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User Guide DiGMapPlus+ Engineering Properties: Excavatability dataset (version 1)

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BRITISH GEOLOGICAL SURVEY

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User Guide DiGMapPlus+ Engineering Properties: Excavatability dataset (version 1)

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Sample of the 'excavatability' dataset.

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Foreword

This report presents a description and review of the methodology developed by the British Geological Survey (BGS) to produce a national scale assessment of Engineering Properties: Excavatability. Much of the methodology has been taken from an internal BGS document which outlines the development of the methodology which is summarised in this report. The purpose of this user guide is to enable those licensing this dataset to have a better appreciation of how the data set has been created and therefore better understand the potential applications and limitations that the dataset may have.

Acknowledgements

A number of individuals in the Information Products and Land Use and Development Programmes have contributed to the project and helped compile this report. This assistance has been received at all stages of the study. In addition to the collection and processing of data, many individuals have freely given their advice, and provided the local knowledge.

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Summary

This report describes the national scale DiGMapPlus+ Engineering Properties: Excavatability dataset. The methods used to create the dataset have been critically assessed and its fitness for purpose determined by specialists in BGS.

This document outlines the background to why the dataset was created, its potential uses and gives a brief description of the content. Technical information regarding the GIS and how the data was created is described and advice is provided on using the dataset.

1 Introduction

This document provides information for users on the 'Engineering Properties: Excavatability' dataset.

Excavations are dug for civil engineering purposes including cuttings, tunnels, borrow pits quarries and mines. Other applications, generally of more limited depth, include foundations, utilities infrastructure, cellar construction and burial pits. A number of excavation methods have been devised to efficiently and cost-effectively remove material. The selection of the method largely depends on the material characteristics, primarily 'strength' and mass characteristics, that is the spacing and orientation of mechanical discontinuities. Materials that behave as engineering soil, that is those described with a principal material type of clay, silt, sand, gravel or cobble, are more easily extracted than those described as rock.

This information is primarily for the near surface, here defined as the top 2 m, but will have application to greater depths for many geological units. This has been driven by the increasingly availability of digital borehole records, the National Geotechnical Properties Database and geological maps, which provides a mechanism to present the excavatability of the point-based observations, within the context of the spatial distribution of rocks and deposits across Britain. The need for this type of information was identified during work for buried utilities, but equally, the information could prove useful to answer more strategic legislative requirements such as the proposed soil-framework directive.

2 About the Engineering Properties: Excavatability dataset

2.1 BACKGROUND

Infrastructure development and mineral exploitation often require the excavation of material. A significant proportion of urban development is founded in the near surface 'zone of human interaction'. This dataset provides information for the uppermost 2m of geological materials (therefore, 0-3m below ground level, assuming a 1m pedological soil profile). This is the typical depth range for many utilities and shallow foundations. Understanding the spatial variability of excavatability for different excavation methods, allows for strategic planning of future development, identifying areas where this is easier or more difficult.

The product is a spatial model of excavatibility information for use within a GIS. The model will allow **demonstration** of the spatial distribution of zones of rock properties defining an 'Excavatability' model for the **uppermost 2 m** of all geological units distributed across Great Britain. Within this limited depth, weathering of material is to be expected and, therefore, the effects of **weathering** (to varying degrees) are considered.

The dataset forms part of a suite of GIS layers for different engineering parameters. It is based upon archive data of engineering soil strength coupled with the BGS DiGMapGB-Plus dataset and displayed via dictionaries of 'strength and excavation classes'.

The dictionaries, measurements and terminology used are in accordance with standard engineering vocabulary as recommended in EuroCode7 and BS9530 standards (BSI, 1999; BSI, 1993).

More specific data of the top 2 m of geological materials are required for near surface infrastructure and excavations. The values supplied are the ***indicative*** minimum, maximum and typical values we would normally expect to encounter per geological unit but limited to the top 2

m. The main difference with other classifications is that these values will, in many cases, be in the weathered zone and may be of lower strength, consistency or density than the typical values or comprise of a mixture of coarse material or rock. The water content within the top metre or so will vary seasonally and annually depending on the weather/climate. This will affect the character of the fine-grained deposits. In wet weather firm or stiff clays 'wet up' and may become soft. In dry weather the top metre or more of deposits such as alluvium and estuarine alluvium are often desiccated and stiffer than the bulk of deposit. Some deposits, such as some alluvium, lacustrine or raised marine deposits, may be soft at depth but firm or stiff clay their upper 1 m or more.

