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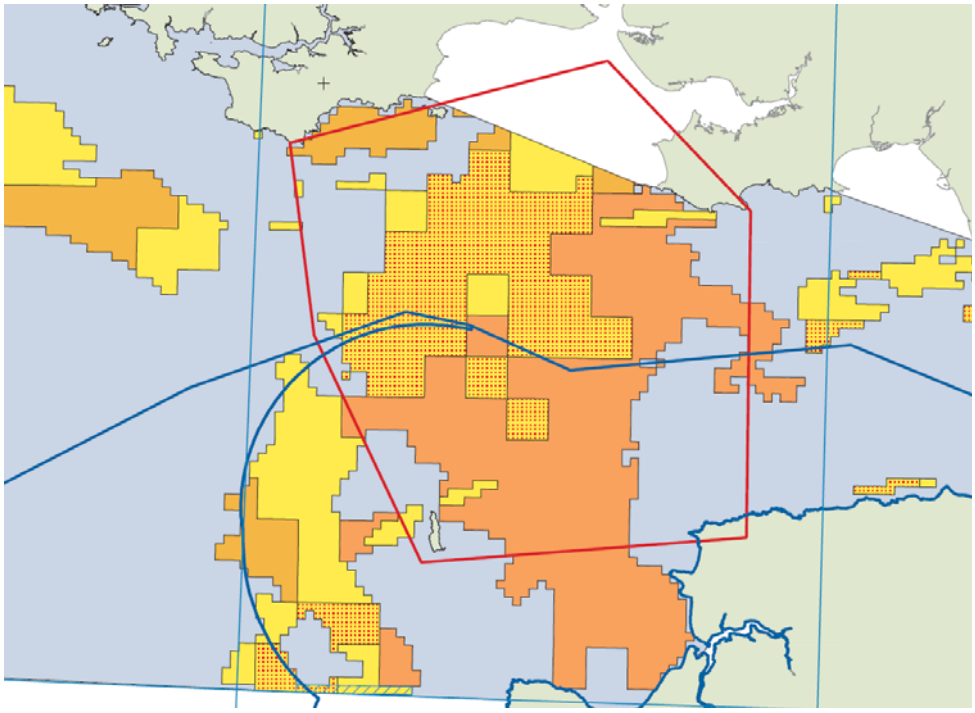
The Mineral Resources of Welsh Waters and the Irish Sea

Minerals and Waste Programme

Open Report OR/12/097



BRITISH GEOLOGICAL SURVEY

MINERALS AND WASTE PROGRAMME

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The Mineral Resources of Welsh Waters and the Irish Sea

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Foreword

This report accompanies the mineral resource map *the marine sand and gravel resources of Welsh waters and the Irish Sea* (Bide et al, 2012). It has been published as part of the research project *Mineral Resource Assessment of the UK Continental Shelf* commissioned by The Crown Estate. The map is one of a series that covers the UK Continental Shelf (UKCS).

Knowledge of mineral resources is essential for effective and sustainable planning decisions. The marine mineral resource maps provide a comprehensive, relevant and accessible information base. This information will allow all stakeholders (planners, industry and members of the public) to visualise the distribution of offshore minerals to a common standard and at a common scale, an important requirement of an integrated offshore planning system. The maps will also facilitate the conservation (safeguarding) of non-renewable mineral resources for future generations in accordance with the principles of sustainable development.

Acknowledgements

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1 Introduction

Minerals are naturally occurring raw materials essential for the development of a modern economy. However, mineral resources are finite and can only be worked where they occur. As their extraction is subject to many constraints, it is important that society uses minerals in the most efficient and sustainable manner. Identifying the distribution of known mineral resources on the UK Continental Shelf (UKCS) and presenting them in a consistent fashion at a national scale allows minerals to be considered in the marine spatial planning process and permits more effective and sustainable management strategies to be developed.

The British Geological Survey (BGS) has undertaken a commission from The Crown Estate to prepare a series of mineral resource maps which cover the UKCS. Mineral resource information was compiled following a desk study of data held by the BGS and external sources. This report summarises the mineral resources depicted on the third of these maps - The area from the Severn Estuary to Southern Scotland (Figure 1). This area includes the North West, and South West Inshore and Offshore marine plan areas as defined by the Marine Management Organisation (MMO) as well as areas around Wales where the Welsh Government have responsibility for planning. This map does not include waters for which the Isle of Man is responsible.

The map has been produced by the collation and interpretation of a wide range of information, much of which is spatially variable and not always available in a consistent and convenient form. The map depicts mineral resources of current or potential future economic interest in the area. It comprises a 1:500 000 scale map (which accompanies this report) depicting marine aggregate (sand and gravel) resources on the sea bed, and two 1:1 500 000 scale maps (as annexes in this report) depicting coal and evaporite resources at depth beneath the sea bed. These map scales are convenient for the overall display of the data. However, all the data are held digitally at larger scales (1:250 000) using a Geographical Information System (GIS), which allows for revision, updating and customisation of the information, as well as integration with other datasets.

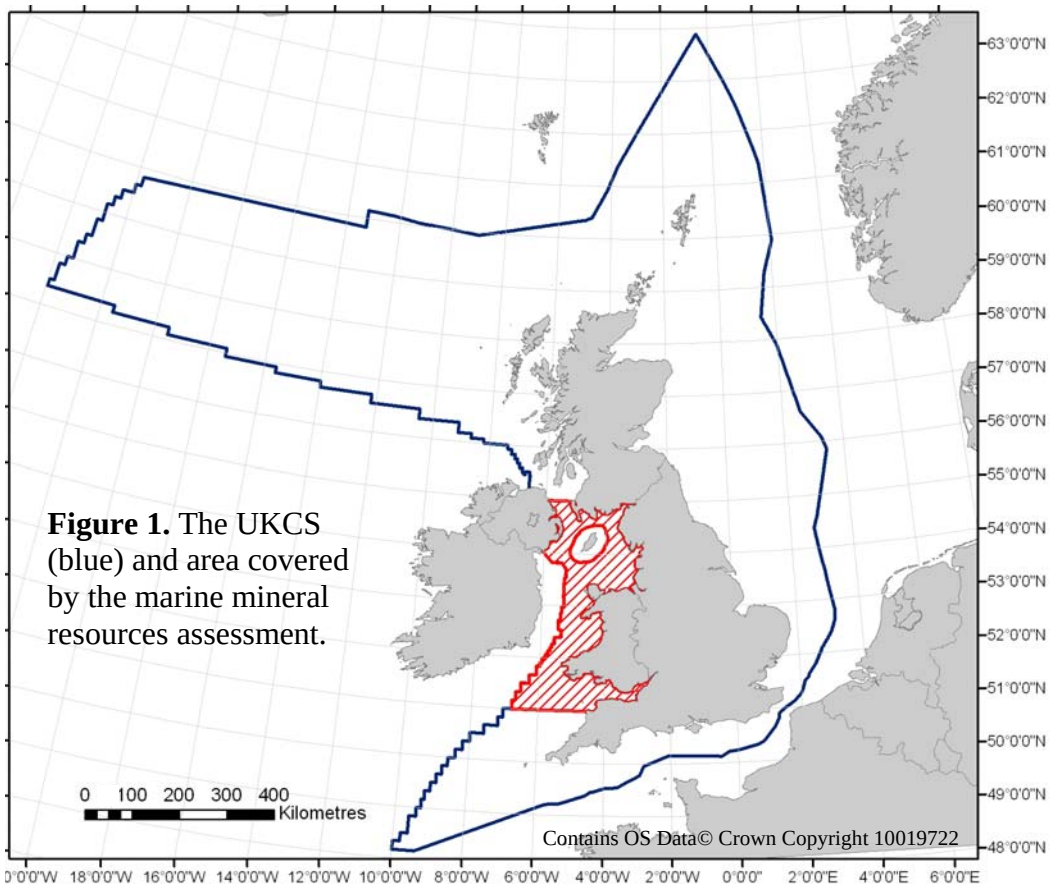


Figure 1. The UKCS (blue) and area covered by the marine mineral resources assessment.

