Ireland-specific Good Practice Guidance for the Development of Ground Gas Conceptual Site Models – An IBN Position Statement

Ireland Brownfield Network

Ground Gas Good Practice Subgroup

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Authors & Editors

David Kerr – Risk and Due Diligence Manager at Amazon Web Services (LinkedIn Profile)

Melanie Thrush – Senior Geoenvironmental Engineer at Arup (LinkedIn Profile)

Sophie McDowell – Environmental Consultant at AECOM (LinkedIn Profile)

Owen Williams – Environmental Advisor at Brownfield Development Services (LinkedIn Profile)

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About the Ireland Brownfield Network

The Ireland Brownfield Network (IBN) was established in February 2012 by a collective of leading brownfield practitioners operating in various professions throughout Ireland. It is voluntarily run and organised by 14 committee members.

The Network aims to encourage constructive dialogue and interaction amongst all those involved in the redevelopment of brownfield land on the island of Ireland. In doing so, the collective learning experiences, good practices and effective strategies can then be shared and distributed.

The Network is free to join and open to all. Since its inception, the Network has run several free-to-attend conferences and networking events and has contributed to numerous government consultations relating to land contamination, planning, and waste - all with the view of improving the re-use of under-utilised lands throughout the island of Ireland.

About the IBN's Ground Gas Good Practice Sub-group

The IBN's Ground Gas Good Practice sub-group was established to promote and encourage the assessment and appropriate management of ground gas risks on brownfield sites in Ireland. Its ultimate objective is to publish an all-Ireland all-ground gas good practice guidance document specific to the region.

To deliver this objective, the IBN proposes to produce a series of Position Statements that will focus on various specific aspects of ground gas risk assessment and management. These Statements will be issued throughout 2023 and 2024 with the view to raise the profile of risks associated with ground gases and to engage with practitioners and developers to ensure good practice approaches are being adopted.

This position statement represents the first of a series of documents and is intended to cover a fundamental aspect of developing robust ground gas risk assessments – the production of a Ground Gas Conceptual Site Model (GGCSM). This cornerstone of the risk identification, assessment and management process is fundamental if existing and new developments are to be appropriately protected from the potential risks associated with ground gases.

Additional future Position Statements are likely to cover the application of risk matrixes and risk determinations, good practice in monitoring ground gases, the use of and application of Gas Screening

Values, the appropriate risk management design and application, and how to demonstrate suitably installed ground gas mitigation measures are in place to achieve sign-off positions.

On production of each Position Statement, it will be circulated for public consultation for further comments and opportunities for practitioners to contribute towards. On completion of all agreed Position Statements, these will be amalgamated into one single All-Ireland All-Ground Gas Good Practice Guidance Document.

Disclaimer

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1 Introduction

This Position Statement serves to define what is meant by a Ground Gas Conceptual Site Model (GGCSM), its importance within the risk assessment process, and provides guidance on how to develop such a model. Finally, an anonymised example GGCSM is presented to provide suggestions as to how GGCSMs are presented in accordance with this document.

All Position Statements and guidance documents serve to act as guidance and sign-posting documents that steer the reader to adopt good practice approaches. As with all contaminated land risk assessments, ground gas risks can be complex and highly site-specific; producing guidance documents for its management cannot therefore be prescriptive in nature and the IBN encourages and supports the application of sound professional judgement at every stage of the risk assessment process. Prior to conducting a ground gas risk assessment, practitioners should satisfy themselves that they have the required level of competency relevant to the site in question. Further guidance on demonstrating competency is available at the Ireland Brownfield Network website.

This Position Statement serves to briefly cover the foundations required to develop a GGCSM. It does not cover the process required for the identification of credible contaminant linkages nor the determination of potential risks.

For the purposes of this Position Statement, ground gases are defined as those that include methane (CH_4), carbon dioxide (CO_2), hydrogen sulphide (H_2S) and/or radon (Rn). Contaminated soils and groundwaters can also emit vapours associated with volatile organic compounds (VOC) that may pose a risk to human health and the environment. Whilst developing a Conceptual Site Model (CSM) for the management of these VOC risks is critical, the IBN's Ground Gas Good Practice sub-group is not currently addressing these potential sources. However, the principles of developing a robust CSM as presented in this Position Statement will still apply and practitioners may consider it suitable to adopt the procedures and approaches detailed herein.

2 What is a Conceptual Site Model?

The CSM has been a cornerstone of the contaminated land risk assessment discipline since its development as a risk- and evidence-based procedure. Consequently, CSM development and definitions appear throughout guidance documents, procedures, and Standards.

In its broadest sense, a CSM is a tool used to depict the relationships between the sources of contamination, the pathways by which contaminants migrate, and the individuals or the environments (the receptors) that could be impacted by the contaminants. The significance of the linkage and the magnitude of the risk that the linkage can cause is then determined by the risk assessment process.

A CSM is therefore the primary tool for organising and disseminating relevant information on which robust decision making can then be made and justified.

As the contaminated land risk assessment process is a tiered phased approach, the CSM remains a live tool throughout a site's risk management process until such time as the risks have been proven to be at an acceptable level. Consequently, all CSMs should be revisited and updated as new information comes to light and the risk assessment process proceeds.

A Ground Gas Conceptual Site Model (GGCSM) is therefore a CSM that deals solely with ground gas related matters (ie, the potential sources, how it can migrate, and who or what is at risk from them). As land contamination risks on sites can often be numerous and complex, in many circumstances it is beneficial to separate out the CSMs associated with soils, groundwater and ground gases. Where appropriate, the IBN would therefore encourage practitioners to produce standalone GGCSMs for inclusion within risk assessment reports.

CSMs can be presented as written descriptions, tabulated, demonstrated graphically or as a combination of all three. The IBN would recommend that, for sites where ground gas is an identified potential risk, a written CSM is supported by a graphical GGCSM that includes cross sections. Examples of anonymised graphical GGCSMs are provided in Appendix A.

Appendix B provides a list of guidance documents that cover the development of CSMs and ground gas risk assessments. Not all documents are relevant depending on the jurisdictional area in which a site is located and not all documents presented are specific to ground gas risk. A brief description of the relevant sections is provided along with a determination (marked with an X) as to which jurisdiction the document is applicable to.

