BGS DIGITAL

User Guide:

BGS GeoScour v2

Open report OR/21/046

British Geological Survey

BRITISH GEOLOGICAL SURVEY

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Front cover
Till with some areas of bedrock exposed (interbedded mudstone and siltstone), directly below the A66. River Greta south of Wescoe. Photo: Kathryn Lee.

Bibliographical reference

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BRITISH GEOLOGICAL SURVEY

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The British Geological Survey is a component body of UK Research and Innovation.

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Foreword

The British Geological Survey (BGS) is a world-leading geological survey, focusing on public-good science for Government and research to understand earth and environmental processes.

We are the UK's premier provider of objective and authoritative geoscientific data, information and knowledge to help society to:

- use its natural resources responsibly
- manage environmental change
- be resilient to environmental hazards

We provide expert services and impartial advice in all areas of geoscience. As a public sector organisation, we are responsible for advising the UK Government on all aspects of geoscience as well as providing impartial geological advice to industry, academia and the public. Our client base is drawn from the public and private sectors both in the UK and internationally.

The BGS is a component body of the Natural Environment Research Council (NERC), part of UK Research and Innovation (UKRI).

DATA PRODUCTS

BGS produces a wide range of data products that align to Government policy and stakeholder needs. These include baseline geological data, engineering properties and geohazards datasets. These products are developed using in-house scientific and digital expertise and are based on the outputs of our research programmes and substantial national data holdings.

Our products are supported by stakeholder focus groups, identification of gaps in current knowledge and policy assessments. They help to improve understanding and communication of the impact of geo-environmental properties and hazards in Great Britain, thereby improving society's resilience and enabling people, businesses, and the government to make better-informed decisions.

Acknowledgments

This report is the published product of a study by the British Geological Survey (BGS) to produce digital datasets depicting the range of geological properties and processes prevalent along the watercourses of Great Britain. The methods used to derive the data were determined by a team of specialists with a broad range of expertise from satellite analysis, engineering geology to landform analysts and statistical modellers. The team includes the following BGS staff (in alphabetical order):

Clive Cartwright, Antonio Ferreira, Henry Holbrook, Andrew Hulbert, Russell Lawley, Katy Lee, Kathrine Linley, Jennifer Richardson, Rob Shaw; Severine Cornillon (previous BGS employee); Agathe Le Floc'h (student).

A large number of individuals in BGS 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 expert knowledge. Of the many individuals who have contributed to the project we would particularly like to thank the following:

Richard Haslam, Timothy Kearsey, Rhian Kendall, Jonathan Lee, Oliver Wakefield, Chris Williams, Katie Whitbread.

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Summary

Developed by the British Geological Survey (BGS), the GeoScour data product informs users and stakeholders about a broad range of geoproperties and processes of riverine environments of Great Britain.

GeoScour is for water companies, catchment management partnerships, Local Authorities, asset owners, hydraulic modellers and researchers who want to underpin their riverine decision making and planning relative to river erosion and catchment evolutionary processes.

BGS GeoScour offers an integrated GIS package of datasets designed to inform and support catchment management and riverine modelling to aid resilience and adaption planning. This means that users can assess morphology, behaviour, and vulnerability of riverine environments, underpinned by the geological and catchment context.

Unlike other catchment and riverine datasets, BGS GeoScour offers a consistent national assessment that includes a detailed analysis of the variation and erosion potential of the riverine sediments and lithologies, especially in complex geological terrains.

The datasets are provided as three packages: Tier 1 and 2 are catchment-level data and Tier 3 datasets are detailed riverine assessments of the geological properties and susceptibility to river scour.

An assessment of the natural riverine properties is key to understanding how to adapt. Our geological knowledge, authoritative source of information, in-house research, and track-record in delivering data products to stakeholders for over 20 years, results in the provision of a key data package that will benefit many users.

The purpose of this user guide is to provide basic information about these datasets, the nature and diversity of geo-properties of the GB catchments and river systems and to act as a quick-start guide to using and understanding this BGS GeoScour dataset product.

1 Introduction

1.1 THE BGS GEOSCOUR DATA PRODUCT

The BGS GeoScour datasets provide an assessment of the natural characteristics and properties of catchment and riverine environments for the assessment of river scour in Great Britain.

River scour can be a threat to in-river structures such as bridges and adjacent riverside assets. Increasing frequency and intensity of storm events could impact on the rivers potential to erode banks and beds. These GIS datasets are designed to be integrated into broader-scale catchment management planning and riverine hydrological assessments, monitoring to highlight areas of potential risk and to inform maintenance regimes or adaptation.

The GeoScour Data Product is a national to local scale scour assessment (based on the variable geological properties) at catchment and sub-catchment scale that will allow users to identify a) catchments with higher erosion activity due to landscape evolution and river sinuosity; b) identify sub-catchments that have a higher risk of scour due to the river morphology, underlying geological factors and catchment size (e.g. ability to shed or retain water); and c) identify specific sections of a given river to higher potential for scour (present day).

It is based on the outputs of numerous BGS research programmes, stakeholder advice and data analytics to provide data sufficient for users to analyse and assess a range of riverine risks.

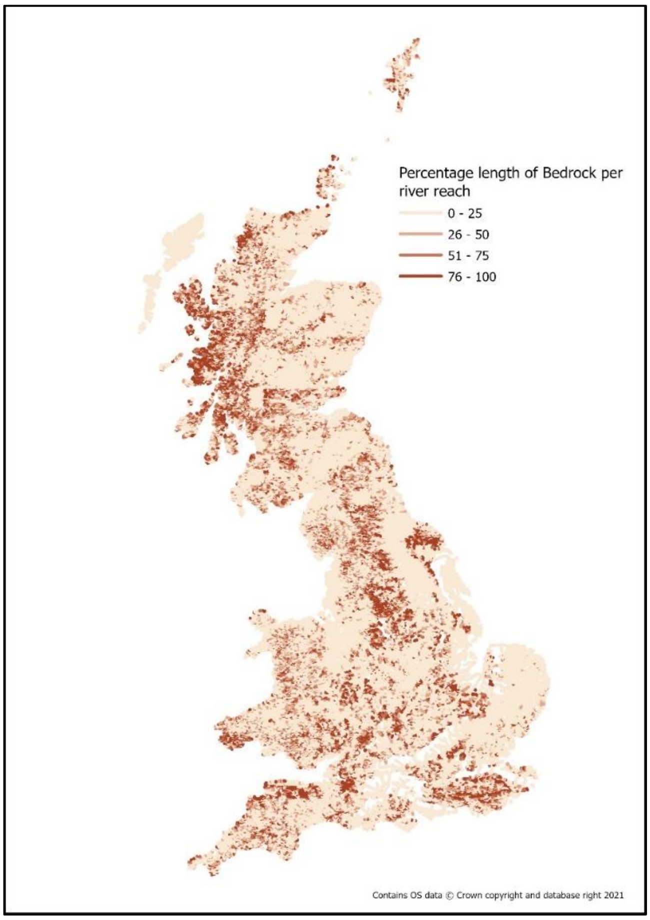
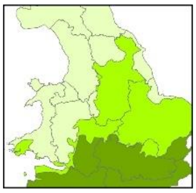


Figure 1 Example dataset showing the national coverage of the GeoScour data product.

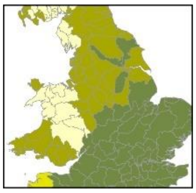
This data product and accompanying document provides information for users on the ***natural*** characteristics and properties of catchment and riverine environments for the assessment of river scour in Great Britain. GeoScour looks specifically at the geological factors that influence scour and does not consider any hydraulic or hydrodynamic factors. Tier 1 and 2 are designed as an overview for river management and Tier 3 riverine data are designed to provide input data into detailed hydraulic modelling algorithms.

1.2 WHAT DOES GEOSCOUR INCLUDE

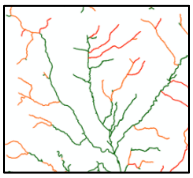
The GeoScour Data Product is designed to be used by multiple stakeholders with differing needs and therefore, can be interrogated on several levels.



Tier 1 dataset provides a summary overview of the catchment characteristics, typical response type, and evolution. It can be used to provide a high-level overview for incorporation into catchment management plans, national reviews, and catchment comparisons.



Tier 2 datasets are available as smaller catchment areas and focus on providing data for more detailed catchment management, natural flood management and similar uses. It analyses geological properties such as flood accommodation space, geological run-off potential and geomorphology types, as well as additional summary statistics for worst, average, and best-case scenarios for underlying surface scour susceptibility.



Tier 3 datasets provide detailed riverine information that is designed to be incorporated into more complex river scour models. It provides the baseline geological context for river scour development and identifies important factors that should be considered in any scour model. Factors such as material mineralogy, strength and density are key properties that can influence a river's ability to scour. In addition, an assessment of river fall, sinuosity and flood accommodation space are also provided. These datasets are of use to those assessing the propensity for river scour for any given reach of a river across Great Britain and can be used as an input into hydraulic/hydrodynamic models.

1.2.1 GeoScour Open

Tier 1 – Catchment level: consists of one dataset which identifies and describes the relative catchment-scale characteristics in terms of landscape evolution, sediment availability and typical response in flood conditions:

- Catchment Stability (1:625 000 scale)

Tier 2 – Sub-catchment level: consists of a suite of 8 sub-catchment datasets (1:250 000 scale) including:

- Catchment Flood Accommodation
- Catchment Morphology
- Catchment Surface Geology Susceptibility layers:
    - Catchment Surface Geology Susceptibility **Average**
    - Catchment Surface Geology Susceptibility **Best**
    - Catchment Surface Geology Susceptibility **Worst**
- Catchment Designated Sites
- Catchment Geological Run-off Potential
- Catchment Urban Coverage

1.2.2 GeoScour Premium

The Premium licenced dataset contains all the datasets in the Open data plus additional detailed datasets at the Tier 3 riverine level.

Tier 3 consists of 9 layers at riverine level (1:50 000 scale):

- River Geological Properties
- River Morphology
- Surface Geology Susceptibility layers:
  - Surface Geology Susceptibility **Average**
  - Surface Geology Susceptibility **Best**
  - Surface Geology Susceptibility **Worst**
- Bedrock Geology Susceptibility layers:
  - Bedrock Geology Susceptibility **Average**
  - Bedrock Geology Susceptibility **Best**
  - Bedrock Geology Susceptibility **Worst**
- River Lateral Erosion

1.3 WHAT IS GEOSCOUR USED FOR

GeoScour provides a national-scale, geologically-influenced, scour susceptibility map for Great Britain by using a nested framework model to determine a 3-tiered data provision allowing increasing levels of understanding at different resolutions from catchment to local (channel/reach) scales. This is designed to feed into decision support tools and hydrological modelling. GeoScour will be useful for stakeholders, especially when used in conjunction with river velocity, dynamics, etc. to advise asset owners or managers (responsible for bridge infrastructure e.g. local authorities) on whether they need to undertake further work on the threat of scour. This will also be transferrable to owners/advisors of other infrastructure assets that are situated on or close to rivers. As well as bridges and the utilities that cross them, this includes infrastructure proximal to rivers such as road, rail, transmission towers and communications.

Geology: a key component of the river scour assessment

Geology varies considerably across Great Britain and has strongly influenced the form and evolution of our river catchments. Catchments are continually changing and evolving over time, sometimes very slowly with limited visible change, others with sudden or rapid changes reflecting dynamic events such as floods and landslides. Landscape morphology/topography and river processes are intrinsically linked to geology because the geology regulates the susceptibility of the channel bed and banks to erosion, plus how much stream power is used by the river to scour rather than transport material. Where hard rock catchments exist, valleys tend to be steep and narrow as the power of water flow gradually erodes and scours downwards. By contrast, in catchments where low durability rocks and sediments occur, rivers tend to develop wider valleys with broad flood plains. Scouring is likely to be ongoing during normal flow but highly-variable (both temporally and spatially) during transient flow conditions. The parameters assessed in this data product reflect variations in the geology across the country and allow a more informed analysis of the geological potential for scour to occur.

1.4 WHY WAS GEOSCOUR DEVELOPED

Following severe storms and flooding over successive winters, the BGS recognised river scouring as an important threat to in-river structures such as bridges. We also identified a gap in current scour modelling, with the geological deposit material having little influence or consideration in current modelling algorithms; this dataset aims to address those gaps. Vulnerability of river banks to erosion is poorly understood, even though consequences can mean sudden and catastrophic failure. Dwindling resources, particularly the public sector, are a major barrier to tackling this growing problem. This data product provides an improved toolkit to more easily assess and raise the profile of scour risk, now and in the future, to help infrastructure providers and funders prioritise resources, identify remedial works to preclude costly and preventable disruptive failures. The GeoScour data product has broad applications through its adaptation to suit multiple types of assets likely to be affected by fluvial erosion. The underpinning information will also assist other environmental professionals seeking to identify the role of 'change' in the sedimentary environment, including remodelling of river channels and defences.

Timeliness: During winter 2015/16 Storm Desmond caused widespread damage to bridges across Cumbria (repair bill of c.£4m). The National Park suffered 257 damaged bridges, with consequent disruption lasting months. Similarly, a total of £3m was approved for remediation following damage caused by Storm Frank across Scotland in 2016. Scour related damage and failure, results in costly repair, isolation of communities and impacts the infrastructure co-located on bridges. The bridge collapse at Tadcaster, Yorkshire (2015) provides a typical illustration of this with repair works costing £4.4m, and the community affected for 13 months, with costs of disruption estimated to be a further c. £5 million.
Understanding of the effect of geological conditions on the processes involved in river scour and erosion and the potential impacts is increasing. Recent increases in extreme events are mostly recognised by the flood impact where homes and assets are widely affected. However, part of these flood events also involved the often overlooked scour of river banks. This affects riverine structures such as bridge piers, utility crossings, and natural deposits. Where these natural deposits are prone to removal under extreme events, adjacent assets may then come under threat (e.g. Tadcaster Bridge, River Wharfe, Yorkshire, also Abergeldie Castle, River Dee, Scotland, and Cockermouth, Cumbria or more recently, Grinton, North Yorkshire).

Change to current practice: Identifying geologically-influenced scour zones at sub-catchment resolution will allow users to make better-informed decisions for particular reaches of each river system. This will enable them to create or compile specific advice in terms of recommended investigations, monitoring, mitigation, or resilience planning as well as identify gaps in knowledge where further investigation might be needed.

Benefits: the key benefits of GeoScour will be in minimising unnecessary mitigation work and provide 'hot spots' of potential risk areas, saving time associated with fewer manual site visits and risk reduction by mitigating asset defences etc. where needed. It can be used as part of a screening or planning tool, and the outputs of this work, when integrated within the river assessment workflows of our intended user base, will help prioritise remedial action, or help define structures at most risk, thereby reducing bridge damage/failure events and potentially saving the costs of rebuild (costs described above), diversion, and disruption (e.g. loss of tourism).

River scour hazards may lead to financial loss for anyone involved in the ownership or management of property, including developers, householders, or local government. These costs could include increased insurance premiums, depressed house prices and, in some cases, engineering works to stabilise land or property. These hazards may also impact on anyone involved in the construction of large structures (deep foundations), infrastructure networks (road or rail) or utility companies. The 3D properties of these materials can be used to identify potential problems at surface, in the shallow sub-surface or deeper underground (e.g. tunnels). Armed with knowledge about potential hazards, preventative steps can be put in place to alleviate the impact of the hazard to people and property. The cost of such prevention may be very low and is often many times lower than the repair bill following ground movement.
The identification of ground instability and other geological hazards can assist regional planners; rapidly identifying areas with potential problems and aid local government offices in making development plans by helping to define land suited to different uses. Other users of these datasets may include developers, construction companies, consulting engineers, builders, homeowners, solicitors, loss adjusters, the insurance industry, architects, and surveyors.

1.5 HOW TO USE THIS USER GUIDE

The purpose of this user guide is to provide a quick start guide to using the GeoScour datasets. A brief overview of the methodology and source datasets used is provided (chapter 3) for understanding the components and data development process. Chapter 4 then details the specific content for each dataset, explaining the attributes and formats. We also provide a case study example to briefly describe how the datasets might be used (chapter 2).
Limitations and notes about accuracy of the data are described in chapter 6 however some key points to note include:

- The data product is based on the natural geological properties and does not take into account artificial features such as flood defences.
- All datasets are hung off the OS Open Rivers WatercourseLink for a consistent GB-wide baseline. This means that the riverine properties will be attribute to this data, which may differ slightly from the exact river locations depicted on different scale OS maps.
- Selected visualisation (layer) files have been provided to help display the datasets, but other attributes are available. Multiple layer files can be based on a single dataset shapefile, the layer files simply highlight one of the attributes.
- Inherent gaps or changes in geology code will be evident in some places as a result of the source datasets used (both BGS and external datasets).

This user guide is not intended as a full method review and peer review research document, however appropriate references are provided. Where appropriate, the BGS will publish its scientific research in peer reviewed journals.