The purpose of the map is to assist all interested parties involved in the preparation and review of marine plans, both in relation to the extraction of minerals and to the protection of mineral resources from sterilisation by development that prevents future mineral extraction. It provides a knowledge base, in a consistent format, on the nature and extent of mineral resources in the area. The primary objective is to provide baseline data which will assist long-term planning for minerals supply. However, it is anticipated that the map and report will also provide valuable background data for a much wider audience, including the minerals industry, other areas of planning, environmental and regulatory bodies and the general public.

2 What is a Mineral Resource?

A mineral resource is a natural concentration or occurrence of material of intrinsic economic interest in or on the Earth's crust in such form, quality and quantity that there are reasonable prospects for eventual economic extraction.

Mineral resources generally correspond to the boundaries defined by geological mapping which may be supplemented by more detailed geological data. The mineral resources defined by this study show the areas within which potentially workable minerals may occur. What may be of economic interest does change over time as markets decline or expand, product specifications change, recovery technology is improved or more competitive sources become available. The spatial extent of mineral resources thus shows all minerals which have resource potential in terms of physical and/or chemical properties that make them suitable for specific uses, irrespective of the extent of the deposit, planning constraints (such as exclusion zones), operational constraints (such as water depth) and proximity to markets or other economic factors.

That part of a mineral resource which has been fully evaluated and is commercially viable to work is called a mineral reserve. In the context of marine planning, the term mineral reserve should strictly be further limited to those minerals for which a valid licence for extraction exists (i.e. permitted reserves). Without a valid planning consent no mineral working can take place and consequently the inherent economic value of the mineral resource cannot be released and resulting wealth created.

3 Marine Aggregate Mineral Resources

The UKCS contains a wide range of minerals. In terms of revenue generated and employment sand and gravel for aggregate use makes a significant contribution to the UK economy. The UK is well endowed with marine aggregate resources and has one of the largest marine aggregate dredging industries in the world. These minerals make an important contribution to the supply of raw materials for both the construction sector and for coastal protection and reclamation (Highley *et al.,* 2007). Sand and gravel has a variety of construction applications including concreting aggregate, aggregates used in mortar, beach nourishment, material for coastal defences and fill applications. To date over 900 million tonnes of marine sands and gravels have been extracted from the UKCS (Selby, 2011). Marine aggregates account for around a third of the UK's production of sand and gravel (Idoine *et al.,* 2012). In 2011, 19.12 million tonnes were extracted from UK waters (The Crown Estate, 2012). Regionally the industry is even more important, making a crucial contribution to sand and gravel supply in London, the South East, North East, North West and South Wales (Highley *et al.*, 2007). Marine-dredged sands make a vital contribution to aggregate supply to South Wales as they are the only significant source of available sand for concrete manufacture. In 2010, around 45 per cent of sand and gravel produced in Wales (0.73 million tonnes) was from marine sources (Idoine *et al*., 2012).

The principal minerals information presented on the marine sand and gravel resource map are:

- The geological distribution of all offshore aggregate minerals – differentiated between those areas containing aggregates suitable for construction or beach nourishment (considered to be resources of national importance) and those suitable for contract fill and land reclamation applications (considered to be resources of regional importance). Areas that are prospective for coarse sand and gravel, where resources are known but lack of data means they cannot be resolved, are also shown.
- The location of current aggregate extraction licences (where planning permission for aggregate extraction has been granted) and application areas (where an exclusive option for mineral extraction has been agreed).
- Areas known to contain important sand and gravel resources.

3.1 METHODOLOGY FOR ASSESSING MARINE AGGREGATE RESOURCES

Areas of aggregate mineral resource have been inferred using existing geological maps depicting Holocene and Pleistocene geological units. Where significant deposits (more than one metre thick) of granular, unlithified, sedimentary material are shown on the geological maps, the BGS's sea bed sample and core dataset was used to ascribe aggregate properties to these deposits. Further interpretation was then undertaken using additional data, where available, including bathymetry, cores and geophysical information and the resultant distribution of sand and gravel resources defined.

Data held by the BGS were augmented by data collected from the Outer Bristol Channel Marine Habitat Study funded principally by the Marine Aggregate Levy Sustainability Fund (MALSF) (www.marinealsf.org.uk). Geophysical data, grab samples and bathymetric data collected and processed as part of these studies was incorporated into the data set used to interpret the distribution of sand and gravel resources.

Marine sand and gravel resources have been categorised into resources considered to be of national importance and those that are only of regional importance. Nationally important aggregate resources are defined as being suitable for construction aggregate and beach recharge applications. They have been defined based on the geological suitability of sediments for aggregate applications, with reference to the relevant European Standards (principally BS EN 12620L:2002, Aggregates for Concrete). Nationally important resources are based on the following criteria: deposits must be more than one metre thick with mud content of less than 10 per cent and a median grain size (D50) of over 0.25 millimetres. These have been further classified into fine aggregate and coarse aggregate using the lithic gravel content (lithic gravel is used to exclude biogenic carbonate which is not considered suitable for aggregate resources). A D50 of 0.35 millimetres has been used as a threshold to further differentiate the fine aggregate fraction into coarse and fine sand. Coarse sand is of particular interest to the aggregates industry because it is an important component in concrete manufacture. A flow sheet depicting the categorisation of aggregate resources can be seen in Figure 2.

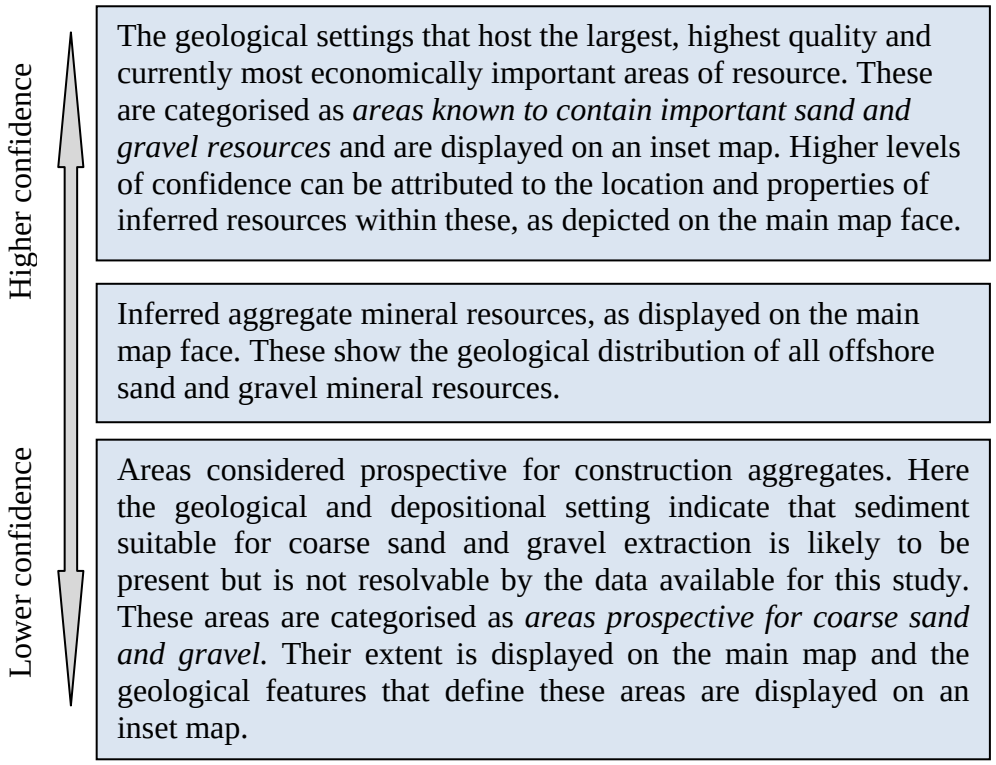
Regionally important aggregate resources are defined as material suitable for contract fill and land reclamation applications. Regionally important resources are based on the following criteria: deposits must be more than one metre thick with mud content of less than 10 per cent and a median grain size of less than 0.25 millimetres.

