Part 4

Foundations

Chapter

4.1

NHBC

Land quality – managing ground conditions

This chapter gives guidance on meeting the Technical Requirements for assessing and managing land quality.

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Introduction

This chapter provides a framework for managing geotechnical and contamination risks, with the objective of ensuring that:

- **all sites are properly assessed and investigated for potential geotechnical and contamination hazards**
- **foundations and substructure designs are suitable for the ground conditions**
- **sites are properly remediated where necessary or appropriate, and design precautions are taken**
- **appropriate documentation and verification is provided to NHBC.**

4.1.1 Compliance

Also see: Chapter 4.2

Assessment of the site and the surrounding area shall comply with the Technical Requirements. Issues to be taken into account include:

1) **suitability of persons for the level of investigation**
2) **geotechnical and contamination issues**
3) **investigation procedures**
4) **notification in writing to NHBC of hazardous ground conditions.**

Ground investigations and management of risk that complies with the guidance in this chapter will generally be acceptable.

4.1.1.1 Suitability of persons for the level of investigation

The following skills and knowledge are required from the person responsible for the Initial Assessment, Basic Investigation and documentation and verification. They should:

- understand the hazards that can affect the development and where they originate
- recognise the signs of potential hazards
- conduct a desk study and walkover survey
- collect information relating to such hazards on and adjacent to the site
- report the findings in a clear and concise manner
- determine when specialist advice and detailed testing is required.

The following criteria should be used as guidance for the appointment of a consultant or specialist responsible for Detailed Investigation, management of hazards, documentation and verification:

Experience	Similar types of site and development
Appropriate discipline(s)	Understanding of all relevant skills required on the project and access to other disciplines, including geologists, hydrogeologists, toxicologists and environmental chemists
Legislation	Understanding of legislation and liabilities associated with the site
Professional indemnity insurance	Appropriate cover for the work being carried out
Health and safety	Awareness of occupational hygiene issues and Health and Safety legislation
Quality assurance	Use of a quality management system, including appropriately accredited laboratories
Project management	Ability to manage a project team consisting of the appropriate disciplines
Site investigation	Ability to design site investigation programmes, including soil sampling, testing and laboratory analysis
Risk management	Ability to conduct risk assessments as required by the risk management process
Reporting and communication	Ability to prepare comprehensive and well-presented reports. Effective communication within their organisation and with the client, statutory authorities and the general public
Engineering design	Understanding of effective risk reduction techniques, eg engineered foundations and substructure details of suitable remediation

4.1.1.2 Geotechnical and contamination issues

Assessment should be carried out by direct investigation and examination of the ground, supplemented by laboratory testing where necessary, in order to determine the geotechnical and contamination characteristics of the site.

Where contamination is suspected or found, the site should be assessed using the Source-Pathway-Receptor framework (known as the pollutant linkage).

For land contamination to occur, a source, pathway and receptor must all exist. A written or diagrammatic representation of the land contamination (known as a Conceptual Model) should be produced to show the possible relationships between each.

4.1.1.3 Investigation procedures

The process to assess and manage the ground conditions is as follows:

Initial Assessment
NHBC requires all sites to be assessed by a desk study and a walkover survey. The results should be used to determine whether or not hazards are known or suspected.

Basic Investigation
Required to support the results of the Initial Assessment where hazards are not suspected.

Detailed Investigation
Required where hazards are known or suspected.

Further Assessment
Required after the Basic or Detailed Investigation has been conducted, to confirm that all objectives have been met. Where results are inconclusive, further investigation will be required.

