National Soil Resources Institute (NSRI)
Natural Perils Directory™

Postcode Unit Assessments User Guide

Version 3.5

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Cover picture: A house built on clay soils is being underpinned.

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2. THE NATIONAL SOIL RESOURCES INSTITUTE, NSRI

The **National Soil Resources Institute (NSRI)** at Cranfield University is an applied research and consulting group dedicated to providing a range of soil-related environmental solutions. NSRI is the official body responsible for collecting and evaluating information about soils, their distribution, properties, behaviour, quality and use in England and Wales. The Institute has unique information, assets and expertise relating to soil science. NSRI leads Cranfield University's applied research in soil science, specifically by:

- Understanding the physical, chemical and biological processes that make up soil systems and that provide capacity for soil-based ecosystem services;
- Creating, maintaining and exploiting inventories and monitoring systems for soil resources;
- Developing digital soil mapping and pedometric methods to represent thematic soil characteristics;
- Describing processes that expose or protect soils from threats (e.g. geohazards, organic matter loss, erosion, contamination, compaction, loss of biodiversity and sealing), and developing policy and better technology for soil management and conservation in both rural and urban areas, including for sports surfaces;
- Applying engineering design and evaluation methods to improve the performance of off-road vehicles, construction equipment and agricultural machines

Led by Director Professor Guy Kirk, NSRI has the status as the leading authority on soils, recognised by the UK Government which has formally appointed NSRI as the UK National Reference Centre for Soil, part of the network of environmental centres co-ordinated by the European Environment Agency. NSRI also holds and manages national soil resource inventories for England and Wales. Our digital soil information is held in our Land Information System 'LandIS' described in detail at www.landis.org.uk. The NSRI corporate website is www.cranfield.ac.uk/sas/nsri.

3. THE NATURAL PERILS DIRECTORY, NPD

The National Soil Resources Institutes (NSRI) Natural Perils Directory™ (NPD) Geohazard thematic dataset comprises a detailed and comprehensive assessment of the environmental vulnerabilities to building structures posed by soil-related subsidence, flood extent, and wind exposure. The dataset is expressed in GIS data format on a vector polygon basis across England, Wales and Scotland (excluding the Isle of Man, Northern Ireland and the Channel Islands). This unique data is provided exclusively by NSRI and represents the most detailed available information for any kind of soil-related vulnerability assessment in the environmental sector. The subsidence peril includes a range of soil-related models together with associated climatic scenarios.

In total, over 1.7 million full Royal Mail Postcode Units (e.g. 'YO10 5DG') have been assessed, which themselves are located within some 9,195 Postcode Sectors (e.g. 'YO10 5'), 2,727 Postcode Districts (e.g. 'YO10') and 120 Postcode Areas (e.g. 'YO'). Also provided with the vulnerability assessments are details of the number and type of properties held within each unit in terms of residential, commercial and large user delivery points.

The NPD data is provided as a continuous spatial GIS dataset for England, Wales and Scotland. A vulnerability assessment for each peril is made across the full spatial data extent.

This manual represents the principal 'NPD' data product produced. This product provides a detailed assessment at each Postcode Unit ('exit level') for each of the vulnerabilities modelled (NPD-3 and NPD-4). The NPD product is offered with two technical support options relating to the degree of Technical Application Support opted for, thus:

Table 1. NPD Products

Features	NPD-3	NPD-4
Number of records by Postcode	≈1.7 million	≈1.7 million
Technical support	Yes	Yes
Technical Manual	Yes	Yes
On-Site Support	1 day	1 day
Technical Application Support	1 day	4 days

The Natural Perils Directory comprises a number of specific geohazard assessments, described below.

3.1. Subsidence

Subsidence damage is the result of ground movement at and around foundation depth. The kinds of soil effects directly associated with ground movement include:

- Clays – shrinkage and swelling of clays, known as *clay-related subsidence*;
- Sands - sandy soils susceptible to sub-surface erosion, causing *sand-related subsidence*;
- Silts - silty soils associated with heave under frosty conditions causing *silt-related subsidence*;
- Soft soils - soft (alluvial and peat) soils being compressible and susceptible to *soft soil-related subsidence*;
- Peats - peat, which shrinks considerably on drying causing *peat-related subsidence*.

Other natural mechanisms are known to cause ground movement and foundation subsidence, including mining subsidence, landslip, solifluction and the formation of swallow holes. At present, the NPD database does not attempt to model these latter causes, concentrating instead on the soil related subsidence types noted above. Of these, it is universally accepted that clay-related movement caused from shrink-swell is by far the most extensive cause of soil-related subsidence in Great Britain and together with the other soil related hazards represents approximately 70-80% of soil subsidence cases. NPD provides a detailed and informed assessment of the location of clays prone to shrinkage across GB.

3.2. Flood Extent

The inundation of properties by flood water can occur in a number of circumstances. Surface run-off can collect on low-lying land from upslope following heavy rainfall. More commonly rivers, lakes and/or the sea extend beyond their normal limits as a result of prolonged or intense rainfall, unusually high tides and/or extreme wind events. Water damage to properties and their contents is often compounded by the deposition of sediment transported in suspension in the flood waters. The spatial distribution of such waterborne sediment (or alluvium as defined in soil science) is one basis upon which land that has been subject to historical flooding can be mapped, and this forms a basis for the present-day flooding extent vulnerability assessment in NPD. The flood extent assessments are not based on direct topographical data, but are derived from the soil map classifications for alluvial soil extents.

Riverine, lacustrine (lake) and marine alluvial soils are identified distinctly within the British soil classification. Combining soil mapping units that are dominated by soil series developed in alluvium across Great Britain is used in NPD to identify most of the land that has been subject to flooding in the past and where there has been standing water which has deposited alluvium. These are the areas that NPD highlights as being considered potentially vulnerable to flooding in the present, especially so in circumstances where existing flood defence measures fail.

3.3. Wind Exposure

Wind exposure vulnerability is based upon several inter-related factors including prolonged wind speed, gustiness, wind direction and air temperature. NPD contains a summary wind exposure assessment made available for the whole of England, Wales and Scotland.

Wind speeds are measured by anemometers at a standard height of 10m above the ground surface in an attempt to record uninterrupted air flow. However, the assessment of exposure is often affected by local circumstances. The instruments are sometimes subject to the effect of locally increased or decreased wind speeds caused by neighbouring buildings, structures or uneven topography. Also, landforms can generate local air circulation through differential heating of land of varying slope and aspect. The NPD wind exposure dataset, compiled at the time the national soil map was created, is based on meteorological information as well as observations made of prolonged exposure to wind on vegetation.

4. NPD PRODUCT DATA FORMAT

Supplied on CD-ROM, the NPD dataset provides a Natural Perils vulnerability assessment for each Postcode Unit (‘exit’ level) for each of the geohazards modelled. The filename incorporates the Geoplan Postcode Revision numbers. Hence, ‘R46_NPD' relates to the R46 Postcode release. The dataset, having approximately 1.7 million rows, is provided in ‘CSV’ comma-separated values ASCII text format, as well as GIS format (both in ESRI Geodatabase and MapInfo MID/MIF file formats); other digital formats can be made available on request. The fields (columns) contained within the data file are as follows:

Table 2. Detailed NPD File Layout

Column	Description	Column Name	Example
1	Commercial Postcode	GEO_UNIT	AB368XL
2	Geoplan Subsector	COM_UNIT	AB36 8XL
3	Commercial Subsector	GEO_SUB	AB368X
4	Geoplan Sector	COM_SUB	AB36 8X
5	Commercial Sector	GEO_SECT	AB368
6	Geoplan District	COM_SECT	AB36 8
7	Commercial District	GEO_DIST	AB36
8	Postal Area	COM_DIST	AB36
9	Commercial Postcode	POSTAREA	AB
10	National Grid Easting	X_COORD	339400
11	National Grid Northing	Y_COORD	809799
12	User Category	USER_	NR
13	Residential Delivery Pts	DELR	14
14	Non Residential Del Pts	DELN	2
15	Large User Delivery Pts	DELL	0
16	Total Delivery Pts	DELALL	16
17	Ward Code	WARD	QBMQ
18	NHS Code	NHS	SN9
19	Postal Town	POSTTOWN	STRATHDON
20	Clay risk – Standard model	CL_STD	8
21	Clay risk – 1 year in 3	CL_3	8
22	Clay risk – 1 year in 6	CL_6	8
23	Clay risk - 1 year in 15	CL_15	8
24	Clay risk - 1 year in 45	CL_45	8
25	Clay risk - 1 year in 150	CL_150	8
26	Sand risk	SAND	2
27	Silt risk	SILT	1
28	Soft soil risk	SOFT	1
29	Peat risk	PEAT	1
30	Flood	FLOOD	1
31	Wind Exposure	WIND	2

Note that non-GB postcode Units, including BT, GY, IM and JE - Northern Ireland, Guernsey, Isle of Man, Jersey – are not assessed by the model.

5. SCIENTIFIC PRINCIPLES

5.1. Clay shrink/swell

Among the inorganic mineral particles that constitute the solid component of any soil, clay particles are the smallest and are defined as being <0.002 mm - equivalent spherical diameter (esd) in size. Clay particles occur in most kinds of soil but they only begin to exert a predominant influence on the behaviour of the whole soil where there is more than 35 per cent (by weight) of clay-sized material present. There are many different types of clay, for instance *kaolinite*, *montmorillonite* and the *hydrous micas*. Some clays are more prone that others to shrinkage and swelling. Clay soils are extensive. In England and Wales they comprise nearly 20% of the stock of soils – but clay particles also occur widely in other soil 'textures' such as clay loams and sandy clays.

