The WHO Guideline values have been amended for the UK standard body weight and behaviour to derive a UK guideline for DWS of TPH (70kg body weight and 2l of water consumed per day).

A complete list of assessment criteria for PAHs is absent from the UK (benzo(a)pyrene is available). However, the risk from PAHs should be considered. The theory presented in the WHO document "Petroleum Products in Drinking Waters, Background document for development of WHO Guidelines for Drinking-water Quality. Ref. WHO/SDE/WSH/05.08/123" has been applied to provide indicative screening values for PAHS with regard to drinking water. Published TDI and ID effects have been amended for the UK standard body weight and behaviour to derive a UK guideline for DWS of PAHs (70kg body weight and 2l of water consumed per day).

The derived TPH and PAH screening values are used as an indication of the risks from TPH and PAHs to human health through drinking water only.

The standards for the substances tested for in this investigation are provided in Table D3 and D4 below.

Table D3 - Screening Values – Surface Water Receptor

	Concentration (ug/ℓ)		
Determinand	**EQS Priority and Specific Priority**	**Surface Water Directive (revoked)**	**Non-Statutory EQS**
Arsenic	50		
Barium		100	
Boron		1,000	
Cadmium	0.45 to 1.5*		
Cobalt			100
Copper	7.26		
Chromium (total)	3.4		
Chromium (VI)	3.4		
Chromium (III)	4.7		
Iron	1		
Lead	7.2		
Manganese	219.55	50	
Mercury	0.07		
Nickel	8.01		
Selenium		10	
Tin			25
Zinc	23.93		
Cyanide (free)	1		
Ammonia (total)	0.3,1.3		
Chloride	2		
Fluoride			3,000 to 15,000
Nitrate		50	
Phosphate			
Sulphate		250,000	

Determinand	Concentration (ug/ℓ) EQS Priority and Specific Priority	Surface Water Directive (revoked)	Non-Statutory EQS
Conductivity		1,000	
Benzene	50		
Ethyl Benzene			20
Toluene	50		
Xylene (p+m)	30	1	
Phenol	7.7		

Footnotes:
NV– No value
(*) – Dependant on Hardness (See DoE circular 7/89).

- Table D4 - Screening Values – Risks to Groundwater

Determinand	Concentration (ug/ℓ) UK Drinking Water Standards	Groundwater Drinking Water Protected Areas	WHO Derived Screening
pH (Acid)	6.2		
pH (Alkaline)	9.5		
Aluminium	200		
Antimony	5		
Arsenic	10		
Boron	1,000		
Cadmium	5		
Copper	2,000		
Chromium (total)	50		
Iron	200		
Lead	10		
Manganese	50		
Mercury	1		
Nickel	20		
Selenium	10		
Zinc		3,750	
Sulphate	250,000		
Cyanide	50		
Ammonia (total)	500		
Bromate	10		
Chloride	250,000		
Fluoride	1,500		
Nitrate	50,000		

	Concentration (ug/ℓ)		
Determinand	UK Drinking Water Standards	Groundwater Drinking Water Protected Areas	WHO Derived Screening
Nitrite	500		
Sodium	200,000		
Sulphate	250,000		
Conductivity	2,500		
Aliphatic EC5 - EC6			17.5
Aliphatic EC6 - EC8			17.5
Aliphatic EC8-EC10			0.35
Aliphatic EC10-EC12			0.35
Aliphatic EC12-EC16			0.35
Aliphatic EC16-EC21			7
Aliphatic EC21-EC35			7
Aromatic EC6-EC7 (Benzene)	1		
Aromatic EC7-EC8 (Toluene)		276	
Aromatic EC8-EC10			
Aromatic EC10-EC12			0.105
Aromatic EC12-EC16			0.105
Aromatic EC16-EC21			0.105
Aromatic EC21-EC35			0.105
Benzene	1		
Ethyl Benzene			300*
Toluene		276	
Xylene		166	
Acenaphthene			210
Acenaphthylene			210
Anthracene			1,050
Benzo(a)anthracene			0.5425
Benzo(a)pyrene	0.01		
Benzo(b)fluoranthene			0.1365
Benzo(g.h.i.) Perylene			12.04
Benzo(k)fluoranthene			3.605
Chrysene			1.085
Di-benzo(a.h.)anthracene			0.01085
Fluoranthene			43.75
Fluorene			140

