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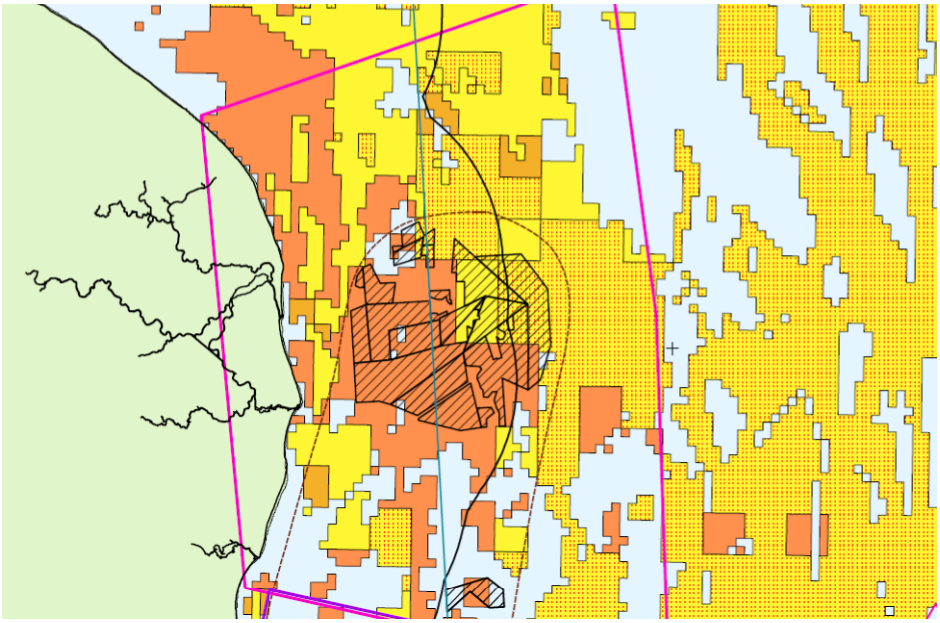
# The Mineral Resources of the East Inshore and East Offshore Marine Plan Areas, Southern North Sea

Minerals and Waste Programme

Open Report OR/12/095



BRITISH GEOLOGICAL SURVEY

MINERALS AND WASTE PROGRAMME

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# The Mineral Resources of the East Inshore and East Offshore Marine Plan Areas, Southern North Sea

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# Foreword

This report accompanies the mineral resource map *the marine sand and gravel resources of the East Inshore and East Offshore Marine Plan Areas* (Bide et al, 2011). 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 the first in a series that will cover 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

The authors would like to acknowledge Ian Selby (The Crown Estate) and Mark Russell (British Marine Aggregate Producers Association) for their help in reviewing and providing advice for this study. They would also like to thank Andrew Bellamy (Tarmac Ltd) for providing advice and data used for the Humber area case study.

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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 first of these maps - the East Inshore and East Offshore Marine Plan Areas in the southern North Sea. These are the first areas (Figure 1) for which the Marine Management Organisation is preparing marine plans (MMO, 2010).

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 using a Geographical Information System (GIS), which allows for revision, updating and customisation of the information, together with integration with other datasets.