In response to this, The British Geological Survey initiated a development programme to produce datasets that identified and assessed a variety of engineering properties in Great Britain. These include strength, excavatability, fill and discontinuities.

Along with the engineering properties datasets, the programme also generated:

- Superficial Thickness Model
- GeoSure ground stability data
- Scans of onshore borehole logs for Great Britain
- Scans of geology and historic topography maps
- Ground permeability data
- Susceptibility to Groundwater Flooding
- Geological Indicators of Flooding
- Environmental sensitivity data
- Radon potential
- Non-coal mining hazards
- Potentially Harmful Elements

2.2 WHAT THE DATASET SHOWS

The excavatability information is based upon archive data of engineering soil strength coupled with the BGS DiGMapGB-Plus: Parent Material Model and displayed via dictionaries of 'excavatability classes'. The GIS model allows demonstration of the spatial distribution of zones of excavatability (and the local factors controlling it) for a range of excavating equipment. The rock types classified include all bedrock and superficial deposits as shown in DiGMapGB-50 V6.

The primary source of engineering content are the BGS archives of geotechnical properties. The data related to excavatability is subdivided into 'excavatability' classes so that the information can be utilised by many different users, with differing knowledge needs.

The data provides national coverage for England, Scotland and Wales at a scale of 1:50,000.

The 'Excavatability' model provides data for the **uppermost 2 m** of all geological units distributed across Great Britain (including consideration of weathering). At present this layer includes limited rock mass discontinuity data. However, this data will be included in future versions.

2.3 WHO WOULD BENEFIT FROM THE DATASET?

It is envisaged that excavatability is of interest to a wide range of organisations concerned with development, including utility companies, local authorities and developers. In addition there is specialised interest in excavatability for forensic purposes as well as military applications. Engineering geologists and ground engineers have long required information on excavatability. Although this information (at a 1:50k scale) provides only a generic assessment and wouldn't be suitable for design purposes, it would however, and is intended to help to inform engineers at the desk study stage thereby allowing for more efficient planning and execution of proceeding ground investigations.

3 Technical Information

3.1 DATA EXAMPLES

Two examples have been provided with your licensed data. These are:

- Excavatability based on coarse soils (density values)
- Excavatibility based on fine soils and rocks (strength values)

Uses are recommended to take both values into account where available as this highlights the potential weathering of the deposit and indicates the potential variation that might be encountered. A weathered and disaggregated rock (i.e. as a coarse soil) would require minimal excavation effort but in an un-weathered state is a medium to strong rock.

For example the Nottingham Castle Sandstone Formation in an un-weathered state may be a medium strong rock, which usually requires ripping. However, where weathered, it is classified as a dense soil and therefore, only hand tools would be necessary for excavation.

It is recommended that all values available should be taken into account when collating a desk study allowing for targeted site investigation and planning. It is important to know the potential variation in engineering characteristics at an early stage as this will affect the costings and design of site investigation and the project.

*Users should note that this data should be used to provide **indicative** information only, and should **not** be used in place of site specific measurements.*

3.2 DEFINITIONS

The description and classification of excavatability depends on the type of deposit. In engineering geology earth materials are split into two groups, 1. soils and 2. rocks as given below:

- ***Soil*** is an aggregate of mineral grains or organic material that can be separated by gentle means such as agitation in water. Their behaviour is determined by the particulate nature, specifically the particle size, particle shape, particle mineralogy, water content and material density. The mass properties are largely influenced by its material characteristics. The principal soil types are clay, silt (fine soils) sand, gravel (coarse soils) cobble and boulder (very coarse soils). Whether the soil is classified principally as fine or coarse is dependent upon the behaviour of the material. Discontinuities affect the mass strength of some soils, primarily clay and silt.
- ***Rock*** is an aggregation of minerals connected by strong and permanent forces. The behaviour of the rock material depends on the material characteristics. The behaviour of the rock mass depends on a combination of the material characteristics and the discontinuities (including spacing, roughness, persistence, filling, orientation and the number of sets).