2 Case studies

This chapter provides a specific case study example to describe a set of issues and challenges relevant to stakeholders and explain how the datasets could potentially be used in such a situation. In this section we focus on a specific bridge, Tadcaster, which was damaged in storm events causing long-term infrastructure and access issues, as well as a broader catchment analysis, demonstrating the potential uses of the GeoScour datasets.

2.1 CASE STUDY 1: TADCASTER BRIDGE

2.1.1 The Problem

Winter storms over previous years have resulted in several bank and bridge collapses across the country with many events hitting the headlines, and costing hundreds of thousands of pounds to assess and remediate. An example is Tadcaster Bridge (Grid ref: 448746, 443453) that collapsed into the River Wharfe during late evening 29th December 2015. This Grade-II listed bridge was seriously damaged and had repairs estimated at £3 million. Bridges also carrying services and the gas main were fractured when the bridge collapsed. Scour was identified as the main cause of the damage.

The bridge is a historic, nine-arch masonry road bridge, that carries the A659 (formerly the A64 main York to Leeds road) over the River Wharfe in the centre of Tadcaster. On that December evening part of its upstream side collapsed into the river which was heavily swollen as a consequence of record rainfall amounts deposited across much of northern England by Storm Eva a few days previously.

2.1.2 The Challenge

Whilst an understanding of river flows during flood events is very important, these are often created without an appreciation of the stability of the sediments within the river itself. This is heavily connected to the geology underlying the river, of which BGS has considerable knowledge. Many bridges across the country are of concern and whilst the more modern constructions carrying major infrastructure are well-engineered and maintained, there are a large number of historic structures that often have very little foundation support and are of increasing concern, both to asset owners, and advisory organisations as evidenced in the statement provided below from the organisations that look after our historic environment.

> *Historic bridges constitute a common yet frequently overlooked building typology. They are a major component of our national infrastructure network and are vital to local communities and the economy. They serve a range of functions; as well as providing crossing points they can act as conduits for services, including the internet, telephone, and utilities. Many bridges also possess historical, architectural, cultural, and aesthetic value, and are important features in the landscape.*
>
> *Information is available on the vulnerability of water courses to flooding, but the vulnerability of bridges to erosion is less well understood, even though the consequences can mean sudden and catastrophic failure. Anecdotal evidence suggests that the incidence of scour of historic bridges is on the rise and it is anticipated that this will accelerate as a result of climate change, putting pressure on the infrastructure network. This comes on top of existing problems seen in many bridges as a result of inappropriate management and lack of maintenance.*
>
> ***CADW, Historic Environment Scotland and Historic England (pers comms).***

2.1.3 The Solution

The BGS GeoScour data product has been developed as a screening tool that stakeholders can either use directly e.g. Water Company, or to advise asset owners on whether they need to undertake monitoring or further work on the threat of scour. This will be transferrable to other asset owners to assess the vulnerability of infrastructure which is situated on or close to rivers. As well as bridges and the utilities that cross them this includes structures such as electricity towers (pylons).

Tadcaster Bridge is situated on relatively young geological deposits, which lie on the bedrock in many areas. They include deposits such as unconsolidated sands and gravels formed by rivers, and clayey tills formed in relation to glacial processes. They may be overlain by landslide deposits or by artificial deposits, or both. The underlying bedrock is the Brotherton Formation, which consists of dolomitic limestone. Where bridge piers are founded directly on the limestone bedrock, additional stability issues to consider include localised dissolution of this potentially soluble bedrock.

Map images and air photos indicate a mid-channel bar located midway along the bridge. Field maps and images from aerial photography also suggest that the bar has changed form and moved position over time. This suggests that the alluvial material is reasonably mobile, and it is evident from geological mapping that the width of the channel has changed over time, possibly due to artificial land reclamation along the banks.

From an assessment of the GeoScour datasets, this bridge falls within the River Wharfe and Lower Ouse catchment and is classed as a Type 2 river system (see **Figure 4**), comprising a mobile alluvial tract overlying a soluble bedrock. In these catchments, higher magnitude events will have a potentially greater and unpredictable effect.

The Tier 2 data can be useful for catchment management planning and regional assessments. This catchment is classed as having a ‘hill and vale’ morphology type, comprising undulating morphology of hill and valley, with local preservation of thick Quaternary deposits within valleys, and weathered bedrock in upland areas. The valleys can be underlain by thick sequences of Quaternary deposits, dominated by fluvial sequences.

The catchment covers an area of 1.32M km^2 of which there is ~500,779 km^2 that is potential low-lying floodplain adjacent to the river tracts.

The catchment also contains 369 designated sites (e.g. SAC, SPA and SSSI), accounting for ~ 15% of its total catchment area, and ~70% of the area has a low run-off potential with low overland flow unless the ground is excessively dry or already saturated. Its urban coverage is classified into 18 large urban areas (covering ~31,136km^2) and 133 small urban areas (covering ~39,732km^2).

The GeoScour data tells us that the River Wharfe at this location is classed as a medium dense deposit (superficial) with a ***medium*** susceptibility (surface geology) to river scour (taking the average score) and ***medium-high*** susceptibility (taking the worst-case score).

The lateral erosion in this area remains at a ***medium-high*** susceptibility (taking the worst-case score) within 5 m of lateral bank erosion (not accounting for any artificial defences), this susceptibility remains the same until there is c. 50 m of lateral erosion and then the class increases to High susceptibility due to a change in the bedrock geological properties.

The bedrock scour susceptibility is also classed as ***medium-high*** susceptibility (average-case score).

This data can be used within catchment management planning practices, for Local Authority planning use or for asset maintenance when interrogated against specific asset types or locations.

2.2 CASE STUDY 2: A BRIDGE SUSCEPTIBILITY ASSESSMENT, CONWY CATCHMENT

2.2.1 The Problem

GB river catchments often have a broad range of geological deposits, river profiles and floodplain accommodation space for floodwater to escape to. Along the waterways within these catchments span a diverse mix of historic and more modern bridges, primarily for road and rail but also for utilities such as pipelines and cables.

A desk study analysis using GeoScour can quickly identify potential areas or deposits that are susceptible to scour and where those areas coincide with bridge structures.

2.2.2 The Challenge

Bridge maintenance regimes require regular site visits to determine the stability of a structure and its surrounding river banks and foundations. This process can be time-consuming and costly. GeoScour looks to help streamline the process according to the geological susceptibility of the associated deposits, bedrock, and superficial properties.

The information can be combined with structural data from the bridge piers and foundations themselves to provide a more informed susceptibility assessment. Taking this a step further, the GeoScour Tier 3 data can be input into a hydraulic modelling assessment to create a potential risk ranking.

2.2.3 The Solution

Using the Conwy catchment in North Wales as an example, there are some 335 bridge structures (such as **Figure 2**) located along a stretch of river classed as medium to high susceptibility to river scour. Hotspot maps can quickly be generated to inform about specific locations that would merit further investigation such as identifying the age and construction, as well as whether there are any defences in place such as culverts, rock gabions or reinforcements.

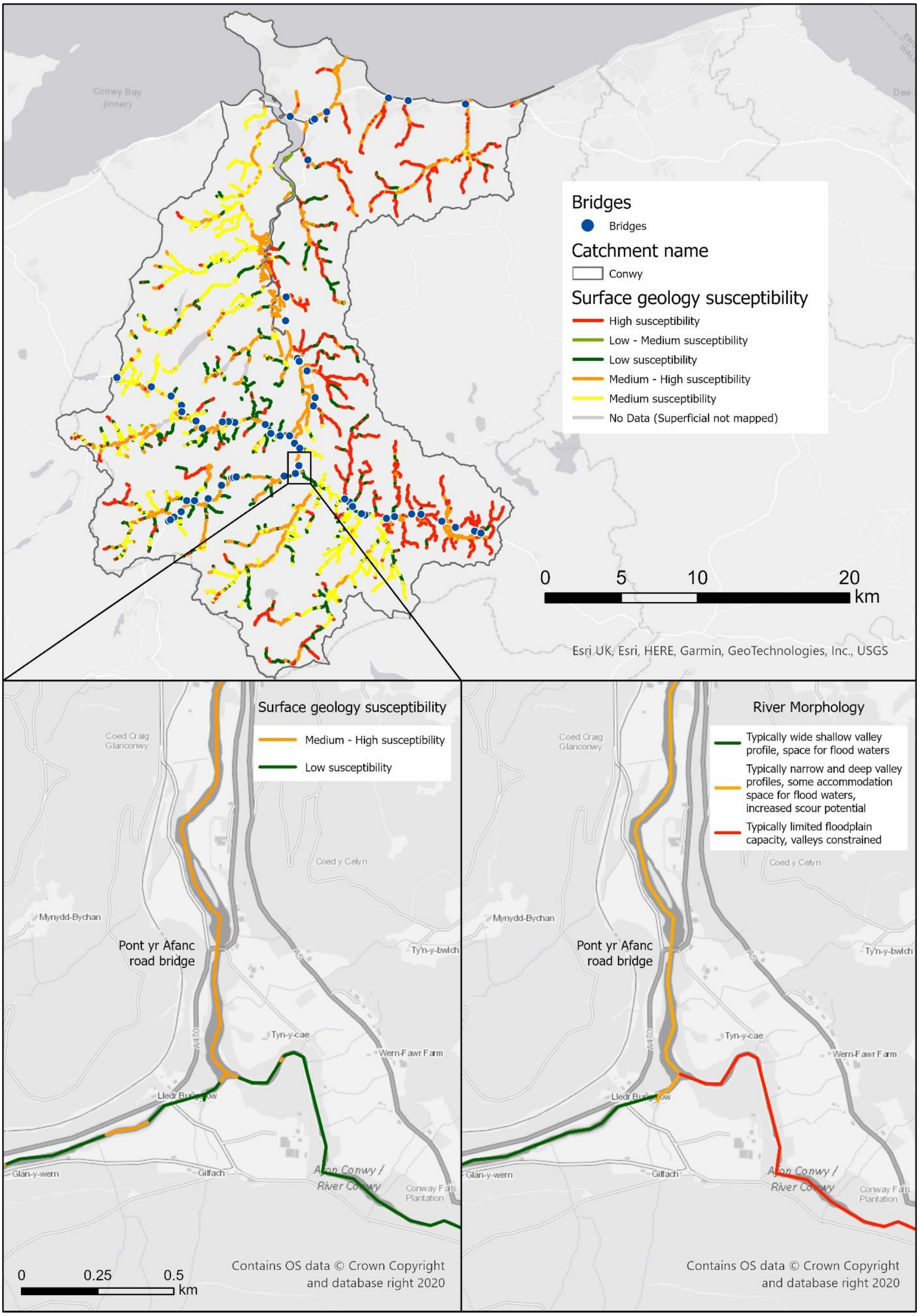


Figure 2 An example at Pont yr Afanc road bridge, on the A470 over the River Conwy.

Once a user has identified the potential assets at risk, a further analysis can then be carried out across the network to assess whether there are further potential issues in terms of critical assets (e.g. pinch points, traffic flow, supplies, connectivity). Maintenance regimes can be adapted, potentially reducing the number of site visits necessary and increasing efficiency for asset managers, and the network can be analysed for connectivity dependencies e.g. pipelines crossing bridges, critical roads, or major transport routes.

3 Methodology

3.1 OVERVIEW

The GeoScour data product presents data at 3 scales, Tier 1 and 2 are catchment-scale datasets that assess a number of factors that could influence or be impacted by river scour. These datasets utilise both geological data and other environmental datasets such as designated SSSI sites, urban areas from OS maps or spatial DTM analyses. Each dataset provides a spatial assessment of the variability and potential influences across Great Britain. A brief method and input datasets used are outlined below.

3.2 TIER 1 DATASET

Catchment Stability dataset

The Tier 1 is composed of a single dataset. The catchment stability data layer was developed as a high-level summary by identifying the glacial limits and quaternary history and attributing typical characteristic behaviours and management considerations using expert elicitation, quaternary domains data and glacial extents. The Quaternary history of a catchment has a large influence on its present-day behaviours such as the availability of material/debris, the amount of erosion experienced, and the amount of ongoing natural landscape readjustment in response to isostatic and tectonic processes. Isostatic adjustment is the restoration to equilibrium of the earth's crust following a period of glaciation. Tectonic adjustment is the rebound in response to earth's tectonic events. These processes happen very slowly over millions of years but means that the landscape is in constant evolution.

Tier 1 catchment stability is a summary overview of the evolution parameters affecting catchment response. It has been divided into three types as depicted below.

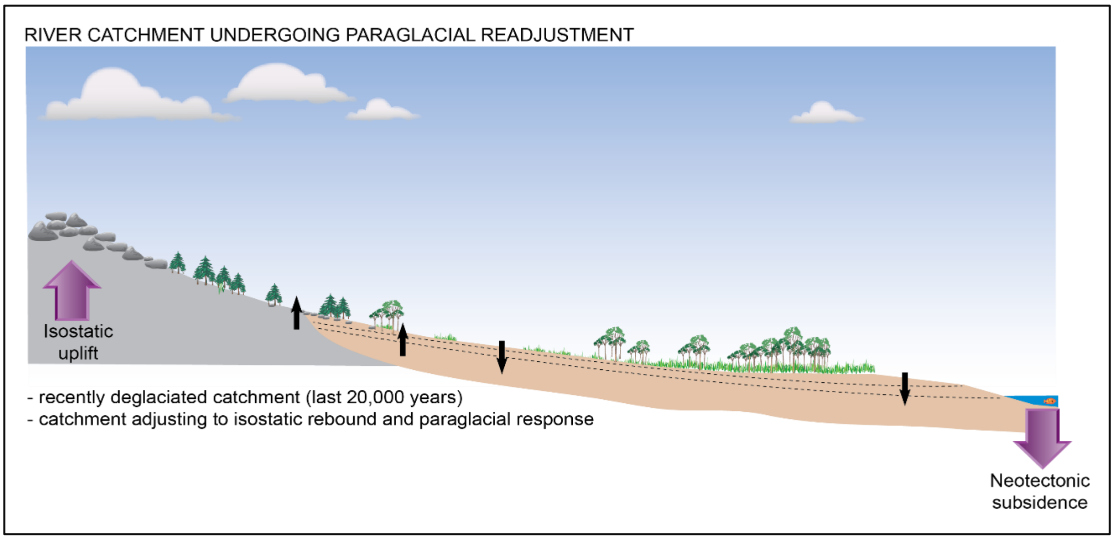


Figure 3 Type 1 - Unstable river catchments.

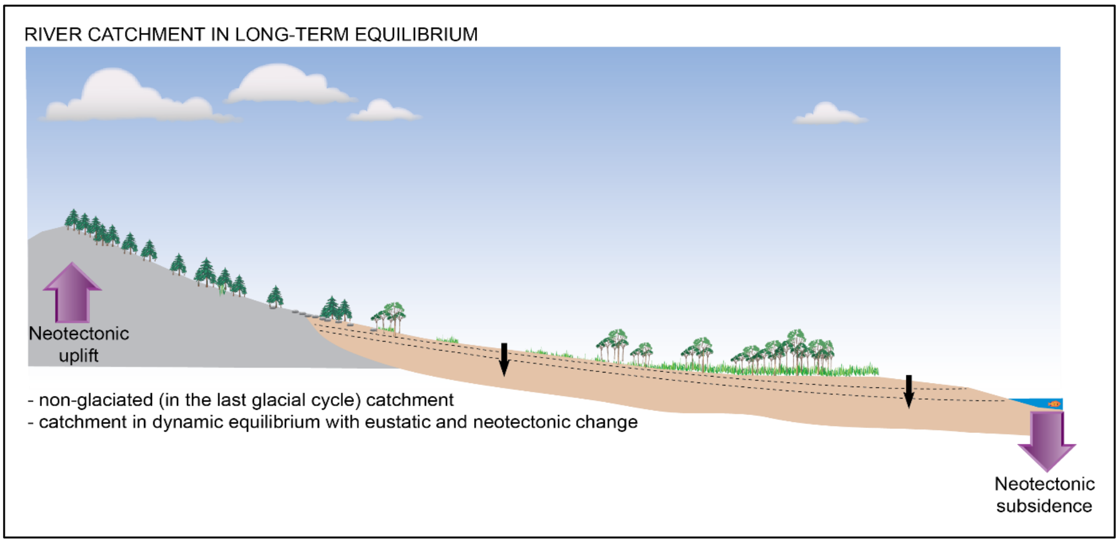


Figure 4 Type 2 - Meta-stable river catchments.

