bre

Radon

Guidance on protective measures for new buildings

Chris Scivyer







IHS

Radon

Guidance on protective measures for new buildings (including supplementary advice for extensions, conversions and refurbishment projects)

2015 edition

Chris Scivyer

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Front cover images
Left: Prefabricated sumps and pipework being laid in a small commercial building (image courtesy of Glencoe Radon Gas Centre Ltd)
Top right: New homes incorporating radon-protective measures
Bottom right: Radon barrier being laid for a school building (image courtesy of Radon Centres Ltd)

Back cover image
Airbrick

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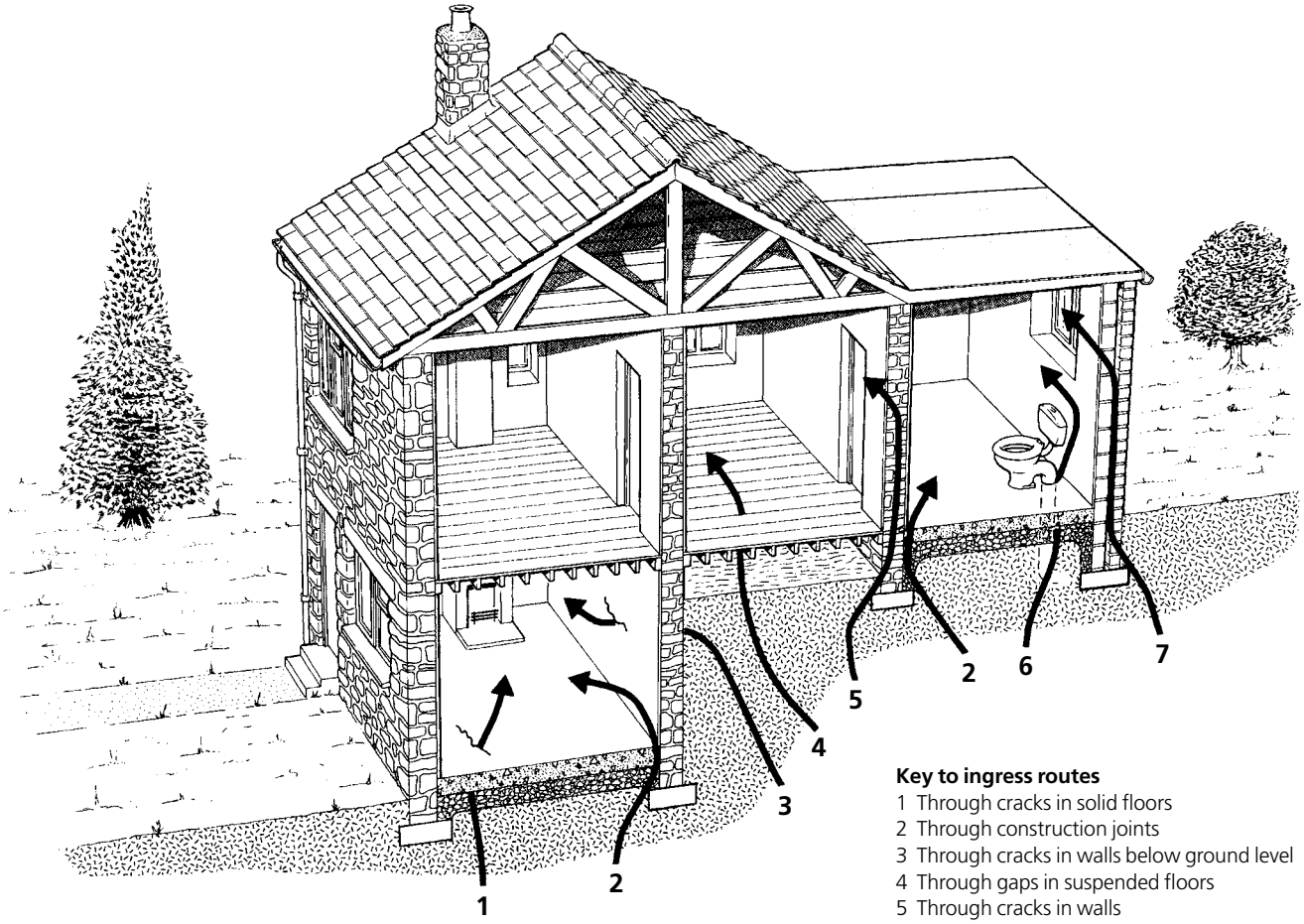
Image courtesy of Glencoe Radon Gas Centre Ltd.

1 Introduction



Key to ingress routes
1 Through cracks in solid floors
2 Through construction joints
3 Through cracks in walls below ground level
4 Through gaps in suspended floors
5 Through cracks in walls
6 Through gaps around service pipes
7 Through cavities in walls

Figure 1: Routes by which radon enters a dwelling

This report gives guidance for reducing the concentration of radon in new buildings, extensions, conversions and refurbishment projects in order to reduce the risk to occupants of exposure to radon. It provides practical details on protective measures for both domestic and non-domestic buildings. This guide is intended for use in England, Wales, Scotland and Northern Ireland. It supports building regulations for England, Wales and Northern Ireland, and building standards for Scotland. This guide was originally introduced in 1991 and amended in 1992, 1999 and 2007.

This guide replaces three earlier guidance documents:

- BRE Report BR 211, *Radon: guidance on protective measures for new buildings*, introduced in 1991 and amended in 1992, 1999 and 2007, covering England and Wales.
- BRE Report BR 376, *Radon: guidance on protective measures for new dwellings in Scotland*, introduced in 1999.
- BRE Report BR 413, *Radon: guidance on protective measures for new dwellings in Northern Ireland*, introduced in 2001.

The principal changes over previous editions are:

- combined guidance for England, Wales, Scotland and Northern Ireland
- clearer explanatory guidance on specifying and installing radon-protective measures
- updated guidance to reflect recent amendments to building regulations and building standards
- additional radon management checklist
- updated maps.

1.1 Background

BRE has been involved with the development of practical, cost-effective radon-protective measures for use in new UK buildings since the mid-1980s. Over the years a range of research and development projects have been carried out by BRE for UK building regulation bodies. This work has included large-scale field trials to demonstrate the efficacy of installing radon-protective measures in new dwellings, as well as studies of protective measures used in non-domestic buildings. Evidence from earlier studies demonstrated that the approaches adopted for new homes in the early 1990s worked well at the time. Follow-up monitoring carried out in a small sample of these homes 10 and 20 years after completion showed that radon levels were maintained at an acceptable level.

Radon-protective measures installed in newbuild properties are expected to reduce radon levels significantly. It is difficult to quantify the effective reduction within individual households. Comparison of radon levels in properties (built in areas of close proximity), with and without protective measures, shows a trend towards lower radon levels in protected properties. However, some newly built homes still have elevated radon levels measuring above the 'action level'*. Enhanced guidance included in this new edition of the report aims to improve the installation of radon-protective measures and therefore further reduce radon levels.

1.2 What is radon?

Radon is a natural, colourless, odourless, radioactive gas. It is formed by the radioactive decay of the small amounts of uranium that occur naturally in all rocks and soils. The gas can move through cracks and fissures in the subsoil and eventually to the atmosphere. Most of the radon will disperse into the air outside, but some will pass from the ground and collect in spaces under or within buildings (Figure 1). For the average UK resident, radon accounts for half of the annual radiation dose received. Exposure to high levels of radon increases the risk of developing lung cancer[1].

Radon is a natural, colourless, odourless, radioactive gas. It is formed by the radioactive decay of the small amounts of uranium that occur naturally in all rocks and soils ... Exposure to high levels of radon increases the risk of developing lung cancer

All buildings contain radon. Certain areas of the UK have been defined with an increased potential for high radon levels. For further information, see the maps in Appendix A. The darker the shading on the radon maps, the greater the chance of a high radon level in a building. Note that not all buildings, even in the most radon-prone areas, have high levels.

With careful design and construction, radon-protective measures can be included relatively easily and cost-effectively within new buildings and extensions, or when converting or refurbishing existing buildings. Radon-protective measures do not completely stop the entry of radon into a building. The areas where radon-protective measures are required are all contained within existing 'radon-affected areas'. Existing advice is that all homes in radon-affected areas should be tested for radon[2], with a similar recommendation for workplaces[3]. (Further information is also available at www.hse.gov.uk.) It is therefore important that new buildings with radon-protective measures are tested for radon once they are occupied. Where elevated radon levels are identified, reduction measures should be applied.

* The level above which action should be taken to reduce or manage radon levels.

2 National building regulation guidance

Throughout this guide, reference is made to national building regulation guidance. Guidance can be found in the following publications, which relate to a specific UK region:

- *England*: The Building Regulations 2010 (England). Approved Document C: Site preparation and resistance to contaminants and moisture[4].
- *Wales*: The Building Regulations 2010 (as amended in Wales). Approved Document C: Site preparation and resistance to contaminants and moisture[5].
- *Scotland*: The Building (Scotland) Regulations 2004. Technical Handbook, Domestic, Environment[6]; and The Building (Scotland) Regulations 2004. Technical Handbook, Non-domestic, Environment[7].
- *Northern Ireland*: The Building Regulations (Northern Ireland) 2012 (as amended). Technical Booklet C: Site preparation and resistance to contaminants and moisture[8].

This guidance is updated from time to time. Readers should ensure that they are using the most current edition and that the guidance is relevant to their region of the UK. The guidance in this report applies to all new buildings, extensions, conversions and refurbishment projects, whether they be for domestic or non-domestic use (unless subject to local exemptions contained within the above regulations).

3 Protective measures

Radon and air are drawn into buildings from the underlying ground. There are two main methods of achieving radon protection in new buildings: passive and active. The passive system involves providing a barrier to the radon (Figure 2) and in more radon-prone areas, where the construction type allows, additional natural underfloor ventilation. This can often be achieved by increasing the general airtightness of the damp protection provided in floors and walls. The active system consists of providing natural or mechanical (fan-assisted) underfloor ventilation, or a powered radon extraction system, as an integral part of the services of the building. The last two options will incur running and maintenance costs for the life of the building. Passive systems are to be preferred in new buildings, although they may need to be supplemented later with active protection.

In areas with an increased radon potential, sufficient protection will be provided by a well-installed 1200 gauge damp-proof membrane (DPM) modified and extended to form a radon barrier across the footprint of the building. This gas-tight barrier is known as 'basic radon protection'.

New buildings in areas of higher radon potential should incorporate full radon protection comprising a radon barrier across the footprint of the building supplemented by provision for subfloor depressurisation or ventilation (either a radon sump or a ventilated subfloor void).

While terminology may vary within the different regional building regulation guidance documents covering England, Wales, Scotland and Northern Ireland, within this guide radon-protective levels are referred to as either 'basic radon protection' or 'full radon protection'.

Although very rare, there may be cases where the building being constructed is located on or adjacent to a landfill site or old coalfield. In such cases additional precautions may be needed to deal with methane and other landfill gases. Appropriate measures for dealing with methane are described in BRE Report BR 414, *Protection measures for housing on gas-contaminated land*[9]. The measures described exceed those required for radon, so where both methane and radon are present, methane-protective measures should be applied and only intrinsically safe (non-sparking) fans and switchgear should be used if activation is required. For guidance on identifying ground gases, see BS 8576:2013[10].

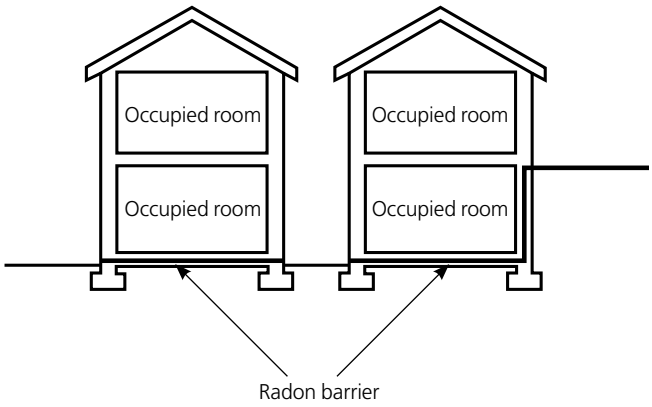


Figure 2: Passive measures to prevent radon entry

4 Determining the level of protection

4.1 Maps in this report

In most cases it is impractical to assess the severity of a radon problem on a particular site accurately until the building has been constructed and occupied. Protective measures should therefore be provided in areas with an identified high radon potential. These areas are shown on the maps in Appendix A as 1 km grid squares. The maps are derived from the *Indicative atlas of radon in England and Wales*[3], *Indicative atlas of radon in Scotland*[11] and *Radon in Northern Ireland: indicative atlas*[12]. These indicate the highest radon potential within each 1 km grid square. The 1 km grid squares are based on the relevant National Grid used by the Ordnance Survey so can be easily cross-referenced to local area Ordnance Survey maps at scales used for planning purposes (eg 1:50 000, 1:25 000 or 1:10 000).

In many cases the radon potential varies considerably within a grid square. Sometimes, only a very small area with a radon potential exceeding the thresholds for basic or full protection occurs within the grid square but, as squares are coded according to the highest radon potential, the whole square has been shaded. If a site falls within a shaded grid square on the maps in Appendix A, that does not necessarily mean that it must have radon protection. A site-specific report that gives the radon potential and the need for protection can be obtained; see Section 4.3, 'Using the site-specific radon risk report'.

The areas requiring protection will need revision as more information becomes available from Public Health England (PHE) or the British Geological Survey (BGS), and the maps will be amended accordingly. The local authority building control officers/building standards surveyors for the district in which you are proposing to build, or your building regulations approving body, will be able to confirm which maps should be used.

4.2 Using the Appendix A maps to determine the level of protection

The level of protection needed is site-specific:

- If the site is in an unshaded square then no radon protection is needed.
- If the site is in a light grey square on the relevant map in Appendix A of this report then basic radon protection should be installed.
- If the site is in a dark grey square on the relevant map in Appendix A of this report then full radon protection should be installed.

Radon barriers provide significant protection and are relatively cheap to install in new buildings, effectively being an enhanced, gas-tight DPM over the footprint of the building. They are also much cheaper and less intrusive than radon-remedial measures used for existing buildings. It is therefore prudent to provide them where there is any reasonable indication that a site has increased radon potential. In addition, someone purchasing a new property may expect their new building to have radon protection if it is in an area at increased risk. Providing protection in borderline cases reduces the need to explain why measures have been omitted.

4.3 Using the site-specific radon risk report

The site-specific radon risk report may allow the applicant to adopt a lower level of protection than indicated in the maps in Appendix A. Also, the radon risk report contributes to providing evidence of compliance with building regulations. It is the responsibility of the applicant to obtain the report.

4.3.1 Reports for new development sites

A BGS site-specific radon risk report may be obtained from:

GeoReports
BGS Central Enquiries Desk
British Geological Survey
Keyworth
Nottingham NG12 5GG
UK
Tel: 0115 936 3143
E-mail: enquiries@bgs.ac.uk
www.bgs.ac.uk/radon

or ordered online at http://shop.bgs.ac.uk/georeports.

Other licensed search providers, including some local authorities, can also provide these reports.

4.3.2 Reports for extensions to existing dwellings

If a postcode and/or postal address is available for an existing dwelling, a site-specific radon risk report may be obtained online from www.ukradon.org, www.bgs.ac.uk/radon or other licensed search providers, including some local authorities.

5 Protective measures: technical approach

National building regulations require protection against moisture from the ground

5.1 Basic radon protection

National building regulations require protection against moisture from the ground. In some ground floor constructions this protection comprises a barrier laid within the floor or solum construction, which is linked to a damp-proof course (DPC) within the walls of the building. To provide protection from radon, the DPC to a cavity wall should be in the form of a cavity tray to prevent radon entering the building through the cavity. Sealing of joints in the barrier and sealing around service penetrations are also required. It is important that attention is paid to detailing and workmanship in jointing of the barrier.

If good standards of design and workmanship are applied to the provision of a 1200 gauge damp-proof barrier to the floor sealed to a DPC/cavity tray through the walls, adequate protection from radon will be provided along with the general function of excluding moisture. However, in areas with higher levels of radon, the additional measures described in Section 5.2, 'Full radon protection', will be required.

Note on illustrations: The figures included in this guidance only illustrate the principles of providing a radon barrier and supplementary sub-slab ventilation. For clarity the positioning of elements such as the damp protection, insulation or method of support of the cavity tray may have been omitted. The illustrations should not be considered working drawings. It is the designer's responsibility to develop final details suitable for individual buildings

5.1.1 Basic radon protection: suspended (beam-and-block) concrete floor (high-level barrier)

In the example illustrated in Figure 3, a radon barrier is provided by a vapour-proof membrane, which is placed above a suspended concrete floor and linked to a cavity tray in the external walls (see also Figure 17 on page 14). The joints between the sheets that form the membrane and the cavity tray must be sealed to make the construction as gas-tight as possible. Seals should also be provided at service penetrations.

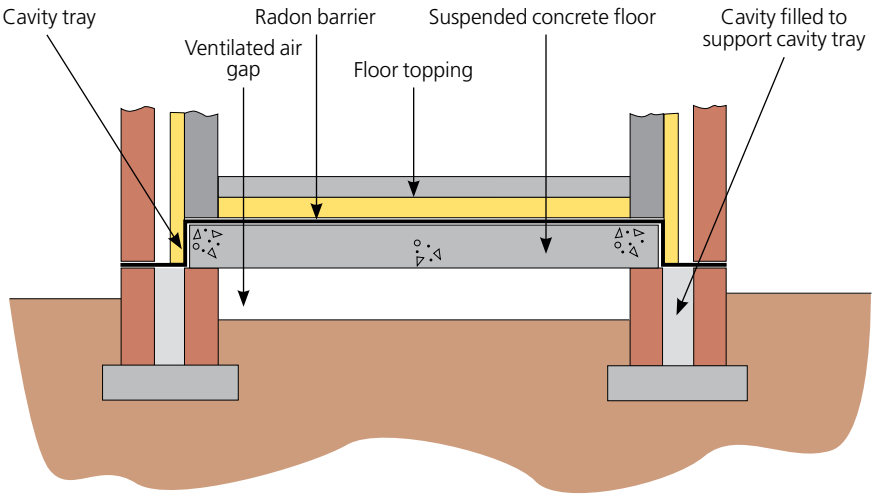


Figure 3: Enhanced DPM providing basic radon protection to a suspended concrete floor

5.1.2 Basic radon protection: suspended (beam-and-block) concrete floor (low-level barrier)

It is especially important that attention should be paid to detailing and workmanship in jointing of the barrier. This ensures that the whole building is sealed, including the cavity walls

In the example illustrated in Figure 4, the radon barrier is laid across the ground before the wall is constructed and separate damp protection is provided. The advantage of this approach is that by separating the radon and damp protection there is no need to provide a cavity tray within the wall except over the underfloor vents. However, because the radon barrier is inserted so early in the construction process, it is important to use a strong membrane material (possibly a reinforced material) and to ensure that it is well protected with sand or lean mix concrete before advancing construction. Protection is essential since there is a risk of damage by subsequent trades dropping concrete beams or blocks onto the barrier when installing the floor structure. The radon barrier should provide adequate radon protection provided that it is no more than 225 mm below ground level.

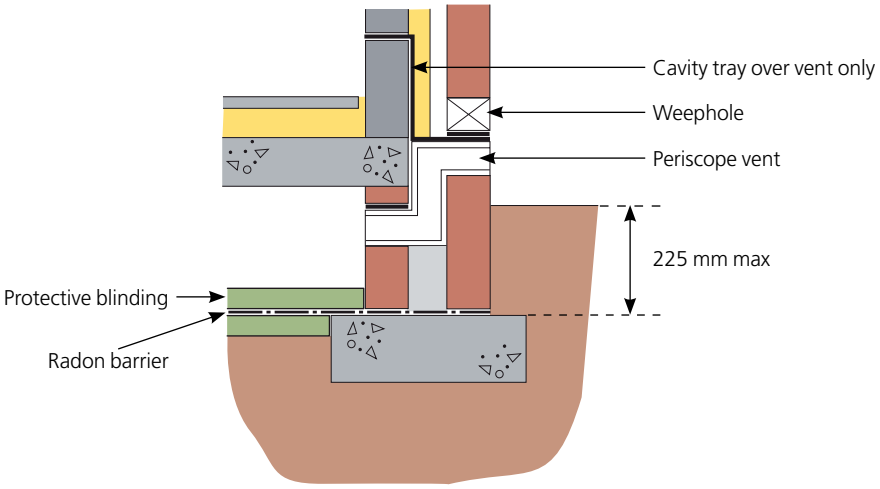


Figure 4: The radon-proofed barrier is laid down before construction and separate damp protection is provided

5.1.3 Basic radon protection: in situ (ground-supported) concrete floor

In the examples illustrated in Figures 5–8, the DPM provides a radon barrier. The joints between the membrane must be sealed to make them as gas-tight as possible. Service penetrations should also be sealed and the cavity tray must be joined to the floor membrane and sealed.

In the example illustrated in Figure 9, the radon barrier is laid across the ground/solum before the wall is constructed and damp protection is provided separately. The advantage is that by separating the radon and damp protection there is no need to provide a cavity tray, which can prove difficult to install. With the radon barrier going in so early in the construction process, it is important to use a strong membrane material (possibly a reinforced material) and to ensure that it is well protected with sand or lean mix concrete before advancing construction. The radon barrier should provide adequate radon protection provided that it is no more than 225 mm below ground level.

Note on illustrations: The figures included in this guidance only illustrate the principles of providing a radon barrier and supplementary sub-slab ventilation. For clarity the positioning of elements such as the damp protection, insulation or method of support of the cavity tray may have been omitted. The illustrations should not be considered working drawings. It is the designer's responsibility to develop final details suitable for individual buildings

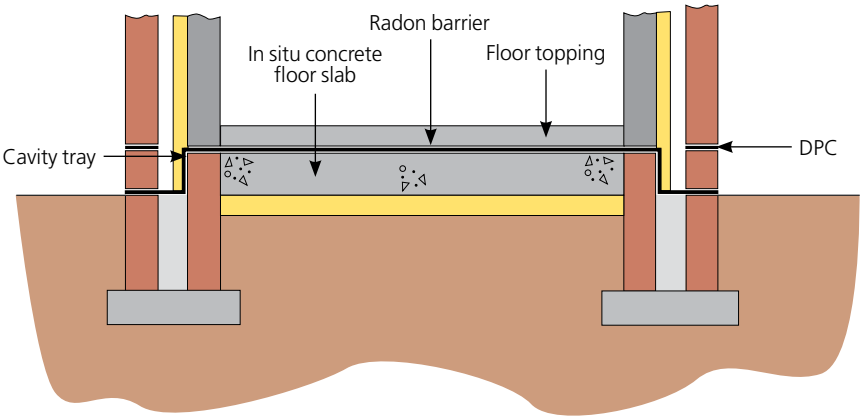


Figure 5: Enhanced DPM providing basic radon protection to an in situ or ground-supported concrete floor with the radon barrier laid over the slab

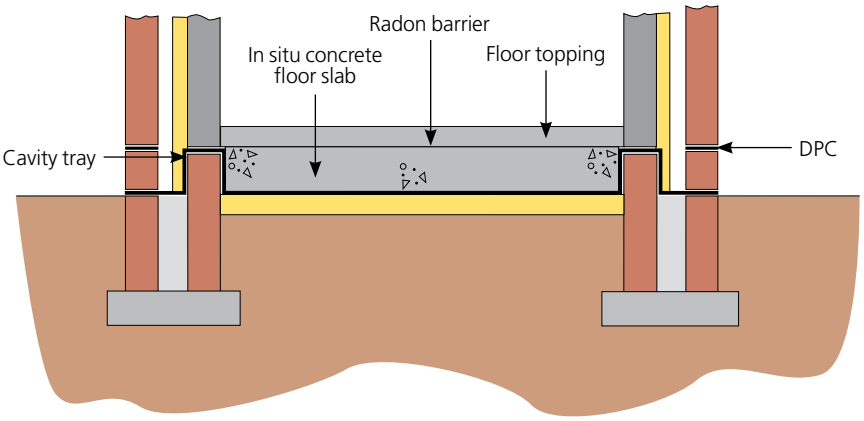


Figure 6: Enhanced DPM providing basic radon protection

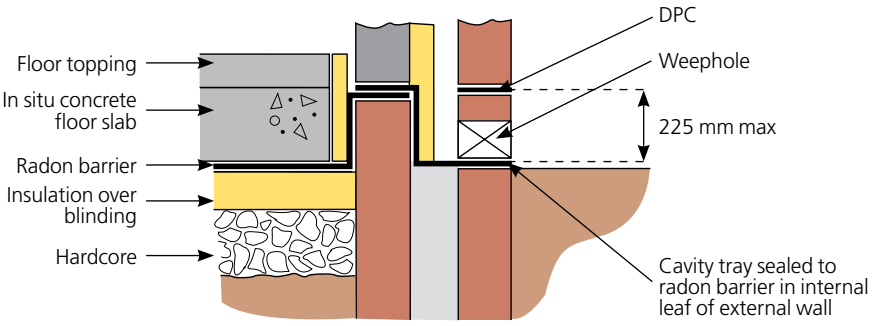


Figure 7: Possible working detail of an enhanced DPM

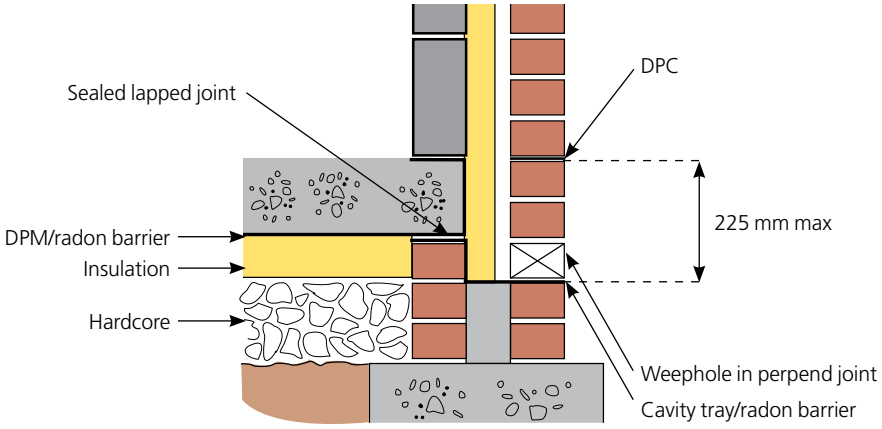


Figure 8: Possible alternative working detail of an enhanced DPM
(Source: NHBC)

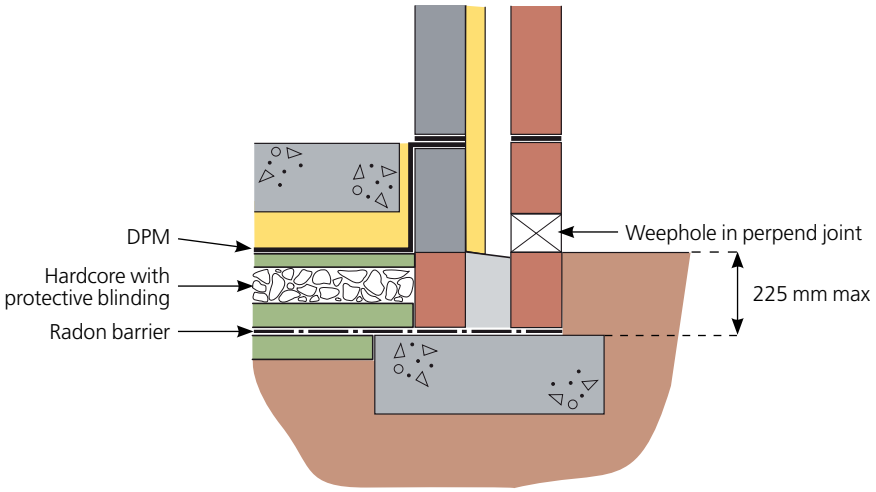


Figure 9: Enhanced DPM providing basic radon protection to an in situ or ground-supported concrete floor with the barrier laid beneath the slab
(Note: Insulation could be located above the slab)

5.2 Full radon protection

For areas where the radon potential is higher, further protection than that offered by the basic radon protection will be needed. It is especially important that attention should be paid to detailing and workmanship in jointing of the barrier. This ensures that the whole building is sealed, including the cavity walls.

It is especially important that attention should be paid to detailing and workmanship in jointing of the barrier. This ensures that the whole building is sealed, including the cavity walls

In areas where there are higher levels of radon, minor imperfections in the DPM in the floor, which also acts as a radon barrier, may let through sufficient radon to cause the action level to be exceeded. In these higher radon areas, the quantity of radon reaching the barrier can be reduced through the provision of protection (either a radon sump or a ventilated subfloor void) that can be activated if needed by the addition of a fan.

Note on illustrations: The figures included in this guidance only illustrate the principles of providing a radon barrier and supplementary sub-slab ventilation. For clarity the positioning of elements such as the damp protection, insulation or method of support of the cavity tray may have been omitted. The illustrations should not be considered working drawings. It is the designer's responsibility to develop final details suitable for individual buildings

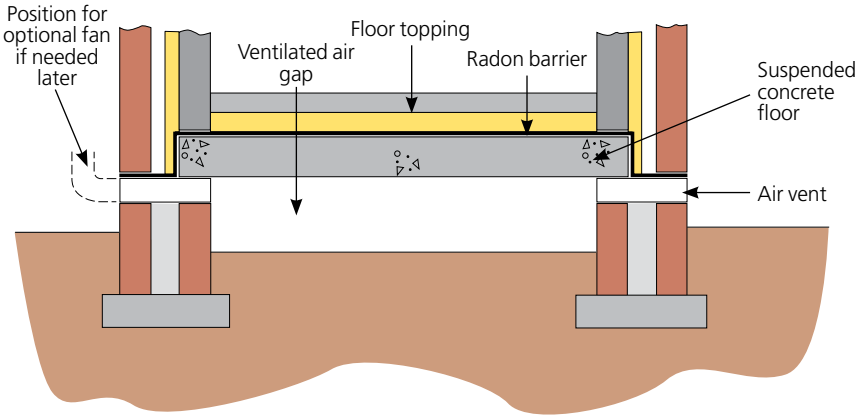


Figure 10: Full radon protection to a suspended concrete floor

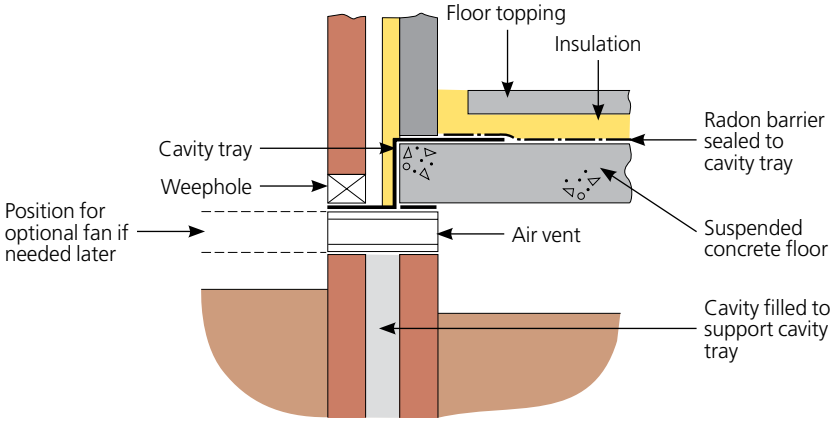


Figure 11: Possible working detail of full radon protection to a supended concrete floor

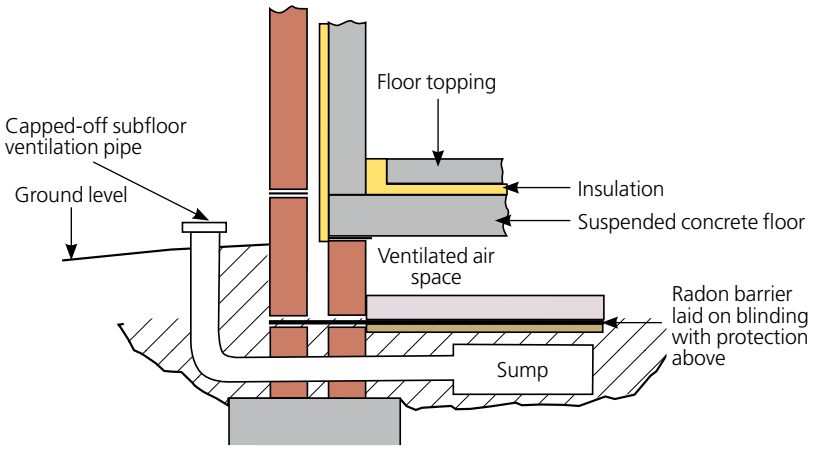


Figure 12: Possible working detail of full radon protection to a supended concrete floor with ground-level barrier

5.2.1 Full radon protection: suspended concrete (beam-and-block) floor

In the examples illustrated in Figures 10 and 11 opposite, the radon barrier is positioned over the floor structure and linked to cavity trays at the edges. Supplementary protection is also provided by locating underfloor vents on two or more sides of the underfloor space. Although underfloor ventilation reduces the amount of radon, which the radon barrier provided in the floor construction has to exclude, it should not be looked upon as a primary defence. An alternative solution is shown in Figure 12. It is of paramount importance that the radon barrier is properly designed and installed.

If it is found, through testing after occupation, that the building still has an unacceptably high radon level, the rate of underfloor ventilation and radon dispersion can be supplemented by the installation of an electrically powered fan. Note that the fan is not required to be installed during construction. For more information, see Section 6.14, 'Monitoring radon in completed buildings and extensions'.

5.2.2 Full radon protection: in situ (ground-supported) concrete floor

It is of paramount importance that DPMs, which also act as the radon barrier, must be properly designed and installed

In the example illustrated in Figure 13, the radon barrier is laid beneath the oversite concrete and continues across the cavity wall. Note that the barrier may also be placed above the slab. The slab needs to be mesh-reinforced and is supported on the inner leaf of the cavity wall, since a traditional ground-bearing slab could settle on completion and rupture the radon barrier at the point where the slab meets the external wall. Alternatively, in the examples illustrated in Figures 14 and 15, the radon barrier is laid over the oversite concrete and continues across the cavity. Again, the slab needs to be mesh-reinforced and is supported on the inner leaf of the cavity wall. It is of paramount importance that DPMs, which also act as the radon barrier, must be properly designed and installed.