Because clay particles are very small and commonly platy in shape they have an immense surface area onto which water can be attracted relative to the total volume of the soil material. For instance Calcium-saturated *montmorillonite* crystals have a surface area of some 100-150m^2/g^{-1}, whereas in a completely dispersed state, *montmorillonite* crystals have a surface area of some 750m^2/g^{-1}. This highlights the enormous surface area of clay particles as well as the effects of the stacking of the crystals. In addition to surface attraction or inter-crystalline absorption of water, some clay minerals, those with three layers of atoms (most other kinds of clay have only two layers of atoms) are able to absorb and hold additional water between these layers. It is these types of clay mineral, which are widespread in British soils and commonly known as *smectites* that have the greatest capacity to shrink and swell.

In a natural undisturbed condition, the moisture content of deep subsoil clay does not change greatly through the year and consequently there are no substantive changes in volume leading to shrinkage and swelling. However, when clays are exposed at or near the ground surface and especially when vegetation (e.g. trees and shrubs) is rooting in them seasonal moisture and volume changes can be dramatic. Plants and trees 'transpire' moisture from the soil to support their growth and to transfer necessary nutrients into their structures. Surface evaporation also takes place from soil and plant structures, and the combination of evaporation from surfaces and transpiration by plants and trees is termed *evapotranspiration*. Thus, the layer of soil material down to 1.5 to 2m depth into which plants will root is critical when assessing the vulnerability of land to subsidence.

Whenever soil moisture is continuously being replenished by rainfall, the soil moisture reserves will be unaffected by the removal of moisture by plants as there is no net loss. However, in many parts of Britain, particularly in the south and east, summer rainfall is small and is exceeded by evapotranspiration. Water reserves are then not sufficiently replenished by rainfall and so a soil moisture deficit develops.

Typically Soil Moisture Deficits build up from about April through to October. The water removed from a clayey soil by evapotranspiration leads to a reduction in soil volume and the consequent shrinkage causes stress in the soil materials leading in turn to stress on building foundations that are resting in the soil. The foundations themselves may then move and thus cause damage to building structures. This problem can be exacerbated by the fact that the soil beneath the structure may not dry out uniformly, so that any lateral pressure exerted on the building foundation is made effectively greater.

5.2. Sandy soils and erosion

Sandy soils contain more than 70 per cent (by weight) sand-sized particles (0.06 to 2.0mm *esd*[1]). They are generally non-compressible as there is very little reduction in volume when such soils are put under load. There is also minimal risk of shrinkage when moisture is abstracted form sandy soils.

However, leaking water pipes buried in sandy material and left unattended can begin to wash away unconsolidated sands leading locally to severe erosion below ground and the formation of cavities, posing a danger to nearby building structures. The age of the property becomes significant in this respect, since there is a greater risk of older pipes bursting and shallow foundations at about pipe depth are most susceptible. The NPD datasets identify the locations of soils most prone to this form of subsidence.

5.3. Silty soils and frost heave

Silty soil materials contain more than 65% (by weight) silt-sized particles (0.002 - 0.06mm *esd*) and generally less than 20% sand-sized particles. Although the most widespread cause of subsidence is the shrinkage and swelling of clays, the heave associated with silty soils under frosty conditions can represent a significant risk to building structures – particularly to those having shallow foundations such as patios, sheds and outhouses and roads and paths made of tarmacadam. When water freezes to ice, due to a realignment of its molecules, the volume increases by approximately 9% and this is enough over time to cause pronounced heave damage effects.

Silty subsoils are often platy in structure and, when moist, water is held on the surfaces of these plates (< 2 mm thick). Subsequent freezing of this water causes it to expand, particularly in the vertical dimension, leading to heave.

[1] 'esd' – Estimated spherical diameter of the particle

5.4. Soft soils and compressibility

Soft soil materials are formed as a result of specific depositional processes. They are produced from the settling out of suspended mineral and organo-mineral materials from fresh or saline waters under the influence of gravity. A range of particle sizes can be involved, fine textured materials are laid down in still water conditions, coarser materials result from fast flowing streams and rivers. The most recent of these deposits, - sand-, silt-, and clay-sized material, laid down in rivers, and seas as riverine and marine alluvium, have remained soft and unconsolidated by geological processes since their deposition (recent in geological time). The same processes occur with the infilling of lakes leading to the formation of very soft fine-textured sediments, called lacustrine deposits.

The other major process leading to the formation of soft soil materials is the deposition of organic matter and peat formation, through the accumulation and partial preservation of plant material under flooded (anaerobic) conditions. These materials have very low bulk densities ($<1.0 g/cm^3$) and are very easily compressed when subjected to loads. Structures and foundations placed in such soft soils may be prone to effects of settlement and displacement over time and thus subsidence.

5.5. Peats and shrinkage

The build up of organic matter under anaerobic conditions and the development of peat leads to another type of soft soil material. Peat is formed where there are insufficient soil organisms to decompose plant residues and incorporate them into the soil. It can be broadly divided into upland and lowland forms. Upland or blanket peat forms in cold wet climates where anaerobic, extremely acid conditions develop. Acid tolerant oligotrophic plant communities dominated by *Sphagnum* moss, cotton-grass (*Eriophorum* spp.) and other grasses and sedges predominate and their residues are very slow to decompose. It has developed throughout upland Great Britain, particularly on the Pennines and in Scotland, at elevations in excess of 300 m where high rainfall, low evapotranspiration, impermeable substrata and level ground results in almost permanent waterlogging.

Lowland peat such as that in East Anglia and the Wash, consisting of fen, fen-carr and raised bog peat, forms in basins with a high ground-water table under warmer less acid conditions than in the uplands. Fen peat forms mainly from reeds (*Phagmites Communis*) and sedges (*Carex* spp) in a nutrient-rich environment. It is yellowish brown or brown, with fibrous or semi-fibrous leaf remains amongst its roots. Fen and fen-carr peats occur in basins and hollows of glaciated landscapes when post glacial thawing caused freshwater flooding. Raised bog peat forms a convex surface, the uppermost layers having developed solely under the influence of rainfall. It is acid and composed of the remains of *Sphagnum* moss with cotton-grass, *Molinia caerulea* and *Calluna vulgaris*.

Peats will shrink considerably as they dry out and, therefore, buildings located on such materials are vulnerable to subsidence. Peat is also soft and very compressible and consequently there is an increased risk of subsidence. Many lowland peats in England (especially the Fens, the south west Lancashire coastal plain, the Somerset levels and the meres and mires of the Welsh Marches) have been drained for agriculture and continue to suffer considerable shrinkage. However, upland peats generally present little risk to buildings as the climate discourages significant drying and does not attract human settlement. Peat at low elevations in Scotland often has the same characteristics as upland peat in that conditions are wet (rainfall >1500mm *per annum*) and the areas are subject to colder climates than is typical of lowland deposits in England.

5.6. Flood Extent Vulnerability on Alluvial soils

Alluvial soils are developed in recent *alluvium* deposited by flood water. The development of these deposits started following the retreat of the ice sheets around 10,000 years ago and continues today. It is likely that all alluvial soils will flood at some time in the future unless suitable preventative measures have been installed (flood protection banks, pumping schemes etc). The regularity and depth of flood waters will depend on local circumstances in the catchment. Alluvial deposits can be divided into three categories:

- Marine;
- Riverine;
- Lacustrine.

Marine alluvium is laid down by sea water in low-lying coastal areas. Much of this land has been reclaimed from the sea by enclosure within a sea wall and the provision of an arterial drainage scheme. The Fens and the lower Trent/Humber valley and parts of Lancashire and Somerset are the largest areas. Most of this land is at, below or close to Ordnance datum (0m O.D.), and human occupation commonly relies on pump drainage whereby water in the field ditches is pumped up into main dykes from whence it drains to the sea during low tide. Tidal sluices prevent re-entry of the water back into the dykes.

Maintenance of the protecting sea defences is a major expense and is subject to cost-benefit analyses of the levels of service, i.e. flood protection by Government. When marine alluvium floods it is usually the result of a high spring tide, with the moon in perigee, combined with a severe weather system with strong on-shore winds. These surge combinations can lead to breaches of the sea defences.

Riverine alluvium is material laid down by flowing fresh water. The full size range of particles is found in such deposits; sands, silts, loams and clays. Fast-flowing streams deposit coarse materials while particles such as silt and clay are deposited by slow flowing water. Hence, sands and coarse silts are deposited in the upper regions of river catchments or at the margins of main channels, and silts and clays are deposited in the broad floodplains of the slow flowing, often meandering, rivers. This effect is termed 'grading' and can be seen also for instance clearly on a shoreline where pebble sizes can vary along a strand.

Floodplains vary greatly in width but in the lower reaches of large rivers, such as the Severn, Trent and Thames, can be more than a kilometre wide. Without flood protection embankments, flooding might occur many times in an average year. Even where protection measures are in place flooding still occasionally occurs and is either the result of overtopping of the main embankments or from flood waters backing up small tributary streams and overtopping their defences.

Lacustrine alluvium is laid down at the margin of lakes where streams and their suspended sediment enters the lake water. Eventually successive infilling might produce dry land above the lake water level. Distinctive soils then develop on this lacustrine alluvium. These deposits are not extensive nationally, but there is a risk of flooding after periods of heavy rain following a general rise in the regional ground water table.

When Peat soils are drained there can be substantial reduction in soil volume and thus associated shrinkage, as anyone familiar with the famous 'Holme Fen' iron post on the edge of what was once Whittlesey Mere, Cambridgeshire, will know – where a post sunk to its tip in Victorian times is now exposed some metres from the ground level due to fen drainage. Properties built on peat and peaty soils may suffer to a lesser degree the same fate where drainage can lead to foundation movement.

