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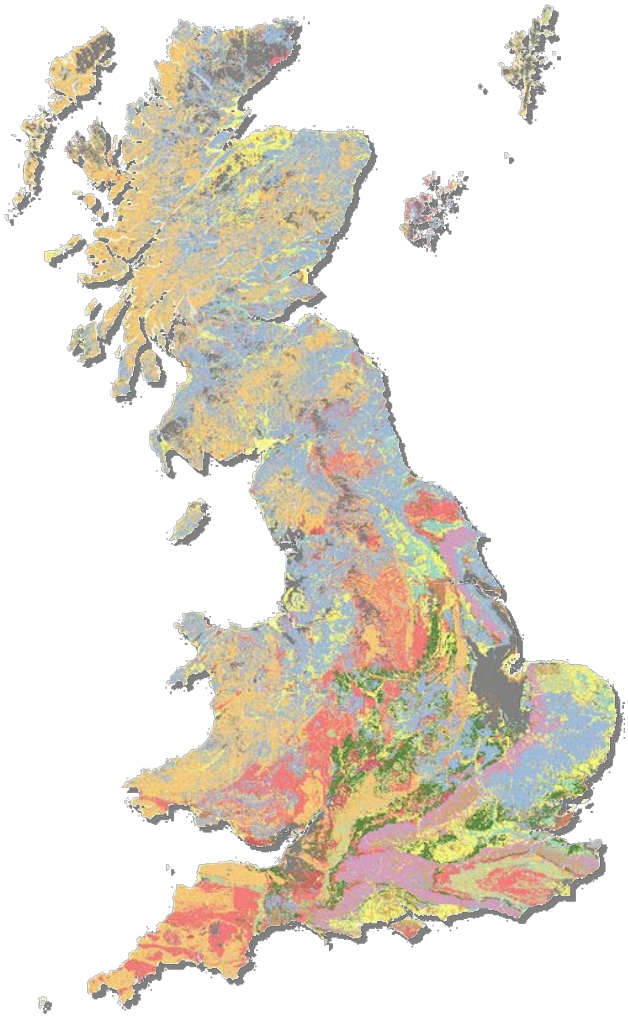
DiGMapPlus Engineering properties: Use as engineered fill. Methodology report.

Information Products Programme

Internal Report IR/12/079



BRITISH GEOLOGICAL SURVEY

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DiGMapPlus Engineering properties: Use as engineered fill. Methodology report.

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Keywords

Engineering properties; Use as engineered fill of rocks & soils; UK.

Front cover

National use as engineered fill map

Bibliographical reference

D ENTWISLE, R LAWLEY, K A LEE. 2013. DiGMapPlus Engineering properties: Use as engineered fill. Methodology report.. *British Geological Survey Internal Report*, IR/12/079. 24pp.

Keyworth, Nottingham British Geological Survey 2013

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Foreword

This report is the published product of a study by the British Geological Survey (BGS). It is the methodology, using the resources available, for producing a ‘use as engineering fill’ GIS for use as a desk study tool.

Acknowledgements

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

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Summary

This report describes the methodology for creating the DiGMapGB-Plus: Engineering Data (for Desk Studies) ‘use as engineering fill’ model for Great Britain. It facilitates and builds upon work already carried out as part of the Parent Material Map (PMM) project and follows on from the findings and recommendations in the scoping report (Booth, *et al*., 2010).

The first part of the report introduces the project and the context of providing this type of data. The data currently available and its collation are then described within the methodology. Ultimately, a specification and methodology is provided for the first model of ‘use as engineering fill’ to be applied across Great Britain at a scale of 1:50,000.

1 Introduction

The ‘use as engineering fill’ of rocks and soils is an important consideration in civil engineering and extractive industry. The rapidly increasing cost of removal of material offsite, and especially disposal of unused material, means that a great deal of effort is now taken to identify how extracted materials are to be used on site. Fill is a material that is used to *fill in* a depression or hole in the ground or create mounds or otherwise artificially change the elevation of the ground. It may be engineered or non-engineered.

Engineered fill is used in earthworks, which includes infill, raising or levelling ground, embankments, foundation pads, road bases and landscaping. The earlier in the process this can be done then the greater the likelihood that it can be done efficiently.

Materials may be used as engineering fill or non-engineered fill (after Scottish Government, 2010) where:

Engineered fill is selected, placed and compacted to an appropriate specification in order that it will exhibit the required engineering behaviour.

***Non*-engineered fill** usually involves the disposal of waste materials. Normally such fill would occur on *sites* where uncontrolled filling has taken place and, therefore, no reliance can be placed on the type of fill material and method of placement.