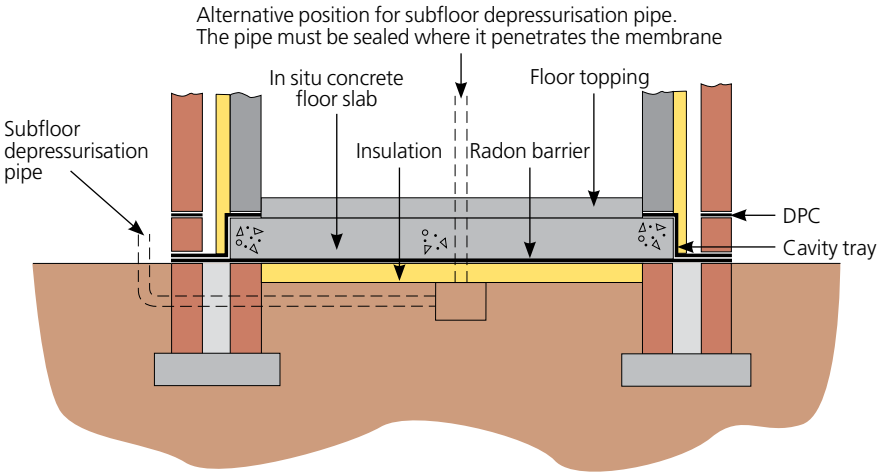


Figure 13: Full radon protection to an in situ edge-supported or ground-supported concrete floor with the barrier laid beneath the slab

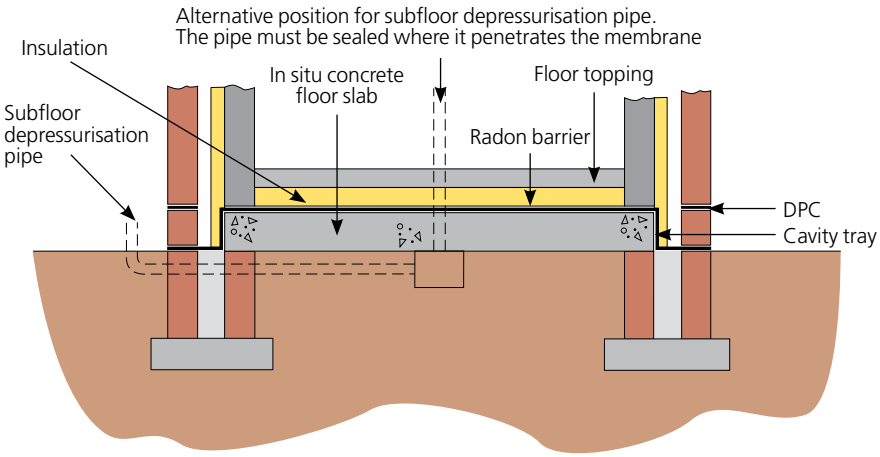


Figure 14: Enhanced DPM providing full radon protection to an in situ or ground-supported concrete floor with the barrier laid over the slab

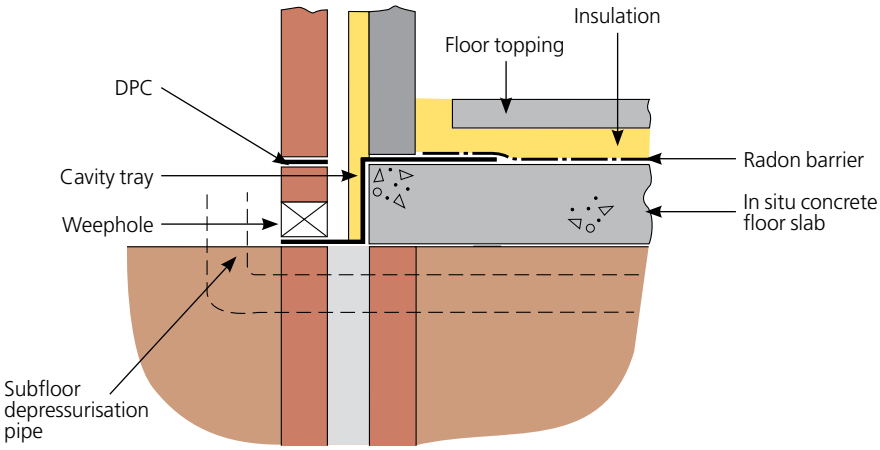


Figure 15: Possible working detail of full radon protection to an in situ concrete floor

In addition to providing the radon barrier, supplementary protection is required in the form of provision for future subfloor depressurisation. This involves providing a radon sump and a short length of pipe beneath the floor slab. If it is found, through testing after occupation, that the building still has an unacceptably high radon level, the rate of radon dispersion can be improved by connecting an electrically powered fan to the pipework. Note that the fan is not required to be installed during construction. It is possible to use the passive stack ventilation principle to disperse radon from sumps installed centrally beneath a building rather than use an electrically powered fan.

These examples are not the only design options available; alternative solutions may be adopted, such as sealed raft foundations and fully tanked basement construction (using asphalt or other waterproofing systems). Once the method by which protection is to be provided has been decided, the guidance detailed in the following sections will need to be applied.

6 Detailed protective measures

6.1 Workmanship and inspection

To be successful, radon-protective measures need to be implemented consistently throughout the construction process from design through to handover. To assist designers and supervisors in managing this process, a checklist of actions is provided in Appendix B. A high standard of workmanship is required if radon-protective measures are to prove successful. Regular supervision and checking is essential. There is no room for an 'out of sight, out of mind' philosophy because subsequent radon measurement will show up any failures. While there is no specific statutory requirement to inspect the radon barrier, BRE strongly recommends that an inspection is carried out prior to covering up the barrier.

6.2 Radon barriers

With careful design and selection of material, and good workmanship, a single barrier will satisfy the requirements of both damp proofing and radon protection. For added reassurance it is worth considering using installers accredited under a National Occupational Standard (NOS), Construction Skills Certification Scheme (CSCS) or similar gas barrier scheme.

6.2.1 Barriers

Generally a membrane of 300 micrometre (1200 gauge) polyethylene sheet will be adequate. (It is acknowledged that some diffusion will occur through the sheet. However, as most radon entry is through cracks, this diffusion can be ignored.) To be successful it must be installed with considerable care and protected once installed.

A building site is a harsh environment and barriers can easily become damaged during construction by operatives or equipment moving across or working over a completed section of barrier. As a consequence, where there is a risk of puncturing the membrane, stronger materials such as thicker or reinforced polyethylene sheet should be considered.

The barrier can be constructed with other materials that match or better the airtightness and waterproofing properties offered by 300 micrometre (1200 gauge) polyethylene. Alternative materials that can prove suitable include prefabricated welded barriers, modern flexible sheet roofing materials, self-adhesive bituminous-coated sheet products, liquid coatings and asphalt.

In terms of installing barrier materials, it should be noted that while thicker products may be more robust they may prove difficult to bend, fold or double up when forming edge or corner details. In such locations it is advisable to use preformed components. These are widely available from barrier manufacturers. Alternatively, use the thicker material under the main slab and use materials that are easier to fold, lap and seal at the perimeter walls and awkward details (Figure 16).

When specifying barrier materials, be aware that some manufacturers market recycled products. Check with the manufacturer that recycled products provide the same or a better level of protection and longevity as that offered by 300 micrometre (1200 gauge) virgin polyethylene.

Prefabricated welded barriers are becoming more widely available and more affordable. They comprise a bespoke one-piece sheet manufactured to fit the full footprint of the building. With all jointing carried out under factory conditions, there is less chance of the barrier leaking.

The barrier should be visually inspected for completeness prior to it being covered by later construction. For greater confidence some specialist installers offer integrity testing of barriers. Typically this involves temporarily pressurising the ground beneath the barrier using air mixed with smoke or a tracer. Any leaks can then be identified by sight or using a tracer gas meter. Any leaks found can be appropriately repaired.

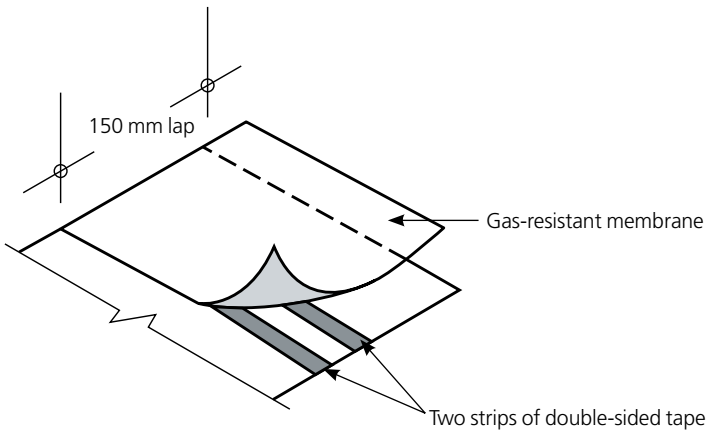


Figure 16: Sealing joints in the radon barrier

The barrier should be continuous and as airtight as possible; all joints, including any in the cavity tray, should be carefully and durably sealed

6.2.2 Protection of the barrier during and after construction

Even with the more robust materials it is important that the radon-proof membrane is not damaged during construction. This might be achieved by installing the membrane at a later stage of construction, eg over the floor immediately before laying of the screed (Figure 17). Another option might be to protect the membrane by sandwiching it between two layers of insulation. If laid beneath the slab, the barrier may need to be protected against damage when placing, compacting and finishing of concrete takes place. If it is intended to power-float a concrete slab, ensure that the edge of the barrier is appropriately detailed or adequately protected so that it cannot be damaged by the action of the power float.

Before the barrier is covered with concrete or other construction work, it is important to check that it is not damaged in any way (ie no holes or tears etc). Damaged areas should be repaired before proceeding with later works. Any damaged part of the barrier can be repaired by overlaying it with a piece of membrane material, held in place by tape or sealant, to provide a minimum overlap of 150 mm (Figure 18).

Concern has been expressed about damage caused to the barrier when fixing sole plates for timber-frame construction. While most fixings, particularly nail fixings, tend to self-seal, it is advisable to apply flexible sealant between the barrier and soleplate at the point where a fixing is made.

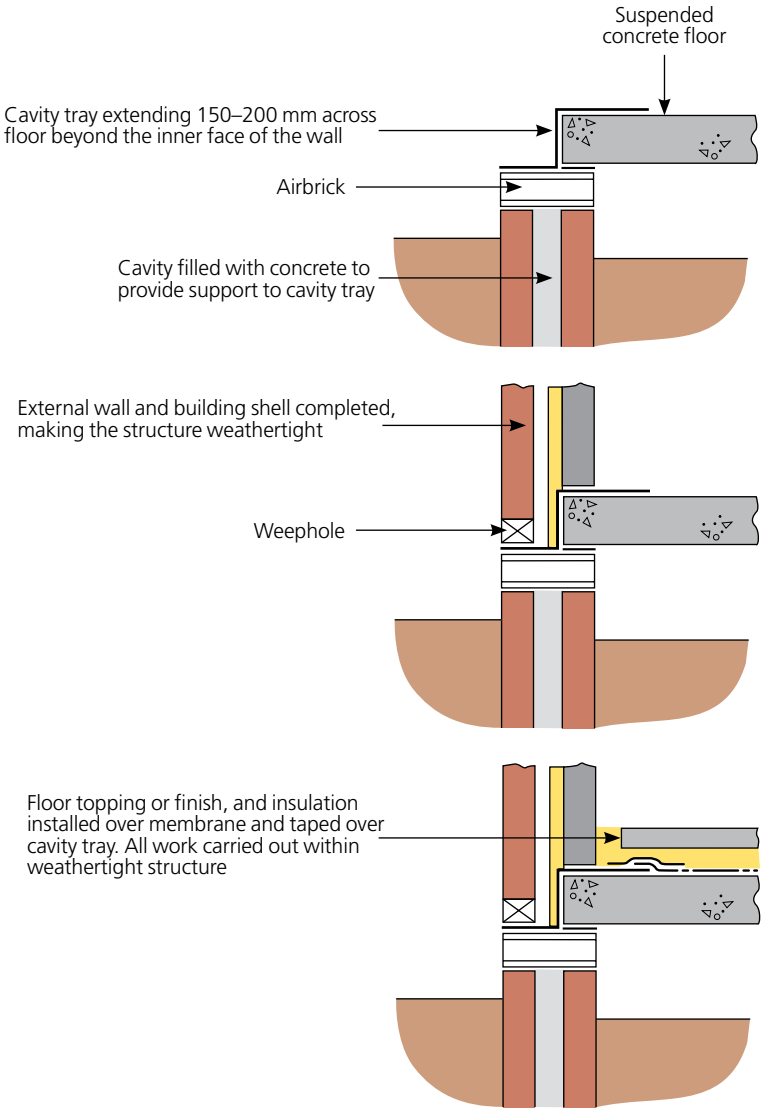


Figure 17: Construction steps to minimise damage to the barrier and enable sealing of barrier joints to be carried out in dry conditions (see also Section 6.5, 'Slip or shear planes')



Figure 18: Radon barrier with fully sealed joints waiting for concrete to be poured
(Courtesy of Glencoe Radon Gas Centre Ltd)

While there is no specific statutory requirement to inspect the radon barrier, BRE strongly recommends that an inspection is carried out prior to covering up the barrier

6.2.3 Radon protection to cavities

One of the routes by which radon might enter a building is by way of the wall cavities, and therefore the radon barrier should extend across the cavity to prevent radon entry. Where the barrier crosses the cavity, it will need to be constructed in the form of a cavity tray (Figures 19 and 20) to prevent the ingress of water from the outer to the inner leaf. The barrier should be continuous and as airtight as possible; all joints, including any in the cavity tray, should be carefully and durably sealed. As with all cavity trays, weepholes will have to be provided in the outer leaf to drain the cavity. To ensure that the cavity tray is fully supported, the cavity should be filled up to the barrier with concrete or other suitable material such as extruded polystyrene foam or expanded polyethylene foam.



Figure 19: Prefabricated cavity tray corner unit
(Courtesy of Cavity Trays Ltd)



Figure 20: Preformed cavity tray to patio door threshold positioned prior to bedding in mortar
(Courtesy of Cavity Trays Ltd)

Radon is a gas, so it is necessary to achieve as gas-tight a seal as possible between all parts of the barrier and to seal penetrations such as service entries and exits

6.2.4 Lapping and sealing of membranes and trays

When the membrane material is selected, consideration should be given to jointing. Some materials are difficult to seal in adverse weather, eg sealant tapes may not fully adhere to barrier materials and substrates in cold or damp conditions. It is always advisable to check with manufacturers' product specifications for suitability. Commonly available materials include adhesive tapes and double-sided, self-adhesive, synthetic rubber-strip sealants. Both can prove effective if installed correctly, although the latter is likely to offer greater confidence in achieving radon-proof joints. Many gun-applied flexible sealants are suitable for sealing membranes. In all cases check that sealant products are compatible with barrier products.

Wherever the membrane or tray needs to be lapped and sealed, care must be taken to ensure a very good standard of work. Attention to detail and good workmanship is essential if the barrier is to be effective. It is important to check that all joints have been correctly sealed prior to covering with later construction. It should be borne in mind that radon is a gas, so it is necessary to achieve as gas-tight a seal as possible between all parts of the barrier and to seal penetrations such as service entries and exits.

6.2.5 Continuity of barriers through internal walls

The radon barrier should be continuous across the whole plan of the building, including taking it through or under internal walls.

Where internal walls sit on top of a ground-bearing concrete slab, which in some cases may have been thickened to provide additional support, the wall should be built off the membrane or its covering in such a way as to leave the membrane intact (Figure 21). Sometimes it will be convenient to build these walls off a 600 mm wide strip of membrane material, and to lap and seal this to the main membrane before screeding. (This will reduce the risk of damage from traffic.)

Where internal walls are constructed with their own foundations, a strip of membrane material that can be sealed to the main membrane will need to be built in. It may be convenient to achieve this by using a 600 mm wide strip of membrane material that can be lapped and sealed to the main membrane before screeding. The radon barrier can double as a DPC within the wall.

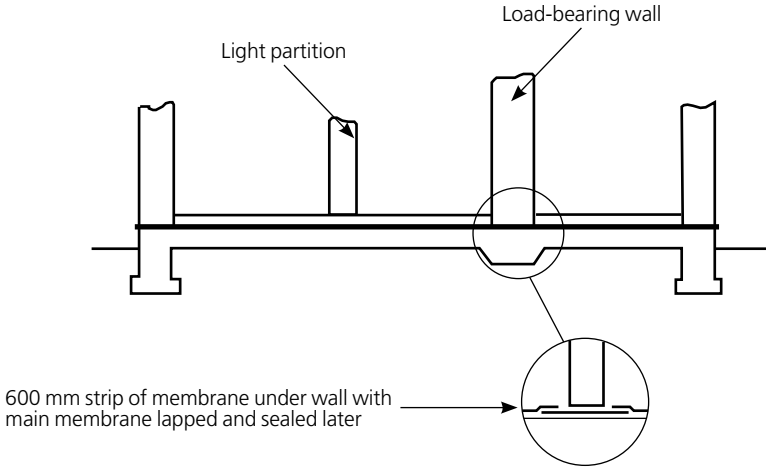


Figure 21: Avoidance of breaking the radon barrier beneath internal walls

6.2.6 Continuity of barriers through steps and staggers in walls and retaining walls

Where possible, stepped foundations should be avoided because they complicate the achievement of radon protection. It may prove less expensive to excavate around the building (Figure 22) to provide a ventilated space than to try to build into the hillside and seal all the faces of the building that are below ground level. This also decreases the likelihood of damp penetration. Where stepped foundations cannot be avoided, consider using proprietary membrane systems. Most of the suppliers of radon membranes offer systems for detailing around steps in construction or for detailing cavity trays on sloping sites (Figures 23 and 24).

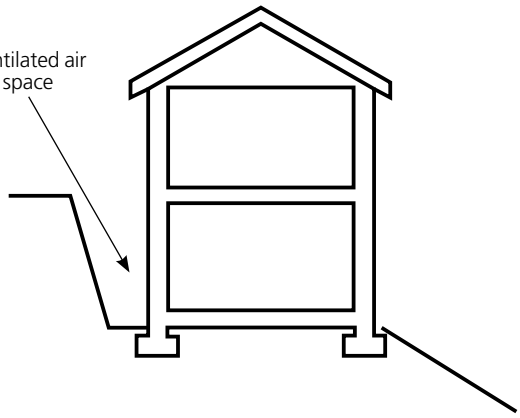


Figure 22: Provision of a ventilated space around a building built into a hillside



Figure 23: Radon barrier installed around staggered walls (Courtesy of PAGeotechnical Ltd)



Figure 24: Radon barrier installed around an inset wall (Courtesy of PAGeotechnical Ltd)

6.2.7 Continuity of barriers through party or separating walls

Semi-detached and terraced properties should be considered with the adjacent dwellings with regard to the installation of the radon barrier. The barrier will need to continue across party or separating walls where they occur. Where the wall is of cavity construction, the barrier will need to be laid so as to drain away moisture.

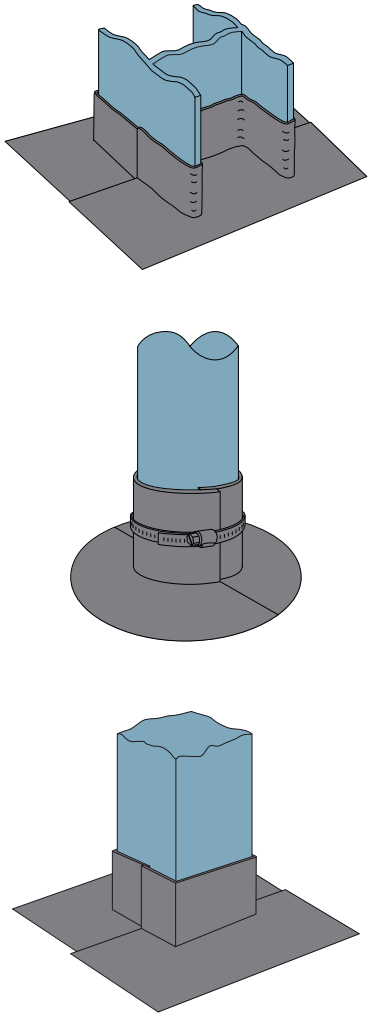


Figure 25: Structural columns that penetrate the radon barrier can be sealed with prefabricated 'boots' to ensure the barrier is sealed

6.2.8 Continuity of barriers at column bases

The radon barrier should be continuous across the whole plan of the building. Where structural columns are used and they penetrate the barrier, the barrier will need to be sealed around the column (Figure 25).

6.2.9 Service penetrations

Where possible, service entries should avoid penetrating the radon-proof membrane. Where this is not possible it will be necessary to construct an airtight seal around each entry (Figures 26 and 27). Prefabricated 'top hat' collars are available from most membrane manufacturers for sealing around pipe entries. Typically this involves using a flexible sealant between the collar and pipe with a jubilee clip holding the collar tightly in place. It is important that any gap between the pipe or duct and the floor slab is filled to provide support for sealing the collar to the membrane. This has been identified as a significant risk with beam-and-block floors, where service penetrations are often formed by simply omitting a whole concrete block. Penetrations should be avoided at points where the membrane is lapped, because of the greater difficulty of resealing. With careful design all supply services, with the exception of mains water and drainage to foul outlets, can be brought up the outside of the building to enter through walls. However, accommodating service entries in walls may limit the locations where internal fixtures can be placed. Traps and other services should be located so as not to damage the radon barrier within the floor slab.

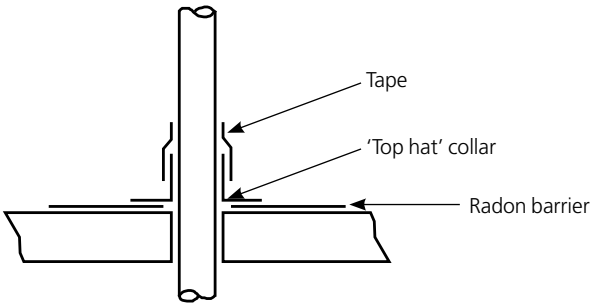


Figure 26: Achieving an airtight seal around service penetrations



Figure 27: Multiple service penetrations sealed with prefabricated 'top hat' collars (Courtesy of PAGeotechnical Ltd)

6.3 Protecting suspended timber floors

Where possible, service entries should avoid penetrating the radon-proof membrane

Care needs to be taken when protecting a suspended timber floor in order not to cause timber rot problems. The floor should be ventilated in accordance with respective regional building regulations, and it is best not to cover the timber floor with an impermeable membrane such as a radon barrier.

One approach to protecting a suspended timber floor is to place the radon barrier over the soil/solum beneath the floor and extend it out through the walls (Figure 28). To avoid the radon barrier being damaged, it should be capped beneath the floor with at least 50 mm site concrete (as is required in Scotland), sand or other form of protection. Concrete is the preferred option and should provide reasonable radon protection. Sand or other forms of protection are unlikely to prove quite as robust as concrete protection or the solutions recommended for concrete floors. As a consequence BRE recommends that a sump should also be provided beneath the barrier, particularly where a sand or other non-concrete capping is to be used. (This recommendation applies regardless of whether the site requires full or basic protection.) It could be argued that providing a sump is unnecessary as a fan could be installed to ventilate the underfloor void instead. While this is true, experience with mechanical underfloor ventilation in existing buildings has shown it to cause noise and discomfort for occupiers. These problems do not occur with sump systems. If the barrier is likely to become flooded, an alternative solution such as suspended concrete beam-and-block floor should be considered.

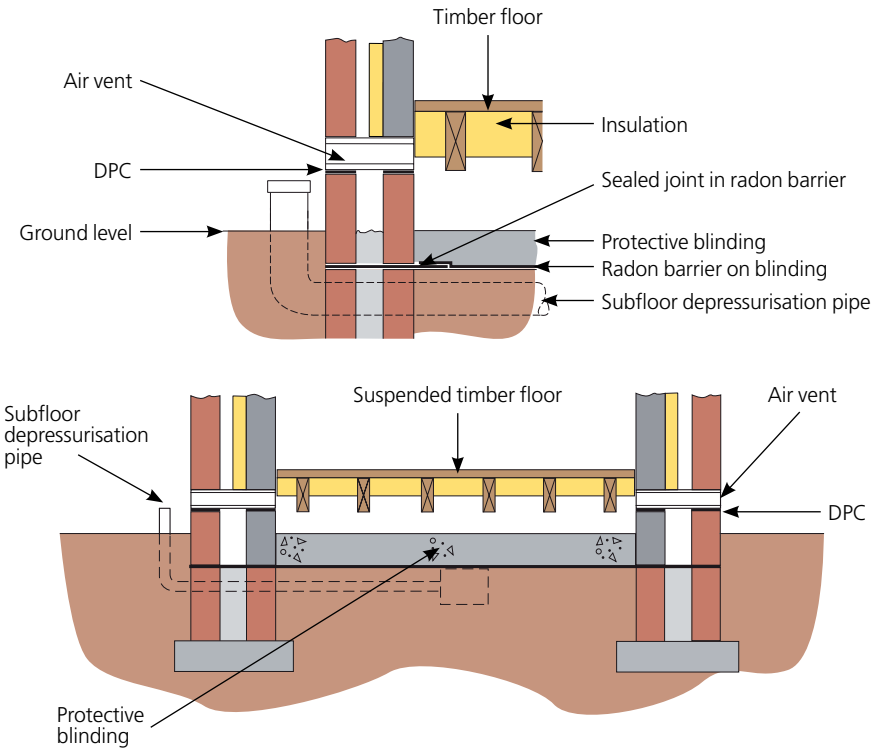


Figure 28: Full radon protection to a suspended timber floor with the barrier laid under the blinding and extended out through the walls

6.4 High water table

In areas where it is known that the water table is particularly high, or the level fluctuates, there is a risk that radon sumps may become waterlogged and therefore ineffective. In such cases tanking should be used to prevent water ingress and provide radon protection. There is then no need to provide a radon sump.

6.5 Slip or shear planes

It is important to ensure that the inclusion of membranes and cavity trays does not adversely affect the structural integrity of load-bearing walls. The designer should consider avoiding having a cavity tray directly on top of a membrane, or vice versa, within any load-bearing wall, as this can create a slip or shear plane. This becomes more important where both of the materials being used have shiny surfaces, like polyethylene. The risk is most severe if the building may be subjected to high lateral loading, as might be the case due to wind in exposed locations across the UK or where the wall acts as a retaining wall. The risk is considered minimal for one- and two-storey dwellings, but it is more significant with taller buildings. In view of the expense of correcting deflected walls, avoidance of slip planes in all construction is advised. One solution is to join the membrane to the cavity tray over the floor instead of within the wall (see also Figure 11 on page 10).

6.6 Blinding

Where a membrane is to be placed over fill or excavated ground, the surface should be blinded (ie its surface finished with a fine material such as sand) to leave a smooth surface that will not puncture the membrane. This is especially important if ordinary building polyethylene is used, but care is required even with tougher reinforced membrane materials. Care must be taken to ensure that the blinding material does not block up the voids in the fill, or the efficiency of the depressurisation system will be impaired. This is particularly important if the permeable fill is of limited thickness. Foam sheeting, geotextile matting or fleece could be used instead of blinding, but this is likely to be more expensive.

One option is to locate the floor insulation between the ground and membrane. Where the radon-proof membrane would otherwise be left exposed within a ventilated space, it is advisable to cover it with a thin topping of 50 mm lean mix concrete or sand to reduce the risk of damage by subsequent trades.

6.7 Reinforced concrete slabs

Where an in situ concrete slab is laid with its edge supported on the inner leaf of an external wall, the slab must be strong enough to prevent cracking in the centre of the slab should the fill beneath settle. Such slabs should be reinforced to prevent cracking and potential damage to a radon barrier laid over the slab.

6.8 Subfloor ventilation

Where periscope subfloor ventilators are used, the joints between the upper and lower halves of the ventilators should be taped to reduce the risk of radon entering the cavity

Where airbricks are recommended as the means of dispersing radon from beneath beam-and-block floors, they should be installed where possible on all sides of the building. Airbricks should be placed at intervals at least as frequent as would be normal for an ordinary suspended timber floor (ie openings should be large enough to give an actual opening of at least equivalent to 1500 mm^2 for each metre run of wall on two opposite sides). Typically this means that vents should be positioned at 2 m maximum centres along the external walls and not more than 450 mm from corners. It is also important to ensure that all airbricks are kept clear. Landscaping works such as paths and driveways must not compromise subfloor ventilation. Due to the need to provide level thresholds, there has been a trend towards locating vents below ground level protected by an open well. Unfortunately, these wells can quickly become filled with debris, dramatically reducing their effectiveness (Figures 29 and 30). It is better to reduce the ground level generally around the building or at least in the vicinity of the vents than to create wells. Where the provision of wells cannot be avoided, they should be designed to prevent future obstruction.

Where periscope subfloor ventilators are used (Figures 31 and 32), the joints between the upper and lower halves of the ventilators should be taped to reduce the risk of radon entering the cavity. As it is difficult to seal a radon barrier or cavity tray to a periscope ventilator, it is important to try to locate ventilators so that they do not penetrate the radon barrier or cavity tray. Where this is unavoidable, consider using prefabricated components that are easier to seal.



Figure 29: Shallow well around underfloor vent partially obstructed with debris

Where the provision of ventilation wells cannot be avoided, they should be designed to prevent future obstruction



Figure 30: Shallow well around underfloor vent completely obstructed with debris



Figure 31: Prefabricated collar to take periscope vent
(Courtesy of Radon Centres Ltd)

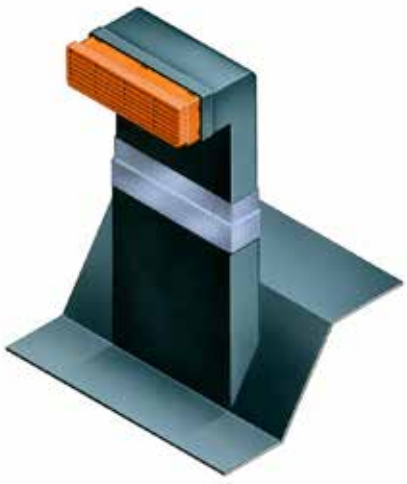


Figure 32: Prefabricated stepped tray and periscope vent
(Courtesy of Cavity Trays Ltd)

6.9 Subfloor depressurisation and sumps

Where a ground-supported floor is to be constructed and full radon-protective measures are required, a radon sump should be provided. This would enable subfloor depressurisation to be introduced with relative ease if desired at a later date. (Subfloor depressurisation involves sucking radon-laden air from beneath a building and discharging it into the atmosphere.) It should be noted that although this report refers to subfloor depressurisation, in some cases, particularly where soils are highly permeable, subfloor pressurisation can prove more effective; for further advice contact BRE. Subfloor depressurisation is appropriate wherever a solid floor is proposed, unless the floor is situated below the water table or flood level, as might be the case with a basement.

6.9.1 Numbers of sumps

For a typical house, a single sump will probably be sufficient. (Where clean permeable fill has been used, a single sump is likely to have an influence over an area of approximately 250 m^2 – ie a radius of approximately 9 m around the sump.) If the subsoil is particularly permeable, a sump may be effective to a radius of up to 15 m. If the building is of modest size and regular shape, an edge-located sump may be acceptable. Otherwise the sump should be positioned centrally under the house (Figure 33) and constructed to ensure that its pipe entry is not blocked when the fill is placed. To allow for maximum depressurisation, fill used beneath the slab should not contain excessive fines.

If the subfloor area comprises several compartments, then sumps may be required for each compartment. These may be connected to a manifold and a single fan (Figures 34a and 34b). However, in most cases there is no need to establish a manifold of pipes. A single sump located alongside the separating wall, with a few bricks omitted or pieces of pipe located within the wall to allow depressurisation, will suffice (Figure 34c).

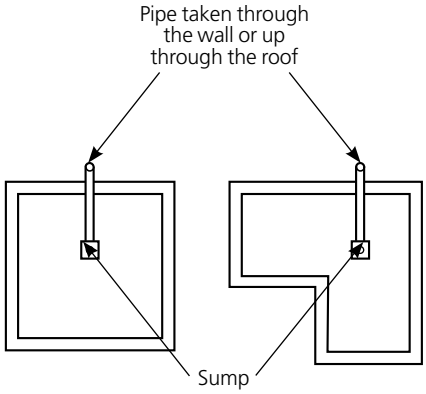


Figure 33: Central positioning of sump underneath dwelling

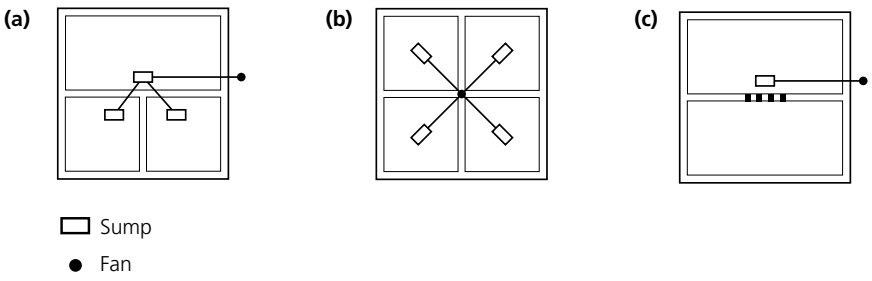


Figure 34: Location of sumps within multi-compartment subfloor areas: a) Pipework manifolded to external fan; b) Pipework manifolded to internal fan; c) Bricks omitted in separating wall

6.9.2 Sumps for non-domestic buildings

Generally, the same rules apply to non-domestic buildings as to dwellings: one sump will have an influence over approximately 250 m^2 of floor area. There are, however, opportunities for economies to be made in terms of the number of sumps and amount of pipework that need to be provided. With larger floor areas, several sumps can be manifolded together to reduce the amount of pipework and number of fans that might need to be fitted in the future. In cases where the fill beneath a floor is uninterrupted by foundation walls, a single sump is likely to be effective over far more than 250 m^2 of floor area. In such cases it is likely that one sump will have an effect over an area of 500 m^2.

The end use of the building will to some extent dictate where to locate sumps. Areas of high ventilation and low occupancy such as warehousing will probably require less attention than warmer, less ventilated areas such as offices, which have higher occupancy levels. Warehousing or factory areas are also likely to have more robust floor construction (thicker and better jointed concrete), again reducing the risk in these areas.

6.9.3 Sump construction

Prefabricated sumps, usually of plastic construction, are widely available from radon barrier suppliers (Figures 35–37). They are easy and quick to install and ensure consistency of construction. Alternatively a simple sump can be constructed using bricks laid in a honeycomb bond so as to form a box around the end of the pipe (Figure 38). To avoid subsequent collapse when compacting fill around the sump, mortar should be used for horizontal joints. It is essential, however, that all perpend joints are left open.

Typically, the pipe from the sump needs to be 110 mm diameter PVC-U, with joints using standard couplings that are sealed and airtight. The pipe needs to leave the building so that it could be coupled to a fan mounted on the external wall. It will therefore ideally need to terminate about 100 mm from the external wall face, and be located preferably at the rear of the house or at a re-entrant corner where subsequent installation of a boxed-in fan and vertical stack will be least obtrusive (see also Section 6.9.5, 'Fan and pipe exit location'). Until such time as a fan is installed, the pipe should be capped off at a minimum of 300 mm above ground level to prevent vermin and rain penetration. The pipe should be capped with an access plug (Figure 39); there is no advantage to be gained by capping with a vent cowl.

An alternative to routing the pipework externally is to take the pipework from the sump up through the building to the roof space and either cap it off in the roof space or take it through the roof covering and finish it with a vent cowl. If capped off in the roof space, a fan could be added later together with an exhaust through the roof covering. With this approach all equipment is concealed from view outside. If the pipework is originally installed to vent through the roof, the stack effect of the building will provide some suction in the pipe that will help to reduce radon entry into the building. It may be just enough to prevent having to provide a fan later (see also Section 6.9.6, 'Passive stack subfloor depressurisation'). If, however, the indoor radon level is still high, a fan could be added to the pipework within the roof space at a later date. Again, all equipment is concealed from view outdoors.

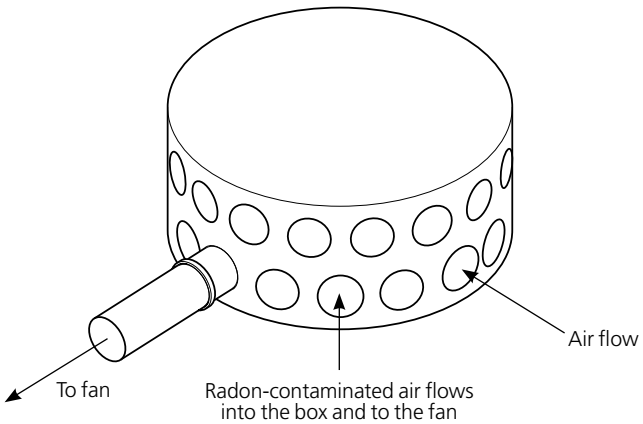


Figure 35: Prefabricated sump



Figure 36: Prefabricated sumps and stub pipes (Courtesy of Glencoe Radon Gas Centre Ltd)



Figure 37: Prefabricated sumps and stub pipes (Courtesy of Glencoe Radon Gas Centre Ltd)

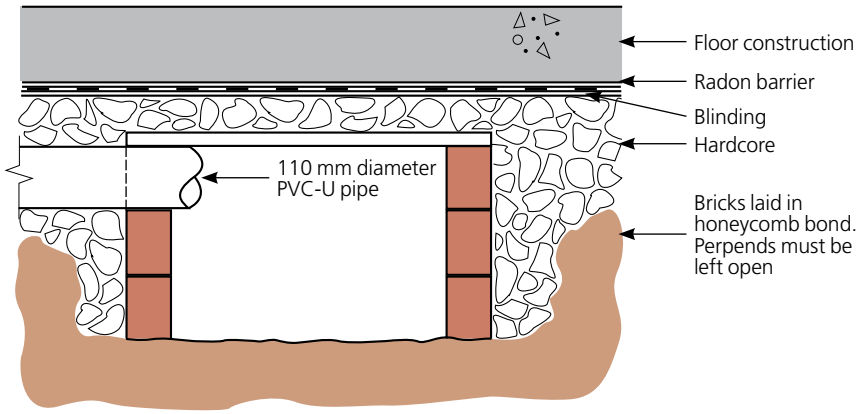


Figure 38: Radon sump details

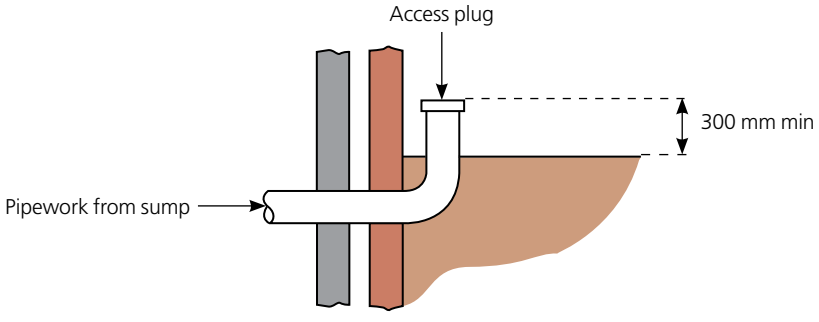


Figure 39: Pipework from sump is capped off with an access plug just above ground level

Where a basement is being constructed in ground above the water table, it will be necessary to consider providing depressurisation to the areas of soil that are backfilled against the external walls. Geotextile drainage matting could be used in place of sumps. It could prove particularly useful for providing a vertical ventilation space behind retaining walls. It may be possible for subsoil drain pipes from these spaces to double up as radon extract pipes.

