is to be installed.

iii) Ventilation by Natural Air Movement

9.4.6.12 As the Project Site is adjacent to Tolo Harbour, wisely use of natural wind resource can facilitate the dispersion of, if any, LFG at the site. Openings on the southern and eastern facades of the car park have been allowed for to facilitate the ventilation by the prevailing wind coming from the east and the south.

Gas Detection System

9.4.6.13 Always-on gas detection system would be provided at all rooms, houses and indoor environment such as car park, lift and staircases, offices, golf shop, changing rooms, staff quarters and overnight accommodation etc. which will be occupied by medium and highly sensitive targets and be involved in the long-term uses. The gas detector is used to monitor the methane, carbon dioxide and oxygen gas concentrations and should be calibrated on a regular basis according to the manufacturers' recommendations. The sensors detect methane, carbon dioxide and oxygen gases by the catalytic oxidation or infra-red principles, and pass data back to a control panel by electrical cabling. **Appendix 9.6b** shows the schematic of automatic gas detection system. In the event of a power failure, the detectors should have an 8-hour battery back-up system, and the procedures should indicate for manual monitoring in the stations in the event of prolonged power failure (of longer than 8 hours).

9.4.6.14 The gas detection system should include an alarm set at the trigger levels as mentioned in **Table 9.10** in order to give warning to the public and evacuate sensitive targets from buildings. The gas detection system will also interlock with the mechanical ventilation system. In case the gas concentrations exceed the trigger levels, mechanical ventilation system will be operated to restore methane, carbon dioxide and oxygen levels to safe concentrations as soon as possible.

Table 9.10 Actions in the event of LFG being detected in the building structure

Parameter	Monitoring Results	Actions
Methane	>10% LEL (i.e. >0.5% v/v)	Inform EPD, Landfill Contractor and the nominated person (e.g. golf course facility manager); Remove all source of ignition from the affected areas of the building; Ventilate the affected area to restore methane to <10% LEL (<0.5% v/v), carbon dioxide to <0.5% v/v and/or oxygen levels to >19% v/v;
Carbon dioxide	>0.5% v/v	
Oxygen	<19% v/v	

Parameter	Monitoring Results	Actions
		Seek specialist to review the existing precautionary measures to ensure the continuous safety of the occupants.
Methane	>20% LEL (i.e. >1% v/v)	Inform EPD, Landfill Contractor and the nominated person (e.g. golf course facility manager); Advise and evacuate occupants/prohibit entry to the affected areas of the building; Remove all sources of ignition from the affected areas of the building; Increase ventilation to restore methane to <10% LEL (<0.5% v/v), carbon dioxide to <0.5% v/v and oxygen levels to >19% v/v; Seek specialist to review the existing precautionary measures to ensure the continuous safety of the occupants.
Carbon dioxide	>1.5% v/v	
Oxygen	<18% v/v	

Good Site Management

9.4.6.15 Proper site management can further reduce the risk of LFG. "No Smoking", "No Naked Flame" and "Potential Hazard of Landfill Gas" signs should be posted in the Project Site clearly visible to the public. Site staff will carry out inspection to ensure that no smoking and no naked flame are in place in the Project Site.

9.4.6.16 In case of power failure, emergency generators would be powered on to maintain the mechanical ventilation system. If the fuel of emergency generators runs out, the occupants in the affected areas should be evacuated immediately. When the power supply is recovered, trained staff with proper safety precautions have to carry appropriate portable gas meters to all rooms and confirm the methane, carbon dioxide and oxygen gas levels are well within the safe limit and the mechanical ventilation system is operated normally. A risk assessment would be conducted by qualified staff to ensure the affected areas are safe prior to re-open for public access.

9.4.6.17 Flame cooking would be banned in all catering facilities. Electronic cooking devices should be used instead. All electric appliances such as ventilation systems, lighting systems, pumps and switches used within Project Site should be spark-proofed.

Entry Safety Procedures

9.4.6.18 Confined spaces, including water storage tanks, manholes, chambers etc., exist in the Project Site during the operational phase. In confined spaces which is large enough to permit access to, personnel should be subject to entry safety procedures as stipulated in the Factory and Industrial Undertakings (F&IU) (Confined Spaces) Regulation.

9.4.6.19 In accordance with the Regulation, "confined spaces" includes any chamber, tank, vat, pit, well, sewer, tunnel, pipe, flue, boiler, pressure receiver, hatch, caisson, shaft or silo in which "specified risk" arises. "Specified risk" means a risk of:

- serious injury to any person at work arising from a fire or explosion;
- the loss of consciousness of any person at work arising from an increase in body temperature;
- the loss of consciousness or asphyxiation of any person at work arising from gas, fume, vapour or the lack of oxygen;
- the drowning of any person at work arising from an increase in the level of liquid; or
- the asphyxiation of any person at work arising from a free flowing solid or the inability to reach a respirable environment due to entrapment by a free flowing solid.

