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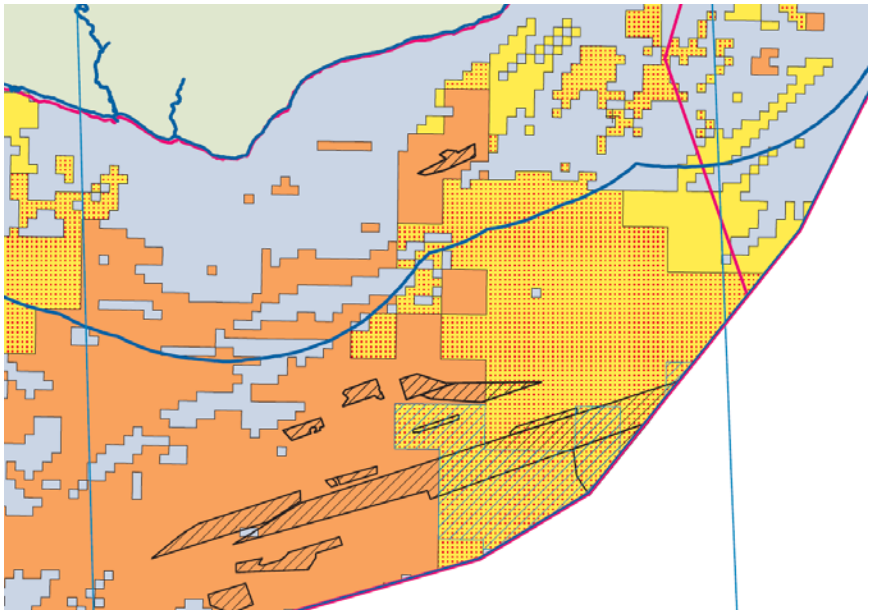
The Mineral Resources of the English Channel and Thames Estuary

Minerals and Waste Programme

Open Report OR/12/096



BRITISH GEOLOGICAL SURVEY

MINERALS AND WASTE PROGRAMME

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The Mineral Resources of the English Channel and Thames Estuary

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Foreword

This report accompanies the Marine mineral resource map t*he marine sand and gravel resources of the English Channel and Thames Estuary* (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 marine 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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Contents

FIGURES

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 second of these maps, the area off southern Britain, from the north Devon coast to the Outer Thames Estuary (Figure 1). This area includes the South West Inshore and Offshore, South Inshore and Offshore and South East Inshore marine plan areas as defined by the Marine Management Organisation (MMO).

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

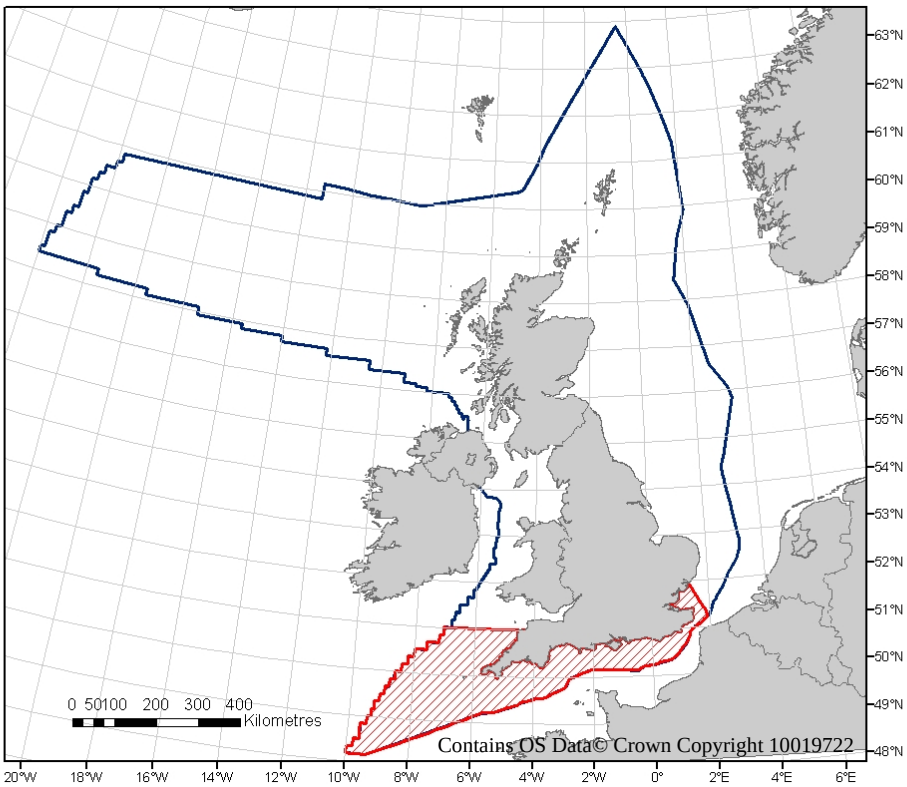


Figure 1. The UKCS (blue) and area covered by the marine mineral resources assessment (red)

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 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 changes 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 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, the North East, the North West and South Wales (Highley *et al.,* 2007). London and the South East are particularly dependent on marine aggregates, (mainly concreting aggregate) a third of demand is met from marine sources (5.8 million tonnes in 2009) (Russell, 2011). Much of this is dredged from the South Coast and East English Channel. Approximately 18 per cent of all aggregates dredged from the South Coast and 58 per cent of all aggregates dredged from the East English Channel are landed in London, a combined total of 2.46 million tonnes (The Crown Estate, 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 for the Outer Thames, South Coast and East English Channel Regional Environment Characterisation (REC) Studies 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:

Higher confidence

The geological settings that host the largest, highest quality and currently most economically important areas of resource. These are categorised as *areas known to contain important sand and gravel resources* and are displayed on an inset map. Higher levels of confidence can be attributed to the location and properties of inferred resources within these, as depicted on the main map face.