Other alternatives to sumps include laying a network or ring of perforated pipe (sometimes referred to as a 'radon ring') or laying geotextile corrugated drainage matting beneath the slab (Figures 40 and 41). Both can be connected to an extract pipe to provide a sump. These options are likely to prove more expensive than a sump.

It should be noted that the sump and pipework, radon ring or geotextile matting are only installed as a fall-back measure and do not provide any radon removal until such time as a fan is installed or until the sump is connected to a passive stack system. Builders may choose to provide a radon sump as a fall-back in areas where there is only a requirement for basic radon protection in case the barrier proves ineffective.

It should be noted that the sump and pipework, radon ring or geotextile matting are only installed as a fall-back measure and do not provide any radon removal until such time as a fan is installed or until the sump is connected to a passive stack system

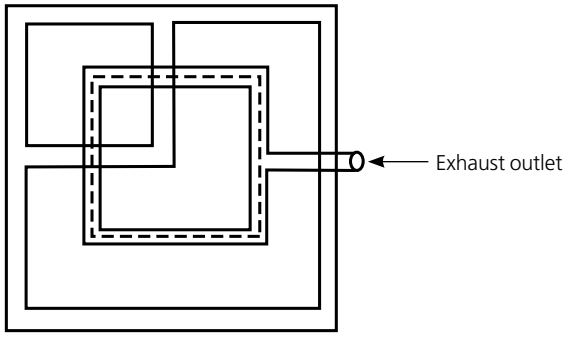


Figure 40: Perforated pipe radon ring system

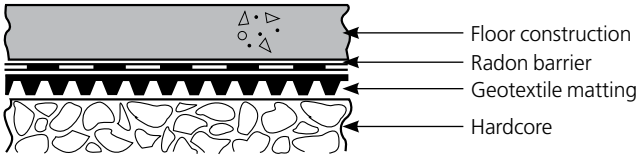


Figure 41: Geotextile matting used as an alternative to a sump

6.9.4 Edge-located sumps

In addition to the use of centrally located sumps, experience gained by BRE in developing radon-remedial measures for use in existing houses has led to the development of externally excavated sump systems. Research has shown that such systems can prove effective in reducing indoor radon levels within small to medium-sized houses. This would suggest that although it is preferable to locate a sump centrally within a new house, an edge-located mini sump would be adequate for small to medium-sized buildings.

The simplest way of constructing an edge-located sump is to use a prefabricated sump positioned just under the edge of the floor slab. Alternatively, a simple edge-located mini sump can be constructed by excavating a small hole (about 400 × 400 × 400 mm) in the hardcore or fill beneath the building alongside the perimeter wall to form an open area around the end of the extract pipe. The sump can be covered with a 600 × 600 mm paving slab or similar to provide permanent formwork to support the floor slab. Whichever form of sump construction you use, it is important to ensure that the pipe is well sealed where it passes through the wall so that if a fan is fitted later all suction will be applied beneath the floor and not to the wall (Figure 42).

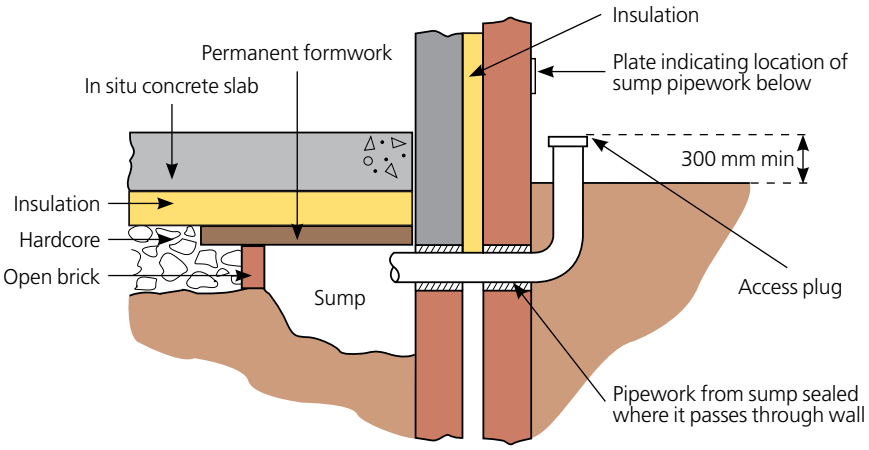


Figure 42: Edge-located sump detail (sump approximately 400 × 400 × 400 mm; radon barrier omitted)

Although installation of the fan is not required at the construction stage, it is important to consider its location

6.9.5 Fan and pipe exit location

Although installation of the fan is not required at the construction stage, it is important to consider its location. The fan should be positioned with the outlet well away from windows, doors and ventilation grilles, ideally discharging just above eaves level. Low-level discharge may be possible if there are no openings or vents close by. To avoid penetrating the radon-proof membrane in the floor unnecessarily, the pipe should preferably be taken through the wall, not up through the floor. However, it may be desirable for aesthetic reasons to route pipework inside the house and to take the outlet from the fan through the roof (Figure 43). The fan must not ventilate into a roof space. Where pipework is routed through the building and a fan is fitted, it should always be placed as close to the outlet as practical. This is to ensure that the pipework is always under suction, as even slight leaks could increase indoor radon concentrations. More detailed advice on activating sump systems is contained in *Radon solutions in homes: radon sump systems*[13].

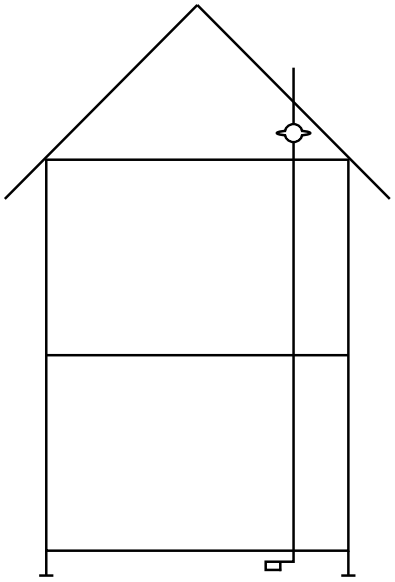


Figure 43: Pipework ducted internally with the fan outlet through the roof and not ventilated into the roof space

6.9.6 Passive stack subfloor depressurisation

Subfloor depressurisation is usually achieved actively using an electric fan to provide suction. However, it may be possible to depressurise the subfloor area sufficiently without using a fan, ie passively. Such a system would comprise a vertical stack pipe run up through the house from the radon sump or radon ring to discharge at a point at or above ridge level. Passive stack ventilation is best suited to centrally located sumps. By installing a passive stack system during construction it may reduce the radon in the ground beneath the building so that it does not enter the building through any imperfections in the radon barrier. From an aesthetic point of view the pipework can be concealed within the fabric of the building, and should the system need to be activated later by adding a fan, it can be located within the roof space. This, together with the relative ease and low cost of installation, has resulted in several countries in Europe and North America recommending the inclusion of passive stack systems in new buildings.

6.9.7 Labelling sumps

It is important to label the capped-off extract pipe so that it can be located in the future and its purpose made clear. A permanent weatherproof sign (of low visibility) fixed to an adjacent wall would suffice. Alternatively, prefabricated plastic access caps (marked 'radon') can be used. Either option should reduce the risk of accidental connection to drainage fittings.

6.10 Garages

Integral garages with occupied rooms above, or with direct access through a doorway from the garage to the house, need the same provision as the rest of the dwelling. This ensures protection to the rest of the dwelling and to the garage area should it be temporarily or permanently converted into an occupied space.

6.11 Extensions

All extensions to dwellings that fall into light grey or dark grey grid squares on the maps in Appendix A should have radon membranes installed

The guidance in this report applies to domestic extensions and conservatories, as noted in national building regulation guidance. Designers should note that radon-protective measures may still be required under building regulations in Northern Ireland, even to otherwise 'exempt' domestic extensions. In any case, designers may wish to consider suitable radon-protective measures.

6.11.1 Protection provision for extensions

All extensions to dwellings that fall into light grey or dark grey grid squares on the maps in Appendix A should have radon membranes installed, including, as necessary, the provision of a cavity tray within new external walls to carry the membrane through the wall construction.

The necessity of providing full radon protection (radon barrier and sump) may be a matter of judgement for the building control body. Large extensions that are designed to provide only ancillary accommodation may be rearranged in the future to provide living accommodation; the size of the extension may be an indicator. If the extension is less than half the ground floor area of the existing house or 30 m^2, whichever is smaller, it could be considered to be relatively small. However, if the accommodation is designed as habitable space, radon protection should be provided at the appropriate level unless it is considered that full protection is not of significant benefit, in which case dispensation could be considered.

In England and Wales, extensions with a ground floor area of more than half that of the existing house or 30 m^2, whichever is smaller, should have full radon protection if the house is in a dark grey shaded square in Appendix A. In such a case there may be no need to obtain a geological assessment or to provide a sump, as it would be of marginal benefit when considered with the risk to the whole of the house. If the house that is being extended already has radon protection, a similar level of protection should be provided to the extension.

6.11.2 Additional points to consider with extensions

If possible, seal the construction joint between the new floor and the existing building (Figure 44). Where radon barriers have been incorporated into both the new floor and the existing floor, the aim should be to seal the two barriers where they meet within the wall of the building. In practice this is difficult to achieve without damaging the existing barrier. A simpler alternative is to cut a chase in the wall slightly above or below the existing barrier. The new barrier can then be tucked into the chase in the wall (Figure 45). This approach can also be used where the existing building does not have any radon protection. While this is probably the best approach, other methods of joint sealing may be used such as polysulphide, high-modulus or high-elasticity-type sealant/filler. Due allowance needs to be made for differential movement between existing and new construction. If the existing building has a beam-and-block or suspended timber floor, care should be taken to ensure that the provision for subfloor ventilation is maintained.



Figure 44: Radon barrier being sealed against an existing wall within a workplace extension (Courtesy of Glencoe Radon Gas Centre Ltd)

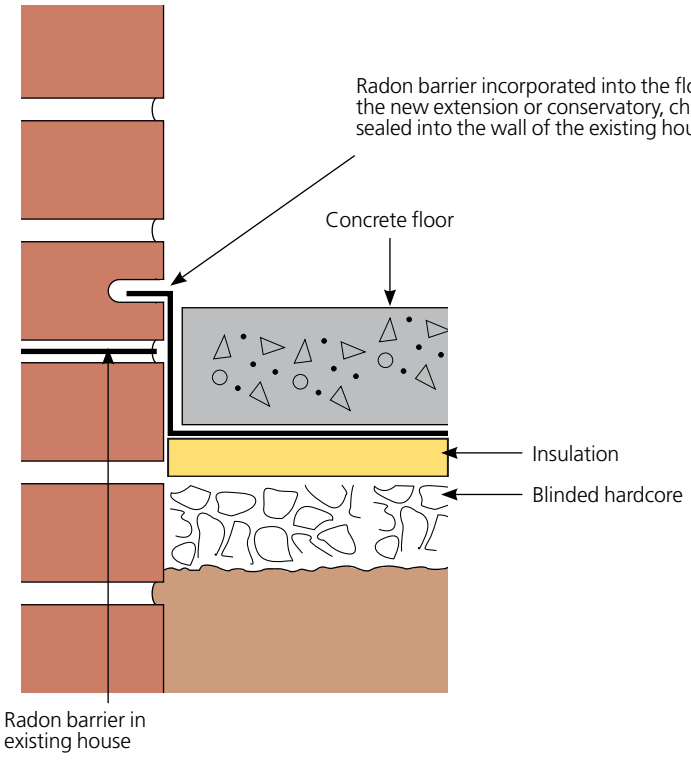


Figure 45: A new barrier sealed into a chase in the wall (Note: For clarity, insulation is not fully shown)

It might seem pointless providing a sump to an extension when the rest of the building is unprotected. If the existing building has a solid ground floor, however, then the sump beneath the extension could be used to reduce the level of radon in both the extension and the existing building. Therefore, it is best to locate the sump at the back of the extension where it abuts the existing building. A hole can be broken through the existing wall and some of the fill from under the edge of the existing floor slab can be scooped out to create a mini sump. The two sumps can then be linked together (Figures 46 and 47).

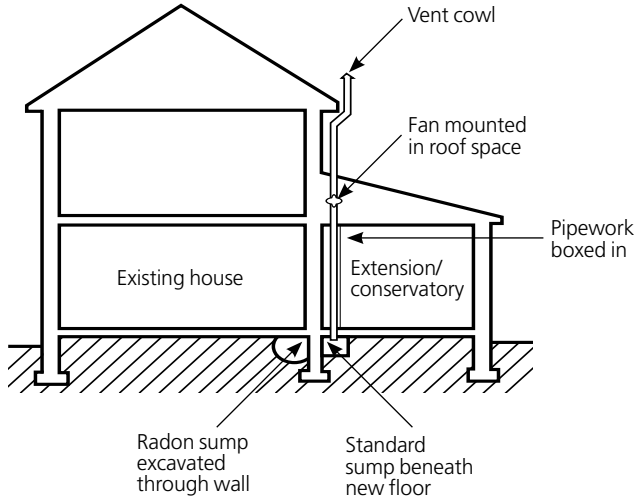


Figure 46: Two sumps linked together

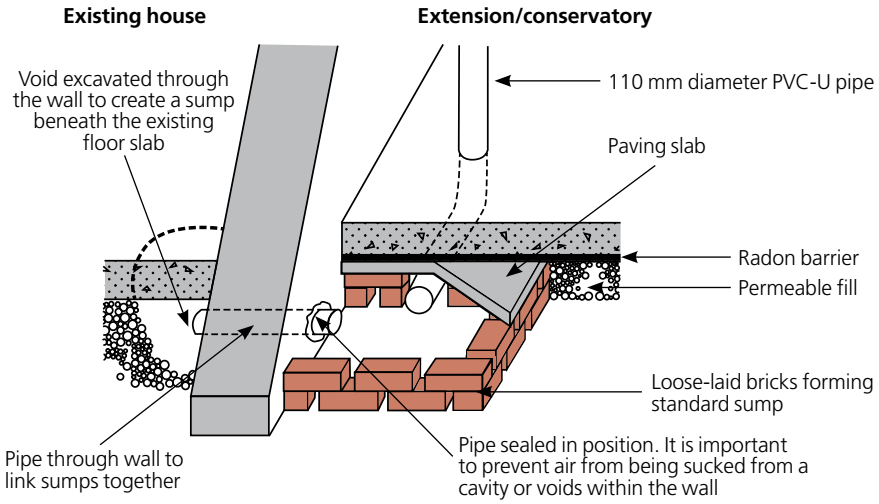


Figure 47: Detail of linked sumps

6.12 Basements or occupied spaces below ground

It is important to ensure that basements and other occupied spaces below ground level are suitably protected against radon. These areas are more at risk because walls are in contact with the ground as well as the floor. For a house with a basement under the entire house, the area in contact with the ground could be several times that of a similar house without a basement. This, coupled with reduced natural ventilation below ground level, increases the risk of elevated radon levels. All basements are at increased risk of elevated levels of radon, regardless of geographic location (see also Section 6.14, 'Monitoring radon in completed buildings and extensions').

Where a new basement is to be created, or an existing cellar converted, waterproofing will be required. A well-constructed waterproofing should be designed to protect against radon also. Guidance and recommendations on basement waterproofing are contained in BS 8102:2009[14], which also advises that radon be taken into account in the design and implementation of waterproofing schemes. Below-ground waterproofing and radon management are specialist activities that can conflict. It is recommended that dual protection systems are designed and installed by specialists who are suitably qualified in both waterproofing and radon management.

Internally located cavity drain membrane systems are often used to provide below-ground waterproofing. Some cavity drain membrane systems are certificated as providing an effective barrier to radon gas. However, using these to line the internal surfaces of a basement could cause the gas to be simply displaced up the cavity into the ground floor accommodation. It is therefore important to ensure that the basement wall membrane fully closes the cavity at its head where it meets the radon barrier within the ground floor or external cavity wall above ground. The cavity behind the membrane could be used later as part of a subfloor depressurisation system.

If the ground around a basement is likely to be waterlogged, there is little benefit in installing a radon sump as subfloor depressurisation is unlikely to work continuously. As with all radon-protective measures installed during construction, the first aim should be to provide a passive solution. This should also be the aim with basement protection.

6.13 Conversions and refurbishment

Radon protection should be considered when non-domestic structures such as barns, warehouses and offices are converted into residential accommodation or where existing buildings are undergoing significant refurbishment

Radon protection should be considered when non-domestic structures such as barns, warehouses and offices are converted into residential accommodation or where existing buildings are undergoing significant refurbishment. It may prove impractical to incorporate a radon barrier across the entire footprint of an existing building and, even if new concrete floors are installed, radon could still enter the property via floor-to-wall joints or through the existing walls. Nevertheless, there are some measures that are worth applying. For example:

- If a new concrete ground floor is being installed, a barrier can be included within its construction together with one or more sumps. An attempt should be made to try to seal the barrier to the wall face in order to seal the gap between the floor slab and the wall. The seal can be made at floor skirting level.
- Similarly, if an existing floor is to be retained, it may be appropriate to install an externally excavated mini sump during construction.

As with new buildings, care should be taken to locate the outlet from the sump in an unobtrusive location (see Section 6.9.5, 'Fan and pipe exit location'). For further information see *Radon solutions in homes: radon sump systems*[13]. All conversion and refurbishment projects must be considered as individual projects on their own merits and with due regard to their location.

In addition to providing radon-protective measures as part of conversions or alteration works, you should also consider ventilation to open-flued combustion appliances in areas affected by radon. All combustion appliances need a sufficient air supply to aid combustion, dilute combustion gases and sometimes to cool the appliance itself. It is important to ensure that adequate ventilation is provided since failure to do so can lead to hazardous spillage of flue gases into occupied areas.

Most modern boilers are room-sealed and take their air supply from outside the dwelling so therefore pose no risk. Unfortunately, though, some systems are open-flued and draw their air directly from the room. When this is the case there are usually only two ways in which ventilation can be provided: either bringing air in from outside via wall or window vents, or from beneath the building via simple vents cut through suspended floors. Unfortunately, in areas where there is a risk from radon, simple floor vents should not be used as they can result in an increase in indoor radon. An alternative supply of outside ventilation must be provided, either via wall or window vents, or by ducting air from outside through the underfloor space (taking care not to allow air from within the floor void to enter the rooms above).

6.14 Monitoring radon in completed buildings and extensions

BRE recommends testing on completion or occupation all new buildings, extensions and conversions with protection fitted. Buildings that have had significant alterations made to them should also be tested

6.14.1 Dwellings

Building regulations do not require a radon test for new dwellings built with radon-protective measures. PHE recommends that a new building should be subject to an appropriate test during the first year of occupation if it is located in a radon-affected area[2]. Further information on radon monitoring is available at www.ukradon.org.

6.14.2 Extensions

Building regulations do not a require a radon test after completion of extensions. The ventilation of the building will be different with structural changes to the building, and therefore the radon levels may change. It is, however, advisable to complete a radon test on the building on completion.

6.14.3 Non-domestic buildings

It is not a requirement of national building regulations to test new non-domestic buildings. Employers must ensure the health and safety of employees and others who have access to their work environment. An assessment of health and safety risks under national regulations[15, 16] should include radon where the workplace is in a radon-affected area, or in any location where there is a basement that is regularly occupied.

BRE recommends testing on completion or occupation all new buildings, extensions and conversions with protection fitted. Buildings that have had significant alterations made to them should also be tested.

7 Information to be provided to the purchaser

BRE recommends that the purchaser of a building is informed of the following:

- The level of radon protection provided within the building, whether it is:
  - Basic radon protection – a radon barrier across the footprint of the building, or
  - Full radon protection – a radon barrier across the footprint of the building supplemented by provision for subfloor depressurisation or ventilation (either a radon sump or a ventilated subfloor void).
- The location of the radon barrier within the construction (eg laid over the ground/solum to a suspended floor, beneath a concrete slab or beneath a screed or floor topping).
- Recorded site checks, inspections and/or reports carried out on the barrier prior to covering up (eg quality management checklist – Appendix B).
- The position of installed sumps and where the exhaust outlet is located. It should be explained what the exhaust outlet is and that it can be used to add a fan to activate the 'standby' sump if radon levels are high. Where both radon and methane are present, only intrinsically safe (non-sparking) fans and switchgear should be used.
- Underfloor vents should be maintained and kept clear.
- PHE recommends that a new building should be subject to an appropriate radon test during the first year of occupation if it is located in a radon-affected area.
- Further information on radon risks and monitoring is available at www.ukradon.org.

8 References and further reading

8.1 References

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10. BSI. Guidance on investigations for ground gas – Permanent gases and volatile organic compounds. BS 8576:2013. London, BSI, 2013.
11. Miles J, Appleton J, Rees D et al. Indicative atlas of radon in Scotland. HPA-CRCE-023. Chilton, Health Protection Agency (HPA), 2011. Available at: www.gov.uk.
12. Daraktchieva Z, Appleton J, Rees D et al. Radon in Northern Ireland: indicative atlas. PHE-CRCE-017. Chilton, Public Health England (PHE), 2015. Available at: www.gov.uk.
13. Scivyer C. Radon solutions in homes: radon sump systems. BRE GR 37-3. Bracknell, IHS BRE Press, 2013.
14. BSI. Code of practice for protection of below-ground structures against water from the ground. BS 8102:2009. London, BSI, 2009.
15. The Management of Health and Safety at Work Regulations 1999. SI 3242. London, The National Archives, 1999.
16. Workplace (Health, Safety and Welfare) Regulations (Northern Ireland) 1993. SI 37. London, The National Archives, 1993.

8.2 Further reading

8.2.1 BRE publications

BRE. Minimising noise from domestic fan systems and fan-assisted radon mitigation systems. BRE GG 26. Bracknell, IHS BRE Press, 1996.

Scivyer C. Major alterations and conversions: a BRE guide to radon-remedial measures in existing dwellings. BRE BR 267. Bracknell, IHS BRE Press, 1994.

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Scivyer C. Radon solutions in homes: positive house ventilation. BRE GR 37-2. Bracknell, IHS BRE Press, 2013.

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8.2.2 Other documents

BSI. Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings. BS 8485:2015. London, BSI, 2015.

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Mallett H, Cox L, Wilson S and Corban M. Good practice on the testing and verification of gas protection systems for buildings against hazardous ground gases. C735. London, Construction Industry Research and Information Association (CIRIA), 2014.

NHBC Standards. Chapter 5.4: Waterproofing of basements and other below-ground structures. Milton Keynes, NHBC, 2014.

8.3 Further information

For further advice regarding radon risks, mapping and measurement across the UK, contact:

Public Health England
Centre for Radiation, Chemical and Environmental Hazards
Chilton
Didcot
Oxon OX11 ORQ
Tel: +44 (0) 1235 822622
www.ukradon.org

For radon technical consultancy services relating to building matters and for radon training services, contact:

BRE
Garston
Watford
Herts WD25 9XX
Tel: +44 (0) 333 321 8811
www.bre.co.uk

For further advice regarding geological matters, contact:

Central Enquiries
British Geological Survey
Keyworth
Nottingham NG12 5GG
Tel: +44 (0) 115 936 3143
www.bgs.ac.uk

For further advice and training for gas membrane installers, contact:

British Geomembrane Association
c/o PAGeotechnical Ltd
Darwin House
Corby Gate Business Park
Corby
Northants NN17 5JG
www.britishgeomembraneassociation.co.uk

For further advice and lists of radon barrier suppliers, installers and providers of radon measurement services, contact:

The Radon Council
PO Box 39
Shepperton
Middlesex TW17 8AD
Tel: +44 (0) 1932 221212
www.radoncouncil.org

or

UK Radon Association
email: secretary@radonassociation.co.uk
www.radonassociation.co.uk

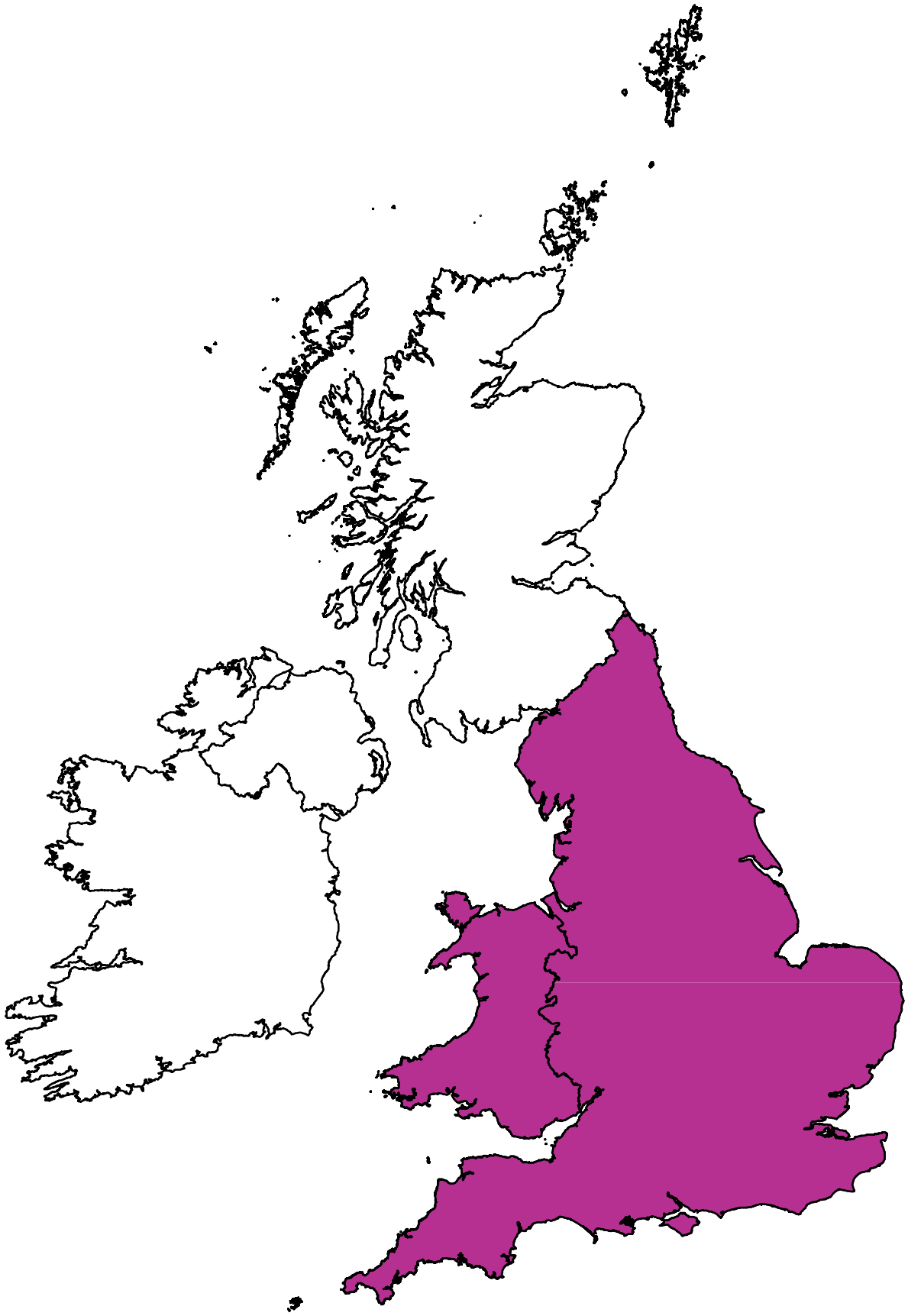
Appendix A

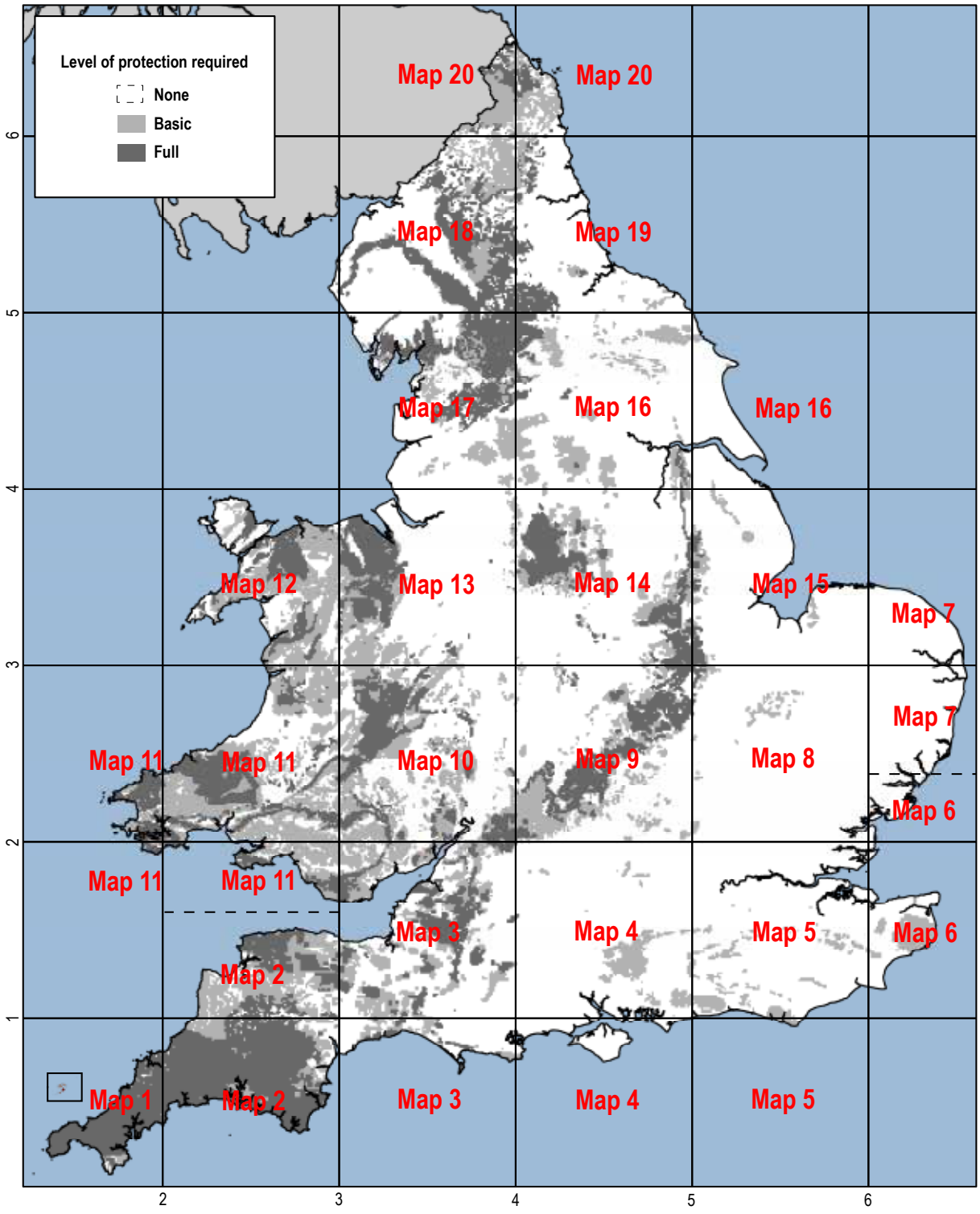
Maps of areas where basic or full protection should be provided



Image courtesy of Glencoe Radon Gas Centre Ltd

England and Wales





Key to larger scale maps (axis numbers are the 100-km coordinates of the National Grid)

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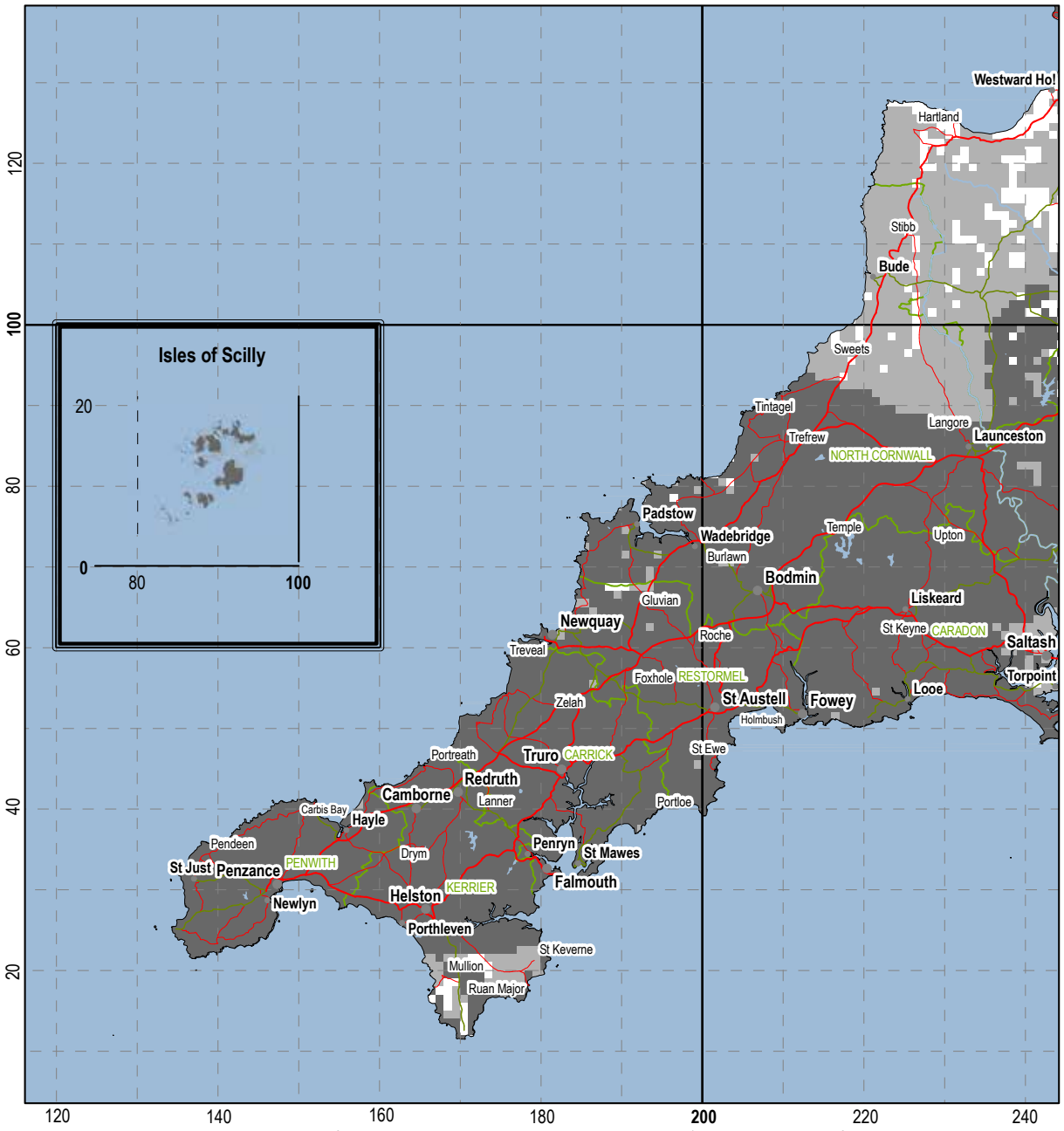

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in Building Regulations Approved Document C. The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org. The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required

- None
- Basic
- Full

Settlements

- Helston
- Padstow
- Portloe
- Carbis Bay

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 1 West Cornwall, 100-km grid square SW (axis numbers are the coordinates of the National Grid)