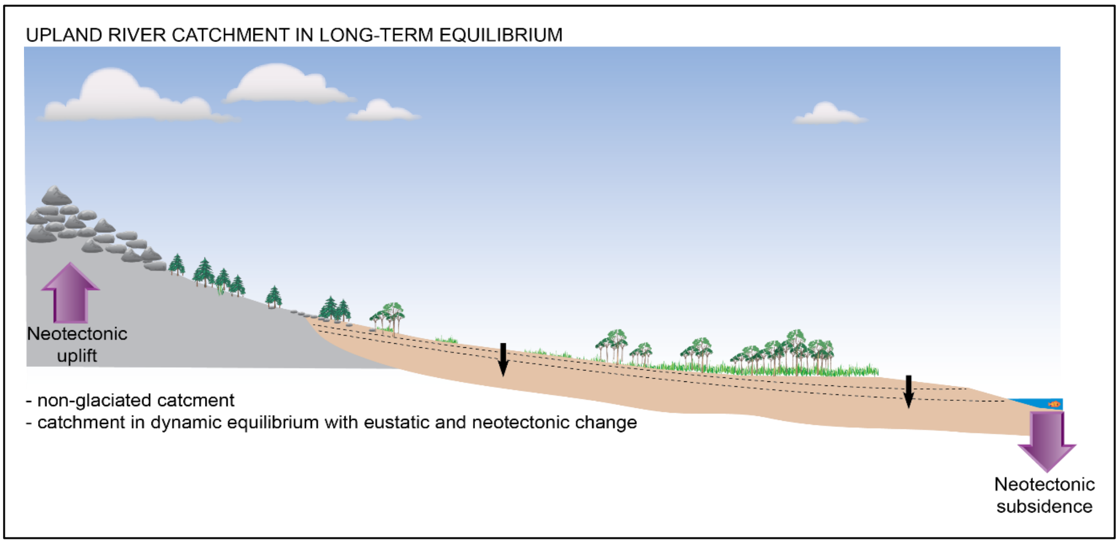


Figure 5 Type 3 - Stable river catchments.

3.3 TIER 2 DATASETS

These datasets provide a suite of information on different catchment parameters. They are calculated using the Water Framework Directive "WFD River Waterbody Catchments Cycle 2" for England and Wales; and Scotland Catchments from the Scottish Environment Protection Agency (SEPA). These were selected as they are widely available and widely used by practitioners and therefore the data should be easy to integrate alongside other datasets as necessary.

Tier 2 contains a suite of six datasets including:

- Catchment Designated Sites
- Catchment Flood Accommodation
- Catchment Geological Runoff Potential
- Catchment Morphology
- Catchment Surface Geology Susceptibility
- Catchment Urban Coverage

3.3.1 Catchment Designated Sites

The inclusion of nationally important designated sites has been provided to allow a catchment assessment comparison and consideration (e.g. comparison with the urban area coverage or

the flood accommodation space). This allows the user to assess the potential threats and competing factors present within and between catchments.
This data layer details the number, area coverage and percentage coverage of designated sites per catchment and includes the following fields:

3.3.2 Catchment Flood Accommodation

The amount of accommodation space for flood waters is an important consideration for catchment management planning and assessing scour potential. Flood accommodation is directly linked to the underlying geology in terms of its strength properties and erosion history. Catchments that have large accommodation spaces tend to have wide shallow valleys with broad flood plains where water can temporarily escape to. These generally have a widespread flood impact but lower erosion impact (depending on the severity of the flood). By contrast, catchments with reduced flood accommodation are more likely to be subject to greater erosion due to reduced energy disputation therefore concentration of erosive power and potential for scour. The underlying rock types provide some control on the magnitude and pattern of specific scour events. For example, the presence of strong resistant rocks can result in the development of downward scour over a longer period of time; weaker sediments and rocks create meandering environments and floodplains, and lateral scour is more apparent.

The catchment flood accommodation space dataset provides the potential total area of the catchment that is subject to flood given a 5 m rise above existing river courses. The base elevation is taken from the DTM of Great Britain (Bluesky International Limited) where intersecting the OS Open Rivers data. An elevation of 5 m a.s.l. was taken as a nominal height for modelling and in-line with an assessment of river gauge levels (used for the Geological Indicators of Flooding dataset (BGS 2010)). The resultant calculated values are simply a measure of increased water levels and does not take into account any simultaneous processes such as infiltration, permeability, flow rates, etc. All derived values were rounded up to the nearest metre for both the sum watercourse length within a catchment, and the sum coverage area within a catchment. Using Based on analysis of the Bluesky DTM (5 m), a 5 metre flood zone was created to provide the necessary statistical output for flood zone coverage by catchment, and the percentage equivalent of flood coverage.

3.3.3 Catchment Geological Runoff Potential

The geological run-off potential is an assessment of the underlying permeability of the catchment. The higher the coverage of impermeable deposits (e.g. clay-rich deposits, mudstones, etc.) the higher the potential for run-off and the increased threat of scour.
This dataset describes the run-off potential of the catchment, based on the geological properties and permeability of deposits. It does not take into account any other factors such as land cover or land use. The dataset provides the area coverage of each run-off potential class and identifies the dominant class and the worst-case for each catchment area.

3.3.4 Catchment Morphology

The morphology of a catchment is an important consideration in assessing river scour potential, as its topography and potential sediment availability are intrinsically linked to the geological deposits and processes occurring both in the past and present. The morphology of a catchment relates to its geological history and provides an indication of the sediment likely to be available and therefore potentially inputting into riverine processes. This also enables the characterisation of the types of deposits and associated parameters including sediment thickness, and weathering potential. The catchment morphology dataset was developed by analysing the dominant morphology type per catchment area, taking into consideration catchment processes provided through a domains dataset, and attributed into one of 4 categories: uplands, lowlands, hill & vale, or mountain.

3.3.5 Catchment Susceptibility

These datasets are an open version of the Tier 3 River Scour Susceptibility datasets and are provided as a catchment-level summary of the individual scour susceptibility classes assigned to each river. Within each catchment the entire length of river has been calculated for each scour class (e.g. High, or Low-Medium) and provided as lengths per class in kilometres.

For each Tier 3 dataset (best-, average-, and worst-case), the total length of river within each of the 5 scour susceptibility classed has been summed to provide a total length per class. The longest, or most dominant class, has then been provided as a separate attribute.

The Catchment Susceptibility layers available through GeoScour Tier 2 are:

- Catchment Surface Geology Susceptibility **Average**
- Catchment Surface Geology Susceptibility **Best**
- Catchment Surface Geology Susceptibility **Worst**

The underlying scoring factors and methodology are the same as those used for the Tier 3 Scour Susceptibility datasets.

3.3.6 Catchment Urban Coverage

The amount of urban coverage of a catchment is another attribute that could aid river catchment planning and assessments. Urban areas cause a 'surface sealing' effect, changing the drainage patterns substantially, often increasing run-off and therefore increasing the speed in which rainwater reaches the river network. Many urban areas have modified watercourses such as weirs, canalisation, flood defences and these should be considered as part of the catchment scour assessment. This data provides a catchment overview of the number and scale of urban areas. Large or very large conurbations will have potentially a much greater impact on the riverine environment as well as potential downstream consequences (e.g. higher erosion and scour creating greater impact on the rocks and sediments) that should be considered.
The catchment urban coverage layers have been provided as number, coverage, and percentage of small and large urban areas. The OS Strategi Urban Region dataset was used and both the large and small urban areas have been extracted independently and exported to create two new layers.

3.4 TIER 3 DATASETS

These datasets provide a suite of information about the different geological properties at a riverine-level. Tier 3 contains a suite of 4 datasets including:

- River geological susceptibility
    - Surface geology susceptibility
    - Bedrock geology susceptibility
- River geological properties
- River morphology
- River lateral erosion

3.4.1 River Geological Susceptibility

This assessment is provided as two datasets:

- **Surface Geology Susceptibility:** an assessment of the uppermost deposits along the river. These data could provide susceptibility classifications for all deposits at surface, therefore that will be superficial deposits where present or bedrock deposits where no superficial is present.
- **Bedrock Geology Susceptibility:** an assessment of the underlying bedrock deposits for susceptibility to scour. These data assess the susceptibility to scour of the bedrock geology whether superficial deposits are present or not. This classification is important especially in areas where the bedrock is a higher susceptibility to scour such as soluble rocks. Even where superficial deposits are present, it is important to understand the underlying properties of the bedrock as more frequent or extreme flood events might remove the overlying sediment to expose the bedrock to erosion.

Both analyses are provided as average-case, best-case and worst-case parameters to convey the variation and heterogeneous behaviour of geological deposits and to allow the user to consider both end members for scour potential according to their needs. These data layers identify the primary geological properties influencing scour potential including material density, strength (in line with technical engineering terminology BS5930:2015), and mineralogy.

The strength and density engineering descriptions range from strong to loose materials (**Figure 6**) corresponding to a variation from well-consolidated to unconsolidated materials. A linear scale has accordingly been used to classify and score the density and strength values. The lowest value of 0.1 (avoiding the value 0 for the next step of the process) has been attributed to the strong and extremely strong materials. Materials classed as 'Strong' are well consolidated and have greater resistance to scouring. The highest value of 1 has been attributed to the 'very loose' and 'loose' materials. Those materials are completely unconsolidated and can be easily removed and displaced by water.

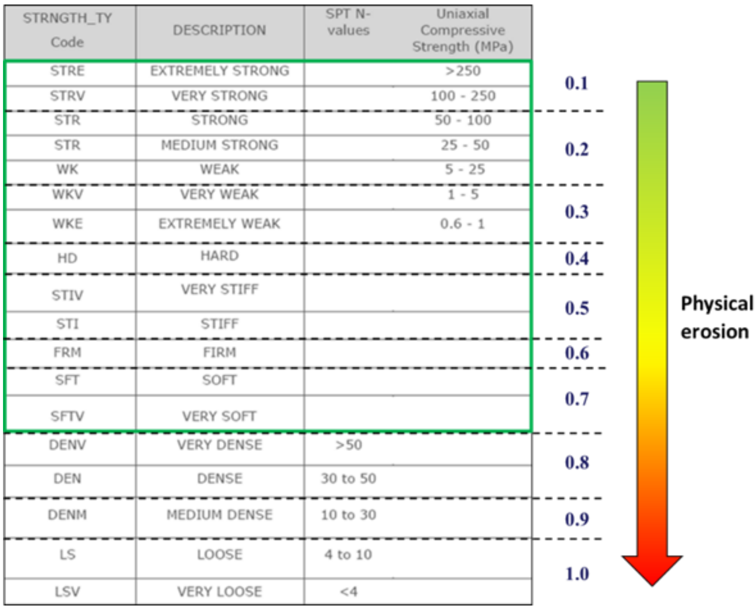

STRNGTH_TY Code	DESCRIPTION	SPT N-values	Uniaxial Compressive Strength (MPa)	
STRE	EXTREMELY STRONG		>250	0.1
STRV	VERY STRONG		100 - 250	
STR	STRONG		50 - 100	0.2
STR	MEDIUM STRONG		25 - 50	
WK	WEAK		5 - 25	
WKV	VERY WEAK		1 - 5	0.3
WKE	EXTREMELY WEAK		0.6 - 1	
HD	HARD			0.4
STIV	VERY STIFF			0.5
STI	STIFF			
FRM	FIRM			0.6
SFT	SOFT			0.7
SFTV	VERY SOFT			
DENV	VERY DENSE	>50		0.8
DEN	DENSE	30 to 50		
DENM	MEDIUM DENSE	10 to 30		0.9
LS	LOOSE	4 to 10		1.0
LSV	VERY LOOSE	<4		

Figure 6 Definition of the Strength and Density scores (STG_SCR) for the average-case scenario underlying river surface scour susceptibility.

Similarly, the mineralogy types have been classified and scored using a linear scale from insoluble to soluble materials (**Table 1**). The lowest value of 0.1 has been given to the silica and/or clay-rich materials (least potential to scour). Intermediate materials have been attributed a score of 0.2 and basic material of 0.3. Iron, ultrabasic, and mixed materials have been attributed a middle score of 0.5, considering their potential unpredictable behaviour depending on the temperature or chemistry of the water or simply the dominant material in the case of a mixed rock type/formation. Any material containing carbonates (Mg carbonates or Ca carbonates regardless the amount and if dominant in the rock) have been attributed a score of 0.7 considering that however limited the portion of the material being carbonates, the rock could be easily weakened and then scoured due to the dissolution of the carbonates portion. Finally, organic and evaporate materials have been attributed a value of 0.8 and 1, respectively.

Table 1 Definition of the mineralogy scores (MNL_SCR)

	D_MN_CODE	DOM_MNRL CLASS	DOMINANT MINERALOGY DEFINITION
	?	UNKNOWN	BULK MINERALOGY IS UNKNOWN
0.1	A	ACID	IGNEOUS ROCKS WITH HIGH SILICA (63%+)
0.3	B	BASIC	IGNEOUS ROCKS WITH LOW SILICA (45-52%)
0.1	C	CLAY	DOMINANT CLAY MINERALS (90%+)
0.7	D	MGCARBONATE	DOMINANT MgCaCO3 (with SOME CaCO3)
1.0	E	EVAPORITE	PREDOMINANTLY SULPHATES AND HALIDES
0.5	F	FERROAN SILICATE-FERROAN CACARBONATE	DOMINANT Fe SiO2 OR Fe-Mg/CaCO3

0.7	G	CACARBONATE-MGCARBONATE	DOMINANT CaCO3 (60%+) SUBORDINATE MgCO3 (40%-)
0.7	H	MGCARBONATE-CACARBONATE	DOMINANT MgCO3 (60%+) SUBORDINATE CaCO3 (40%-)
0.2	I	INTERMEDIATE	IGNEOUS ROCKS WITH MOD SILICA (52-63%)
0.7	J	SILICA-CACARBONATE	DOMINANT SILICA (60%+) SUBORDINATE CaCO3 (40%-)
0.7	K	CACARBONATE-SILICA	DOMINANT CaCO3 (60%+) SUBORDINATE SILICA (40%-)
0.7	L	CACARBONATE	DOMINANT CaCO3 with SOME MgCO3
0.7	M	CLAY-CACARBONATE	DOMINANT CLAY (60%+) SUBORDINATE CaCO3 (40%-)
0.7	N	CACARBONATE-CLAY	DOMINANT CaCO3 (60%+) SUBORDINATE CLAY (40%-)
0.8	O	ORGANIC	DOMINANT ORGANIC MATERIAL (90%+)
0.7	P	MGCARBONATE-SILICA-CLAY	DOMINANT MgCaCO3 (60%+) SUBORDINATE SILICA-CLAY (40%-)
0.1	Q	SILICA-CLAY	DOMINANT SILICA (60%+) SUBORDINATE CLAY (40%-)
0.1	R	CLAY-SILICA	DOMINANT CLAY (60%+) SUBORDINATE SILICA (40%-)
0.1	S	SILICA	DOMINANT SILICA (90%+)
0.7	T	CACARBONATE-SILICA-CLAY	DOMINANT CaCO3 (60%+) SUBORDINATE SILICA-CLAY (40%-)
0.5	U	ULTRABASIC	IGNEOUS ROCKS WITH VERY LOW SILICA (45%-)
0.7	V	CLAY-SILICA-CACARBONATE	DOMINANT CLAY & SILICA (60%+) SUBORDINATE CaCO3 (40%-)
0.7	W	SILICATE-MGCARBONATE	DOMINANT SILICA-CLAY (60%+) SUBORDINATE MgCaCO3 (40%-)
0.5	X	MIXED	BULK MINERALOGY IS VARIABLE DUE TO LITHOLOGY
	?	N/A	NO APPLICABLE MINERALOGY

Each river segment corresponds to a change in the underlying geology.

GIS Note: The layer fields containing the value -999 relate to No Data information due to the geological deposits having not been mapped (e.g. are under water areas) and therefore, the material density, strength and mineralogy are not defined.

3.4.2 River Geological Properties

This dataset layer provides the representation or coverage of four geological properties (bedrock, strength, density, and mineralogy of materials) per river reach. It assesses the percentage length of each type of geological property (different densities, strengths, mineralogy) and the percentage length of bedrock for each individual river reach.

The material strength and density values are provided as standard geotechnical engineering values as described in BS5930 (BS5930:2015). The mineralogical component is derived from BGS databases and the BGS Parent Material Map.

3.4.3 River Morphology

The River Morphology dataset layer contains information on the key morphological characteristics of the catchment at the riverine level.
These include the following attributes:

- **Flood accommodation space:** available per river reach, the vertical fall of the river per reach and the sinuosity factor. These factors can influence the location of, and intensity of scour processes and are strongly determined by the underlying geological deposits. The accommodation space available for a river to flood is a key factor in determining scour potential. The wider and low-lying the valley, the more space there is for flood waters, allowing water flows to decrease and dissipate energy, which in turn, decreases the potential for scouring. The narrower and more constrained the river valley, the greater the likelihood for scour and vertical erosion reducing the level of the riverbed. This data layer provides an initial assessment of this accommodation space by classifying the river valleys into three categories - low, medium, and high.
- **River fall:** The fall of the river is often coincidental with the underlying geology, (which can reflect changes in the geology) and influences the amount of stream power within specific sections of river reach. Generally, the steeper the fall, the more the potential for scour processes to occur. The river fall is calculated as the difference in elevation of the start and end of the river reach divided by the distance between the start and end points. The result shows the drop in metres from end to end of each river segment. The range in this dataset is between 0 – 1.14154 metres.