Although nearly all earth materials can be used as fill there are restrictions in their use in engineered fill and this report and the GIS is primarily for engineered fill. ‘Suitability as engineering fill’ was one of the characteristics included in many of the series of BGS Technical Reports on ‘A geological background for planning and development’ funded by the Department of the Environment during the 1980’ and 1990’s (reviewed in Smith and Ellison, 1999). It is also 1 000 000 scale in the engineering geology maps of the United Kingdom (Dearman et al., 2011a, b, c, Dobbs et al., 2012).

Much of the classification used here is based on the ‘Specification for Highway Works’ Series 600 (Highways Agency, 1991, 1991a). More detailed specification tests will be required when the materials are used on site. Other materials, which are considered here to be suitable, may not be as they are outside the specifications requirements for the project, for instance specific material having very high or extremely high plasticity clays. The GIS and this report are a guide to the suitability as fill but does not include information required for use such as plasticity and water content and as assessment of use will required for each project.

Some materials are extracted as resources and have increased value over and above use as engineering fill. These include materials that may be used as a part of the project such as aggregate used in concrete aggregate and construction sand. Others that may be relevant include specialist aggregate for road surfaces, coated roadstone and railway ballast. Other materials are used in industry such as gypsum, calcium carbonate from pure limestone and chalk, kaolinite, ‘fuller’s earth’ and foundry sand. Construction materials include clay for bricks, roofing slate and building stone. These units and the materials are identified in a separate field.

Some of the classifications are necessarily broad reflecting the lithological variation within mapped geological unit, for example, the Coal Measures Group is often mapped as mudstone, sandstone, siltstone and coal. Mudstone, particularly where weathered, may be used as fine-grained (cohesive) fill, whilst coal is unsuitable. This is classed as mixed rock fill reflecting the variation of rock types, however, at a site scale the different rock types may be separated out into their component fill types.

The purpose of this methodology is to provide general guidance on the use of geological units, as defined on DigMap-50 via LEX_RCS, for ‘use as engineered fill’ GIS layers systematically at 1:50K scale.

1.1 RATIONALE

The BGS Engineering properties dataset is a series of digital map layers based on the BGS Digital Geological Map of Great Britain at the 1:50,000 scale (DiGMapGB-50, BGS, 2009). Current coverage includes England, Wales and Scotland. It characterizes Bedrock and Superficial Deposits on DiGMapGB-50 in terms of their engineering properties. This report provides the methodology for creating a ‘use as engineered fill’ digital map for Great Britain.

2 Overview

2.1 WHAT IS ENGINEERED FILL

Fill is material that is moved from one place to another to raise land, landscape, backfill voids, construct foundation footings and construct embankments and for other reasons. The materials used need to be characterised using a series of mostly laboratory before material selection, emplacement and compaction. This may involve a number of processes including some compactive effort to provide the material with suitable characteristics.

2.2 WHO IS INTERESTED IN A SUITABILITY AS ENGINEERING FILL CLASSIFICATION MODEL

It is envisaged that suitability of engineered fill is of interest to a wide range of organisations concerned with development and construction including utility companies and organisations, local authorities, developers and engineering consultants and contractors.

2.3 WHAT IS THE PROJECT AIMING TO CREATE

The project is aiming to create a GIS spatial model of suitability as engineering fill information. It is part of a suite of GIS layers for different engineering parameters and information. It is based upon the lexicon (LEX), rock classification scheme (RCS) and the classification based on the Specification for Highway Works: Embankments (Highways Agency, 1991, 1991a), with the BGS DiGMapGB-Plus dataset and displayed via dictionaries of ‘suitability as engineered fill’.

The GIS model will allow **demonstration** of the spatial distribution of suitability as engineered fill. This covers England, Scotland and Wales. The GIS model could be incorporated into other BGS GIS datasets, products and/or created as a Value Added Reseller (VAR) product. The data related to use as engineering fill are collated and subdivided into ‘use as fill classes’ so that the project output can be used by many different users, with differing requirements.

3 Data Classifications

3.1 WHAT CLASSIFICATIONS ALREADY EXIST

The classification is based on the Highways Agency ‘Specification for High Works’ (Highways Agency, 1991, 1991a). This document is part of the Manual of Contract Documents for Highway

Works, which is provides the specification for all highway works in 6 volumes. This classification is used on site specific cases rather than nationally as it is here. This classification is further informed by the geological background for planning and development reports and in particular Bradford (Walters et al., 1996). The Highways Agency specification identifies the final use the relevant classes given in section 3.1.1.

3.1.1 Highways Agency 'Specification for Highway Works' Series 600: Earthworks

The classes of fill are general granular fill, general cohesive fill, selected granular fill, selected cohesive fill and chalk. Each has different specifications depending on the use. The properties required for use as fill for each class depend on the type of material.