	Concentration (ug/ℓ)		
Determinand	**UK Drinking Water Standards**	**Groundwater Drinking Water Protected Areas**	**WHO Derived Screening**
Indeno(1,2,3-cd)pyrene			1.5505
Naphthalene			70
Phenanthrene			43.75
Pyrene			105

*WHO Drinking Water Standard

Ground Gas and Volatile Organic Compounds Generic Assessment Criteria

Ground Gas

Introduction

Under Part IIA of the Environmental Protection Act 1990, Building Regulations Approved Document C 2004, and the NPPF there is a requirement to ensure ground gases from anthropogenic and natural sources are considered on a risk assessment basis. The most common gases assessed with respect to development are methane and carbon dioxide. Methane forms a potentially explosive mixture when mixed with air within certain concentration limits, known as the ‘explosive range’. The Lower Explosive Limit (LEL) for methane is 5%. Carbon dioxide is a dense gas, capable of accumulating in confined spaces creating a potential asphyxiation hazard. The Occupational Exposure Limit (OEL) for a short term exposure to carbon dioxide is 1.5% over a 15-minute period. Both gases when present at high concentrations can act as simple asphyxiates by reducing the oxygen content by dilution.

Potential methane and carbon dioxide sources include;

- Land filled wastes;
- Degradable material present within the soil matrix of Made Ground;
- Peat and organic matter within alluvial deposits;
- Migrating landfill leachate;
- Foundry sands;
- Sewage sludge, dung pits/heaps;
- Burial grounds;
- Spilled or leaked petroleum hydrocarbons;
- Silt present in water bodies;
- Natural deposits, including chalk and coal measures; and
- Leaks of main gas and sewer gas.

Other gases that may be present on sites at significant levels include hydrogen sulphide, carbon monoxide, and hydrogen cyanide. These gases should be monitored in addition to oxygen, methane, and carbon dioxide, where potential for these gases to be present at unacceptable levels exist.

Guidance

Current UK guidance has been produced by CIRIA and the British Standards Institution (BSI). The following documents have been prepared to date;

- CIRIA C665 – Assessing the risks posed by hazardous ground gases to buildings, 2007;
  - Aims to consolidate good practice in investigation, facilitate the collection of relevant data, instigate appropriate monitoring programmes, all in a risk based approach to gas contaminated land.
- BS8576 – Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs), 2013;
  - Provides guidance on the monitoring and sampling of ground gases, including methane, carbon dioxide, oxygen, and VOCs. Guidance is not provided on the risk evaluation and site characterisation, the selection and design of protective measures, verification of protective measures, sampling of atmospheric gases, and the monitoring and sampling of radon.
- CIRIA C735 – Good practice on the testing and verification of protection systems for buildings against hazardous ground gases, 2014; and
  - Sets out the good practice guidance for the designer, installer, verifier, and regulator on the verification and integrity testing of gas protection systems.
- BS8485 – Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings, 2015.
  - Provides guidance on the appropriate ground gas parameters that can be used to identify a range of possible design solutions for protection against methane and carbon dioxide on a development.

Both the CIRIA and BSI publications have been prepared to be generally consistent with CLR11, *Model Procedures for the management of land contamination,* (DEFRA and the Environment Agency, 2004a) and follow a step by step approach summarised below:-

1. Desk Study and Site Walkover
2. Development of a Preliminary Conceptual Model and Risk Assessment
3. Site Investigation (If deemed necessary from stage 2)
4. Risk Assessment and Site Characterisation
5. Recommendation and Mitigation

Where, the preliminary conceptual model has deemed further investigation necessary to characterise the ground gas regime, an appropriate site investigation and monitoring regime is designed and undertaken. In-depth guidance to assist in the investigation design is provided within C665 and BS8576, which describes intrusive investigation techniques and provides guidance on selecting the number and location of monitoring wells based on the site specific conceptual model.

Waterman has generally followed the approach recommended in CIRIA C665, BS8576, and BS8485 with respect to characterising a site and determining the levels of gas protection methods required. Where deviations from the methodology detailed within above guidance occurs, the reasoning behind the deviation and implication of the analysis of the results has been included within the report.

Risk Assessment

In accordance with C665, to assess the ground gas regime at a site, the ground gas monitoring data should be assessed by determining the Gas Screening Value (GSV) (l/hr). BS8485 details further guidance on which GSV can be adopted based on a number of modifiers.