3.3 HOW THE DATASET WAS CREATED

Lithological type and variability are implicitly classified in the BGS Rock Classification scheme for each LEX-RCS code, and so the minimum/maximum and typical strength parameters/values have been determined for all LEX-RCS coding units.

Codes and values for strength, consistency or density have been assessed using information in the BGS National Geotechnical Properties Database, technical reports, site investigation reports and by expert opinion. Categorisation is based on a formation level.

The dataset of excavatability information is based upon archive data of engineering soil strength coupled with the BGS DiGMapGB-Plus: Parent Material Model and displayed via dictionaries of 'excavatability classes'. The GIS model allows demonstration of the spatial distribution of zones of excavatability (and the local factors controlling it) for a range of excavating equipment.

The categorisation of excavatability is based on strength-data collated for geological formations as identified in the BGS Lexicon Rock Classification Scheme (LEX-RCS). This has been further subdivided to account for regional/lateral variation where sufficient data exists. The degree of weathering has also been incorporated where possible.

A variety of methods are used to excavate the ground depending on the properties of the ground and these are summarised by Pettifer and Fookes (1994) using the three broad excavatability classes: Digging; Ripping; Drilling and blasting. The simplified relationship between these classes and the factors controlling them are strength and discontinuity spacing as shown (simplified) in Table 1 below.

Material type	**Excavation requirements**
Very soft to firm clays	Hand tool (Easy digging)
Very loose to medium dense sands	
Stiff to hard clay	Power tools (hard digging)
Dense to very dense sand Very weak to weak	
Moderately weak to strong	Ripping
Very strong to extremely strong	Drill and Blast

Table 1: Primary assessment of excavation requirements

The EXCAVATABILITY GIS dataset uses **only** the excavatability classification for the **TYPICAL** density and **TYPICAL** strength rating for the **0-2m depth** range.

These four excavatability ratings correspond with the 'BS5930_term' which denotes the STRENGTH rating of the materials and the 'mode_of_excavation' denotes one of the four excavatability classes as shown in table 2 below.

BS5930_term	MODE OF EXCAVATION
Extremely Strong	BLASTING
Very Strong	BLASTING
Strong	RIPPING
Medium Strong	RIPPING
Weak - Strong	RIPPING
Weak - Medium Strong	RIPPING
Weak	POWER TOOLS
Very Weak - Very Strong	POWER TOOLS
Very Weak - Strong	POWER TOOLS
Very Weak	POWER TOOLS
Extremely Weak	POWER TOOLS
Hard	POWER TOOLS
Very Stiff	POWER TOOLS

Stiff to Very Strong	POWER TOOLS
Stiff - Weak	POWER TOOLS
Stiff - Very Weak	POWER TOOLS
Stiff	HAND TOOLS
Firm - Stiff	HAND TOOLS
Firm	HAND TOOLS
Soft - Firm	HAND TOOLS
Soft	HAND TOOLS
Very Soft - Soft	HAND TOOLS
Very Soft	HAND TOOLS
Very Dense - Weak	HAND TOOLS
Very Dense	HAND TOOLS
Dense	HAND TOOLS
Medium Dense - Dense	HAND TOOLS
Medium Dense	HAND TOOLS
Loose - Medium Dense	HAND TOOLS
Loose	HAND TOOLS
Very Loose	HAND TOOLS
Variable	VARIABLE
Not Applicable	N/A

Table 2: Strength and corresponding mode of excavation requirements

3.3.1 Field descriptions

The data fields included in this dataset are described below. Full class descriptions as they appear in the dataset are shown in Appendix 1.

General lithology (GEN_LITH)

This is a simplified geological description of the parent material and is derived from the original DiGMapGB-50 LEX-RCS coding compared with the hierarchical classification of UK rocks from the BGS RCS system. In general the aim is to provide the user with as simplified a lithological description as possible.