- **Sinuosity:** is an important factor in evolving river morphology and again, can be influenced, to some degree, by the geological properties. The sinuosity component of the River Morphology dataset has used published literature to classify the data, for example, Hydraulic Design Manual, Notice: 2016-1. Sinuosity measures the deviation of a line from the shortest path, calculated by dividing total length of each river reach by shortest possible path. A sinuosity value of 1 indicates a straight line (i.e. 1-1.05 = Straight; 1.05-1.25 = Sinuous; 1.25-2 = Meandering; and >2 = Highly meandering.)

These data do not include any artificial defences or modifications to the river, it is an assessment based purely on the geology and terrain morphology. This is useful to understand, especially in cases where artificial features might fail or be no longer maintained.

3.4.4 River Lateral Erosion

This dataset provides an assessment of any lateral change in susceptibility to scour, which is calculated on the scouring bank of the river course in the direction of river flow. An interpretation of the geology and its susceptibility to scour is assessed over set distances using transects perpendicular to the river line (OS WatercourseLink 2021).

The assessment is based on the worst-case geological susceptibility data (see 4.3.3.4) and considers transects up to 200 m from the line of the river. This assessment allows owners of riverside assets, such as road or pipeline infrastructure, to assess the location of any change in geology and therefore any change in susceptibility

3.5 SOURCE DATASETS

A variety of source datasets have been used to inform and incorporate into the development of GeoScour. The table below lists the source input datasets that have been used for each Tier of GeoScour of information.

Table 2 List of source datasets used to develop the GeoScour data product.

Dataset name	Input / source datasets
Tier 1	
Catchment Stability dataset	Water Framework directive River Basin Districts Cycle 2 (Environment Agency (EA) (WFD River Basin Districts Cycle 2)) catchment polygons for England & Wales. Scottish Environment Protection Agency (© SEPA), based on the Local Plan Districts (see https://www.sepa.org.uk/media/219258/lpd-areas.pdf) regions for Scotland.
Tier 2	
Catchment Designated Sites	EA WFD Management Catchments Cycle 2 England 2014, NRW WFD Management Catchments Cycle 2 Wales, SEPA G0280676 FRM LPD, Natural England Ramsar 2019, Natural England Ancient Woodland Inventory 2019, Natural England National Nature Reserves 2019, Natural England Special Areas of Conservation 2019, Natural England Special Protection Areas 2019, Natural England Sites of Special Scientific Interest 2019, SNH Ramsar 2005, SNH Ancient Woodland Inventory 2010, SNH National Nature Reserves 2018, SNH Special Areas of Conservation 2018, SNH Special Protection Areas 2019, SNH Sites of Special Scientific Interest 2019, NRW Ramsar 2018, NRW Ancient Woodland Inventory 2011, NRW National Nature Reserves 2018, NRW Special Areas of Conservation 2018, NRW Special Protection Areas 2018, NRW Sites of Special Scientific Interest 2019.
Catchment Flood Accommodation	EA WFD Management Catchments Cycle 2 England 2014, NRW WFD Management Catchments Cycle 2 Wales, SEPA G0280676 FRM LPD, OS Open Rivers WatercourseLink (October 2021), Bluesky DTM (5 m), BGS Geology 50k GB.

Catchment Geological Run-off Potential	EA WFD Management Catchments Cycle 2 England 2014, NRW WFD Management Catchments Cycle 2 Wales, SEPA G0280676 FRM LPD, OS Open Rivers WatercourseLink (October 2021), BGS Geology 50k, BGS Permeability v8, BGS Advanced Superficial Thickness Models (ASTM).
Catchment Morphology	EA WFD Management Catchments Cycle 2 England 2014, NRW WFD Management Catchments Cycle 2 Wales, SEPA G0280676 FRM LPD, OS Open Rivers WatercourseLink (October 2021), BGS Quaternary domain descriptors (morphology descriptions), BGS GeoScour v2, Tier 3: River Morphology.
Catchment Urban Coverage	EA WFD Management Catchments Cycle 2 England 2014, NRW WFD Management Catchments Cycle 2 Wales, SEPA G0280676 FRM LPD, OS Open Rivers WatercourseLink (October 2021), OS Strategi Urban Region 2016.
Catchment Geological Susceptibility	EA WFD Management Catchments Cycle 2 England 2014, NRW WFD Management Catchments Cycle 2 Wales, SEPA G0280676 FRM LPD, OS Open Rivers WatercourseLink (October 2021), BGS GeoScour v2, Tier 3: Surface Scour Susceptibility.
Tier 3	
Surface Scour Susceptibility	BGS Civils Strength and Density v6, BGS Parent Materials v6 (Lawley, 2011), DiGMapGB-50 v6, OS Open Rivers WatercourseLink (October 2021).
Bedrcock Scour Susceptibility	BGS Parent Materials v6, DiGMapGB-50 v6, OS Open Rivers WatercourseLink (October 2021).
River geological properties	BGS Civils Strength v6, BGS Parent Materials v6, BGS Geology 50k Bedrock V8, OS Open Rivers WatercourseLink (October 2021).
River morphology	Bluesky DTM (5 m), OS Open Rivers WatercourseLink (October 2021).
River lateral erosion	BGS GeoScour v2, Tier 3: Surface Geology Susceptibility, OS Open Rivers WatercourseLink (October 2021).

4 Technical Information

This section provides more detailed information on the data product and its content, the component suite of datasets provided and an explanation of each of the attributes.

4.1 SCALE

The GeoScour dataset is a three-tiered suite of datasets providing a range of catchment and riverine statistics and attributes. The recommended resolutions for use are:

- Tier 1 is produced for use at 1:625 000 scale
- Tier 2 is produced for use at 1:250 000 scale
- Tier 3 is produced for use at 1:50 000 scale (All spatial searches of the maps should be undertaken using a minimum 50 m buffer. This is because the smallest detectable feature at this scale is 50 m by 50 m in size.)

These data will allow an indication of the scour susceptibility in relation to geological conditions as contained within BGS geological records. They can be used for input into hydrological modelling algorithms (Tier 3 data) or as a planning tool prior to detailed site investigation.

All datasets within the GeoScour data product are provided with a full coverage of Great Britain.

Different elements of the dataset are provided as vector polygons, lines, or points, and are available in ArcGIS (.shp) format. Other formats such as MapInfo (.tab) are available on request.

Multipart polygons have been used in Tier 1 (304 multipart features) and Tier 2 (1537 multipart features) which involves a geographic dispersion of the features (e.g. Islands). Considering the nature of the information given in GeoScour, these multipart features were necessary to provide information for the whole catchments, especially in coastal areas where catchments are divided by river estuaries.

We also recognise **overlaps** between catchments for England and Scotland in Tier 1 (24 overlaps) and Tier 2 (28 overlaps). These overlaps have been kept as they reflect the difference between the source datasets provided by the Environment Agency and the Scottish Environment Protection Agency. We recommend that the catchment names are viewed to determine the geographic extent appropriate for user needs.

4.2 COVERAGE

Each dataset has coverage of Great Britain. Tier 1 and Tier 2 have catchment-scale spatial coverage. Tier 3 has river line coverage based on OS Open Rivers WatercourseLink October 2021.

4.3 ATTRIBUTE DESCRIPTIONS

The GeoScour datasets have individual attributes according to their content and use. The sections below provide users with explanations of the attributes for each dataset. GeoScour is provided with additional ArcGIS .lyr files as suggested ways of displaying the data. Further information on displaying the data is provided in Appendix 1.

4.3.1 GeoScour Open: Tier 1 Field Attributes

The Tier 1 catchment stability data contains the following fields:

Table 3 Tier 1 Catchment Stability fields and descriptions.

Field name	Field Attributes
FMP_NAME	The name of the management catchment area.

TYPE	The name of the catchment type.
DESC1	A description of the river system.
DESC2	A description of previous glaciations.
BEHAVIOUR1	A description of typical catchment behaviours.
BEHAVIOUR2	A description of typical catchment behaviours (continued).
BEHAVIOUR3	A description of typical catchment behaviours (continued).
BEHAVIOUR4	A description of typical catchment behaviours (continued).
MANAGMNT1	A description of potential issues for management.
MANAGMNT2	A description of potential issues for management (continued).
MANAGMNT3	A description of potential issues for management (continued).
MANAGMNT4	A description of potential issues for management (continued).
PRODUCT	The name of the product this dataset is associated with.
TIER	The tier number within the data product.
DATASET	The name of the dataset feature layer.

Note: not all fields are populated depending on the category and information available. Multiple fields for 'behaviour' and 'management' are provided due to the text limitation within each GIS field.

4.3.1.1 Individual descriptors within Tier 1 catchment stability layer

The 3 types of river catchment stability described within this data layer are described as follows:

Unstable River Catchments

Table 4 Unstable River Catchments.

Field name	Field Attributes
DESC1	River systems that are still undergoing landscape adjustment following the last glaciation (i.e. the catchment was glaciated).
BEHAVIOUR1	A dynamic catchment with hillslopes and rivers still adjusting to non-glacial conditions.
BEHAVIOUR2	Unpredictable river catchment response that is not in equilibrium with its host geology or relief.
BEHAVIOUR3	Elevated sediment supply to rivers driven by hillslope instability and catchment fill.
BEHAVIOUR4	Highly-variable changes in discharge and flow regime.
MANAGMNT1	Highly-unpredictable river catchment at all temporal and spatial scales.
MANAGMNT2	Elevated hillslope instabilities contributing higher and more variable levels of sediment to channels.
MANAGMNT3	High and complex patters of river scouring and floodplain aggradation.

MANAGMNT4	High-magnitude (e.g. storms) and transient (e.g. periods of prolonged rainfall) events, plus localised changes in catchment management (e.g. land-use, drainage, channel modification) are likely to have a high impact on channel processes.

Semi-stable River Catchments

Table 5 Semi-stable River Catchments.

Field name	Field Attributes
DESC1	River systems that were not glaciated during the last glaciation and are not undergoing a period of paraglacial adjustment.
DESC2	Catchment has been glaciated previously during the Quaternary.
BEHAVIOUR1	A river catchment that is generally in equilibrium with both external (e.g. climate and tectonics) and internal (e.g. geology, relief) drivers of landscape change.
BEHAVIOUR2	Unpredictable river catchment response that is not in equilibrium with its host geology or relief.
MANAGMNT1	Fairly predictable catchment processes (scour and aggradation) under normal conditions.
MANAGMNT2	Unpredictable behaviour likely to be localised and due to either local catchment management practices (e.g. land-use, drainage, channel modification) or high-magnitude (e.g. storms) / transient (e.g. prolonged periods of rainfall) events.

Meta-stable River Catchments

Table 6 Meta-stable River Catchments.

Field name	Field Attributes
DESC1	River systems that were not glaciated during the last glaciation and are not undergoing a period of paraglacial adjustment.
DESC2	Catchment has not been glaciated previously during the Quaternary.
BEHAVIOUR1	A river catchment that is generally in equilibrium with both external (e.g. climate and tectonics) and internal (e.g. geology, relief) drivers of landscape change.
BEHAVIOUR2	Limited sediment fill and availability; available materials largely restricted to pre-existing valley bottom sediments (terraces, alluvium, mass-movement deposits); available materials on slopes limited to soils and rock falls.
BEHAVIOUR3	Much reduced hillslope instability and sediment delivery to river systems due to limited sediment availability (due to limited occurrence of Quaternary deposits e.g. glacial deposits, river terraces).
MANAGMNT1	Fairly predictable catchment processes (scour and aggradation) under normal conditions.
MANAGMNT2	Reduced sediment budgets suggest rivers may be prone to more localised and widespread scouring especially in response to high-magnitude (e.g. storms), transient events (e.g. prolonged rainfall).
MANAGMNT3	Reduced sediment budgets suggest rivers may be prone to more localised and widespread scouring especially in response to changes in catchment management practices (e.g. land-use, drainage, channel modification).

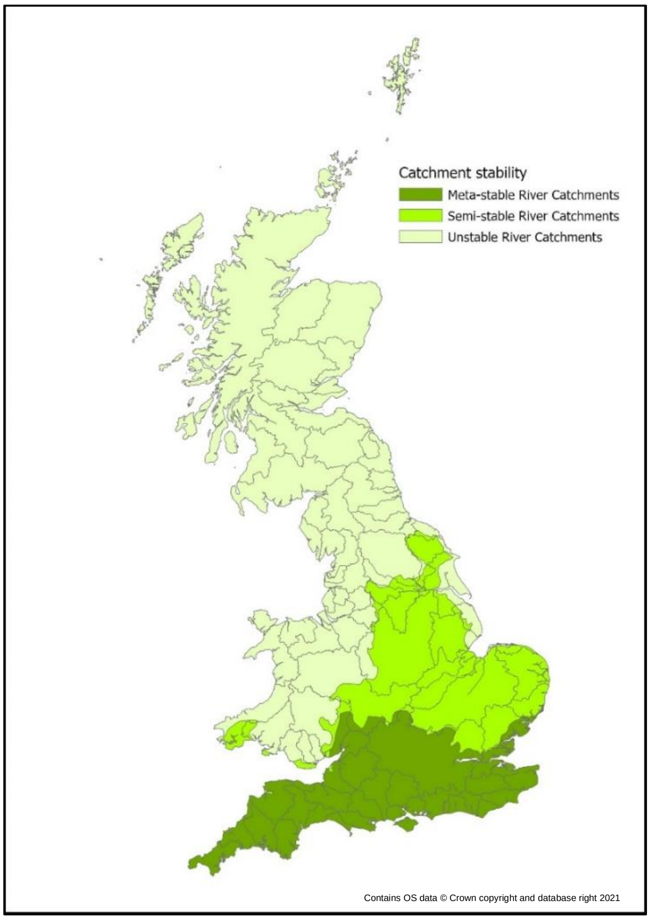


Figure 7 Catchment Stability Map.

[*Local Plan Districts are sourced from SEPA: IHDTM Inflow grid derived catchment boundaries available free of charge under the terms of the current Open Government Licence (OGL) as per SEPA's licence with CEH. Required Acknowledgements: © SEPA. Some features of this information are based on digital spatial data licensed from the Centre for Ecology and Hydrology © NERC (CEH). Contains OS data © Crown copyright.*]

4.3.2 GeoScour Open: Tier 2 Field Attributes

Tier 2 catchment-level information provides a suite of six datasets as follows:

- Catchment Flood Accommodation
- Catchment Morphology
- Catchment Geology Susceptibility layers:
    - Catchment **Average** Surface Susceptibility
    - Catchment **Best** Surface Susceptibility
    - Catchment **Worst** Surface Susceptibility
- Catchment Designated Sites
- Catchment Urban Coverage
- Catchment Geological Run-off Potential

4.3.2.1 Catchment Flood Accommodation attributes

The Tier 2 Catchment Flood Accommodation dataset contains the fields presented in **Table 7**. The dataset is designed to provide an estimate of the amount of flood space potential available within the catchment area both as a percentage and area. These are calculated according to topography and do not take into account any flood defences or artificial flood constructions. **Figure 8** below shows the data ranges based on percentage available flood space.

Table 7 Tier 2 Catchment Flood Accommodation fields and descriptions.

Field name	Field Attributes
MNCAT_NAME	The name of the management catchment area.
AREA	Total Area (in m^2) of the catchment.
FLOODZONE	Area (in m^2) of the flood accommodation space in the catchment.
AREA_PCT	% coverage of flood accommodation space per catchment.
LENGTH	Total length (in m) of rivers in the catchment.
PRODUCT	The name of the product this dataset is associated with.
TIER	The tier number within the data product.
DATASET	The name of the dataset feature layer.

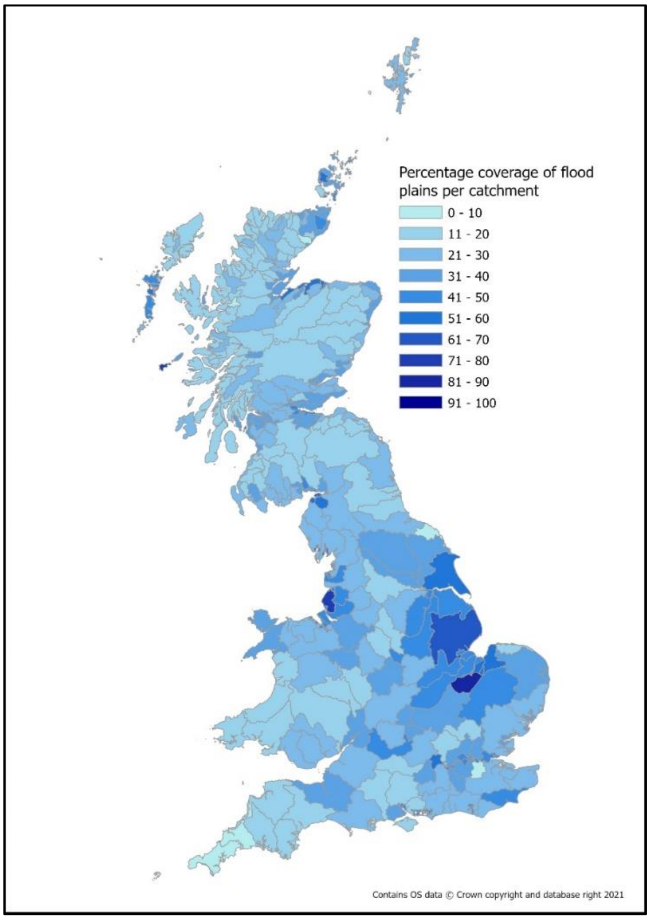


Figure 8 Catchment Flood Accommodation.