The IBN considers that the normative reference for CSM standards relevant to both jurisdictions as being the ISO 21365:2020 *Soil quality. Conceptual site models for potentially contaminated sites* and would encourage practitioners to adopt its procedures when developing GGCSMs.

2.1 What are the Constituents of a GGCSM?

In IBN's opinion, there are six key elements of a GGCSM, and these are covered in more detail in Section 3:

1. The legal framework under which the risk assessment has been commissioned or conducted;

2. The stage of a site's assessment, development, and management;
3. The potential ground gas Sources;
4. The potential Pathways by which ground gases can migrate;
5. The current and future relevant Receptors that could be impacted by ground gases; and,
6. All uncertainties, assumptions and foreseeable events that could have a bearing on the risk understanding process.

3 Constituents of a GGCSM

3.1 Legal Context

The legal context under which a risk assessment is conducted has a bearing over the assessment's objectives and risk profiles. To support a GGCSM, the IBN considers it good practice to ensure that the legal context under which the assessment is conducted is provided.

Potential relevant legislative reasons for conducting a ground gas risk assessment would include, but are not limited to:

- Environmental Impact Assessments conducted as a requirement of Directive 2011/92/EU and 2014/52/EU if in ROI, or the Planning (Environmental Impact Assessment) Regulations (Northern Ireland) 2017 if in NI;
- Contaminated land risk assessments conducted in support of Planning applications on brownfield sites in compliance with requests from Local Planning Authorities under the Planning and Development Act 2000 if in the ROI, or the Planning Act (Northern Ireland) 2011 if in NI;
- Site Condition Reports conducted in accordance with Permit applications or surrenders in compliance with the EPA (Integrated Pollution Control)(Licensing)(Amendment) Regulations 2020 (S.I. No. 189 of 2020) if in the ROI, or the Pollution Prevention and Control Regulations (Northern Ireland) 2003 if in NI;
- Third party claims where damage has been alleged to have occurred under the Civil Liability & Courts Act 2004 if in ROI, or the Clean Neighbourhoods and Environment Act (Northern Ireland) 2011 if in NI; or,
- Environmental damage investigations under the European Communities (Environmental Liability) Regulations (2008 to 2011) if in the ROI, or the Environmental Liability (Prevention and Remediation) (Amendment) Regulations (Northern Ireland) 2015 if in NI.

3.2 Site Development and Risk Assessment Stage

Contaminated land risk assessments are a phased and re-iterative process. As an assessment progresses, so too does the understanding of the hazards present and the risks that they may pose. Consequently, it is beneficial to present the stage in the risk assessment process (Preliminary, Generic or Detailed Quantitative Risk Assessments, Options Appraisals, Remediation Implementation Plans, etc) that the developed GGCSM refers to so that the reviewer is made aware of the current site understanding and the likely next steps of the process.

Similarly, as a site progresses through the development cycle, the risk scenario will change. Consequently, it is beneficial to also present the stage of a site's development that the GGCSM is referring to (ie, current state, pre-construction, during construction, post construction phases, etc).

As the development of a GGCSM is a live and re-iterative process, this demonstration of the risk assessment and development context in which the GGCSM refers to allows for defensible decision-making throughout a site's progression and ensures that all identified potential risks are taken forward through the process to their appropriate conclusion.

3.3 Potential Sources

The primary sources of ground gases in Ireland can be categorised into naturally occurring or man-made sources. Each have their own gas composition characteristics, generation potential and risk profiles. Identifying all potential sources that may influence a site is an important step in understanding the potential risks that ground gas hazards could present and in the finding of appropriate and proportional solutions to any identified unacceptable risks present.

Naturally occurring primary sources of ground gas include:

- Soils and rock (shales, granite, gneiss, limestone, etc) containing naturally occurring uranium and capable of emitting radon gas. The degradation products of radon have the potential to damage lung tissue and cause lung cancer. Maps of potential high radon areas are available at www.epa.ie/environment-and-you/radon/radon-map for the ROI and at www.gov.uk/government/publications/radon-indicative-atlas-for-northern-ireland for NI;
- Carbonate-rich strata (limestone and chalk) capable of producing carbon dioxide gases when in contact with acidic water. Carbon dioxide gas is a greenhouse gas and an asphyxiant, causing noticeable health impacts when concentrations begin to exceed 0.5% in air. This source is considered to have a Very Low gas generation potential (Figure 6, page 32 of BS8576); and,
- Organic-rich deposits (shales, peat and alluvial deposits) capable of emitting methane gases. Methane has a greenhouse gas potency greater than carbon dioxide and is explosive when concentrations in air are between 5 and 15%. This source is considered to have a Low to Very Low gas generation potential (Figure 6, page 32 of BS8576) .

Man-made primary sources of ground gas include:

- Re-worked surface deposits (Made Ground). Depending on its Total Organic Carbon content, Made Ground has the potential to generate carbon dioxide and methane. This source is considered to have a Low to Very Low gas generation potential (Figure 6, page 32 of BS8576);

- Dredged material deposited on land. Large areas of Belfast (Figure 1a) and Dublin (Figure 1b) have been reclaimed from intertidal areas through the deposition of dredged materials. Dredging material (or Dock Silt) has a Low potential to generate carbon dioxide and methane (Figure 6, page 32 of BS8576);
- Landfill sites. Depending on their age, content, state and construction details, landfills have the potential to generate methane, carbon dioxide, carbon monoxide, hydrogen sulphide, and trace gases (The Environment Agency's 2010 LFTGN04 Guidance for Monitoring Trace Components in Landfill Gas). These sources have the potential to generate significant volumes of gas over many decades. However, not all landfills are capable of producing sustained gas generation rates. Consequently, this source has a very site-specific and wide range of gas generation potentials ranging from Very Low to Very High (Figure 6, page 32 of BS8576); and,
- Coal Mines, adits, and shafts. Coal mines have the potential to generate methane, carbon dioxide, carbon monoxide and oxygen depleted air. The distribution of coal mines in Ireland is limited to the Arigna area in County Sligo, the Carlow Coalfields to the west of Carlow, the Tipperary Coalfields to the west of Kilkenny, the Abbeyfeale Coalfields in west County Limerick and the Drominagh Coalfields in the north-west County Cork, Ballycastle in the north of Antrim and Coalisland in County Tyron (Northern Mine Research Society). Coal mines have gas generation potentials ranging from Moderate to Very High (CL:AIRE's 2021 Publication: Good Practice for Risk Assessment for Coal Mine Gas Emissions).

