

BS 8485:2015+A1:2019



BSI Standards Publication

**Code of practice for the design of
protective measures for methane
and carbon dioxide ground gases for
new buildings**

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Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 30 June 2015. It was prepared by Technical Committee EH/4, *Soil quality*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

BS 8485:2015 superseded BS 8485:2007, which has been withdrawn.

BS 8485:2015+A1:2019 supersedes BS 8485:2015, which is withdrawn.

Information about this document

This was a full revision of the standard, and introduced the following principal changes:

- inclusion of more detailed recommendations on the interpretation of gas monitoring data and assignment of the gas screening value;
- inclusion of four building type definitions and amendments to the gas protection scores recommended for different characteristic situations;
- inclusion of recommendations for reporting of gas protection measures at the design, installation and post-construction (verification) stages;
- revision of recommendations on the design of ventilation protective measures;
- inclusion of recommendations on membrane selection and verification;
- inclusion of a method of site characterization without gas monitoring data (based on RB17 [1]);
- inclusion of worked examples of solution choices for a range of different ground gas conditions and building types;
- inclusion of informative guidance on radon gas and volatile organic compounds in [Annex G](#) and [Annex H](#), respectively;
- inclusion of cross references to BS 8576:2013 and BS 10175:2011+A1:2013 as the key sources of good practice on investigations for ground gas; and
- inclusion of cross references to other relevant UK good practice guidance published since the publication of BS 8485:2007, including guidance from CIRIA, NHBC, CL:AIRE and Wilson, Card and Haines.

Text introduced or altered by Amendment No. 1 is indicated in the text by tags A1 A1. Minor editorial changes are not tagged.

Use of this document

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

The word “should” is used to express recommendations of this standard. The word “may” is used in the text to express permissibility, e.g. as an alternative to the primary recommendation of the Clause. The word “can” is used to express possibility, e.g. a consequence of an action or an event.

Notes and commentaries are provided throughout the text of this standard. Notes give references and additional information that are important but do not form part of the recommendations. Commentaries give background information.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Introduction

Toxic, asphyxiating and flammable and potentially explosive ground gases can enter buildings and other structures on and below the ground. They variously pose potential risks to occupants and users, and to the structures themselves.

This British Standard is intended to be used by designers of gas protection measures and by regulators involved in the assessment of design solutions. It recognizes that there are a number of factors requiring consideration which affect the sensitivity of a development to the effects of ground gas, and that there is a range of design solutions available for different situations. It is anticipated that specialist advice is needed in the assessment of the ground gas data and in the risk assessment phase.

This British Standard provides a framework, in line with *Model procedures for the management of land contamination*, CLR11 [2], which provides designers with information about what is needed for an adequate ground gas site investigation. It also provides an approach to determine appropriate ground gas parameters that can be used to identify a range of possible design solutions for protection against the presence of methane and carbon dioxide on a development site. The framework is not prescriptive and professional judgement may be made as to the acceptability of risk and whether there might be benefit in undertaking more rigorous site assessment or adopting conservative measures in design. Emphasis is placed on the justification and recording of risk assessments and design decisions throughout the process.

A variety of gases might be present in the ground naturally, or be present as a result of contamination of the ground, or arise from buried wastes. In addition to the main components found in air (nitrogen and oxygen), ground gas can contain other gases (e.g. methane, carbon dioxide, carbon monoxide, hydrogen sulfide, ammonia, helium, neon, argon, xenon, radon, etc.). It can also contain volatile organic compounds (VOCs) or inorganic vapours (mercury).

Methane (which is flammable and an asphyxiant) and carbon dioxide (which is toxic and an asphyxiant) can originate from a range of sources including:

- land-filled wastes;
- degradable material present within the soil matrix of made ground;
- peat and organic matter within alluvial deposits;
- migrating landfill leachate;
- spilled or leaked petroleum hydrocarbons;
- silt formed in water bodies (e.g. ponds, docks and rivers);
- some natural deposits (e.g. chalk and coal measure strata); and
- leaks of mains gas (natural gas) and sewer gas.

Wherever biodegradable materials are present, microbial activity produces methane and/or carbon dioxide depending on whether conditions are aerobic or anaerobic. A number of additional trace gases can also be produced.

Permanent gases such as methane, carbon dioxide and carbon monoxide which might be present in coal measure strata can also emanate from old mine workings (guidance is given in *CIRIA Report 130* [3]). Combusting coal measure strata, including waste in colliery spoil tips, can release carbon monoxide, as can smouldering domestic waste. Under some circumstances, sulfur rich deposits such as gypsum waste and some slags can release substantial quantities of hydrogen sulfide; for example, when sulfur-bearing wastes and domestic refuse are mixed.

1 Scope

This British Standard gives recommendations on ground gas site characterization and the choice of solutions for the design of integral gas protective measures for new buildings to prevent entry of carbon dioxide and methane, and provide a safe internal environment.

This British Standard gives a process that can be used to demonstrate that risks posed by the potential or actual presence of carbon dioxide and methane have been addressed.

This British Standard does not cover protection of new buildings against other hazardous ground gases. Nor does this British Standard cover protection of buildings into which methane and carbon dioxide might be introduced by the activities for which they are used (for example, water pumping stations).

The retrospective design of protection measures for completed buildings and the design of retrospective protection measures after completion of building construction are not covered in this British Standard.

NOTE 1 Guidance on radon and VOCs is given in [Annex G](#) and [Annex H](#).

NOTE 2 This British Standard does not give recommendations on oxygen depletion.

NOTE 3 The assessment and decision making stages are presented in the form of process flow charts ([Figure 3](#), [Figure 5](#) and [Figure 6](#)), accompanying information and explanatory guidance and, where appropriate, references to other guidance and information. The contents of this British Standard are shown in the document flow chart in [Figure 1](#).

NOTE 4 Full protection of buildings might require a range of measures (for example, to control gas migration, to protect car parking and garden areas, and to monitor gas concentrations) in addition to those incorporated into the building. However, guidance on these is not provided and is available in the *Ground Gas Handbook* [\[4\]](#) and CIRIA Report 149 [\[5\]](#).

