British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

# User Guide British Geological Survey Coastal Vulnerability Dataset (Version 1)

GeoAnalytics and Modelling Programme

Open Report OR/17/025

BRITISH GEOLOGICAL SURVEY

GEOANALYTICS AND MODELLING PROGRAMME

OPEN REPORT OR/17/025

# User Guide British Geological Survey Coastal Vulnerability Dataset (Version 1)

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*Keywords*

Coastal vulnerability, erosion, flooding, inundation, engineering geology, User Guide, GIS, National dataset.

*National Grid Reference*

SW corner 100000,3000
Centre point 415238, 293007
NE corner 666000,660000

*Front cover*

Coastal erosion at Happisburgh, Norfolk.

*Bibliographical reference*

JENKINS, G O, MEE, K, RICHARDSON, J F M, LEE, K A, WESTHEAD, R K, CARTER, G D O, JORDAN H M, PAYO A.. 2017. User Guide British Geological Survey Coastal Vulnerability Dataset (Version 1). *British Geological Survey Open Report*, OR/17/025. 18pp.



Keyworth, Nottingham British Geological Survey 2017

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# Foreword

This report is the user guide for the BGS Coastal Vulnerability Dataset 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 Dataset. 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.

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# Summary

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

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

# 1 Introduction

The Coastal Vulnerability Dataset (CVD) is a Geographic Information System (GIS)-based analysis for indicating multi-hazards and interdependencies within the coastal zone of Wales and England. Version 1 of the CVD does not include islands (e.g. Isle of Wight, Anglesey).

The mainland of Wales and England is surrounded by over 12 000 km 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 coastline of Wales and England to erosion and overtopping by waves and storm surges, but when responding to media enquiries it became clear that a national picture of the sections of coastline susceptible to erosion, based on geology didn't exist. The Coastal Vulnerability Dataset has been created to fill this knowledge gap. Due to its complex geometry, the coastline of Scotland has not been included in version 1.

With climate change forecasts of an increase in the frequency and intensity of winter storms, BGS has developed a coastal vulnerability dataset, 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 CVD will offer anyone with assets or an interest in the coastline around Wales and England access to easy-to use datasets 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 CVD represents the natural geological coastline (around the mainland of Wales and England) as if no coastal defences or made ground are present. This will be of particular value in areas where coastal defences are no longer maintained. Subject to availability, it is intended that future versions of the CVD will include all coastal defences and made ground.

# 2 About the Coastal Vulnerability Dataset

## 2.1 BACKGROUND

Within the coastal market, changing weather patterns, increased development and demand on the land and its associated hazards are the 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 which is dispersed and in variable formats. A scoping study (Jenkins et al., 2014) identified several existing BGS datasets that could along with external datasets be adapted, combined and analysed to produce the CVD and address the needs of stakeholders. Currently however, there is no national data to assess cliff stability.

## 2.2 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 CVD data will help inform these.

The CVD product will initially target the local authority and coastal management sectors but in time will also include:

- Archaeologists (e.g. Historic England)
- VARs,
- Conservation organisations (e.g. RSPB, WWT, National Trust) 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).

## 2.3 WHAT THE DATASET SHOWS

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

### 2.3.1 Backshore (Erosion susceptibility)

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

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

A scoring system was derived based on a range of geological and engineering properties and applied to each rock layer within the cliff stratigraphy. These scores were summed to produce an overall score of erosion susceptibility.

### 2.3.2 Foreshore (Holocene Buffers)

The Foreshore dataset contains the spatial extent of coastal geomorphological features (beaches, tidal flat deposits, saltmarshes or wave-cut platforms or any combination of these) that would potentially act to dissipate wave energy before it meets the cliff. These features would effectively "buffer" the cliff or backshore, potentially decreasing rates of erosion from waves and currents.

### 2.3.3 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. The original data has been resampled at a 50 m interval around the coastline of England and Wales.

### 2.3.4 Inundation

The Inundation dataset has been derived from the Geological Indicators of Flooding (GIF) dataset and the Groundwater Flooding dataset. Both datasets were clipped using a 1km coastal buffer from the OS Strategi coastline. The Groundwater Flooding dataset was then clipped to the GIF dataset so that both datasets are of the same areal extent (removing Groundwater Flooding from areas of higher ground when neither coastal nor fluvial flooding occur). The purpose of the Inundation dataset is to highlight areas where coastal flooding is likely to occur during extreme storm events and the potential exacerbation of the coastal flooding from coincident groundwater flooding. It also highlights areas susceptible to fluvial flooding which may also exacerbate coastal flooding when the two hazards coincide.

More information on the source datasets is outlined below:

#### 2.3.4.1 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. For the purposes of the Inundation dataset in the CVD, the fluvial classes have all been merged into one category.