4.3.2.2 Catchment Morphology Attributes

The Tier 2 Catchment Morphology data describes the dominant catchment morphology type and contains fields as defined in **Table 8**.

Table 8 Tier 2 Catchment Morphology fields and descriptions.

Field name	Field Attributes
MNCAT_NAME	The name of the management catchment area.
DOM_MORPH	The name of the dominant morphology type in catchment.

DESCRIPTOR	The description of the catchment morphology type.
PRODUCT	The name of the product this dataset is associated with.
TIER	The tier number within the data product.
DATASET	The name of the dataset feature layer.

The morphology types indicated by the DOM_MORPH variable represent 6 types defined in the table below.

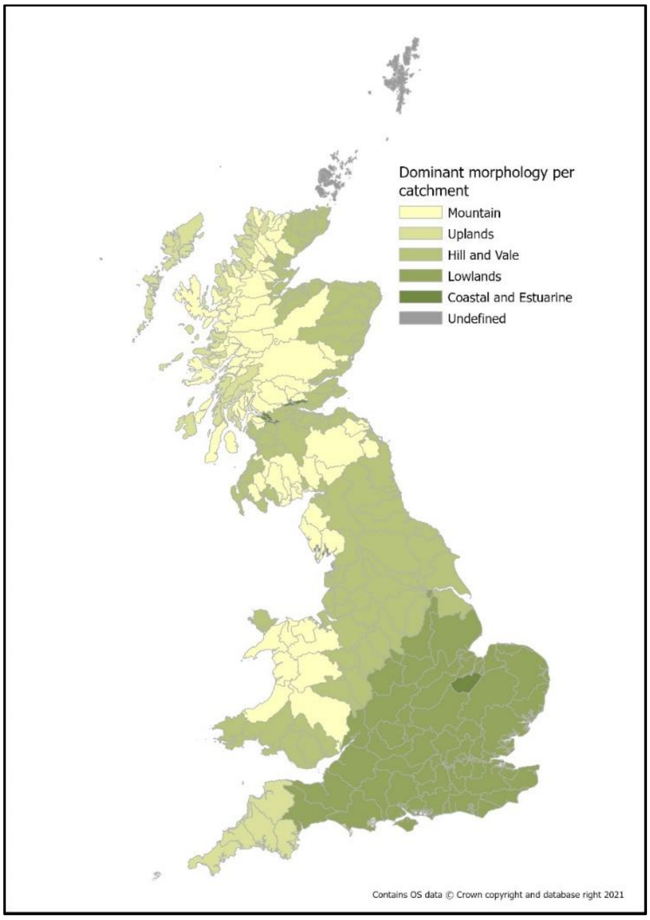


Figure 9 Dominant Catchment Morphology.

4.3.2.3 Catchment Geological Susceptibility

The Tier 2 Catchment Geological Susceptibility dataset calculates the length of river within each catchment for each scour susceptibility class. For example: The River Tay catchment contains 67.1km cumulative length of rivers classed as high susceptibility and 120.7 km cumulative length classed as medium susceptibility, and so on. This is presented in the attributes as:

> High susceptibility (67.1km); Medium - High susceptibility (120.7km); Medium susceptibility (37.5km); Low - Medium susceptibility (2422.7km); Low susceptibility (302.9km); No Data (Superficial not mapped) (4.1km)

The dominant class is also provided as a separate attribute, therefore using the Tay example, the dominant class is Low-medium susceptibility have the majority (2422.7 km) of river within this classification. **Table 9** below explains the attribute fields.

Table 9 Tier 2 Catchment Geological Susceptibility fields and descriptions (average-case).

Field name	Field Attributes
MNCAT_NAME	The name of the management catchment area.

AVERAGE_D	The length of rivers within each susceptibility class per catchment based on the average-case susceptibility scoring. Classes are: High susceptibility, Medium – High susceptibility, Medium susceptibility, Low – Medium susceptibility, Low susceptibility. Length provided in km. (Values also provided for Best- and Worst-case classes in separate datasets).
DOM_SUSC	The dominant susceptibility of the river scour classes per catchment, i.e. the class with the longest cumulative length per catchment.
PRODUCT	The name of the product this dataset is associated with.
TIER	The tier number within the data product.
DATASET	The name of the dataset feature layer.

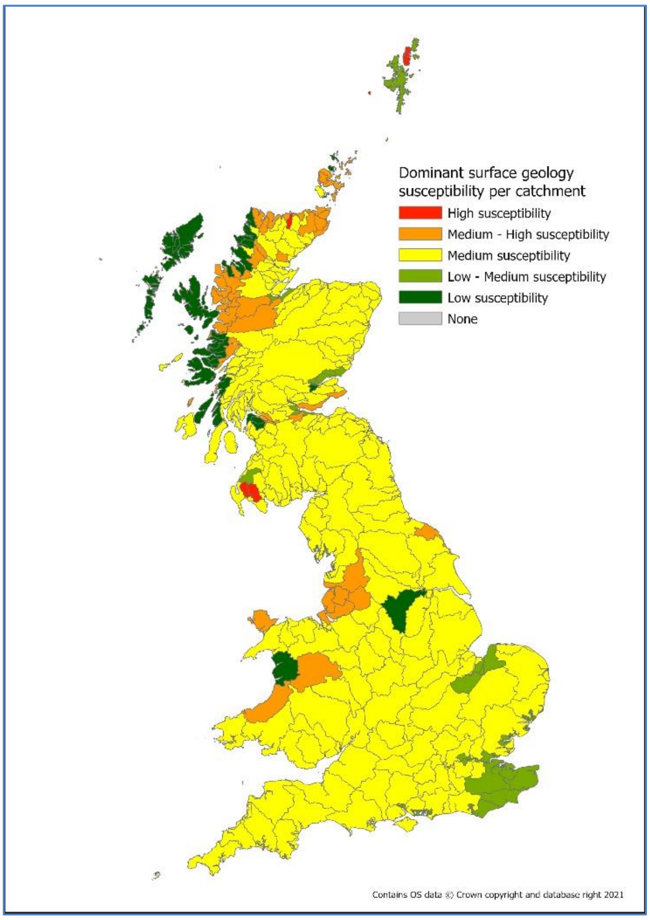


Figure 10 Dominant Surface Geology Susceptibility by catchment - Average.

4.3.2.4 Catchment Designated Sites attributes

The Tier 2 Catchment Designated Sites dataset (**Figure 11**) is a polygon shapefile that describes the number, area and coverage percentage of designated (or protected) sites per catchment using the Water Framework Directive (WFD) Management Catchments Cycle 2 for England, Wales and Scotland, respectively. This dataset contains 18 fields (**Table 10**).

Table 10 Attributes of the catchment designated sites dataset.

Field name	Field description
MNCAT_NAME	Management catchment name.
NB_ALL	Total number of all designated sites per catchment.
AREA_ALL	Total coverage of all designated sites (m^2) per catchment.

PERC_ALL	Percentage coverage of all designated sites per catchment.
NB_AWI	Total number of Ancient Woodland Inventory sites per catchment.
AREA_AWI	Total coverage of Ancient Woodland Inventory sites (m^2) per catchment.
PERC_AWI	Percentage coverage of Ancient Woodland Inventory sites per catchment.
NB_NNR	Total number of National Nature Reserves per catchment.
AREA_NNR	Total coverage of National Nature Reserves (m^2) per catchment.
PERC_NNR	Percentage coverage of National Nature Reserves per catchment.
NB_RAM	Total number of Ramsar sites per catchment.
AREA_RAM	Total coverage of Ramsar sites (m^2) per catchment.
PERC_RAM	Percentage coverage of Ramsar sites per catchment.
NB_SAC	Total number of Special Areas of Conservation per catchment.
AREA_SAC	Total coverage of Special Areas of Conservation (m^2) per catchment.
PRODUCT	The name of the product this dataset is associated with.
TIER	The tier number within the data product.
DATASET	The name of the dataset feature layer.

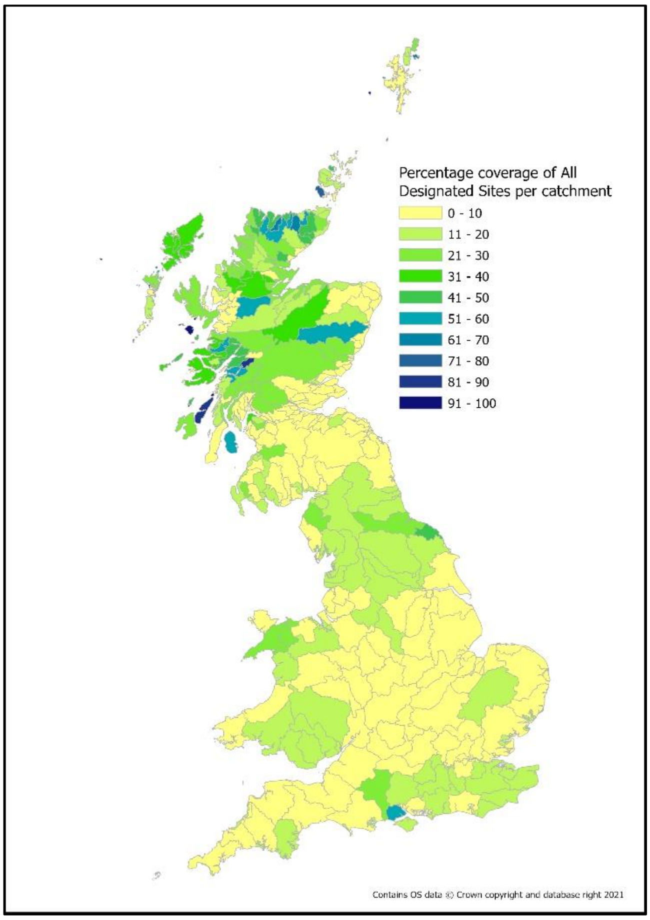


Figure 11 Percentage coverage of designated sites per catchment.

4.3.2.5 Catchment Urban Coverage attributes

The Tier 2 Catchment Urban Coverage dataset is a polygon shapefile that describes the number, area and coverage percentage of small and large urban areas per catchment using the Water Framework Directive (WFD) Management Catchments Cycle 2 (see **Figure 12**). The data layer contains 10 attribute fields (**Table 11**). Statistics for each catchment include:

Table 11 Attributes of the catchment urban coverage dataset.

Field name	Field description
MNCAT_NAME	Management catchment name.
NB_LARGE	Total number of large urban areas within catchment.
AREA_LARGE	Total coverage (m^2) of large urban areas within catchment.
PERC_LARGE	Percentage coverage of large urban areas.
NB_SMALL	Total number of small urban areas within catchment.
AREA_SMALL	Total coverage (m^2) of small urban areas within catchment.
PERC_SMALL	Percentage coverage of small urban areas.
PRODUCT	The name of the product this dataset is associated with.
TIER	The tier number within the data product.
DATASET	The name of the dataset feature layer.

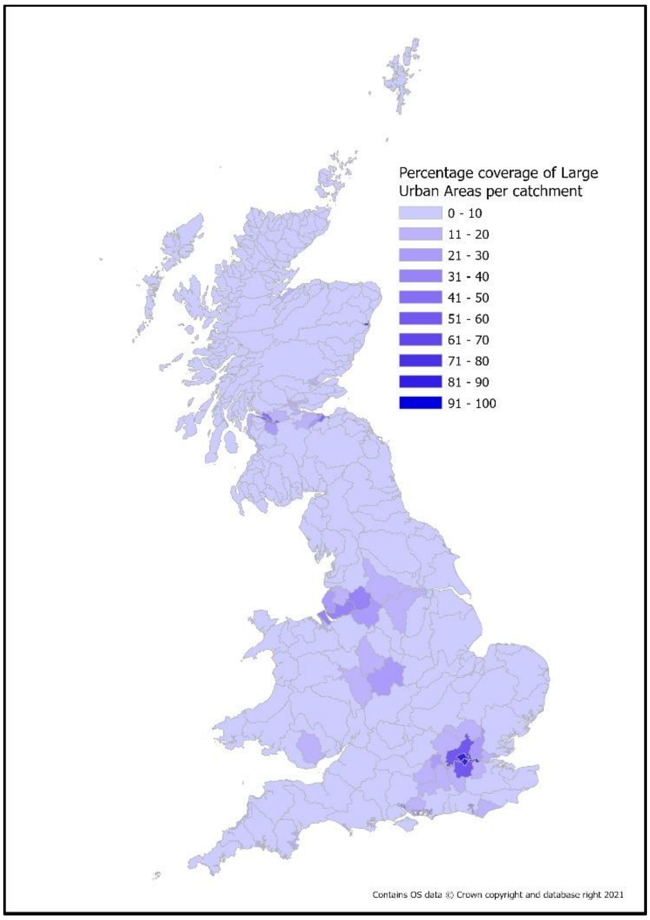


Figure 12 Percentage coverage of large urban areas per catchment.

4.3.2.6 Catchment Geological Run-off Potential attributes

The Tier 2 Catchment Geological Run-off Potential dataset provides a summary representation of the propensity for surface water to drain into local watercourses based on the overall geological properties, and permeability of deposits, of the surface geology by catchment (**Figure 13**). The data layer contains 11 fields describing the area coverage of each run-off potential class and identifies the dominant class and the worst, best and average-case for each catchment area (**Table 12**).

Table 12 Attributes of the catchment geological runoff potential dataset.

Field name	Field description
MNCAT_NAME	Management catchment name.
PERC_LOW	Percentage coverage of catchment classed as low run-off potential.
PERC_MOD	Percentage coverage of catchment classed as moderate run-off potential.
PERC_HIGH	Percentage coverage of catchment classed as high run-off potential
DOM	Dominant run-off class.
DOM_DESC	Description of the dominant class.
WORST	Worst-case scenario run-off class.
WORST_DESC	Description of the worst-case scenario class.
PRODUCT	The name of the product this dataset is associated with.
TIER	The tier number within the data product.
DATASET	The name of the dataset feature layer.

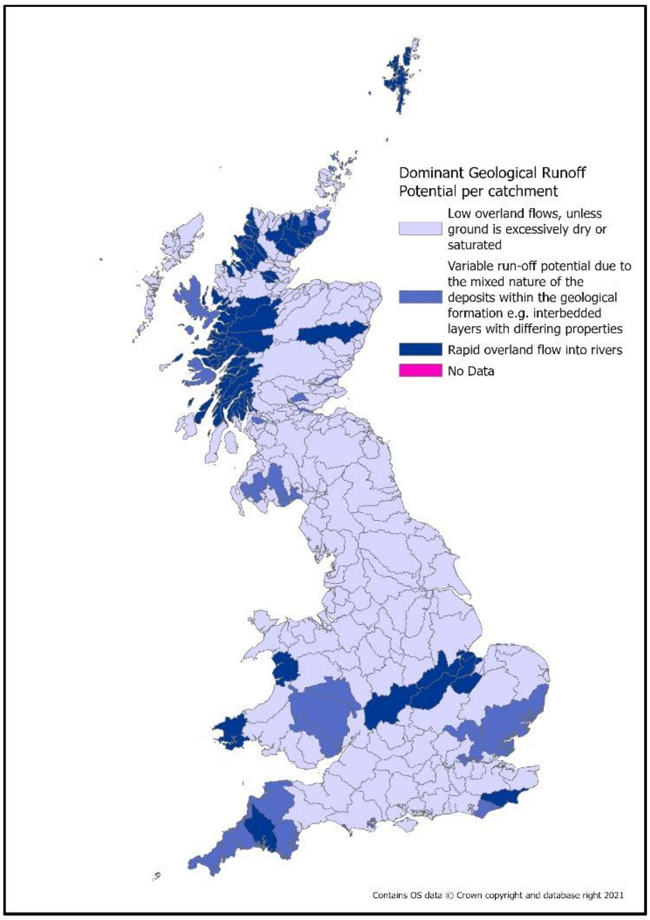


Figure 13 The dominant geological run-off potential per catchment.

4.3.3 GeoScour Premium: Tier 3 Field Attributes

Tier 3 contains a suite of nine dataset layers. Three of these layers (river geological susceptibility) have been provided as best-case, worst-case and average parameters to convey the variation and heterogeneous behaviour of geological deposits and to allow the user to consider both end members for scour potential according to their needs.

Tier 3 contains a suite of nine datasets:

- River Geological Properties
- River Morphology
- Surface Geology Susceptibility layers:
    - Surface Geology Susceptibility **Average**
    - Surface Geology Susceptibility **Best**
    - Surface Geology Susceptibility **Worst**
- Bedrock Geology Susceptibility layers:
    - Bedrock Geology Susceptibility **Average**
    - Bedrock Geology Susceptibility **Best**
    - Bedrock Geology Susceptibility **Worst**
- River Lateral Erosion

> **GIS Note**: The total number of features within the layers varies due to the methodologies used. The geological susceptibility layers have been assessed by intersecting the geology layers with the river network while the geological properties and morphology layers have been assessed by river reach (river segment contained between two river junctions).