The above list is not exhaustive but serves to present the most likely primary ground gas sources to be encountered in Ireland.

Once identified, assessing the constituents, characteristic and generation potential of these primary sources then becomes a constituent part of the risk assessment process. Further good practice documents relating to risk assessment methodologies and approaches will be published in future IBN practice notes.

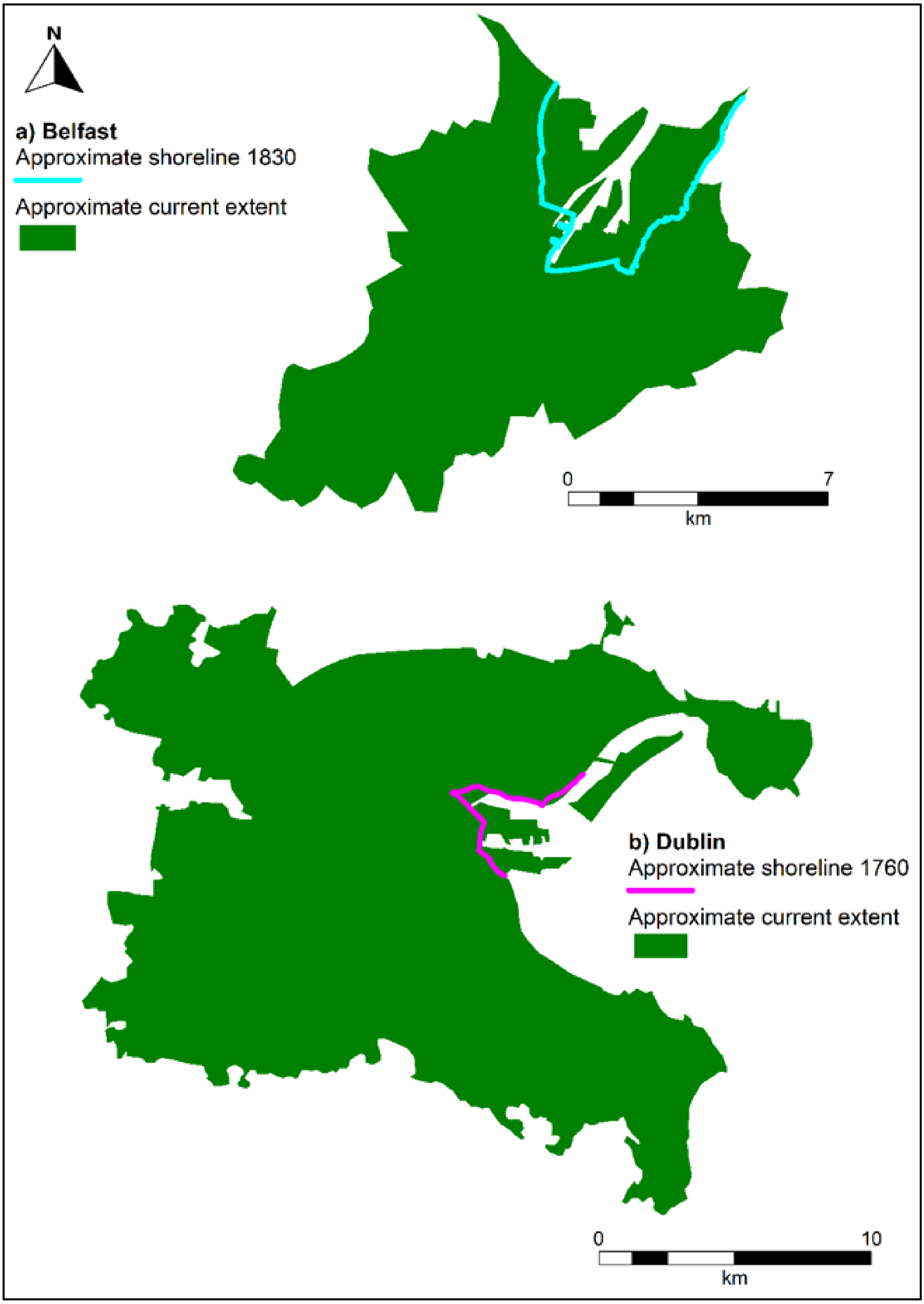


Figure 1: Approximate original shorelines of Belfast (1830) and Dublin (1760) and land reclaimed from inter-tidal areas.

3.4 Potential Pathways

Ground gases can migrate laterally and vertically through unsaturated and saturated soils and rocks until they meet a confined air space within an overlying structure or escape to the atmosphere. Ground gas movement is driven by diffusion and/or by pressure differential (sometimes referred to as advective flow). The influence of these driving factors on a site's ground gas risk will be covered in future Position Statements.

Dependent on the rate at which ground gases are generated, diffusion coefficients and pressure differentials present on a site, gases can move through pores and fissures within the unsaturated zones. The ability of the strata to allow gases to migrate will depend on the physical properties of that strata (pore size, void fraction, particle density, etc). Dissolved gases can also migrate through the saturated zone and become liberated into the unsaturated zone or to atmosphere.

Consequently, understanding the physical properties of soils and strata beneath a site is an important aspect for conceptualising a site and for the risk assessment process. Many geotechnical properties (hydraulic conductivity and transmissivity for instance) used to measure a soil or strata's groundwater characteristics are directly relevant to understanding a soil or strata's ability to allow ground gases to migrate.

For instance, Irish clays are considered to have permeability rates of less than 0.005 meters per day, whereas sands and gravels have permeability rates of more than 5 meters per day (Table 7 IrishAquifersPropertiesAreferencemanualandguideVersion10March2015.pdf (gsi.ie))

Probably the most effective pathway for ground gas migration is along preferential pathways. These natural or man-made voids have the potential to transfer gases at significant volumes over significant distances from its source. Examples of in-ground preferential pathways include but are not limited to:

- Gravel or sand lenses within less-porous strata such as clays;
- Permeable fill material;
- Rock fractures, desiccation cracks and macropores;
- Existing or new service trenches, ducts and access chambers;
- Service pipework and casings, and attenuation tanks;
- Existing, new and abandoned site investigation monitoring wells;
- Mine shafts (CL:AIRE's 2021 Publication: Good Practice for Risk Assessment for Coal Mine Gas Emissions); and,

- Certain piled and deep foundations (ICE Publication 2021: Piled Foundations and Pathways for Ground Gas Migration).