3.1.1.1 General granular fill

There are three subclasses of general granular fill, well graded granular fill, uniformly graded granular fill and coarse graded granular fill. The material properties include a number of requirements and selection may be required for each subclass. The tests include the particle size grading, the uniformity coefficient, water content and moisture condition value. There is no specific requirement of the source of the material or combination of materials other than chalk should not be used in uniformly graded granular material.

3.1.1.2 General cohesive fill

There are four classes of general cohesive fill relevant to natural materials. They are wet cohesive material, dry cohesive material, stony cohesive material and silty cohesive material. Laboratory tests vary for the different subclasses and include particle size distribution, plastic limit, water content, moisture condition value and the undrained shear strength of the remoulded material. Any suitable material or combination of materials other than chalk can be used.

3.1.1.3 Chalk

Chalk and associated materials are a different class and chalk may be excluded from some fill uses for instance in general cohesive fill. Tests required for general fill include water content and in situ dry density.

3.1.1.4 Selected granular fill

Selected granular fill has many uses and in general the sources of the material are listed as natural gravel, natural sand, crushed gravel and crushed rock. The restrictions may exclude argillaceous rock in any constituent and for some uses chalk cannot be used in combination with any other constituent. There are a wide range of tests depending on the uses including particle size, uniformity coefficient, plasticity index, sulphate and oxidisable sulphides.

3.1.1.5 Selected cohesive fill

Selected cohesive fill in general includes any suitable materials or combination of materials. The sub classes include fill for structures, fill to reinforced soil and overlying fill for corrugated steel buried structures. In some cases argillaceous rocks is excluded. Tests can include grading, water content, liquid limit, strength information, organic content, oxidisable sulphides and water soluble sulphate content.

3.1.2 Guidance to geological units and 'use as fill' - A geological background for planning and development reports classifications

Several of the reports commissioned by the Department of the Environment during the 1980's and 1990's considered use as engineered fill for bedrock and superficial deposits. The geological units and where required, material types were classed as to their use as engineered fill. This included a class of rock fill that is not included in the Highways Agency classification. However, the term 'rock' (Highways Agency, 1991b) is used to describe a constituent to certain fills having durability and strength requirements. This class also implies that the rock may require crushing to the required particles sizes before use. Table 1 contains an example from the report content on Bradford (Waters et al., 1996).

Table 1. Suitability of deposits as engineered fill for the Bradford area (after Waters et al., 1996)

Suitability	Use as fill	Rock type	Comments
Suitable	Rock/ granular fill	Sandstones of the Millstone Grit and Pennine Coal Measures Group	May be suitable as rockfill if care is taken in selection and excavation. Use as high grade fill may be limited by variable amounts of clay and silt particles that may cement some of the sandstones and intercalated clay/mudstone bands. For compaction purposes, the sandstones are generally classed as graded granular fill.
	Granular fill	Glaciofluvial Deposits River Terrace Deposits	In some areas, near-surface deposits tend to be uniformly graded, becoming more well-graded with depth (e.g. in the Wharfe Valley).
	Cohesive fill	Mudstones and shales of the Bowland Shale Formation (Millstone Grit Group) and Pennine Coal Measures Group	Highly to moderately weathered mudstone and shales are generally classified as 'cohesive' fill and fresh to slightly weathered rock as 'dry cohesive fill'.
		Glacial Till (Yorkshire Dales Till Formation)	Should be suitable as cohesive fill if care is taken in selection and extraction. Laminated clays and silts, which may occur locally within the Till are generally unsuitable for use as fill, as may be the Till near water bearing sand and gravel beds.
Possibly/ partly suitable	Variable	Alluvium Glaciolacustrine deposits Head Hummocky Glacial Deposits Head	Alluvium, often with intercalated peat, are usually unsuitable for use but alluvial sand and gravels may be suitable if care is taken in selection and excavation. Hummocky Glacial Deposits, generally variable composition, may be suitable as granular fill. Fine-grained Head deposits may be suitable as bulk fill but may be too wet for compaction.
Not suitable	Organic soil	Peat	Highly compressible organic material

3.1.2.1 ADDITIONAL BEDROCK UNITS USE AS FILL

Other reports in the series and BGS reports provide guidance for other geological units use as fill and are list below:

1. Suitable as rock fill

   Brotherton and Cadeby formations (Magnesium Limestone) selection required, weaker material may be suitable for bulk fill only (Barclay et al., 1990, Lake et al., 1992).

2. Cohesive fill

   Roxby and Edlington formations – general fill (Barclay et al., 1990), Mercia Mudstone Group (mudstone) (Hobbs et al. 2002),

3. 'Dry' cohesive fill

   Manchester Marl Formation (Forster et al., 1995)

4. Coarse/granular fill

   Shirley Hill Sand Formation (Forster et al 1995)

5. 'General' fill

   Denstone, Keele, Newcastle and Etruria formations (sandstones) (Waine and Hallam, 1991), Collyhurst Sandstone Formation, Sherwood Sandstone Group (sandstones and gravelly sandstones) (Forster et al., 1995).

