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NATURAL ENVIRONMENT RESEARCH COUNCIL

User Guide BGS Coastal Vulnerability Index version 1

GeoAnalytics and Modelling Programme

Open Report OR/16/039

BRITISH GEOLOGICAL SURVEY

GEOANALYTICS AND MODELLING PROGRAMME

OPEN REPORT OR/16/039

User Guide BGS Coastal Vulnerability Index version 1

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Coastal erosion at Happisburgh, Norfolk.

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Foreword

This report is the user guide for the BGS Coastal Vulnerability Index for Geographic Information System (GIS) for use as a planning or desk study tool.

Acknowledgements

A number of individuals in the GeoAnalytics and Modelling and Engineering Geology Programmes have contributed to the development of the Coastal Vulnerability Index. This assistance has been received at all stages of the study. In addition to the analysis of available information and data, individuals have freely given their advice to improve this product.

Contents

TABLES

Summary

This report describes the national scale BGS Coastal Vulnerability Index. The methods used to create the dataset have been critically assessed and its fitness for purpose determined by specialists in BGS.

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

1 Introduction

Coastal vulnerability indexing is a GIS-based analysis tool for indicating multi-hazards and interdependencies within the coastal zone of Great Britain (GB). The mainland of Great Britain is surrounded by over 11 000 miles of coastline. It is a very diverse coastline both in terms of geology and geomorphology, ranging from the high chalk cliffs of Sussex to the flat expanses of The Wash and Morecambe Bay.

The coast has been shaped by the continual forces of erosion from the wind, waves and tide and the characteristics and composition of the coastline dictate the degree of its vulnerability.

The winter storms of 2013-14 starkly demonstrated the vulnerability of the GB coastline to erosion and overtopping but during media enquiries it became clear that a national picture of the sections of coastline susceptible to erosion didn't exist. The Coastal Vulnerability Index (CVI) has been created to bring together a suite of data to fill this knowledge gap.

With climate change forecasts of an increase in the frequency and intensity of winter storms, BGS has developed a coastal vulnerability index (CVI), drawing on existing BGS datasets and expertise, and we intend to work in collaboration with other organisations to help manage these changes in the future.

The CVI will offer anyone with assets or an interest in the coastline around Great Britain access to easy-to use indexes linked to geohazard data. This will allow users to interpret potential interdependencies in terms of erosion, flooding, habitat and other vulnerabilities.

Version 1 of the CVI represents the natural geological coastline (around the mainland of GB only) as if no coastal defences or made ground are present. Due to their complex geometry, the coastlines of N and W Scotland have not been included in version 1. This will be of particular value in areas where coastal defences are no longer maintained. Future versions of the CVI will include all coastal defences and made ground.

1.1 BACKGROUND

Within the 'coastal' market, changing weather patterns, increased development and demand on the land and its associated hazards are a key criteria for assigning budgets and protection strategies for many organisations. Companies have a desire to better understand the levels of potential change and risk to their infrastructure and assets (BGS focus group feedback).

There has been a large amount of research carried out and data available for the coast however this is very dispersed and in variable formats. The BGS has produced several national datasets that can be adapted, combined and analysed to produce the CVI. Previous work carried out by BGS identified the BGS datasets that would be of most use along with the identification of any potential external datasets that could be incorporated in future versions (i.e. not version 1) to enhance the CVI product and address the needs of stakeholders. There is no national data to assess cliff stability.

2 Who would benefit from the dataset?

A 'future coastal evolution study', known as Futurecoast was commissioned in October 2000 by the UK national government Department for Environment, Food and Rural Affairs (DEFRA) to provide predictions of coastal evolutionary tendencies over the next century. This work was very well supported at the time by many organisations. However since the project ended, little of the research has moved forward. Although outdated it does provide a substantial platform and much can be learnt from it.