5.7. Wind exposure

Average annual wind speeds were calculated using records from meteorological stations across England, Wales and Scotland. A method for assessing exposure over large areas was devised in Scotland using the heights and shapes of trees and dwarf shrubs. This assessment methodology was used in England and Wales to survey and record the visible effects of wind exposure on vegetation. The assessment of the levels of exposure, therefore, was consistent between England, Wales and Scotland but the assessment is subjective since different plants respond differently to the same conditions. Climatic variations and the effect of soil and land management influences had also to be evaluated.

The distribution of the *very exposed* and *exposed* classes on the west and south-west coasts reflects the prevailing westerly and south westerly air stream over the British Isles. On the east coast of England however, the prevailing westerlies are replaced by sea breezes which penetrate 5-8 km inland for up to 4 hours a day, and by occasional strong easterly winds.

The altitudes at which *moderately exposed* and *exposed* classes occur tend to increase with distance from the sea. The assessment methodology is insufficiently precise to identify relatively small sheltered valleys or small exposed hill slopes.

6. DATASETS UNDERPINNING THE DIRECTORY

6.1. Postcode Geography: Background to PAF/Geoplan

The Postcode data used within the system is provided by GEOPLAN (UK) Limited. This data has been derived from the Royal Mail's Postcode Address File (PAF) which simply provides a National Grid reference (to 100m resolution) for the first postal address in each Postal Unit. This level of resolution can lead to a 'stacking' effect with one or more Postcode Units being assigned the same reference. GEOPLAN have attempted to overcome this problem by processing the data using a series of tessellation techniques to provide each Unit Centroid with a unique National Grid Reference. The Geoplan datasets include a range of geodemographic data related to the Postcode. These data are retained in the NPD product as a useful reference.

6.2. Soil Data

Staff from the National Soil Resources Institute (NSRI), incorporating the former Soil Survey and Land Research Centre (SSLRC) and its forebears, have been collecting information on soils for some 80 years in England and Wales. NSRI has developed a comprehensive soil classification system, and have mapped the distribution of soil types, collected thousands of soil samples and subjected them to a range of physical and chemical analysis. There are 953 individual *soil series* (or soil types) identified in Great Britain and represented on soil maps. Each of these soil series belong to one of ten Major Soil Groups. A brief description of the characteristics of each of these Groups is provided in Appendix A. Any area of land shown on a soil map in Great Britain can be classified according to the major soil group of its *dominant* soil series. This wealth of information is incorporated exclusively into the Natural Perils Directory. NSRI can offer training services to assist in the understanding and interpretation of these datasets.

6.3. Shrink/swell potential

Cracking caused by drying and subsequent shrinkage is a common feature in summer months particularly in soils with high clay content. The exact amount of shrinking and cracking depends upon clay content and type, density and previous weather conditions. The potential of a soil to shrink-swell has been determined from direct laboratory measurements on a large number of samples taken in the UK. Cracking usually reflects the inherent structural development of a soil (routinely described and measured by NSRI) and this together with an understanding of the mineralogy of clay soil, allows each soil series identified in Great Britain to be classified according to its potential to shrink and swell (SSWELL) when moisture is either extracted or absorbed.

SSWELL is normally assessed at a depth of 1 metre. Five classes of shrink-swell potential are recognised and all UK soils are allocated to one of these classes on the basis of the extensive laboratory measurement of volumetric shrinkage. This is defined as the change in volume between field capacity [winter wetness state equating with 0.05 bar (5kPa) suction], and permanent wilting point [very dry summer conditions equating with 15 bar (1500 kPa) suction], and is expressed as a percentage of the volume at field capacity. Shrink-swell classes range from *very low* (<3% volumetric shrinkage) and *low*, through *moderate*, to *high* and *very high* (>15% volumetric shrinkage). These soil measurements of shrink-swell constitute a unique and comprehensive dataset of shrinkage potential that has ever been assembled for the study of subsidence in the UK and the methods are reported in the scientific literature.

6.4. Climatic data: Potential Soil Moisture Deficit (PSMD)

In predicting soil subsidence vulnerability, it is important to understand the cycle of wetting and drying in soil profiles at different locations in the country. Using rainfall and evaporation data, the cycle of wetting and drying can be expressed in terms of the overall Potential Soil Moisture Deficit - PSMD:

Potential Soil Moisture Deficit: $PSMD = \Sigma(r-pt)$ (mm)

Where 'r' is rainfall and 'pt' is evapotranspiration.

PSMD is accumulated over a season and at any time represents the excess of evapotranspiration (pt) over rainfall. PSMD is a positive number and is expressed in *mm* rainfall equivalent; the greater the value the larger the deficit. It is conventional to use a short green crop such as a grass sward when calculating PSMD. However, this can be a conservative estimate as where large trees with deep roots occur, the mean maximum PSMD can be significantly greater than under grass. Average values of maximum PSMD have been derived from 30 years of weather data collected at more than 1,000 field meteorological stations representing the full range of conditions in England, Wales and Scotland. The average maximum value of PSMD, irrespective of the month in which it occurs, is used for modelling purposes. The resultant PSMD data surface is expressed on a grid, with a spatial resolution of 1km x 1km.

In the driest parts of south-east England, where the annual average rainfall totals about 500mm, the mean maximum PSMD is in excess of 225mm. In central England, mean maximum PSMD values of 125mm to 175mm are common, with values declining to less than 50mm in the uplands of western Britain where annual average rainfall totals exceed 1,200mm.

Trees and large shrubs can exert a profound effect on localised moisture deficits and, when proximal to a structure, often present a key factor in causing or exacerbating subsidence. However, the average maximum PSMD, as calculated for a 'short grass sward' may be considered a good benchmark for estimating the climate pressure to dry out the soil.

7. NATURAL PERILS DIRECTORY INTERPRETATIVE DATA KEYS

The NPD data provided has categorical numerical codes assigned for each assessment. This section explains how to interpret these codes. Appendix B provides example mapping for each of these geohazard assessments across Great Britain.

7.1. Clay-related subsidence

Identifying the type of soil present at a site provides an indication of the potential for shrink-swell or heave. However, climatic data are needed to identify the risk of that potential being realised. In predicting the subsidence vulnerability, knowledge of the cycle of wetting and drying in the particular soil at a given location is used. The Underground Foundation Stability (UFS) model within the system combines PSMD and shrink-swell data and incorporates expert knowledge of soil behaviour to derive 9 vulnerability classes. These classes range from Extremely Low (EL) with Very Low shrink-swell potential and a PSMD of <100mm to Extremely High (EH) with Very High shrink-swell potential and a PSMD of >200mm.

Soils have a capacity to store water in their pores and fissures that is available for plant growth and this is called the available water capacity (AWC). The available water in a soil profile is calculated by integrating the capacity of each soil horizon down to 1 metre in depth. Typically, a metre depth of soil will have a profile AWC of between 125mm and 175mm rainfall equivalent. Peat soils can store in excess of 250mm in the top metre whereas shallow soils (rock at <80cm depth) can have profile AWC's of <100mm. Hence, an average maximum PSMD of greater than 150mm will cause many soils to dry out to depths of at least one metre in an average year assuming deep rooted plants have been growing in them through the year. In areas where the PSMD exceeds 200mm, all soils apart from peat will dry out to depths greater than 1 metre.

Natural patterns of soil distribution mean that clay soils can occur adjacent to sandy, silty or loamy materials with changes in soil texture and structure taking place over short distances in some areas. The detailed understanding of soil distribution contained in the system allows these changes in soil properties to be incorporated.

Clay related subsidence vulnerability classes range from extremely high to extremely low and are expressed numerically as shown in the following table.

Table 3. Clay-related Subsidence Classes

CLASS	VALUE
Extremely High	0
Very High	1
High	2
Medium High	3
Medium	4
Medium Low	5
Low	6
Very Low	7
Extremely Low	8
Water	9
Miscellaneous	10
Unclassified	11

7.1.1. Variations to the standard PSMD

The Standard model uses the mean maximum PSMD value calculated from the PSMD dataset. This can be considered as representing 'average' conditions. Also provided in the database are results generated when considering a range of extreme conditions. These extremes are modelled by increasing the mean maximum PSMD value by the addition of the standard deviation, or fractions, or multiples thereof.

The higher the standard deviation the more extreme the event is likely to be. Assuming a normal distribution, addition of one standard deviation (SD) to the mean maximum PSMD represents conditions that are likely to occur in the driest year in 6. Adding larger multiples of the standard deviation leads to lower frequencies, e.g. 1 in 45 for the addition of 2.0 SD. It is less easy to estimate the frequencies for the addition of fractions of the standard deviation but adding 0.5 SD, 1.5 SD and 2.5 SD to the mean maximum PSMD probably represents a reasonable estimate of the driest year in 3, the driest year in 15 and the driest year in 150 respectively.

7.2. Sand-related subsidence

As described, sandy soils are susceptible to underground erosion caused by leaking service pipes. A specific risk can therefore be attached to sandy soils.

There are three defined vulnerability classes expressed numerically as shown in the following Table.

Table 4. Sand-related Subsidence Classes

CLASS	VALUE
High	0
Moderate	1
Minimal	2
Water	3
Unclassified	4

7.3. Silt-related subsidence

As noted, silt-rich soils are susceptible to heave following frosty conditions. Two vulnerability classes have been defined as shown in the table below where silty soils are assigned a high risk and non-silty soils assigned minimal risk.

Table 5. Silt-related Subsidence Classes

CLASS	VALUE
At Risk	0
Minimal	1
Water	2
Unclassified	3

7.4. Soft Soil-related subsidence

All alluvial and organic soils are loosely packed, have low bulk densities and consequently have low bearing strengths.