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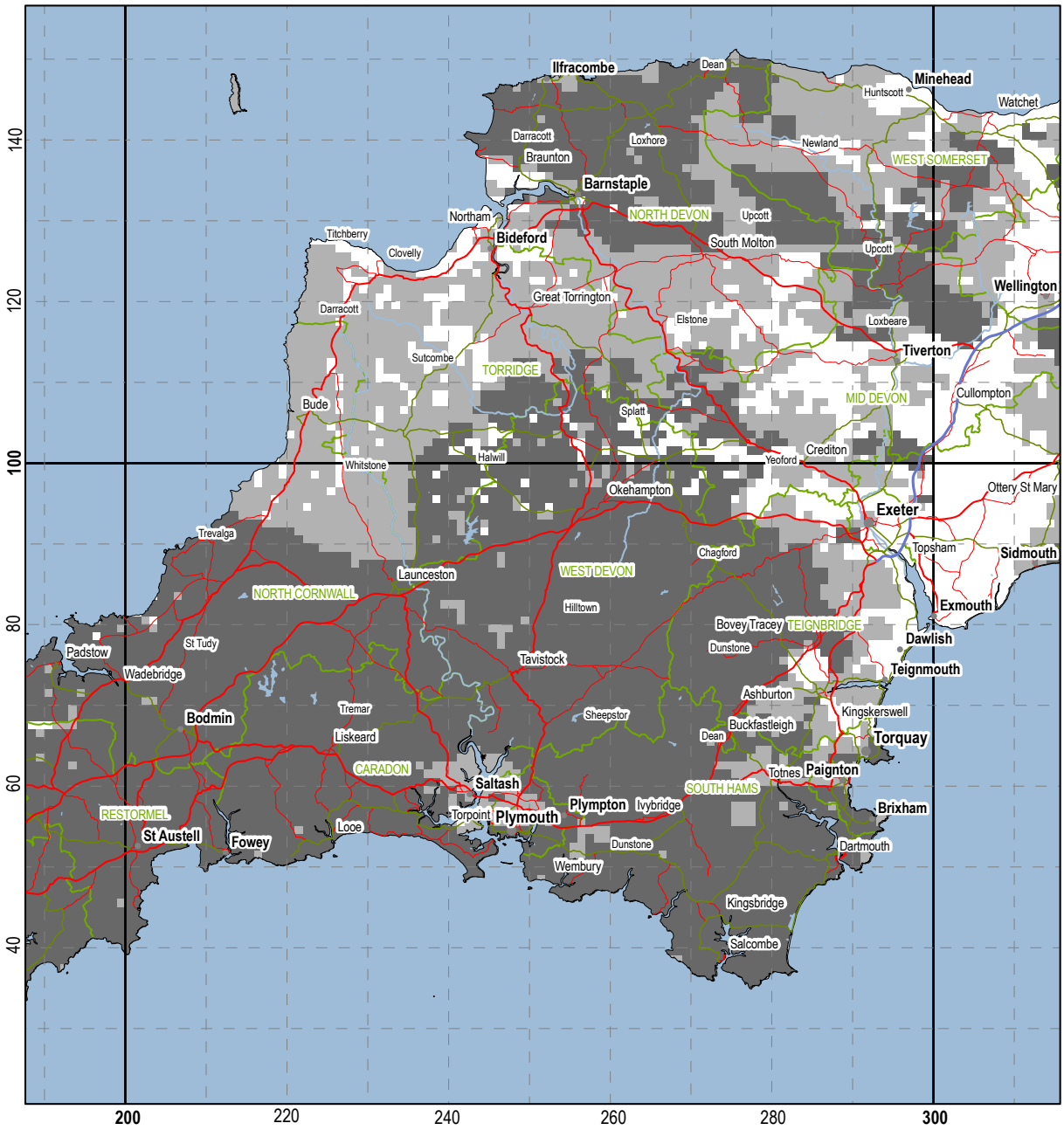

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in Building Regulations Approved Document C. The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org. The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required

- None
- Basic
- Full

Settlements

- Torquay
- Bodmin
- Bude
- Huntscott

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 2 East Cornwall and west Devon, 100-km grid squares SS and SX (axis numbers are the coordinates of the National Grid)

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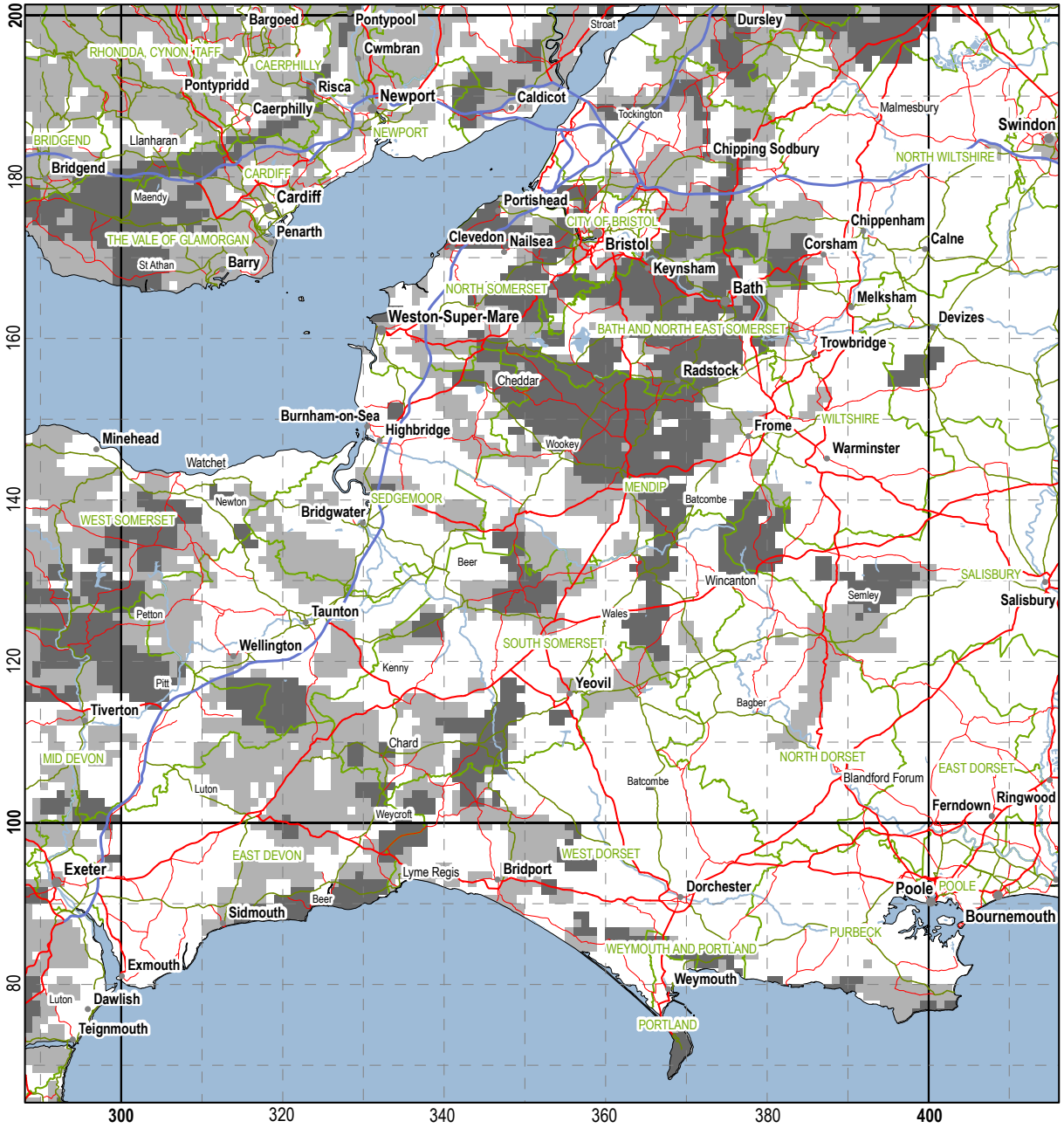

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in Building Regulations Approved Document C. The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org. The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required

- None
- Basic
- Full

Settlements

- Bath
- Weymouth
- Watchet
- Semley

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 3 Dorset, Somerset, Wiltshire and the Bristol Channel, 100-km grid squares ST and SY (axis numbers are the coordinates of the National Grid)

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The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in Building Regulations Approved Document C. The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org. The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required

- None
- Basic
- Full

Settlements

- Reading
- Salisbury
- Midhurst
- Cadley

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 4 Hampshire, Berkshire and south Oxfordshire, 100-km grid squares SU and SZ (axis numbers are the coordinates of the National Grid)

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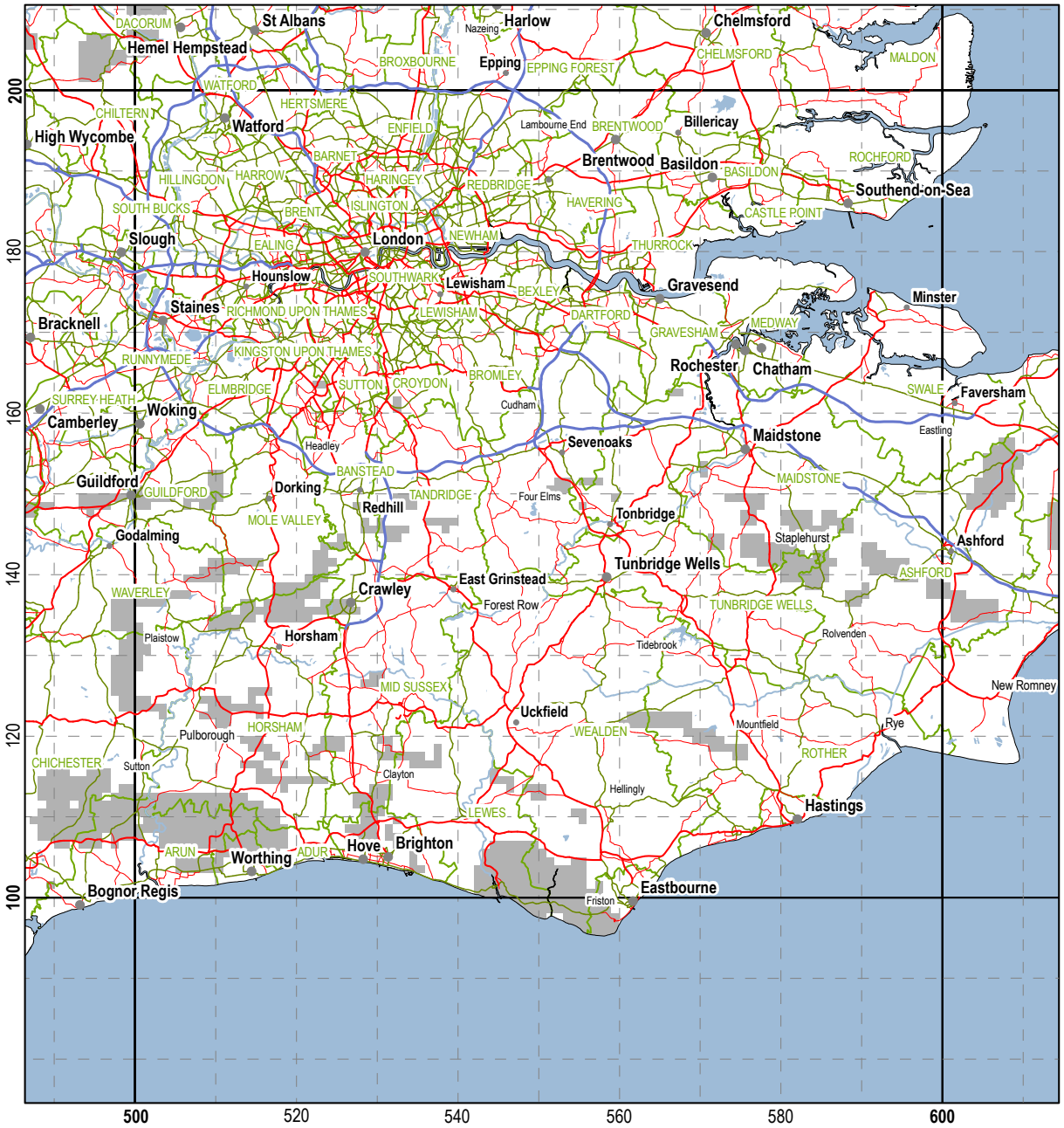

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in Building Regulations Approved Document C. The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org. The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required

- None
- Basic
- Full

Settlements

- London
- Horsham
- Rye
- Sutton

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 5 London, Sussex and west Kent, 100-km grid squares TQ and TV (axis numbers are the coordinates of the National Grid)

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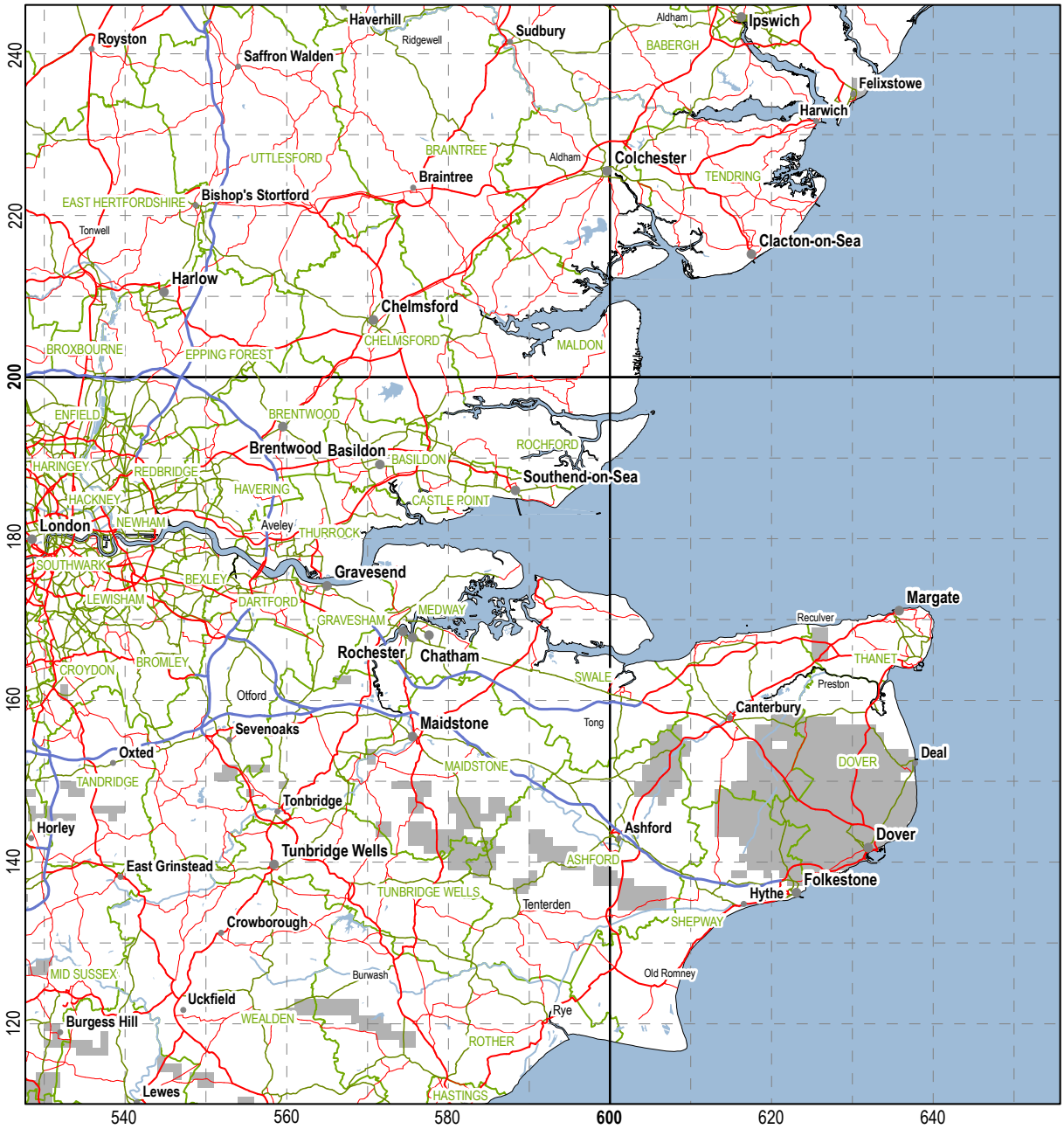

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in Building Regulations Approved Document C. The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org. The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required

- None
- Basic
- Full

Settlements

- Chelmsford
- Hythe
- Aveley
- Aldham

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 6 Essex, Thames estuary and east Kent, 100-km grid squares TM and TR (axis numbers are the coordinates of the National Grid)

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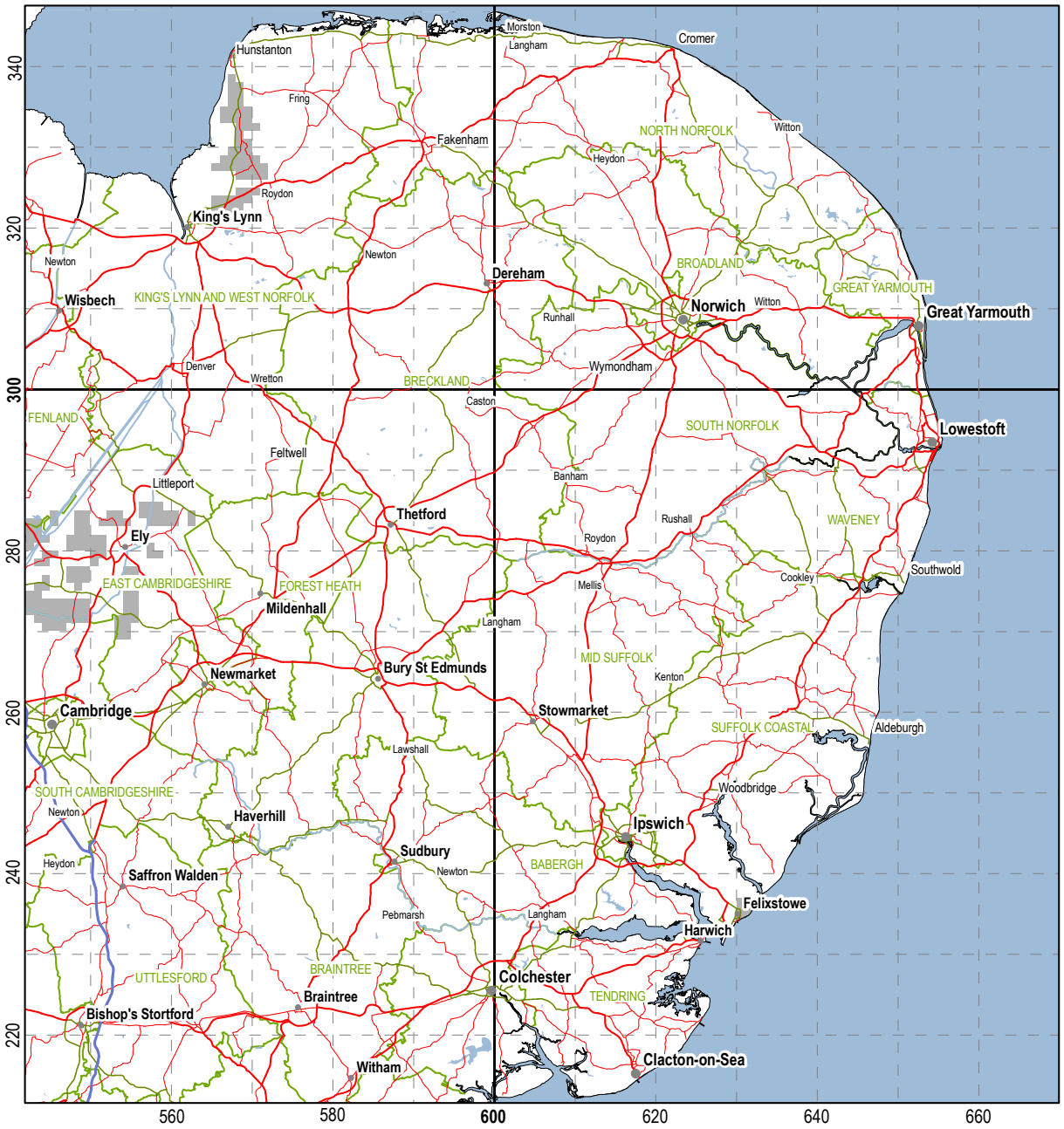

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in Building Regulations Approved Document C. The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org. The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required

- None
- Basic
- Full

Settlements

- Norwich
- Harwich
- Cromer
- Pebmarsh

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 7 Suffolk and Norfolk, 100-km grid squares TG and TM (axis numbers are the coordinates of the National Grid)

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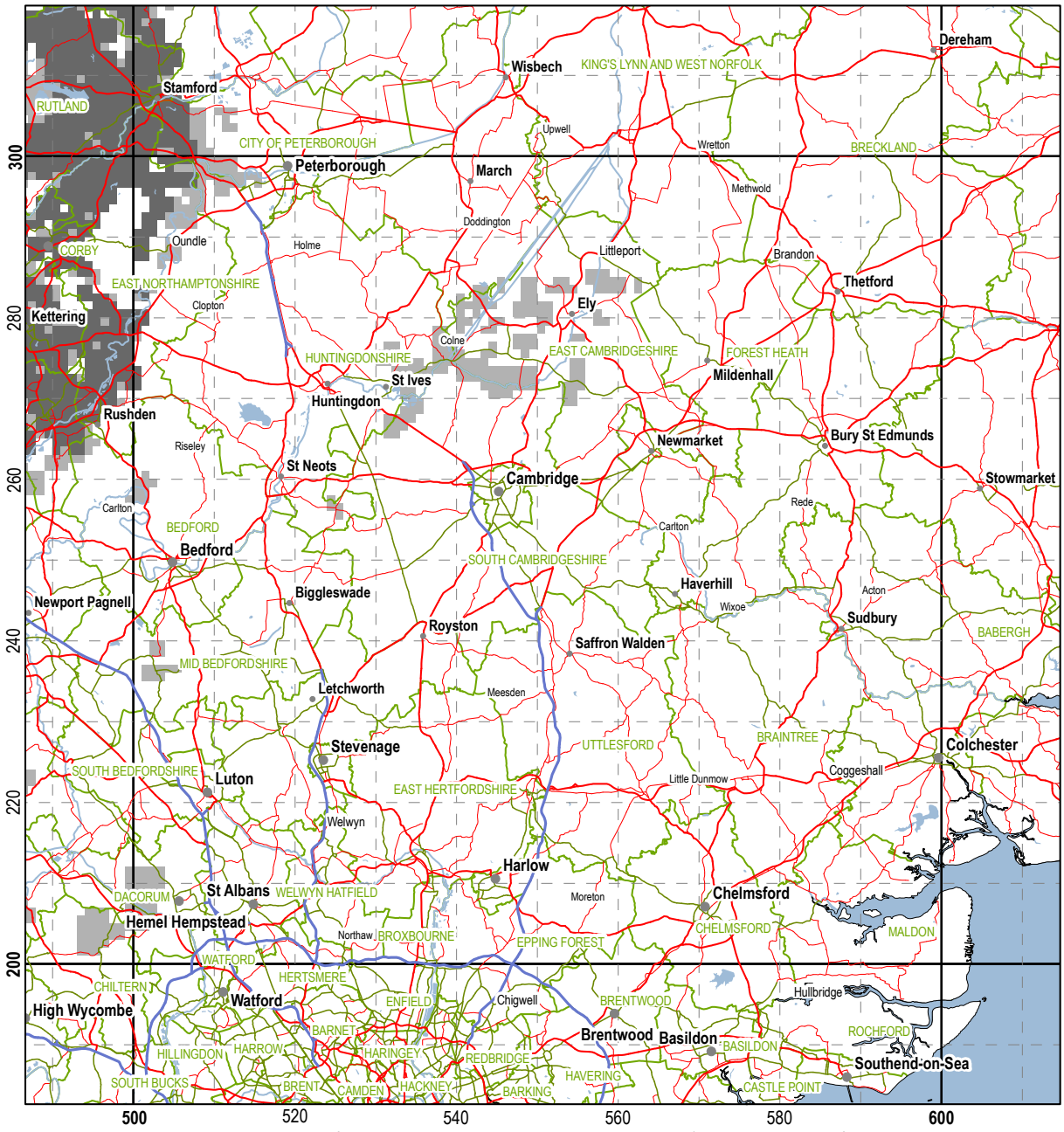

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in Building Regulations Approved Document C. The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org. The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required

- None
- Basic
- Full

Settlements

- St Albans
- Sudbury
- Brandon
- Holme

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 8 Cambridgeshire and Hertfordshire, 100-km grid square TL (axis numbers are the coordinates of the National Grid)

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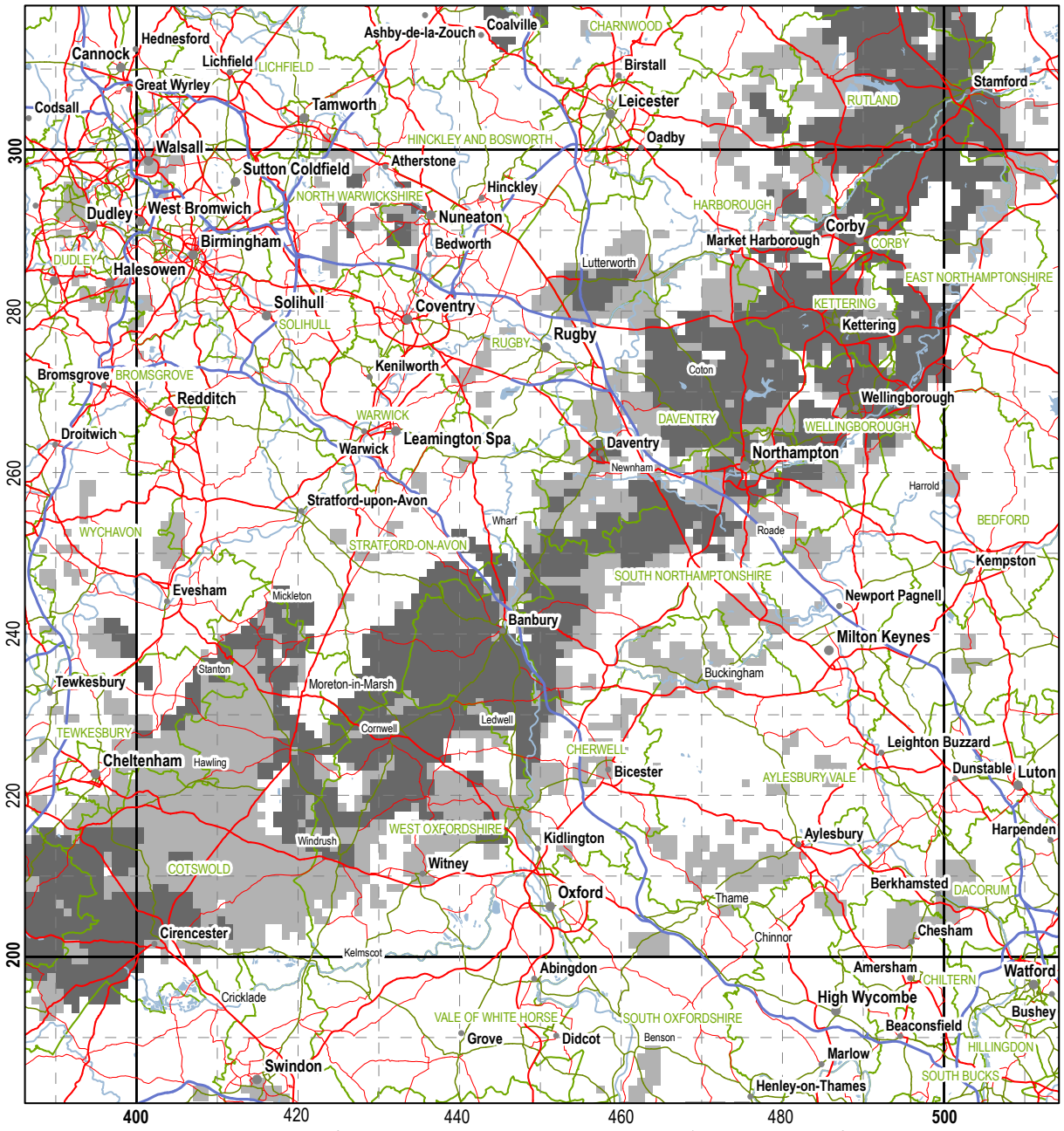

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in Building Regulations Approved Document C. The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org. The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required

- None
- Basic
- Full

Settlements

- Solihull
- Aylesbury
- Lutterworth
- Stanton

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 9 Oxfordshire, Northamptonshire and Warwickshire, 100-km grid square SP (axis numbers are the coordinates of the National Grid)

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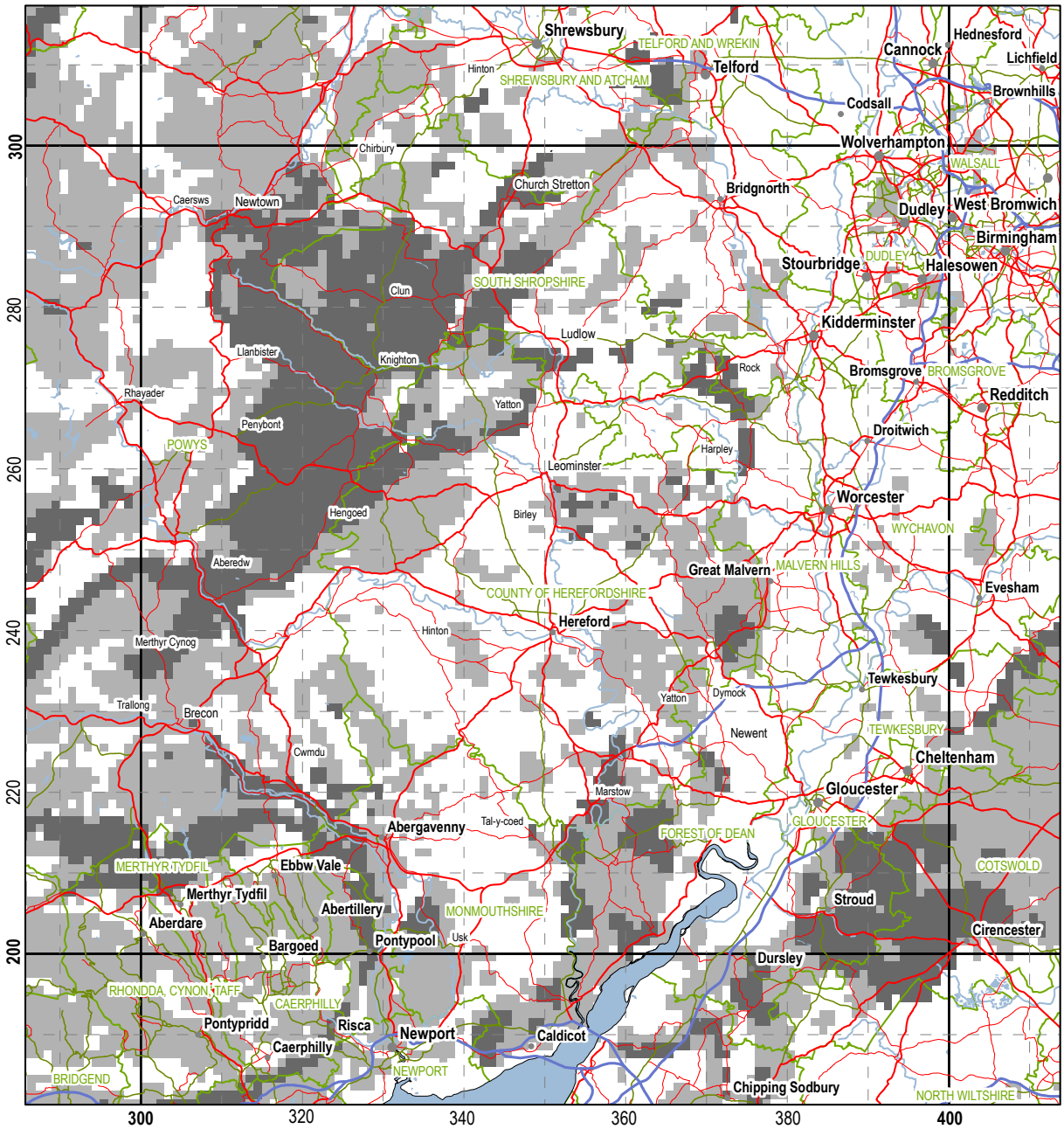

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in Building Regulations Approved Document C. The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org. The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required

- None
- Basic
- Full

Settlements

- Gloucester
- Ebbw Vale
- Ludlow
- Caersws

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 10 Southern Welsh Marches and Gloucestershire, 100-km grid square SO (axis numbers are the coordinates of the National Grid)

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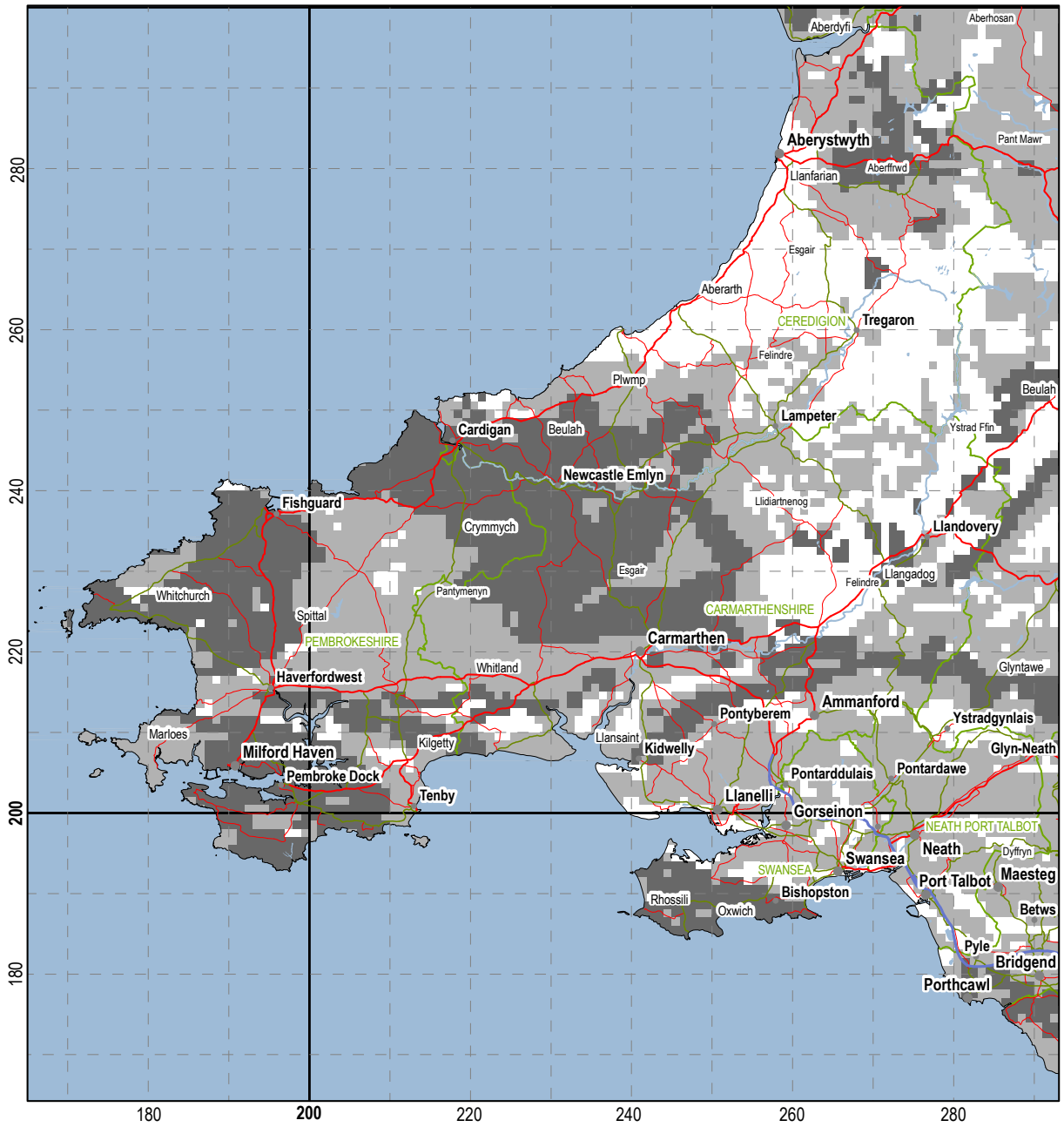

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in Building Regulations Approved Document C. The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org. The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required

- None
- Basic
- Full

Settlements

- Swansea
- Lampeter
- Whitchurch
- Dyffryn

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 11 Southwest Wales, 100-km grid squares SM, SN, SR and SS (axis numbers are the coordinates of the National Grid)