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

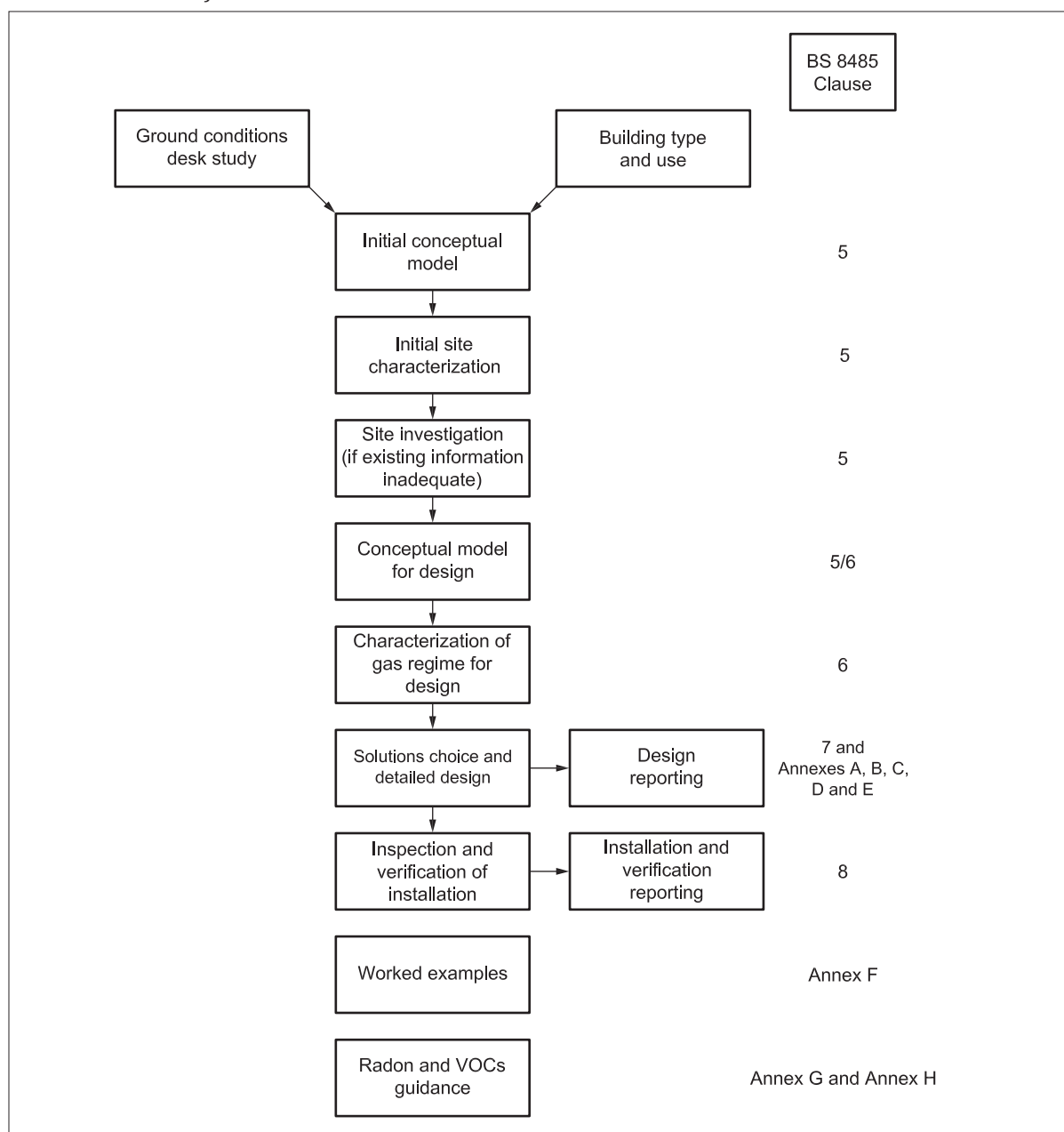
[BS 8576:2013](#), *Guidance on investigations for ground gas — Permanent gases and Volatile Organic Compounds (VOCs)*

[BS 10175:2011+A1:2013](#), *Investigation of potentially contaminated sites — Code of practice*

[BS EN 13137](#), *Characterisation of waste — Determination of total organic carbon (TOC) in waste, sludges and sediments*

Other publications

[N1] MALLETT, H., COX, L. (nee TAFFEL-ANDUREAU), WILSON, S. and CORBAN, M. *Good practice on the testing and verification of protection systems for buildings against hazardous ground gases (C735)*. CIRIA, London, 2014.

Figure 1 — BS 8485 document flow chart

3 Terms and definitions

For the purposes of this British Standard, the terms and definitions given in BS 8576, BS 10175 and BS EN ISO 11074 and the following apply.

NOTE Where definitions differ between BS 8576 or BS 10175 and BS EN ISO 11074, those from BS 8576 and BS 10175 are to be used.

3.1 borehole hazardous gas flow rate (Q_{hg})

flow rate (volume per unit time) of a specific hazardous gas (Q_{hg}), either methane or carbon dioxide, from a borehole standpipe

NOTE 1 It is calculated from individual borehole measurements of total gas flow emission and the concentration of the specific hazardous gas.

NOTE 2 Q_{hg} is usually expressed as litres per hour (L/h).

NOTE 3 The majority of borehole standpipes installed in contamination ground investigations are of 50 mm internal diameter although other diameter pipes are also sometimes used.

3.2 characteristic gas situation (CS)

ground gas regime assumed for design of gas protective measures from the refined conceptual site model after an adequate site investigation

NOTE Characteristic gas situations range between CS1 (very low hazard potential) to CS6 (very high hazard potential) and have a defined range of gas screening values.

3.3 gas resistant membrane

membrane placed above, below or within the floor slab construction (and walls of a basement) to restrict methane and carbon dioxide migration from the ground into a building

3.4 gas screening value (GSV)

flow rate of a specific hazardous gas representative of a site or zone, derived from assessment of borehole concentration and flow rate measurements and taking account of all other influencing factors, in accordance with a conceptual site model

NOTE 1 This definition is different from the definition of GSV in CIRIA C665 [6].

NOTE 2 GSV is based on measured data but ultimately derived using professional judgement.

3.5 ground gas

all gases occurring and generated within the ground whether in made ground or natural deposits

NOTE The reference to all gases includes methane, carbon dioxide and VOCs or inorganic vapours.

3.6 made ground

all deposits which have accumulated through human activity and may consist of natural materials and/or materials manufactured by man in some way, such as through crushing or washing, or arising from an industrial process

3.7 measured flow rate (q)

total gas flow from a borehole standpipe measured in volume per unit time

3.8 measured hazardous gas concentration (C_{hg})

quantity of a hazardous gas measured as a percentage of the total volume of gas flowing from a borehole standpipe

3.9 monitoring event

occasion on which ground gas data, other relevant information or samples are collected

[SOURCE: BS 8576:2013, 3.5]

NOTE Periodic monitoring, high-frequency monitoring and continuous monitoring typically comprise a number of monitoring events varying from a few to many. See BS 8576:2013, 3.1, 3.4 and 3.9 for further information.

3.10 permanent gas

element or compound that is a gas at all ambient temperatures likely to be encountered on the surface of the earth

[SOURCE: BS EN ISO 11074, 4.1.16]

NOTE Under extremely hot circumstances, some substances might become gases that would not otherwise be. These are not permanent gases.

A1 3.11 gas transmission rate

volume of gas passing through a plastic material, per unit area and unit time, under unit partial-pressure difference between the two sides of the material

[SOURCE: BS ISO 15105-1:2007, 3.1 A1]

4 Overview of ground gas protection*COMMENTARY ON [CLAUSE 4](#)*

Toxic, asphyxiating and flammable and potentially explosive ground gases can potentially enter buildings and other built structures, and consequently pose various risks to occupants and users, and to the structures themselves. Potential gas ingress routes and areas of gas accumulation for a conventional residential property are illustrated in [Figure 2](#).

Gas protection measures are most commonly required when there are sources of ground gases beneath the building or at a nearby location or depth at which it is not feasible to prevent gas migrating to beneath the building.

It might also be necessary to apply gas protection measures to the building when an external barrier is in place for an off-site gas source, as an additional protection measure for the building, in case the barrier fails to work as intended.

To complete an assessment of the risks posed by the presence of permanent and other ground gases, the potential sources of gas in and around a site should be identified; guidance on the collection of the relevant information is provided in BS 8576.