**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.

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

Within the CVD package flooding and inundation information is provided for the 1km terrestrial coastal zone.

#### 2.3.4.2 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.

Within the CVD package the groundwater flooding dataset is constrained to the 1km terrestrial coastal zone.

# 3 Technical Information

## 3.1 SCALE

The coastal vulnerability datasets are produced for use at 1:50 000 scale providing 50 m ground resolution.

## 3.2 FIELD DESCRIPTIONS

### 3.2.1 Backshore (Erosion susceptibility)

Attribute table field descriptions.

#### 3.2.1.1 CLASS

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

#### 3.2.1.2 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.

#### 3.2.1.3 LAYERS

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

#### 3.2.1.4 SCORE

The Backshore score is derived using the methodology outlined in section 2.3.1. It represents the total of all criteria for each section of coast.

#### 3.2.1.5 VERSION

The version number of the dataset.

### 3.2.2 Foreshore (Holocene buffers)

Attribute table field descriptions.

#### 3.2.2.1 HOL_BUFFER

The spatial extent of a beach, tidal flat, saltmarsh or wave-cut platform or any combination of these geomorphological features.

#### 3.2.2.2 VERSION

The version number of the dataset.

### 3.2.3 Cliff Top Height

Attribute table field descriptions:

#### 3.2.3.1 HEIGHT_M

Cliff spot heights in metres spaced at 50 metre intervals, sampled from NEXTMap around the England and Wales mainland coast.

#### 3.2.3.2 VERSION

The version number of the dataset.

### 3.2.4 Inundation

Attribute field descriptions:

#### 3.2.4.1 GWFLOOD

The potential for groundwater flooding to occur, derived from the GroundwaterFlooding dataset.

#### 3.2.4.2 GIF

The potential for coastal or fluvial flooding to occur, derived from the GIF dataset.

#### 3.2.4.3 INUNDATION

The potential for coastal inundation based on a combined analysis of the Groundwater Flooding and GIF datasets. It adopts a combination of the existing classifications used in these two datasets respectively and is reclassified into the following categories:

| Inundation category | Description |
|---|---|
| 1 Coastal with no GWFlood | Areas with a higher flood potential from the sea with no potential for exacerbation of coastal flooding from groundwater flooding. |
| 1 Coastal with GWFlood limited | Areas with a higher flood potential from the sea with limited potential for exacerbation of coastal flooding from groundwater flooding. |
| 1 Coastal with GWFlood below surface | Areas with a higher flood potential from the sea with limited potential for exacerbation of coastal flooding from groundwater flooding below the ground surface. |
| 1 Coastal with GWFlood at surface | Areas with a higher flood potential from the sea with limited potential for exacerbation of |

| | |
|---|---|
| | coastal flooding from groundwater flooding at the ground surface. |
| 2 Coastal with no GWFlood | Areas with a lower flood potential from the sea with no potential for exacerbation of coastal flooding from groundwater flooding. |
| 2 Coastal with GWFlood limited | Areas with a lower flood potential from the sea with limited potential for exacerbation of coastal flooding from groundwater flooding. |
| 2 Coastal with GWFlood below surface | Areas with a lower flood potential from the sea with limited potential for exacerbation of coastal flooding from groundwater flooding below the ground surface. |
| 2 Coastal with GWFlood at surface | Areas with a lower flood potential from the sea with limited potential for exacerbation of coastal flooding from groundwater flooding at the ground surface. |
| Fluvial | Areas where coastal inundation may be exacerbated by fluvial flooding. |

#### 3.2.4.4 VERSION

The version number of the dataset.

## 3.3 CREATION OF THE DATASET

### 3.3.1 Backshore (Erosion susceptibility)

#### 3.3.1.1 CLASSIFICATION OF THE VERTICAL CLIFF LITHOLOGIES

Deposits above the mean high water mark i.e. cliff or low-lying, but not including the beach were classified to formation level using the BGS Lex-RCS system (Lexicon – Rock Classification Scheme).

This identification and interpretation was carried out 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.

#### 3.3.1.2 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 characterised for:
    - 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) and scores assigned.

**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 potential instability within the cliff might be present. 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 to provide a total score. The five cliff stability classes are derived from this total score and included in the dataset.

### 3.3.2 Foreshore (Holocene Buffers)

This layer was created in a similar way to the Backshore data layer, with each geologist assigned a shapefile for their section of coastline. The geologist attributed the line to depict the presence of beaches, tidal flats, saltmarshes or wave-cut platforms (or any combination of these) using aerial photography.

### 3.3.3 Cliff Top Height

The creation of the cliff height dataset utilises NEXTMap digital terrain model (DTM) at a 5m resolution. This processing has been developed to calculate a detailed cliff height using novel feature extraction technique 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.