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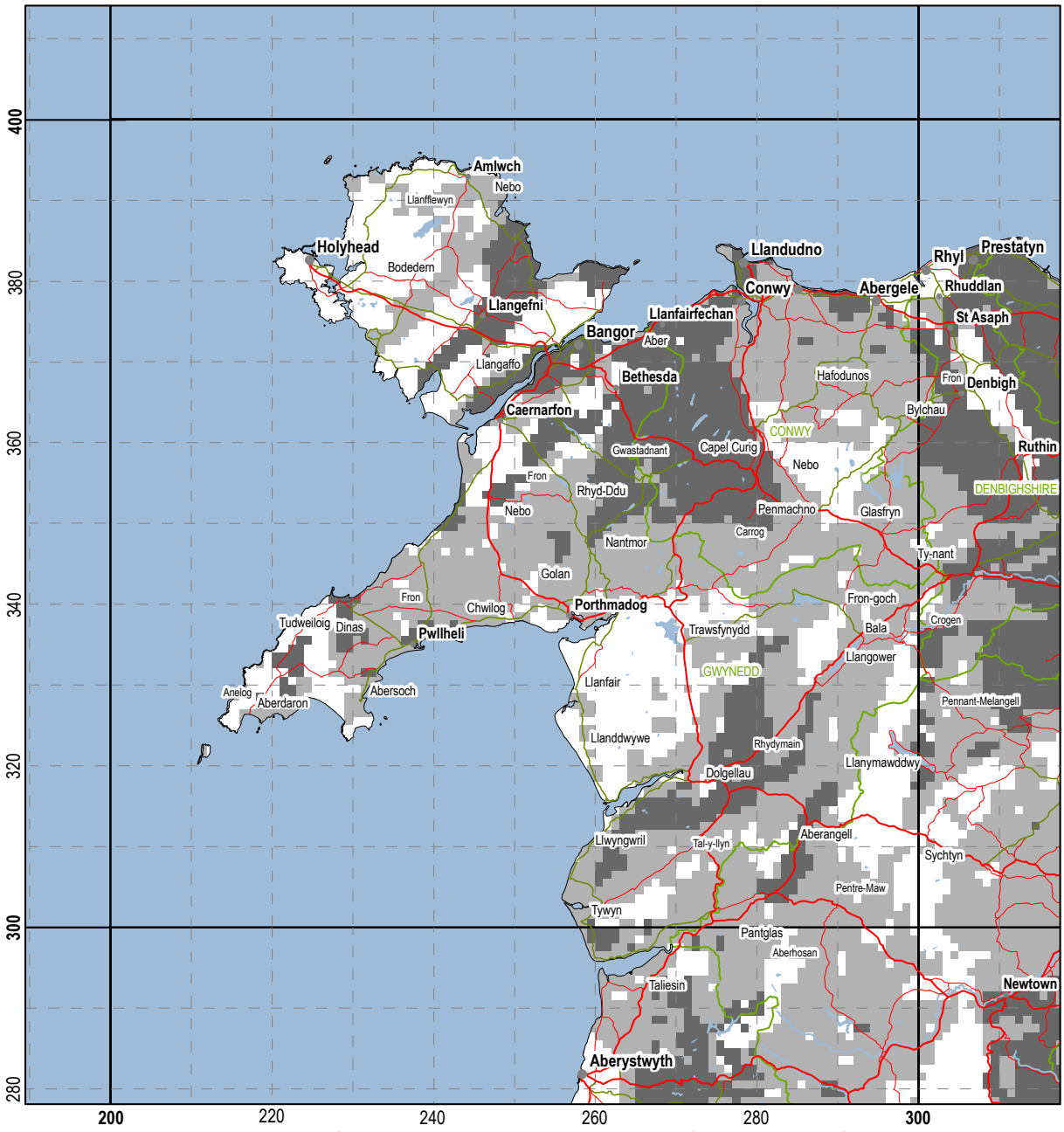

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in Building Regulations Approved Document C. The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org. The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required

- None
- Basic
- Full

Settlements

- Bangor
- Porthmadog
- Dolgellau
- Carrog

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 12 Northwest Wales, 100-km grid square SH (axis numbers are the coordinates of the National Grid)

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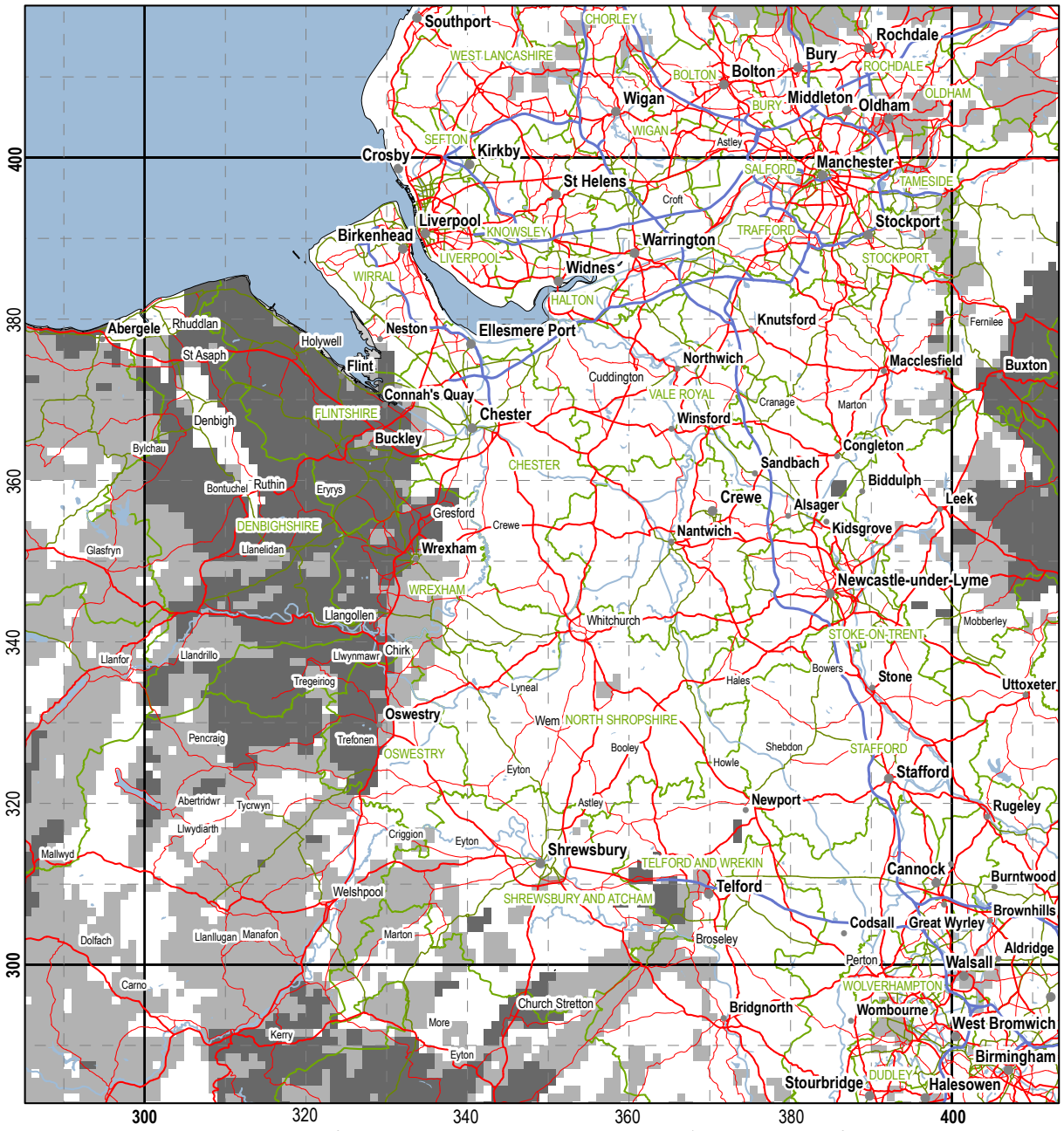

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in Building Regulations Approved Document C. The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org. The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required

- None
- Basic
- Full

Settlements

- Chester
- Oswestry
- Rhuddlan
- Bowers

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 13 Northern Welsh Marches and Liverpool, 100-km grid square SJ (axis numbers are the coordinates of the National Grid)

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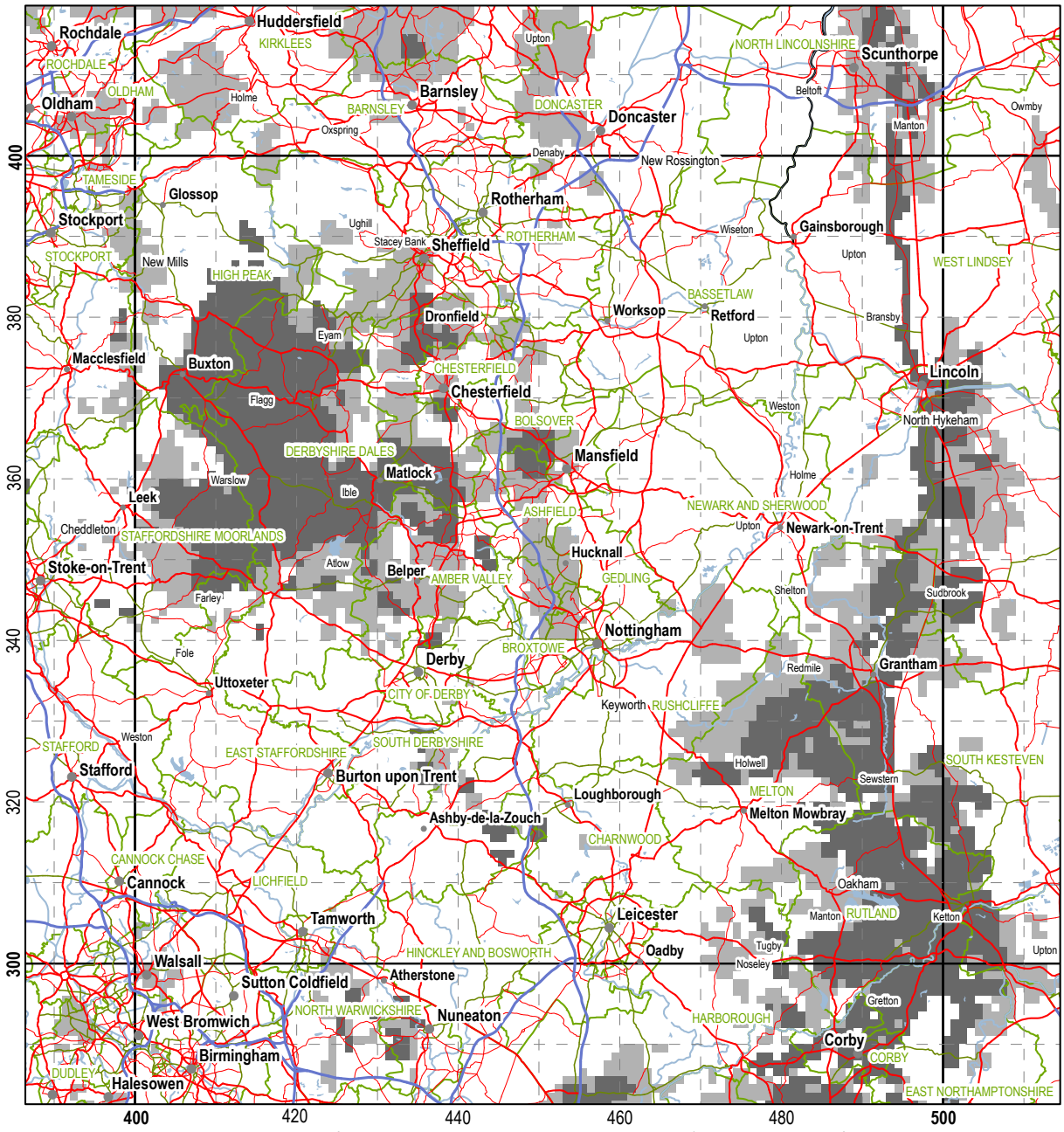

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in Building Regulations Approved Document C. The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org. The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required

- None
- Basic
- Full

Settlements

- Derby
- Grantham
- Oakham
- Eyam

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 14 Derbyshire, Leicestershire and Nottinghamshire, 100-km grid square SK (axis numbers are the coordinates of the National Grid)

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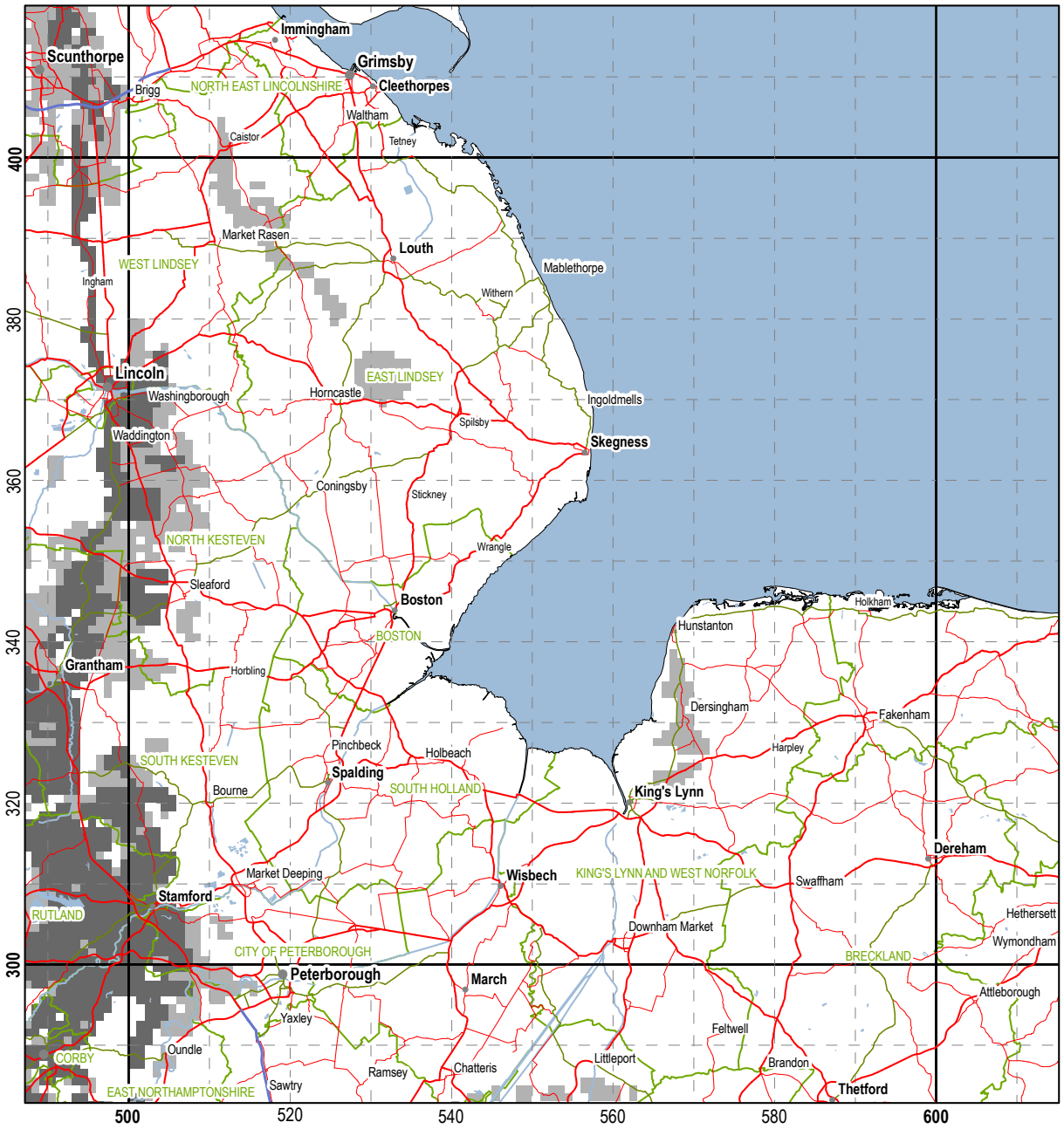

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in Building Regulations Approved Document C. The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org. The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required

- None
- Basic
- Full

Settlements

- Lincoln
- Spalding
- Holbeach
- Spilsby

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 15 Lincolnshire and the Wash, 100-km grid square TF (axis numbers are the coordinates of the National Grid)

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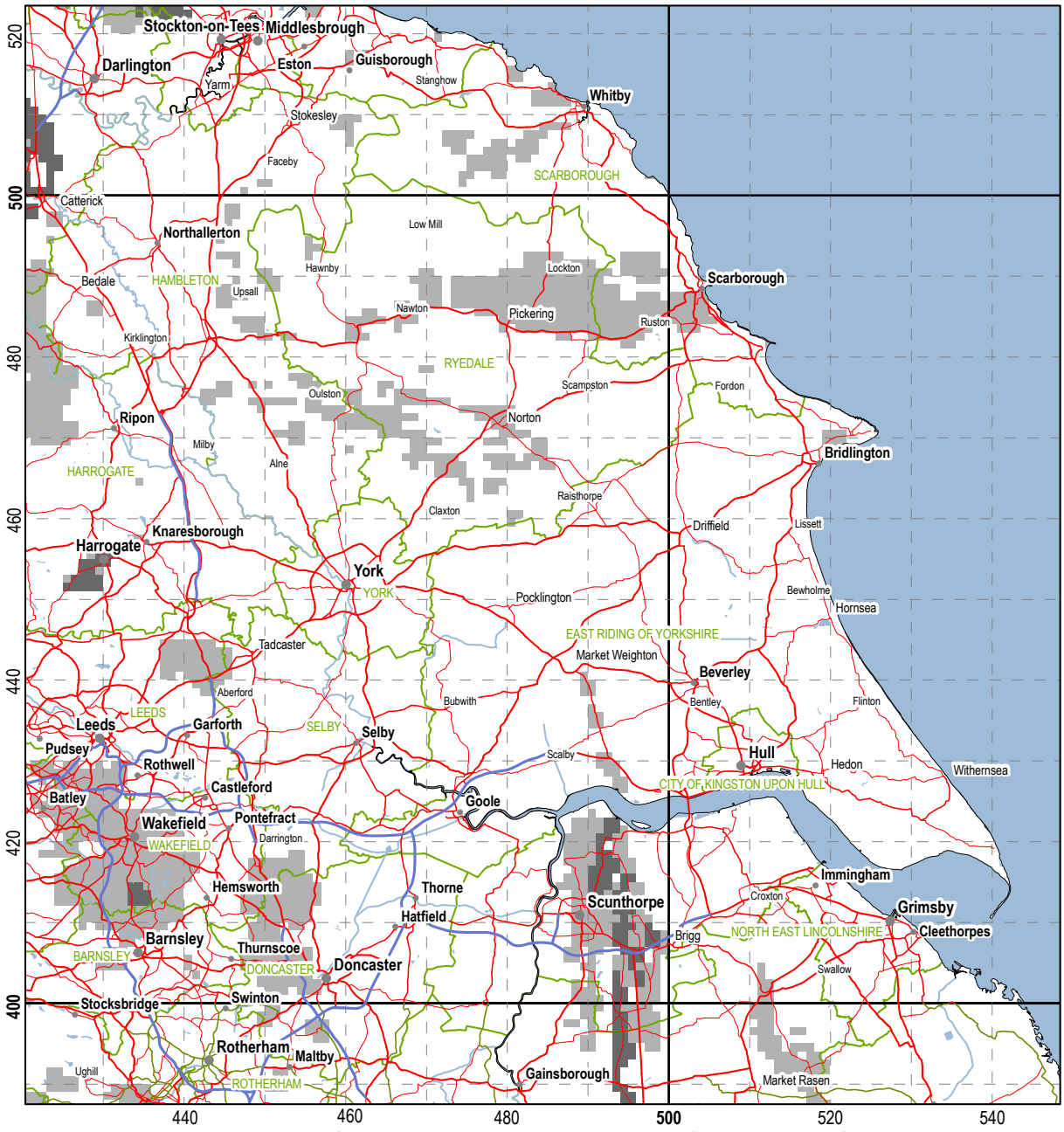

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in Building Regulations Approved Document C. The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org. The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required

- None
- Basic
- Full

Settlements

- York
- Batley
- Brigg
- Lissett

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 16 Humberside and eastern North Yorkshire, 100-km grid squares SE and TA (axis numbers are the coordinates of the National Grid)

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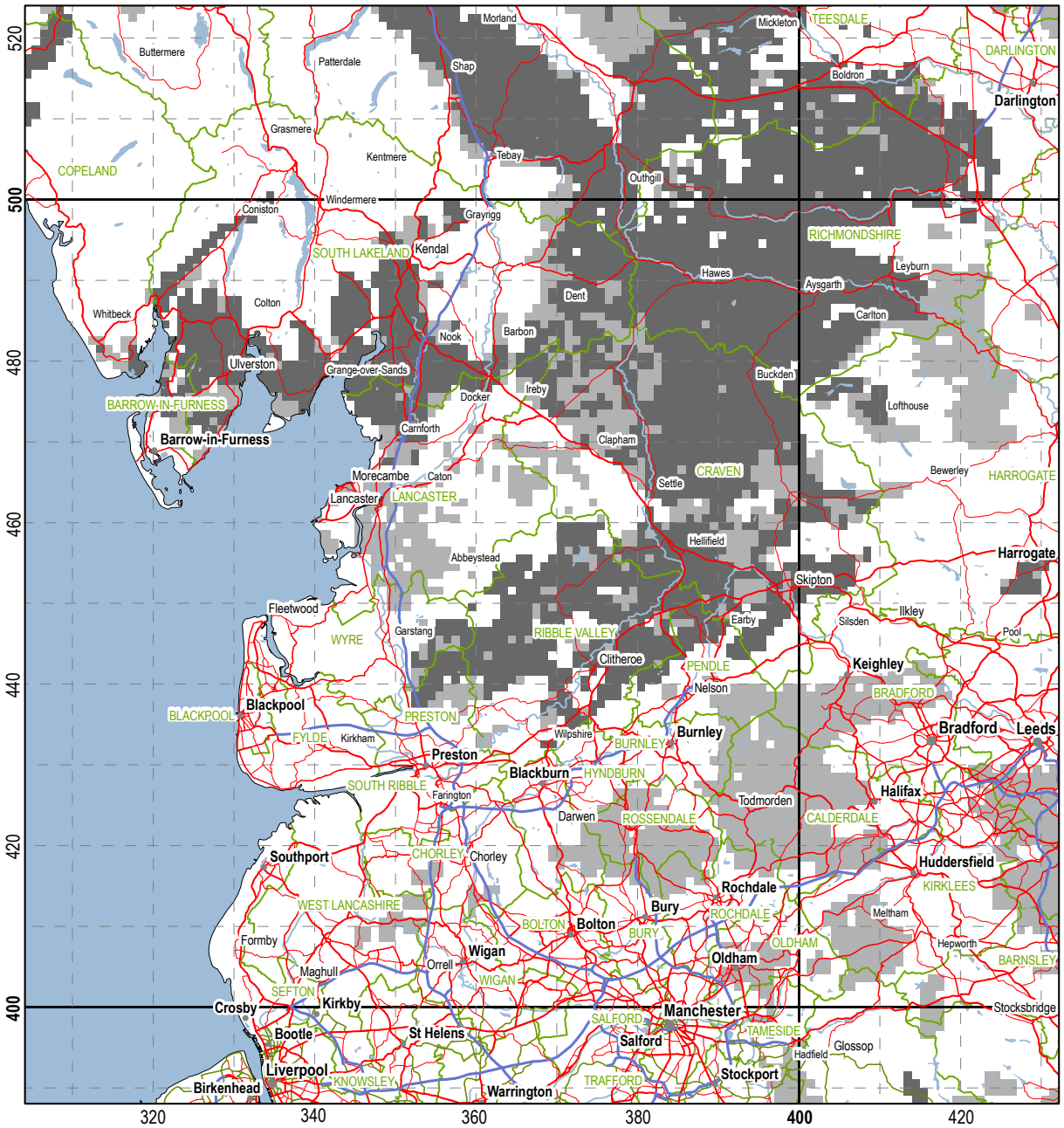

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in Building Regulations Approved Document C. The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org. The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required

- None
- Basic
- Full

Settlements

- Blackburn
- Keighley
- Hawes
- Coniston

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 17 Lancashire, south Cumbria and western North Yorkshire, 100-km grid squares SD and SE (axis numbers are the coordinates of the National Grid)

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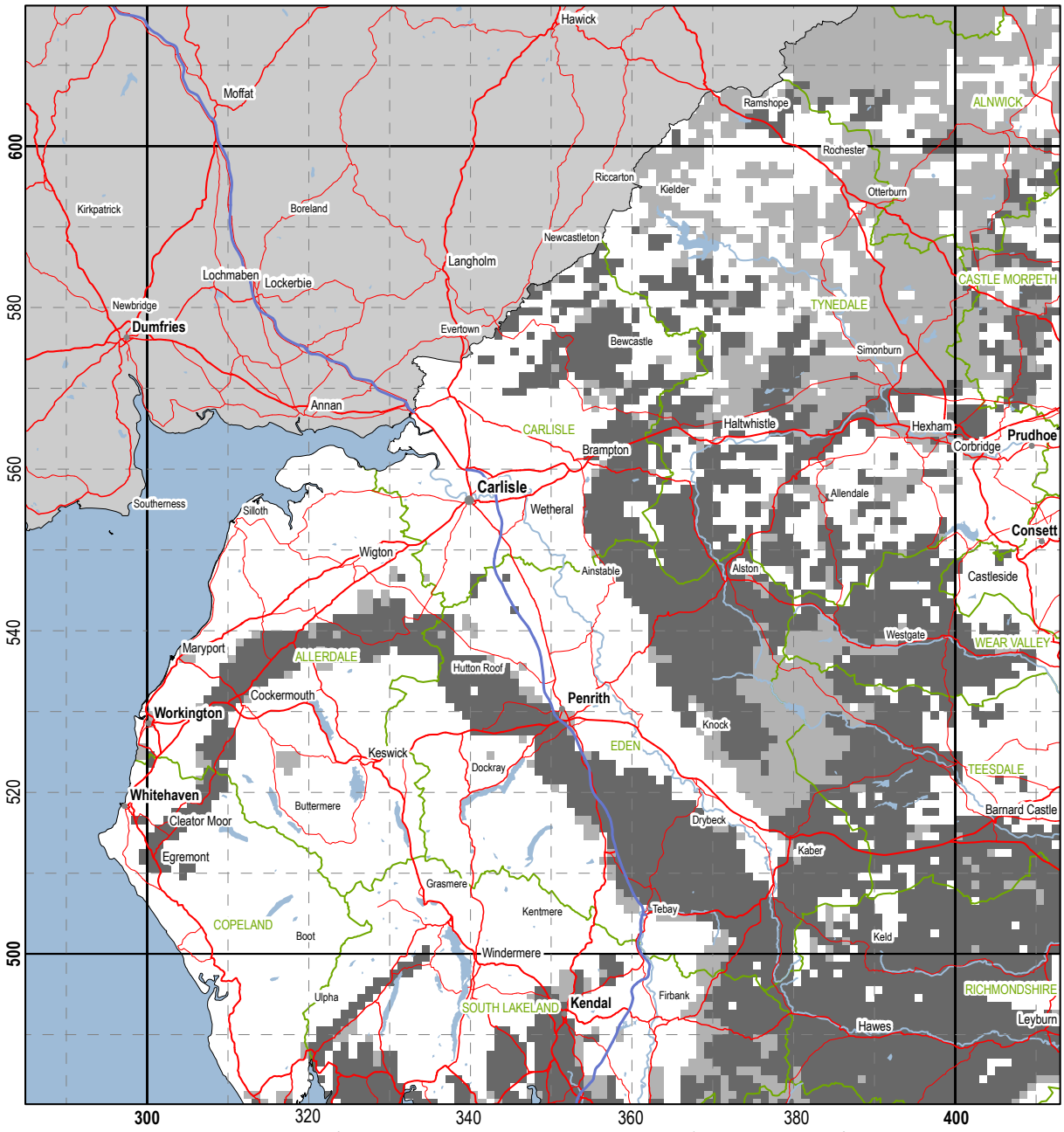

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in Building Regulations Approved Document C. The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org. The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required

- None
- Basic
- Full

Settlements

- Carlisle
- Penrith
- Wigton
- Grasmere

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 18 North Cumbria, 100-km grid square NY (axis numbers are the coordinates of the National Grid)

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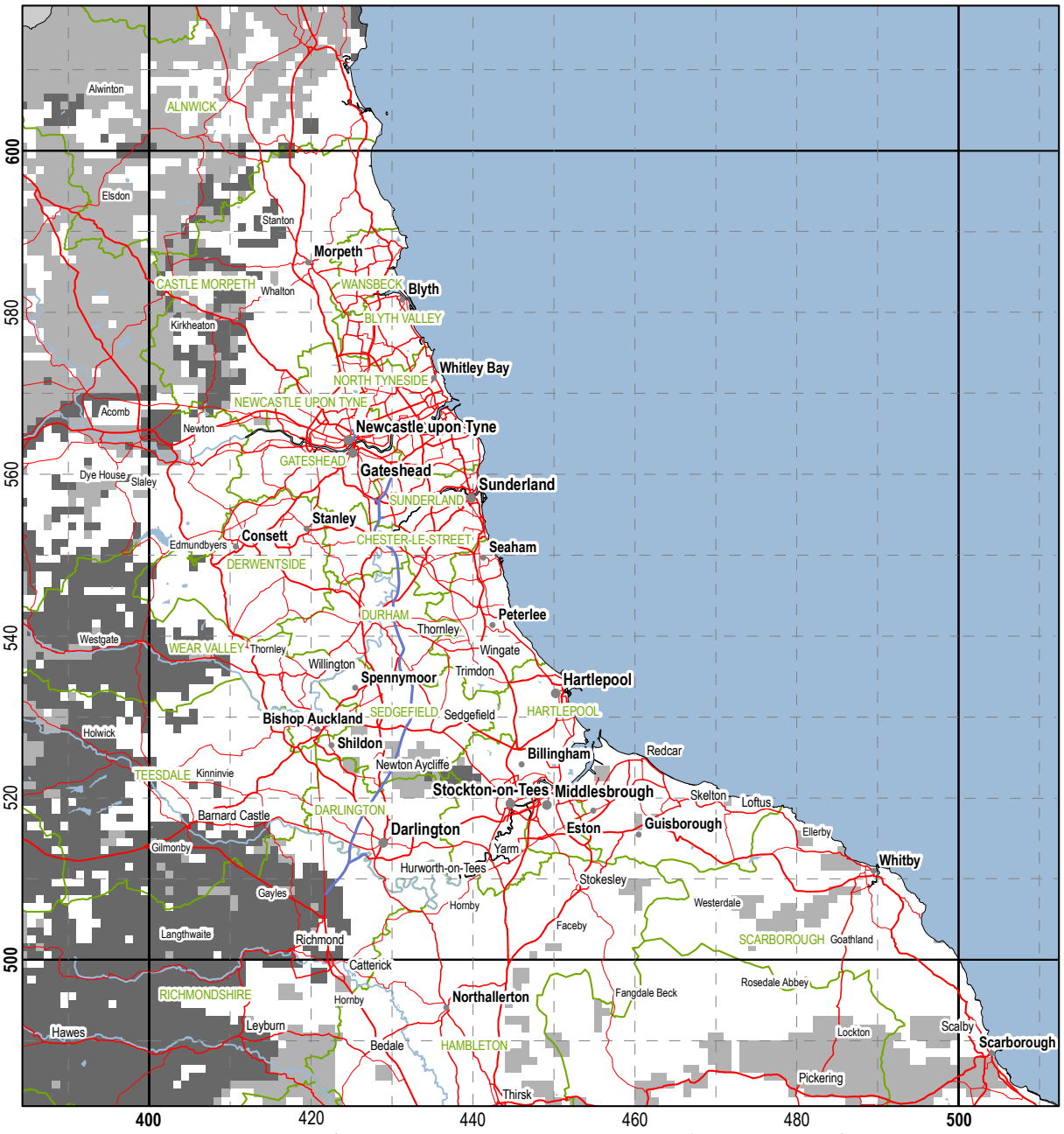

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Level of protection required

- None
- Basic
- Full

Settlements

- Sunderland
- Peterlee
- Yarm
- Slaley

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 19 Teeside, Tyneside and Wearside, 100-km grid square NZ (axis numbers are the coordinates of the National Grid)

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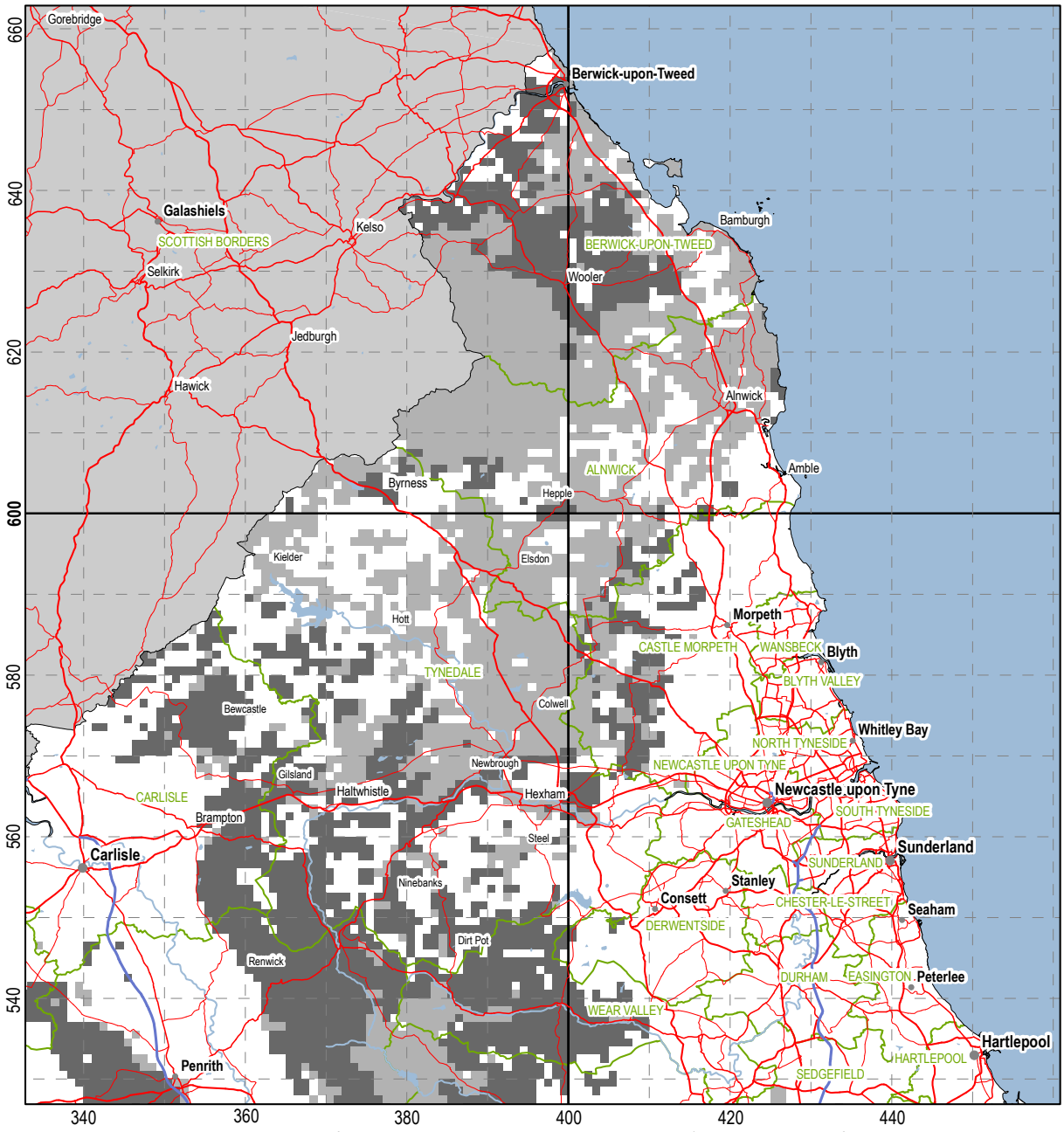

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in Building Regulations Approved Document C. The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org. The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required

- None
- Basic
- Full

Settlements

- Newcastle upon Tyne
- Berwick-upon-Tweed
- Alnwick
- Hepple

Roads

- Motorways
- Primary Roads
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other Features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 20 Northumberland, 100-km grid squares NT and NU (axis numbers are the coordinates of the National Grid)