Shoreline Management Plans (SMPs) were introduced in order to assess the processes, record changes and suggest management of the entire coastline of England and Wales. These plans, which were first published in the late 1990's (now known as SMP1s) and re- published in 2010-11, cover the whole coast of England and Wales and set suggestions for coastal management into the long-term future. There are four main management policies for each stretch (cell) of coast ('hold the line', 'advance the line', 'managed retreat', 'do nothing'), and options presented have been rigorously appraised and publicly consulted upon. Since the first generation of SMPs (SMP1), awareness of the effects of climate, sea level change, coastal evolution and changes in coastal defences has improved. In response to this, a second generation of SMPs were produced with a greater emphasis on improved links with planning systems, effects on the environment and longer term coastal policies. SMP2s recommended that these timescales should correspond broadly to time periods (epochs) of: 0 to 20 years (short term), 20 to 50 years (medium term) and 50 to 100 years (long term). They also aim to acknowledge the uncertainties associated with predicting future coastal requirements and provide maps of coastal risks from factors such as flooding and erosion.

This second generation of SMPs are being produced by Coastal Groups, consisting of the Environment Agency (EA) and relevant local authorities and it is planned that the CVI data will help inform these.
The CVI product will initially target the local authority and coastal management sectors but in time will also include:

- Archaeologists (e.g. Historic England)
- VARs,
- RSPB and other reserves/habitats

Other key stakeholders include the Insurance sector, conservation organisations (e.g. National Trust), infrastructure managers, key asset holders at the coast (e.g. Gas terminals, power stations).

3 What the dataset shows

Version 1 of the CVI consists of four data layers in Geographic Information System (GIS) format that identify areas susceptible to flooding and coastal erosion in Great Britain within 1km of the British coast. This data has been produced by geologists including engineering and coastal specialists and information specialists at the British Geological Survey. The separate layers are briefly explained below:

3.1 EROSION SUSCEPTIBILITY

The erosion susceptibility assessment considers a number of geological engineering properties of cliff sections around the GB coastline using the BGS Civils data suite, which includes discontinuities and excavatability, and the BGS Permeability dataset.

The erosion susceptibility assessment also takes into account any cliff sections that are solely comprised of superficial material, as these are deemed to be particularly soft stretches of coastline and therefore more vulnerable to erosion.

Scores derived from these properties were assigned to each layer within the cliff stratigraphy based and summed to produce an overall score of erosion susceptibility.

3.2 CLIFF TOP HEIGHT

This is a point dataset derived from the NEXTMap digital terrain model (DTM) at a 5m resolution which depicts the height of the cliff top.

3.3 GEOLOGICAL INDICATORS OF FLOODING

The Geological Indicators of Flooding (GIF) dataset is a digital map based on the BGS Digital Geological Map of Great Britain at 1:50 000 scale (DiGMapGB-50). Coverage includes England, Wales and Scotland. It characterises superficial deposits on DiGMapGB-50 in terms of their likely susceptibility to flooding, either from coastal inundation or fluvial (inland) water flow.

In summary, GIF includes categorisation of deposits that may be susceptible to:-

Fluvial Zone 1 & Zone 2: Flooding from rivers where the capacity of the river channel is exceeded and water overflows. This is identified as "fluvial" in the GIF, and is subdivided into higher (zone 1) and lower (zone 2) susceptibility categories;

Coastal Zone 1 & Zone 2: Flooding from the sea as a result of high tides and storm surges is identified as "coastal" flooding in the GIF. This is similarly subdivided into higher (zone 1) and lower (zone 2) susceptibility categories.

Both classifications are also subject to an element of pluvial flooding from land as a result of an episode of heavy intense rainfall. We do not have a specific category to identify this type of event.

Typically, GIF does not currently identify the presence of permanent standing bodies of water such as lakes or canals.

Flooding and inundation information is provided for the 1km terrestrial coastal zone.

3.4 GROUNDWATER FLOODING

BGS has produced a dataset for Great Britain that provides an assessment of the susceptibility to groundwater flooding. Based on geological and hydrogeological information, the digital data can be used to identify areas where geological conditions could enable groundwater flooding to occur and where groundwater may come close to or above the ground surface.