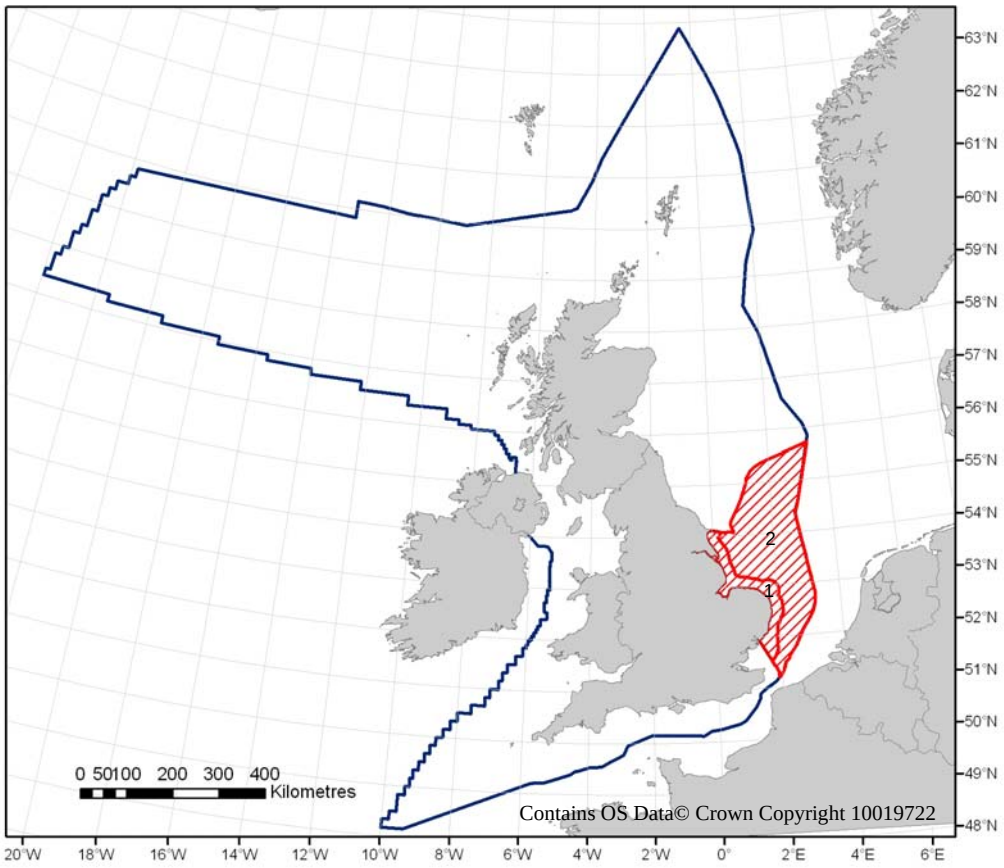


**Figure 1. The UKCS (blue) and East Inshore (1) and East Offshore (2) Marine Plan Areas (in red)**

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 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 different sectors of 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 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 900 million tonnes of marine sands and gravels have been extracted from the UKCS (Selby, 2011). Marine aggregates (15.25 million tonnes extracted from UK waters in 2009) account for almost a third of the UK's production of sand and gravel (Bide *et al.,* 2010). 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). London and the South East are particularly dependent on marine aggregates, with a third of demand for primary aggregates (mainly concreting aggregate) being met from marine sources (5.8 million tonnes in 2009) (Russell, 2011). Much of this is dredged from the East Inshore and East Offshore Region. Approximately 54 per cent of all aggregates dredged from the East Coast Region and 93 per cent of all aggregates dredged from Thames Estuary are landed in London (Selby, pers. comm., 2011).

The principal minerals information presented on the marine sand and gravel resource maps 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 considered prospective for construction aggregates, where the geographical and depositional setting indicate that geological features and associated deposits are likely to be present but are not resolvable by data available for this work.
- 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).

## 3.1 METHODOLOGY FOR ASSESSING MARINE AGGREGATE RESOURCES

Areas of aggregate mineral resource have been inferred using 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, vibrocores, sediment cores, rock 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 Regional Environment Characterisation Reports (REC) funded by the Marine Aggregate Levy Sustainability Fund (MALSF) (www.marinealsf.org.uk). Three of these studies have been undertaken in the East Inshore and East Offshore areas - The Humber, The East Coast, and the Outer Thames Estuary. 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.

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. The reasons for this are explained in the case study below.