### 3.3.4 Inundation

The Inundation layer was derived by combining the existing BGS Geological Indicators of Flooding and Groundwater Flooding datasets for a 1 km coastal buffer to highlight areas where coastal flooding may be exacerbated by the effects of groundwater flooding.

More information on the source datasets used to derive the Inundation layer is provided below:

#### 3.3.4.1 Geological Indicators of Flooding

This information is based on the presence of previous flooding events 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 known as floodplains and coastal plains.

The mapping of floodplains and coastal plain landforms, in conjunction with characterisation of deposits that underlie them, allows determination of 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. These mapped extents that are provided within the CVD within the 1km coastal zone.

#### 3.3.4.2 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.

## 3.4 DATASET HISTORY

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

## 3.5 COVERAGE

Data is provided to indicate coastal vulnerability (erosion and flooding) for mainland England and Wales (erosion datasets) and mainland GB (flooding datasets). Islands (e.g. Isle of Wight, Anglesey) are not included in version 1.

## 3.6 DATA FORMAT

The datasets are released as individual layers as points (Clifftop), lines (Backshore and Foreshore) and polygons (Inundation). The data are available in a range of GIS formats, including ArcGIS (.shp), ArcInfo coverages and MapInfo (Tab). More specialised formats may be available but may incur additional processing costs.

## 3.7 LIMITATIONS

There are limitations to the detail and accuracy of the BGS Geology 50k (formerly 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. In areas that are geologically complex an exact representation of the geological units present may not always be possible.

Sections of coastline that are structurally geologically complex have been simplified. Without the benefit of detailed local knowledge or field observations it can be 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. For example cliff sections that include a greater number of geological formations currently this would correspond to a greater number of attributes, as each is scored and the scores added together. A higher score would result reflecting the number of attributes not necessarily a greater risk of cliff failure. A statistical solution to this problem will be explored for the next version.

The coastline of Scotland is not included in version 1 due to the complexity (sinuosity) of the coastline. Including every loch and tidal inlet using the current methodology would present a number of problems, therefore a more generalised approach is being explored for version 2.

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. Consideration is currently being given to a new revised scoring system for low-lying coastlines. If successful it will be integrated into future versions of CVD.

The Inundation layer has been derived from two datasets. The GIF dataset is based on the extent of the polygons of mapped geological deposits, whereas the Groundwater Flooding dataset has been generated to a 50 m by 50 m gridded structure. Therefore there will be artefacts (slivers) where the two datasets do not spatially coincide.

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

The CVD 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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# Contact information

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# Appendix 1 Coastal Vulnerability Dataset V1 Legends

**Backshore 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 | Version of the dataset |

**Backshore 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 |

**Foreshore classification**

| Holocene Buffer |
|---|
| Beach |
| Beach and Tidal Flat |
| Beach and Wave Cut Platform |
| None |
| Saltmarsh |
| Saltmarsh and Beach and Tidal Flat |
| Saltmarsh and Tidal Flat |
| Tidal Flat |
| Wave Cut Platform |

**Cliff top height classes**

| Height_m |
|---|
| 0-2 |
| 2-5 |
| 5-10 |
| 10-20 |
| 20-50 |
| 50-100 |
| >100 |

**Inundation**

| Inundation category | Description |
|---|---|
| 1 Coastal with no GWFlood | Areas with a higher flood potential from the sea with no potential for exacerbation of coastal flooding from groundwater flooding. |
| 1 Coastal with GWFlood limited | Areas with a higher flood potential from the sea with limited potential for exacerbation of coastal flooding from groundwater flooding. |
| 1 Coastal with GWFlood below surface | Areas with a higher flood potential from the sea with limited potential for exacerbation of coastal flooding from groundwater flooding below the ground surface. |
| 1 Coastal with GWFlood at surface | Areas with a higher flood potential from the sea with limited potential for exacerbation of coastal flooding from groundwater flooding at the ground surface. |
| 2 Coastal with no GWFlood | Areas with a lower flood potential from the sea with no potential for exacerbation of coastal flooding from groundwater flooding. |
| 2 Coastal with GWFlood limited | Areas with a lower flood potential from the sea with limited potential for exacerbation of coastal flooding from groundwater flooding. |
| 2 Coastal with GWFlood below surface | Areas with a lower flood potential from the sea with limited potential for exacerbation of coastal flooding from groundwater flooding below the ground surface. |
| 2 Coastal with GWFlood at surface | Areas with a lower flood potential from the sea with limited potential for exacerbation of coastal flooding from groundwater flooding at the ground surface. |
| Fluvial | Areas where coastal inundation may be exacerbated by fluvial flooding. |