NOTE 1 It is usually also necessary to collect information on other aspects of the site and the surrounding land, including, for example, the natural and man-made geology of the site and surrounding areas, the hydrogeological regime, and the current and historical uses of the site and surrounding land. These aspects are dealt with in BS 10175.

Protection should be provided by:

- a) preventing gas entering buildings;
- b) designing to avoid the build-up of hazardous gas beneath buildings or in subsurface infrastructure, e.g. inspection chambers and service runs; and
- c) designing to avoid the build-up of hazardous gas within buildings.

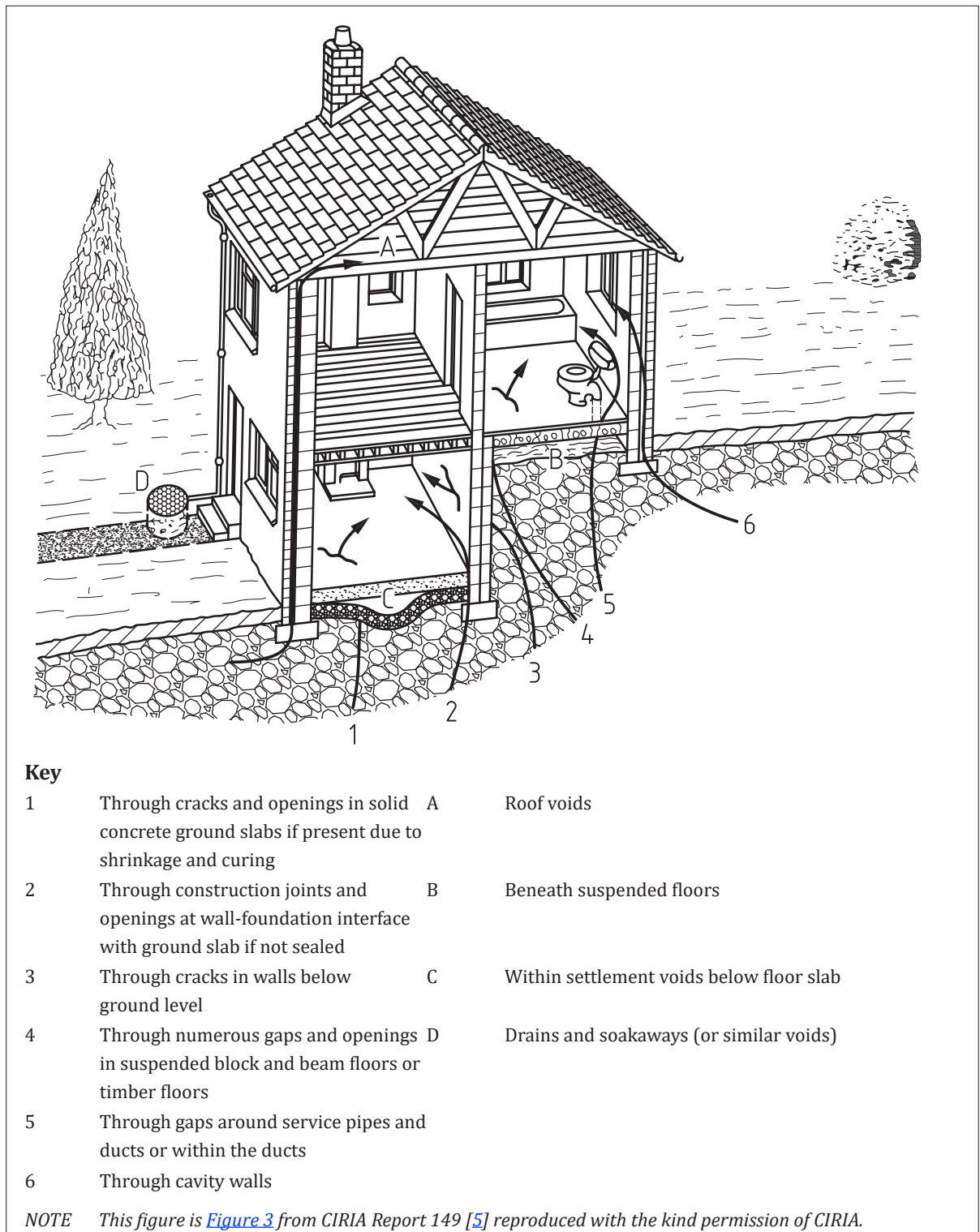
NOTE 2 Protective measures are given in [Clause 7](#) and [Annex A](#), [Annex B](#) and [Annex C](#).

NOTE 3 The following additional protection measures might be required:

- monitoring during occupation or use;
- management measures (see [7.1](#));
- site-wide measures designed to reduce the gas hazard beneath the building.

Guidance on these additional measures is not provided in this British Standard but can be found in a number of published guidance documents including Ground Gas Handbook [\[4\]](#) and CIRIA Report 149 [\[5\]](#).

Figure 2 — Key ground gas ingress routes and accumulation areas within unprotected conventional residential buildings



The measures used should be:

- a) effective: in that they do what they are intended to do;
- b) robust: in that they are not easily compromised, particularly during construction;
- c) durable: in that they remain effective for the required design life; and

- d) buildable: in that they can be built given an appropriate standard of workmanship, supervision and verification.

Effectiveness should be assessed in terms of:

- the theoretical effectiveness assuming perfect installation; and
- the practical effectiveness (i.e. what it is reasonable to expect to achieve under normal conditions); and
- likely long-term effectiveness given the likely durability of materials, etc.

Extreme events (e.g. exceptional changes in atmospheric pressure, rapid groundwater rise and/or flooding) should be taken into account when defining the CS (see [6.2.1](#)) and when selecting the protective measures.

Protective measures should include the use of materials that have a defined design life or no known critical time deterioration properties, and should be placed where they might reasonably be expected to continue to perform for the life of a building, that might be in excess of 100 years.

NOTE 4 Measures (especially ventilation) can be designed from first principles (see [6.2](#)) or selected from “deemed to satisfy” solutions following the recommendations in [Clause 7](#).

Risk assessment and all design decisions should be documented and recorded in the design phase report (see [8.1](#)).

5 Site investigation for ground gases

5.1 General

Investigations for ground gas should be carried out in accordance with BS 8576, which gives guidance on carrying out a preliminary investigation prior to any field work (see [5.2](#) for how to carry out a preliminary investigation). Before embarking on the design of protective measures, designers should check that the site investigation has been carried out in accordance with BS 8576 and BS 10175 and that it has provided data that is sufficient for the task in hand in terms of type, quantity and quality of the data and other information obtained.

NOTE 1 The process of ground gas site investigation (given in [5.2](#) to [5.4](#)) and interpretation of the investigation results (given in [6.1](#) to [6.3](#)) are summarized in [Figure 3](#).