6. Sulphate/sulphide prone cohesive fill

   Lias Group - Mudstones (Hobbs, 2012).

7. Unsuitable

   Alluvium, Glaciolacustrine laminated deposits (Forster et al. 1995, Hines et al. 1991), Glacial silt (Hines et al. 1991)

3.1.2.2 OTHER CONSIDERATIONS

The concern over thaumasite attack of concrete has meant that sulphide and sulphate are now included in laboratory tested for certain types of fill (Highways Agency, 1991a). It is, therefore, necessary to identify those deposits that are likely to contain sulphate minerals, that is calcium sulphate (gypsum and anhydrite), and sulphide minerals, primarily iron sulphide (iron pyrites), that are likely to oxidise to produce sulphate ions when the material is used as fill.

3.2 CLASSIFICATION USED

The classification for 'use as fill' primarily follows the Highways Agency classification but informed by the methods previously used by the BGS. It also includes other characteristics such as the rock fill class and includes some indication of the higher value uses (see 3.3). Also, the term 'coarse' is used in preference to 'granular' as stated in the Highways Agency classification with reference to the BS5930 (BSI, 1999). The classification has to take into consideration the characteristics of geological units as defined by the Geological Lexicon and Rock Classification Scheme (LEX-RCS). Although many of the codes have similar material type others are more varied and multilithic. This variation is reflected in the classification. However, in some sites one material type will dominate but in others there will be different materials present covered by the same LEX-RCS code and separation of the different material types may be necessary. Some sandstones or breccias are weathered near surface or have varied cementing such as parts of the Upper Greensand producing a mixture of rock that may be used for rock fill and sand. Some heterolithic deposits, such as the Coal Measures Group, contain strong rocks classified as 'rock fill' and weak mudstone, which may be used as 'dry cohesive' fill.

Clays having a liquid limit exceeding 90% or a plasticity index of greater than 65% are generally unsuitable. The clays of the Fuller's Earth Formation and Sandgate Formation (lower Greensand Group) were both quarried for fuller's earth, which contain extremely high plasticity clay, and, which may be unsuitable. These units are identified as specialist clays. Specific parts of some geological units such as the Gault, London Clay and Speeton Clay formations have unacceptably high plasticity for some applications but may be suitable for others or may be blended with other materials. These cases are not classified separately as a vast majority of each of these formations are suitable. Materials that are generally unsuitable are identified and include peat, highly organic clay, which are too compressible and their characteristics may change with time, and deposits containing salt water such as tidal flat deposits are not normally used for engineering purposes.

The principal and secondary classes are listed below:

A. Materials that are generally easily extracted (mostly engineering soils)
    1) Mixed fine and coarse 'soil'
        a. Both fine and coarse beds, generally soil, 'cohesive' and 'granular' fill
        b. Both fine and coarse beds, generally soil, 'cohesive' and 'granular' fill, may be partly unsuitable for engineered fill
    2) Coarse 'granular' fill
        a. Geological unit likely to contain mixed or well graded sand and gravel
        b. Geological unit likely to contain more uniform sand or gravel
        c. Geological unit likely to contain mixed or well graded sand, gravel and cobbles
    3) Fine 'cohesive' fill
        a. Generally suitable for fine 'cohesive' fill
        b. May be used for 'dry cohesive' fill
        c. May be used as 'stony cohesive' fill
        d. Likely to be used for 'silty cohesive' fill
        e. Generally suitable for fine 'cohesive' fill but may contain sulphate or sulphide
        f. May contain extremely high plasticity clay and used for specialist uses or could be unsuitable unless blended with other material
        g. Cohesive material that may be too wet to use for engineering fill
B. Chalk or units likely to contain chalk
        a. Chalk (Southern Province Chalk)
        b. Chalk with flint (Southern Province Chalk)
        c. Northern Province Chalk
        d. Chalk and calcareous mudstone
C. Materials that have to be broken up by crushing before use – Rock fill
        a. Rock fill of similar rock type
        b. Rock fill, has been used for crushed rock aggregate
        c. Rock fill, has been used for higher value material than rock fill and crushed rock aggregate
        d. Rock fill, has different rock types that may have different uses

e. Rock fill may contain sulphate or sulphide

D. Mixed materials that may be easily extracted or require crushing prior to use

a. Mixed rock fill (sandstone, breccias) and coarse ‘granular soil’ (sand, gravelly sand, sandy gravel)

b. Mixed rock fill and cohesive fill or coarse ‘granular soil’

c. Mixed rock fill and cohesive fill or coarse ‘granular soil’, cohesive fill may contain sulphate or sulphide

E. Generally unsuitable for engineered fill but may have other uses

F. Unknown (no RCS available from DiGMapGB50v6)

Definition of terms in the above list:

‘**Soil**’ means engineering soil as defined in BS5930 (BSI, 1999)

‘**Granular**’ means coarse material defined in BS5930 (BSI, 1999)

‘**Cohesive**’ means fine material defined in BS5930 (BSI, 1999)

‘**Rock**’ fill means that the material is likely to require crushing before use.