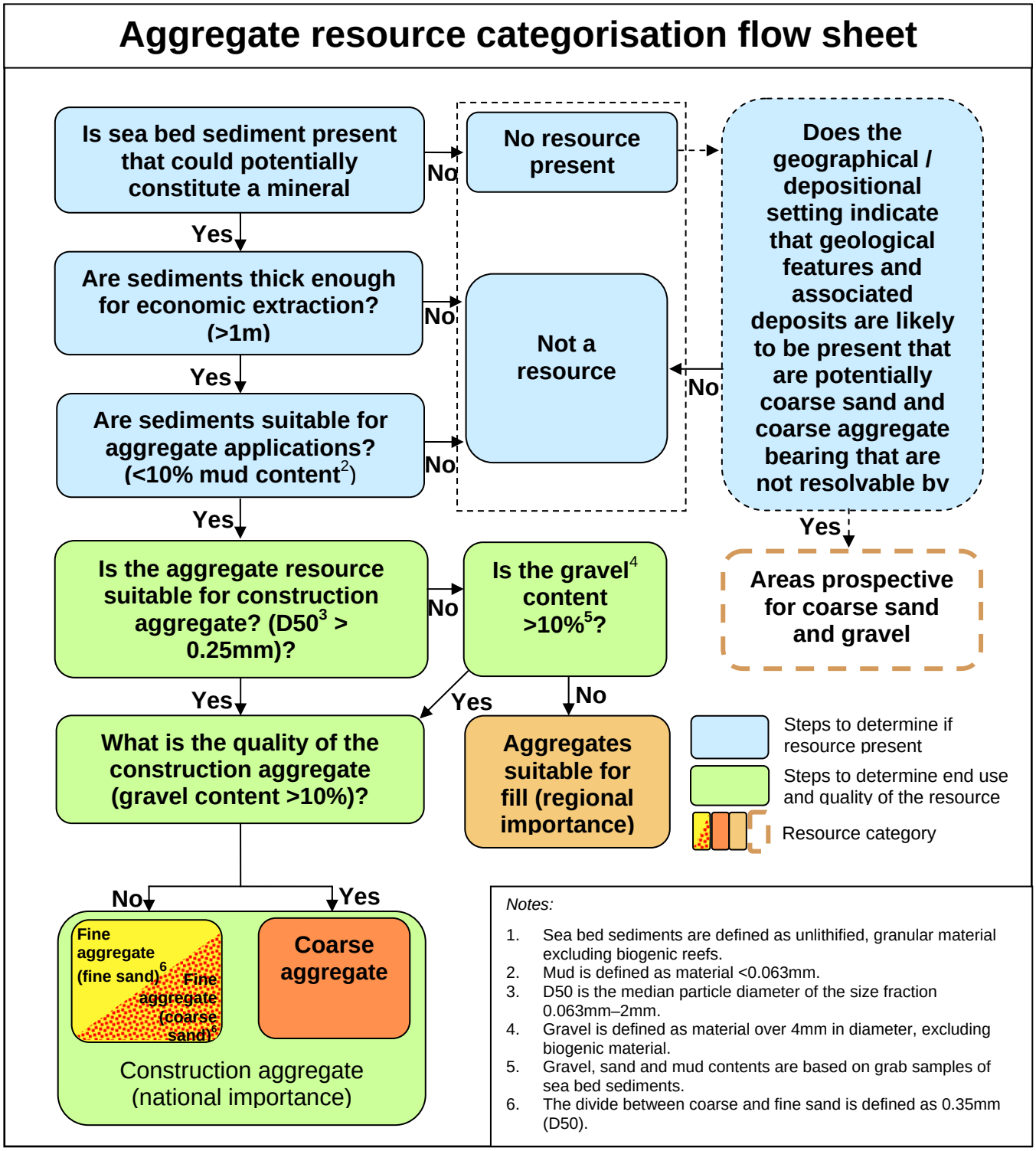


**Figure 2. Aggregate resource categorisation flow sheet**

### *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.

Three prospective areas are identified: (i) the Humber Estuary extending east to the edge of the study area, (ii) offshore East Anglia and (iii) the outer Thames Estuary (Appendix 1).

The Humber prospective area is based on the presence of a broad plateau of glacial deposits, much of which is till and not prospective for aggregates. However, deposits prospective for aggregate such as outwash fans, moraines and glaciofluvial deposits are also present. The area is bound to the north by a major break in slope, beginning in the north east with the Outer Silver Pit, and to the south by the limit of the mapped extent of the Devensian till deposits.

Off East Anglia, the prospective area for sand and gravel is based on both the presence of channel deposits that could potentially be gravel bearing, and the widespread outcrop of the Pleistocene Yarmouth Roads Formation. This geological unit was deposited by a deltaic – fluvial system and contains coarse sands and gravels. It is also possible that glacial deposits of Anglian age are present in the south of the area. A known break in slope and a system of sand banks, which extend north over the area around the Norfolk coast, form the western boundary to the prospective area. To the south it is bounded by the surface extent of the London Clay Formation, which precludes the presence of Pleistocene aggregate bearing deposits. The area is bounded to the east by an area of sand waves which obscure earlier sediments.