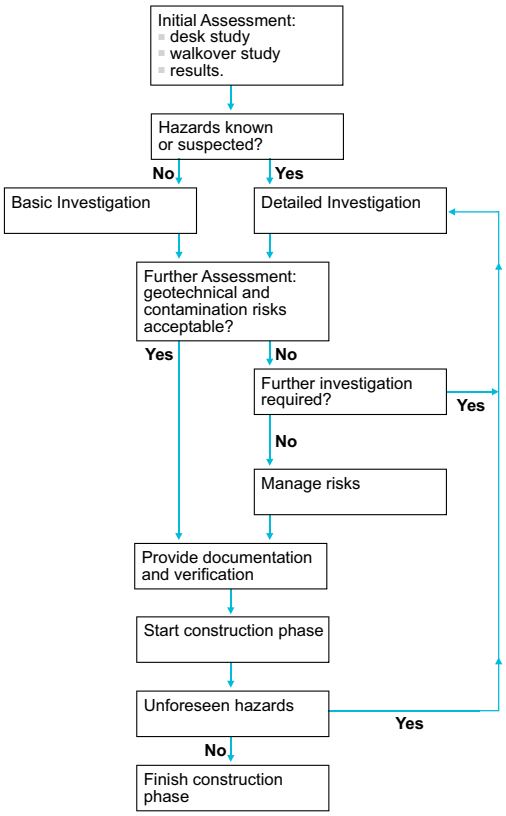
Hazards
Where hazards are identified, design precautions or remediation will be required to minimise their effects.

If any unforeseen hazards are found during the course of construction, further investigation is likely to be required.

Documentation and verification
NHBC requires documentation and verification to show that:

- the site has been properly assessed and investigated
- where necessary, suitable precautions are incorporated into the design
- all necessary remediation has been carried out.

Figure 1: Procedure flow chart



4.1.1.4 Notification in writing to NHBC of hazardous ground conditions

If a site (defined in the NHBC Rules as an area of land that is covered by a single detailed planning consent or series of consents relating to continuous development) is classed as ‘hazardous’, NHBC must be notified in writing a minimum of eight weeks before work starts. Failure to provide such information may delay the registration process, the construction work and the issuing of NHBC warranty.

Table 1: Potential hazards and associated risks

Potential hazard	Associated risk
High water table or low-lying land	• flooding • the effects from toxic or noxious materials which could be concentrated or transported by groundwater
Mining (past, present and proposed)	• ground movement as a result of the type of mining and materials extracted • ground gases, including methane and carbon dioxide
Trees and vegetation (eg Japanese knotweed or Bamboo — 'running' type)	• shrinkage and heave of clay soils • physical damage caused by roots
Peat	• acid attack • changes in volume due to variations in moisture content • production of methane and carbon dioxide
Infill and made ground, including tipping	• release of gases which may be explosive or asphyxiating • low bearing capacity causing excessive total and/or differential settlements • consolidation characteristics which may result in subsidence, settlement and/or excessive tilt • localised ground variability (laterally and with depth) which may result in subsidence, settlement and/or excessive tilt • collapse compression or inundation settlement of non-cohesive fills which may result in subsidence, settlement and/or excessive tilt
Low bearing capacity ground	• settlement of foundations and substructures
Former buildings or structures	• underground obstructions producing variations in bearing capacity and settlement characteristics
Adjacent buildings	• effect on stability of both new and existing buildings
Drains, including land drains	• contamination, flooding, waterlogging and interruption of land drainage systems
Sulfates and sulfides in ground or groundwater	• expansive reaction • chemical attack on concrete, mortar and bricks or blocks made with cement
Contamination	• from substances which may be carcinogenic, toxic, asphyxiating, corrosive, phytotoxic, combustive, explosive or radioactive
Solution features in chalk, gypsum and limestone, including swallow holes	• underground cavities
Unstable ground subject to landslip	• ground movement
Seas, lakes and rivers adjacent to land	• erosion • exposure to saline

4.1.2 Initial Assessment – desk study (all sites)

A desk study of the site and the surrounding area, that covers key and existing site information, shall be undertaken by a suitable person and include investigation of soils, geology, surface water, groundwater, current and historical uses.

A desk study is the collection and examination of existing information obtained from a wide variety of sources. It should indicate potential hazards at an early stage and provide a basis for the investigation. Potential problems should be assessed according to the current and historical uses of the site and surrounding area, including those which may have been left by:

- industrial, commercial and agricultural uses, including storage
- mining
- quarrying
- landfilling and tipping.