Potential preferential pathways into buildings include, but are not limited to:

- Service entry and egress points;
- Cavity wall vents;
- Cracks and gaps within floor slabs, basement walls, and around service entry points; and,
- Lift shaft pits.

Dependent on the site development and risk assessment stage (Section 3.2) that the GGCSM refers to, it may be relevant to include and refer to future pathways that will be generated by the development itself and/or be introduced at some foreseeable event in the future (Section 3.6).

3.5 Relevant Receptors

As the receptor drives the risk profile in an assessment, some practitioners argue that the Receptor should be the first aspect of the contaminant linkage to be considered and defined. For instance, a receptor incorporating an open car park would have a significantly differing risk profile to a receptor incorporating a small airtight building infrequently visited (such as a pumping station).

Consequently, to 'set the risk scene' and to immediately focus relevant attention to the development of a GGCSM, practitioners may wish to commence the building of its CSM with a detailed review of the relevant receptors present on its site (once having completed sections 3.1 and 3.2).

Potentially relevant receptors include:

- Atmosphere;
- On- and off-site users and visitors to a site; and,
- Built structures on and below the surface of a site and within close proximity of a site.

As some ground gases have a global warming potential, risk assessments may need to consider the impact on the immediate and global atmosphere. Dependent on site uses and gassing potential, site visitors and users may also need to be included within the GGCSM.

The construction and use of a building strongly influences the potential risk profile for buildings and above ground structures. To assist in the categorisation of this risk profiling, BS 8485:2015+A1:2019 uses the following Building Types to distinguish between building ownership for future proposed constructions:

- Building Type A (a high-risk building) is a residential housing or small retail premises in private ownership where future alterations and maintenance are uncontrolled;
- Building Type B (a high to medium risk building) is a private or commercial property where some degree of management control on alterations and property maintenance are exerted (such as schools, hospitals, and hotels);
- Building Type C (a medium-risk building) is a commercial building with management control of alterations and building maintenance (such as offices, retail premises and public buildings); and,
- Building Type D (a low-risk building) is a building in corporate ownership with full building management controls of alterations and building maintenance (such as retail parks, factories and warehouses).

In addition to building ownership, building use (frequency of visits, type of users, etc), internal void spaces and ventilation rates is an important consideration for the GGCSM. Type A buildings with small internal rooms (broom cupboards, living spaces, etc) will have a very different risk exposure to ground gasses than a Type D large volumed warehouse with roller shutter doors. Existing and future build designs, and their current and foreseeable uses all therefore need to be presented within a GGCSM.

In terms of buildings, floor and foundation construction detail is critical. Most private dwellings across Ireland have historically been constructed on ground bearing floor slabs.

The ROI's Building Regulations 2020 Technical Guidance Document C, Site Preparation and Moisture Ingress and NI's Building Control's 2013 Site preparation and resistance to contaminates and moisture: Approved Document C outlines the requirements for floor and foundation design in new builds, mainly aimed at preventing Radon ingress into domestic properties.

In the ROI, and in a response to the issue relating to pyrite containing aggregates being used in certain parts of the country, Document C contains direct reference to Standard Recommendation 21 (SR21) which is the Irish implementation of EN 13242, the European Norm for unbound aggregates for use in construction. This document includes specifications for materials for use beneath floor slabs. At the request of the Radiological Protection Institute Ireland, a material type was included in the specification named *T2 Perm*. This material is a 4 to 40mm clean graded stone which was specified to act as a preferential pathway for radon. Given the Building Regulations call up the inclusion of these materials in all new builds in ROI, it is now common to find standard construction details for residential properties that include a 200mm thick layer of gas permeable fill directly beneath the floor slab as shown in Diagram 4 of the Technical Guidance Document C, Site Preparation and Moisture Ingress.

Finally, receptor details for a robust GGCSM should also include all construction related preferential pathways as listed in Section 3.4.

3.6 Uncertainties, Assumptions and Foreseeable Events

Regardless of the stage of the risk assessment process, all GGCSMs need to stipulate and present the uncertainties and assumptions inherent in the model and in the way that it was developed. Only when all uncertainties and assumptions are presented can robust and transparent determinations of risk be produced on which all stakeholders can then have reliance upon.

Using the GGCSM as a vehicle for identifying assumptions and uncertainties also allows for practitioners to robustly demonstrate the next phases of assessment to address the outstanding uncertainties or demonstrate that an exit from the risk assessment process is fully justified.

Section 3.2 requires a GGCSM to stipulate at what stage in a site's life- or development-cycle it was developed for. As time progresses and a site progresses through the development process, events may occur that may alter the ground gas risk profile of a site. Many of these changes should be foreseeable to the practitioner and, in keeping with ISO21365, GGCSMs should therefore incorporate an inclusion of 'foreseeable events.'

The IBN consider, as a minimum, the foreseeable events that should be considered by practitioners during the development of a GGCSM include:

- Possibilities of new sources (such as new fill materials, off-site active landfill gas extraction systems being decommissioned, etc) new exposure pathways and new receptors being introduced during its construction and during the lifetime of the development;
- Flooding (fluvial, groundwater and seawater);
- Rising groundwater and seawater levels;
- Extreme weather conditions and climate change influenced site alterations;
- Ground heave or settlement;
- Changes of use, alterations and additions to a building or site; and
- Changes in build techniques and construction detail.

A significant proportion of the foreseeable future events that a practitioner must consider within a GGCSM relates to climate change and the IBN would encourage the use of referenced site-specific sources of climate change predictions. Within the ROI, climate change predictions are currently being standardized through Met Eireann's Translate Project and climate change related changes to groundwater bodies is being considered by the Geological Survey Ireland's GWClimate Project. NI-specific data is less evolved however, the UK's Environmental Information Data Centre intends to increase its coverage of NI with its eFLaG Project.