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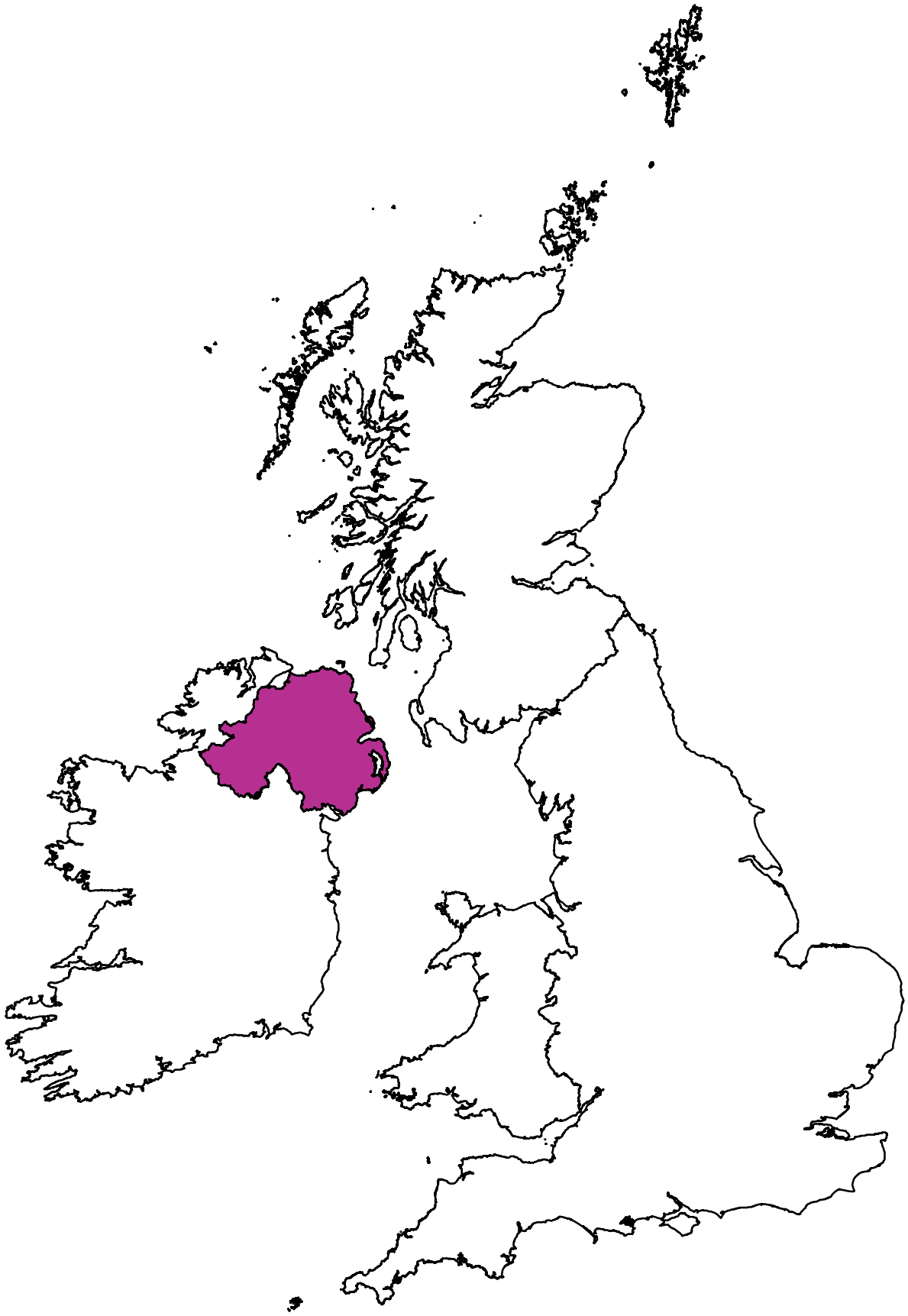
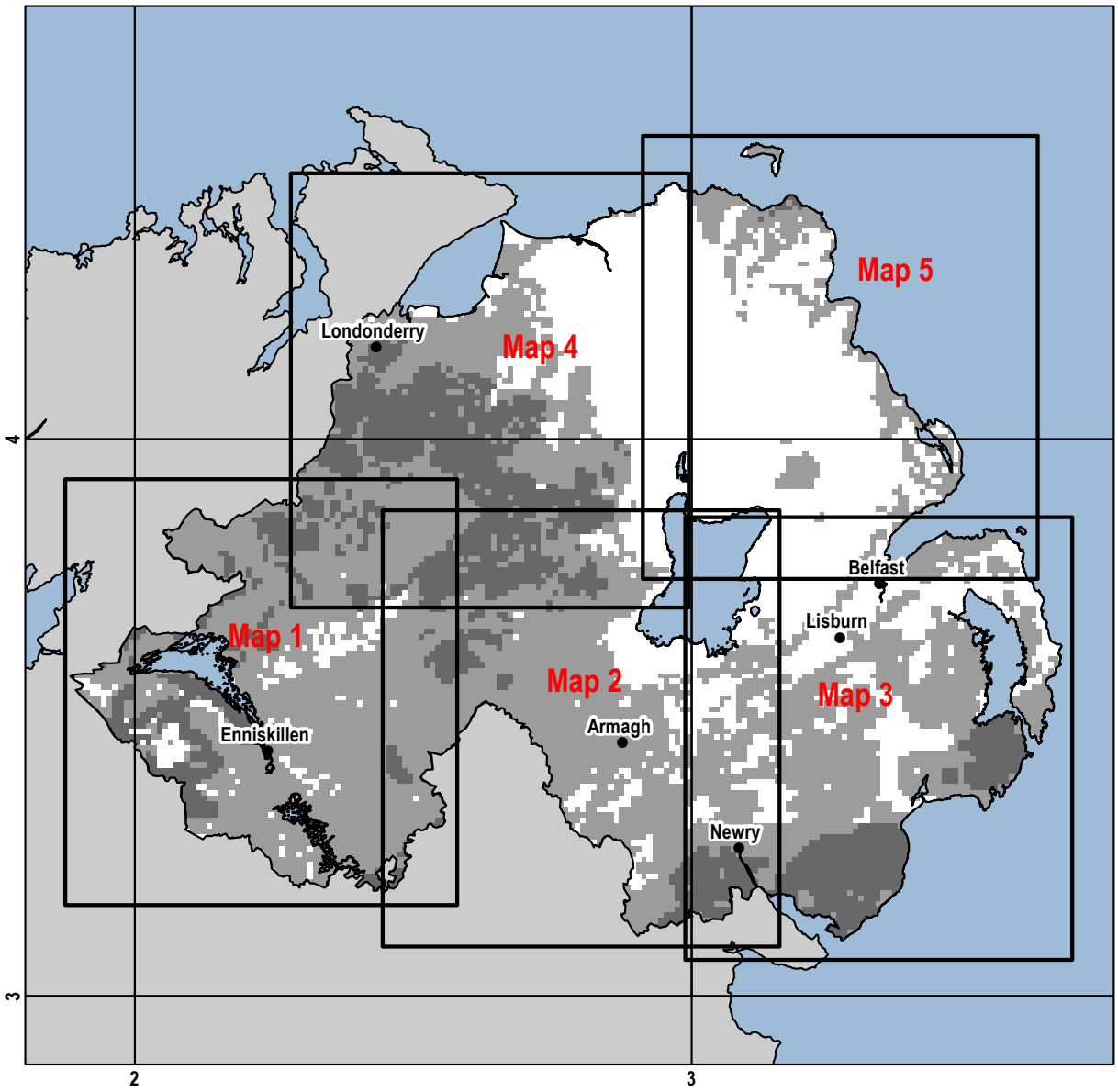
Northern Ireland





Key to larger scale maps of radon Affected Areas in Northern Ireland (the axis numbers are the 100-km coordinates of the Irish Grid)

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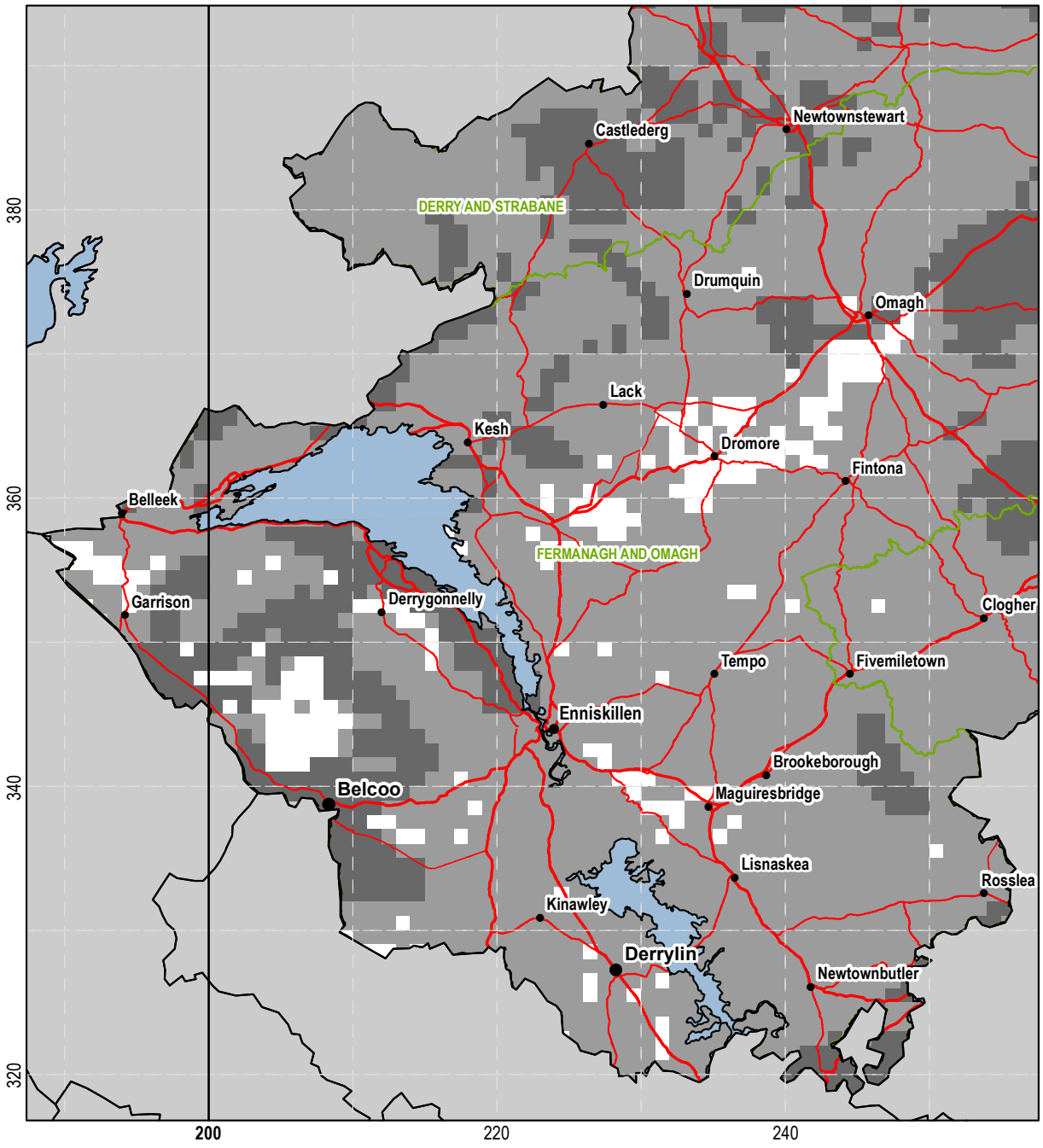

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in The Building Regulations (Northern Ireland) 2012, Technical Booklet C.
The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org.

Level of protection required
- None
- Zone 1
- Zone 2

Settlements
- Enniskillen
- Omagh

Roads
- Motorways
- A Roads
- B Roads
- Minor Roads

Irish Grid
- 100 km
- 10 km

Other features
- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 1 Southwest Northern Ireland (axis numbers are the coordinates of the Irish Grid)

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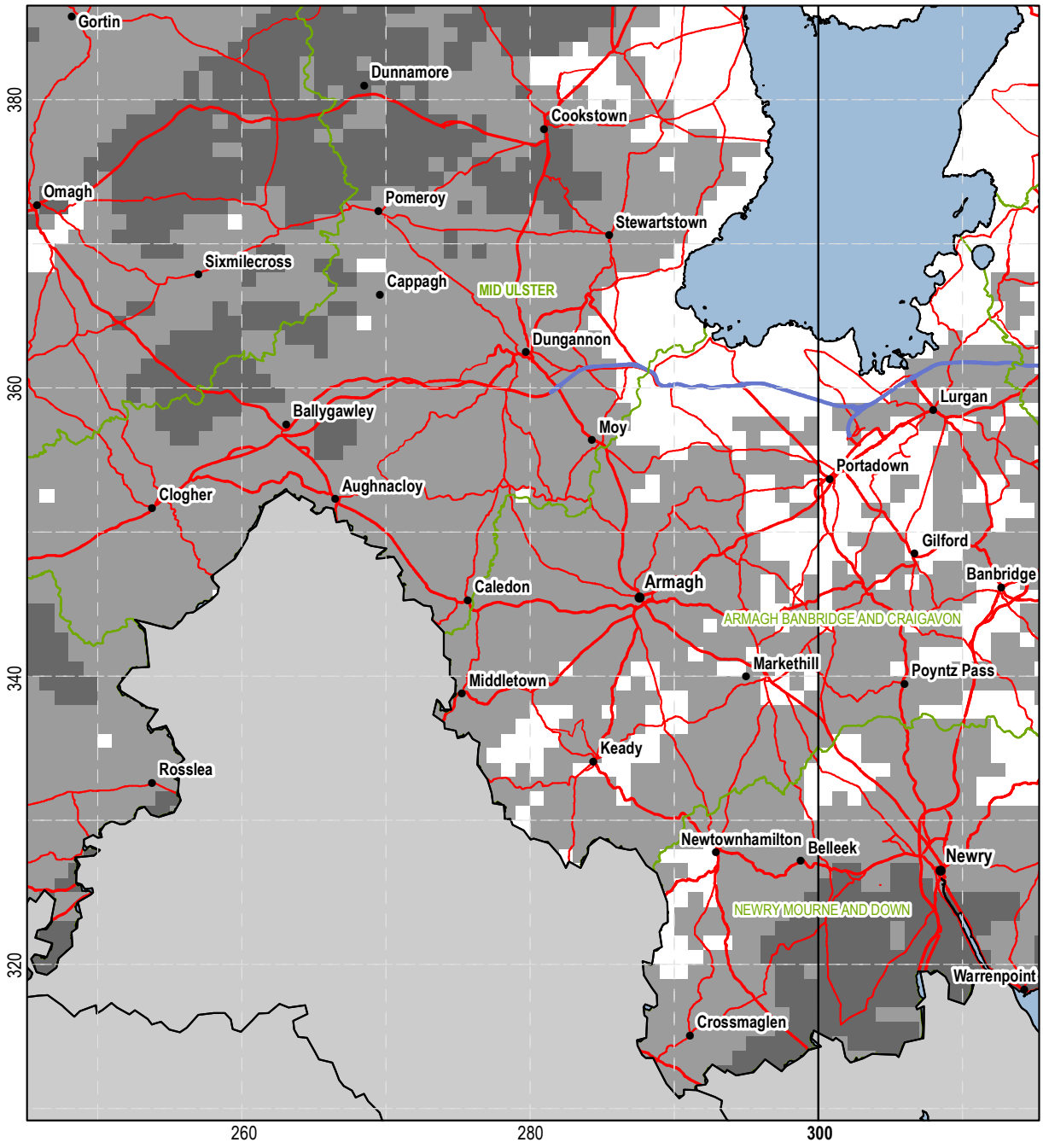

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in The Building Regulations (Northern Ireland) 2012, Technical Booklet C.

The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org.

Level of protection required

- None
- Zone 1
- Zone 2

Settlements

- Armagh
- Sixmilecross

Roads

- Motorways
- A Roads
- B Roads
- Minor Roads

Irish Grid

- 100 km
- 10 km

Other features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 2 Southern Northern Ireland (axis numbers are the coordinates of the Irish Grid)

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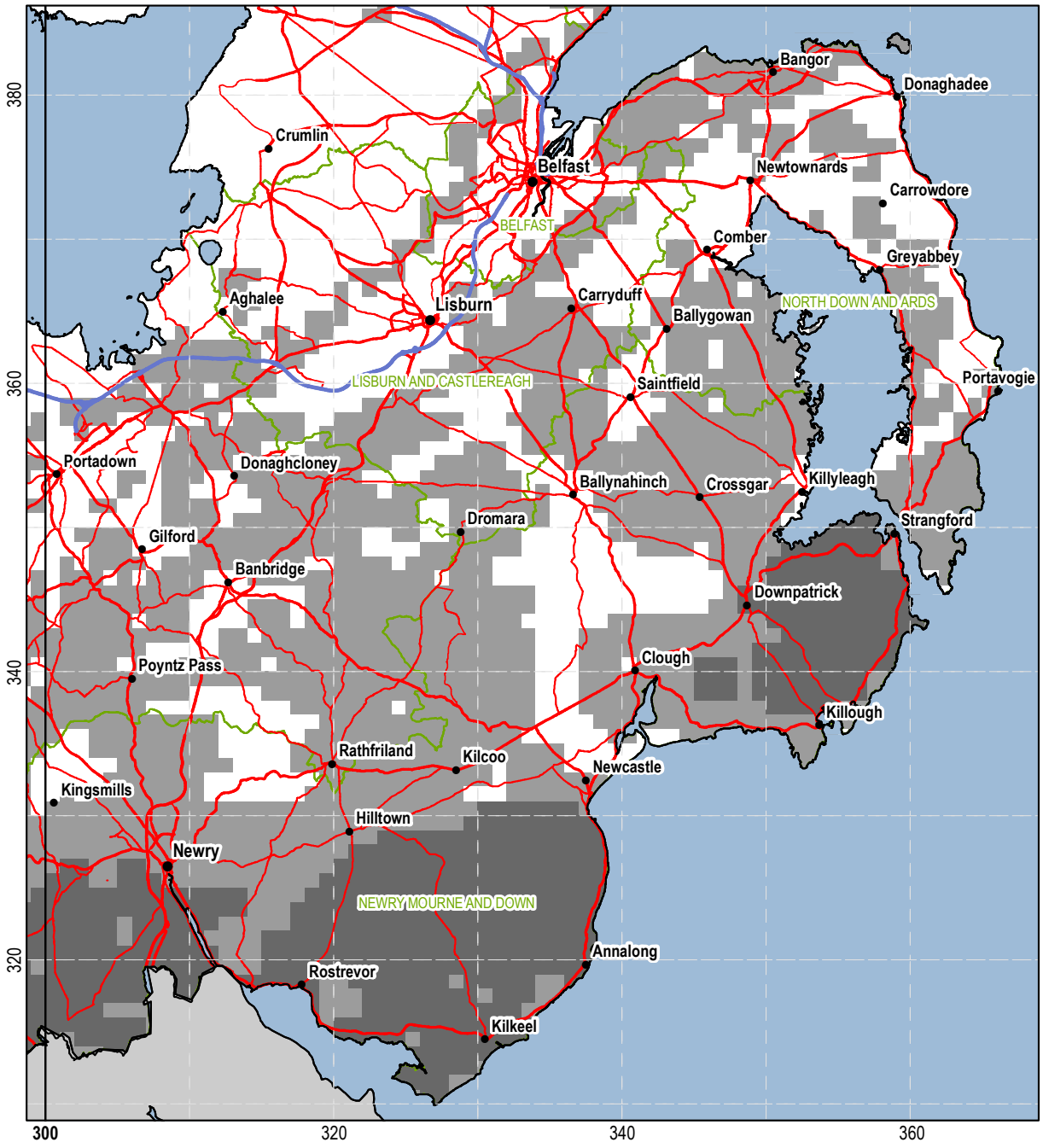

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in The Building Regulations (Northern Ireland) 2012, Technical Booklet C.
The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org.

Level of protection required
- None
- Zone 1
- Zone 2

Settlements
- Newry
- Ballygowan

Roads
- Motorways
- A Roads
- B Roads
- Minor Roads

Irish Grid
- 100 km
- 10 km

Other features
- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 3 South-eastern Northern Ireland (axis numbers are the coordinates of the Irish Grid)

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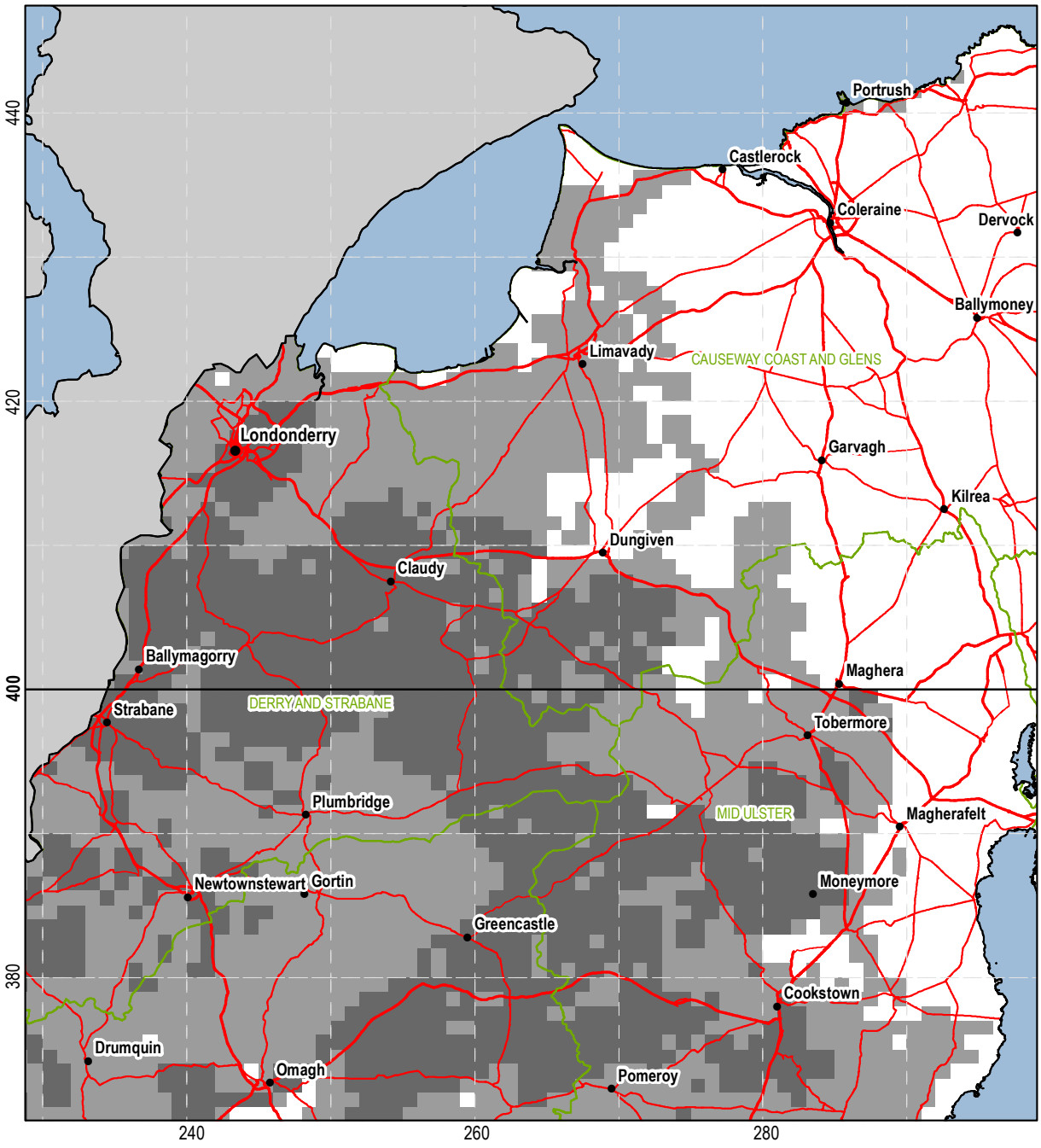

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in The Building Regulations (Northern Ireland) 2012, Technical Booklet C.

The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org.

Level of protection required

- None
- Zone 1
- Zone 2

Settlements

- Londonderry
- Moneymore

Roads

- Motorways
- A Roads
- B Roads
- Minor Roads

Irish Grid

- 100 km
- 10 km

Other features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 4 North-western Northern Ireland (axis numbers are the coordinates of the Irish Grid)

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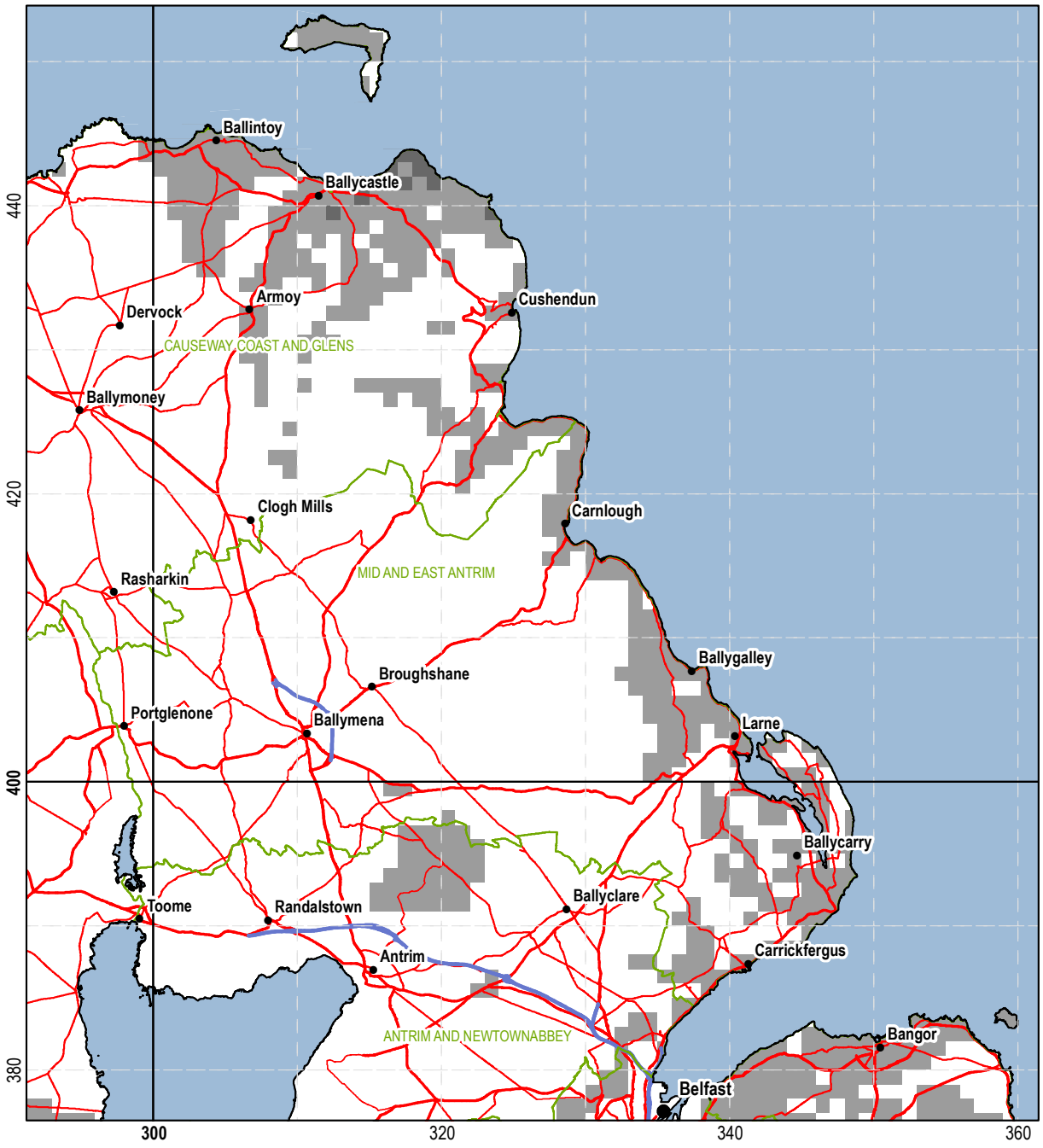

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in The Building Regulations (Northern Ireland) 2012, Technical Booklet C.
The requirement for an existing building with a valid postal address can be obtained for a small charge from www.ukradon.org.

Level of protection required
- None
- Zone 1
- Zone 2

Settlements
- Belfast
- Ballycastle

Roads
- Motorways
- A Roads
- B Roads
- Minor Roads

Irish Grid
- 100 km
- 10 km

Other features
- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 5 North-eastern Northern Ireland (axis numbers are the coordinates of the Irish Grid)

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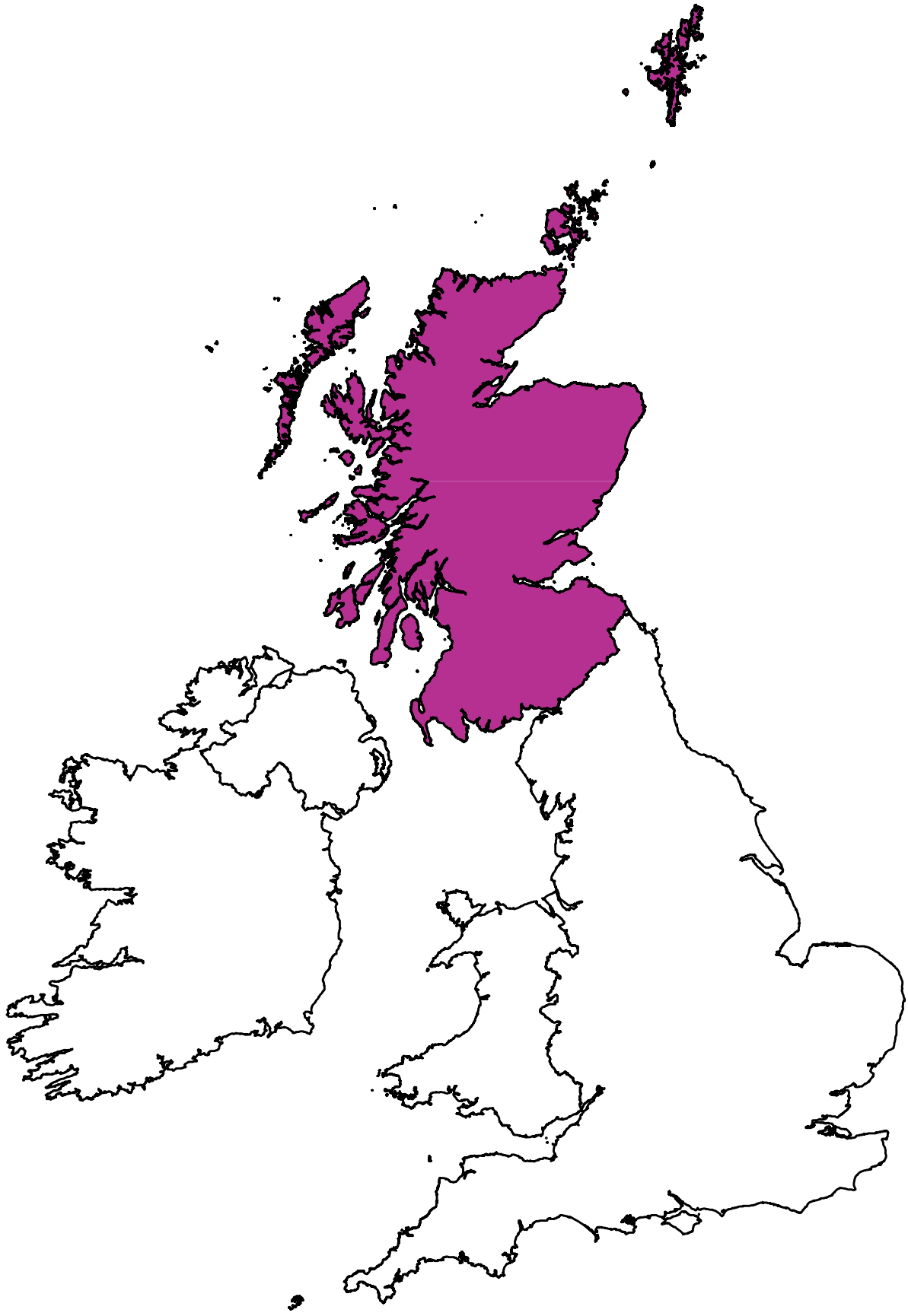
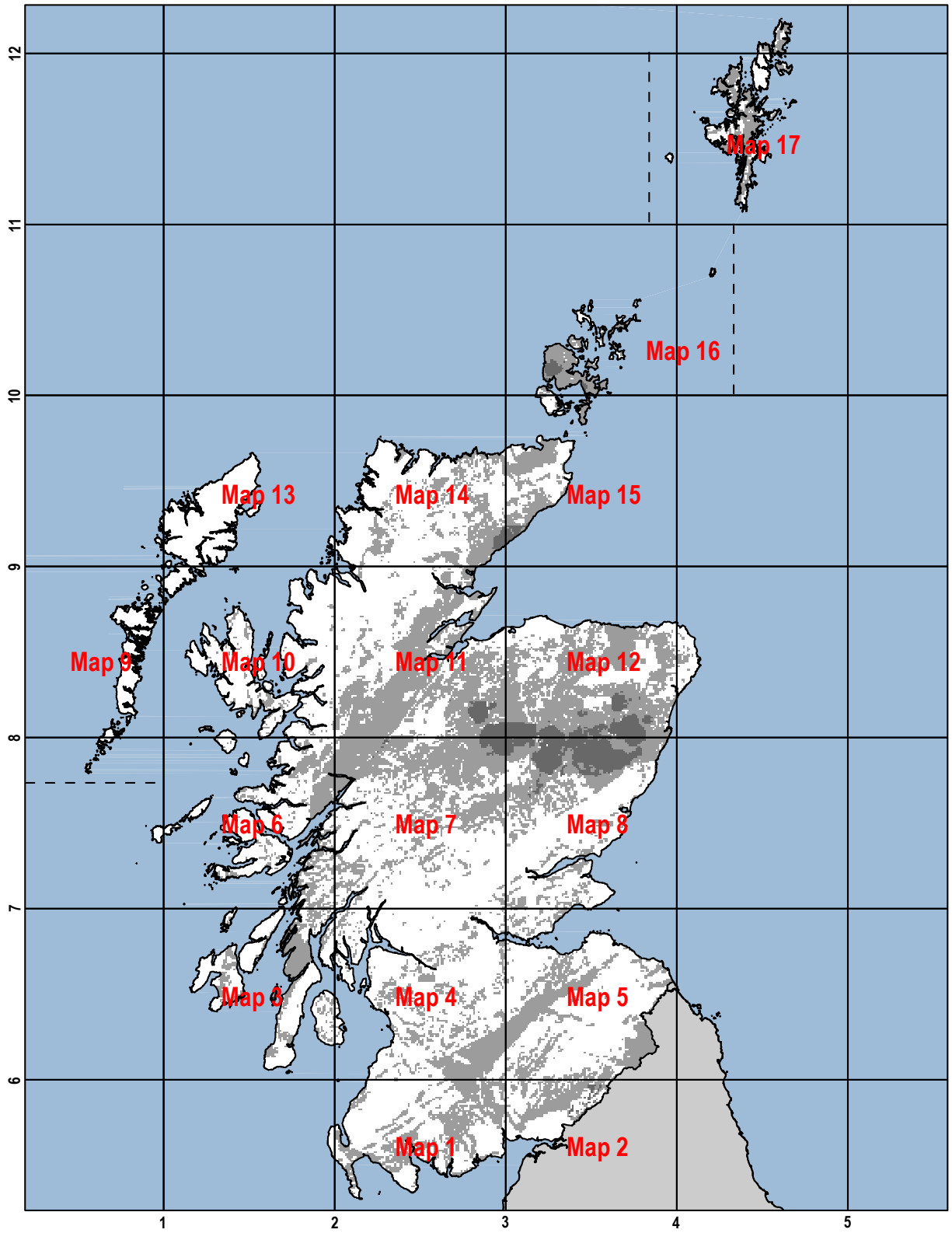
Scotland





Key to larger scale maps (axis numbers are the 100-km coordinates of the National Grid)