Key information sources include:

- Environment Agency or its equivalent — eg coastal erosion, landfill sites, details of water abstraction
- the local authority — eg planning and environmental health
- British Geological Survey, maps and information
- Ordnance Survey, current and previous editions of plans and aerial photographs
- Coal Authority, mining reports — past, present and proposed mining
- utility companies
- county records offices, libraries, museums and local history sources
- soil survey maps
- the site vendor
- in-house information
- ongoing monitoring
- the internet.

4.1.3 Initial Assessment – walkover survey (all sites)

To assess ground conditions, a walkover survey of the site and the surrounding area shall be undertaken by a suitable person.

A walkover survey is a direct inspection of the site and the surrounding area carried out in conjunction with the desk study. Indications of any potential hazards should provide a basis for the investigation. A photographic record of the site can help in the reporting of the walkover survey.

Table 2: Potential hazards

Source of information	Issues to be taken into account
Topography	• abrupt changes in slope • valley bottoms or depressions which may be soft or filled • evidence of overburden on slopes • excavations at the base of the slope • signs of landslip, eg tilting trees, posts or walls • signs of subsidence • evidence of imported soil, including local surface depressions, tipped material or rubbish, particularly if it is hot or has an odour
Soils and rocks	• the basic ground type • evidence of peat, silt or other highly compressible material at or below the surface • cracking or stickiness of the surface which may indicate a shrinkable subsoil • sudden changes in conditions, eg clay to chalk or soil to rock
Surface water and vegetation	• a high water table indicated, eg by waterlogged ground • signs of flooding • reeds or water-loving plants • springs, ponds, wells, ditches or streams • the source of any discoloured water
Vegetation	• vegetation which may indicate the nature of the soils • sparse dead or dying vegetation • type and condition of vegetation on land adjoining the site • species, height and condition of the trees • species, height, spread and condition of hedges and scrub on clay • evidence of former trees, hedges or scrub on clay
Structural information	• damage to structures, eg cracking in buildings, on or around the site • other evidence of movement, eg tilting or distortion • any structures or services below ground
Local information	• local knowledge of the site, eg mining, refuse tipping or flooding • local industrial history records indicating past and present uses of the site • place names and street names that may give clues to previous site usage, eg Brickfield Cottage, Water Lane, Tin Shop Hill

4.1.4 Initial Assessment – results

Also see: BS 5930

The results of the desk study and walkover survey shall be recorded and evaluated by a suitable person.

Initial results should be evaluated for suspected hazards and the results recorded, and include the following as appropriate:

- site plans, including dates, previous and current uses, and proposed site layout
- geology of the site, including geological maps, previous site investigations and laboratory test results
- photographs, including aerial photographs, showing points of interest or concern (eg areas of ground instability), interpretation of aerial photographs, and dates of photographs
- list of sources of information consulted and copies of the information obtained.

4.1.5 Basic Investigation (sites where hazards are not identified or suspected)

Where hazards are not suspected, a Basic Investigation of the site, including geotechnical and contamination investigations, shall be carried out by a suitable person and recorded to the satisfaction of NHBC.

The Basic Investigation aims to provide assurance for all sites, regardless of how free of hazards they may appear, and forms the minimum requirement for a site investigation. Further advice may be found in BS EN 1997-2.

The number and depth of trial pits should be located so they are representative of the site and will depend upon the:

- proposed development
- nature of the site
- inconsistency of the soil and geology across the site.

Trial pits should be located outside the proposed foundation area, and generally be a minimum of 3m deep. The distance from the edge of the foundation should not be less than the depth of the trial pit. Where trial pits do not provide sufficient information, boreholes will be necessary.

Basic geotechnical and contamination investigations should be conducted and include:

- physical tests, such as Plasticity Index tests, to support the results of the Initial Assessment
- a basic contamination investigation based on sampling and testing of soil taken from trial pits during the geotechnical investigation.

During the excavation of the trial pits, the use of sight and smell may help to identify certain contaminants.