The above classification has been interpreted for the GIS as in Table 2.

Table 2. Fill class and notes used in the Fill GIS

Fill Group	Fill class	Fill Use Notes
Mixed ‘soil’	0	Both fine and coarse beds, generally soil, 'cohesive' and 'granular' fill
	0A	Both fine and coarse beds, generally soil, 'cohesive' and 'granular' fill, may be partly unsuitable for engineered fill
Coarse ‘granular’ soil fill	1	Coarse 'granular' fill (sand, gravel, possible cobbles)
	1A	Well-graded sand and gravel 'granular' fill
	1B	Uniform-graded sand or gravel ‘granular’ fill
	1C	Well-graded coarse soil ‘granular’ fill containing cobbles
	1D	Generally coarse but may contain unsuitable material
Fine ‘cohesive’ fill	2A	Generally suitable for ‘cohesive’ engineering fill
	2B	Generally ‘dry cohesive’ fill
	2C	Mostly gravelly clay 'stony cohesive' fill, may contain sand and gravel beds or silt and clay beds
	2D	Silty ‘cohesive’ fill
	2E	Fine ‘cohesive’ fill that may contain sulphide or sulphate
	2F	Contains specialist clays commonly of very high or extremely high plasticity clay
	2G	‘Cohesive’ material that may be too wet for engineered fill
Chalk	3	Chalk
	3A	Chalk with flint
	3B	Northern Province Chalk
	3C	Chalk and calcareous mudstone
Rock fill	6	Rock fill but may have higher grade fill uses
	6A	Rock fill that has been used for crushed rock aggregate
	6B	Rock fill that has been used for higher value uses than rock fill or aggregate
	6C	Rock fill with mixed lithology, which may have different uses
	6D	Rock fill sometimes with mixed lithologies that may contain sulphide or sulphate
Mixed rock and ‘soil’ fill	7A	Mixed materials uses: Rock fill and/or coarse granular fill (coarse rock sandstone, breccias, conglomerate or sand, gravel)
	7B	Mixed rock fill and ‘cohesive’ or coarse fill.
	7C	Mixed rock fill and 'cohesive' fill sometimes coarse 'granular' fill, 'cohesive' fill may contain sulphide or sulphate
Unsuitable	8	Generally unsuitable may have special uses identified during the project or require extra processing
Unknown	9	Unknown rock type or unknown suitability

3.2.1 ‘Added value materials’

Some of the materials extracted as part of civil engineering activities will have additional value over and above use as engineering fill. Although it may not be practical to sell these materials to others as part of the project, the intention of this information is to indicate more specific uses as part of the project. Laboratory testing will generally be required in this assessment.

The UK has a variety of mineral resources that have considerable economic importance. Some of these resources are used in construction. There are many quarries and mines recently or currently active and they are listed in the in the BGS Britpits database (Cameron, 2011). Knowing the use of these materials not only identifies potential higher value use but indicates the potential use as engineered fill or other uses on site. Table 3 is a classification of extracted use. In some cases, only part of a geological unit will be suitable for the use specified particularly where it contains more than one material type. For instance, a geological unit comprising sandstone and mudstone

only the sandstone may be extracted perhaps for as a construction material. In other cases both may be used, sandstone for building stone and mudstone used for manufacturing bricks. Any assessment should be done at the site level. In many cases it would be impractical to use small amounts of material produced on a construction site that is not used on site and may require processing offsite increasing costs. However, in certain situations higher value material may be exploited.

Table 3. Uses of the geological units.

Use type	Description	Code
General aggregate	Used as general aggregate but may have high value uses	A
Crushed rock aggregate	Crushed rock aggregate	A1
Special aggregate	Aggregate with high value uses – railway ballast, road aggregate including high specification road aggregate, armour rock	A2
Construction sand	Building sand, concrete sand, asphalting sand	A3
Special sand	Silica sand, glass sand, foundry and moulding sand, blast cleaning sand	A4
Building materials	Building stone, slate, decorative stone	B
Construction clay	Brick, tiles, pipes	C
Special clay	Whiteware clay, ceramic clay	C1
Industrial clay	Paper making, fillers, fuller's earth	C2
Energy	Coal	D
Chemical industry	Gypsum, calcium carbonate (limestone, chalk), fluorspar, flux, cement	E
Peat	Horticultural	F
Unknown	Quarried but the use is unspecified in Britpits	G

4 Methodology

All DiGMapPLUS data sets follow a standard workflow for their creation. The workflow is outlined as a five stage process:

Stage 1: Source data/literature assessment and Dictionary definition

Stage 2: Lithological re-attribution

Stage 3: Spatial attribution

Stage 4: QA, QC and reattribution.