9.4.6.20 The key issues with regard to confined spaces which are at risk of LFG build-up are set out below:

- The entry or access point should be clearly marked with a warning notice (in English and Chinese) which states that there is the possibility of flammable and asphyxiating gas accumulating within.
- The warning notice should also give the telephone number of an appropriate competent person who can advise on the safety precautions to be followed before entry and during occupation of the manhole.
- Personnel should be made aware of the dangers of entering confined spaces potentially containing hazardous gases and, where appropriate, should be trained in the use of gas detection equipment.
- Prior to entry, the atmosphere within the chamber should be checked for the levels of methane, carbon dioxide and oxygen. The chamber may then only be entered if oxygen is greater than 18% v/v, methane is less than 10% of the LEL (0.5% v/v) and carbon dioxide is less than 0.5% v/v.
- If either carbon dioxide or methane is higher, or oxygen lower, than the values given above, then entry to the chamber should be prohibited and expert advice sought.
- Even if conditions are safe for entry, no worker should be permitted to enter the chamber without having another worker present at the surface. The worker who enters the chamber should wear an appropriate safety/recovery harness and be provided with a portable methane, carbon dioxide and oxygen metre.

9.4.6.21 In general, when work is being undertaken in confined spaces, sufficient approved resuscitation equipment, breathing apparatus and safety torches should be available. Persons involved in or supervising such work should be trained and practised in the use of such equipment. A permit-to-work system for entry into confined spaces should be developed by appropriate qualified person such as Safety Officer who is consistently employed. These measures shall be applicable to all confined spaces in the Project Site, including but not limited to water storage tanks, manholes and chambers.

Design Measures for Building Services

9.4.6.22 To further reduce the LFG migration through the pipes and underground utilities, the following design measures should be implemented wherever practicable:

i) Generic protection measures

9.4.6.23 LFG Barrier ─ As for barriers used to prevent movement of gas through the ground, use may be made of clay (or clay-rich soils), bentonite or polymeric membranes (e.g. HDPE) as shown in **Appendix 9.6c**. A LFG 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 membrane should be either key into low permeability strata or extends at least 1m below the lowest groundwater level. The schematic diagrams of the proposed LFG barriers by HDPE for the Project are provided in **Appendix 9.8**. 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 as shown in **Appendix 9.6d**.

9.4.6.24 Gas Vents ─ Vent pipes (**Appendix 9.6e**) or gridded manhole covers (**Appendix 9.6f**) may be used to avoid build-up of gas in manholes of underground utilities and water storage tanks. Venting stacks may be built into inspection chambers or connected to collection pipes within high permeability drainage layers adjacent to LFG barriers.

9.4.6.25 Mechanical Ventilation System ─ Mechanical ventilation system such as exhaust fans may be useful to avoid LFG accumulation at confined spaces (e.g. chambers, manholes and water storage tanks with significant size). It will interlock with the always-on gas detection system, also installed in the confined spaces, to regulate the air flow based upon the methane, carbon dioxide and oxygen gas concentrations. In case the gas concentrations exceed the trigger levels (see **Table 9.10**), the mechanical ventilation system will be operated to restore the gas concentrations back to safe concentrations as soon as possible.

9.4.6.26 Location of Service Entry Points Above Ground ─ In some cases, it is possible to route service entries into a building above ground level, thereby providing a discontinuity in the gas migration pathway and thus

eliminating the risk of gas entry to the building interior. **Appendix 9.6g** and **Appendix 9.6h** show the typical service entry above ground and typical surface detail for above ground termination of services within the Consultation Zone respectively.

ii) Service conduits passing through the Consultation Zone

9.4.6.27 In addition to the general guidance given above, the following recommendations apply to service conduits which pass through the Consultation Zone with connections to developments outside the Zone:

- The service run through the Consultation Zone may remain "unprotected" since the risks will be minimised by the protection measures installed at the perimeter of the Consultation Zone and as the general public may not have access to such underground features.
- The service run should be designated as a "special route" and the utility companies should be informed to that effect so that they may implement precautionary measures.
- Any future works such as maintenance or extensions should be subject to the recommendations specified in the LFG Hazard Assessment Guidance Note.
- Any above ground (minor) termination features e.g. telecom cabinets should be considered to be "buildings" and should be protected by e.g. membrane barriers to minimise the possibility of gas ingress.
- Trenches, service pipes, manholes and other subsurface utilities should be properly designed to allow regular LFG monitoring within these facilities. Monitoring should be conducted at least once a month to evaluate the potential of LFG accumulation.