GSV = (Measured Maximum CO_2 or CH_4 Gas Concentration (%) / 100) x Maximum Measured Gas Flow Rate from boreholes (l/hr)

Both C665 and BS8485 dictate where the gas flow has been measured as less than the detection limit of the instrument used (typically <0.1l/hr), the limit of detection of the instrumented should be used as the gas flow rate.

As per the guidance given in BS8485 where a negative flow has been recorded, and there is an absence of a positive flow, a qualitative assessment has been undertaken into whether under different temporal conditions, a similar positive flow could occur. When the cause for negative flow is reasonably understood, it has been possible to rule out a corresponding credible positive flow, and discount the negative flow.

The GSV is used to classify the site, subject to the proposed end use of the site, falling into either Situation A or Situation B;

- Situation A – All development types except low rise housing with a ventilated underfloor void (150mm)
- Situation B - Low rise housing with a ventilated underfloor void (minimum 150mm)

Situation A – For All Development Types except Low Rise Housing with a ventilated underfloor void (150mm)

For Situation A, the Modified Wilson and Card classification system is used. This system attributes a Characteristic Situation (CS) value to the site/zone depending upon the calculated GSV. When attributing a CS, additional factors including the maximum recorded gas concentration and the maximum recorded gas flow rate should also be taken into account and may result in an increase in the CS value. The table below, outlines the CS values, associated GSV's, and additional factors which must be taken into account.

Characteristic Situation (CIRIA 149)	Risk Classification	Gas screening value (CH_4 CO_2) l/hr	Additional Factors	Typical source of generation
1	**Very low risk**	**<0.07**	Typically methane ≤1% and / or carbon dioxide ≤5%. Otherwise consider increase to CS 2.	Natural soils with low organic content 'Typical' Made Ground
2	**Low risk**	**<0.7**	Borehole air flow rate not to exceed 70 l/hr. Otherwise consider increase to CS 3.	Natural soil, high peat/organic content. 'Typical' Made Ground
3	**Moderate risk**	**<3.5**		Old landfill, inert waste, mineworking flooded
4	**Moderate to high risk**	**<15**	Quantitative risk assessment required to evaluate scope of protective measures.	Mineworking – susceptible to flooding, completed landfill (WMP 26B criteria)
5	**High risk**	**<70**		Mineworking unflooded inactive with shallow workings near surface
6	**Very High risk**	**>70**		Recent landfill site

Notes:
1) Gas screening value: litres of gas / hour is calculated by multiplying the gas concentration (%) by the measured borehole flow rate (l/hr)
2) Source of gas and generation potential/performance must be identified.
3) If there is no detectable flow use the limit of detection of the instrument.

Following determination of the site's CS, the requirements and scope of gas protection measures can be proscribed based on the guidance given in BS8485:2015.

Situation A - Ground gas protection measures: BS8485-2015

BS8485 details the required ground gas protection measures for a Situation A development using a points based system, whereby a certain number of points must be accumulated through the installation of various protection measures to mitigate the risk to structures or buildings from the accumulation of methane or carbon dioxide. The number of points assigned will be dependent on the building type, and the CS.

Building types are separated into four distinct scenarios.

Modifier	Building Type			
	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

Further details on the description of the building types, along with examples are included in BS8485.

Following identification of the appropriate Building Type and CS, the minimum gas protection score can be determined through the use of the following table.

Characteristic Situation	Minimum Gas Protection Score			
	Type A	Type B	Type C	Type D
1	0	0	0	0
2	3.5	3.5	2.5	1.5
3	4.5	4	3	2.5
4	6.5[A]	5.5[A]	4.5	3.5
5	N/A[B]	6.5[A]	5.5	4.5
6	N/A[B]	N/A[B]	7.5	6.5

[A]Residential buildings should not be built on CS4 or higher sites unless the type of construction or site circumstances allow additional levels of protection to be incorporated, e.g. high performance ventilation or pathway intervention measures, and an associated sustainable system of management of maintenance of the gas control system e.g. in Institutional and/or fully serviced contractual situations.

[B]The gas hazard is too high for this empirical method to be used to define the gas protection measures.