Stage 5: Standard BGS checking procedures and publication.

4.1 SOURCE DATA ASSESSMENT AND DICTIONARY DEFINITION

This activity is represented by a primary stage of literature review (to identify external standards and protocols, followed by a secondary stage to identify BGS-sourced (or publicly available) datasets that can contribute to the outputs. Finally there is a tertiary stage of 'Dictionary Definition' whereby the main characteristics of 'fill' (as defined by the literature review) and their possible definition/exemplification by available datasets (from the dataset review) are compiled into a list of specific 'definitions' (effectively 'rules') that we can use to identify classes of fill type and their relationship to lithological units.

4.1.1 Primary literature sources

The primary literature resource used to scope the internal/external requirement for 'use as engineering fill' are defined elsewhere in this document but are summarised broadly as follows:

1. Highways Agency Contract documentation for Highways works
2. BS5930
3. BGS Technical reports (various)
4. BGS specialist research reports (various)
5. Engineering papers (Various, multiple journals)

4.1.2 Primary datasets used

The primary datasets used for the 'use as engineering fill' GIS are:

1. Parent Material Map V6 dataset.
2. BRITPITS information.
3. National Geotechnical Properties Database.
4. DiGMapGB-Plus Strength.
5. DiGMapGB-Plus Excavatability
6. Engineering geology maps of the United Kingdom

The Parent Material Map contains attributed information for the following characteristics: Lithology, texture, mineralogy, strength, structure, colour, age, variability. Lithological type and variability are implicitly classified in the BGS Rock Classification scheme for each LEX-RCS code defined in the PMM. The strength and excavatability of the soils and rocks also has implications on the use in that it used to identify those materials that will require crushing prior to use and those that will behave as soils when worked by site machinery such as weaker mudstones and mixed sandstone and sand. Strength of rocks and soils are from the DiGMapGB-PLUS:Strength layers (Lee et al., 2011). It is necessary to consider the behaviour of materials used as engineering fill from near surface that may be may be weakened or altered by weathering and those that are less affected by weathering and including those that are from deeper cuttings and tunnels. Consideration is also given to the likelihood of the unit forming sulphate either because it contains a sulphate mineral, generally calcium sulphate as gypsum of anhydrite, or contains sulphides that, when oxidised due to weathering or during engineering reworking and emplacement, becomes calcium sulphate.

4.1.3 Dictionary Definition

At this stage, engineers and geoscientists synthesise already published classifications of engineering properties into textually 'mappable' domains, i.e. the range of fill types, and the criteria that define their use (or limitation) in the UK, as defined in published standards or

engineering papers/journals are ‘re-defined’ into a simple set dictionary of terms that can be directly related to available BGS map-resources and databases. For ‘Fill’ the ‘Specification for Highways Works’ Volumes 1 and 2 (1991) were extensively correlated onto BGS lithostratigraphic units (as defined within the BGS lexicon). This process identified essential ‘criteria’ outlined in the publications such as presence of sulphide/sulphate, strength etc and then identified either specific BGS data that could be used to ‘identify the units concerned, or a ‘proxy’ for the units concerned.

In general, DiGMapPlus datasets will use domains or classifications as defined by BS5930, or commonly used engineering publications. Where the dictionary concerns BGS-sourced information, the data is processed into the ‘simplest’ possible distribution of class types. In the case of BRITPITS uses this required a simple collation of all possible uses into a generally acceptable ‘listing’ of ‘use’ (i.e. and expert judgement to identify the commonly acceptable uses of the materials).

Dictionaries are generally created in Microsoft Excel and comprise fields for any **published** definition of a ‘code’ (e.g. “2E”), a full **description** of that code (e.g. “Cohesive Fill with Sulphide content) and a **definition** of the code (e.g. “A fine grained engineering soil with a known mineralogical content that contains or includes sulphide or sulphate compounds”).

4.2 LITHOLOGICAL RE-ATTRIBUTION

This activity is represented by ascribing the definitions identified and constrained from stage 1 onto known litho-types available across Great Britain. In many cases, it is either a simple analysis of spatially correlated observational data, or an extrapolation of known ‘behaviours/characteristics’ across ‘similar’ units (using expert judgement).

At this stage, a list of all unique LEX-RCS values present in the Parent Material Map, that are relevant to the data set are assessed. The purpose of the assessment is to assign one or more of the defined dictionary terms to each LEX-RCS code, so that it ‘adequately’ represents the deposit nationally.