The third area prospective for sand and gravel lies in the outer Thames Estuary and occurs due to the presence of channels incised into the London Clay Formation which could potentially be filled with coarse-grained clastic material. It is bounded to the north by the surface extent of the London Clay Formation and to the east by a major break in slope and broad sand wave field.

***Case study: sand and gravel deposits not resolved south east of the Humber Estuary***

Areas offshore from the Humber Estuary have been identified by the marine aggregate industry as discrete glaciofluvial deposits overlying till. An example of this is production licence area 197, located near Protector Overfalls, which is worked by Tarmac Marine Dredging Ltd. This area comprises mounds and low banks which flank possible channel features incised into underlying till. The mounds and banks consist of coarse-grained sand and mainly fine-grained gravel. The deposits are interpreted as localised glacial outwash features that have undergone some surficial reworking during the subsequent Holocene marine transgression.

These deposits, as shown in Figure 3, can only be resolved by detailed surveying, typically with a seismic line spacing of 250 metres or less. Operationally viable deposits can cover small areas, less than one square kilometre, (the smallest grid spacing used on the marine aggregates map) but importantly can still potentially contain significant volumes of sand and gravel. Where deposit thickness is significant, for example area A, the western part of area D and the southern part of area E, these complex deposits have been resolved on the sand and gravel resource map. However, for other smaller areas, such as area B, C and the northern sections of areas D and E, these are not included on the marine aggregates map. However, as is shown from detailed surveys undertaken by the industry, these also contain significant sand and gravel resources. Their omission from the marine aggregates map in this case is due to their limited extent and the difficulty of mapping these complex, highly heterogeneous, glacial deposits at a regional scale. As a result these areas of resource have not been resolved on the regional scale map.


**Figure 3: Resource isopachs, complied by a detailed site-specific survey, for licence area 197, overlain on the sand and gravel map (for resource isopachs darker shading indicates thicker resource)**

## 3.2 AGGREGATE RESOURCES OF THE EAST INSHORE AND EAST OFFSHORE MARINE PLAN AREAS

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).

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 North Sea were exposed, glaciated or crossed by major river systems. Most relict sand and gravel deposits in the North Sea are related to a combination of major deltaic river systems, formed in periglacial conditions that prevailed before the last major ice age, and glacial sediments related to late Pleistocene major glacial events. These glacial events provided an abundance of coarse-grained sediment from glaciofluvial meltwaters and morainic deposits and scoured major channels into what is now the sea bed, some of which later filled with aggregate minerals. More 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 re-working and sorting sand into semi-mobile banks and sand waves.

Aggregate resources in the East Inshore and East Offshore Marine Plan Areas (Figure 4) comprise all types of deposit mentioned above. In the north of the region the vast majority of the sea floor is covered by a thin veneer of gravels and sands less than one metre thick, mostly less than 0.5 metres thick, overlying stiff clays of glacial origin. In the south, thick accumulations of finer-grained sand deposited by palaeo-river systems are prevalent. As such, some of the most prospective areas for sand and gravel may be related to the palaeo-river systems of the river Yare, Thames and its tributaries.

The largest gravel deposits occur in the Humber region and offshore East Anglia. In the Humber region these are relict deposits of glaciofluvial origin and can relate to outwash fans, moraines and glacial drainage systems, deposits are usually intercalated with till and can be unpredictable in extent and location. Further east sediments are generally fine-grained. Major concentrations of sand occur in sand banks and sand waves which are spread across the region, and thick accumulations of post glacial sediments occur around Dogger Bank, south of Markham's Hole and to the east of Flamborough Head. Mud contents are generally low in this region with the exception of areas adjacent to river estuaries and some of the larger bathymetric deeps to the east of the region such as Markham's Hole and the Outer Silver Pit.

Shell content varies across the region. The deposits formed from sand banks and sand waves have typically low shell content but can be higher in thick post-glacial sedimentary sequences. Shell content is also low for the majority of relict gravel deposits. Sediment composition varies with quartzite, sandstone, siltstone, flint, igneous and metamorphic rock types all represented although the most predominant lithologies are quartz, quartzite and flint.