If the Basic Investigation reveals the presence of geotechnical and/or contamination hazards, or has not addressed all of the original objectives, or where there is any doubt about the condition of the ground, further Detailed Investigation should be conducted.

4.1.6 Detailed Investigation (sites where hazards are identified or suspected)

Also see: BS 10175

Where hazards are identified or suspected, a Detailed Investigation of the site shall be conducted under the supervision of a consultant or specialist acceptable to NHBC to determine and report on the nature and extent of the conditions.

A Detailed Investigation should be carried out where hazards are identified or suspected:

- from the outset
- from the initial results of the desktop study and walkover survey, or
- from the Basic Investigation.

A consultant or specialist acceptable to NHBC should be appointed to:

- design and supervise the Detailed Investigation
- present all the factual data obtained from the Detailed Investigation.

In addition to the Basic Investigation, the Detailed Investigation should adopt a clearly defined, structured approach, gathering information which considers the:

- immediate site and the adjacent area
- possibility of future development in the vicinity of the site
- nature of the development
- complexity of the ground conditions
- extent of influence of the proposed foundations
- presence of ground gas (if there is any possibility a full gas investigation should be carried out and include flow measurements)
- surface water and groundwater conditions, soils and geology, and site history.

The problems and liabilities which have to be managed in order to develop the site should be clearly communicated in the Detailed Investigation report.

Further investigation should be conducted if the Detailed Investigation has not satisfactorily addressed all of the original objectives.

4.1.7 Managing the risks (sites where hazards are found)

Also see: CIRIA Reports C716 and SP164

Hazardous ground conditions shall be satisfactorily managed under the supervision of a consultant or specialist acceptable to NHBC. Issues to be taken into account include:

1) **design precautions**
2) **remediation techniques**
3) **remediation method statement and report.**

The consultant or specialist should:

- identify any results which show that design precautions and/or remediation may be necessary
- conduct a risk assessment to determine appropriate design precautions and/or remedial treatment
- specify the options for remediating any contamination that may be present and provide a remediation method statement
- make recommendations for appropriate design precautions as necessary, including all underground services on the site and any ground improvement techniques
- ensure the works are appropriately supervised
- produce a remediation report.

The proposed solutions for dealing with geotechnical and/or contamination hazards should make due allowance for any constraints that apply, for example:

- factors associated with the site and surrounding area which could restrict the design precautions or remediation techniques should be identified
- local and statutory requirements should be met to avoid abortive works
- time constraints may influence the choice of solution, but do not alter the requirement for effective remediation.

4.1.7.1 Design precautions

Solutions for dealing with geotechnical hazards include:

- specialist foundations such as rafts, pile, pier and beam foundations, see Chapter 4.4 Raft, pile, pier and beam foundations
- vibratory ground improvement techniques, see Chapter 4.5 Vibratory ground improvement techniques
- engineered fill, see Chapter 4.6 Engineered fill.

When dealing with hazardous gases, note:

- some radon barriers and gas membranes are manufactured from recycled products. However, these should not be used. Also see Annex C of BS 8485
- where protective measures are required for both radon and other hazardous gases, eg methane or carbon dioxide, it should not be assumed a radon barrier will be effective in such circumstances and further specialist advice should be sought. Also see Annex G of BS 8485
- on sites where radon or hazardous ground gases are present and cavities need to be sealed, it is still necessary to ensure downward movement of water within cavities is deflected from the cavity to the exterior of the building envelope. To ensure all relevant functional performance requirements of DPCs, cavity trays and gas barriers are met when such site conditions occur, and that products are compatible and detailed to ensure continuity, specialist advice should be sought. Also see, Clause 6.1.17.

4.1.7.2 Remediation techniques

Solutions for dealing with contamination hazards include:

- risk avoidance by changing the pathway or isolating the target, by adjusting the layout and/or by building protective measures into the construction
- engineering-based treatments that remove or isolate contaminants or modify the pathway by excavation, providing ground barriers or covering and capping
- process-based treatment to remove, modify, stabilise or destroy contaminants by physical, biological, chemical or thermal means.