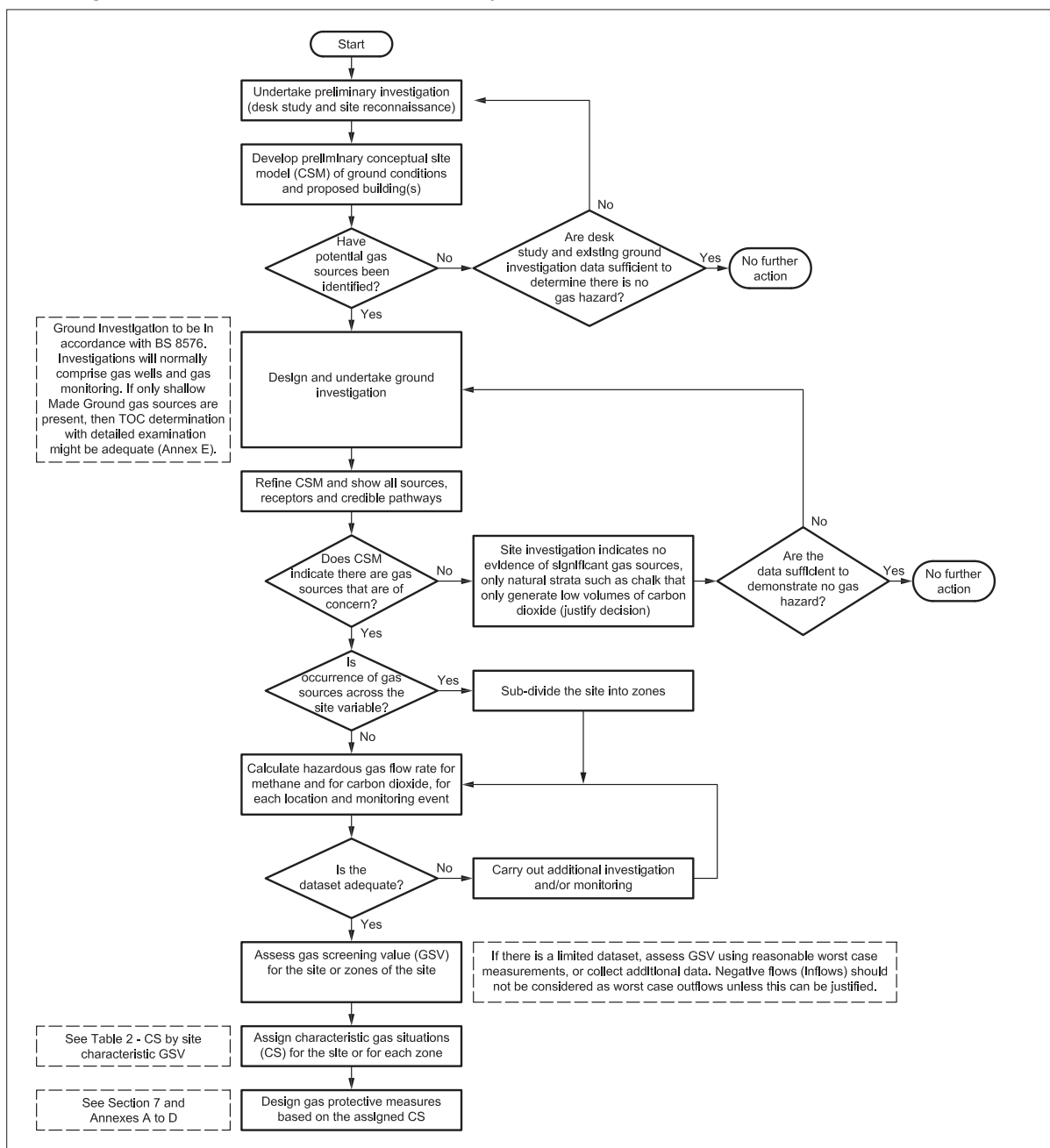
The evaluation of the adequacy of the site investigation should be carried out in accordance with [Table 1](#).

NOTE 2 Guidance on the sufficiency of gas monitoring data is provided in BS 8576:2013, [Annex E](#)

5.2 Preliminary investigation

The first phase of site investigation that should be undertaken is the preliminary investigation (desk study and site reconnaissance).

Information about the history and current use(s) of the site and its surrounding area should be used to identify the likely ground gas sources, migration pathways and receptors.

Figure 3 — Ground gas site characterization and assessment flow chart

All potential gas sources should be identified; these sources might include natural geological sources, mine workings, waste materials, landfills and made ground. For each source an understanding of the nature of the gas generation processes involved should be formulated.

NOTE 1 Some of the sources might be discounted as not being of concern during further investigation and subsequent assessment.

Table 1 — Check list for assessing the adequacy of a site investigation

Aspect of the investigation	Questions that should be adequately answered
Preliminary investigation	Has the preliminary investigation (desk study and site reconnaissance) been completed in accordance with BS 10175 and BS 8576? Are there any information gaps that need to be filled?
Scope of the investigation	Has the investigation been sufficient in scope to: • establish the geology and hydrogeology of the site; • determine whether made ground and/or contamination is present; and • identify source(s) and the nature of the mechanism of gas generation? Has appropriate monitoring, sampling and analysis been carried out?
Geophysical techniques	Where appropriate, have geophysical/remote sensing techniques been used to help delineate the extent of landfill or made ground and the location of the methanogenic material?
Monitoring installations	Were the type and depth of monitoring installations and response zones adequate to identify on-site gas sources and migration pathways, and to determine whether receptors were likely to be impacted? Are there sufficient monitoring installations to evaluate effects of off-site sources, where this is relevant?
Distribution of monitoring points	Were monitoring locations distributed such that sources, migration pathways and receptors can be adequately characterized?
Monitoring instrumentation	Were the instruments used to monitor gas appropriate, and properly maintained, calibrated and operated?
Monitoring parameters	Is enough information regarding gas composition, concentrations, atmospheric and differential borehole pressures and flows available to characterize risk, and is there sufficient data concerning the factors that affect gas migration and emission to assess the likely variability of the gas regime? Was the data accurately measured and reported?
Monitoring frequency	Was the frequency of monitoring sufficient to characterize the consistency or inconsistency of the gas regime over the monitoring period (see 5.3)?
Monitoring period	Was the period of monitoring long enough to monitor changes in ambient conditions that influence gas generation and migration (see 5.4)?

The geology and hydrogeology of the site, and the presence of contamination, and how it might affect gas sources and gas migration should be assessed; this includes assessing the effect of groundwater level variations, including tidal variations (and how these can affect gas sources and gas migration).

All potential pathways should be identified, which includes natural geological pathways, services, underground structures and mine workings. Pathways that are not credible should be discounted.

Potential receptors, both on- and off-site, should be identified and their sensitivity assessed.

The desk study should be used to develop the preliminary conceptual site model that guides the approach to assessing gas risk on a site and the requirements for field investigation, laboratory testing and gas monitoring.

NOTE 2 Guidance on the development of the preliminary conceptual site model is given in BS 8576:2013, [Clause 6](#).

5.3 Field investigation and monitoring

The need for an intrusive investigation to be designed to assess ground gases at different lateral and depth zones, and/or for samples to be collected for total organic carbon (TOC) should be determined, taking the desk study into account.

NOTE 1 For example, where a site encompasses an old landfill area and adjoining area of natural ground, then boreholes located in the landfill are likely to define the source hazard that directly impacts any development above.

Boreholes in the natural ground (external to the old wastes) should be located and designed to assess the migration pathway.

NOTE 2 There might be a reduction in gas hazard with increasing distance from the source, if the site is sufficiently large.

The design and implementation of field investigations for ground gases should be in accordance with BS 8576:2013, [Clause 7](#) to [Clause 12](#).

The TOC of soils should be determined using the method in BS EN 13137.