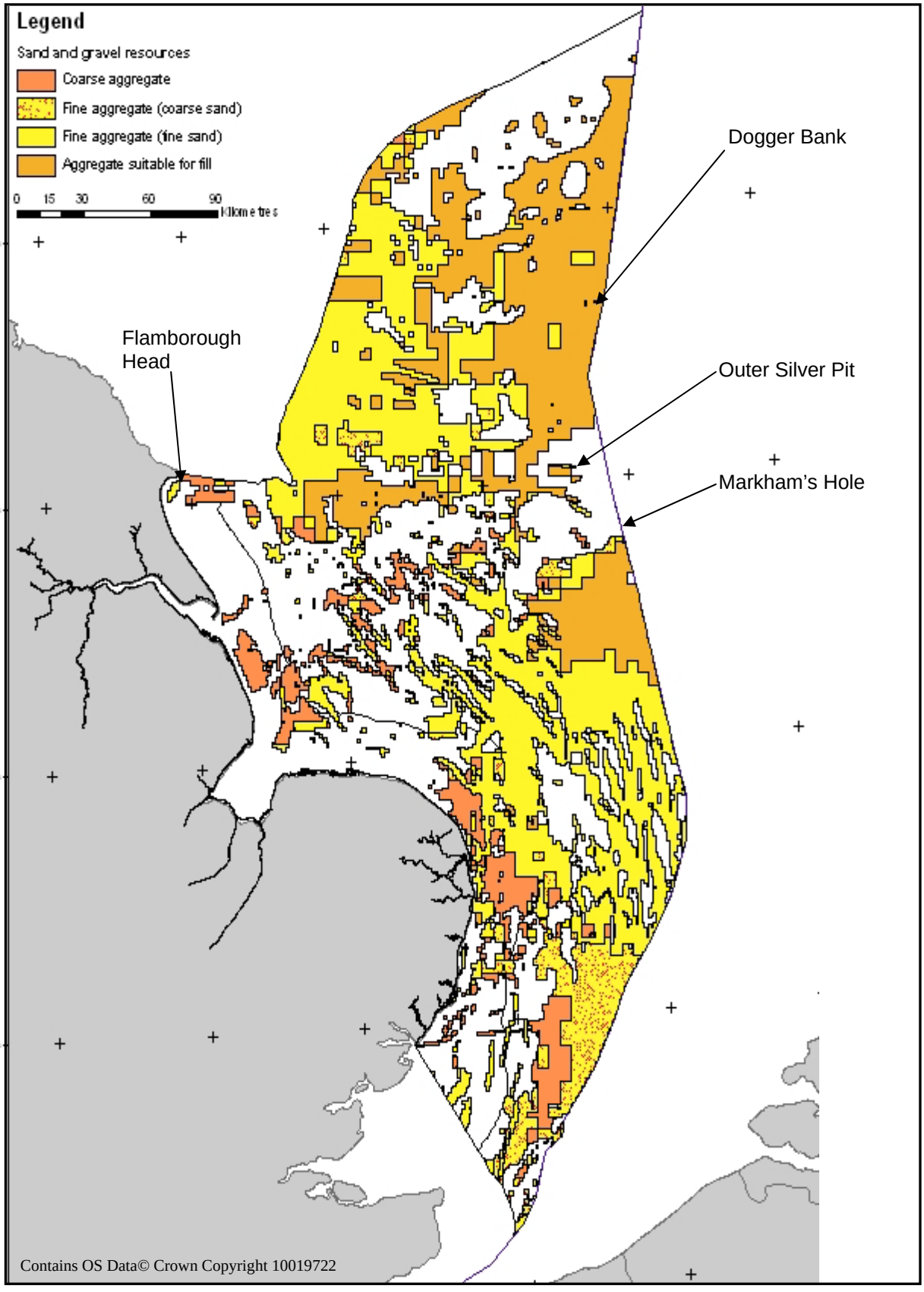


**Figure 4. Sand and gravel resources of the East Inshore and East Offshore areas**

# 4 Other minerals

Significant resources of both coal and evaporite minerals are located beneath the sea bed. Evaporite mineral resources have been worked from onshore deep mines which extend for

limited distances under the sea In the East Inshore and East Offshore Marine Plan Areas. Coal and evaporite minerals are an important national asset and adequate and steady supplies are needed to maintain current and future economic development.