The weight of building structures is often larger than the bearing strength of soft soil material and this can lead to subsidence. Areas most at risk from this kind of subsidence are largely confined to the floodplains of rivers and streams, the coastal flats underlain by marine alluvium, and areas covered by lacustrine deposits and peat. The Natural Perils model identifies all these materials as highly compressible.

There are two vulnerability classes available for soft soils and compressibility, which are expressed numerically as shown in the following Table:

Table 6. Soft Soil-related Subsidence Classes

CLASS	VALUE
At Risk	0
Minimal	1
Water	2

Unclassified	3

7.5. Peat-related subsidence

As described, the drying out of peat and its consequent shrinkage can cause the foundations of building structures to subside. The Natural Perils model identifies the occurrence of peat soils and attributes a high risk of shrinkage for peat compared to a low risk for non-peaty soils.

There are two vulnerability classes available for peats and shrinkage, which are expressed numerically as shown in the following Table.

Table 7. Peat-related Subsidence Classes

CLASS	VALUE
At Risk	0
Minimal	1
Water	2
Unclassified	3

7.6. Flood Extent

The Natural Perils model identifies alluvial land vulnerable to flooding. There are four vulnerability classes available for Flood Extent, which are expressed numerically as shown in the following Table.

Table 8. Flood Extent Vulnerability Classes

CLASS	VALUE
Major Risk	0
Local Risk	1
Water	2
Unclassified	3

Included in the 'Major Risk' class are predominately low-lying areas that are vulnerable to inundation by flood waters. The 'Local Risk' class includes all other areas. In the local vulnerability class there will inevitably be areas that are vulnerable to local flooding. The risk will be highest on low-lying land adjoining units of 'Major Risk' and along water courses where alluvial soils are too narrow in extent to show on soil maps.

7.7. Wind Exposure

The Natural Perils model identifies areas vulnerable to the effects of prolonged wind exposure. There are five vulnerability classes, which are expressed numerically as shown in the following Table:

Table 9. Wind Exposure Classes

CLASS	VALUE
Extremely Exposed	0
Very Exposed	1
Exposed	2
Moderately Exposed	3
Sheltered	4
Unclassified	5

These classes do not constitute a linear scale but they indicate the consequences of sustained wind exposure and identify locations where wind damage to buildings is on average most likely. As they are based on averages, they do not reflect spatially where extreme events may occur.

8. APPENDIX A – THE 10 MAJOR SOIL GROUPS

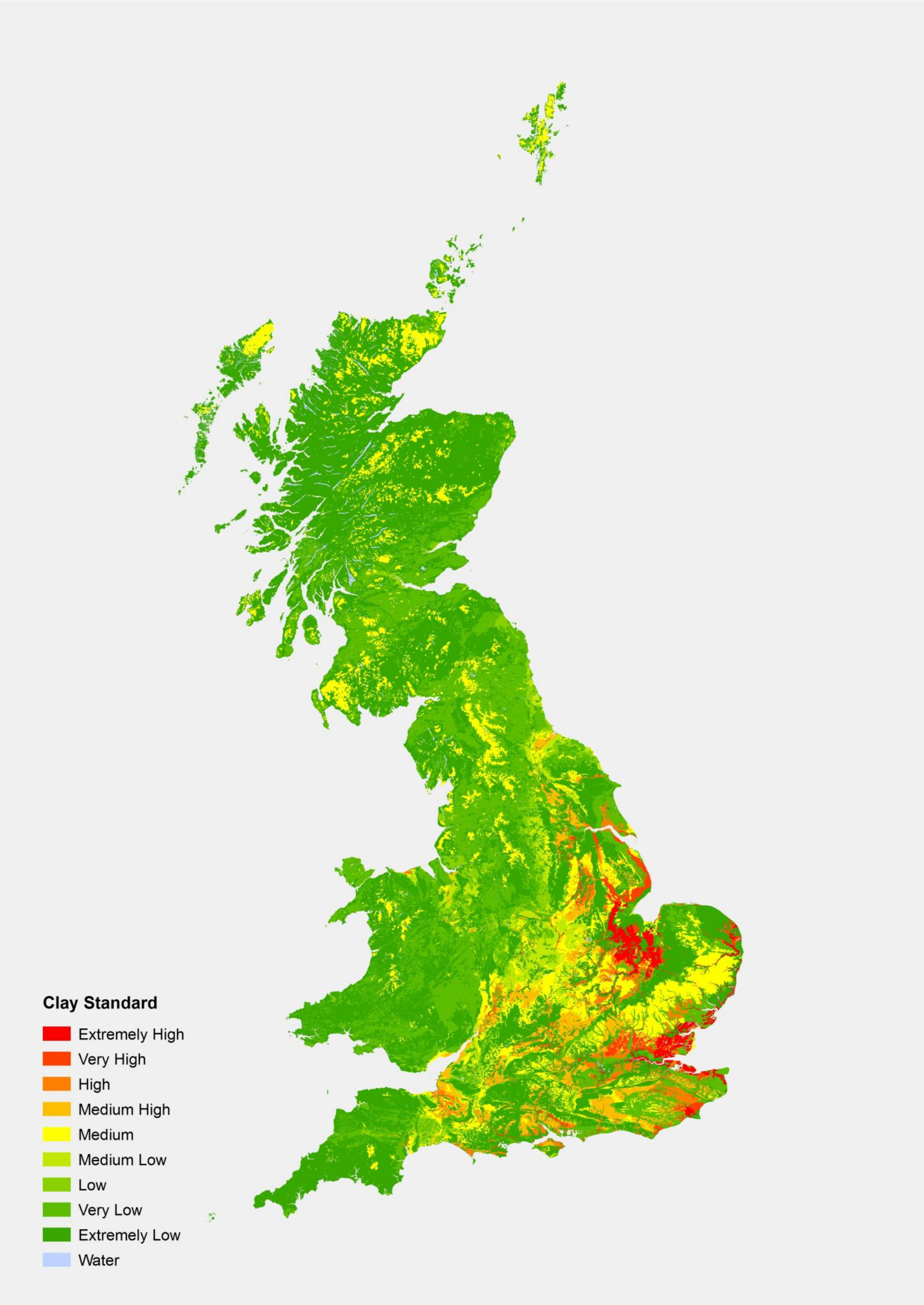
1. **Terrestrial Raw Soils** – Mineral soils in very recently formed material, with no soil horizons other than a superficial organic or organo-mineral layer less than 5cm thick, unless buried beneath a recent deposit more than 30cm thick.
2. **Raw Gley Soils -** Mineral soils in material that has remained anaerobic and waterlogged since deposition. Prominently mottled or greyish within 40cm depth. Mainly confined to inter-tidal flats and saltings that represent stages in the development of mature salt marshes.
3. **Lithomorphic Soils -** Shallow soils, with a distinct, humose or peaty topsoil, but no subsurface horizons more than 5cm thick (other than a bleached horizon). Normally over bedrock, very stony rock rubble or little altered soft consolidated deposits within 30cm depth.
4. **Pelosols -** Non-alluvial clayey soils that crack deeply in dry seasons, but are slowly permeable when wet. They have a coarse blocky or prismatic structure and no prominently mottled non-calcareous subsurface horizons within 40cm depth.
5. **Brown Soils -** With dominantly brownish or reddish subsoils and no prominent mottling or greyish colours (gleying) above 40cm depth. They are developed mainly on permeable or moderately permeable materials at elevations below about 300m Ordnance Datum (O.D). Most are in agricultural use.
6. **Podzolic Soils -** With black, dark brown or ochreous humus and iron-enriched subsoils formed as a result of acid weathering conditions. Under natural or semi-natural vegetation, they have an unincorporated acid organic layer at the surface.
7. **Surface-water Gley Soils -** Non-alluvial, seasonally waterlogged slowly permeable soils, formed above 3m O.D. and prominently mottled above 40cm depth. They have no relatively permeable material starting within and extending below 1m of the surface.
8. **Ground-water Gley Soils -** Seasonally waterlogged soils affected by a shallow fluctuating groundwater-table. They are developed mainly within or over permeable material and have prominently mottled or greyish coloured horizons within 40cm depth. Most occupy low-lying or depressional sites.
9. **Man-made Soils -** With a thick man-made topsoil or a disturbed subsurface layer (containing disturbed fragments of soil horizons) to at least 40cm depth. They result from an addition of earth containing manures, or the restoration of soil material after mining or quarrying.