Post determination of the minimum gas protection score, a combination of two or more of the following three types of protection measures should be used to achieve the score;

- The structural barrier of the floor slab, or of the basement slab and walls if a basement is present;
- Ventilation measures; and
- Gas resistant measures.

Through combining at least two ground gas protection measures, the lack of redundancy in the use of a single protection measure approach is negated. The ground gas protection measures should work independently and collaboratively.

The tables below detail the specific ground gas protection measures and their associated scores.

Structural Barrier

Floor and substructure design	Score[A]
Precast suspended segmental subfloor (I.e. beam and block)	0
Cast in-situ ground bearing floor slab (with only nominal mesh reinforcement)	0.5
Cast in-situ monolithic ground bearing raft or reinforced cast in-situ suspended floor slab with minimal penetrations	1 or 1.5[B]
Basement floor and slab conforming to BS8102:2009, Grade 2 waterproofing[C]	2
Basement floor and walls conforming to BS1802:2009, Grade 3 waterproofing[C]	2.5

[A]The scores are conditional on breaches of floor slabs, etc., being effectively sealed.

[B]To achieve a score of 1.5 the raft or suspended slab should be well reinforced to control cracking and have minimal penetrations cast.

[C]The score is conditional on the waterproofing not being based on the use of a geosynthetic clay liner waterproofing product.

Ventilation Measures

Protection element/system	Score	Comments
Pressure relief pathway (usually formed of low fines gravel or with a thin geocomposite blanket or strips terminating in a gravel trench external to the building.	0.5	Whenever possible a pressure relief pathway (as a minimum) should be installed in all gas protection measure systems. If the layer has a low permeability and/or is not terminated in a venting trench or similar, then the score is zero.
Passive sub floor dispersal layer: Very good performance: Good performance: Media used to provide the dispersal layer are; • Clear void; • Polystyrene void former blanket; • Geocomposite void former blanket • No-fines gravel layer with gas drains; • No-fines gravel layer	 2.5 1.5	The ventilation effectiveness of different media depends on a number of different factors including the transmissivity of the medium, the width of the building, the side ventilation spacing, and type and thickness of the layer. The selected score should be assigned taking into account the recommendations in Annex B of BS8485 2015. Passive ventilation should be designed to meet at least good performance, see in Annex B of BS8485 2015. .
Active dispersal layer, usually comprising fans with active abstraction (suction) from a subfloor dilution layer, with roof level vents. The dilution layer may compromise a clear void or be formed of geocomposite or polystyrene void formers.	1.5 to 2.5	This system relies on continues serviceability of the pumps, therefore alarm and response systems should be in place. There should be robust management systems in place to ensure the

		continued maintenance of the system including pumps and vents. Active ventilation should always be designed to meet at least good performance as described in in Annex B of BS8485 2015.
Active positive pressurization by the creation of a blanket of external fresh air beneath the floor slabs by pumps supplying air to points across the central footprint of the building into a permeable layer, usually formed of a thin geocomposite blanket.	1.5 to 2.5	This system relies on continues serviceability of the pumps, therefore alarm and response systems should be in place. The score assigned should be based on the efficient coverage of the building footprint and the redundancy of the system. Active ventilation should always be designed to meet at least good performance.
Ventilated car park (floor slab of occupied part of the building under consideration is underlain by a basement or undercroft car park).	4	Assumes that the car fumes is vented to deal with exhaust fumes designed to *Buildings Regulations 2000, Approved Document F.*

It should be noted that for Type A buildings Active ventilation systems are inappropriate.

Membrane

Protection element/system	Score	Comments
Gas resistant membrane meeting all of the following criteria; • Sufficiently impervious to the gases with a methane gas transmission rate <40ml/day/m^2/atm (average) for sheet and joints (tested in accordance with BSO ISO 15105-1 manometric method); • Sufficiently durable to remain serviceable for the anticipated life of the building and duration of gas emissions; • Sufficiently strong to withstand in-service stresses (e.g. settlement if placed below the floor slab) • Sufficiently strong to withstand the installation process and following trades until covered (e.g. penetration from steel fibres in reinforced concrete, penetration of reinforcement ties, tearing due to working above it, dropping tools, etc); • Capable, after installation, of providing a complete barrier to the entry of the relevant gas; and • Verified in accordance with CIRIA C735.	2	The performance of membranes is heavily dependent on the quality and design of the installation, resistance to damage after installation and integrity of joints. For example a minimum 1.4mm thickness (equivalent to 370g /m2 for polyethylene), reinforced membrane (virgin polymer) meets the performance criteria. If a membrane is installed that does not meet the all the criteria in column 1 then the score is zero.