4 Idealised Example of a GGCSM

To demonstrate the requirements of what the IBN would consider represents a robust and practical GGCSM, Appendix A presents the conceptualisation of a theoretical site being progressed through the Planning process in Northern Ireland for a private residential development.

Figure 1 of Appendix A represents the findings of a pre-construction and preliminary assessment of ground gas risks based on available desk-based data and information. Evidence suggests the presence of an off-site potential gas source associated with a former landfill c.150m east of a site being considered for development. Enquiries with the local Environmental Health Department also indicated the potential presence of Made Ground on the site. Reviews of large-scale geology and deposit maps indicate that the site is located on sands and gravel riverbed deposits overlying a mudstone greywacke bedrock. These findings would be described within the text of a report but also should also be summarised in graphical form similar to that presented in Figure 1 of Appendix A.

Based on the findings of this preliminary assessment, two potential sources are identified, where the potential lateral and vertical migration of gases could impact on a single receptor (being the atmosphere). Uncertainties within this preliminary GGCSM include:

- the unknown depths of the various geological strata;
- the existence and level of an underlying groundwater body;
- the gassing generation rates of the landfill and whether it is suitably capped;
- the gassing generation rates of the made ground; and,
- whether the permeability of the unsaturated zone is able to facilitate lateral and vertical migration of gasses.

These uncertainties are demonstrated on the graphic by using '?' marks.

The site is then progressed to the design and implementation of an intrusive site investigation. The findings and the uncertainties detailed within the preliminary GGCSM are used to assist in the formulation of these investigations.

In order to progress with the risk assessment process and post findings of the site investigation, a further GGCSM is developed Figure 2 of Appendix B. This investigation and further risk assessment allows for the graphical clarification of the uncertainties identified above, the addition of the future receptors, an additional potential pathway, and the monitoring data and the locations from where the data originated from. Based on this graphical interpretation and supporting detailed information within a risk assessment report itself, the practitioner can then make informed and justified risk-based decisions relating to the next phase of this site's management.

Examples of remaining uncertainties not covered by Figure 2 of Appendix B GGCSM could include:

- Foundation design for the proposed properties;
- Location of service ducts and trenches and their ability to act as preferential pathways;
- The presence of an active landfill gas management system on the closed landfill;
- The validity of the results obtained from a flooded response zone at BH3; and,
- The permeability of the sands and gravel to allow for horizontal migration of ground gases.

Examples of future foreseeable events that would require inclusion within the GGCSM (possibly through an additional graphic but most certainly through explanatory text included within a risk assessment) might include:

- Changes in groundwater levels and the associated impact on the landfill's gas generation and migration potential;
- Amendments to the landfill's management such as changes to its gas management systems or capping layers;
- Changes to proposed foundation design of the new builds;
- Future occupiers of the site amending or extending their dwellings and constructing structures in the garden areas (sheds, garden offices, etc);
- Etc.

5 Conclusion

CSMs are a critical aspect of understanding risks associated with contaminated sites. Considering the importance of this tool, the IBN trusts that practitioners find value in this Position Statement in their assessment of, and management of, ground gases in Ireland.

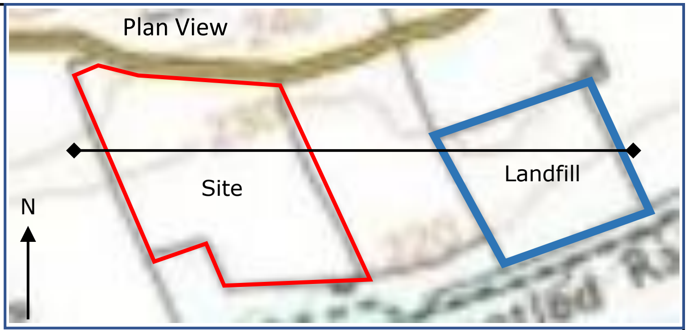
This Position Statement has been prepared with the view of supporting the continual improvement of ground gas management in Ireland. To that end, it will remain a live document being continually reviewed and updated as good practice and Standards evolve. The Position Statement has been through a period of formal peer reviewing and public consultation. However, practitioners are encouraged to contribute to this Statement's evolution at any time convenient to themselves and to contact the IBN at info@irelandbrownfieldnetwork.com.

Now that the principles and general content of a GGCSM have been detailed, the IBN will progress to producing Position Statements relating to CSM-led ground gas monitoring strategies, CSM-appropriate risk assessment procedures and CSM-influenced gas mitigation measures.

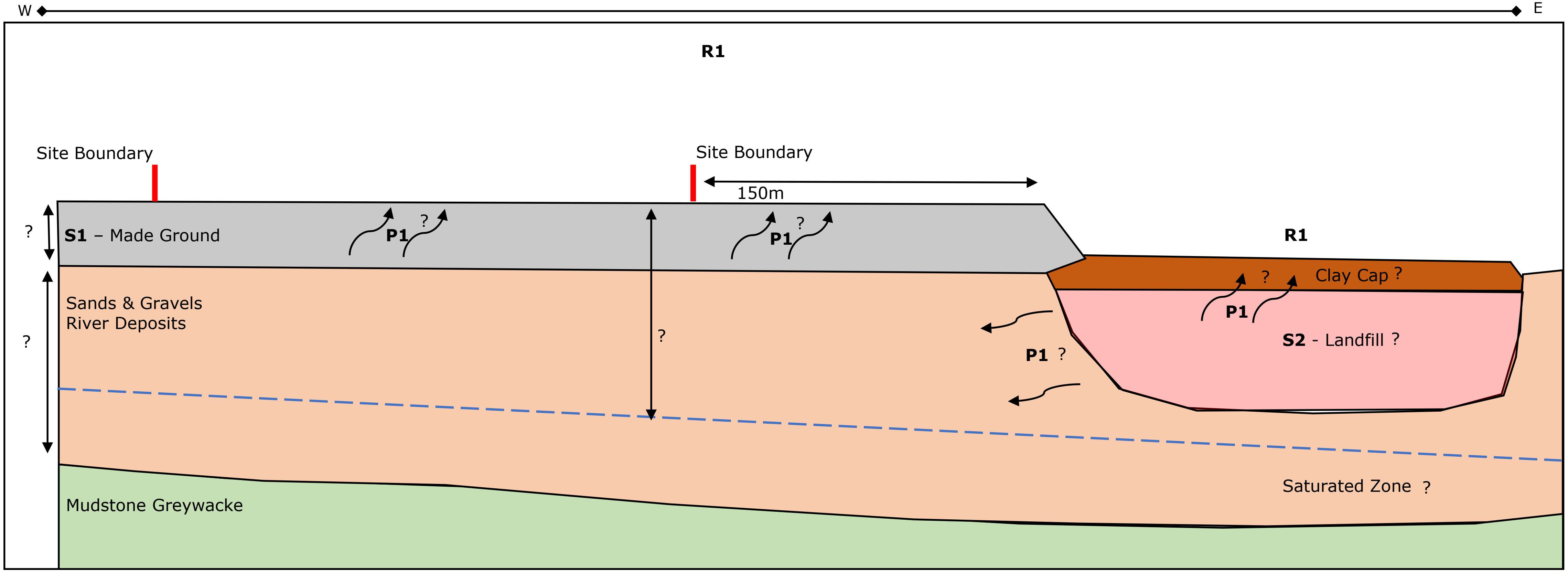
Appendix A - Example Graphical Ground Gas Conceptual Site Models