NOTE 3 Different methods of determination of TOC give different results.

5.4 Conceptual site model for design of gas protection system

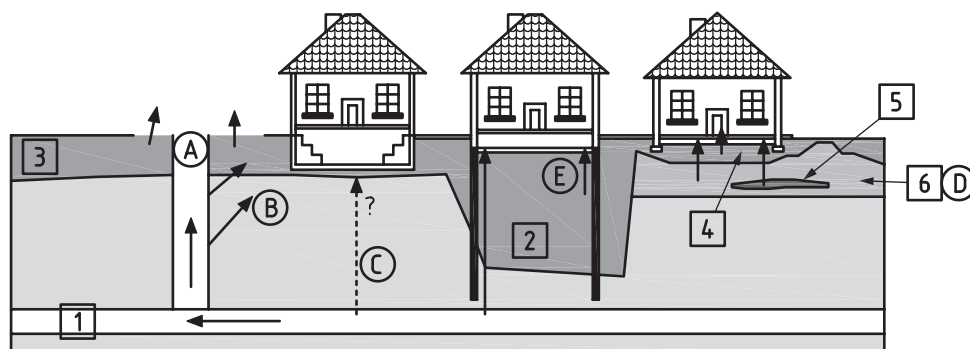
The information gathered during the site investigation should be used to refine the preliminary conceptual site model and provide the conceptual site model for design purposes (see [Figure 3](#) and BS 8576:2013, [Clause 13](#)).

The conceptual site model should define the ground gas sources, the sensitive receptors (persons using the building, and the building structure and fabric) and the pathways between the sources and receptors.

NOTE 1 Receptors are most at risk in spaces within the building where gas could accumulate to concentrations that are potentially explosive or harmful to human health.

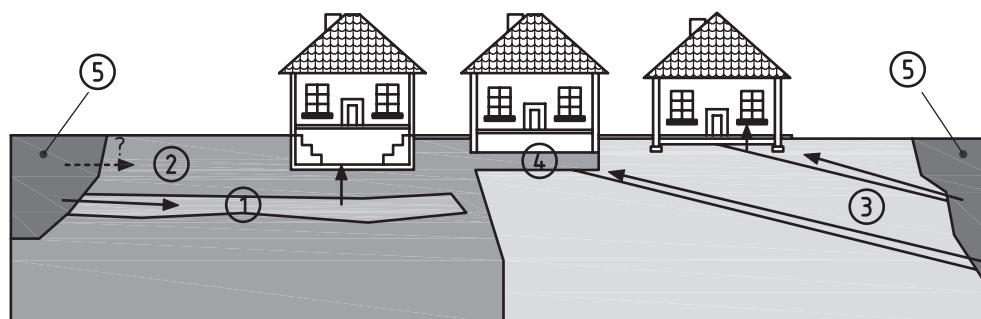
NOTE 2 Example cross-section conceptual site models for design are given for gas sources below buildings and off-site from the building in question in [Figure 4](#).

The conceptual site model should also include plans or other information that are required to demonstrate an understanding of the ground and gas sources in and around the site.

Figure 4 — Example design conceptual site model cross sections

a) Examples of on-site sources of gas below buildings

Key	Sources	Pathways
1	Shallow mineworks	(A) Shafts, adits or other openings to mine workings
2	Deeper areas of made ground, or landfill, infilled railway cuttings	(B) Fractured rock
3	Shallow made ground	(C) Soil or rock above mine workings if it is sufficiently permeable to allow gas to migrate to surface
4	Shallow infill ponds	(D) Pathway only exists if soil above peat is sufficiently permeable to allow gas to migrate to the surface
5	Peat layers or layers of other organic material	(E) Migration via stone columns or around some types of piles
6	Alluvium, chalk or other natural soils	



b) Examples of off-site sources of gas migrating to below buildings

Key	Sources
1	More permeable layers (e.g. sand layers in glacial till)
2	Intervening strata, if soil is sufficiently permeable to allow gas migration
3	Migration in fractures or bedding in rock
4	Impermeable ground beneath building could prevent gas reaching surface
5	Landfill

NOTE With nearby landfills, the potential for gas migration depends on a number of factors, including:

- design and operation of the landfill (presence of liners, permeability of capping layer, gas extraction system in operation, whether it is continuous or not); and
- type of waste and age of landfill.

6 Process for ground gas characterization and hazard assessment

6.1 Risk assessment for ground gases

Before integral protective measures for buildings can be designed, an appropriate risk assessment should be carried out to decide:

- whether there is a potentially hazardous situation; and
- what the magnitudes of associated risks are.

NOTE 1 Guidance on how to conduct risk assessment can be found in CIRIA C665 [6].

NOTE 2 Use of fault tree analysis can help to identify critical states including what might go wrong. Guidance on fault tree analysis is provided in CIRIA Report 152 [7] and the Ground Gas Handbook [4].

NOTE 3 Ground gas characterization and hazard assessment are the initial parts of the risk assessment process. The subsequent stages are the analyses of source pathway receptor linkages.

NOTE 4 Risk assessment results are only reliable if data and other information available about the site are sufficient in terms of quality, quantity and appropriateness (see 5.1).

Any uncertainty should be reflected in the design of the gas protection system.

NOTE 5 Information on the sources, properties and the hazards presented by carbon dioxide and methane is provided in BS 8576:2013, Annex D. The information includes an indication of the magnitude of the hazards in relation to concentrations and the control limits for various situations current at the time BS 8576:2013, Annex D was prepared.

Risk assessment and all design decisions should be documented and reported (see Clause 8 for further information and guidance on documenting and reporting).

6.2 Methodologies for ground gas characterization

COMMENTARY ON 6.2

The scope and nature of gas protection measures required may be determined by:

- an empirical, semi-quantitative approach; and/or
- a detailed quantitative assessment approach.

6.2.1 Empirical, semi-quantitative approaches

6.2.1.1 Empirical approach using gas monitoring data

COMMENTARY ON 6.2.1.1

The empirical, semi-quantitative approach most commonly used is described in detail in 6.3. It involves the use of a conceptual site model and monitoring data collected from gas monitoring standpipes installed in the ground.

When this approach is used there should be sufficient site investigation information available to define the conceptual site model and sufficient gas monitoring measurements (see 5.1 and 5.4). This approach derives an appropriate GSV, or several GSVs if a site is zoned. The GSV should then be used to select an appropriate CS for design, which is then used to inform the choice of protective measures (see Clause 7).

NOTE The method is empirical because it is based on an assumption directly relating gas monitoring standpipe emission measurements to future gas emissions from a fixed volume of ground around the standpipe. The method is based on judgement and experience which has been shown to yield practical and reliable outcomes. Because of the empirical assumption of the method, the boundaries between CSs as defined by GSVs in Table 2 are also empirical.

6.2.1.2 Empirical approach using TOC

COMMENTARY ON 6.2.1.2

Sometimes where the gas source is made ground with low organic content it might be possible to adopt an alternative empirical approach that uses the conceptual site model, the TOC content of the strata identified as the gas source(s) and observations on the nature of the natural or made ground soil materials in the gas source(s).

The TOC approach should only be used when the conceptual site model indicates a very low to moderate potential gas hazard; such an approach is described in RB17 [1]. This method should not be used to assess coal workings, or sites with off-site gas sources or materials associated with active or recent waste disposal sites.