4 Classification

4.1 EROSION SUSCEPTIBILITY

Attribute table field descriptions

4.1.1 Class

This is the range within which the erosion susceptibility score lies. It consists of five categories, rated A-E, with A being a low rating and E being a high rating.

4.1.2 Legend

This provides an explanation of the nature of the cliff according to the class rating:

CLASS A	Strong rock cliff composed of igneous, metamorphic, or well-lithified, massive rocks.
CLASS B	Cliff with relatively strong, massive, geological formations.
CLASS C	Layered cliff with moderate to strong geological formations and moderate structural discontinuities.
CLASS D	Multi-layered cliff with relatively weak geological formations and abundant structural discontinuities.
CLASS E	Weak, unlithified (superficial deposits), low or no cliff.

Terminology:

Lithified refers to the degree to which an unconsolidated sediment has been turned into a solid rock.

Massive is a geological term used to describe a rock with few to no internal structural features such as fractures or bedding.

Structural discontinuities are weaknesses in the rock such as fractures, joints or bedding planes.

4.1.3 Layers

This specifies the number of formations present in a cliff/low lying section, classified as either single, double or multiple.

4.1.4 Score

This is the erosion susceptibility score, derived using the methodology outlined in section 5.1.

4.1.5 Version

The version number of the dataset.

4.2 CLIFF TOP HEIGHT

Attribute table field descriptions:

4.2.1 Height_M

Cliff spot heights in metres spaced at 50 metre intervals, sampled from NEXTMap around the Great Britain mainland coast.

4.2.2 Version

The version number of the dataset.

4.3 GEOLOGICAL INDICATORS OF FLOODING

Attribute table field descriptions

4.3.1 Class

This is the '*zone'* and '*mode*' combined giving 4 possible types of flooding-

- Coastal flood deposits

  Zone 1 – areas susceptible to the first influx of flood waters

  Zone 2 – areas that are susceptible in extreme flood events (e.g. storms surges and exceptionally high tides)

- Fluvial – inland fluvial flood deposits

  Zone 1 – areas susceptible to the first influx of flood waters

  Zone 2 – areas that are susceptible in extreme flood events

4.3.2 Zone

Indicates the level of potential flooding, it is divided into 2 zones; *'Zone 1'* are areas with a high potential to flood; *'Zone 2'* are secondary flood areas that may be susceptible in extreme or prolonged events.

4.3.3 Mode

This indicates the type of flood that an area might be susceptible to; either *'fluvial'* or *'coastal'* flooding.

4.3.4 Legend

A brief explanation of the type of flooding potential.

4.3.5 Version:

The version number of the dataset.

4.4 GROUNDWATER FLOODING

Attribute table field descriptions

4.4.1 Class

This is the range within which the groundwater flooding lies. It consists of three categories, rated A-C. With A being a low rating and C being a high rating.

4.4.2 Floodtype

This describes the flood type and consists of two categories:
Clearwater flooding is flooding caused by a rising water table in an unconfined aquifer.
Superficial deposits flooding is flooding caused by permeable superficial deposits overlying bedrock of low permeability.

4.4.3 Version

The version number of the dataset.

4.4.4 Legend

A brief explanation of the type of flooding potential.

5 How the dataset was created

5.1 EROSION SUSCEPTIBILITY

5.1.1 Stage 1: classification of the vertical cliff lithologies

The first deposits above the mean high water mark (cliff or low-lying, not including the beach) were classified to formation level using the BGS Lex-RCS system (Lexicon – Rock Classification Scheme). These were identified and interpreted by a team of geologists with expertise in specific coastal regions. The classification also included information on where there were single units, double units or multiple units forming the cliff section.

5.1.2 Stage 2: application of geological properties for each formation within the cliff.

The properties of each formation present were attributed and scored using the following datasets:

- BGS Civils – Discontinuities
    - Rock mass
    - Stratification
    - Foliation
    - Additional
- BGS Civils – Excavatability (describes the strength of tools required to excavate the soil or rock)
- BGS Permeability dataset

The differences between adjoining formations (upper and lower) were then assessed for contrasting excavatability (Table 1) and permeability (Table 2).