Diagrammatic Pre-construction Ground-gas Conceptual Site Model for Quarry Road, County X.

Potential Ground-gas Source	Potential Pathways	Current Receptors
S1 On-site Made Ground deposits of re-worked clays **S2** Off-site 1990 landfill	**P1** Lateral and vertical migration through the unsaturated zone	**R1** Atmosphere



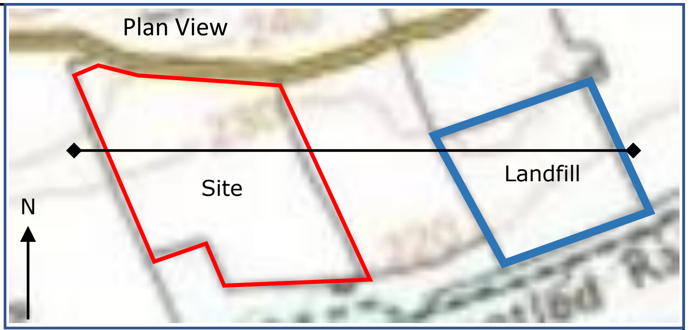
Cross Section View

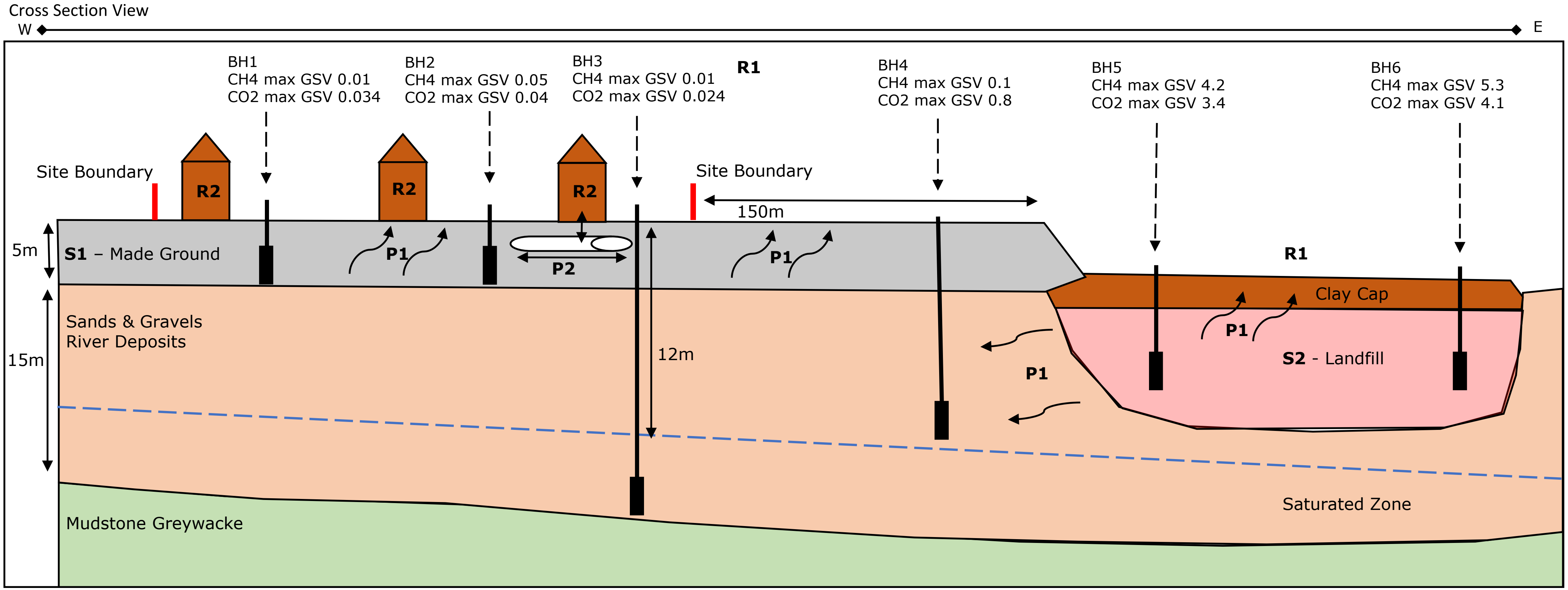


Not to scale – For Diagrammatic Presentation Only   Site Address: 42, Quarry Road, County X, Postcode.   Drawn by: X   Checked by: Y

Diagrammatic Post-construction Ground-gas Conceptual Site Model for Quarry Road, County X.