Areas where the carbonate content of sand exceeds 50 per cent are also defined on this map. This is to highlight the large accumulations of biogenic material in some areas which has implications to the use of sediment for aggregate applications. High carbonate sands are considered to be suitable for lower specification applications than those with a high silica content. A limit of 50 per cent has been used as this defines the boundary between a carbonate

sediment and a siliclastic sediment. There are no defined carbonate limits in European Standards for aggregate applications.

There are areas of the map where no resource has been inferred. These represent areas where, at a regional scale and using data available to this study, there is no evidence for the presence of aggregate resources, although it is possible that some limited areas of resource may be present.

All mineral resources depicted on the marine sand and gravel resource map are inferred resources. An inferred mineral deposit is that part of a mineral resource for which volumes and quality can only be estimated with a low level of confidence. It is inferred from geological evidence and assumed but not verified geological continuity. It is based on information gathered through appropriate techniques such as cores, sea bed sediment samples and shallow geophysics which can be limited or of uncertain quality and reliability. However, some level of differentiation can be applied to areas of inferred mineral resources. Due to geological uncertainty, and variations in the base data used, the following categories have been used to compile these maps to ensure areas of high quality and economically important minerals are given due consideration:



Areas prospective for coarse sand and gravel

Areas prospective for coarse aggregate and coarse sand are also shown on the map. These areas relate to geological features (such as palaeochannels or glacial deposits) that may be prospective for sand and gravel but are unresolvable with the current levels of data available to this study (as explained in the case study below). These areas are based on the presence of regional geological formations and features that have been proved to contain economic deposits of sand and gravel in specific localities (i.e. aggregate licence areas). The geological features and environments that these deposits are derived from are shown on an inset map. These areas indicate the likely presence of nationally important sand and gravel resources.

One prospective area has been identified in the Welsh waters and Irish Sea area: the East Irish Sea (see Appendix 1). This area occurs due to the presence of glacial deposits that are likely to contain coarse sand and gravel. It is bounded to the east by the muddy sediments of the Irish Sea

mudbelt and to the west by the limit of till formation in which coarse sand and gravel are known to occur.

Areas known to contain important sand and gravel resources

Areas known to contain important sand and gravel deposits have been delineated on an inset map. These give an indication to the location of important aggregate resources. Within these areas, and unlike areas prospective for coarse sand and gravel, a high level of confidence can be attributed to the location and extent of sand and gravel deposits. Three such areas occur in the Welsh waters and Irish Sea area all within the Bristol Channel (see Appendix 2). In addition some economic factors have also been considered, such as distance to markets, to give an indication of what are currently the most important areas of marine sand and gravel resources.

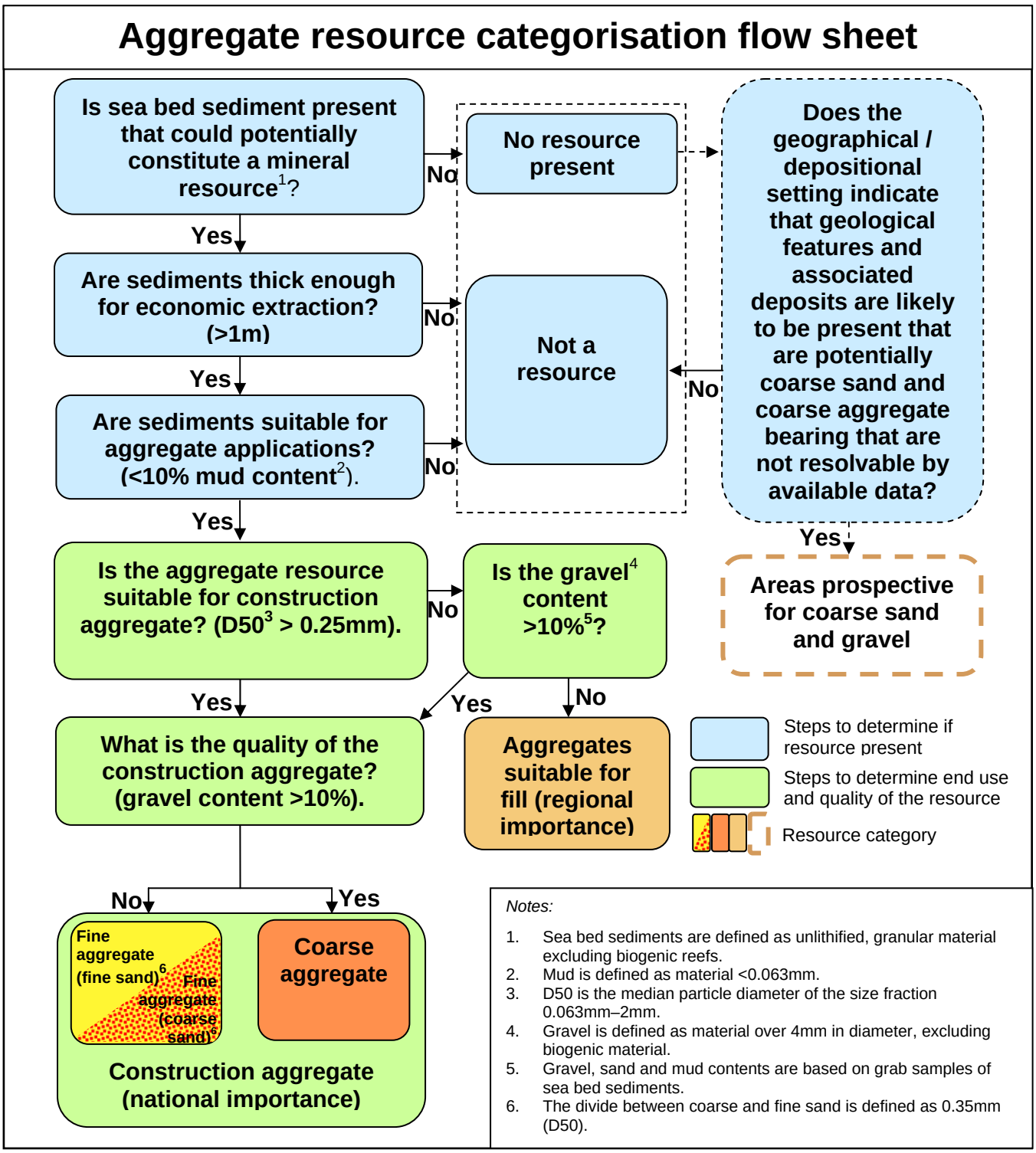


Figure 2. Aggregate resource categorisation flow sheet.