Table 1 Excavatability scores for adjoining formations

All adjacent excavatability combinations				
Top layer	**Strong**	**Strong**	**Weak**	**Weak**
Bottom layer	**Strong**	**Weak**	**Strong**	**Weak**
Score	**1**	**3**	**2**	**4**

Table 2 Permeability scores for adjoining formations

All adjacent permeability combinations									
Top layer	**High**	**High**	**High**	**Variable**	**Variable**	**Variable**	**Low**	**Low**	**Low**
Bottom layer	**High**	**Variable**	**Low**	**High**	**Variable**	**Low**	**High**	**Variable**	**Low**
Score	**1**	**2**	**4**	**2**	**3**	**4**	**2**	**2**	**1**

This information identifies where instability within the cliff might be present or susceptible for example:

- Where weak, highly fractured rocks overlie a strong, massively bedded formation, then toppling failures might be more common.
- Where a highly permeable sandstone overlies an impermeable mudstone, in-cliff slip planes might develop.
- Where a permeable or unconsolidated lithology forms the base of a cliff, wave erosion might be prevalent.

The range of factors described above are collated into a total score and provided as five cliff stability score categories in the final dataset.

5.2 CLIFF TOP HEIGHT

The creation of the cliff height dataset utilises NEXTMap digital terrain model (DTM) at a 5m resolution and the Ordnance Survey (OS) Strategi coastline. This processing has been developed to calculate a detailed cliff height using novel feature extraction techniques to analyse cross-shore transects, generate elevation profiles and identify the cliff top as the spike in profile curvature. Spot heights are provided every 50 m along the coastline.

5.3 GEOLOGICAL INDICATORS OF FLOODING

This information is based on the presence of previous flooding events having deposited material from coastal inundation. It characterises superficial deposits on DiGMapGB-50 in terms of their likely susceptibility to flooding, either from coastal inundation. The majority of these coastal and fluvial superficial deposits are considered ‘young' in geological terms, most having been formed within the last few tens of thousands of years. Typically they have been laid down by processes of erosion and deposition and they have produced subtle topographical features, resulting in low-lying landforms we call floodplains and coastal plains.

The mapping of floodplains and coastal plain landforms, in conjunction with characterisation of deposits that underlie them, allows us to determine the extent of the coastal and inland flooding that created them. Observations made during recent major inland and coastal flooding events have demonstrated that the current floodplains and coastal plains continue to play a role in controlling where and how flooding occurs.

It is these mapped extents that are provided within the CVI within the 1km coastal zone.

5.4 GROUNDWATER FLOODING

In terms of coastal vulnerability, the following definition of groundwater flooding has been adopted:

> *Groundwater flooding is the emergence of groundwater at the ground surface away from perennial river valleys or the rising of groundwater into man-made ground under conditions where the 'normal' range of groundwater levels and groundwater flows is exceeded.*

This definition encompasses flooding that may have relatively widespread areal extent as well as flooding caused by the activation of new point emergences or springs, or anomalous discharge from perennial or ephemeral springs leading to groundwater flooding down the topographic slope. Flooding associated with urban groundwater rebound, mine water discharge (mine water rebound), with urban drainage, or any other flooding associated with changes in the engineered environment, is not included in the definition and has been excluded from the current dataset. The data provided identifies areas within the 1km coastal zone that might be susceptible to groundwater flooding.

6 Technical information

6.1 FORMAT

The datasets are released in ESRI shapefile formats (.shp). Other formats such as MapInfo TAB are available on request. The standard data supplied to customers has points, polygons and polylines in a single layer or theme.

6.2 COVERAGE

Data is provided to indicate coastal vulnerability (erosion and flooding) for mainland Great Britain, (excluding north and west Scotland for the erosion susceptibility layer).

6.3 DATA HISTORY

Version 1 (released 2016): Derived from DiGMapGB-50 version 6.