This alternative approach needs a carefully planned and executed investigation strategy and should not be applied retrospectively to an investigation that has been completed and which did not take the intention to apply the method into account in its design.

NOTE [Annex D](#) provides informative guidance on the application of such an approach.

6.2.2 Detailed quantitative assessment approach

Detailed quantitative assessment of ground gas emission and its effects should involve one or more of the following:

- gas generation and migration models;
- flow models to estimate surface emission rates (both advection and diffusion);
- numerical models to estimate migration and surface emission rates;
- models to assess the potential for hazardous gases to accumulate beneath or within buildings;
- fault tree analysis (or other quantitative risk assessment).

If the detailed quantitative assessment approach is used it should be supported by sufficient data and a robust conceptual site model.

NOTE Recommendations on undertaking a detailed quantitative approach are given in [6.4](#).

6.3 Characterization using conceptual site model and gas monitoring data

COMMENTARY ON 6.3

This sub-Clause sets out an empirical semi-quantitative method of assessment of hazards from permanent ground gases. It also sets out how the data collected during site monitoring visits that measure hazardous gas emissions from specific monitoring points is assessed and used to designate a GSV that represents the gas hazard present at the whole site (or GSVs for different zones of a site if zoning is fully supported by a developed conceptual site model and is not just based on gas monitoring data).

The process set out represents good practice and is based on CIRIA C665 [6], NHBC Guidance on evaluation of development proposals on sites where methane and carbon dioxide are present [8] and the Ground Gas Handbook [4]

6.3.1 General

COMMENTARY ON 6.3.1

The development of the GSV for the site or the zone follows a process in which:

- borehole hazardous gas flow rates are calculated for each borehole standpipe for each monitoring event (see [6.3.3](#)) and included in a database;

- the reliability of the measured gas flow rates and concentrations is assessed taking into account borehole construction, etc (see [6.3.4](#) and [6.3.5](#));
- decisions are made as to whether to use peak gas flow rates or steady-state rates in each calculation (see [6.3.6](#));
- decisions are made about how to deal with any temporal or spatial shortages in the data (see [6.3.7.3](#));
- a decision is made about whether the site might be zoned or not (see [6.3.7](#)); and
- judgements are made about what GSV to use for design purposes taking all relevant information into account.

The designation of GSV should be made after consideration of the available monitoring data ([6.3.5](#) and [6.3.6](#)) and all other relevant aspects of an adequate conceptual site model and with knowledge of the development's sub-structure and foundation arrangement.

The presence of significantly elevated concentrations of methane or carbon dioxide with zero flow rates should be assessed and not dismissed. Even if all the monitoring indicates no gas emissions, an assessment should be made about whether or not different atmospheric or groundwater conditions might have led to measurable flows, whether any significant diffusive flow from the ground might occur, or whether typically lower pressures within buildings might pose a risk to the building development.

NOTE 1 Numerical modelling can be used to assess diffusive flows.

NOTE 2 Application of characterization using degradable organic fraction (see [Annex D](#)) might also help decision making, where the source is a relatively thin layer of made ground.

6.3.2 Gas monitoring data

COMMENTARY ON [6.3.2](#)

Good practice gas monitoring provides field data that includes initial readings of gas concentration and gas flow, and subsequent data at time periods commonly recorded at 15 seconds, 30 seconds, 45 seconds, and so on until a steady state is achieved. An appropriate assessment of this field data is an important part of assessing gas hazards and when progressing from calculation of Q_{hg} (L/h) values for each location and each monitoring round toward derivation of an appropriate GSV (L/h) for the site or zone.

When taking measurements the initial flow reading (when the gas tap is first opened) might record a peak gas flow that is not sustained, and which reduces to a low flow or even falls below the instrument's limit of flow detection within the first 60 to 90 seconds.

Sufficient gas monitoring data should be collected in accordance with BS 8576. This data should be consistent with the sources of gas and migration pathways identified at the site being assessed.

6.3.3 Zoning of sites

Review of the data might suggest that a large site should be separated out into a number of separate zones. Sites should be zoned only where there is a clear reason for variations in gas monitoring results (e.g. different geology). The reasons for zoning a site should be clearly stated. Sites should not be zoned only on the basis of variations in gas monitoring data, unless clear trends, compatible with the conceptual site model, are established, such as sometimes occur with increasing distance from a landfill source adjacent to a large development site.

6.3.4 Calculation of borehole hazardous gas flow rate — Q_{hg}

The following gas monitoring data should be used to calculate the borehole hazardous gas flow rate (Q_{hg}):

- measured ground gas concentrations expressed as percentage-by-volume of each hazardous ground gas being considered (methane and carbon dioxide); and
- measured borehole flow rate, i.e. volume of total gas flow (of all gases present) being emitted from the monitoring point, q , expressed in litres per hour (L/h).

The maximum concentration recorded during the monitoring event should be used, unless the use of lower values can be justified, together with steady state values of gas flows.

NOTE 1 q may be measured in other volume per time period units, depending on the measuring method or flow pod being used, but needs to be converted to litres per hour for use in the equations that follow. The difference between flow rates measured by various instruments is covered in BS 8576:2013.

The borehole Q_{hg} (in L/h) should be calculated for each monitoring location and each monitoring event using the following (for each hazardous gas):

$$Q_{hg} = q \left(\frac{C_{hg}}{100} \right) \quad (1)$$

where:

q is the measured flow rate (in litres per hour) of combined gases from the monitoring standpipe.

C_{hg} is the measured hazardous gas concentration (in percentage volume/volume).

NOTE 2 In equation (1), the measured hazardous gas concentration C_{hg} is expressed as a percentage (%), i.e. as parts per hundred.

NOTE 3 As an example, if a total borehole flow of 6 L/h is measured, and of that total flow (of mixed gases) 10% is methane, then the flow of methane gas (i.e. the borehole Q_{hg} for methane – $Q_{hg}CH_4$) is 0.6 L/h (of methane), calculated as:

$$\begin{aligned} Q_{hg}CH_4 &= 6 \times \frac{10}{100} \\ &= 0.6 \end{aligned}$$

i.e. 0.6 L/h of methane is being emitted, mixed with a flow of 5.4 litres of other gases.

If 25% of the total flow (of mixed gases) is carbon dioxide, then similarly the borehole Q_{hg} for carbon dioxide is 1.5 L/h (of carbon dioxide) calculated as:

$$\begin{aligned} Q_{hg}CO_2 &= 6 \times \frac{25}{100} \\ &= 1.5 \end{aligned}$$

i.e. 1.5 L/h of carbon dioxide being emitted from that borehole, on that monitoring event, mixed with the other gases.

If a gas borehole flow is not detected, it should be assumed that it is at the detection limit of the equipment used for the purpose of this calculation.

If a negative flow is recorded it should not automatically be discounted. Rather, an assessment of whether, under different temporal conditions, a similar positive out-flow of gas could occur should be undertaken, consistent with development of the conceptual site model. Only when the reason for the negative value is reasonably understood, and a positive flow can be credibly ruled out, should a negative value be discounted.