4.1.7.3 Remediation method statement and report

The remediation method statement should detail the strategy for the site and include the:

- original risk assessment, identification of the remediation objectives and outline information for the method chosen
- remediation objectives for ground, groundwater and ground gas
- working method for implementing remediation
- waste classification and methods for control and disposal
- proposed supervision and monitoring of remediation
- validation sampling and testing to be implemented.

The report should include the following information:

- photographic records, especially for work which will be buried (eg membranes)
- site diaries or drawings, environmental supervisor's site diary and independent witness statements where appropriate
- accurate surveys of the levels and position of all remediated areas
- a description of any remedial materials used
- details of soil movements and waste transfer notes
- results of post-remediation sampling (laboratory certificates should be provided in appendices)
- validation test results
- results of monitoring
- details of all consultations and meetings with statutory authorities.

4.1.8 Unforeseen hazards

Where additional or unforeseen hazards arise during construction, the builder shall ensure investigation and management satisfactory to NHBC.

Where additional or unforeseen hazards arise, specialist advice is required so that the hazard is properly investigated, managed and verified.

4.1.9 Documentation and verification

Documentation and verification shall be provided to the satisfaction of NHBC to demonstrate that the site is suitable for the proposed development. All relevant information, designs, specifications and reports shall be produced in a clearly understandable format and distributed to appropriate personnel.

Where the site is within an area susceptible to radon, it will be necessary to follow appropriate guidance in the relevant Building Regulations and associated documents. The information detailed in Table 3 should be provided to NHBC.

Table 3: Information required by NHBC

Geotechnical hazards present:	Yes	No	Yes	No
Contamination hazards present:	Yes	Yes	No	No
Initial Assessment, Further Assessment and Basic Investigation	●	●	●	●
Detailed Investigation	●	●	●	
Proposals to manage geotechnical risks	●		●	
Proposals to manage contamination risks	●	●		
Verification evidence	●	●	●	●

Note

1. Evidence may still be required by NHBC to substantiate that contamination and hazards are not present on the site.

4.1.10 Guidance for investigations

Site investigations shall be undertaken in accordance with BS EN 1997-2 and recognised practice. Issues to be taken into account include:

1) investigation technique
2) sampling
3) testing.

4.1.10.1 Investigation technique

A site investigation normally comprises techniques which are classed as either indirect or direct. Further advice may be found in BS EN 1997-2.

Indirect investigations use geophysical techniques, including electromagnetic, resistivity, seismic, gravity and ground radar, to interpret ground conditions. Conducted from the surface, they measure variations in properties of the ground, both horizontally and vertically, to define subsurface conditions. Geophysical methods rely on contrasts in the physical properties, for example between sand and gravel and rockhead. Contrast may also be provided by faulting, underground cables and pipelines or by cavities.

Direct investigation techniques involve intrusive activities to enable the retrieval and examination of the ground using trial pits, trenches, boreholes or probes.

Trial pits allow the detailed inspection, logging, sampling and in-situ testing of large volumes of natural soil or fill and the assessment of groundwater conditions. Trenches are extended trial pits, or linked trial pits, which are excavated where greater exposure of the ground conditions is required. Trial pits and trenches should be positioned where they will not affect future foundations.

Boreholes are typically formed using the following techniques:

Light cable percussion drilling	A shell and auger rig — typically used in the UK to drill boreholes in soils and weak rocks
Continuous flight auger	Exploratory boreholes may be drilled in soils by mechanical continuous flight augers of various sizes. Hollow stem methods are typically employed where sample retrieval is required
Rotary drilling	Either open-hole drilling or rotary coring is used to investigate rock and sometimes stiff soils, such as boulder clay
Probing techniques	Used to analyse the relative density of soils and for environmental sampling and monitoring (such as chemical and physical testing of gases, liquids and solids)

4.1.10.2 Sampling

The number and type of samples taken should be:

- appropriate for the results of the desk study, the walkover survey and the site investigation
- appropriate for the range of ground materials encountered and the proposed development
- taken, stored and transported so that they avoid cross contamination.