4.3.3.1 River Geological Properties

The River Geological Properties dataset provides detailed information about the engineering properties of the riverine deposits for each river reach as described in **Table 13** below.

Table 13 Tier 3 River Geological Properties fields and descriptions.

Field name	Field Attributes
	Bedrock coverage
BEDROCK	% length of reach classed as bedrock.
	Material strength
FIRM	% length of reach classed firm.
FIRMSTIFF	% length of reach classed from firm to stiff.
SOFT	% length of reach classed soft or very soft.
SOFTFIRM	% length of reach classed from soft to firm.
STIFF	% length of reach classed stiff or very stiff.
STIFFVWEAK	% length of reach classed from stiff to very weak.
STIFFWEAK	% length of reach classed from stiff to weak.
STRONG	% length of reach classed as very strong or extremely strong.
VWEAK	% length of reach classed as very weak.
VWEAKSTRON	% length of reach classed from very weak to strong.
WEAKSTRONG	% length of reach classed from weak to strong.

	Material density
DENSE	% length of reach classed dense or very dense.
MDENSE	% length of reach classed as medium dense.
LOOSE	% length of reach classed as loose.
VARIABLE	% length of reach classed as variable.
	Material mineralogy
BASIC	% length of reach classed as predominantly as basic igneous rocks.
CARBONATES	% length of reach classed as predominantly carbonates.
EVAPORITE	% length of reach classed as predominant sulphates and halides.
INTERM	% length of reach classed as predominantly as intermediate igneous rocks.
IRON_MIXED	% length of reach classed as predominantly iron or mixed lithology.
ORGANIC	% length of reach classed as predominantly as organic material.
SILICACLAY	% length of reach classed as predominantly silica and clay.
NODATA	% length of reach where superficial deposits are not mapped.
PRODUCT	The name of the product this dataset is associated with.
TIER	The tier number within the data product.
DATASET	The name of the dataset feature layer.

GIS Note: The percentage fields should not be all sum together but need to be looked at individually per category (e.g. sum percentages of material strength).

However, the NODATA field percentages can be summed with any of the other categories (bedrock coverage, material strength, material density and material mineralogy) for a given feature.

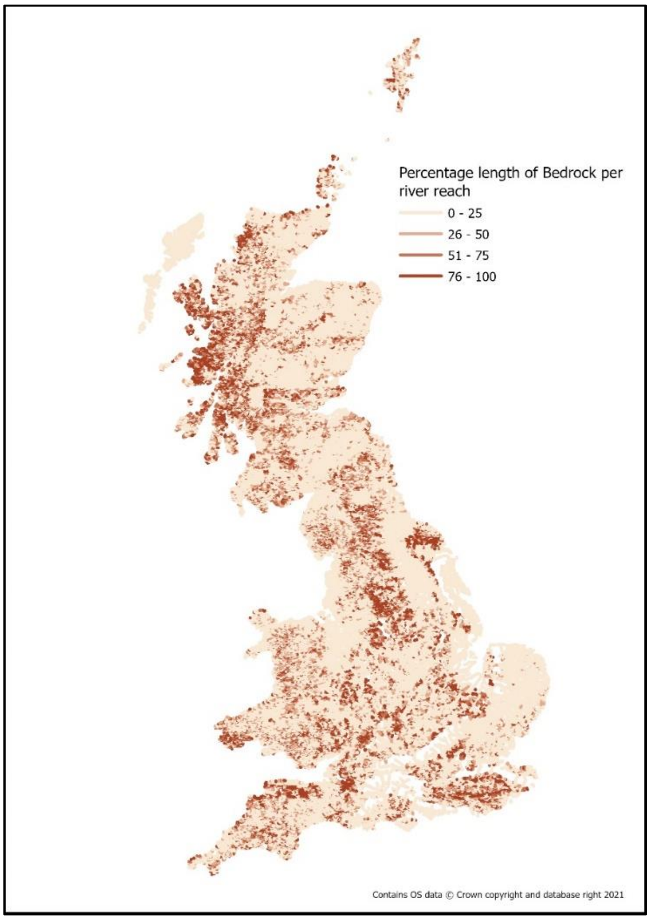


Figure 14 River Geological Properties data (BEDROCK).

4.3.3.2 River Morphology

The River Morphology datasets assesses three primary factors of the morphology including the amount of accommodation space available for flood waters, the fall of the river along its course and the sinuosity of the river. These attributes are described in the **Table 14** below.

Table 14 Tier 3 River Morphology fields and descriptions.

Field name	Field Attributes
PERC_LOW	% length low flood accommodation space.
PERC_MED	% length medium flood accommodation space.
PERC_HIGH	% length high flood accommodation space.
DOM	Dominant flood accommodation space class value.
DOM_DESC	Dominant flood accommodation space class description.
WORST	Worst-case flood accommodation space class value.
WORST_DESC	Worst-case flood accommodation flood class description.
FALL	The gradient between the elevation of the start point of the river reach and the end point. Range between 0 - 1.14154 metres.
SINUO	Numeric value of the sinuosity between 1 and 2. (1= straight line, and 2= Highly meandering.)
SINUO_DESC	Sinuosity value description. (i.e. Straight, Sinuous, Meandering, Highly meandering).
PRODUCT	The name of the product this dataset is associated with.

TIER	The tier number within the data product.
DATASET	The name of the dataset feature layer.

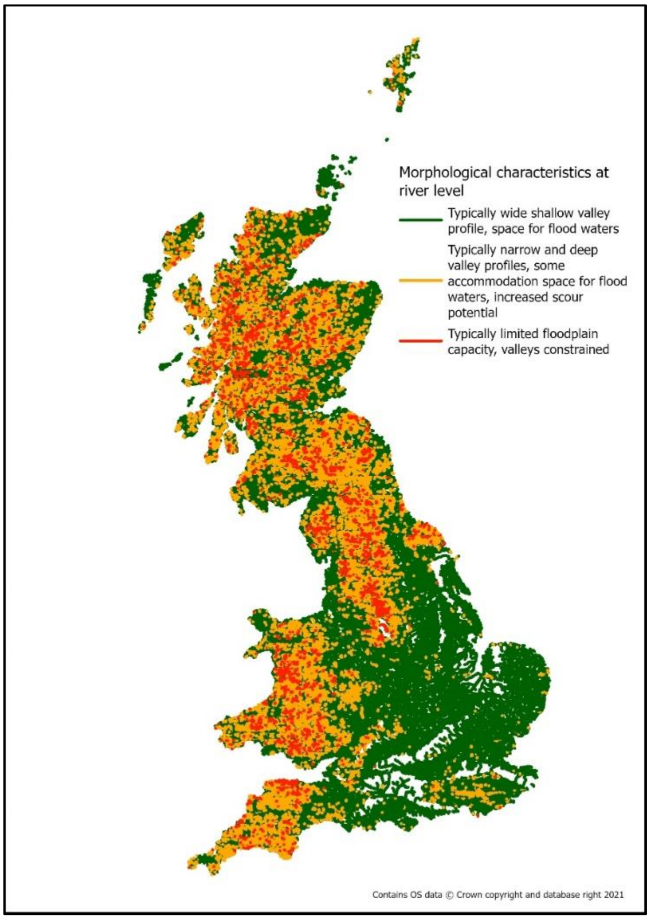


Figure 15 River Morphology (DOM_Desc).

4.3.3.3 River Geological Susceptibility attributes

The geological scour susceptibility are calculated for two factors:

- surface geology susceptibility and
- bedrock geology susceptibility.

The surface scour considers the uppermost deposits associated with the riverine environment (i.e. predominantly superficial deposits) however where superficial deposits are not present, bedrock geology is included. The bedrock scour considers the bedrock geology across the whole area regardless of any superficial cover.

Both assessments are provided as best-, average-, and worst-case scenarios and have the same attributes, as described in the tables below.

The field NODATA corresponding to rivers parts where the geology has not been mapped and therefore, the material density, strength and mineralogy are not defined.

Average Surface Geology Susceptibility

The average surface geology susceptibility uses both the density and strength information for given geological formations and calculates the average score. (e.g. STR_TY = Strong = 0.2 and DEN_TY = Medium Dense = 0.9, overall score for strength will be 0.55). The attributes for the average-case scour susceptibility are provided in **Table 15** below.

Table 15 Tier 3 Surface geology susceptibility fields and descriptions (average-case).

Field name	Attributes
MINERALOGY	Average geological description of material mineralogy.
MNL_SCR	Average mineralogy score per river segment.
DENSITY	Average engineering description of geological material density.
STRENGTH	Average engineering description of geological material strength.
STG_SCR	Average density/strength score per river segment.
AVERAG_SCR	Average geological susceptibility total score.
SCR_DESC	Average geological susceptibility description.
PRODUCT	The name of the product this dataset is associated with.
TIER	The tier number within the data product.
DATASET	The name of the dataset feature layer.

Surface Geology Susceptibility (best-case)

The best-case river scour susceptibility data layer uses only the strength values of the materials without integrating the density (DEN_TY field). However, some density values (Dense) are still provided in the STG_TY field (**Table 16**). This is because we are only considering the best-case scenario for river scour and therefore the most resistant/strong scores for each formation are calculated. The attributes for the best-case scour susceptibility are provided in **Table 16** below.

Table 16 Tier 3 Surface geology susceptibility fields and descriptions (best-case).

Field name	Field Attributes
MINERALOGY	Best-case geological description of material mineralogy.
MNL_SCR	Best-case mineralogy score per river segment.
DENSITY	Best-case engineering description of geological material density.
STRENGTH	Best-case engineering description of geological material strength.
STG_SCR	Best-case density/strength score per river segment.
BEST_SCR	Best-case geological susceptibility total score.
SCR_DESC	Best-case geological susceptibility description.
PRODUCT	The name of the product this dataset is associated with.
TIER	The tier number within the data product.
DATASET	The name of the dataset feature layer.

Surface Geology Susceptibility (worst-case)

The worst-case assessment uses the density values over the strength values, which means that when both density and strength are present for a given geological formation, only the density value is used to determine the overall strength score. This is because we are assessing the worst-case scour susceptibility of a given geological deposit and therefore only considering the weakest, most susceptible lithology scores (e.g. STR_TY = Strong = 0.2 and DEN_TY = Medium Dense = 0.9, overall score for strength will be 0.9). The attributes for the worst-case scour susceptibility are provided in **Table 17** below.

Table 17 Tier 3 Surface geology susceptibility fields and descriptions (worst-case).

Field name	Field Attributes
MINERALOGY	Worst-case geological description of material mineralogy.
MNL_SCR	Worst-case mineralogy score per river segment.
DENSITY	Worst-case engineering description of geological material density.
STRENGTH	Worst-case engineering description of geological material strength.
STG_SCR	Worst-case density/strength score per river segment.
WORST_SCR	Worst-case geological susceptibility total score.
SCR_DESC	Worst-case geological susceptibility description.
PRODUCT	The name of the product this dataset is associated with.
TIER	The tier number within the data product.
DATASET	The name of the dataset feature layer.

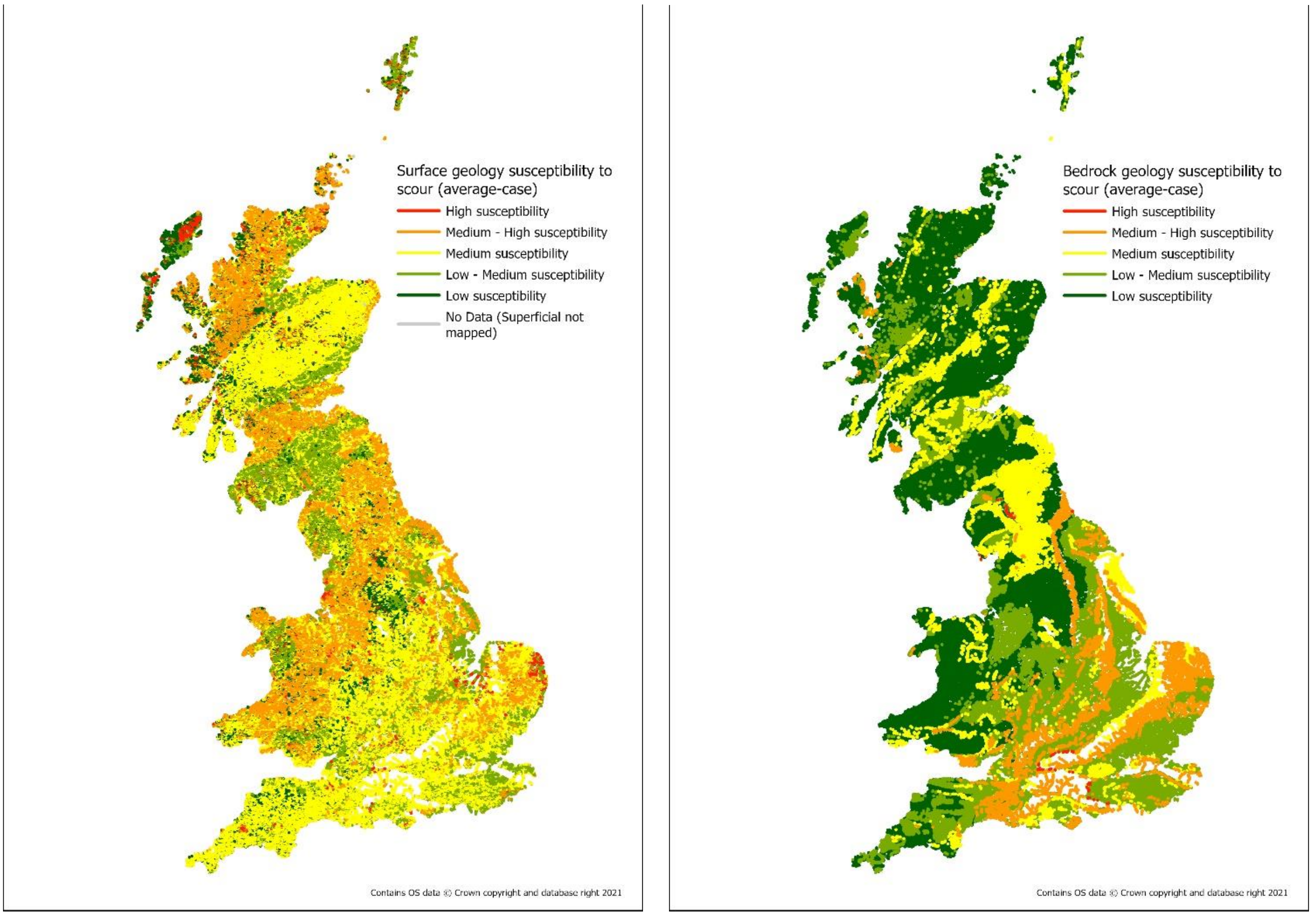


Figure 16 Surface Geology Susceptibility (left) and Bedrock Geology Susceptibility (right).

4.3.3.4 Lateral River Erosion

The lateral erosion dataset is an important consideration and identifies the potential change in scour susceptibility, given an amount of continued lateral erosion of the river bank (i.e. if erosion of a bank was to continue to encroach, where can a change in the geology result in a change in the scour susceptibility). The attributes for the lateral erosion scour susceptibility are provided in the **Table 18** and seven ranks are provided, ranging from Low susceptibility to High susceptibility.

Table 18 Lateral River Erosion fields and descriptions.

Field name	Field Attributes
SCR_DESC	Shows the geological susceptibility on the scouring side of the river bank.
DIST_5m	Shows the geological susceptibility 5 metres beyond the scouring side of the river bank.
DIST_10m	Shows the geological susceptibility 10 metres beyond the scouring side of the river bank.
DIST_20m	Shows the geological susceptibility 20 metres beyond the scouring side of the river bank.
DIST_25m	Shows the geological susceptibility 25 metres beyond the scouring side of the river bank.
DIST_50m	Shows the geological susceptibility 50 metres beyond the scouring side of the river bank.
DIST_200m	Shows the geological susceptibility 200 metres beyond the scouring side of the river bank.
INFLECTION	Shows the scouring side of the river bank (Left or Right).
PRODUCT	The name of the product this dataset is associated with.
TIER	The tier number within the data product.
DATASET	The name of the dataset feature layer.