Potential Ground-gas Source	Potential Pathways	Receptors
S1 On-site Made Ground deposits of re-worked clays **S2** Off-site 1990 capped landfill	**P1** Lateral and vertical migration through the unsaturated zone **P2** Lateral migration and vertical penetration along service trenches and entry points	**R1** Atmosphere **R2** Residential Properties





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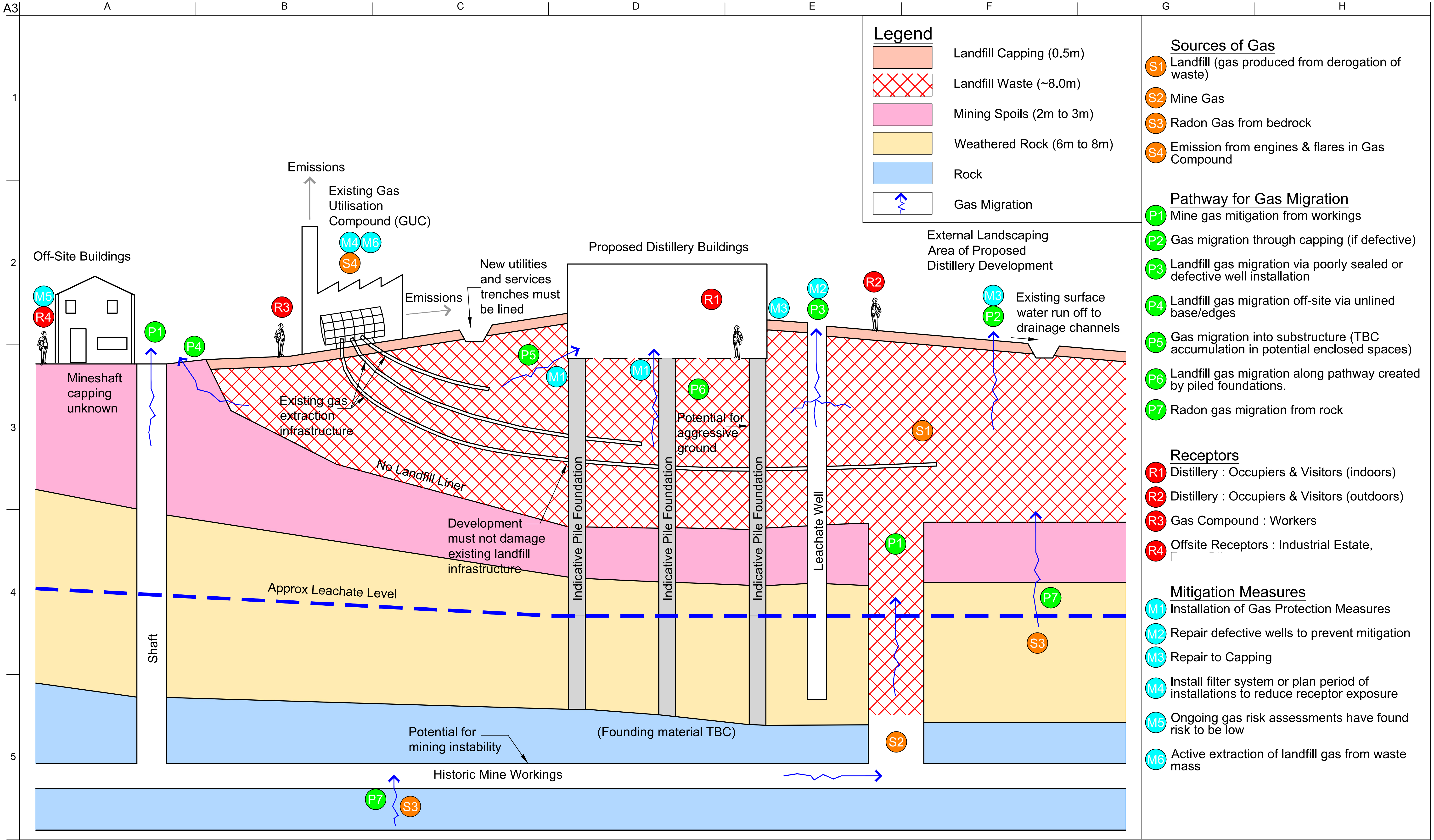

Drawing Title

Conceptual Site Model
(for Landfill related issues)

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Appendix B - Guidance documents for the development of Conceptual Site Models

Generic CSM Guidance Documents:

ROI	NI	Category	Guidance	Summary of relevance to CSMs
	X	Environment Agency guidance	Land contamination risk management (LCRM) (available at https://www.gov.uk/government/publications/land-contamination-risk-management-lcrm)	• Refers to the importance of a conceptual site model throughout the various risk assessment stages, emphasising that it is an iterative process that should be updated as you progress through LCRM. • Notes that you can present a conceptual site model in different ways (written description, tabular or matrix description, drawing or other diagrammatic illustration). • Specifically notes that the conceptual site model should be included in the verification report to demonstrate that the remediation objectives have been met.
	X	Environment Agency guidance	Model Procedures for the Management of Land Contamination (CLR11).	• Figure 2A, insert quotes from Page 50, Although formally withdrawn in the UK, many guidance documents within the ROI and NI continue to refer to its content
	X	Environment Agency guidance	Guidance on Desk Studies and Conceptual Site Models in Ecological Risk Assessment. Science Report – SC070009/SR2a. (2008)	• Not specific to Ground Gas but good section on CSMs
	X	British Standard	BS 10175:2011+A2:2017 'Investigation of potentially contaminated sites – Code of practice'	• Definition of CSM as 'characteristics of a site that are relevant to the occurrence and potential effects of ground contamination that describe the nature and sources of contamination; the ground, groundwater, surface water, ground gases and volatile organic compounds (VOCs) that could be present; the environmental setting; potential migration pathways; and potential receptors'. • Usually presented in tabular, textual and/ or diagrammatic form. • Emphasises the importance of revising the conceptual model throughout the site investigation process; preliminary investigation, exploratory investigation, detailed investigation, supplementary investigations. • Separate conceptual models can/should be developed for separate zones. • Data gaps and uncertainty in conceptual model should be highlighted.
	X	Environment Agency Guidance	National Groundwater & Contaminated Land Centre report NC/99/38/2 'Guide to Good Practice for the Development of Conceptual Models and the Selection and Application of	• Definition of conceptual model as 'A simplified representation of how the real system is believed to behave based on a qualitative analysis of field data. A quantitative conceptual model includes preliminary calculations for key processes'. • Section 3 provides significant detail on development of conceptual models. • States that 'preparation of plans, contour maps, cross-sections and block diagrams is essential in the development of a conceptual model'.