Samples are used to enable soil and rock descriptions to be made and to provide material for physical and chemical testing.

‘Undisturbed’ soil and rock samples undergo minimal disturbance, so provide a more reliable indication of the physical soil properties than ‘disturbed’ samples.

Groundwater should be collected from appropriately designed monitoring wells which should be screened and sealed to ensure that the relevant stratum is being monitored.

Gas sampling should be carried out from appropriately designed monitoring wells. Boreholes or window sampling holes are typically used. Identification of the probable source and the measurement of gas flow are important for risk assessments.

4.1.10.3 Testing

Testing may be undertaken in-situ, or in a laboratory.

A wide variety of in-situ tests can be used to support the results of direct testing. These range from basic tests undertaken by geologists or engineers using simple hand-held devices or portable test kits to methods that require specialist personnel and equipment.

Testing laboratories should participate in quality assurance programmes and be accredited for relevant tests by bodies such as UKAS and MCERTS. Physical tests on soil and rock materials are carried out to provide the following information on ground:

- strength
- relative density
- deformation
- settlement
- consolidation characteristics
- permeability.

Chemical tests on soils, rocks, groundwater and gases can be carried out to provide an indication of potential contamination on the site.

4.1.11 Further information

- *BRE: Report BR211 — Radon: Guidance on protective measures for new dwellings (including supplementary advice for extensions, conversions and refurbishment projects)*
- *BRE: Report BR414 — Protective measures for housing on gas contaminated land*
- *BRE: Digest 383 — Site investigation for low-rise buildings: Soil description*
- *BS 5930 — Code of practice for site investigations*
- *BS 8485 — Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings*
- *BS 8576 — Guidance on investigations for ground gas — Permanent gases and volatile organic compounds (VOCs)*
- *BS 10175 — Investigation of potentially contaminated sites*
- *BS EN ISO 14688 — Geotechnical investigation and testing. Identification and classification of soil: Part 1. Identification and description. Part 2. Principles for a classification*
- *BS EN ISO 22476 — Geotechnical investigation and testing. Field testing*
- *CIRIA C665 — Assessing risks posed by hazardous ground gasses to buildings*
- *CIRIA C682 — The VOCs Handbook. Investigating, assessing and managing risks from inhalation of VOCs at land affected by contamination*
- *CIRIA C716 — Remediating and mitigating risks from volatile organic compounds (VOC) vapours from land affected by contamination*
- *CIRIA C735 — Good practice on the testing and verification of protection systems for buildings against hazardous ground gases*
- *CIRIA C758D — Abandoned mine workings manual*
- *CIRIA C773 — A guide to small brownfield sites and land contamination*
- *CIRIA C801 — Hazardous ground gas - a site management guide*
- *CIRIA SP164 — Remedial treatment for contaminated land, Volumes I - XII*
- *DLUHC and its predecessor departments' publications*
- *DEFRA and its predecessor departments' publications*
- *Environmental Protection Act 1990: Part 2A Contaminated Land Statutory Guidance — April 2012*
- *Department of the Environment Industry Profiles — Information on the processes, materials and wastes associated with individual industries*
- *CLEA (Contaminated Land Exposure Assessment) guidance and software Science Reports SR 1, 2, 3 and 7*
- *NHBC and Environment Agency R&D Publication 66 — Guidance for the safe development of housing on land affected by contamination*
- *CL:AIRE — Control of Asbestos Regulations 2012: Interpretation for Managing and Working with Asbestos in Soil and Construction and Demolition materials: Industry guidance*
- *CL:AIRE — Good Practice for Risk Assessment for Coal Mine Gas Emissions*
- *HSE — Control of Asbestos Regulations 2012*
- *NHBC Foundation NF94 — Hazardous ground gas — an essential guide for housebuilders*
- *NHBC/RSK Group Plc Guidance on evaluation of development proposals on sites where methane and carbon dioxide are present Edition No.: 04 March 2007*

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