9.4.6.28 In summary, by adopting multiple gas control measures and good site management, the risk of the sensitive targets within the indoor areas of the Project is reduced to acceptable level. **Table 9.11** summarised the precautionary measures proposed for the indoor areas of the Project Site. The detailed design with mitigation measures incorporated shall be submitted to EPD for design check and approval.

Table 9.11 Summary of protective and precautionary measures proposed for the indoor areas during the operational phase

Location	Public Access	Risk Level	Passive Control			Semi-active Control	Active Control	Gas Detection System[1]	Good Site Management		Entry Safety Procedures	Design Measures for Building Services
			Gas-proof Membrane	Compacted High Density Concrete	Ventilation by Natural Air Movement	Wind Scoop	Mechanical Ventilation System		Warning Signs[2]	Evacuate Occupants under Emergency[3]		
Scenario 1												
Car park	Yes	High	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Other ancillary facilities with free public access (e.g. lift, staircase, offices, changing rooms, nursery & play area etc.)	Yes	High	Yes	Yes	No[4]	No[4]	Yes	Yes	Yes	Yes	No	Yes
Ancillary facilities without free public access (e.g. E&M plant rooms, workshop areas etc.)	No	Medium	Yes	Yes	[5]	[5]	[5]	Yes	Yes	Yes	No	Yes
Confined spaces (e.g. water storage tank)[6]	No	Medium	Yes	Yes	No	No	[7]	[7]	Yes	Yes	Yes	Yes
Scenario 2												
Overnight accommodation	Yes	High	Yes	Yes	No[4]	No[4]	Yes	Yes	Yes	Yes	No	Yes
Staff quarters	No	Medium	Yes	Yes	No[4]	No[4]	Yes	Yes	Yes	Yes	No	Yes

Notes:

[1] Methane, carbon dioxide, oxygen gas concentrations will be monitored by the gas detection system.

[2] Warning signs include “No Naked Flame”, “No Smoking” and “Potential Hazard of Landfill Gas” in both Chinese and English.

[3] Emergency situations include 1) power failure when mechanical ventilation system or gas detection system cannot work properly; or 2) oxygen is lower than 18% v/v, methane is higher than 20% of the LEL (1.0% v/v) or carbon dioxide is higher than 1.5% v/v.

[4] Air conditioning system integrated with mechanical ventilation system will be provided for such facilities. Thus, ventilation by natural air movement and wind scoop are not applicable.

[5] For the E&M plant rooms, golf club repairing workshops and staff quarters, either active control or combination of semi-active control and ventilation by natural air movement should be provided. In other words, if wind scoop and openable windows cannot be provided, mechanical ventilation system should be provided. The mechanical ventilation system will interlock with the always-on gas detection system. In case the gas concentrations exceed the trigger levels, the mechanical ventilation system will be operated to restore the gas concentrations back to safe concentrations as soon as possible.

[6] Confined spaces are defined under F&IU (Confined Spaces) Regulation. See **Section 9.4.6.18** and **Section 9.4.6.19**.

[7] Mechanical ventilation system such as ventilation fans could be installed at chambers, manhole or tanks with significant sizes to enhance ventilation and avoid LFG accumulation. The ventilation fans will interlock with the always-on gas detection system. In case the gas concentrations exceed the trigger levels, the mechanical ventilation system will be operated to restore the gas concentrations back to safe concentrations as soon as possible.

9.4.6.29 For the outdoor golf course, the overall risk level is **Low**. With reference to **Table 9.3** and **Table 9.4**, provision of passive control would be adequate. In view of that the Project Site is located adjacent to Tolo Harbour where the natural wind resources are sufficient, the outdoor golf course can rely on the natural wind for dispersion of LFG. Nevertheless, regular monitoring of surface gas emission in the golf course area will be continuously conducted by the existing landfill operator. The effectiveness of the implemented protection measures as well as the safety of the golf course users can be well evaluated.

9.4.7 Evaluation of Potential Impacts on Landfill Restoration Facilities

9.4.7.1 During the design stage of the Project, the existing locations of restoration facilities, including active LFG extraction wells, leachate monitoring wells, leachate pumphouses, drain pipes etc., will be identified. The surface drainage system will have been re-provided during the operational phase to facilitate the drainage of surface water and reduce water percolation to the waste mass and leachate formation. Landfill wells susceptible to filling activities during the construction phase will have been modified in the operational phase. Their functions will be maintained and the accesses for monitoring and maintenance will be preserved.