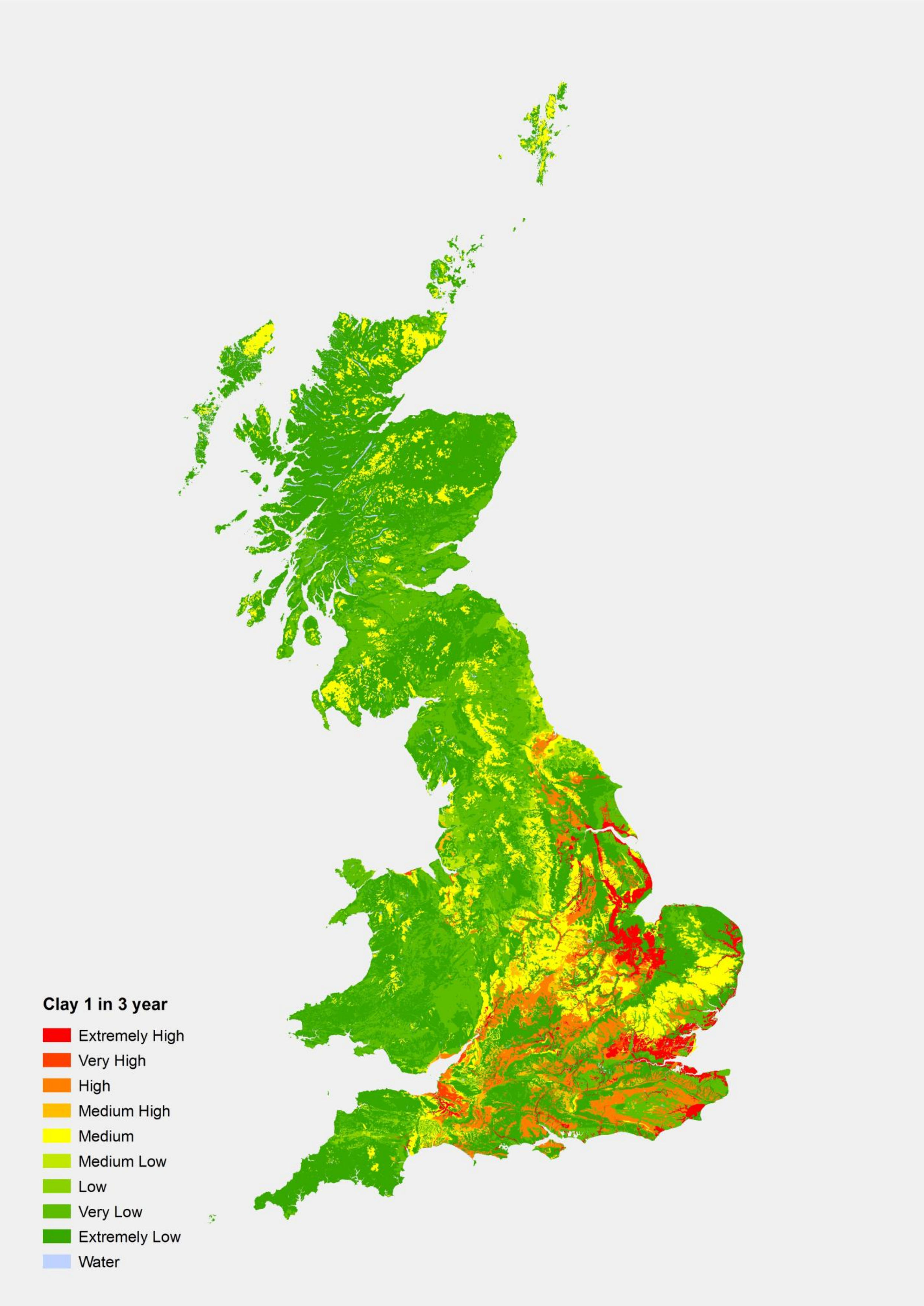
10.	**Peat Soils -** With more than 40cm of organic material in the upper 80cm or with more than 30cm of organic material over bedrock or very stony rock rubble.

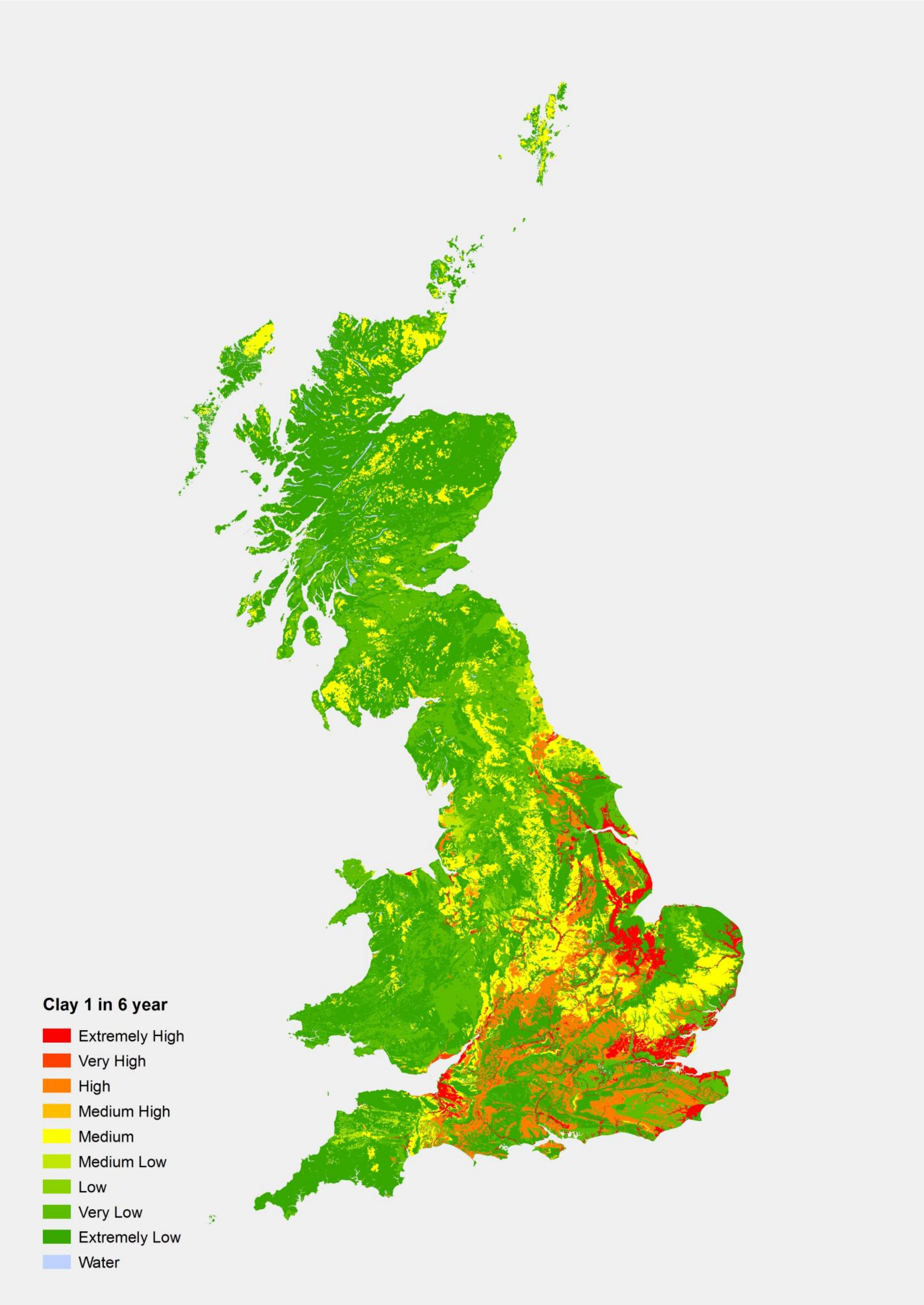
For a general overview of soils, please consult our educational website at www.soil-net.com

9. APPENDIX B – GEOHAZARD MAPPING ACROSS GREAT BRITAIN

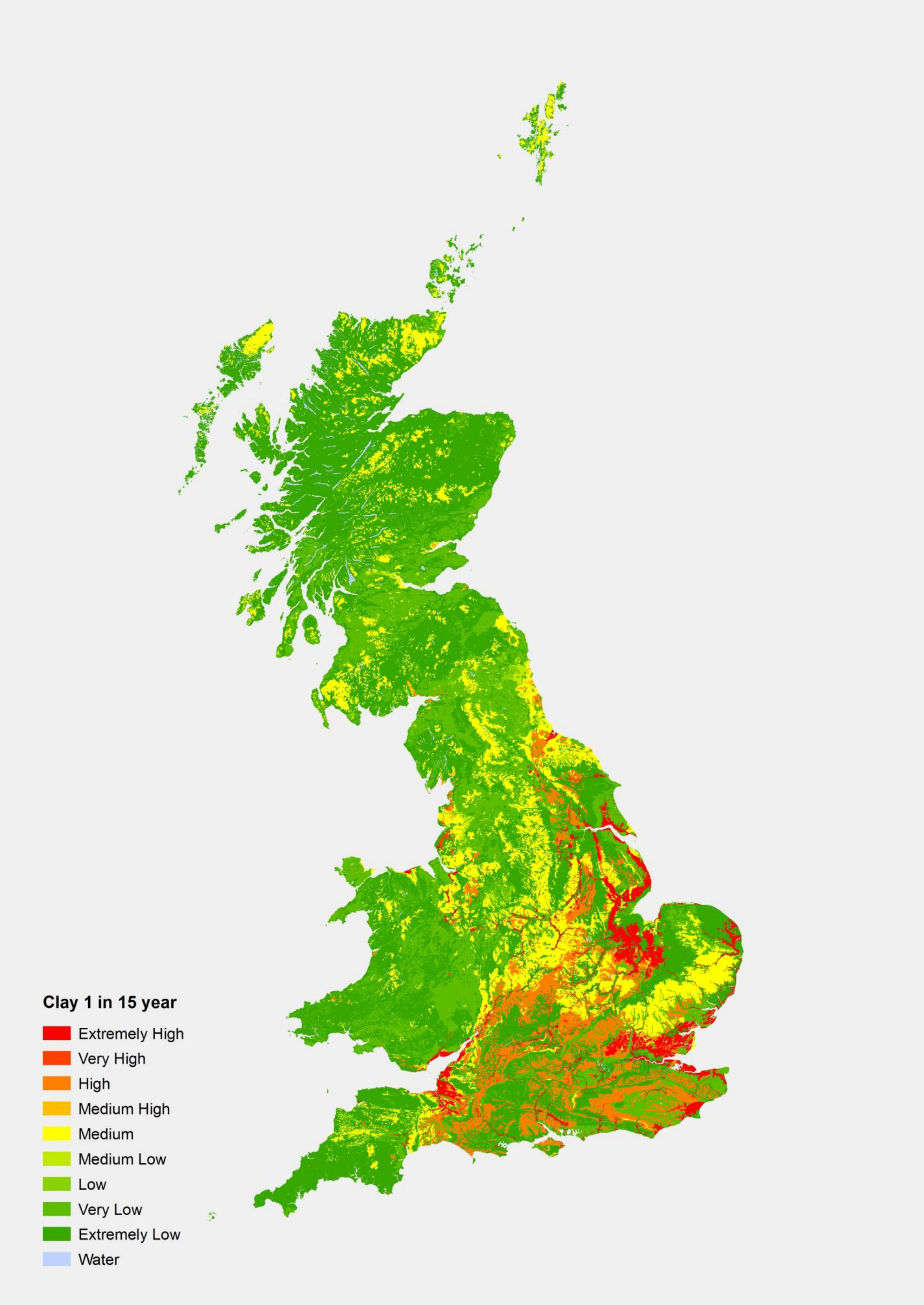
The following mapping presentations provide an overview across Great Britain, for each of the geohazards provided in NPD, together with the spatial extents across the vulnerability classes.