6.3.5 Reviewing the database

The accumulated database of calculated hazardous gas flow rates should be reviewed on completion of each successive monitoring round taking account of the gas regimes anticipated, consistent with the conceptual site model. Aspects considered in the review process should include:

- the monitoring response zones, i.e. whether the response zone and location are designed to be (and are likely to be) representative of the source, pathway or receptor;
- the atmospheric pressure trends; and
- differential borehole pressure and groundwater level at the time, and atmospheric pressure and weather conditions, preceding and at the time of the monitoring event.

NOTE 1 Waterlogged or frozen ground surfaces might affect the migration/venting of gases during such monitoring events.

The database should be designed to enable data representative of the source, and/or pathway and/or receptor (as appropriate to each specific development) to be clearly identified and understood.

NOTE 2 Monitoring point specific Q_{hg} can be usefully visualized on plan and section views. Colour coding can aid such 3D spatial understanding of the gas regime, or regimes, that are present. Such presentation can be extended to assess temporal variability.

6.3.6 Combining field data

When assessing how to combine the field data to aid derivation of an appropriate GSV, the following factors should be taken into account:

- the spatial adequacy of the monitoring locations compared to the variability of the underlying ground conditions;
- the relative position of the standpipe response zone and the groundwater table;
- the range of temporal atmospheric and groundwater conditions (including tidal if relevant) at which measurements were recorded; and
- atmospheric pumping, especially where a sudden fall in atmospheric pressure occurs.

The response zone of the gas monitoring standpipe should be wholly or partly above groundwater level to provide valid data for the guidance that follows.

NOTE 1 Gas standpipes with flooded response zones might exhibit measurements of elevated methane or carbon dioxide. This could be due to dissolved gases or presence of biodegradable material in the groundwater.

If water is present above the top of the slotted section of the gas standpipe, any peak flow recorded is likely to be due to a build-up of pressure caused by rising water trapping the gas within the solid section of pipe; in this case, the initial peak flow is not representative of the rate of gas generation within the ground, and new, better designed standpipes should be installed and decisions made about whether to carry out further monitoring from the existing installation.

6.3.7 Derivation of GSVs

6.3.7.1 General

The designation of GSV should be made by inspection of all the data based on the conceptual site model for the situation with the development's sub-structure and foundations in place.

NOTE 1 Adopting a GSV based on Q_{hg} calculated from peak flow measurements might result in a disproportionately high gas hazard prediction, and assignment of an over-precautionary CS.

*NOTE 2 Examples of how monitoring data is considered to derive a GSV are given in Annex **A1** F **A1**.*

Where a development is to be built directly on or very close to the source of gas, then the Q_{hg} adopted as the site or zone GSV should be based on gas measurements of the source. For a development off-set from a source, an assessment of the degree of hazard reduction afforded by the pathway between the source and the receptor should be made.

NOTE 3 If the source has been monitored and is at some distance off-set from the development, then selection of the GSV based on an application of the Q_{hg} obtained from the source is inappropriate.

A similar form of assessment of source hazard reduction should be made if the source is organic degradable material (e.g. peat) within an alluvial sequence that is conceptualized as being capable of supporting a reservoir of gas, but where the development above is protected to some degree by a lower permeability strata. In this case the alteration to the pathway that the building's foundation solution might incur should also form a key part of the assessment.

6.3.7.2 Representative and comprehensive data set

Where the dataset is representative and comprehensive, the GSV should be the maximum Q_{hg} measured for all the monitoring events. The data set should only be considered representative and comprehensive if it captures temporal variation.

A decision should be made to determine if peak or steady state maximum readings are to be used, taking into account the conceptual site model and the acute one-off nature of the risk. Data recorded at all the other gas monitoring locations should also be taken into account.

6.3.7.3 Temporally or spatially limited data sets

If the data set is temporally or spatially limited, peak or maximum steady state data can be combined from more than one monitoring standpipe location and different monitoring rounds, for each gas source; however, before doing so a decision should be made about the need to collect further monitoring data in preference. If further data is not collected then the GSV should be derived as the worst case, see [6.3.7.4](#).

NOTE The purpose is to derive a GSV that captures known temporal variation and also seeks to account for a plausible data combination, that the more limited dataset has not captured, and to derive a GSV that is suitably precautionary in principle, to take account of the data set limitations.

6.3.7.4 Worst case check

Irrespective of the apparent comprehensiveness of the dataset, the plausible worst case condition should be calculated for each hazardous gas by multiplying the maximum recorded flow in any standpipe in that strata (and zone) with the maximum gas concentration in any other standpipe in that strata (and zone), but discounting any peak instantaneous flows and negative flows that have been judged to be unrepresentative of a possible worst case.

If this worst case check indicates that a greater hazard could reasonably exist, then either this worst case Q_{hg} should be adopted as the GSV, or further monitoring should take place to provide evidence that the worst case should not be used. To adopt the worst case Q_{hg} as the GSV, the assessor should be confident that to do so is prudent and reasonable and does not result in unnecessarily conservative protection of the development. The basis for decisions should be set out clearly and justifications stated.

NOTE Sensitivity analysis can inform the decision to undertake more monitoring, or to adopt the precautionary principle. If adoption of a precautionary worst case Q_{hg} as the GSV, in lieu of additional monitoring might have serious construction implications for the development, then collection of an improved dataset is prudent. Conversely, where the additional protection is not practical to apply, then adopting a precautionary approach is appropriate.

6.3.8 Characteristic gas situation (CS)

COMMENTARY ON 6.3.8

Trace permanent gases might also be present at much lower concentrations than those of methane and carbon dioxide. The site classification and design of protection measures based on methane and carbon dioxide flows might be adequate to provide protection against the acute effects from trace permanent gases, but a formal risk assessment is likely to be needed. The human health risk assessment might indicate that remediation to deal with trace gases or vapours is needed in addition to any building ground gas protection measures. The human health risk assessment might also need to include a consideration of the emissions from any under floor venting system to the ambient air around the building.

The CS should be determined from the adopted GSV (see 6.3.2 to 6.3.7) and the ranges given in Table 2; a CS for both methane and carbon dioxide should be determined.

NOTE See Annex F for examples of the assignment of a CS by site characteristic GSV.

6.4 Quantitative assessment of gas risk to characterize a site

A detailed quantitative assessment of gas emissions should be carried out in appropriate situations, such as where sites have moderate to high hazards, where buildings have complex foundations, and where the approach described in 6.3 suggests an over-conservative assessment of risk posed by the presence of gas in the ground.

NOTE 1 The different types of models that can be used are explained in 6.2.3. These more detailed analyses are used to estimate the flow of gas through and from the ground.

The models in 6.2.2 are based on fluid flow through the ground by advection and diffusion and should be compared to gas monitoring data wherever possible, with sensitivity analyses undertaken.

Table 2 — CS by site characteristic GSV

CS	Hazard potential	Site characteristic GSV ^{A)} L/h	Additional factors
CS1	Very low	<0.07	Typically <1% methane concentration and <5% carbon dioxide concentration (otherwise consider an increase to CS2)
CS2	Low	0.07 to <0.7	Typical measured flow rate <70 L/h (otherwise consider an increase to CS3)
CS3	Moderate	0.7 to <3.5	–
CS4	Moderate to high	3.5 to <15	–
CS5	High	15 to <70	–
CS6	Very high	>70	–

^{A)} The figures used in this column are empirical.

NOTE The CS is equivalent to the characteristic GSV in CIRIA C665 [6].