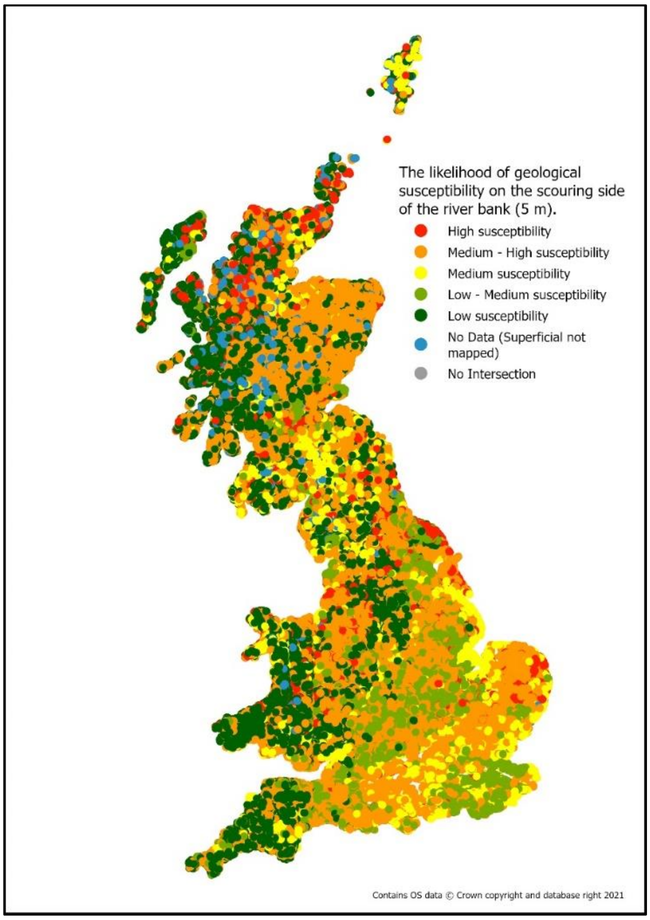


Figure 17 Lateral River Erosion data.

4.1 DATA FORMAT

The BGS GeoScour Data Product is available as a vector GIS dataset. The dataset comprises both polygon and polyline data and are available in ESRI ArcGIS (.shp) GIS formats. Other spatial formats such as geopackages may be available but may incur additional processing costs.

4.2 DATA HISTORY

- Version 1 (released 2019): Contained GeoScour Open (Tier 1 and Tier 2) and GeoScour Premium (Tier 3) datasets.Derived from OS Open Rivers WatercourseLink (April 2019) and BGS Geology 50k v8.
- Version 2 (released 2022): New additions in V2 include GeoScour Open Tier 2 Geological Scour Susceptibility datasets (based on Tier 3 river-level data this summarises the lengths of river per catchment for each scour susceptibility class) and GeoScour Tier 3 Lateral Scour Susceptibility and Bedrock Scour Susceptibility datasets. Derived from OS Open Rivers WatercourseLink (October 2021) and BGS Geology 50k v8, incorporating updated BGS Permeability V8, and new Bluesky DTM.

5 Licencing the data

5.1 BGS LICENCE TERMS

The British Geological Survey does not sell its digital mapping data to external parties. Instead, BGS grants external parties a licence to use this data, subject to certain standard terms and conditions. In general, a licence fee will be payable based on the type of data, the number of users, and the duration (years) of a licence.
All recipients of a licence (potential licensees) are required to return a signed digital data licence document before authorisation for release of BGS digital data is given.

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- make internal use of the dataset(s)
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- place (any part of) the dataset(s) on the Internet

The BGS is committed to ensuring that all the digital data it holds which is released to external parties under licence has been through a robust internal approval process, to ensure that geoscientific standards and corporate quality assurance standards are maintained. This approval process is intended to ensure that all data released: (i) is quality assured; (ii) meets agreed BGS data management standards; (iii) is not in breach of any 3rd party intellectual property rights, or other contractual issues (such as confidentiality issues), that would mean that release of the data is not appropriate.

When the BGS digital datasets are revised any upgrades will be automatically supplied to the licensee, at no additional cost. Geological map datasets are revised on a periodic rather than on an annual basis, licensees will therefore not automatically receive a new dataset each year unless changes have been made to the data.

These are general comments for guidance only. A licensee of BGS' digital data is provided with full details of the basis on which individual BGS datasets licensed to them are supplied.
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BGS IPR will usually be able to provide reassurance that the licence will cover individual user requirements and/or to include additional 'special conditions' in the licence documentation, addressing specific requirements within BGS' permitted usage.

5.2 DATA ACKNOWLEDGMENTS

Please use the following acknowledgements when using BGS GeoScour.

GeoScour Premium licenced data: 'Derived from BGS Digital Data under Licence (cite your licence number) British Geological Survey © UKRI. All rights reserved.'

GeoScour Open data: 'Contains British Geological Survey materials © UKRI 2022'

5.3 CONTACT INFORMATION

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NG12 5GG
Direct Tel: +44(0)115 936 3143
Email: digitaldata@bgs.ac.uk

6 Limitations

6.1 DATA CONTENT

BGS GeoScour datasets are concerned with the geological properties and propensity for scour processes related to **NATURAL** geological conditions only. This version does NOT cover any man-made components, such as flood defences, weirs. It does not account for flow rates, sediment budget or other scour modelling parameters.

BGS GeoScour dataset is based on, and limited to, an interpretation of the records in the possession of The British Geological Survey at the time the data set was created.

An indication of natural geological scour susceptibility does not necessarily mean that a location will be affected by scour or experience failure.

6.2 SCALE

BGS GeoScour has been developed as three tiers of information:

- Tier 1: 1:625 000 scale
- Tier 2: 1:250 000 scale
- Tier 3: 1:50 000 scale

It is intended for use as a desk study screening tool prior to detailed site investigations, input into catchment management planning or input into river scour models (Tier 3). It should not be taken as a substitute for specialist interpretations, professional advice and/or detailed site investigations.

6.3 ACCURACY AND UNCERTAINTY

Site specific assessments should be carried out by suitably qualified and experienced professionals and using appropriate methods. The information provided in these data are designed for DESK STUDY phases and input into scour models alongside other data (e.g. flow rates, sediment budgets, etc.).

Whilst BGS has carried out all the necessary quality checks on the 11 layers within the GeoScour product it accepts no warranty as to quality of the third-party products that have been used to create GeoScour.

The creation of the individual datasets relies upon several assumptions regarding the procedure and technical methodology. The procedures for the assessment of these methodologies were largely based upon the expert judgement of geologists, engineering /hydro geologists and extensive discussion with district geologists. Further technical assumptions were also made:

- The description given by LEX-RCS is correct and representative of the lithology.
- Surface and bedrock geology is correctly represented by BGS Geology 50k.
- Expert judgement and BGS data sources are appropriate and applied consistently.
- Processes within the shallow subsurface are properly represented by the distribution of data as modelled from BGS Geology 50k and the data extracted from the BGS Parent Material Map.
- The surface slope model derived from the Bluesky DTM is accepted as providing a reasonable model of slope morphology.
- Ordnance Survey data are an accurate representation of locations, features, and river courses.
- Not all LEX_RCS codes from BGS Geology 50k were present in the BGS Civils and Parent Material (PMM) datasets. BGS Civils/PMM are based on BGS Geology V6 (published 2010), whereas BGS Geology 50k is currently V8 (published 2017). Therefore, appropriate replacement LEX_RCS codes from V6 were substituted for the purpose of the scoring matrix.

6.4 ARTEFACTS

Geological mapping: The mapping accuracy associated with the BGS GeoScour datasets is based on that of the BGS Geology 50k and Parent Material Map datasets, which represent data from different times and origins of survey. This can result in inconsistencies between older, and more recently gathered, observations (such as boreholes). Consequently, adjacent geological sheets/tiles (of different survey dates) may not seamlessly fit together spatially, or in terms of lithological description. This can result in some map-sheet ‘edges’ that exhibit contrasting colours/attribution. This in turn can affect the representation of the GeoScour layers.

Artificial structures: GeoScour only considers the natural geology of the river and catchment. In some locations, artificial features including flood walls and protective gabions may carry the attributes of the geology that lies behind.

OS Open datasets: The Tier 3 datasets are all provided using the OS Open Rivers WatercourseLink (October 2021) as the national basis. It is recognised that accuracy varies within the dataset and the river line is not always coincident with other ‘mapped’ river locations, and not all small tributaries are included, especially when considering first order streams in mountainous areas. GeoScour can be provided using alternative base data if required.

6.5 DISCLAIMER

Components of the GeoScour datasets are developed using data obtained from 3rd parties. Whilst BGS strives to make its products as accurate as possible, we can offer no warranty about fitness-for-purpose or accuracy of information. Furthermore, the information provided is the result of modelled output and thus provided as 'best available', scientifically modelled data only.

7 Frequently asked questions

These questions and answers have been provided to address any potential issues relating to how the product can be used or how it can be interpreted. If you have any additional questions, please contact digitaldata@bgs.ac.uk

Q: What is the BGS GeoScour data product?
A: GeoScour is a package of 18 digital datasets that provides river scour susceptibility information on the natural geological characteristics and properties of catchment and riverine environments in Great Britain.

Q: What does GeoScour include?
A: GeoScour includes 18 digital datasets that are presented in three scaled tiers, ranging from a summary overview dataset of the catchment characteristics (Tier 1), 8 sub-catchment area scale datasets that focus on providing data for more detailed catchment management (Tier 2), and detailed information datasets 9 datasets at riverine scale (Tier 3).

Q: How can GeoScour be used?
A: It provides an improved toolkit to more easily assess and raise the profile of scour risk, now and in the future, to help infrastructure providers and funders prioritise resources, identify remedial works to preclude costly and prevent disruptive failures. The data product has broad applications through its adaptation to suit multiple types of assets likely to be affected by fluvial erosion. GeoScour looks specifically at the geological factors that influence scour and does not consider any hydraulic or hydrodynamic factors.

Q: Who is GeoScour for?
A: The identification of ground instability and other geological hazards can assist catchment and water management authorities and regional planners; rapidly identifying areas with potential problems and aid local government offices in making development plans by helping to define land suited to different uses, as well as for use in erosion potential modelling by environmental protection agencies and consultancy firms. Other users of these datasets may include developers, construction companies, consulting engineers, builders, homeowners, solicitors, loss adjusters, the insurance industry, architects and surveyors.

Q: What data formats are provided?
A: The dataset is provided as vector data in ESRI Shapefile and Geopackage format. More specialised formats may be available but may incur additional processing costs. Please email iprdigital@bgs.ac.uk to request further information.

Q: What map scale is the BGS GeoScour dataset provided?
A: The datasets are provided as three packages: Tier 1, a summary overview of the catchment characteristics (1:625 000 scale) and Tier 2, smaller catchment areas with a focus on providing data for more detailed catchment management (1:250 000 scale) are catchment-level data. Tier 3 datasets are detailed riverine assessments of the geological properties and susceptibility to river scour, produced for use at 1:50 000 scale providing 50 m ground resolution, and must not be used at larger scales. All spatial searches against Tier 3 data should be done with a minimum 50 m buffer.

Q: Why do we need information about river scour/erosion?
A: River scour can be a threat to in-river structures such as bridges and adjacent riverside assets. Increasing frequency and intensity of storm events could impact on the rivers potential to erode banks and beds. These GIS datasets are designed to be integrated into broader-scale catchment management planning and riverine hydrological assessments, monitoring to highlight areas of potential risk and to inform maintenance regimes or adaptation.

Q: How should I use the worst-, average- and best-case assessments?

A: Some of the scour susceptibility outputs are provided as average-case, best-case and worst-case parameters to convey the variation and heterogeneous behaviour of geological deposits and to allow the user to consider the extremes for scour potential according to their needs. To provide an example, some deposits such as the Mercia Mudstone Group consist of interbedded layers of mudstone, sandstone, siltstone with some gypsum/halite and therefore each individual lithological layer has different properties, sandstone is stronger than siltstone, whereas limestone or gypsum could be more soluble. Therefore, the worst-case rating in GeoScour will convey the weakest and most susceptible mineralogy properties of the whole deposit; whilst the best-case rating will convey strongest, least susceptible properties. If users have high value, or critical assets in close proximity to a river, with no defences and high flow rates, then it may be worth considering the worst-case rating for the asset. Where users that have lower value, or modern, resilient assets, behind flood defences, or in areas of low flow rates; then the best-case scenario might be more appropriate. As a first phase assessment, we recommend reviewing the average- and worst-case ratings and then adapting the data (or understanding about an asset) to take into account other factors as needed. Please see section 3.4.1 of the User Guide for more details.

Q: How are the 5 scour susceptibility classes divided?
A: The 5-fold classification for scour susceptibility is based on the scores of the underpinning data analyses (deposit strength/density and mineralogy). These intervals reflect a change in the lithological properties used to determine the thresholds. For example, a very strong rock with high silica mineralogy will be classified as Low Susceptibility whereas a loose sand deposit with dominant carbonate mineralogy will be classified as High Susceptibility.

<0.3	Low susceptibility
0.3 to <0.4	Low-Medium susceptibility
0.4 to <0.5	Medium susceptibility
0.5 to <0.725	Medium-High susceptibility
>0.725	High susceptibility

Q: Why do you provide both surface geology susceptibility and bedrock geology susceptibility datasets?
A: The surface geology considers the uppermost deposits associated with the riverine environment (i.e. predominantly superficial deposits) however where superficial deposits are not present, bedrock geology is included. The bedrock geology considers the bedrock geology across the whole area regardless of any superficial cover.

Q: How accurate is this dataset?
A: The mapping accuracy for all the Tier 3 datasets associated with the GeoScour is primarily based on that of the BGS Geology 50k dataset. Derived by vector capture from paper map archives, this data has a nominal +/-1 mm precision at map scale (1:50 000), which equates to +/-50 m in real space. This is only a measure of how faithfully the lines were captured from their legacy paper-map sources. Consequently, this dataset must not be used at scales finer than 1:50 000. The Tier 2 data is based on summary analysis of GeoScour Tier 3 data using Water Framework Directive “WFD River Waterbody Catchments Cycle 2” for England and Wales; and Scotland Catchments from the Scottish Environment Protection Agency (SEPA) catchment data at 1:250 000 scale. Tier 1 is composed of a single dataset of 1:625 000 scale.

Q: How often will this dataset be updated?
A: Version 1 was released in 2019. The current version (V2) was released in 2022. The dataset will be revised when sufficient source data is updated and there is a user demand. An ongoing programme of product development is in place and frequent reviews will determine when a new version of the dataset will be released.

Q: Can I use this dataset as part of a commercial application?
A: This dataset is licenced from BGS, please refer to the terms of your licence or contact iprdigital@bgs.ac.uk for further information.

Appendix 1 Displaying the data

7.1 GEOSCOUR OPEN: TIER 1 ATTRIBUTES

Catchment Stability Dataset

There are 15 attribute fields for the Catchment Stability, however for a general overview it is suggested that users use the TYPE field. To replicate the colours as used to display these data in this document and the associated layer files delivered as part of GeoScour dataset package, refer to table **Table 19**.

Table 19 Catchment Stability map colour look-up table.

TYPE	RED	GREEN	BLUE	HEX	LOOKS LIKE
Meta-stable River Catchments	112	168	0	#70A800	
Semi-stable River Catchments	170	255	0	#AAFF00	
Unstable River Catchments	233	255	190	#AAFF00	

7.2 GEOSCOUR OPEN TIER 2 ATTRIBUTES

Catchment Flood Accommodation Dataset

There are 8 attribute fields provided with the Catchment Flood Accommodation dataset. For a general overview, users are recommended to consider the AREA_PCT field which represents the percentage coverage of flood accommodation space per catchment.

To replicate the colours as used to display these data in this document and the associated layer files delivered as part of GeoScour dataset package, refer to **Table 20**.

Table 20 Catchment Flood Accommodation map colour look-up table.

AREA_PCT	RED	GREEN	BLUE	HEX	LOOKS LIKE
0 - 10	181	237	240	#B5EDF0	
11 - 20	153	209	237	#99D1ED	
21 - 30	125	186	235	#7DBAEB	
31 - 40	92	163	230	#7DBAEB	
41 - 50	54	140	227	#368CE3	
51 - 60	33	117	217	#2175D9	
61 - 70	34	89	199	#2259C7	
71 - 80	28	61	181	#1C3DB5	
81 - 90	23	39	163	#1727A3	
91 - 100	9	9	145	#090991	

Catchment Morphology

There are 6 attribute fields provided with the Catchment Flood Accommodation dataset. For a general overview, users are recommended to consider the DOM_MORPH field which represents the percentage coverage of flood accommodation space per catchment.

To replicate the colours as used to display these data in this document and the associated layer files delivered as part of GeoScour dataset package, refer to **Table 21**.

Table 21 Catchment Morphology map colour look-up table.

DOM_MORPH	RED	GREEN	BLUE	HEX	LOOKS LIKE
Mountain	255	255	191	#FFFFBF	
Uplands	219	224	155	#DBE09B	
Hill and Vale	184	196	124	#B8C47C	
Lowlands	148	166	94	#94A65E	
Coastal and Estuarine	115	138	69	#738A45	
Undefined	156	156	156	#9C9C9C	

Catchment Surface Geology Susceptibility Datasets

There are 6 attribute fields provided with the Catchment Flood Accommodation dataset. For a general overview, users are recommended to consider the DOM_SUSC field which represents the percentage coverage of flood accommodation space per catchment.

To replicate the colours as used to display these data in this document and the associated layer files delivered as part of GeoScour dataset package, refer to **Table 22**.

Table 22 Catchment Surface Geology Susceptibility map colour look-up table.