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 with potential for coal resources is included in Appendix 2 and the map depicting the extent of sub-sea evaporite-bearing geological formations (salt, potash and halite resources) is included in Appendix 3.

## 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, 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.

The Southern North Sea Basin hosts extensive coal-bearing deposits of Late Carboniferous age. Coal seams have been proved offshore between 2000 to 3000 m below Sea Level in the Westphalian A (up to 750 metres in thickness) and the overlying Westphalian B (up to 450 metres in thickness) successions. Coal seams form about five percent of these Westphalian successions. In the absence of information on coal rank and quality from offshore, data has been taken for comparison from the Westphalian coalfield successions of the UK onshore area, where the coal seams are considered to be broadly similar in character. In general the coals within the Westphalian A succession show a higher calorific value than those of the Westphalian B.

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. Good prospects should have adequate levels of methane (>7 $m^3$/tonne), which generally increase with coal rank. However, permeability, rather than seam gas content, is the most critical factor. In general, UK coals exhibit low permeabilities, which limits their potential for CBM.

'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 the southern North Sea is found at depths between 1000 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 in the Southern North Sea Basin 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 times in north-east England resulted in several cycles of evaporite deposition. The most extensive episode led to the deposition of the Billingham Anhydrite Formation and the overlying Boulby Halite Formation which, along with the Boulby Potash Member, are known offshore as the Leine Halite. In the deeper parts of the basin, these salts are prone to halokinesis causing them to migrate and be concentrated in salt domes.

Reserves of potassium salts and halite from the Leine Halite Formation are extracted from Boulby Mine located on the coast north of Whitby. Offshore, the Leine Halite Formation is up to 300 metres thick, although the centre of the basin has been affected by halokinesis. It has been split into three units: at the base L1 – relatively pure halite (50 to 200 metres thick), L2 – varying proportions of potassium/magnesium salts and halite (11 to 100 metres thick) and L3 – relatively pure halite (3 to 11 metres thick). L1 is the most widespread unit with L2 and L3 having a more restricted distribution (Johnson *et al.*, 1994).

Sylvite (potassium chloride, KCl) is the most important global source of potash. This mineral has high solubility and potassium content, and accounts for all potash currently produced in the UK. Since most potash is used as a fertiliser, demand is primarily linked to agricultural food production and commodity prices. The extent to which resources offshore are accessed from mines located onshore will depend on the market value of the potash being mined. The operations at Boulby Mine currently extend about 11 kilometres offshore. In addition to the sylvite-bearing ore, there is also the possibility of mining polyhalite ($K_2Ca_2Mg(SO_4)_4{\cdot}2(H_2O)$) from the Leine Halite Formation. Polyhalite-derived products are a growing market segment within the fertiliser industry.

Halite (rock salt) is produced as a by-product from Boulby Mine. This has a much lower value than potash and, despite extensive deposits in the Leine Halite Formation, is unlikely to be worked except as a by-product of the potash mining.

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 the commodity prices, geology, available technology, depth of deposits, distance to shore and other factors.

Further information on the UK's potash resources can be found in the BGS Mineral Planning Factsheet on Potash (http://www.bgs.ac.uk/downloads/start.cfm?id=1367).

# 5 Limitations

The purpose of the maps is to show the broad distribution of mineral resources present in the East Inshore and East Offshore Marine Plan Areas. 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.

**Anglian:** A cold period of extensive glaciation during the middle Pleistocene.

**Anhydrite:** An evaporite mineral comprising calcium sulphur and oxygen.

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

**Chert:** A cryptocrystalline variety of silica.

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

**Devensian** A cold period of extensive glaciation at the end of the Pleistocene epoch.

**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.

**Gypsum:** An evaporite mineral formed from the hydration of anhydrite.

**Halokinesis:** The mobilisation and flow of subsurface salt into domes and diapirs.

**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 from a glacier.

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

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

**Potash:** A potassium chloride evaporite mineral.

**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.

**Sandstone:** A sedimentary rock made of abundant fragments of sand size set in a fine-grained matrix or cementing material. The sand particles are usually of quartz.