Case study: Complex sand and gravel deposits in the Eastern Irish Sea

An area in the East Irish Sea has been identified as a prospective area for coarse sand and gravel due to insufficient data to resolve the complex geology.

The area contains highly variable glacial and fluvial sediments, often modified and concealed by reworking during the last marine transgression. Glacial tills, which do not constitute a resource, comprise structureless, stiff clays with a wide range of clast sizes often winnowed at the sea bed to form a thin gravel veneer. These tills are overlain by both proglacial lagoonal sediments and sand and gravel deposits which are often incised into the till, representing a sequence typical of glacial retreat and sea level rise. This localised incision and infilling which can reach thicknesses of over 20 metres is revealed by seismic sections and core records.

These sediments are often overlain by more recent mobile marine sands and intertidal sediments. These intertidal sediments form a complex sequence of intertidal marshes and flats overlying beach deposits as well as sands and gravels of possible fluvial origins formed when the major rivers systems in the area flowed out across Liverpool Bay, at times of much lower sea level. This complex sequence of geological events and processes has left sand and gravel deposits that are localised, discontinuous and problematic to predict. This is illustrated in Figure 3 which shows simplified cross sections through some of the sedimentary deposits found in this area.

The difficulties in resolving this complex geological sequence is compounded by sparse coverage of data available to this study in the East Irish Sea. For example, due to the age of surveys (1969-1975), no seismic data of sufficient resolution for shallow sediments is available. The properties of aggregate resources in this area also vary greatly at depth and may not be the same as the surface sediments, (one of the main sources of information needed to produce the map). These factors result in low levels of confidence being attributed to the properties and locations of sand and gravel resources in this area and it is possible that good quality sand and gravel resources may occur locally but have not been resolved on this map. Further, operationally viable deposits can cover small areas, less than one square kilometre, (the smallest grid spacing used on the marine aggregates map) but can still potentially contain significant volumes of sand and gravel. As a result any sand and gravel resources in this area can only be resolved by detailed surveying.

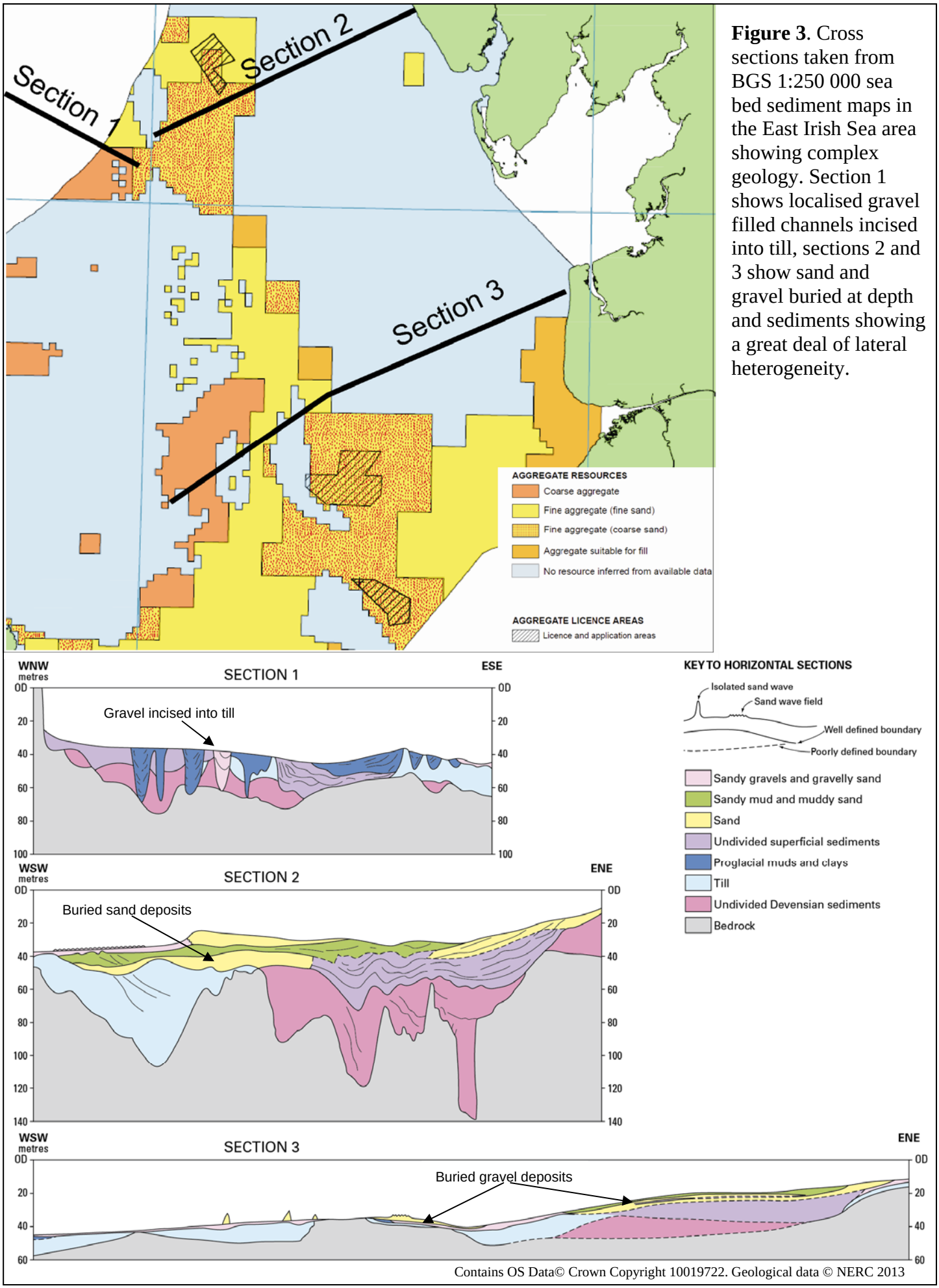


Figure 3. Cross sections taken from BGS 1:250 000 sea bed sediment maps in the East Irish Sea area showing complex geology. Section 1 shows localised gravel filled channels incised into till, sections 2 and 3 show sand and gravel buried at depth and sediments showing a great deal of lateral heterogeneity.

3.2 REGIONAL REVIEW

Map coverage extends from the northern part of the Celtic Sea to the Irish Sea and includes the UK portion of St Georges Channel (Figure 4), Cardigan Bay, the Severn Estuary and the Bristol Channel. The map also includes several major embayments, such as Morecambe Bay, Liverpool Bay, the Solway Firth, Conway Bay, Swansea Bay and Carmarthen Bay. Generally data coverage for these areas is poor and sediments are highly variable and as such they have not been included in the study. Bay closing lines, which delineate the boundary between inshore and offshore waters as defined by the UK Hydrographic Office, as well as boundaries defined by BGS, have been used to determine the extent of these areas. The Severn Estuary and Bristol Channel have been included in their entirety due to both large amounts of data for these areas and the presence of important sand and gravel resources.

3.3 AGGREGATE RESOURCES OF WELSH WATERS AND THE IRISH SEA

Sand and gravel deposits are accumulations of durable rock fragments and mineral grains which have been derived from the weathering and erosion of bedrock mainly by glacial and fluvial processes, but also by marine and wind erosion. The properties of gravel, and to a lesser extent sand, largely depend on the properties of the original bedrock from which they were derived. However, hydrodynamic processes are an effective mechanism for wearing away weaker particles, as well as separating different size fractions. Most economic sand and gravel is composed of particles that are durable and rich in silica (quartz, quartzite and flint). The marine sand and gravel resources of Welsh waters and the Irish Sea are shown in Figure 4. This is a smaller scale version of the published map *The marine sand and gravel resources of Welsh waters and the Irish Sea*.