NOTE 2 The results from the models can be used to determine the scope of gas protection measures needed for a building and to design any necessary underfloor ventilation.

NOTE 3 This approach is of particular use where gas migrates through the ground from a source adjacent to the site (e.g. where landfill gas migration occurs).

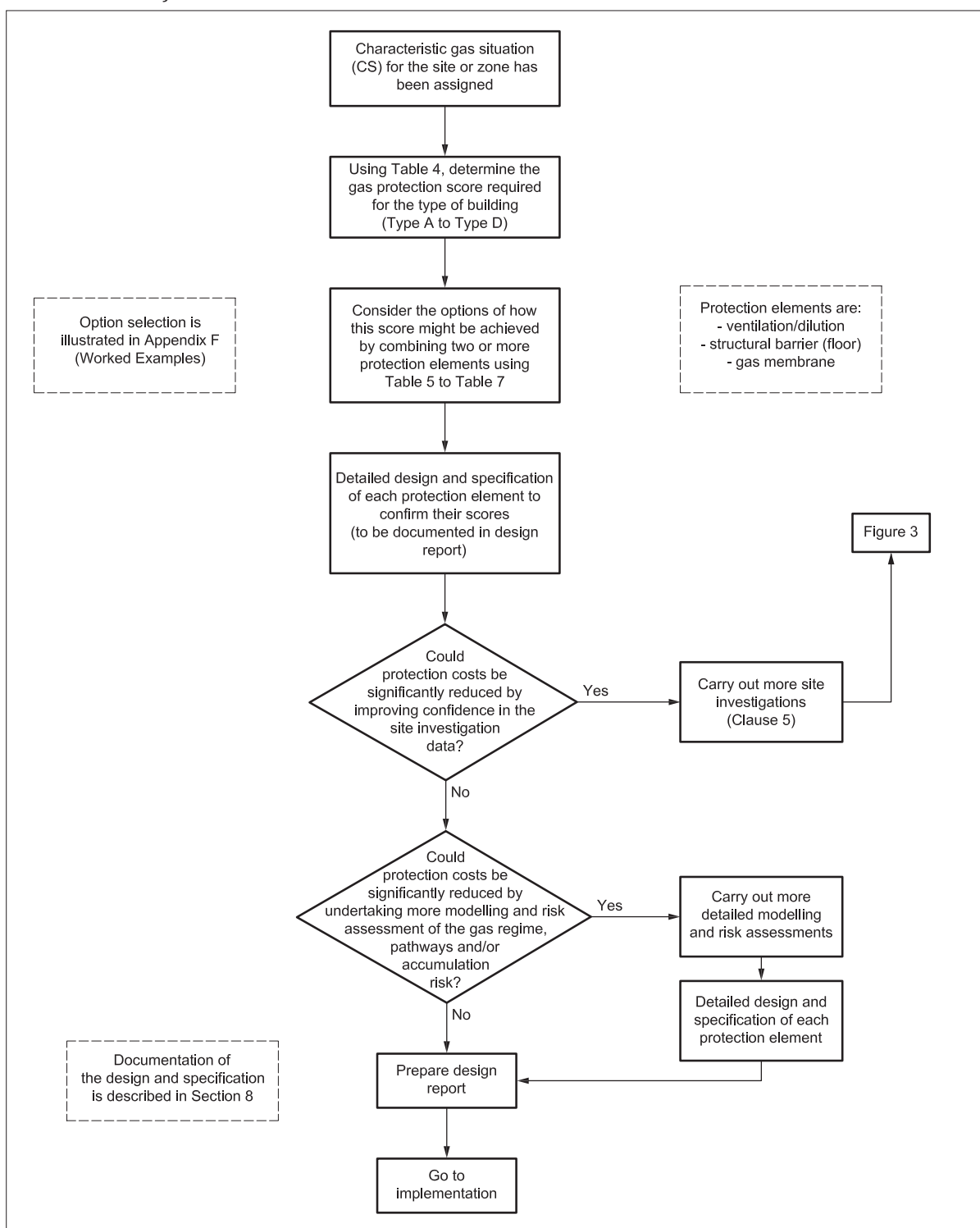
NOTE 4 Further information on detailed quantitative risk assessment is provided in the Ground Gas Handbook [4].

7 Solutions choice and detailed design

7.1 Approach

Appropriate gas protection measures should be selected based on the CS using the steps illustrated in [Figure 5](#) and described in [7.1](#), unless the protective measures are designed using quantitative modelling methods (see [6.4](#)).

NOTE 1 Guidance on radon and VOCs is given in [Annex G](#) and [Annex H](#). These annexes provide valuable information to designers of gas protection systems for methane and carbon dioxide at sites which might also need protection against these gases.

Figure 5 — *Solutions choice flow chart*

The construction and use of the building, together with the control of future structural changes to the building and its maintenance (the building's management) should be assessed, since potential risks posed by ground gases are strongly influenced by these factors. The assessment should lead to the categorization of the building as a whole, or each different part of the building, into one of four building types: Type A, Type B, Type C or Type D.

New buildings should be categorized in accordance with [Table 3](#) and the descriptions that follow.

Table 3 — *Building types*

	Type A	Type B	Type C	Type D
Ownership	Private	Private or commercial/public, possible multiple	Commercial/public	Commercial/industrial
Control (change of use, structural alterations, ventilation)	None	Some but not all	Full	Full
Room sizes	Small	Small/medium	Small to large	Large industrial/retail park style

- **Type A building:** private ownership with no building management controls on alterations to the internal structure, the use of rooms, the ventilation of rooms or the structural fabric of the building. Some small rooms present. Probably conventional building construction (rather than civil engineering). Examples include private housing and some retail premises.
- **Type B building:** private or commercial property with central building management control of any alterations to the building or its uses but limited or no central building management control of the maintenance of the building, including the gas protection measures. Multiple occupancy. Small to medium size rooms with passive ventilation of rooms and other internal spaces throughout ground floor and basement areas. May be conventional building or civil engineering construction. Examples include managed apartments, multiple occupancy offices, some retail premises and parts of some public buildings (such as schools, hospitals, leisure centres) and parts of hotels.
- **Type C building:** commercial building with central building management control of any alterations to the building or its uses and central building management control of the maintenance of the building, including the gas protection measures. Single occupancy of ground floor and basement areas. Small to large size rooms with active ventilation or good passive ventilation of all rooms and other internal spaces throughout ground floor and basement areas. Probably civil engineering construction. Examples include offices, some retail premises, and parts of some public buildings (such as schools, hospitals, leisure centres and parts of hotels).
- **Type D building:** industrial style building having large volume internal space(s) that are well ventilated. Corporate ownership with building management controls on alterations to the ground floor and basement areas of the building and on maintenance of ground gas protective measures. Probably civil engineering construction. Examples are retail park sales buildings, factory shop floor areas, warehouses. (Small rooms within these style buildings should be separately categorized as Type B or Type C).

NOTE 2 Type A buildings are those where the risk of failure of the gas protection measures is likely to be most significant to the safety of the occupants and Type D buildings are those where this same risk is likely to be least significant.

From the design CS and the type of building (A, B, C or D) the minimum level of gas protection (score) in the range 0 to $\frac{A_1}{6}$ $\frac{A_1}{1}$ should be determined in accordance with [Table 4](#).