Lexicon Rock Classification Scheme (LEX_RCS)

This field is the standard DiGMapGB-50 code that describes the geological units found in Great Britain. It provides the starting point for the parent material characterisation. It comprises a 'stratigraphic' code (LEX) and 'Lithology' code RCS).

Excavatabilility (STR_TYP_EX) (DEN_TYP_EX)

The mode of equipment required to excavate the typical deposit present.

Nominal Scale (Nom_Scale)

This field describes the notional x-y spatial scale of the data. Most geological map data in the dataset is captured and presented at a scale of 1:50,000. The field identifies a combination of scales used to create the map from the bedrock and superficial map sources. The available scales are show as follows:

Field Value	Meaning
50	No superficial data is present for this sheet and bedrock data is available at 1:50,000 scale
250	No superficial data is present for this sheet and bedrock data is available at 1:250,000 scale
625_50	Superficial data is present for this sheet at a scale of 1:625,000 and Bedrock data is available at a scale of 1:50,000
50_50	Superficial data is present for this sheet at a scale of 1:50,000 and Bedrock data is available at a scale of 1:50,000

35_50	Superficial data is present for this sheet at a scale of 1:35,000 and Bedrock data is available at a scale of 1:50,000
35_250	Superficial data is present for this sheet at a scale of 1:35,000 and Bedrock data is available at a scale of 1:250,000

3.4 DATA FORMAT

The ***Engineering Properties: Excavatability*** dataset is produced for use at 1:50000 scale providing 50 m ground resolution.

The data are released in ESRI shapefile formats. Other formats such as MapInfo TAB are available on request. The standard data supplied to customers has polygons or areas in a single layer or theme.

3.5 COVERAGE

Data is provided to indicate the Excavatability of rocks and soils across Great Britain to a depth of 2 metres. The scales of map data available to create this dataset are shown in Appendix 3.

3.6 DATA HISTORY

Version 1 (released 2012): Derived from DiGMapGB-50 version 6.

3.7 LIMITATIONS

- The Engineering Properties datasets have been developed at 1:50 000 scale and must not be used at larger scales. All spatial searches against the data should be done with a minimum 50 m buffer.
- The spatial distribution of the data is limited by the distribution of the site investigation exploratory holes from which the geotechnical data have been extracted (shown in Appendix 2) and digital geological map data (DiGMapGB-50) (Appendix 3). Although the National Geotechnical Properties Database is the ‘first port of call’ for data it has limited coverage so other descriptive data from exploratory hole logs or from Site Investigation Reports has been used.
- Excavatability data are created as vector polygons and are available in a range of GIS formats, including ArcGIS (.shp), ArcInfo Coverages and MapInfo (.tab). More specialised formats may be available but may incur additional processing costs.
- Excavatability dataset is concerned with the strength and excavatability of NATURAL geological deposits and conditions only. It does NOT cover any man-made constructions, such as engineered fill.
- Excavatability is based on, and limited to, an interpretation of the records in the possession of The British Geological Survey at the time the dataset was created.
- An indication of the typical natural excavatability of a rock or soil does not necessarily mean that the rock properties are consistent throughout the outcrop. Such an assessment can only be made by inspection of the area by a qualified professional.
- This version of the excavatability GIS is based primarily on strength and includes limited discontinuity information. This will be improved and further detail added in the next version of this GIS.

The Excavatability dataset provides information for the **uppermost 2 metres** of all geological units distributed across Great Britain. Within this limited depth, weathering of material is to be expected and, therefore, the effects of **weathering** (to varying degrees) are considered. Further information regarding details of geological units at greater depths can be provided on request (see contact information below)