For ‘Fill’, each LEX-RCS code is assigned its most common or most relevant ‘Fill’ code. For example, BCMU-MDST is assigned a code of ‘2E’ because samples from the Branscombe Mudstone Formation (BCMU) formation have been observed and tested recorded for the mudstone (MDST) component and they comprise cohesive materials, with potential for sulphide/sulphate content. Some key formation across Great Britain will have multiple samples available and these are ‘synthesised’ into the most appropriate grouping or range of descriptions.

Where a geological unit has no known sampling (or evidence to support a particular classification) the engineers and geologists will use their expert judgement to allocate the most ‘likely’ attribution for that unit. This expert judgement utilises a number of factors, primarily similarity with other lithotypes (age, type, mineralogy) as well as ‘local knowledge’.

For the ‘Alternative uses’ definitions a spatial assessment of BRITPITS locations associated with their LEX-RCS code has been made (i.e. each BRITPIT location has been assigned a LEX-RCS code relevant to its location), and each BRITPIT location has been categorised into one or more classes of use ‘Use types’. For example, The BCMU-MDST unit has been noted (across its crop) to have been used in BRITPITS for the manufacture of construction clays (Bricks, Tiles, Pipes).

Lithological attribution tables are generally created in Microsoft Excel and comprise a unique listing of LEX-RCS codes and a one-to-one listing of ‘codes’ relating to the Fill or alternative Fill dictionaries.

4.3 SPATIAL ATTRIBUTION AND CHECKING (GIS CREATION)

At this stage, the spatial framework (the Parent Material Map v6) is 'joined' to the relevant DiGMapGB+ 'Fill' dictionary via the LEX-RCS field primary key. A further join is then made to ensure that each lithological unit is joined to its correct 'Alternative-use' dictionary definition.

Spatial joins are a standard function in ARCGIS (and many other GIS). It is usual practice to 'materialise' the joined files into a single 'flat' database (the contents of this materialised view are detailed in section 7 below). The 'flat' file forms the basis of the new FILL product.

The flat file receives a final review of its data structure to remove any extraneous data that is not directly relevant to its purpose (the spatial framework is derived from the Parent Material V6 data set, any attribute content relating to PMM, but NOT to FILL is removed).

4.4 QA, QC, REATTRIBUTION AND FINAL PUBLICATION CHECKS

At this stage, basic QA and QC procedures are followed to ensure that all spatial objects are correctly reattributed with the required 'Fill' information. The spatial distribution of the proposed 'Fill' information is re-evaluated to assess where further amendments may be required to address local-regional variations in geological-material type, or engineering practice.

Any corrections that are required are made via the Lithological-reattribution process (stage 2). The checking and reattribution phase is iterative (i.e. stages 2 – 4 are repeated until it is considered that the data is as representative of known information (expert judgement), as is possible). When the project engineer and GIS team are happy with the data, it is submitted for final BGS publication procedures

4.5 STANDARD BGS CHECKING AND PUBLICATION PROCEDURES

All DiGMapGB+ datasets are published via a final series of standardised checks.

These are checks include tests for

- Data completeness
- Data cleanliness
- Data Documentation
- Scientific sign-off
- Data management sign off

The standard checks are available in
https://ishare.apps.nerc.ac.uk/teams/gis/bgs_datachecking/Wiki%20Pages/Home.aspx

5 GIS Content

The GIS data was processed using ArcGIS 9.3. A materialised view of all contributing spatial and textual data is created using standard ARCGIS tools.

The dataset covers Great Britain (England, Scotland & Wales) with the exception of the Isle of Man.

The map is processed with a British National Grid Projection. Other projections are possible.

The following fields are visible to end-users:

General lithology (GEN_PMLITH)
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).

Use as engineering fill (FILL_CODE)

This is the code used by BGS to identify a type of 'use as engineering fill'. It is provided to enable identification of properties of a geological unit and for data management purposes (this code is a unique identifier of the Fill 'Details' field, see tables below).

Use as engineering fill (FILL_TYPE)

This is a description of the broad type of 'engineering fill' associated with the geological materials. The following values are used:

Table 4. Explanation of the 'fill type' descriptor

Fill Code(s)	Fill type	Meaning
0,0A	Mixed 'soil' fill	Mixed coarse and fine engineering 'soils'
1,1A,1B,1C,1D	Coarse 'granular' soil fill	Coarse-grained engineering soils
2A,2B,2C,2D,2E,2F,2G	Fine 'cohesive' fill	Fine-grained engineering soils
3,3A,3B,3C	Chalk fill	Chalk materials
6,6A,6B,6C,6D	Rock fill	Generic 'rock' materials
7A,7B,7C	Mixed rock and 'soil' fill	Mixed 'rock' and engineering 'soil' materials
8	Unsuitable for fill	Unsuitable for fill (contains unsuitable materials, i.e. Peat)
9	Unknown	Rock/Soil type is unknown, suitability is not yet known, or site is located in a body of water

Use as engineering fill (FILL_USES)

This is a description of the typical USE of the 'engineering fill' associated with the geological materials. It is a slightly more informative version of the FILL_TYPE field as it identifies key 'fill' characteristics that are important to test for, or ascertain, at an early stage of site investigation. For example it identifies fill types that may be 'partly' unsuitable. See the DETAIL section below for further description).