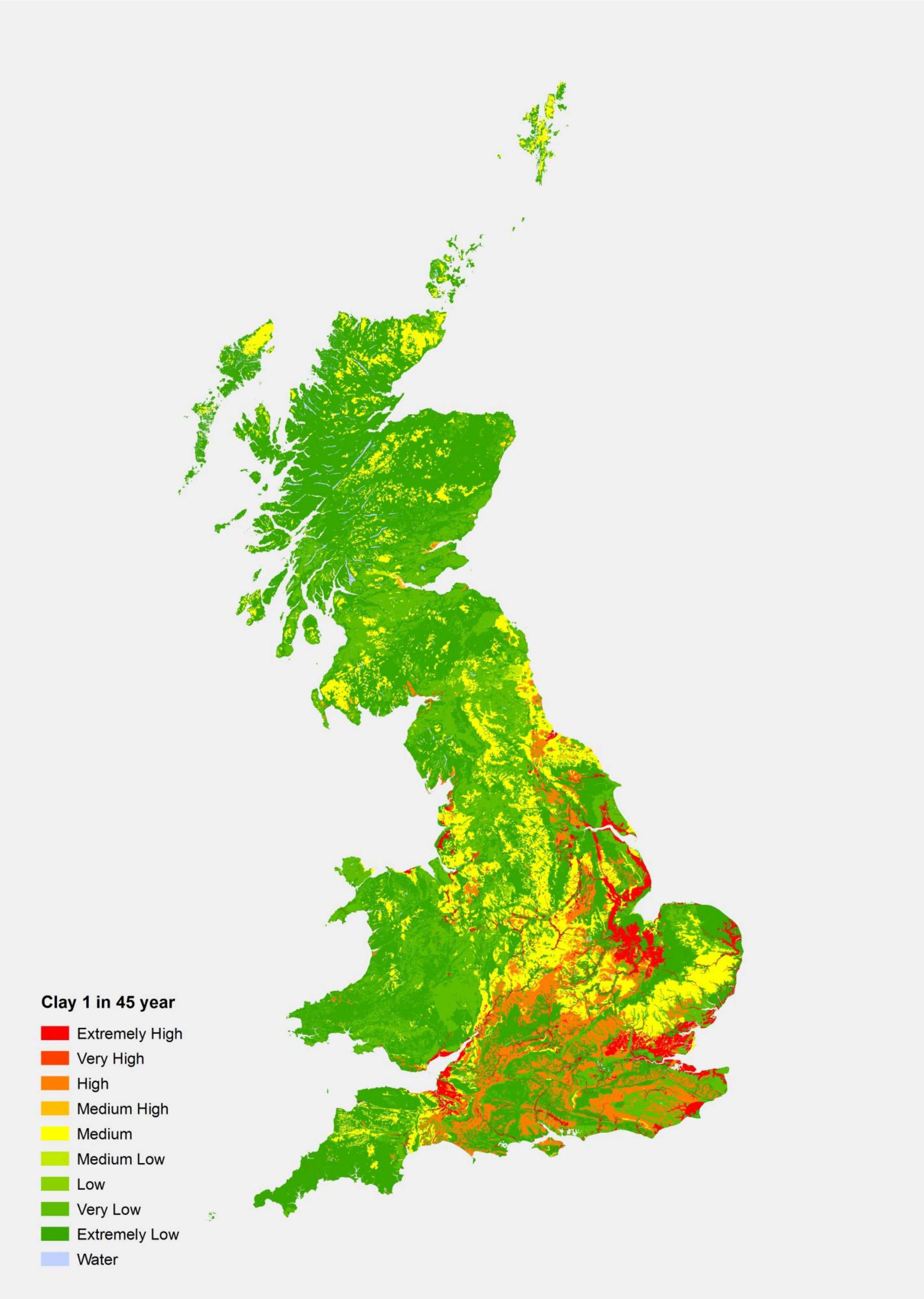

Clay Standard
Extremely High
Very High
High
Medium High
Medium
Medium Low
Low
Very Low
Extremely Low
Water

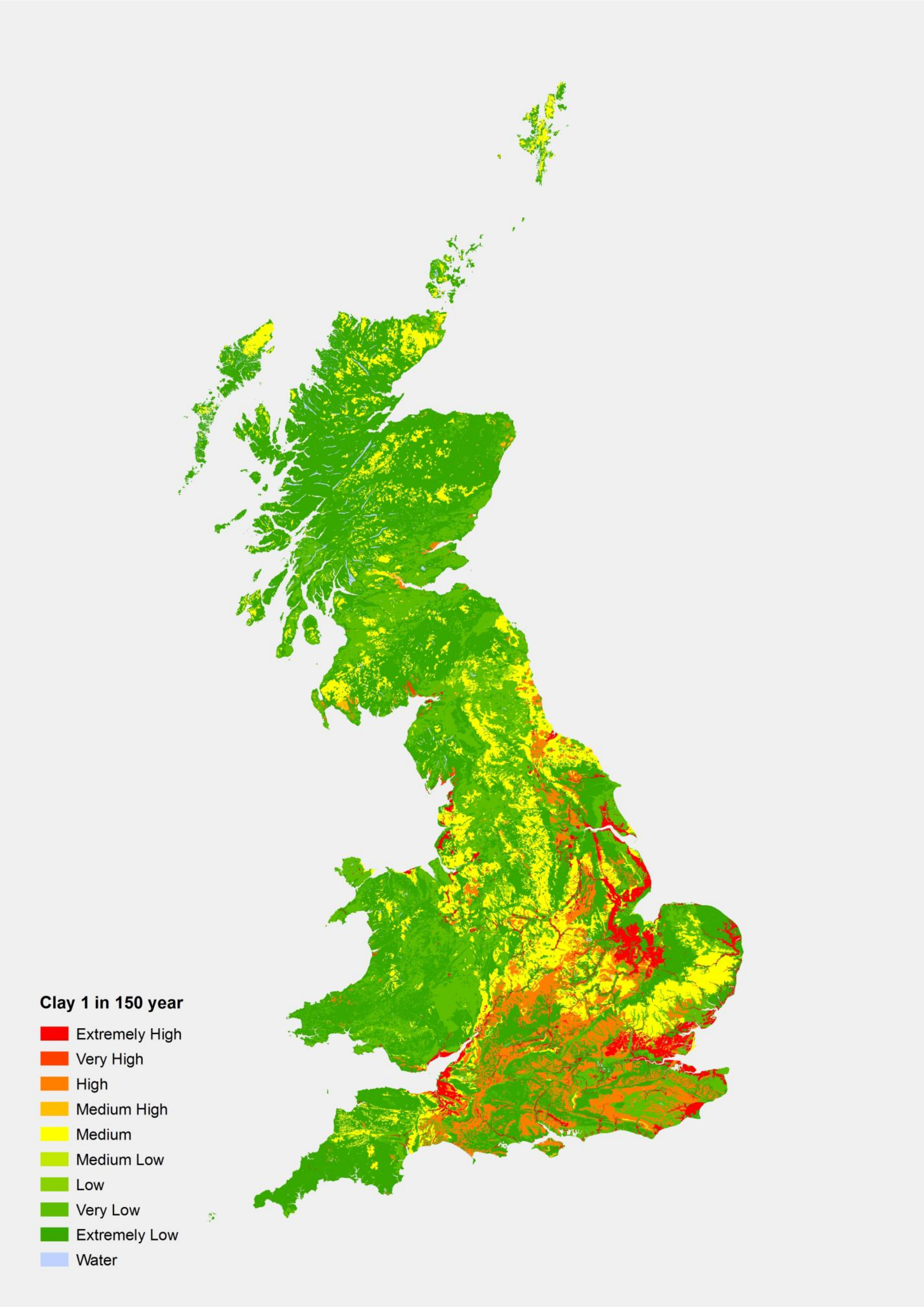

Clay 1 in 3 year
Extremely High
Very High
High
Medium High
Medium
Medium Low
Low
Very Low
Extremely Low
Water