Offshore sands and gravels have similar origins to their land-based equivalents and are mainly derived from glacial and fluvial depositional systems. Many marine aggregate resources are relict deposits that were formed during times when the sea level was much lower than present. During these periods large parts of the sea bed were exposed, glaciated or crossed by major river systems.

The Irish Sea and the northern part of the Celtic Sea contain examples of this type of relict sand and gravel deposits, which were formed as glaciers advanced and subsequently retreated over the area and deposited thick glacial, periglacial and glacio-marine sediments. These glacial deposits comprise mainly very muddy sediments or till that are not considered prospective for sand and gravel. However, areas of localised heterogeneous gravels do occur within till deposits in the Eastern Irish Sea, around the Isle of Man and, locally, off the Irish coast. These deposits have been formed by a range of complex processes, most likely derived from glacial meltwater channels from retreating glaciers and the deposits left behind within palaeo-river valleys. The area where these sediments occur is outlined in Appendix 1. These deposits form important aggregate resources but their extent is poorly defined due to insufficient data to resolve the complex geology.

Glacial sediments also form important resources in the outer Bristol Channel, where retreating ice left extensive coarse sand and gravel deposits. The properties and extent of these deposits are much better known than those of the Irish Sea and the area where they occur is depicted in Appendix 2. These glacial events have also deposited several linear gravel bodies, most likely to be morainic features known as ‘sarns’, in Cardigan Bay.

Modern marine sand deposits (gravel is generally only mobilised by the most extreme sea bed currents in the modern marine environment) are formed from tidal currents and wave action reworking and sorting sand into semi-mobile banks and sand waves. There are extensive sand wave fields as well as numerous sand banks present. Sand waves are common throughout the Irish Sea, Celtic Sea and Bristol Channel. Three of the largest sand wave fields extend south west from the Lleyn Peninsula, to the north west of Anglesey and to the west of Lundy. Sand

waves to the west of Lundy and off the coast of Pembrokeshire comprise fine sand and have wavelengths of around 300 metres and heights of 5 to 10 metres. Sand waves in Cardigan Bay comprise coarse sands with variable wavelengths and heights between 5 and 20 metres. These sand wave fields are remote from aggregate markets and may not represent a major resource, however significant sand wave fields are also present in major estuaries and embayments, such as the Bristol Channel which are much more prospective for aggregate resources. The heights and morphology of these sand waves vary greatly but they are generally over two metres high. Sand banks are mostly confined to estuaries and near shore environments with strong tidal regimes. Numerous large sand banks can be found in the Bristol Channel, many of which contain coarse sand. Broad intertidal sand banks occur in the Inner Bristol Channel. These comprise fine sand and material suitable for fill applications, however current dredging operations also extract material suitable for construction aggregate. Other modern mobile sea bed sediments form sand and gravel resource in the estuaries and embayments. The most prospective in terms of aggregate resources are found in the Inner Bristol Channel and Severn Estuary. The resource consists of coarse-grained material filling bathymetric deeps. Areas in the Bristol Channel and Severn Estuary where these sediments occur are depicted in Appendix 2.

Lower current velocities cause muddy sediments to accumulate for example, in Bridgwater Bay and the eastern Irish Sea mud belt off the coast of Cumbria and Lancashire. This accumulation of fine-grained sediments means there is little potential for sand and gravel resources. Outside these areas mud contents are generally low.

Shell content varies across the region. It is higher in areas of low sediment input such as the northern Irish Sea and the parts of the Celtic Sea close to the median line. The deposits within sand banks and sand waves have typically low shell content but some deposits to the north of the Isle of Man have shell contents exceeding 50% of the sand fraction, reducing their potential as sand and gravel resources. Sediment composition varies with sandstone, siltstone, flint, igneous and metamorphic rock types all represented although the most predominant lithologies are quartz and quartzite.

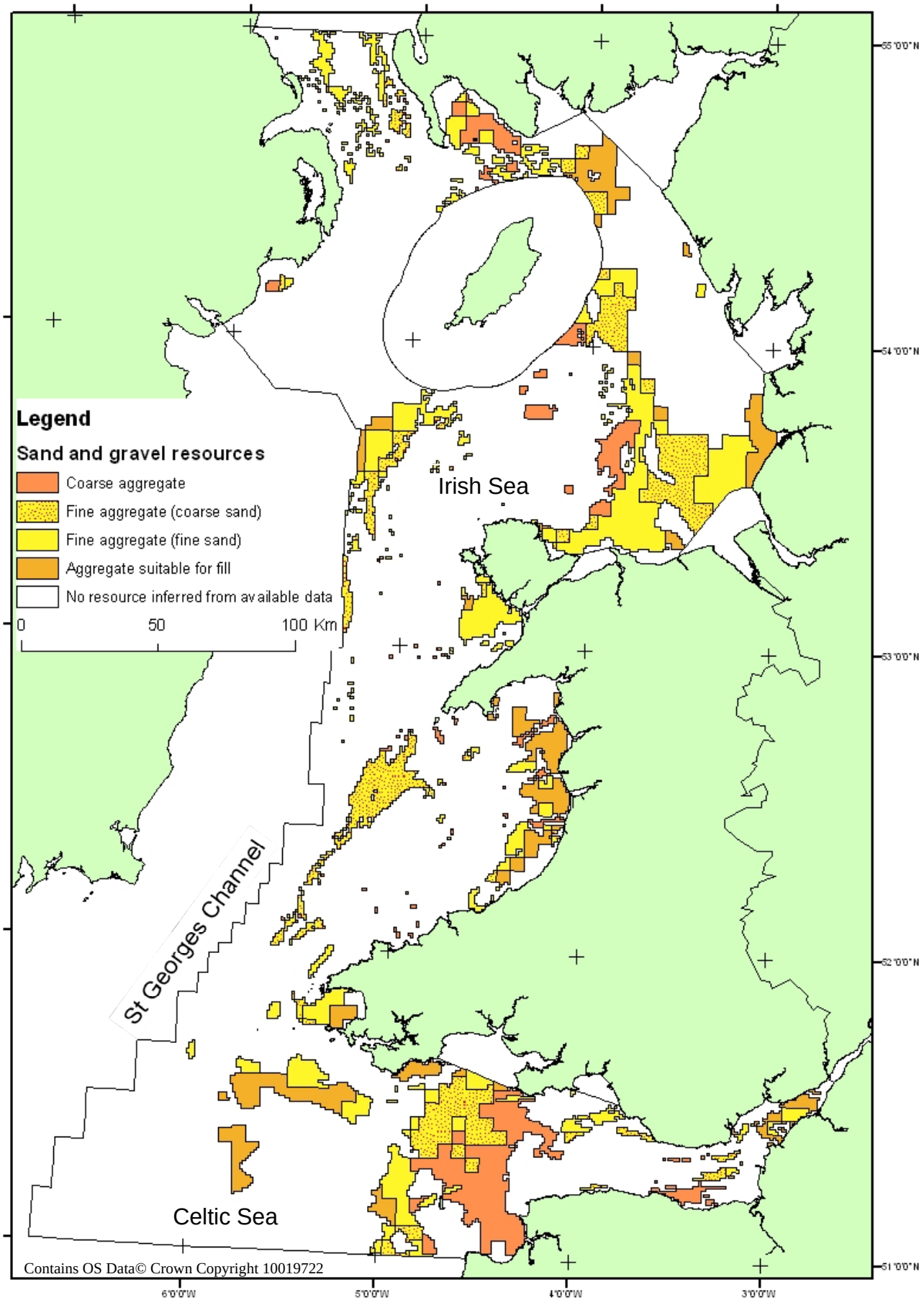


Figure 4. Sand and gravel resources of the Wales and Irish Sea area based on *the marine sand and gravel resources of Welsh waters and the Irish Sea*.