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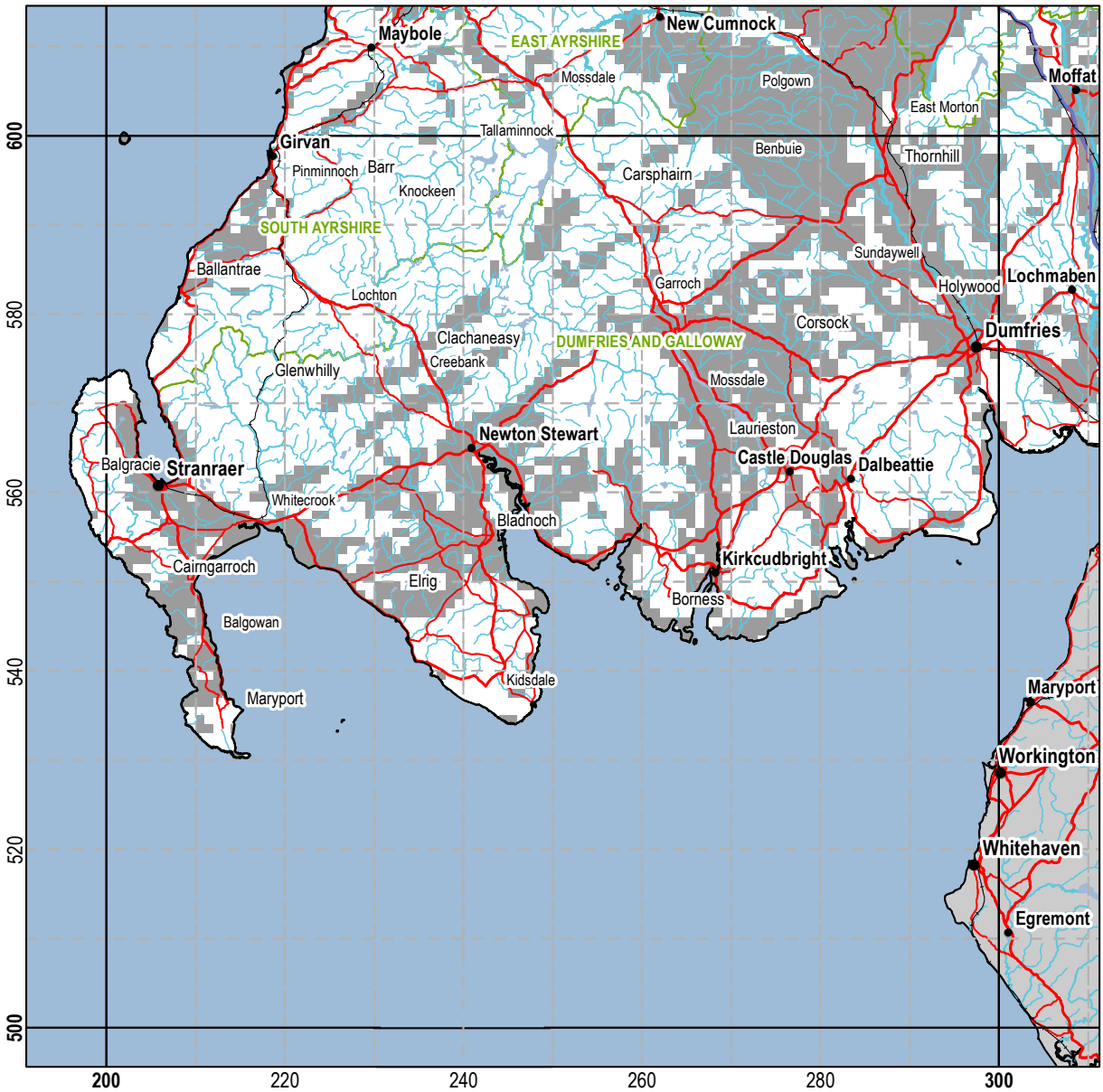

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in The Building (Scotland) Regulations 2004, Domestic and Non-Domestic Technical Handbooks - Section 3.
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The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required
- None
- Basic
- Full

Settlements
- Stranraer
- Dalbeattie
- Borness
- Knockeen

Transport Network
- Railway Lines
- Motorways
- A Roads
- B Roads

National Grid
- 100-km
- 10-km

Other features
- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 1 South-western Scotland, 100-km grid square NX (axis numbers are the coordinates of the National Grid)

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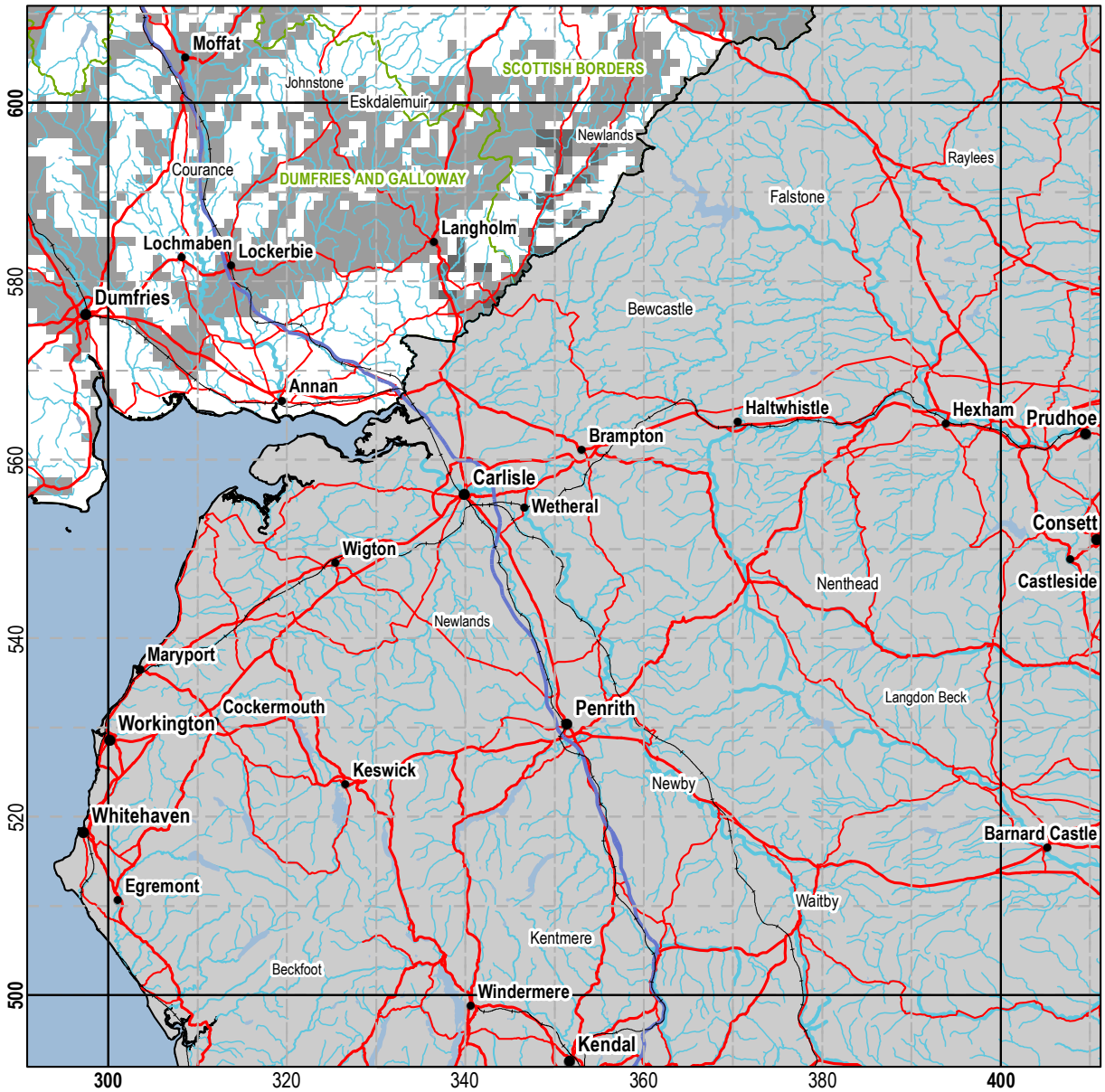

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Level of protection required
- None
- Basic
- Full

Settlements
- Dumfries
- Langholm
- Eskdalemuir
- Newlands

Transport Network
- Railway Lines
- Motorways
- A Roads
- B Roads

National Grid
- 100-km
- 10-km

Other features
- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 2 South-western Scottish Borders, 100-km grid square NY (axis numbers are the coordinates of the National Grid)

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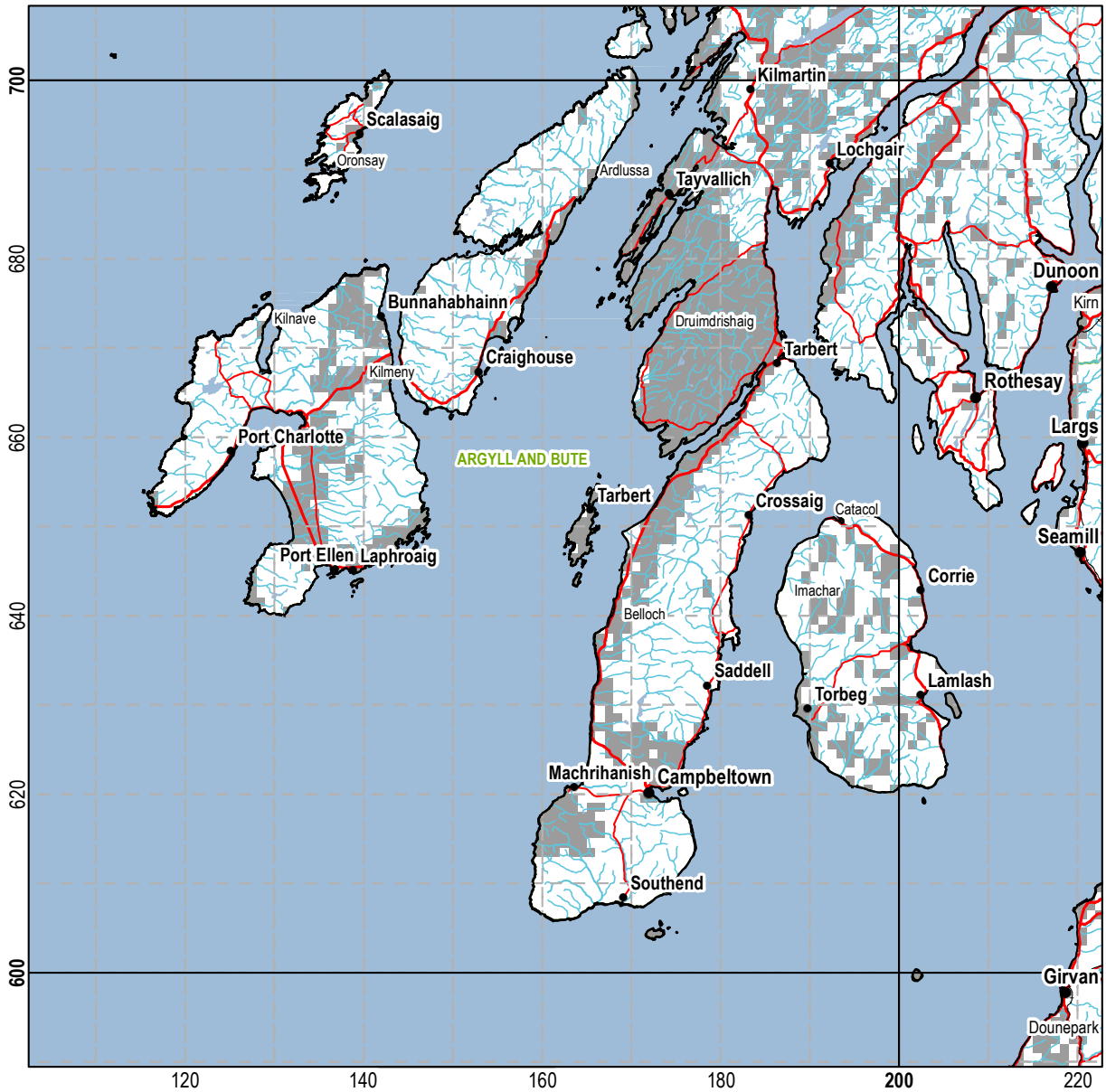

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The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required
- None
- Basic
- Full

Settlements
- Campbeltown
- Port Charlotte
- Dounepark
- Ardlussa

Transport Network
- Railway Lines
- Motorways
- A Roads
- B Roads

National Grid
- 100-km
- 10-km

Other features
- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 3 Kintyre and the Islands of Islay, Jura and Arran, 100-km grid square NR (axis numbers are the coordinates of the National Grid)

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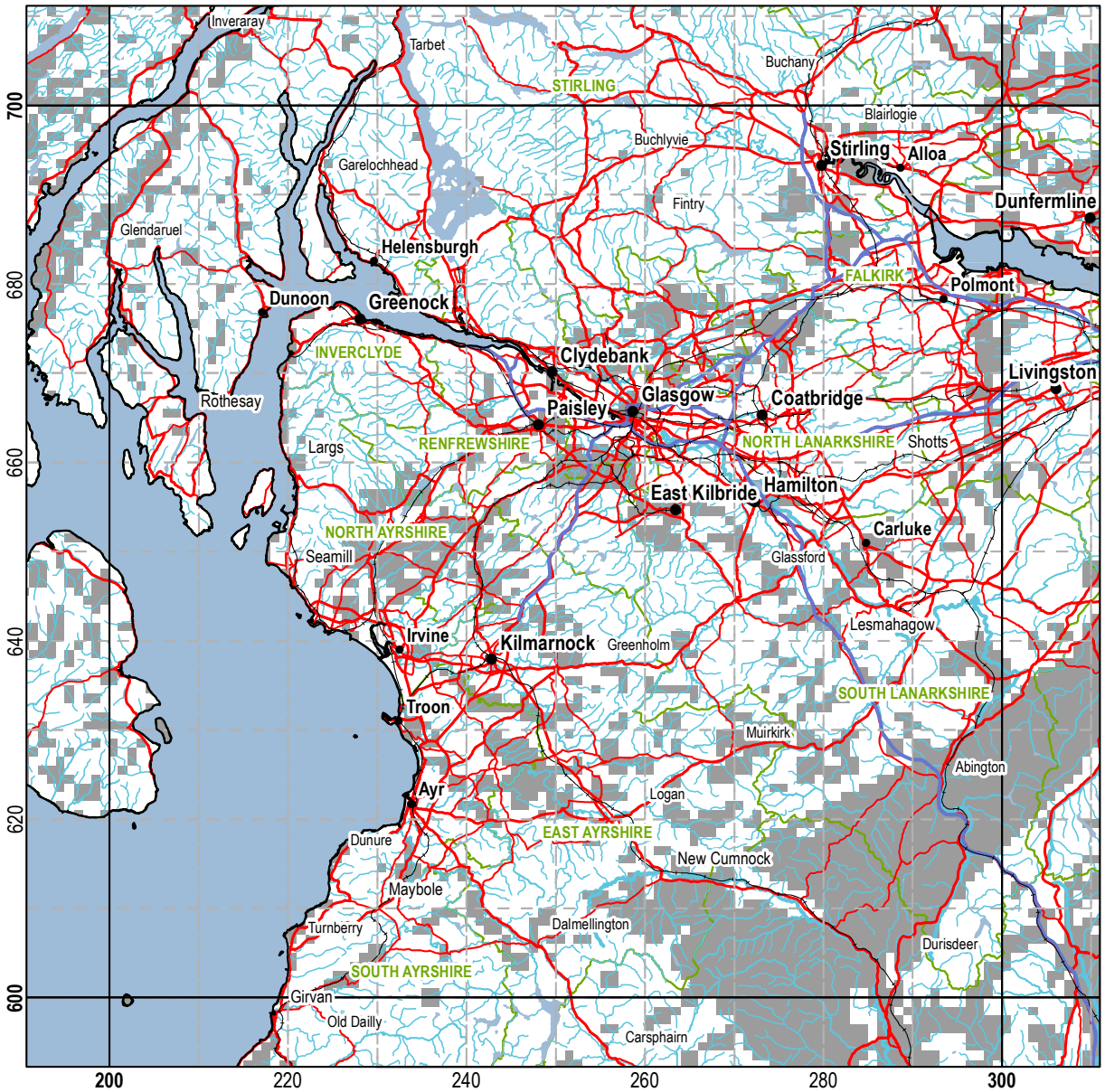

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in The Building (Scotland) Regulations 2004, Domestic and Non-Domestic Technical Handbooks - Section 3.

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Level of protection required

- None
- Basic
- Full

Settlements

- Glasgow
- Alloa
- Maybole
- Durisdeer

Transport Network

- Railway Lines
- Motorways
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 4 Glasgow and the south-western Lowlands, 100-km grid square NS (axis numbers are the coordinates of the National Grid)

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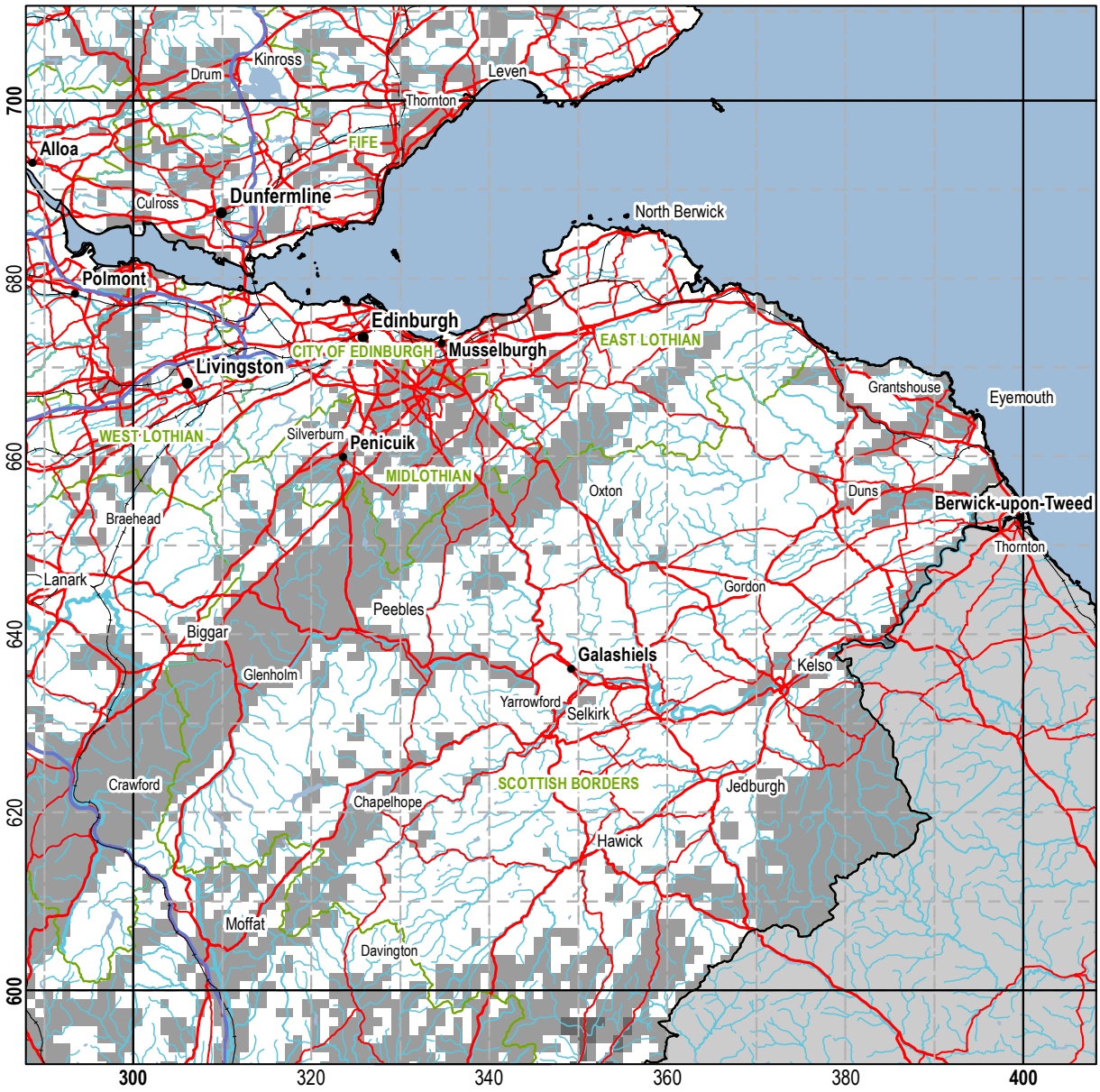

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in The Building (Scotland) Regulations 2004, Domestic and Non-Domestic Technical Handbooks - Section 3.

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Level of protection required

- None
- Basic
- Full

Settlements

- Edinburgh
- Galashiels
- Moffat
- Grantshouse

Transport Network

- Railway Lines
- Motorways
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 5 Edinburgh and the south-eastern Scottish Borders, 100-km grid square NT (axis numbers are the coordinates of the National Grid)

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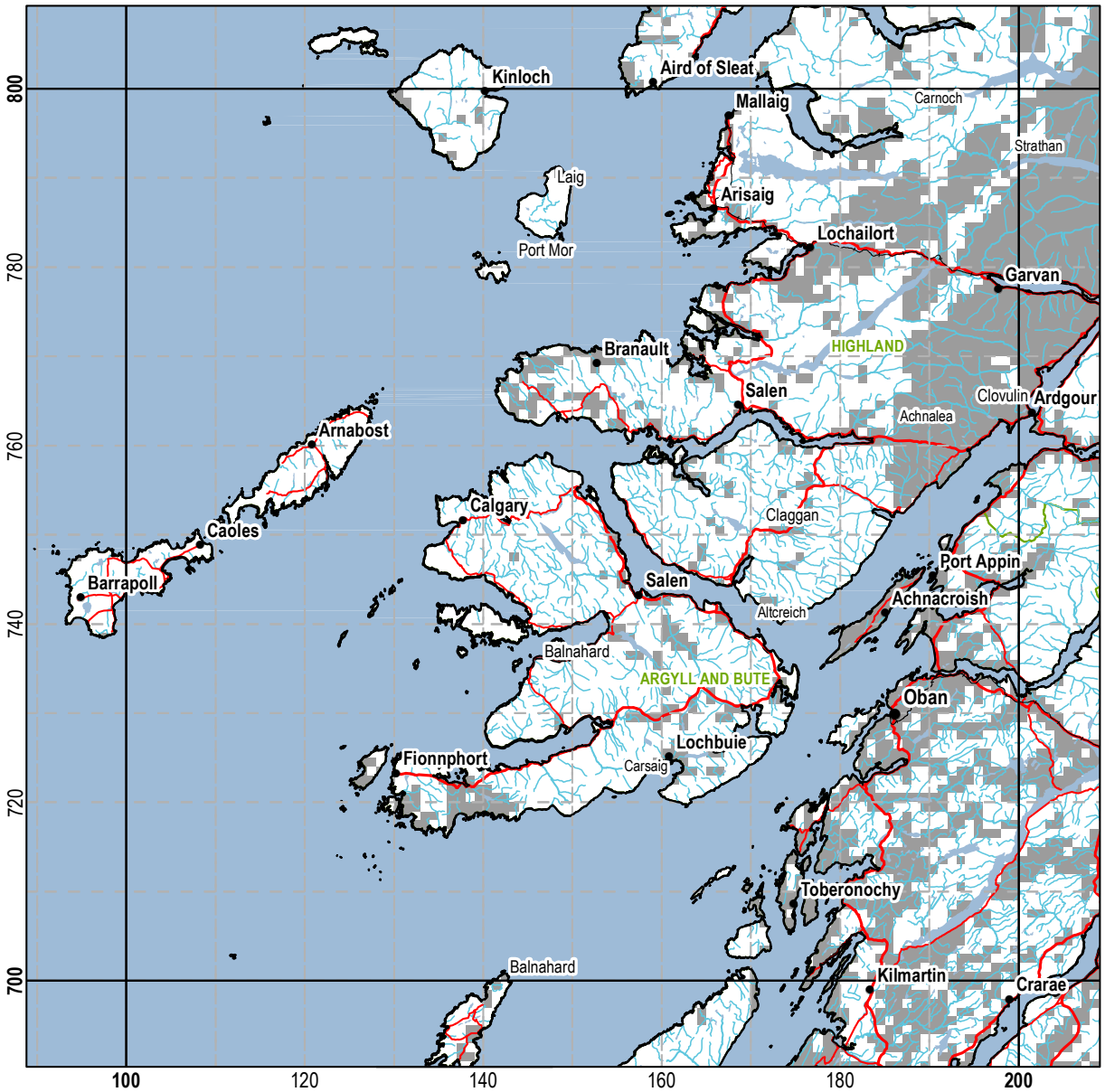

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The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required
- None
- Basic
- Full

Settlements
- Oban
- Mallaig
- Balnahard
- Carnoch

Transport Network
- Railway Lines
- Motorways
- A Roads
- B Roads

National Grid
- 100-km
- 10-km

Other features
- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 6 North-western Argyll and Bute and the south-western Highlands, 100-km grid square NM (axis numbers are the coordinates of the National Grid)

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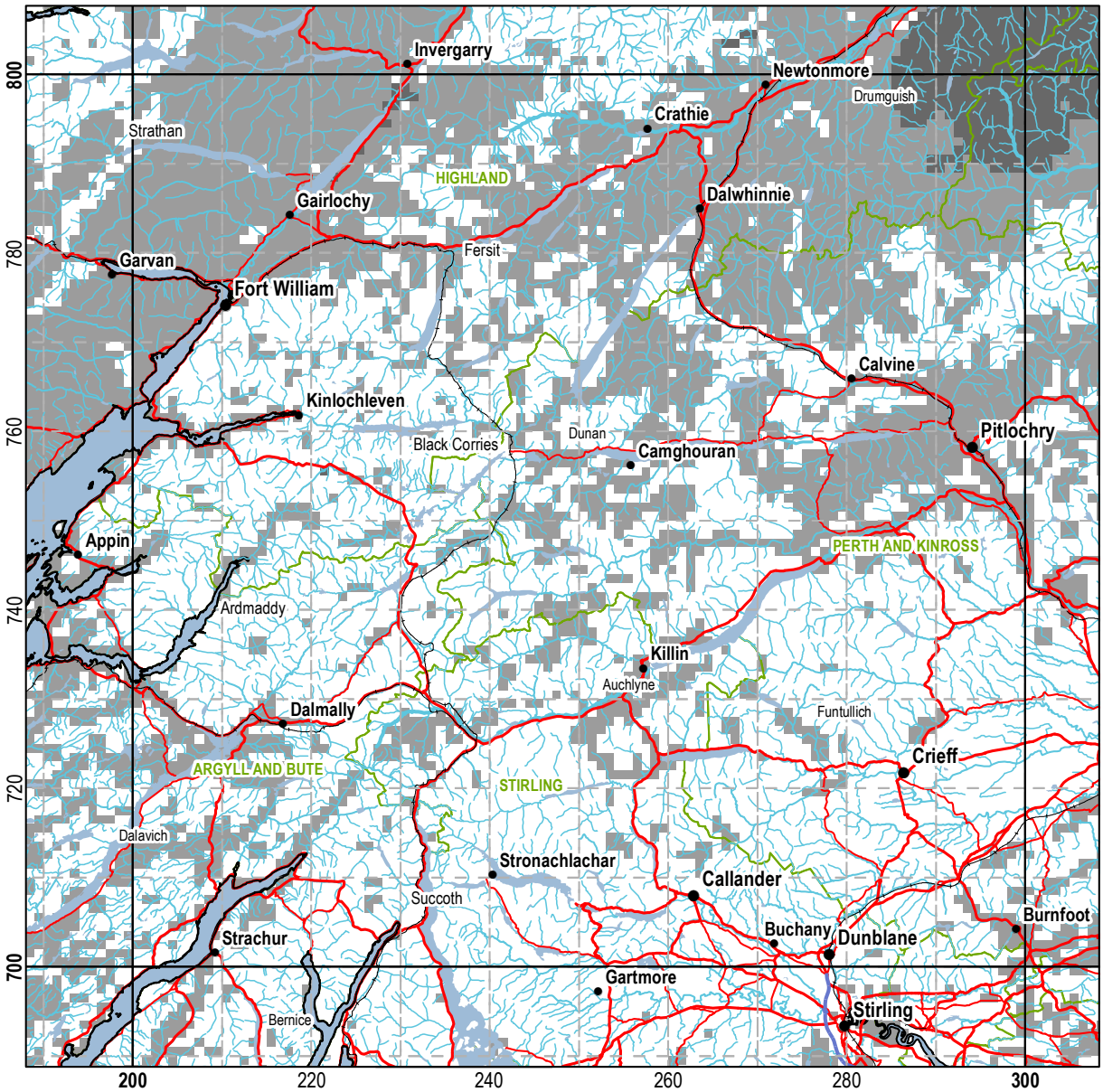

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in The Building (Scotland) Regulations 2004, Domestic and Non-Domestic Technical Handbooks - Section 3.

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Level of protection required

- None
- Basic
- Full

Settlements

- Pitlochry
- Dalmally
- Strathan
- Bernice

Transport Network

- Railway Lines
- Motorways
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 7 Central Scotland, 100-km grid square NN (axis numbers are the coordinates of the National Grid)

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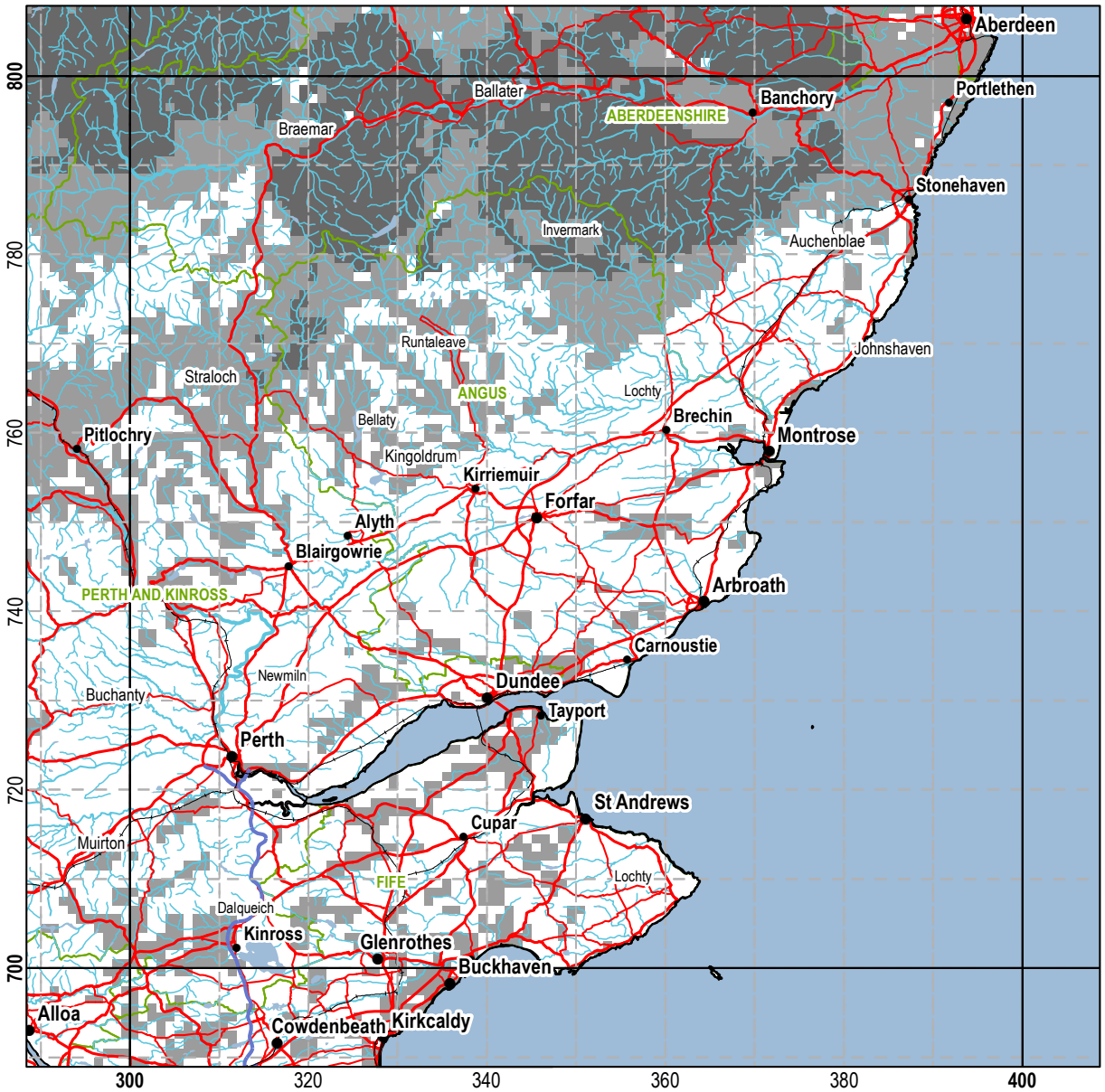

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in The Building (Scotland) Regulations 2004, Domestic and Non-Domestic Technical Handbooks - Section 3.
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Level of protection required
- None
- Basic
- Full

Settlements
- Dundee
- Brechin
- Buchanty
- Invermark

Transport Network
- Railway Lines
- Motorways
- A Roads
- B Roads

National Grid
- 100-km
- 10-km

Other features
- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 8 Tayside, Angus and southern Aberdeenshire, 100-km grid square NO (axis numbers are the coordinates of the National Grid)

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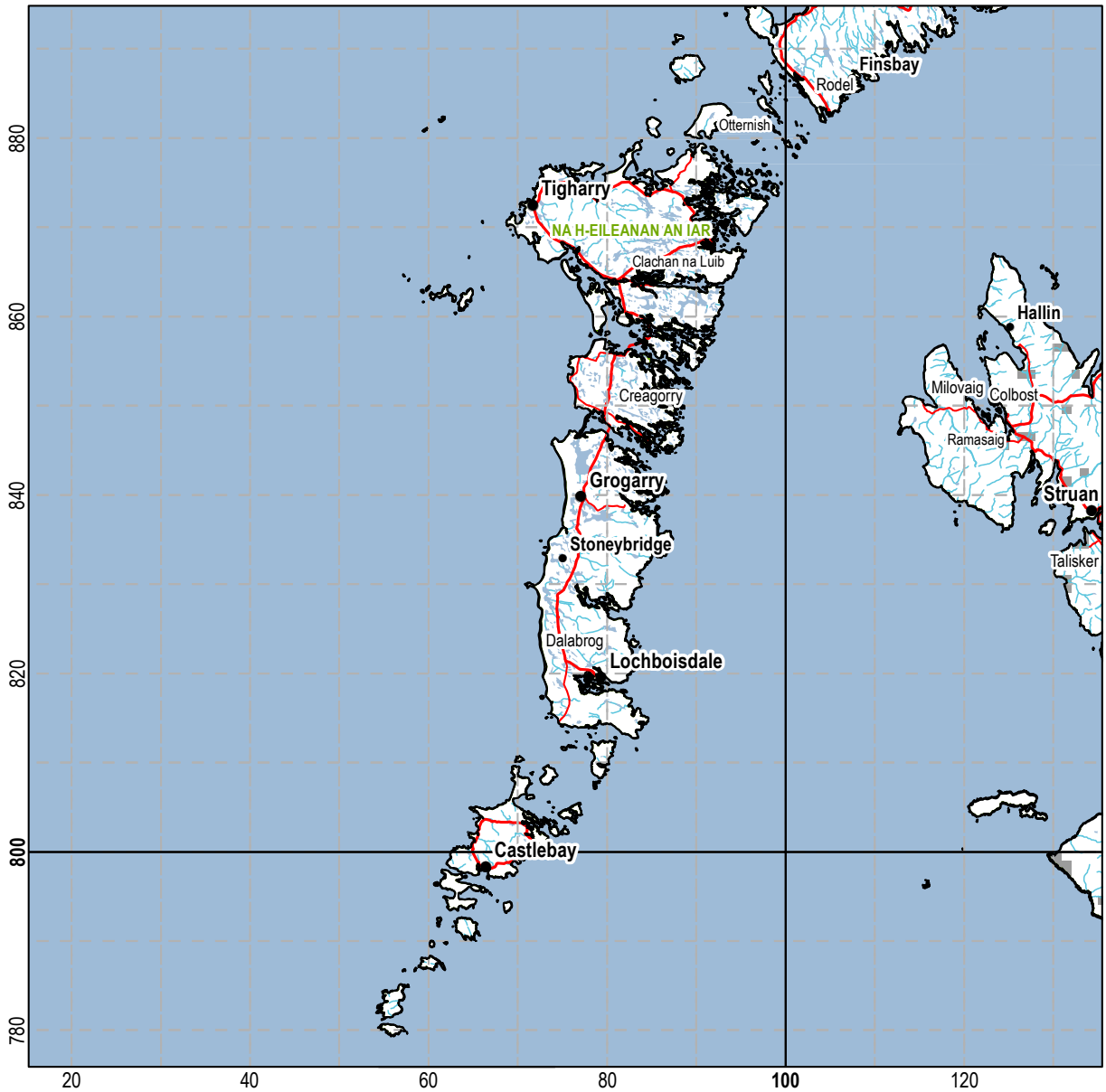