6.4 LIMITATIONS

There are limitations to the detail and accuracy of the DigMapGB50 dataset used in the cliff stratigraphy assessment. Most geological maps are collated at 1:10 000 scale. The linework from these maps is then transferred to a 1:50 000 scale map which has the inevitable consequence of a loss of detail and accuracy in the geology depicted. Therefore in areas that are geologically complex an exact representation of the geological units present may not always be possible.

The cliff stability scoring methodology does not currently consider the protective effects of "Holocene buffers" such as wave cut platforms or beaches which would act to dissipate wave energy before it meets the cliff. Version 2 of the CVI will include a "Holocene buffers" input to the overall cliff stability.

The OS Strategi coastline was chosen to avoid IPR issues and it was the best-fit coastline that was available. However the linework in places is very coarse and of poor detail and in some areas does not follow the desired coastline (e.g. harbours, piers, tidal inlets). A customised coastline, based on DTM analysis of the cliff toe is being developed but will require more work before it is suitable for release.

Narrow, elongate headlands have been difficult to depict in the cliff height dataset analysis, due to the methodology used to extract the heights from the DTM. This may lead to inaccuracies in the cliff heights around headlands. However, the cliff top points, even where slight inaccuracies occur, provide a good general approximation of the cliff/coastal slope height.

Sections of coastline that are structurally geologically complex have been simplified. Without the benefit of detailed local knowledge or field observations it is difficult to ascertain the precise geological succession within the cliff.

There is potentially an issue with the over-representation of the number of geological formations in a cliff; i.e. cliff sections that include a greater number of geological formations and therefore a corresponding greater number of attributes (which are added together), end up with a higher score. A statistical solution to this problem will be explored for version 2.

North and west Scotland are not included in version 1 due to the complexity (sinuosity) of the coastline in these areas. It would be very time-consuming to include every loch and tidal inlet using the current methodology. Therefore a more generalised approach will need to be explored for version 2 of the CVI.

For the purposes of version 1, low-lying areas and their associated superficial deposits (e.g. sand dunes, salt marshes) have been incorporated using the same scoring system as bedrock cliffs. These will be treated separately in version 2 and a new, revised scoring system will be devised for low-lying coastlines.

The data is intended for use down to 50m resolution.

The CVI is intended to provide an assessment of susceptibility to coastal erosion either by flooding, wave action or cliff instability. It is provided at a national scale and is not intended for very detailed site specific analysis. Further detailed commissioned research is available if detailed assessments are required. Please see the contact information below if you require information.

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Appendix 1 Coastal Vulnerability Index V1 Legends

Erosion susceptibility legend

Field name	Description
CLASS	A erosion rating of increasing susceptibility from A to E
LEGEND	A brief description of the nature of the cliff rock mass and discontinuities
LAYERS	The number of formations present in a cliff/low lying section, classified as either single, double or multiple
SCORE	The total susceptibility score between 0 and 100
VERSION	Map metadata

Erosion susceptibility classes

Class	LEGEND
A	Strong rock cliff composed of igneous, metamorphic, or well-lithified, massive rocks.
B	Cliff with relatively strong, massive, geological formations
C	Layered cliff with moderate to strong geological formations and moderate structural discontinuities
D	Multi-layered cliff with relatively weak geological formations and abundant structural discontinuities
E	Weak, unlithified (superficial deposits), low or no cliff

Cliff top height classes

Height_M
0-2
2-5
5-10
10-20
20-50
50-100
>100

Geological indicators of flooding classes

Class	Legend
1 Coastal	Higher flood potential from the sea: the first areas to experience the effects of coastal flooding.
2 Coastal	Lower flood potential from the sea: areas affected in extreme cases due to combined factors e.g. very high tides/high wind speeds/large storm surge.
1 Fluvial	Higher flood potential from rivers: the first areas to experience the effects of inland flooding in a river catchment.
2 Fluvial	Lower flood potential from rivers: areas affected by secondary flooding in extreme cases as a result of a prolonged flood event.

Groundwater Flooding Susceptibility classes

CLASS	LEGEND
A	Limited potential for groundwater flooding to occur
B	Potential for groundwater flooding of property situated below ground level
C	Potential for groundwater flooding to occur at surface