4 Other minerals

Coal, evaporite and metallic mineral resources are located on or beneath the sea bed. Coal and evaporite minerals are an important national asset and adequate and steady supplies are needed to maintain current and future economic development. The UK metallic minerals industry has declined over recent years but substantial resources remain.

Coal and evaporite mineral resources have been inferred from geological mapping data and the interpretation of boreholes. These resources have not been evaluated on any systematic basis by drilling or by other sampling methods for the purpose of mineral exploration. The map depicting the distribution of geological formations hosting coal resources is included as Appendix 3 and the map depicting the extent of sub-sea evaporite-bearing geological formations (salt-bearing halite resources) is included as Appendix 4. Data on offshore metallic minerals is sparse and the location and properties of resources are poorly known. The presence of these resources is inferred from geochemical data, geological sampling and explorative actives by the extractive industry.

4.1 COAL RESOURCES

Coal is a combustible carbonaceous sedimentary rock derived from lithified plant remains. It was formed by the alteration of dead plant material that initially formed as a superficial deposit of peat and has been buried by subsequent layers of younger sediments. As temperatures rose underground due to increasing depth of burial, the initial superficial peat deposits were altered by the process of coalification forming first brown coals, including lignite and sub-bituminous coal, to black or hard coals that encompass bituminous coal, semi-anthracite and anthracite (Kendall *et al.*, 2010).

The process of coalification involves the loss of water and volatiles leading to an increase in carbon content, from about 60 per cent in peat to greater than 95 per cent in anthracite. The calorific value of coal also increases from about 15 megajoules per kilogram in peat, to about 35 megajoules per kilogram in bituminous coals and anthracite (Kendall *et al.*, 2010).

Coals are commonly defined by their content of moisture, volatiles, ash and fixed carbon. These properties together determine a coal's rank, or degree of coalification. For example, anthracite is classed as a high rank coal whereas lignite is classed as low rank.

Within the Welsh waters and the Irish Sea map area coal resources are located in the East Irish Sea Basin and Bristol Channel Basin. The East Irish Sea Basin hosts reasonably extensive coal deposits of Carboniferous age. Carboniferous coal-bearing strata in the central area of the East Irish Sea Basin occur at depths of approximately 2000 to 3000 metres, reaching a maximum depth of 4000 metres. However, coal-bearing strata in the western parts of the basin are more likely to occur at depths of up to 3000 metres.

The Bristol Channel Basin also contains Carboniferous coal-bearing strata. However, the offshore extent of these coals is limited compared to other areas of the UKCS. Onshore the coals are represented by Lower, Middle and Upper Coal Measures (Westphalian A to Westphalian D), observed in the South Wales and Bristol Coalfields. Detailed information about equivalent offshore coal for this area of the UKCS is sparse; however, offshore coals are likely to be broadly similar to those onshore.

Where circumstances permit, certain coal seams may be a source for alternative fossil fuels. Sometimes known as 'unconventional hydrocarbons', alternative fossil fuels may present a viable replacement for natural gas. Obtaining alternative fossil fuels requires extraction technologies which are very different to those used to extract conventional hydrocarbons. Of relevance to offshore coal resources is methane recovered from undisturbed or 'virgin' coal seams (usually known as coalbed methane (CBM)) and underground coal gasification (UCG).

The prime requirements for CBM prospects are unworked coal seams thicker than 0.4 metres at depths of between 200 and 1200 metres. Low permeability and high drilling costs currently make deeper targets unattractive.

'Underground coal gasification' (UCG) involves combustion of underground coal seams *in situ* to produce synthetic gas ('syngas'). Coals located at depths in excess of 1200 metres are considered unsuitable for Underground Coal Gasification (UCG), with ideal depths being between 600 and 1200 metres (Holloway *et al.*, 2005).

Only a small amount of coal in Welsh waters and the Irish Sea is found at depths between 600 and 1200 metres, with most located below 2000 metres. As such, the majority is too deep for both CBM and UCG.

The potential to exploit offshore coal resources is uncertain. Any attempt to extract coal using conventional deep mining techniques from onshore would incur significant development costs given the depths and distances involved. Therefore, conventional extraction is currently unlikely. Likewise, it is unlikely that offshore coal resources will be exploited more than a few kilometres from shore by any of the above new technologies (CBM and UCG) in the near future. Research is required to obtain a better indication of their potential. Further information on the UK's coal resources can be found in the BGS Mineral Planning Factsheet on coal

(http://www.bgs.ac.uk/downloads/start.cfm?id=1354).

4.2 EVAPORITE RESOURCES

Evaporite minerals, including gypsum and anhydrite, halite (rock salt) and, more rarely, potash and magnesium salts, are precipitated during the evaporation of seawater. The arid conditions that existed during Permian and Triassic times across England and Wales resulted in several cycles of evaporite deposition, represented by numerous halite sequences. These resources have the potential to be extracted at depth via brine pumping, and the resulting cavities have potential for underground gas storage.

The Welsh waters and Irish Sea area contains several basins which host evaporite deposits; the East Irish Sea Basin, the Solway Firth and North Channel Basins, the Central Irish Sea Basin Bristol Channel Basin and Cardigan Bay Basin (Appendix 4).

The East Irish Sea Basin is perhaps the most prospective for evaporite resources and comprises the Permian St Bees Evaporite Formation as well as six Triassic halite formations, of which the Presall Halite Formation is worked onshore. This unit is the thickest halite unit within the Mercia Mudstone Group of the East Irish Sea. It comprises clean halite with thin partings of mudstone and siltstone. The formation is present throughout most of the East Irish Sea Basin. The formation varies in thickness ranging from between 100 to 600 metres, generally thickening towards the north. The depth of the formation varies greatly across the basin, with a maximum of over 5 km at the centre.

Triassic and upper Permian halites also occur in the Solway Firth and in the North Channel Basin, to the north-west of the Isle of Man, however the extent and properties of these rocks are poorly known.

Evaporites from the Triassic Mercia Mudstone Group in the Central Irish Sea are also present in Cardigan Bay, the South Celtic Sea and the Bristol Channel. These units have been proved in boreholes but their extent is unknown.

Although there are extensive offshore evaporite resources on the UK Continental Shelf, their extraction may not always be economically viable. Feasibility of mining these resources depends on factors such as the commodity prices, geology, available technology, depth of deposits, distance to shore.

Further information on the UK's salt resources can be found in the BGS Mineral Planning Factsheet on salt (http://www.bgs.ac.uk/downloads/start.cfm?id=1368).

4.3 METALLIC MINERALS

Marine processes can lead to the concentration of metallic minerals in sea bed sediments. Currently metallic minerals are not exploited on or under the UKCS. However, several types of mineral have been recorded in potentially economic concentrations and the working of some deposits has been considered in the past.

There are very limited records of metallic minerals around the Welsh coast however minor amounts of gold have been recovered from sediments of the Mawddach Estuary, North Wales by trials and small scale panning. During the early 1970s RioFinex, a subsidiary of RTZ Ltd carried out some exploration in the Mawddach Estuary during its onshore investigations at nearby Coed-y-Brenin, where significant copper and gold mineralisation is known. These studies suggest significant quantities of placer gold could be contained in the estuary, however, environmental constraints halted further exploration.