A gas protection score should only be assigned to a membrane which is formed of a material with suitably low gas permeability and which has been installed so it completely seals the foundation (including effective seals around all penetrations) and does not sustain damage from in-service stresses.

Situation B – For Low Rise Housing with a ventilated underfloor void (min 150mm)

Situation B should be used for low-rise residential housing constructed using a beam and block floor construction and a clear sub-floor void. Where a sub-space void is not proposed, the development falls under the Situation A classification system.

For situation B, the National House Building Council's (NHBC) Traffic Light classification system is used. This system attributes a colour to a site/zone depending upon the calculated GSV. As with the Wilson and Card system, in addition to the GSV, additional factors including the maximum recorded gas concentration and the maximum recorded gas flow rate must be taken into account when determining the Traffic Light classification. The table below outlines the Traffic Light classification system, based on the calculated GSV's and additional factors which must be taken into account.

NHBC traffic light system for 150mm void

Traffic Light	Methane		Carbon Dioxide	
	Typical Maximum Concentration (% v/v)	Gas Screening Value (GSV) l/hr	Typical Maximum Concentration (% v/v)	Gas Screening Value (GSV) l/hr
Green				
	1	0.16	5	0.78
Amber 1				
	5	0.63	10	1.56
Amber 2				
	20	1.56	30	3.13
Red				

Notes:

- The worst gas regime identified at the site, either methane or carbon dioxide, recorded from monitoring in the worst temporal conditions, will be the decider as to what Traffic Light and GSV is allocated.
- Generic GSVs are based on guidance contained within latest revision of Department of the Environment and the Welsh Office (2004 edition) "The Building Regulations: Approved Document C" [Ref:17] and used a sub-floor void of 150mm thickness.
- This assessment is based on a small room e.g. downstairs toilet with dimensions of 1.5 x 2.5m, with a soil pipe passing into the sub-floor void.

- The GSV, in litres per hour, is as defined as the bore hole flow rate multiplied by the concentration of the particular gas being considered.
- The typical maximum concentrations can be exceeded in certain circumstances should the conceptual site model indicate it is safe to do so. This is where professional judgement will be required based on a thorough understanding of the gas regime identified at the site where monitoring in the worst case temporal conditions has occurred.
- The GSV threshold should not generally be exceeded without completion of a detailed gas risk assessment taking into account site specific conditions.

Once the Traffic Light classification has been determined, the requirements and scope of gas protection / mitigation measures can be determined based on the following table (CIRIA C665):

Gas Protection Measures for Low-Rise Housing Development Based Upon Allocation NHBC Traffic Light (Boyle and Witherington, 2006)

Traffic Light Classification	Protection Measures Required
Green	Negligible gas regime identified and gas protection measures are not considered necessary.
Amber 1.	Low to intermediate gas regime identified, which requires low-level gas protection measures, comprising a membrane and ventilated sub-floor void to create a permeability contrast to limit the ingress into buildings. Gas protection measures should be as prescribed in BRE Report 414 (Johnson 2001). Ventilation of sub-floor void should facilitate a minimum of one complete volume change per 24 hours.
Amber 2.	Intermediate to high gas regime identified, which requires high level gas protection measures, comprising a membrane and ventilated sub-floor void to create a permeability contrast to prevent the ingress of gas into buildings. Gas protection measures should be as prescribed in BRE Report 414. Membranes should always be fitted by a specialist contractor. As with Amber 1, ventilation of the sub-floor void should facilitate a minimum of one complete volume change per 24 hours. Certification that these passive protection measures have been installed correctly should be provided.
Red	High gas regime identified. It is considered that standard residential housing would not normally be acceptable without a further Gas Risk Assessment and / or possible remedial mitigation measures to reduce and / or remove the source of gas.

Volatile Organic Compounds

Similar to ground gas, under the Environmental Protect Act 1990, Building Regulations Approved Document C 2004, and the NPPF there is a requirement to ensure that Volatile Organic Compounds (VOC) are considered on a risk assessment basis.