4 Licensing Information

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4.1 CONTACT INFORMATION

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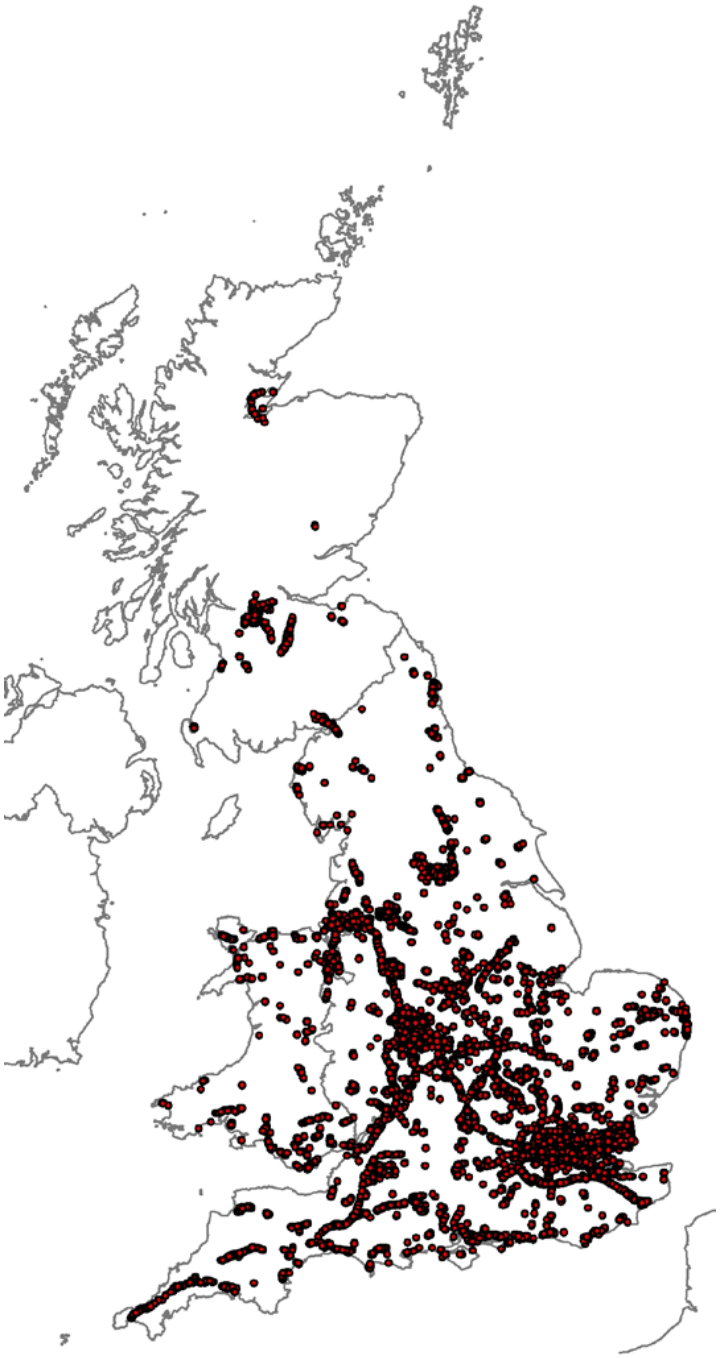
Email: enquiries@bgs.ac.uk