5 Limitations

The purpose of the maps described in this report is to show the broad distribution of mineral resources present in the Welsh waters and Irish Sea area. They delineate areas within which potentially workable minerals may occur. These areas are not of uniform or equal potential and also take no account of planning constraints that may limit their working. The economic potential of individual sites can only be proved by a detailed evaluation programme. Such an investigation is also an essential precursor to the submission of a planning application for mineral working.

With reference to the marine aggregates map, extensive areas are shown as having no mineral resource potential, but some aggregates dredging does occur in these areas. The presence of these operations generally reflects local or specific situations that are not resolved by the density of data that are available for compilation of this regional-scale map and require site-specific investigation to identify. Therefore, marine mineral licences may be located in areas where no resource is shown. It is also possible that local variations in geology that are too subtle to be resolved by this regional-scale survey can contain substantial volumes of resource, which could prove to be significant in the future.

Glossary

Aggregate: Particles of rock which, when brought together in a bound or unbound condition, form part or whole of a building or civil engineering structure.

Biogenic: A material formed by organisms or biological activity.

Carboniferous: A period of geological time from 359 to 299 million years ago.

Clast: A rock fragment; commonly applied to a fragment of pre-existing rock included in a younger sediment.

Evaporite: A mineral formed from precipitation from concentrated brine.

Flint: Variety of chert occurring in the Chalk of northern Europe.

Fluvial: Relating to a river; a deposit produced by the action of a river.

Glaciofluvial: May be applied to sediment transported and deposited by running water discharged from an ice mass.

Glacial deposits: Heterogeneous material transported by glaciers or icebergs and deposited directly on land or in the sea. Often poorly sorted.

Gravel: Granular material in clasts between 4 and 80 millimetres; coarse aggregate. Used for general and concrete applications.

Holocene: The youngest epoch of the Quaternary period from 0.01 million years to present.

Mineral: A naturally formed chemical element or compound and normally having a characteristic crystal form and a distinct composition.

Moraine: A landform deposited directly by a glacier.

Permian: A period of geological time from 299 to 251 million years ago.

Periglacial: Cold, dry climatic conditions occurring away from glacial ice.

Placer: A deposit of economic minerals formed by natural (often gravity driven) processes).

Pleistocene: An epoch of the Quaternary period from 2.58 to 0.01 million years ago.

Quartz: Crystalline silica; an important durable rock-forming mineral.

Reserve: That part of a mineral resource that is economical to work and has been fully evaluated on a systematic basis by drilling and sampling and is free from legal or other obstruction that might inhibit extraction.

Resource: Natural accumulations of minerals, or bodies of rock, that are, or may become, of potential economic interest as a basis for the extraction of a commodity.

Sand: A granular material that is finer than 4 mm, but coarser than 0.063 mm.

Siliclastic: A clastic sediment predominantly (over 50%) composed of silicate minerals.

Till: Glacial sediments, often unsorted clay and boulders deposited directly from glaciers.

Triassic: A Period of geological time from 250 to 200 million years ago.

Westphalian: A Period of geological time during the late Carboniferous.