9.4.7.2 The major human activities atop the Project Site would be golfing and routine lawn mowing, but they are unlikely to affect the existing landfill restoration facilities such as passive vent trenches/pipes, active gas extraction wells, GMPs and landfill capping layer. Significant physical changes on the Project Site is not anticipated.

9.4.7.3 At the future detailed design stage, the architects and design engineers should review the locations and layout of existing landfill facilities. They shall incorporate protective design for the landfill to ensure the development of the golf course would not impose any adverse irreversible impact on the Shuen Wan Restored Landfill. Thus, adverse impacts on the existing landfill restoration facilities are not anticipated.

9.4.8 Recommended Precautionary and Protective Measures on Landfill Restoration Facilities

9.4.8.1 No adverse impacts on the landfill restoration facilities are anticipated during the operational phase of the Project. Notwithstanding, continuous monitoring would be undertaken by EPD's Landfill Operator to detect if any damage of landfill restoration facilities during the operation of the Project. A surge of LFG concentration or leachate level is a sign of damage of the landfill capping layer.

9.4.8.2 In case of any sign of damage of the landfill capping layer, EPD should be informed to arrange a detail inspection. Once damage of any landfill

restoration facility is confirmed, rectification works should be undertaken by the PP the soonest for acceptance by EPD.

9.4.8.3 During the operational phase, if the operator/site owner wishes to make any alteration, relocation or deletion of the existing landfill restoration facilities, including GMPs, active gas extraction wells, passive vent trenches/pipes, leachate pumphouses, leachate drain pipes and geomembrane of the landfill capping layer, EPD's approval should be obtained. Design Plan/Works Plan with method statement should be prepared with the certification by an independent Landfill Consultant and submitted to EPD for approval according to **Section 9.3.8** and **Section 9.3.9**.

9.4.8.4 The future golf course operator shall conduct rodent and pest control to minimise the damage of restoration facilities such as electrical and signal cables in particular for the pumping chambers.

9.5 Conclusion

9.5.1 Construction Phase

9.5.1.1 The results of this qualitative risk assessment for LFG hazards indicate the risk level from the Project during the construction phase is **Medium**. With the implementation of appropriate protective and precautionary measures according to LFG Hazard Assessment Guidance Note, adverse impacts on the targets are mitigated to acceptable level.

9.5.1.2 In addition, potential impacts from construction activities on existing landfill restoration facilities have been assessed. These include soil erosion arising from tree felling, site formation (include excavation and filling), relocation, modification, reprovision and demolition of existing landfill restoration facilities, road works and utilities installation, civil, electrical and mechanical works for buildings and ancillary facilities and provision of temporary site offices. With proper mitigation measures adopted, adverse impacts on the landfill restoration facilities are not anticipated.

9.5.2 Operational Phase

9.5.2.1 The results of this qualitative risk assessment for LFG hazards indicate the risk level from the Project during the operational phase is from **Low** to **High**. For the high risk targets such as indoor areas with free public access, a combination of active control system, passive control system, gas detection system and good site management should be provided. For the medium risk targets such as indoor areas with limited public access, semi-active control measures, together with passive control systems, gas detection system and good site management, should be provided. Maintenance staff working in the confined spaces should implement entry safety procedures as stipulated in the F&IU (Confined

Spaces) Regulation. By the provision of active and semi-active control systems, passive control system, gas detection system, good site management and entry safety procedures, the risk of the targets have been reduced to acceptable levels.

9.5.2.2 In addition, the operational impacts on the landfill restoration facilities have been reviewed. The major human activities atop the Project Site would be golfing and routine lawn mowing, but they are unlikely to affect the existing landfill restoration facilities. Adverse impacts on these facilities are not anticipated when appropriate maintenance, precautionary and protective measures are in place.

9.6 References

[1] Ireland EPA. 1999. Landfill Manual – Landfill Restoration and Aftercare. https://www.epa.ie/pubs/advice/licensee/EPA%20Landfill%20Restoration%20and%20Aftercare.pdf

[2] US EPA. 2012. A Citizen's Guide to Capping. https://clu-in.org/download/Citizens/a_citizens_guide_to_capping.pdf

[3] Wisconsin Department of Natural Resources. 2017. Development at Historic Fill Sites and Licensed Landfills: Considerations and Potential Problems. http://dnr.wi.gov/files/pdf/pubs/rr/rr683.pdf

[4] Wong C.T., Leung M.K., Wong M.K., & Tang W.C. 2013. Afteruse development of former landfill sites in Hong Kong. Journal of Rock Mechanics and Geotechnical Engineering 5 (2011), P443-451

[5] Annual Environmental Audit Report. 2012-2016.