DOM_SUSC	RED	GREEN	BLUE	HEX	LOOKS LIKE
High susceptibility	255	34	0	#FF2200	
Medium - High susceptibility	255	153	0	#FF9900	
Medium susceptibility	255	255	0	#FFFF00	
Low - Medium susceptibility	122	171	0	#7AAB00	
Low susceptibility	0	97	0	#006100	
None	204	204	204	#696969	

Catchment Designated Sites

There are 18 attribute fields provided with the Catchment Designated Sites dataset. For a general overview, users are recommended to consider the PERC_ALL field which represents the percentage coverage of flood accommodation space per catchment.

To replicate the colours as used to display these data in this document and the associated layer files delivered as part of GeoScour dataset package, refer to **Table 23**.

Table 23 Catchment Designated Sites map colour look-up table.

PERC_ALL	RED	GREEN	BLUE	HEX	LOOKS LIKE
0 - 10	255	255	128	#FFFF80	
11 - 20	190	247	92	#81ED39	
21 - 30	129	237	57	#7DBAEB	
31 - 40	56	224	9	#38E009	
41 - 50	62	199	78	#3EC74E	
51 -60	0	168	181	#00A8B5	
61 - 70	0	132	168	#0084A8	
71 - 80	34	99	156	#22639C	
81 - 90	29	56	138	#1D388A	
91 - 100	12	16	120	#0C1078	

Catchment Geological Run-off Potential

There are 11 attribute fields provided with the Catchment Geological Run-off Potential dataset. For a general overview, users are recommended to consider the WORST_DESC field which represents the percentage coverage of flood accommodation space per catchment.

To replicate the colours as used to display these data in this document and the associated layer files delivered as part of GeoScour dataset package, refer to **Table 24**.

Table 24 Catchment Geological Run-off Potential map colour look-up table.

WORST_DESC	RED	GREEN	BLUE	HEX	LOOKS LIKE
Low overland flows, unless ground is excessively dry or saturated	214	214	255	#D6D6FF	

Variable run-off potential due to the mixed nature of the deposits within the geological formation	84	107	201	#546BC9	
Rapid overland flow into rivers	0	56	148	#003894	
No Data	255	0	197	#FF00C5	

Catchment Urban Coverage

There are 10 attribute fields provided with the Catchment Urban Coverage dataset. For a general overview, users are recommended to consider the PERC_LARGE field which represents the percentage coverage of flood accommodation space per catchment.

To replicate the colours as used to display these data in this document and the associated layer files delivered as part of GeoScour dataset package, refer to **Table 25**.

Table 25 Catchment Urban Coverage map colour look-up table.

PERC_LARGE	RED	GREEN	BLUE	HEX	LOOKS LIKE
0 - 10	204	204	255	#CCCCFF	
11 - 20	188	179	252	#BCB3FC	
21 - 30	171	155	250	#AB9BFA	
31 - 40	152	131	247	#9883F7	
41 - 50	135	110	245	#876EF5	
51 - 60	116	89	240	#7459F0	
61 - 70	97	69	237	#6145ED	
71 - 80	73	49	232	#4931E8	
81 - 90	50	30	230	#321EE6	
91 - 100	0	0	224	#0000E0	

7.3 GEOSCOUR PREMIUM: TIER 3 ATTRIBUTES

River Geological Properties

There are 27 attribute fields provided with the River Geological Properties dataset. For a general overview, users are recommended to consider the BEDROCK field which represents the percentage coverage of flood accommodation space per catchment.

To replicate the colours as used to display these data in this document and the associated layer files delivered as part of GeoScour dataset package, refer to **Table 26**.

Table 26 River Geological Properties map colour look-up table.

BEDROCK	RED	GREEN	BLUE	HEX	LOOKS LIKE
0 - 25	250	233	212	#FAE9D4	
26 - 50	230	171	142	#E6AB8E	
51 - 75	201	114	83	#C97253	
76 - 100	171	65	36	#AB4124	

River Morphology

There are 13 attribute fields provided with the River Morphology dataset. For a general overview, users are recommended to consider the DOM_DESC field which represents the percentage coverage of flood accommodation space per catchment.

To replicate the colours as used to display these data in this document and the associated layer files delivered as part of GeoScour dataset package, refer to **Table 27**.

Table 27 River Morphology map colour look-up table.

DOM_Desc	RED	GREEN	BLUE	HEX	LOOKS LIKE
Typically wide shallow valley profile, space for flood waters.	0	97	0	#006100	
Typically narrow and deep valley profiles, little accommodation space for flood waters, increased scour potential.	255	170	0	#FFAA00	
Typically limited floodplain capacity, valleys constrained.	255	34	0	#FF2200	

River Surface and Bedrock Susceptibility

There are 10 attribute fields provided with the River Surface and Bedrock Susceptibility datasets. For a general overview, users are recommended to consider the SCR_DESC field which represents the percentage coverage of flood accommodation space per catchment.

To replicate the colours as used to display these data in this document and the associated layer files delivered as part of GeoScour dataset package, refer to **Table 28**.

Table 28 River Surface and Bedrock Susceptibility map colour look-up table.

SCR_DESC	RED	GREEN	BLUE	HEX	LOOKS LIKE
High susceptibility	255	34	0	#FF2200	
Medium – High susceptibility	255	153	0	#FF9900	

Medium susceptibility	255	255	0	#FFFF00	
Low – Medium susceptibility	122	171	0	#7AAB00	
Low susceptibility	0	97	0	#006100	

River Lateral Erosion

There are 10 attribute fields provided with the River Lateral Erosion dataset. For a general overview, users are recommended to consider the DIST_*m field which represents the percentage coverage of flood accommodation space per catchment.

To replicate the colours as used to display these data in this document and the associated layer files delivered as part of GeoScour dataset package, refer to **Table 29**.

Table 29 River lateral Erosion map colour look-up table.

DIST_*m	RED	GREEN	BLUE	HEX	LOOKS LIKE
High susceptibility	255	34	0	#FF2200	
Medium – High susceptibility	255	153	0	#FF9900	
Medium susceptibility	255	255	0	#FFFF00	
Low – Medium susceptibility	122	171	0	#7AAB00	
Low susceptibility	0	97	0	#006100	
No Data (Superficial not mapped)	40	146	199	#2892C7	
No Intersection	156	156	156	#9C9C9C	

Glossary

Term	Explanation
Aggradation	Deposition of sediment that results in an increase in land elevation within the river system. Aggradation occurs where the sediment supply is higher than the amount of material being transported.
Alluvial	Deposits of sediment, usually sand and gravel transported and deposited by a river.
ArcGIS	Geographic information system (GIS) software for working with maps and geographic information maintained by the Environmental Systems Research Institute (ESRI).
Artificial ground	Ground surface has been significantly modified by human activity. Examples include recent anthropogenic or artificially modified ground where the ground surface has been significantly modified by human activity including quarrying, landscaping, land-raise, cuttings and embankments.
Attribute	Named property of an entity. Descriptive information about features or elements of a database. For a database feature like census tract, attributes might include many demographic facts including total population, average income, and age. In statistical parlance, an attribute is a variable, whereas the database feature represents an observation of the variable.
Bedrock	The main mass of rocks forming the earth, laid down prior to 2.588 million years ago. Present everywhere, whether exposed at the surface in rocky outcrops or concealed beneath superficial deposits, artificial ground or water. Formerly called solid.
DSM	DSM (Digital Surface Model): a digital elevation model (DEM) representing the surface topography including the tops of trees, buildings and other more temporary surface features. This differs to a Digital Terrain Model (DTM).
DTM	DTM (Digital Terrain Model): a digital elevation model (DEM) representing the bare surface topography i.e. with trees, buildings and other more temporary surface features removed. This differs to a Digital Surface Model (DSM).
DEM	DEM (Digital Elevation Model): a digital model of surface elevations that may or may not include more temporary surface features. Encompasses both Digital Terrain Models (see entry for DTM) and Digital Surface Models (see entry for DSM).
Deposit	A general term for the accumulation of sediments.
Environmental designations	Areas that have been defined by their environmental importance in the planning process, such as National Parks, AONBs, SSSIs etc.
ESRI	Environmental Systems Research Institute (ESRI) is an international supplier of geographic information system (GIS) software, web GIS and geodatabase management applications.
Fluvial	Sedimentary deposits consisting of material transported by, suspended in, and laid down by a river or stream.
Formation	Part of the BGS rock-age ordering hierarchy. A formation is the fundamental rock unit for mapping purposes. Located within a defined hierarchical structure Supergroup>Group>FORMATION>Member>Bed

Geographical Information System	Geographic Information Systems (GIS) provides accurate information, assistance, support, and maintains and creates information to aid in the development of maps and data analysis.
Geohazard	A potentially damaging event or phenomenon. Geological and environmental conditions, involving long and short-term processes which may lead to widespread damage. There are many different types of geohazard with different natural and artificial processes causing them to occur. All have the potential to create problems for development of the human environment and threats to the safety and well-being of people. Geohazards can develop quickly (seconds or minutes) in response to the processes that drive them, or take tens, hundreds, or thousands of years to develop to a point where they pose a danger. They are found in most parts of the world, including marine and fluvial environments.
Geology	The study or science of the earth, its history, and its life as recorded in the rocks; includes the study of geologic features of an area, such as the geometry of rock formations, weathering and erosion, and sedimentation.
Geospatial data	Data that has a geographic component to it. This means that the records in a dataset have locational information tied to them such as geographic data in the form of coordinates, address, city, or postcode.
Geotechnical	The application of technology to engineering problems caused by geological factors.
Glacial	Material deposited by glaciers. Glacial deposits are poorly sorted consisting of mostly coarse-grained sediments i.e. sand and gravel; with some finer-grained layers i.e. clay and silt.
Glaciofluvial	Sediments laid down primarily by waters issuing from ice sheets and glaciers. The source of the water also includes rainfall and run-off from ice-free slopes as well as melting ice. Deposits consist mainly of sand and gravel, but include silt, clay and diamicton (unsorted to poorly sorted material containing particles ranging in size from clay to boulders, suspended in a matrix of mud or sand).
Ground resolution	The detail with which the location and shape of geographic features is depicted. The larger the map scale, the higher the possible resolution. As scale decreases, resolution diminishes and feature boundaries must be smoothed, simplified, or not shown at all; for example, small areas may have to be represented as points.
Heterogeneity	Diverse and not comparable, lacking in uniformity, similarity or consistency.
Hydrogeology	Area of geology that deals with the distribution and movement of groundwater in the soil and rocks of the Earth's crust (commonly in aquifers).
Lacustrine	Sediments deposited in low-energy lake environments.
LEX_RCS	A two-part attribute code describing the name of the geological unit(s) or deposit(s) represented and their composition. Lexicon (or LEX) computer code used to identify the rock unit(s) or deposit(s) as listed in the BGS lexicon of Named Rock Units. A rock-classification scheme (RCS) code of up to 6 characters (mostly letters forming the second part of the primary LEX-RCS attribute e.g. MDCO. The code can represent a single lithology or multiple lithologies.
Lexicon	Vocabulary defining rock names, the BGS Lexicon of Named Rock Units database provides BGS definitions of terms that appear on our

	maps and in our publications. https://www.bgs.ac.uk/lexicon/home.html
Lithological units	A rock identifiable by its general characteristics of appearance colour, texture and composition defined by the distinctive and dominant, easily mapped and recognizable petrographic or lithologic features that characterize it.
Lithology	Rocks maybe defined in terms of their general characteristics of appearance: colour, texture and composition. Some lithologies may require a microscope or chemical analysis for the latter to be fully determined.
Lithostratigraphy	Age and lithology. Many rocks are deposited in layers or strata and the sequence of these strata can be correlated from place to place. These sequences of different rocks are used to establish the changing geological conditions or geological history of the area through time. The description, definition and naming of these layered or stratified rock sequences is termed lithostratigraphy (rock stratigraphy). Lithostratigraphy is fundamental to most geological studies. Rock units are described using their gross compositional or lithological characteristics and named according to their perceived rank (order) in a formal hierarchy. The main lithostratigraphic ranks in this hierarchy are Bed (lowest)>Member,>Formation>Subgroup>Group>Supergroup (highest). The units are usually named after a geographical locality, typically the place where exposures were first described.
Metadata	Data about data or a service. Metadata is the documentation of data. In human-readable form, it has primarily been used as information to enable the manager or user to understand, compare and interchange the content of the described data set. In the Web Services context, XML-encoded (machine-readable and human-readable) metadata stored in catalogs and registries enables services to use those catalogs and registries to find data and services.
Metastable	River systems that were not glaciated during the last glaciation and are not undergoing a period of paraglacial adjustment.
Nomenclature	A set or system of names or terms, used in a particular community e.g. a rock naming hierarchy.
OpenGeoscience	OpenGeoscience is a free service where you can view maps, download data, scans, photos and other information. https://www.bgs.ac.uk/opengeoscience/ Open data is data that is available to everyone to use, access and share.
Ordnance datum	In the British Isles, an ordnance datum or OD is a vertical datum (fixed starting point of a scale) used by Ordnance Survey as the basis for deriving altitudes on maps.
Paraglacial adjustment	Processes related to landscape response following previous glaciations. River systems that are still undergoing landscape adjustment following the last glaciation
Permeability	The term permeability, used in a general sense, refers to the capacity of a rock to transmit water. Such water may move through the rock matrix (intergranular permeability) or through joints, faults, cleavage or other partings (fracture or secondary permeability). A stricter definition of permeability is that it is a measure of the relative ease with which a porous medium can transmit a fluid under a potential gradient. It is the property of the medium only and is independent of the fluid. Commonly, but imprecisely, taken to be synonymous with the term Hydraulic Conductivity which implies the fluid is water.

Polygon	Polygons are a representation of areas. A polygon is defined as a closed line or perimeter completely enclosing a contiguous space and is made up of one or more links.
Porosity	The ratio of the volume of the interstices to the total volume of rock expressed as a fraction. Effective porosity includes only the interconnected pore spaces available for groundwater transmission; measurements of porosity in the laboratory usually exclude any void spaces caused by cracks or joints (secondary porosity).
Quaternary	The current and most recent time period which includes the Pleistocene (2.588 million years ago to 11.7 thousand years ago) and the Holocene (11.7 thousand years ago to today).
Quaternary deposits	All unconsolidated material deposited in the last 2.6 million years.
Resolution	Resolution expresses the size of the smallest object in a spatial data set that can be described. It refers to the amount of detail that can be discerned. It is also known as granularity.
Risk	The impact of the hazard on people, property or capital. e.g. a weak scour-prone deposit could be perceived as a hazard, but the likelihood of it causing structural damage would be the risk. A high hazard does not necessarily translate to a high risk. For example, if a particular location has a relatively high scour potential, but the assets have taken this into account, and are designed to withstand the hazard, they will not have a comparable level of risk. This is because the likelihood of the hazard causing any loss has been reduced due to the design of the asset. The GeoScour dataset does not identify the cost of a hazard being realised, and therefore does not consider risk. It only examines the conditions that leave an area exposed to the hazard.
River scour	The removal of sediment or engineered materials from the bed or banks of a watercourse, which can occur when the forces imposed by the flow on a sediment particle exceed the stabilizing forces (Kirby, *et al.* 2015, Highways Agency, 2006). In this dataset, the natural environment is considered only.
Scale	The relation between the dimensions of features on a map and the geographic objects they represent on the earth, commonly expressed as a fraction or a ratio. A map scale of 1/100,000 or 1:100,000 means that one unit of measure on the map equals 100,000 on the earth.
Scour rating	Scale or classification used to indicate low to high degree of identified threat.
Scour susceptibility	Likelihood of a vulnerability occurring at a given location.
Shapefile	The shapefile format is a geospatial vector data format for geographic information system software. It is developed and regulated by ESRI as a mostly open specification for data interoperability among ESRI and other GIS software products.
Sedimentary	Rocks that originated from the broken up or dissolved and re-precipitated particles of other rocks. Examples include clay, mudstone, siltstone, shale, sandstone, limestone and conglomerate. Sedimentary rocks cover more than two-thirds of the Earth's surface. They are formed from the weathering and erosion products of rock material, which have been transported (usually by water or wind), redeposited and later consolidated.
Sediments	Silt, sand, rocks, fossils, and other matter carried and deposited by water, wind, or ice.
Source data	Source data is raw data (sometimes-called atomic data) that has not been processed for meaningful use to become Information.

Spatial data	Data describing anything with spatial extent; i.e. size, shape or position. In addition to describing things that are positioned relative to the Earth, spatial data may also describe things using other coordinate systems that are not related to position on the Earth, such as the size, shape and positions of cellular and sub-cellular Spatial Things described using the 2D or 3D Cartesian coordinate system of a specific tissue sample.
Superficial	The youngest geological deposits formed during the most recent period of geological time, the Quaternary. They date from about 2.6 million years ago to the present.
Tectonics	Tectonic adjustment is the rebound in response to earth's tectonic events such as plate collision (mountain building).
Vector	A representation of the spatial extent of geographic features using geometric elements (such as point, curve, and surface) in a coordinate space.

References

The 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 https://envirolib.apps.nerc.ac.uk/olibcgi

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