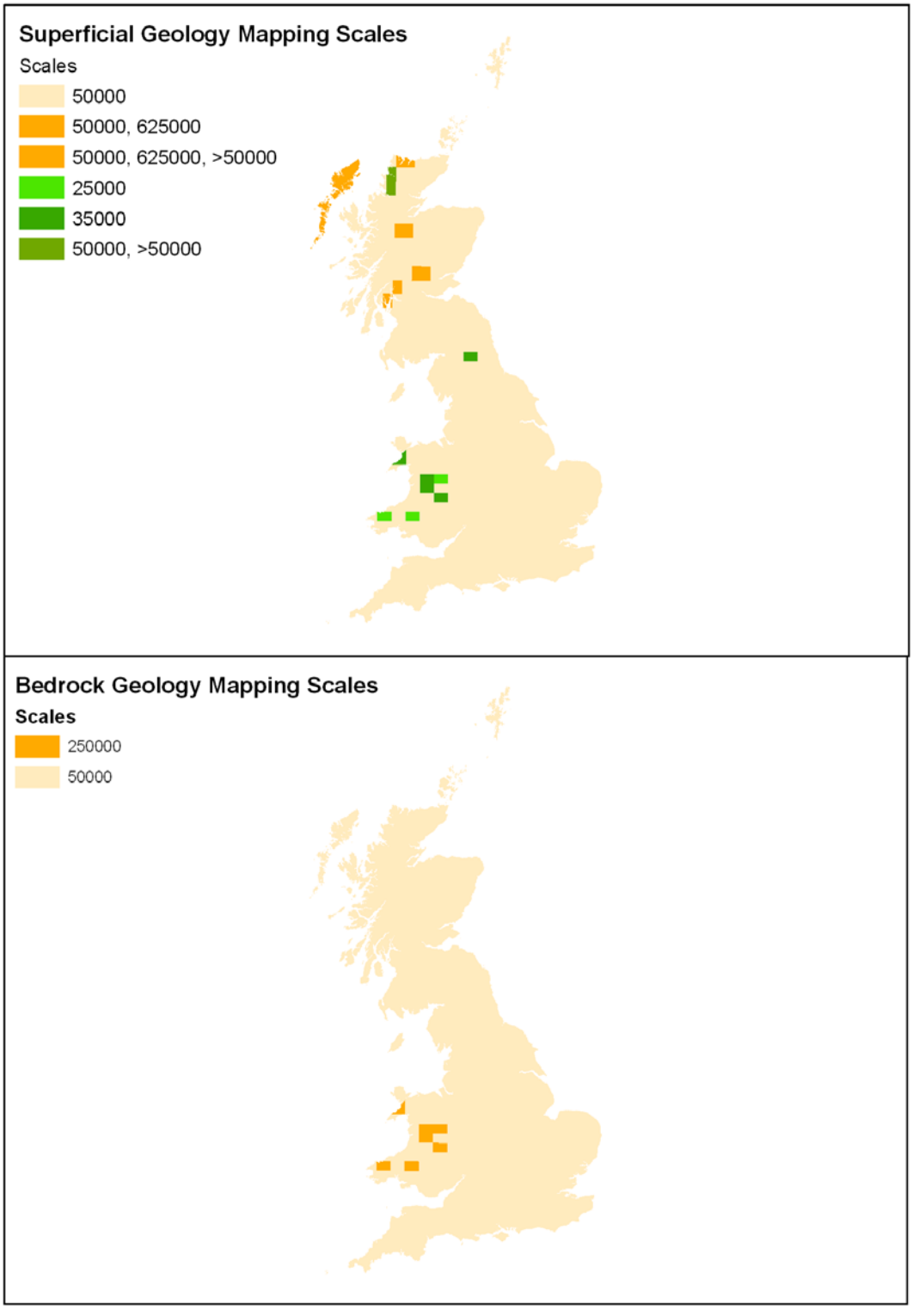
Appendix 1 Engineering Properties: Excavatability Legend

Field name	Field description	Description
GEN_PMLITH	Generalised lithology description	This is a simplified geological description of the parent material and is derived from the original DiGMapGB-50 LEX-RCS coding compared with the hierarchical classification of UK rocks from the BGS RCS system. In general the aim is to provide the user with as simplified a lithological description as possible.
LEX_RCS	BGS Lexicon-rock classification code	This field is the standard DiGMapGB-50 code that describes the geological units found in Great Britain. It provides the starting point for the parent material characterisation. It comprises a 'stratigraphic' code (LEX) and 'Lithology' code RCS).
STR_TYP_EX	Typical Strength Excavation type	Type of tool required for excavation of this deposit.
DEN_TYP_EX	Typical Density Excavation type	Type of tool required for excavation of this deposit.
NOM_SCALE	***Nominal Scale*** Nominal use scale	This field describes the notional x-y spatial scale of the data. Most geological map data in the dataset is captured and presented at a scale of 1:50,000. The field identifies a combination of scales used to create the map from the bedrock and superficial map sources.
UID	Unique identifier	Map metadata
VERSION	Version of the dataset	Map metadata

Appendix 2 Distribution of data held in the National geotechnical properties database



Appendix 3 Mapping Scales



References

British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: http://geolib.bgs.ac.uk.

Pettifer, G S and Fookes, P G. 1994. A revision of the graphical method for assessing the excavatability of rock. *Quarterly Journal of Engineering Geology and Hydrogeology*, **27**, 145 – 164.