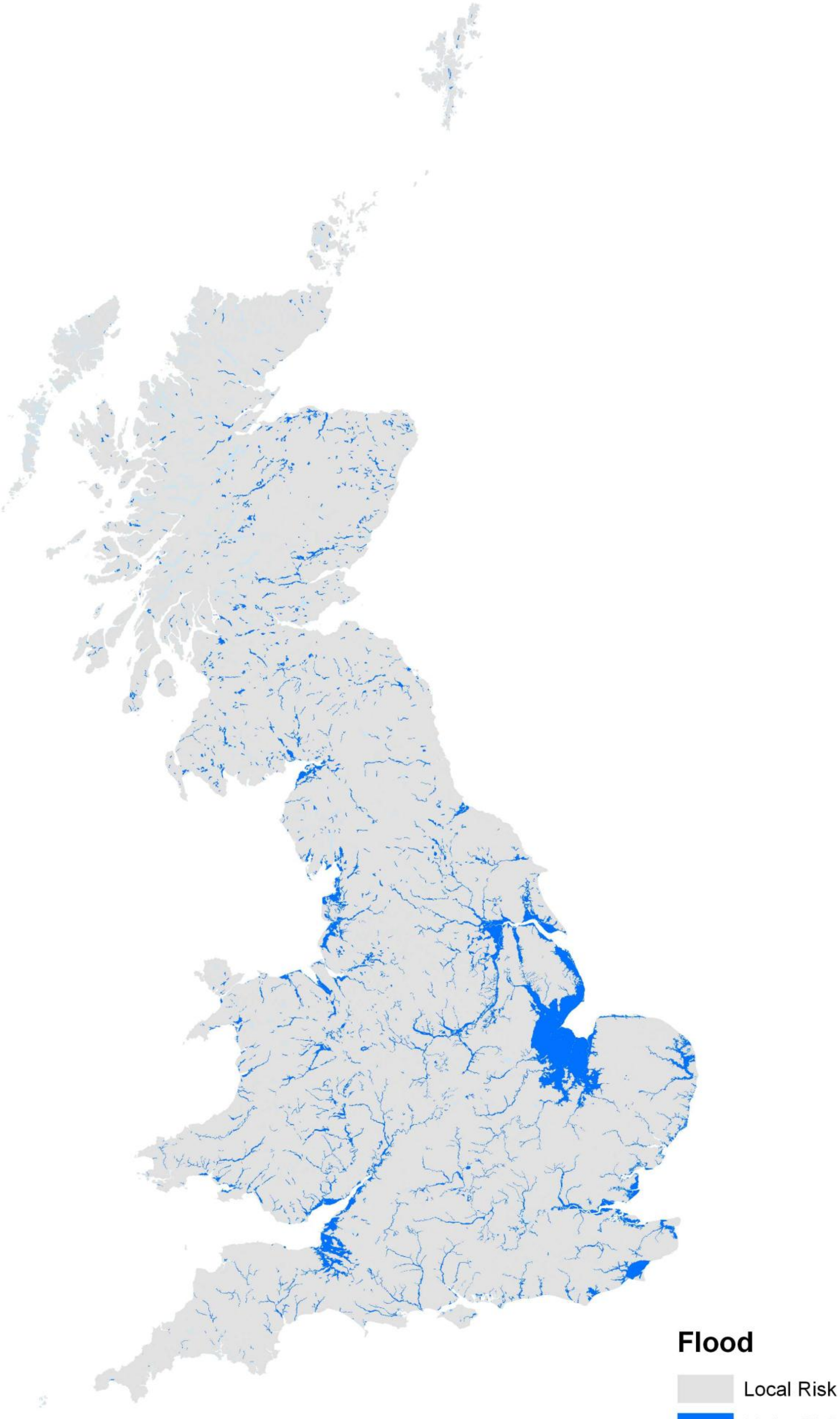
Clay 1 in 6 year
Extremely High
Very High
High
Medium High
Medium
Medium Low
Low
Very Low
Extremely Low
Water


Clay 1 in 15 year
Extremely High
Very High
High
Medium High
Medium
Medium Low
Low
Very Low
Extremely Low
Water

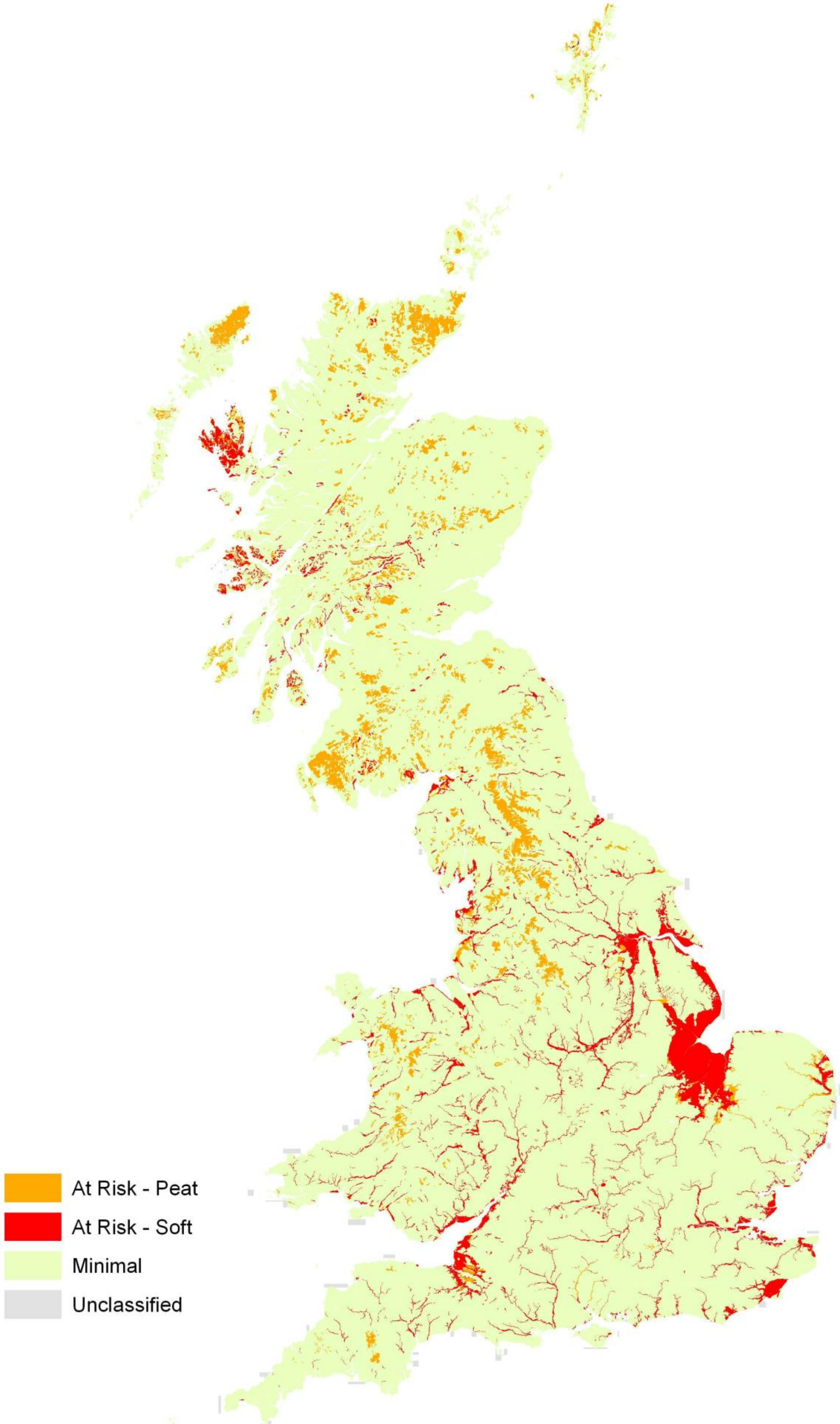

Clay 1 in 45 year
Extremely High
Very High
High
Medium High
Medium
Medium Low
Low
Very Low
Extremely Low
Water


Clay 1 in 150 year
Extremely High
Very High
High
Medium High
Medium
Medium Low
Low
Very Low
Extremely Low
Water