References

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

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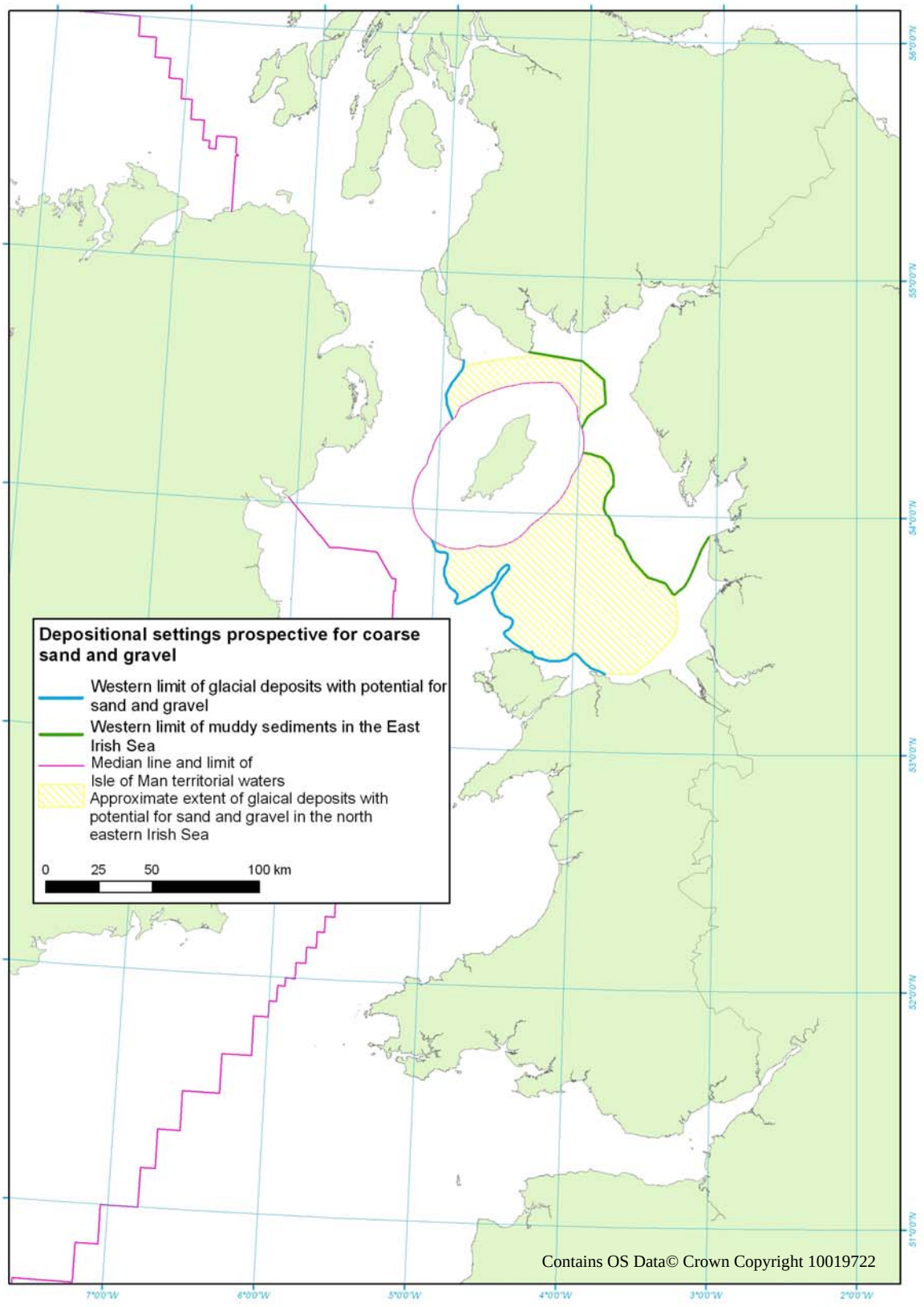
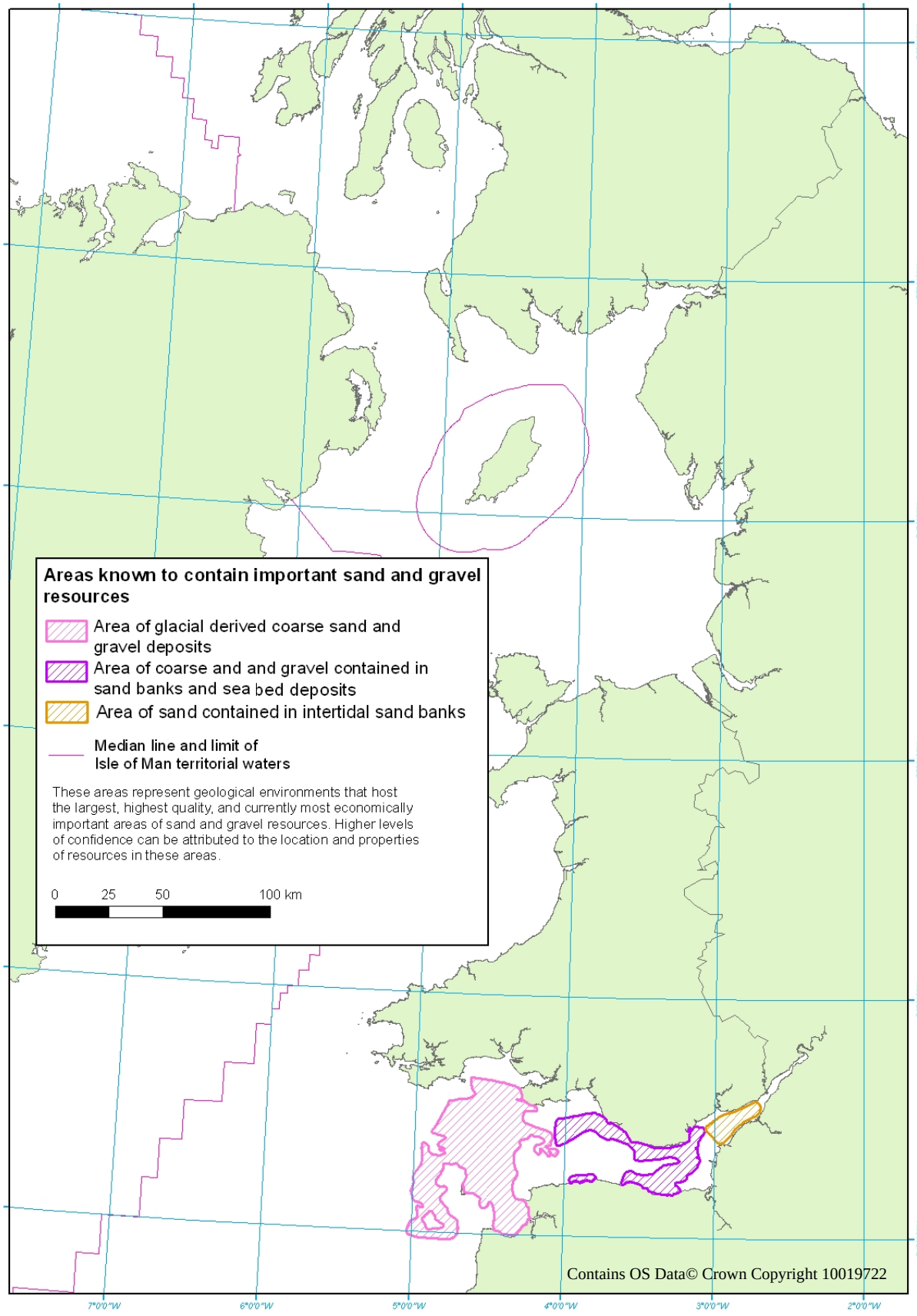
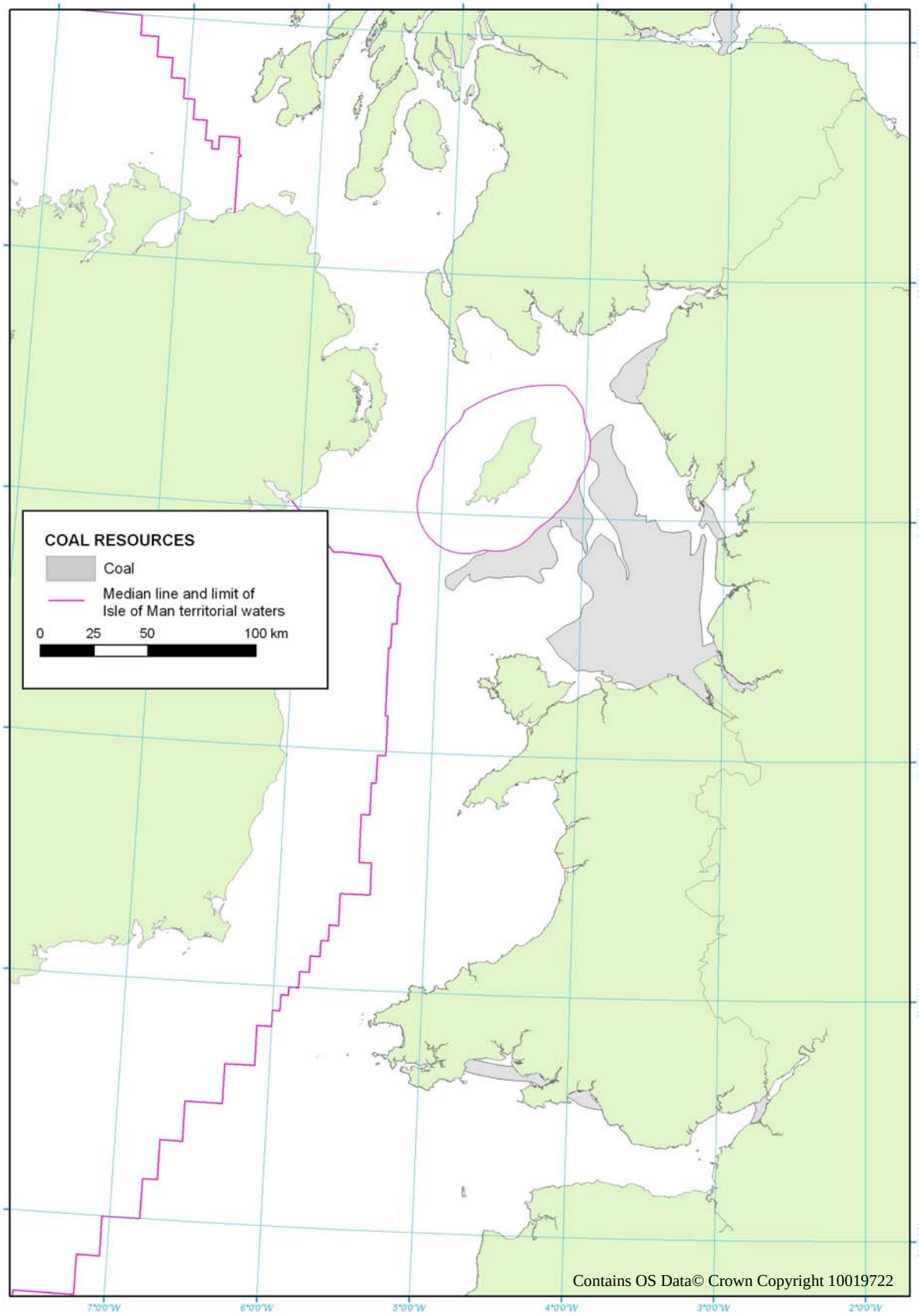
Appendix 1 Map depicting the geological features used to identify areas prospective for coarse sand and gravel



Appendix 2 Map depicting areas known to contain important sand and gravel resources



Appendix 3 Map of coal resources



Appendix 4 Map of evaporite resources