Use as engineering fill (DETAIL)

This is a verbose description of the 'engineering fill' associated with the geological materials. It is a more descriptive and informative version of the FILL_USE and FILL_TYPE fields as it identifies key 'fill' characteristics that are important to test for, or ascertain, at an early stage of site investigation. It outlines the full range of subdivisions of fill-use in this dataset. The following values are used.

Table 5. Description of the engineering fill materials

FILL_USES	DETAIL
Mixed 'soil' fill	Both fine and coarse beds, generally soil, 'cohesive' and 'coarse' fill
Mixed 'soil' fill (partly unsuitable)	Both fine and coarse beds, 'cohesive' and 'coarse' fill, may be partly unsuitable for engineered fill
Coarse 'granular' soil fill	Coarse 'granular' fill (sand, gravel, possible cobbles)
	Well-graded sand and gravel 'granular' fill
	Uniform-graded sand or gravel 'granular' fill
	Well-graded coarse soil, 'granular' fill containing cobbles
Coarse 'granular' soil fill (partly unsuitable)	Generally coarse, may be partly unsuitable material
Fine 'cohesive' fill	Generally suitable for 'cohesive' engineering fill
Fine 'cohesive', dry fill	Generally 'dry cohesive' fill
Gravel clay	Mostly gravelly clay 'stony cohesive' fill, may contain sand and gravel beds or silt and clay beds
Fine soil (silty)	Silty 'cohesive' fill
Fine soil (sulphide/sulphate)	Fine 'cohesive' fill that may contain sulphide or sulphate
Fine soil (specialist clay)	Contains specialist clays commonly of very high or extremely high plasticity clay
Fine soil ('wet')	'Cohesive' material that may be 'too wet' (in its typical natural state) for engineered fill.
Chalk fill	Chalk
	Chalk with flint
	Northern Province Chalk
	Chalk and calcareous mudstone
Rock fill	Rock fill but may have higher grade fill uses
	Rock fill that has been used for crushed rock aggregate
	Rock fill that has been used for higher value uses than rock fill or aggregate
	Rock fill with mixed lithology, which may have different uses
Rock fill (sulphide or sulphate)	Rock fill sometimes with mixed lithologies that may contain sulphide or sulphate
Mixed rock and soil	Mixed materials uses: Rock fill and/or coarse 'granular' fill (coarse rock sandstone, breccias, conglomerate or sand, gravel)
	Mixed rock fill and 'cohesive' or coarse 'granular' fill
Mixed rock and soil (sulphide/sulphate)	Mixed rock fill and 'cohesive' fill sometimes coarse 'granular' fill, 'cohesive' fill may contain sulphide or sulphate
Unsuitable for fill	Generally unsuitable may have special uses identified during the project or require special processing
Unknown	Unknown material or suitability

Use of the unit as identified from BRITPITS (OTHER_USE)

The possible alternative or recorded use of the geological materials as found in BRITPITS. There are multiple entries where the units are used for different purposes. This may be for the same lithology or for different lithologies found at the quarry/pit (at different depths). Note that this does not mean that the entire unit is used for that purpose, in many cases, only part of the unit may have alternative uses. The following descriptive terms are used:

- Used as general aggregate (but may have high value uses)
- Rocks that require crushing prior to use,
- Aggregate with high value uses (railway ballast, road aggregate, armour rock),
- Building sand, concrete sand, asphalting sand
- Silica sand, glass sand, foundry and moulding sand, cleaning sand,
- Building stone, slate, decorative stone,
- Bricks, tiles, pipes
- Ceramic clay, Pottery (whiteware),
- Paper making, fillers, fullers earth

- Coal
- Gypsum, calcium carbonate (limestone, chalk), fluorspar, flux, cement
- Peat products
- Quarried (unspecified use in Britpits)

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. It is part of the fundamental metadata of the original Parent Material Map V6 dataset. 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:

Table 6. Nominal scales of geological maps at which the data used is captured.

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

Two additional fields were created to contain map metadata:

UID

This is a unique object identifier based on DNF notation and arc indexing using a field calculation based on the following pseudo code: “bgsn:DPF_V6_” & FID.

VERSION

This is a layer identifier based on BGS standard practice using a field calculation based on the following pseudo code: “DiGMapPlus_Fill_V6)

The dataset was then submitted for the usual BGS data checking procedures.

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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.

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