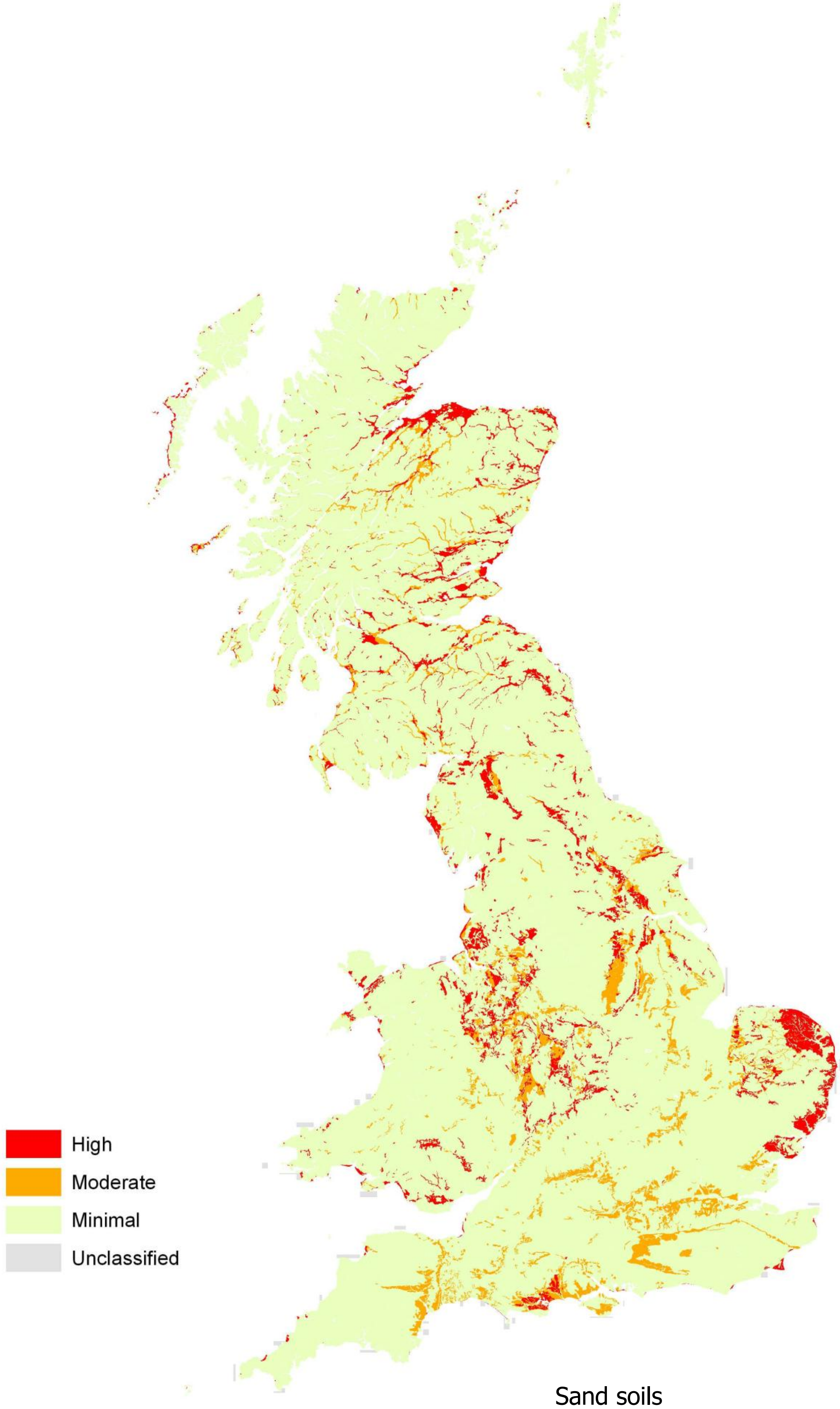
Cranfield UNIVERSITY



Flood Extent

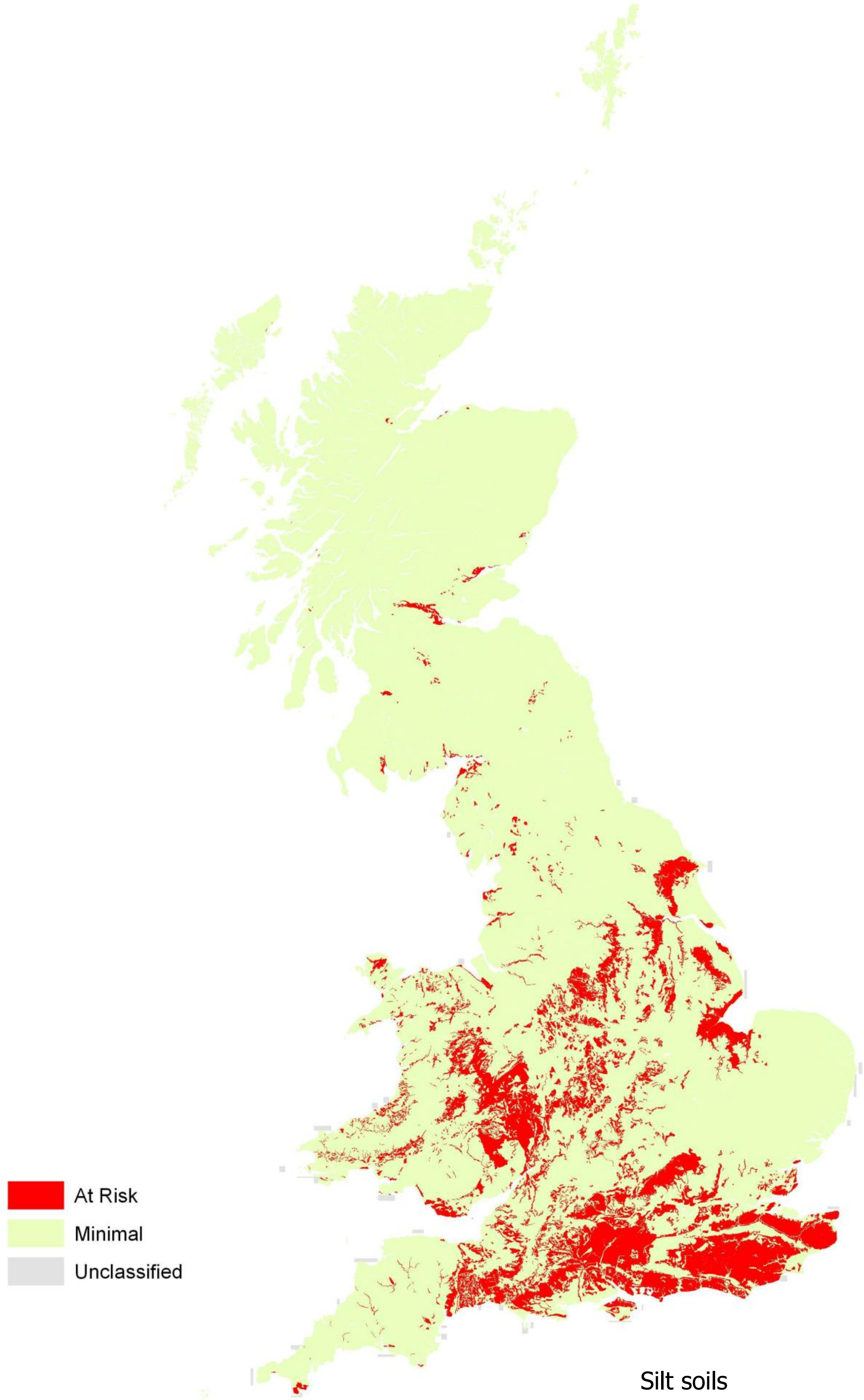


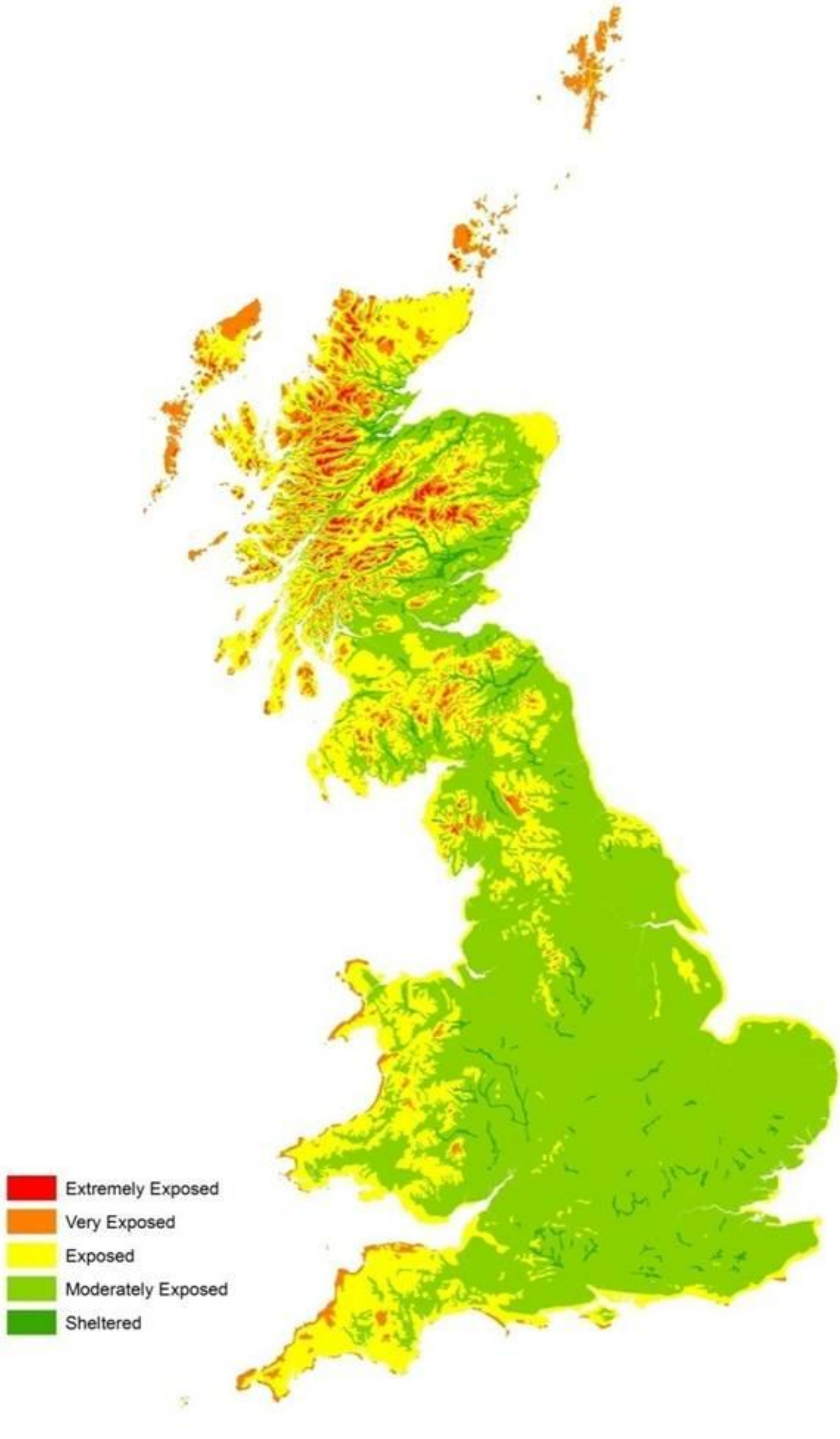
Peat and Soft Soils



Sand soils

Cranfield UNIVERSITY





Wind Exposure