# References

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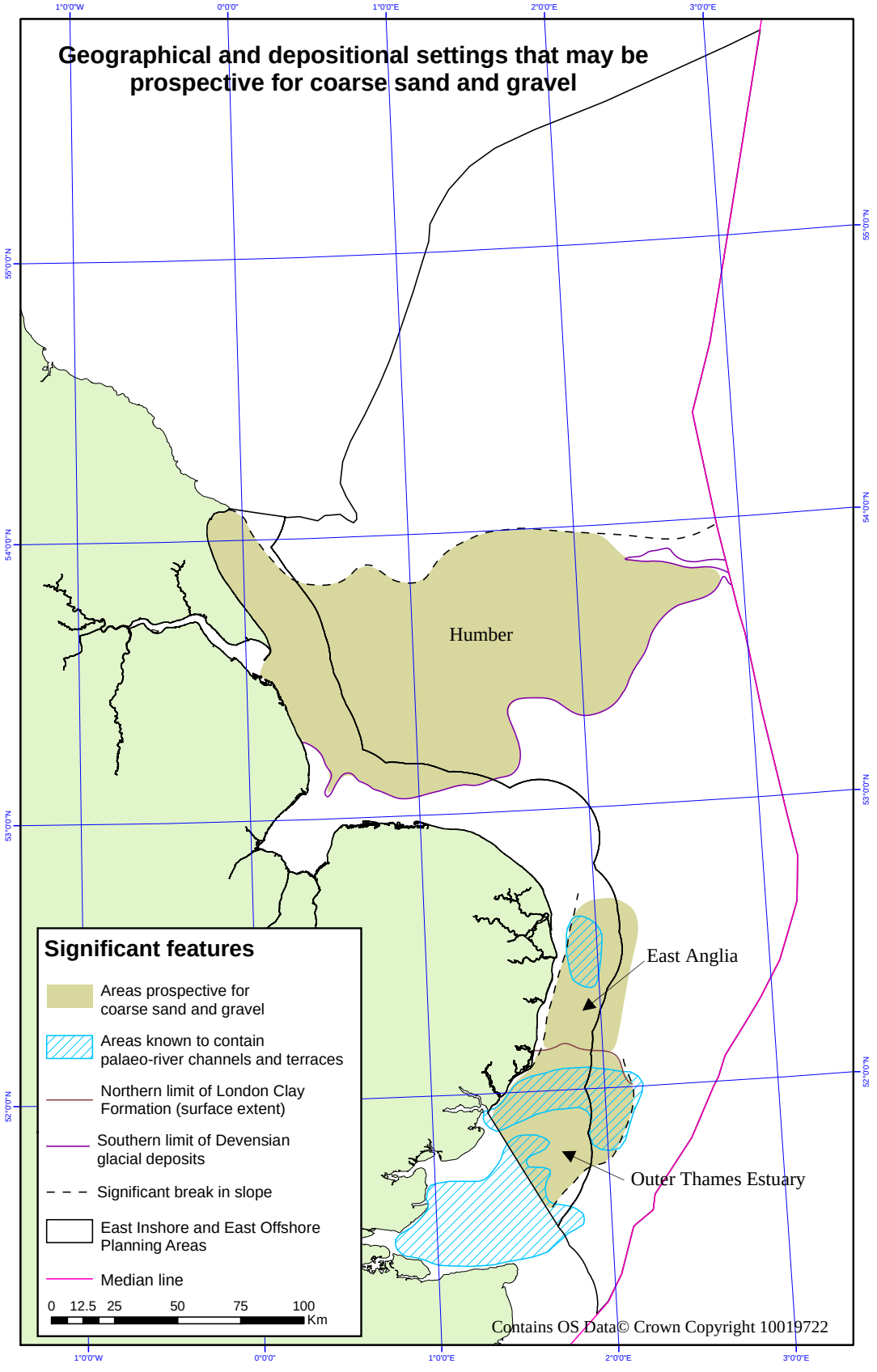
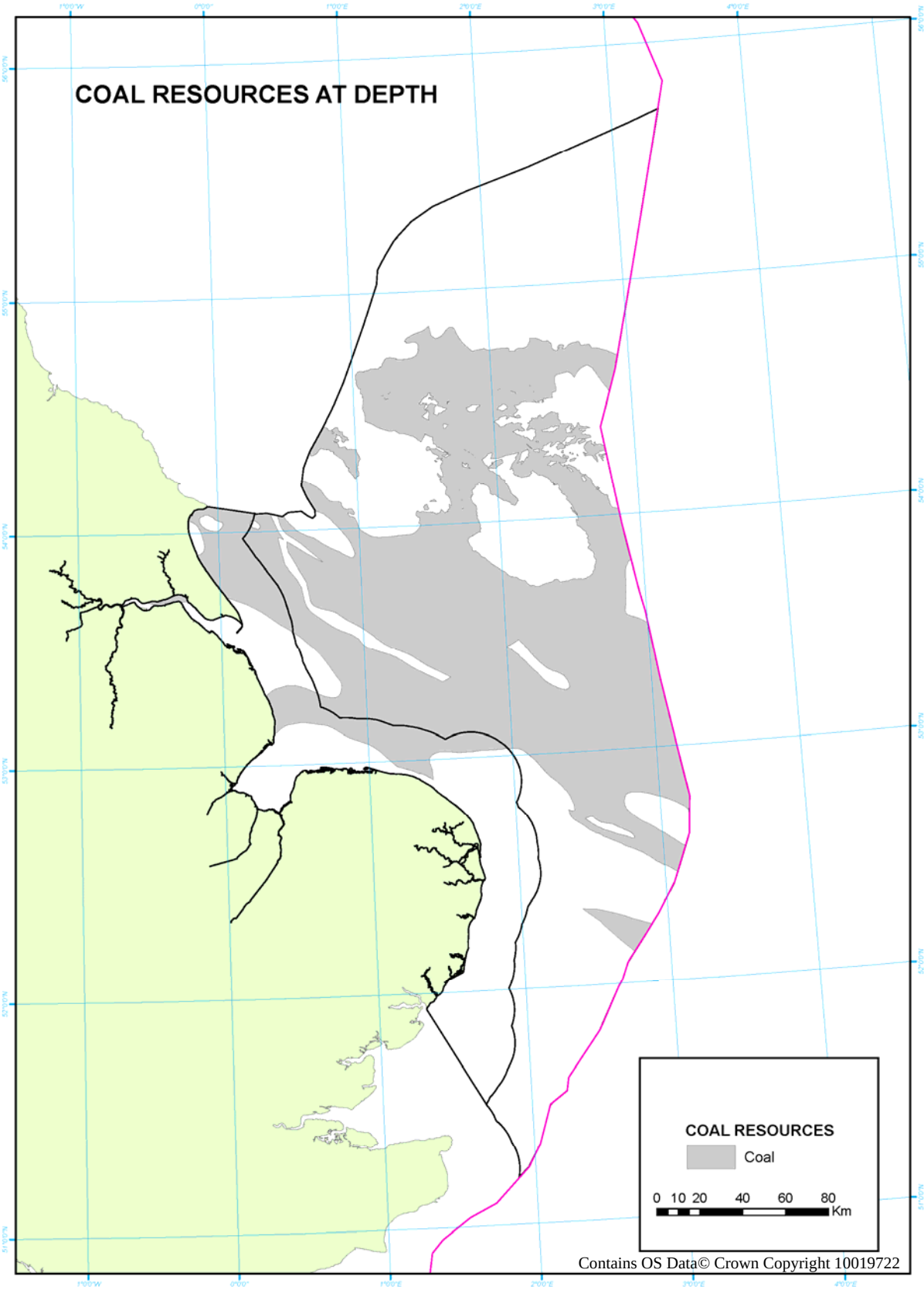
# Appendix 1 Map depicting the geological features used to identify areas prospective for coarse sand and gravel



# Appendix 2 Map of the coal resources of the Southern North Sea



# Appendix 3 Map of the evaporite resources of the Southern North Sea