VOCs are organic compounds that are volatile under normal atmospheric conditions. However, they may be found in the solid, liquid, and the dissolved phase as well as in the gaseous phase. VOCs are typically found in the following contaminants;

- Petroleum (non-halogenated) hydrocarbons (e.g. benzene, toluene, and butylbenzenes);
- Halogenated hydrocarbons (e.g. chlorinated ethenes and ethanes (dry cleaning fluids or degreasers) or chlorofluorocarbons (freons)); and
- Organic compounds containing nitrogen, sulphur, and oxygen (e.g. tetrahydrofuran).

The likely sources of the above contaminants include;

- Spills, leaks, and discharges from industries;
- Landfills;
- Buildings, furnishings, and common household products;
- Vehicle emissions;
- Marshland; and
- Uncontrolled waste disposal.

The risk to receptors from VOC occur from inhalation (acute and chronic), and a flammable/explosive risk when present at high concentrations in confined spaces.

Current UK guidance for VOCs are limited in comparison to ground gas, and is primarily given in the *"The VOCs Handbook; Investigating, assessing and managing risks from inhalation of VOCs at land affected by contamination"*, CIRIA Report C682, 2009.

The risk to receptors from VOCs has been assessed on a semi-quantitative basis as set out by CIRIA C682. Whereby the vapour concentration recorded during headspace analysis of soils, SVOC/VOC contaminant concentration within soil and groundwater samples, and the vapour concentration within installed boreholes are qualitatively assessed to determine whether a significant risk of a potential pathway exists.

Where a significant risk of a potential pathway exists further assessment will be required, this may include, vapour sampling, further intrusive investigations, or a Detailed Quantitative Risk Assessment (DQRA). Dependent on the results of the further assessment, remedial measures will be required to mitigate the risk to receptors.

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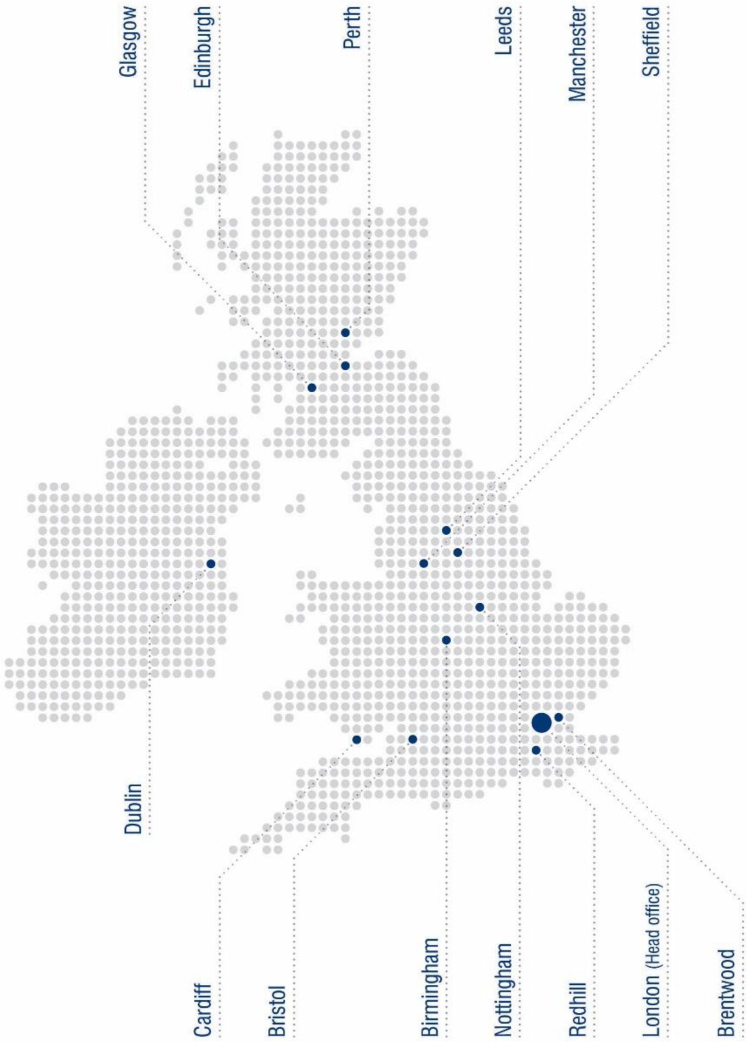
UK and Ireland Office Locations



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