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Level of protection required
- None
- Basic
- Full

Settlements
- Tigharry
- Hallin
- Rodel
- Otternish

Transport Network
- Railway Lines
- Motorways
- A Roads
- B Roads

National Grid
- 100-km
- 10-km

Other features
- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 9 Southern Hebrides, 100-km grid squares NF and NG (axis numbers are the coordinates of the National Grid)

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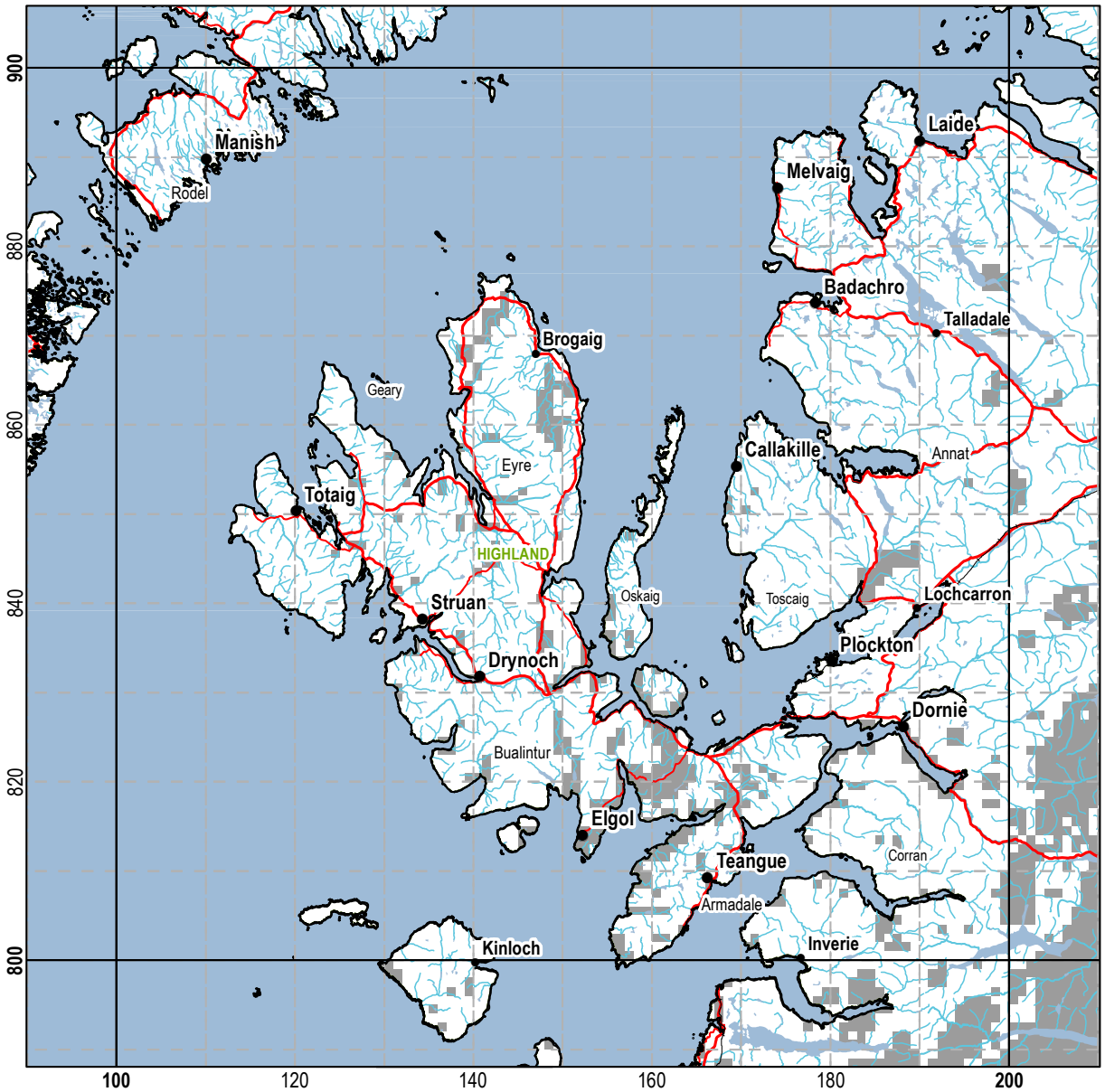

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Level of protection required
- None
- Basic
- Full

Settlements
- Dornie
- Brogaig
- Rodel
- Corran

Transport Network
- Railway Lines
- Motorways
- A Roads
- B Roads

National Grid
- 100-km
- 10-km

Other features
- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 10 Skye and the western Highlands, 100-km grid square NG (axis numbers are the coordinates of the National Grid)

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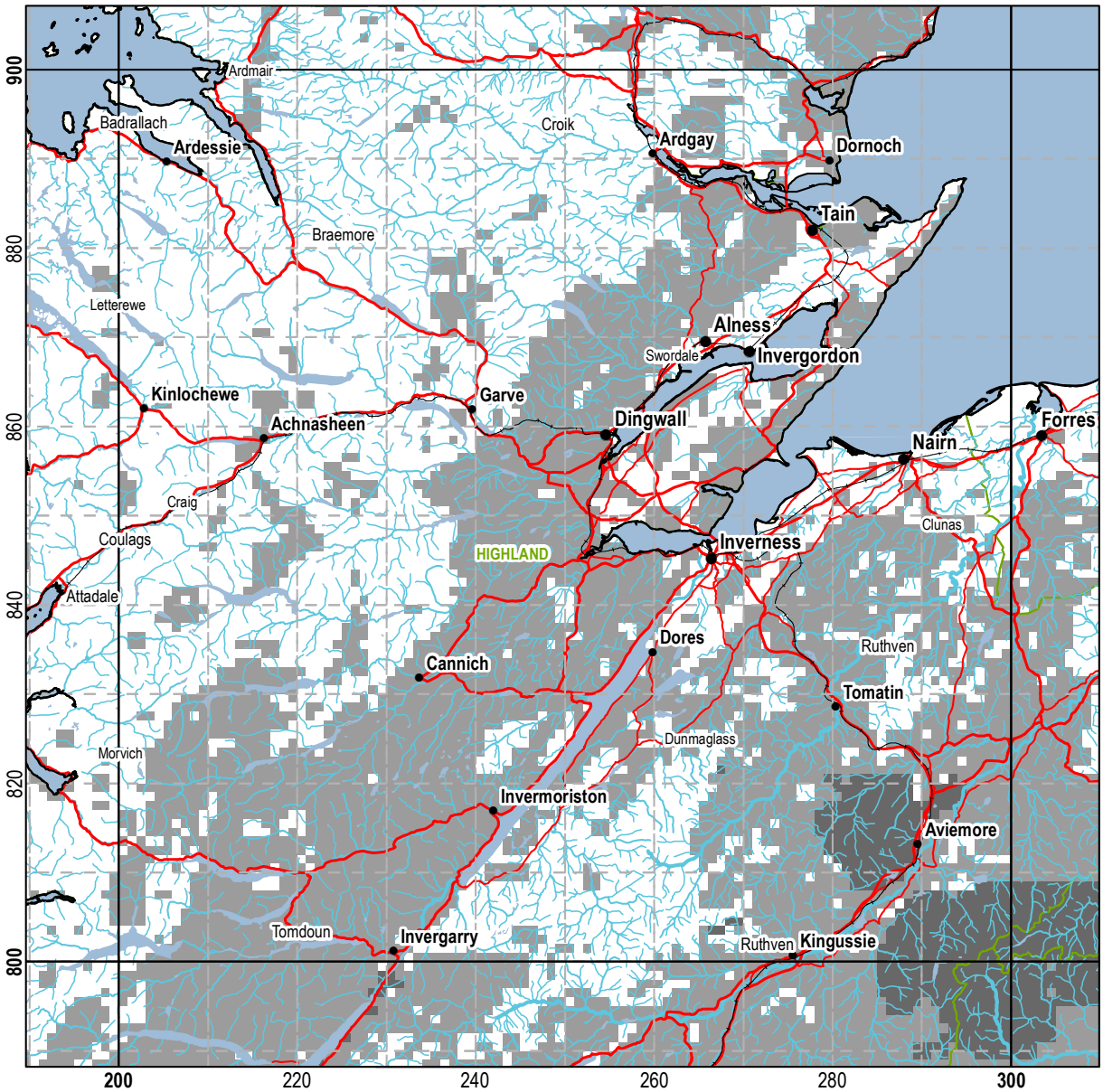

The shading indicates the maximum requirements for radon protective measures in any location within each 1-km grid square to satisfy the guidance in The Building (Scotland) Regulations 2004, Domestic and Non-Domestic Technical Handbooks - Section 3.

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Level of protection required

- None
- Basic
- Full

Settlements

- Inverness
- Invergarry
- Badrallach
- Dunmaglass

Transport Network

- Railway Lines
- Motorways
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 11 Central Highlands, 100-km grid square NH (axis numbers are the coordinates of the National Grid)

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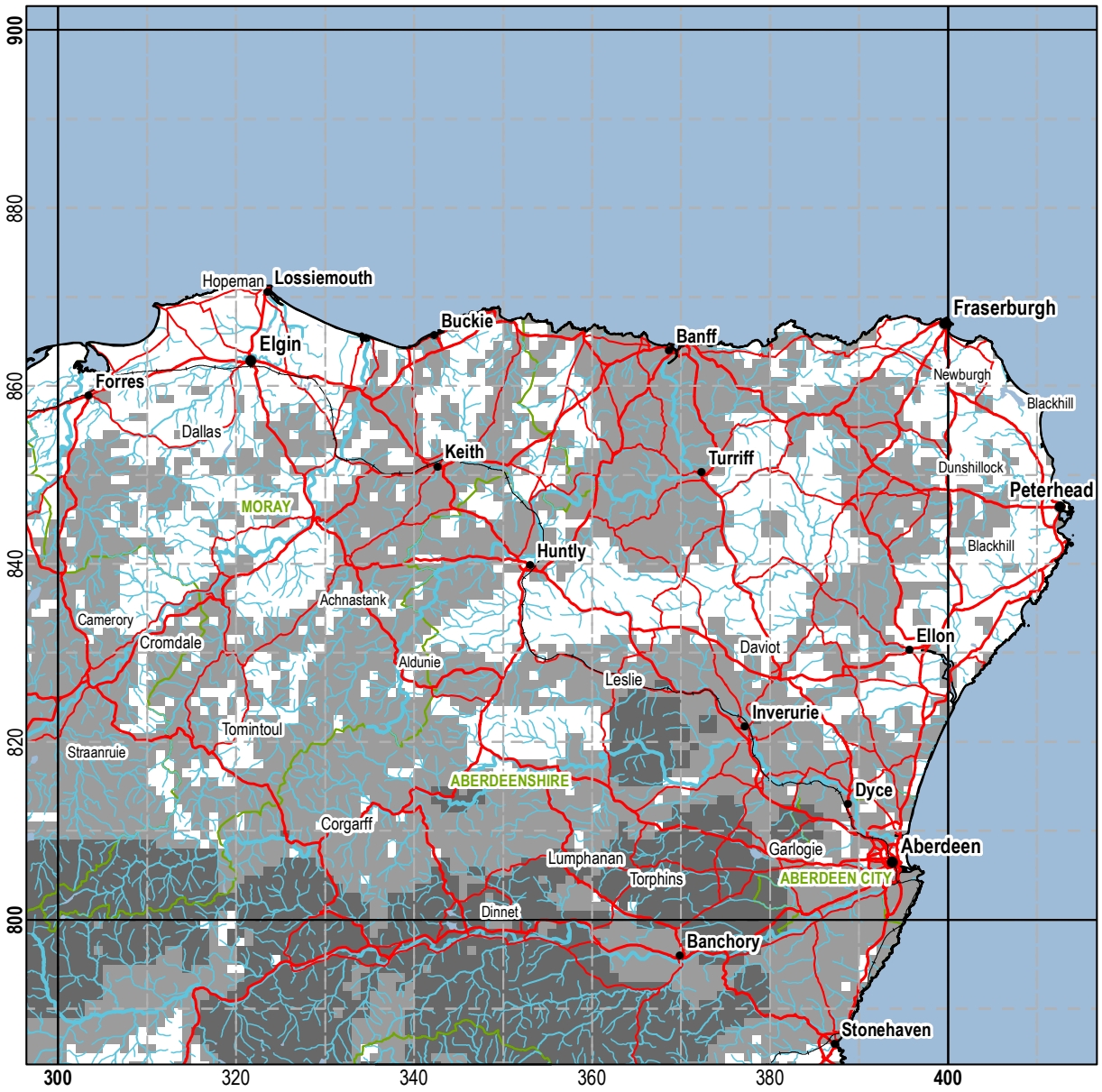

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Level of protection required

- None
- Basic
- Full

Settlements

- Aberdeen
- Buckie
- Tomintoul
- Dinnet

Transport Network

- Railway Lines
- Motorways
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 12 Moray and northern Aberdeenshire, 100-km grid square NJ (axis numbers are the coordinates of the National Grid)

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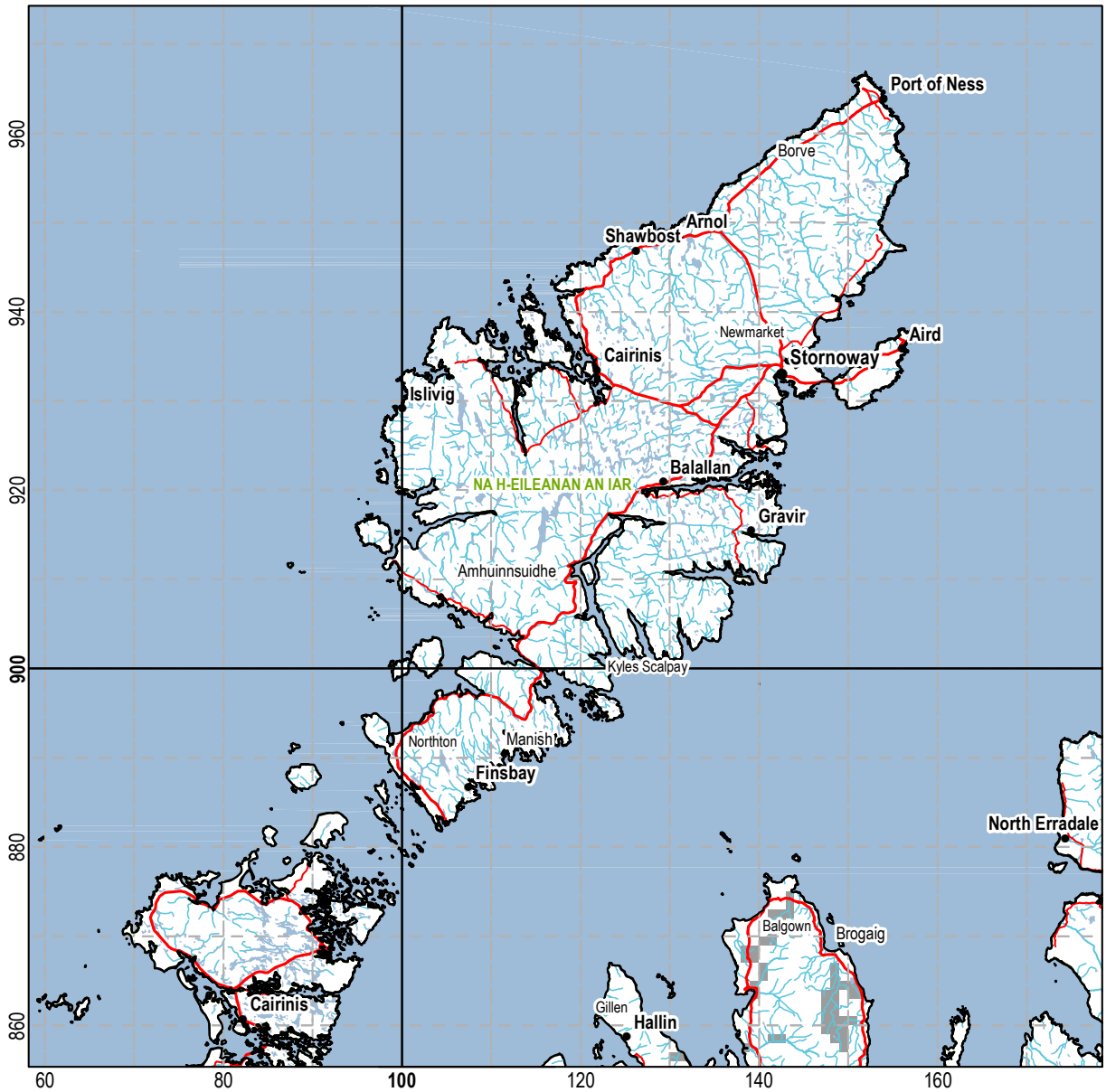

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Level of protection required
- None
- Basic
- Full

Settlements
- Stornoway
- Finsbay
- Borve
- Northton

Transport Network
- Railway Lines
- Motorways
- A Roads
- B Roads

National Grid
- 100-km
- 10-km

Other features
- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 13 Northern Hebrides, 100-km grid squares NB, NF and NG (axis numbers are the coordinates of the National Grid)

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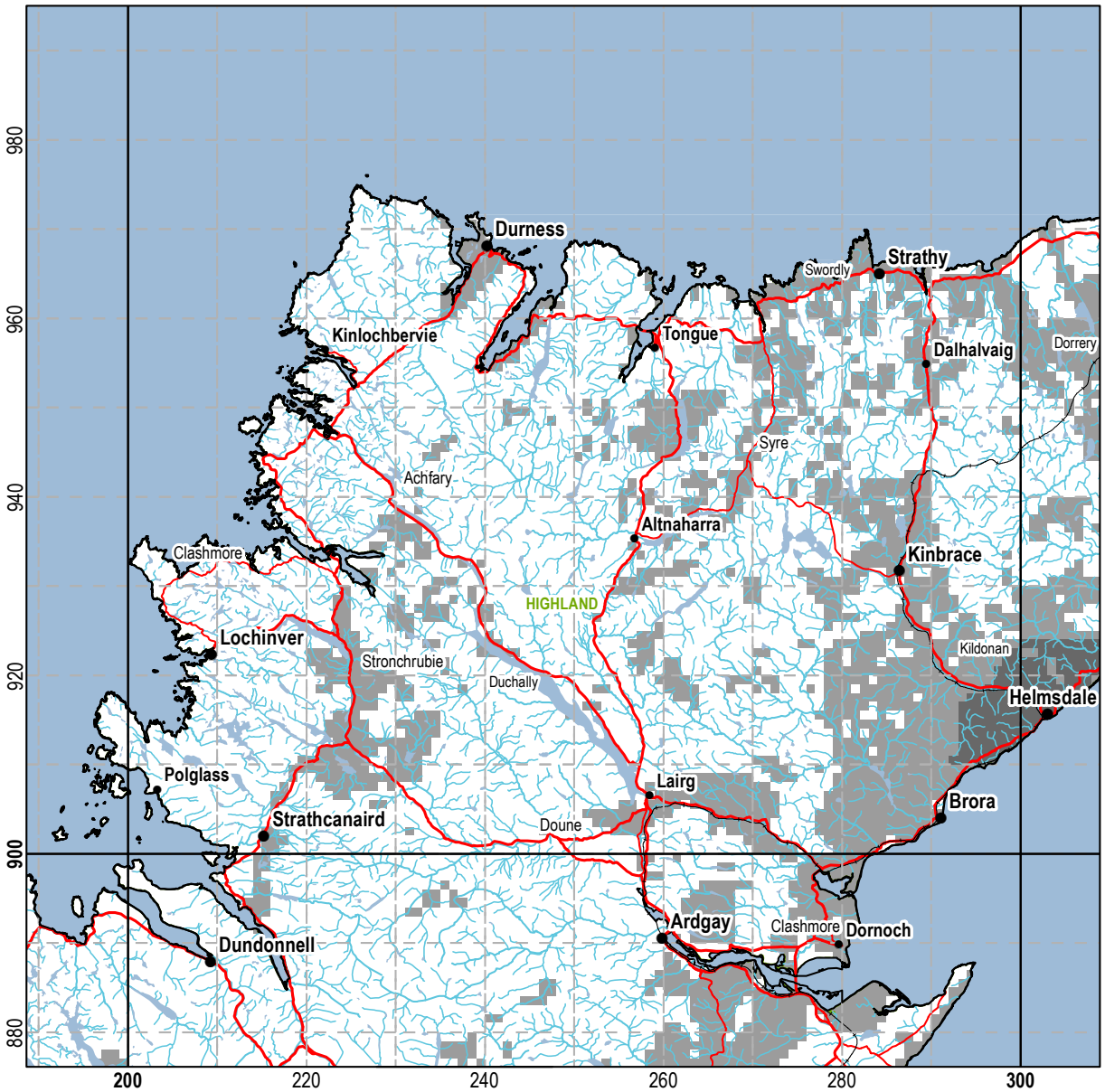

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Level of protection required
- None
- Basic
- Full

Settlements
- Brora
- Polglass
- Clashmore
- Swordly

Transport Network
- Railway Lines
- Motorways
- A Roads
- B Roads

National Grid
- 100-km
- 10-km

Other features
- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 14 North-western Scotland (Sutherland), 100-km grid squares NC and NH (axis numbers are the coordinates of the National Grid)

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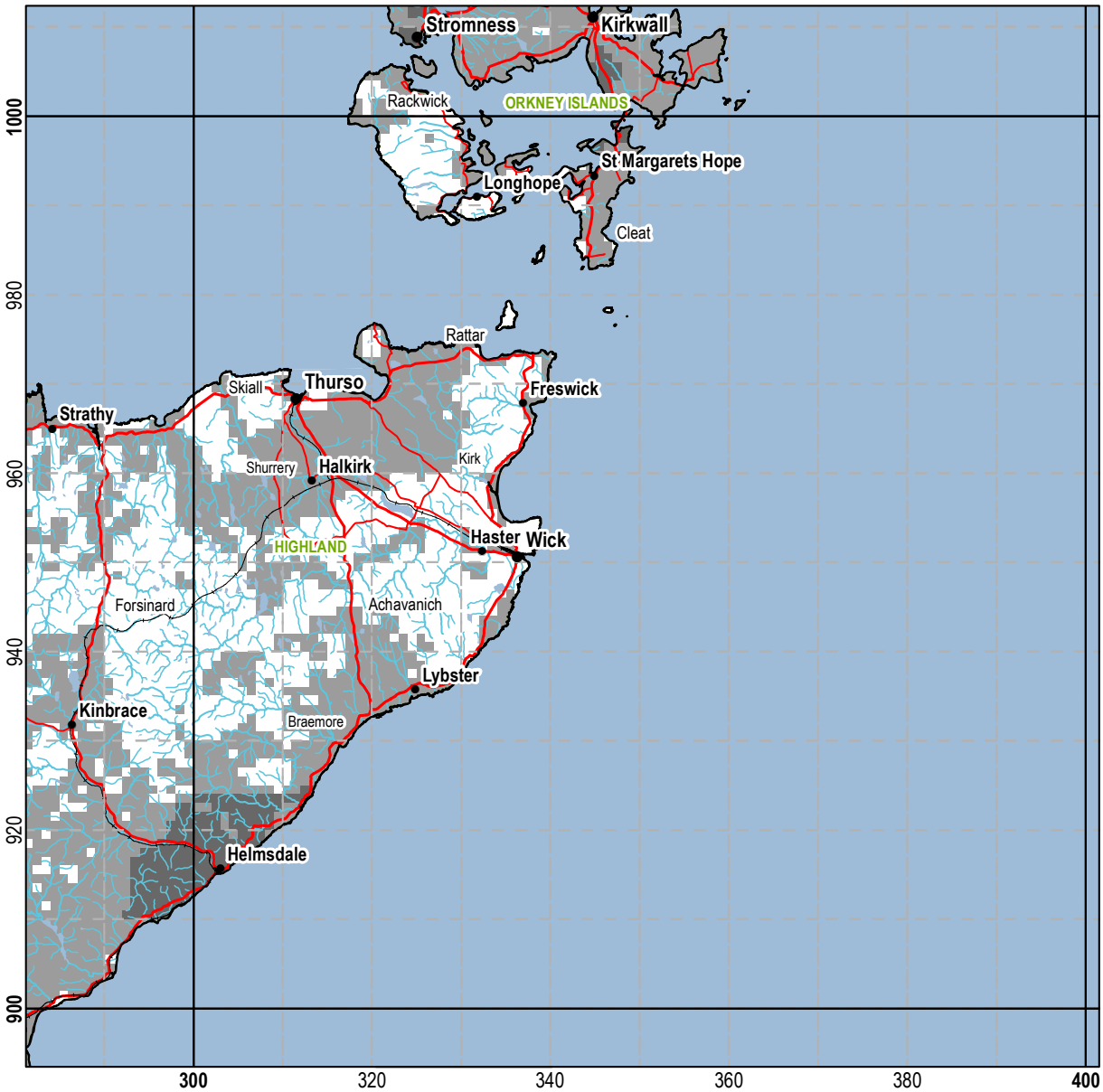

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The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required
- None
- Basic
- Full

Settlements
- Wick
- Strathy
- Cleat
- Braemore

Transport Network
- Railway Lines
- Motorways
- A Roads
- B Roads

National Grid
- 100-km
- 10-km

Other features
- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 15 North-eastern Scotland (Caithness), 100-km grid squares NC and ND (axis numbers are the coordinates of the National Grid)

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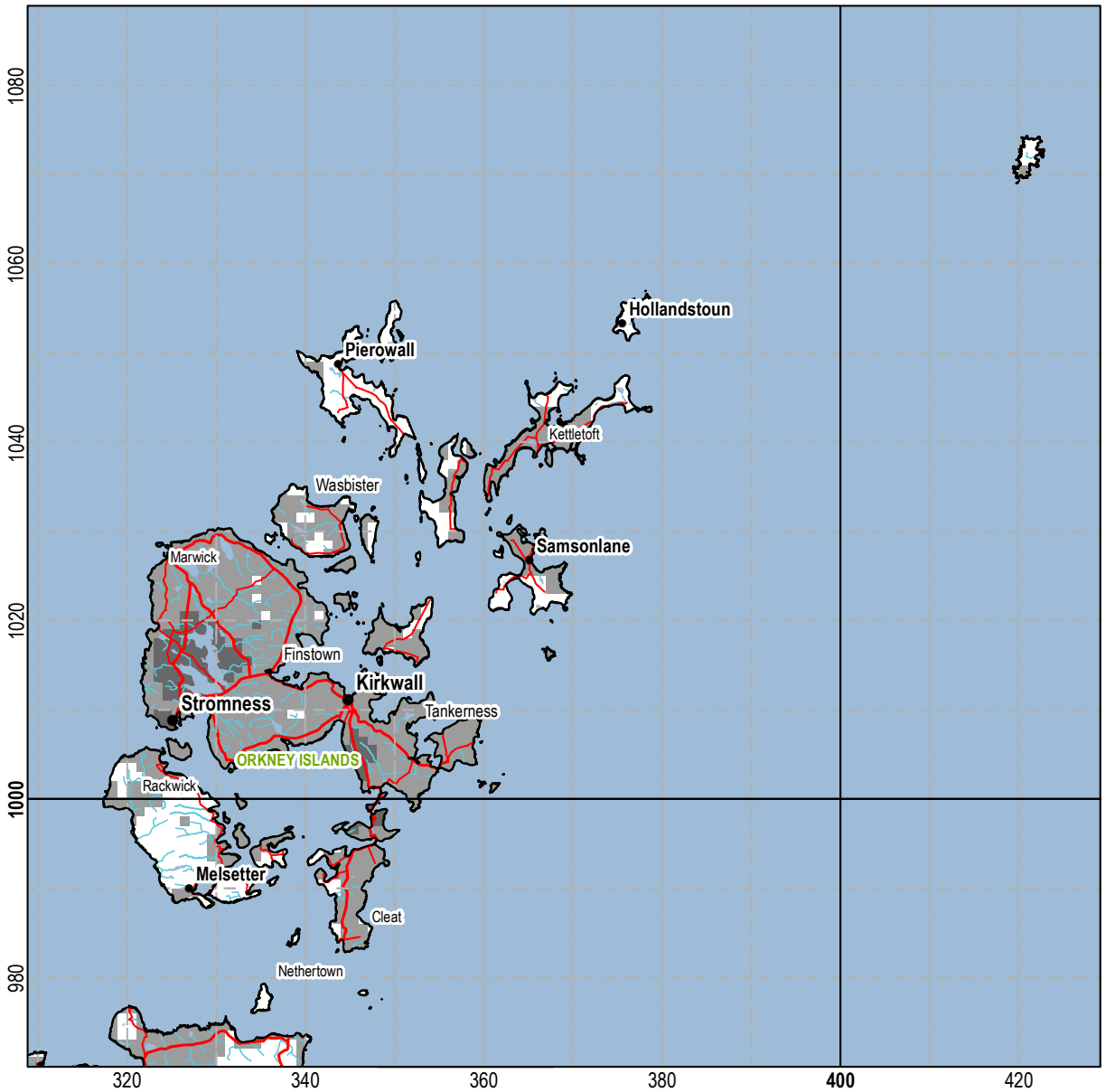

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Level of protection required
- None
- Basic
- Full

Settlements
- Kirkwall
- Hollandstoun
- Wasbister
- Kettletoft

Transport Network
- Railway Lines
- Motorways
- A Roads
- B Roads

National Grid
- 100-km
- 10-km

Other features
- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 16 Orkney Islands and Fair Isle, 100-km grid squares HY, HZ and ND (axis numbers are the coordinates of the National Grid)

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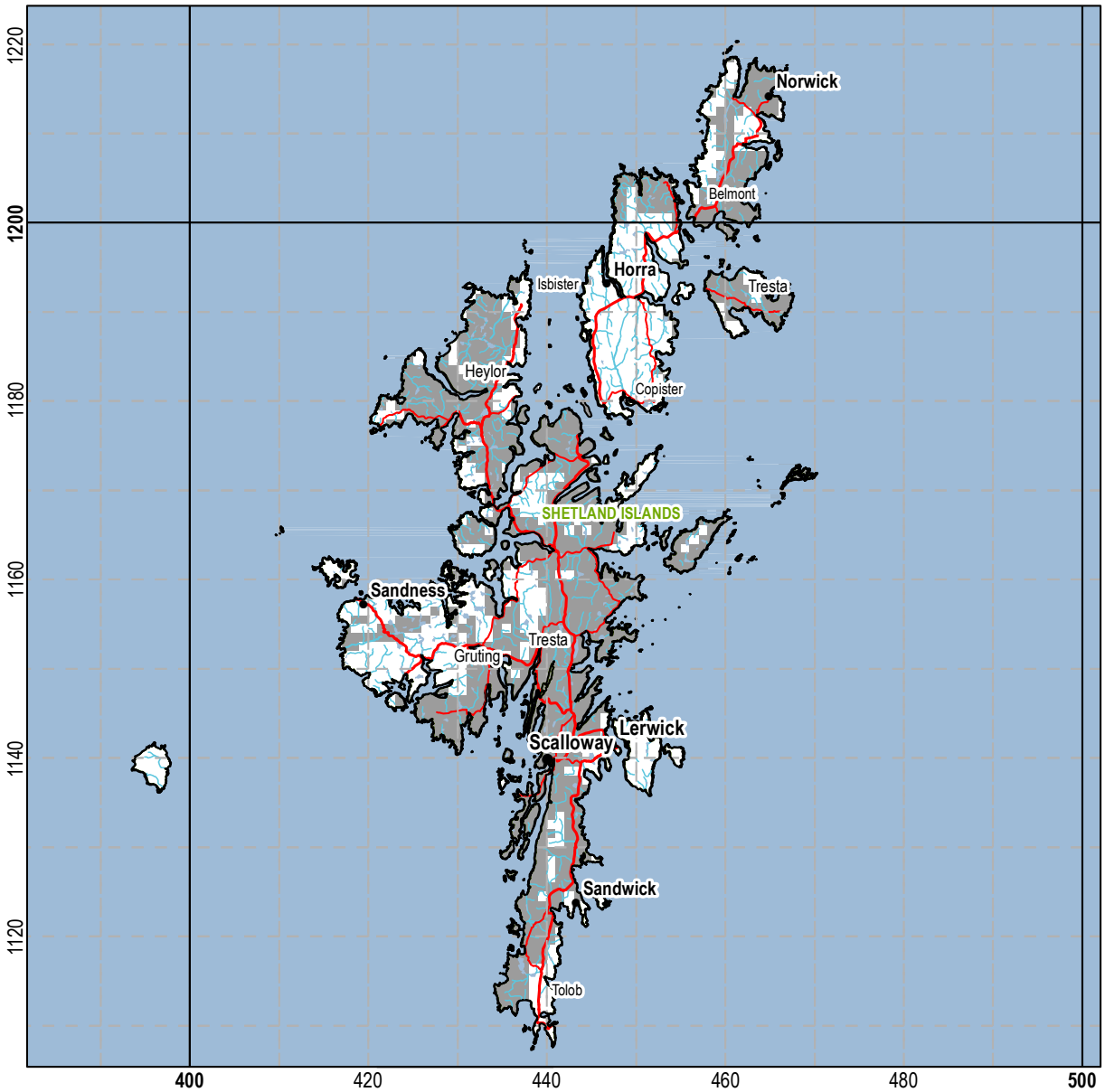

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The requirement for a site without a postal address is available through the British Geological Survey GeoReports service, http://shop.bgs.ac.uk/GeoReports/.

Level of protection required

- None
- Basic
- Full

Settlements

- Lerwick
- Norwick
- Tresta
- Copister

Transport Network

- Railway Lines
- Motorways
- A Roads
- B Roads

National Grid

- 100-km
- 10-km

Other features

- LOCAL ADMINISTRATIVE DISTRICT
- Water features

Map 17 Shetland Islands, 100-km grid squares HP, HT and HU (axis numbers are the coordinates of the National Grid)

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Appendix B

Radon-protective measures – quality management checklist



Image courtesy of Glencoe Radon Gas Centre Ltd

Construction stage	What to check	Allocate contractual responsibility	OK ✓
Design			
Radon search	Carry out a radon search to establish what level of protection is required.		
Drawings	Identify the line of construction that is to form the radon barrier. Ensure there is continuity of the barrier across the full footprint of the building. With full radon protection, identify the location of sumps and their exhaust outlets or underfloor vents (ensuring adequate numbers on at least two faces of the building to ensure a cross flow of air). Liaise with building control.		
Specification	Specify appropriate materials. Check with manufacturers and suppliers that components, materials and sealants are compatible with each other and are suitable for use as a radon barrier. Consider using accredited installers, particularly for more complex projects that require tanking.		
Buildability	Consider buildability and the order of construction necessary to achieve a continuous barrier.		
Construction			
Procurement of materials and installers	Ensure that materials purchased match the requirements set in the project specification; reduced specification is likely to result in reduced protection. Consider using accredited installers, particularly for more complex projects that require tanking.		
Order of work	Ensure that the barrier is installed at the right time so that it can be laid correctly. Joints and penetrations should be fully sealed. Allow time for inspection before the work is concealed by following works.		
Weather conditions	Avoid installation of barriers in wet, windy or cold weather. Minimise the length of time that the barrier is exposed to the weather. It is easier to lay a barrier internally just before laying a protective layer such as a floor topping.		
Barriers within floors	Ensure cavity trays are installed with an adequate step to prevent damp penetration, all joints in the tray and where it abuts the main floor barrier are sealed, and weepholes and cavities are clean. Carry out visual inspection.		
	Check that the membrane is laid on a smooth, level surface (typically blinding or insulation), all joints in the membrane and where it abuts barriers through walls are sealed, and all penetrations for services or structural members are fully sealed. Carry out visual inspection.		
Sumps	Ensure that sumps are correctly located and assembled. Check that exhaust pipework is not damaged and exits the building away from doors, windows and vents, and is suitably labelled. Carry out visual inspection.		
Underfloor ventilation	Check that sufficient underfloor vents have been installed as required, and that they are clear. Carry out visual inspection.		
Prior to covering up	Protect the completed barrier and inspect for damage, repairing as necessary immediately prior to covering up with later construction.		
Completion			
Prior to handover	Check that the exhaust outlet from the sump is labelled and the outlet and/or underfloor vents have not been covered up by landscaping works.		
Handover to purchaser	Explain the protection provided (see Section 7, 'Information to be provided to the purchaser'). For example, the location of the barrier, sump, exhaust outlet and how to add a stack or fan if required and the importance of keeping underfloor vents clear.		
Radon monitoring	PHE recommends that a new building should be subject to an appropriate test during the first year of occupation.		

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