ROI	NI	Category	Guidance	Summary of relevance to CSMs
			Mathematical Models of Contaminant Transport Processes in the Subsurface'	• Figures 3.4, 3.5, 3.6 and 3.7 provide example CSMs.
X		EPA Contaminated Land Guidance	Management of Contaminated Land & Groundwater at EPA Licenced Sites (2013)	• The CSM is identified as a critical element of the methodology and something that underpins the whole for the assessment of the land and groundwater environment. • Diagrammatic CSMs are the preferred model and should always be used (sample CSM provided). Well-constructed matrices and network diagrams may also be effective, particularly in the latter stages of the process when attention is focused on specific and determined contaminant linkages.
X		EPA Code of Practice	EPA Code of Practice: Environmental Risk Assessment for Unregulated Waste Disposal Sites (2007)	• CSM defined as a textual or graphical representation of the relationship(s) and receptor(s) developed on the basis of hazard identification and refined during subsequent phases of assessment' (Environment Agency, 2000). • CSM development determined to be an iterative process and the principles applied are closely aligned with the proposed approach to risk assessment. There are essentially three key stages of CSM development: 1) Desk Study and Site Inspection (including walkover survey)(which provides information for the initial development of a CSM). 2) Site Investigation (that may be required to test and refine the initial model). 3) Environmental monitoring/modelling to validate the CSM

Specific Ground Gas Guidance Documents and sections where CSM is discussed:

ROI	NI	Category	Guidance	Summary of relevance to CSM
	X	British Standard	BS 8576:2013 'Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs)'	• Emphasises importance of conceptual model from preliminary risk assessment stage through to designing and completing the site investigation. • Examples of conceptual models provided in Figures 1-3. • Specifically states in Section 6 that geological cross sections should be provided if the ground gas investigation is to assess migration of gas outside a source or to assess gas emissions to buildings or other receptors immediately above the source. These cross sections should show credible migration pathways and sources of gas, and should be used to decide where the response zones of monitoring wells should be located.
	X	British Standard	BS 8485:2015+A1:2019 'Code of practice for the design of protective measures for methane and carbon dioxide	• Conceptual site model should define the ground gas sources, sensitive receptors (persons using the building, the building structure and fabric) and the pathways between the sources and receptors. • Figure 4 provides an example conceptual site model.

ROI	NI	Category	Guidance	Summary of relevance to CSM
			ground gases for new buildings’	• Emphasises the importance of interpreting the ground gas data in accordance with the conceptual site model.
X	X	Guidance (specific to ground gases)	CIRIA C665 ‘Assessing risks posed by hazardous ground gases to buildings’	• Defines conceptual site model as ‘a representation of the characterisation of a site in diagrammatical and/or written form that shows the possible relationships between the contaminants, pathway and receptors. This shows the potential risks that the site poses given the intended operations and future use on the site’. • Initial conceptual site model to identify principal contaminant linkages. • Section 3.2.3 specifically deals with conceptual site models, providing an example in Figure 3.1. • Notes that the conceptual site model should be adequately described in the text and illustrated by appropriate plans, drawings, cross sections etc. • In Section 8.6 notes that ‘a proper understanding of the conceptual site model is critical in any subsequent assessment of risk (qualitative or quantitative)’.
X	X	Guidance (specific to VOCs)	CIRIA C682 ‘The VOCs Handbook, Investigating, assessing and managing risks from inhalation of VOCs at land affected by contamination’	• Defines conceptual site model as ‘A representation of the characterisation of a site in diagrammatical and/or written form that shows the possible relationships between the contaminants, pathway and receptors. This helps to evaluate the potential risks that the site poses given the intended operations and future use of the site’. • Figure 2.3 provides schematic CSM. • Quick reference 4.1 on conceptual site model development. • Appendix A4 provides a conceptual site model checklist.
X	X	Guidance (specific to methane and carbon dioxide ground gases)	NHBC guidance ‘Guidance on evaluation of development proposals on sites where methane and carbon dioxide are present’ (Report edition No. 4, March 2007)	• Conceptual Site Model must be capable of predicting worst case temporal conditions that the site may experience, so that these can be used in the ground gas risk assessment. Ground gas protection measures to be installed must be capable of coping with this event. • Section 8 specifically deals with Developing a Conceptual Site Model, stating that it is a simple model of all known site features used to identify potential contaminant linkages. • Factors to be included in CSM are source of ground gas, natural and anthropogenic migration pathways, meteorological conditions, geology and surface effects.
	X	Guidance (specific to ground gases)	Chartered Institute of Environmental Health: London ‘The Local Authority Guide to Ground Gas’ (September 2008)	• Conceptual model defined as ‘A theoretical representation of the ground below and around a site, including potential gas sources, migration pathways, receptors and natural barriers to gas migration’. • Notes that the first step in modelling gas migration is to develop a conceptual model for the site which identifies potential migration pathways.

ROI	NI	Category	Guidance	Summary of relevance to CSM
				• Example conceptual model provided in Figure 6.1. It is noted that the best and most easily understood way of creating a conceptual model is to draw a diagrammatical cross-section of the site. • Conceptual model should include ground conditions, all potential sources of ground gases or vapours, all potential migration pathways, all potential receptors and any natural barriers to gas migration.
X	X	Research bulletin (specific to ground gases)	Cl:aire Research Bulletin RB 17 'A Pragmatic Approach to Ground Gas Risk Assessment'	• Notes that the development of a conceptual model is important and should be based on an understanding of the history of the site and the nature of the source material, as well as pathways and receptors. • 'Clear graphical representation of the conceptual model is recommended' and can be best achieved using geological cross sections which also show topography and the proposed development.
X	X	Technical Bulletin (specific to ground gases)	Cl:aire Technical Bulletin TB 18 'Continuous Ground-Gas Monitoring and the Lines of Evidence Approach to Risk Assessment'	• Notes that a schematic conceptual site model should be used to understand the characteristics of the site and possible contaminant linkages before ground gas monitoring is carried out.
	X	NHBC	Guidance for the Safe Development of Housing on Land Affected by Contamination R&D66: (2008) Volume 1	• Section 1.6, Pages 31 to 33 - Not specific to Ground Gas but good section on CSMs