Inferred aggregate mineral resources, as displayed on the main map face. These show the geological distribution of all offshore sand and gravel mineral resources.

Lower confidence

Areas considered prospective for construction aggregates. Here the geological and depositional setting indicate that sediment suitable for coarse sand and gravel extraction is likely to be present but is not resolvable by the data available for this study. These areas are categorised as *areas prospective for coarse sand and gravel*. Their extent is displayed on the main map and the geological features that define these areas are displayed on an inset map.

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) 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. 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 is identified in the English Channel and Thames Estuary area: the outer Thames Estuary (Appendix 1). This area occurs due to the presence of localised and often discontinuous river terrace and channel sands and gravels deposited during times of lower sea level. It is bounded to the north by the surface exposure of the London Clay Formation and to the east by a major break in slope and a broad sand wave field.

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 of 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. One such area occurs in the English Channel and Thames Estuary area in extensive filled channel deposits (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.

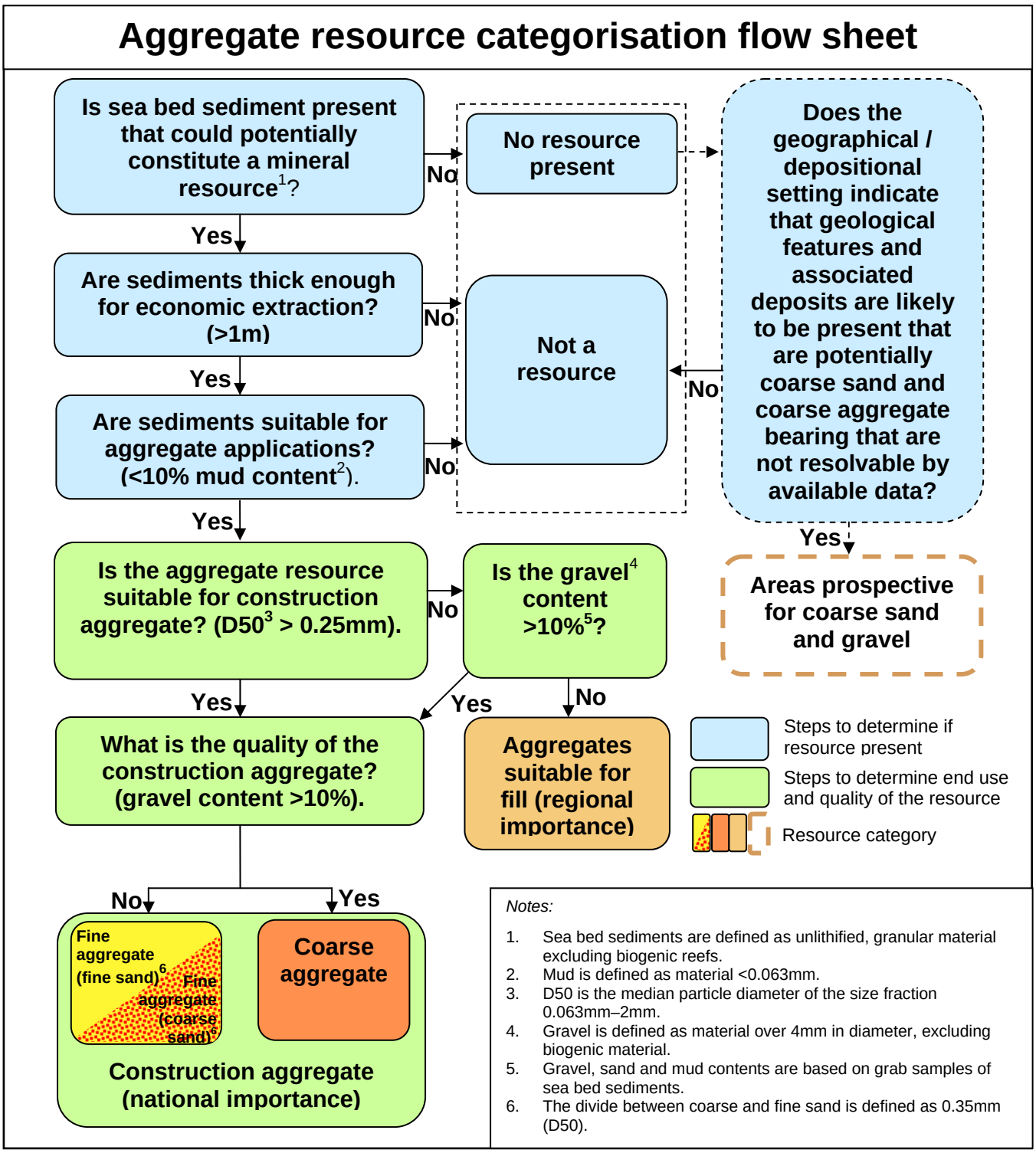


Figure 2. Aggregate resource categorisation flow sheet.

Case study: sand and gravel deposits not resolved in the Outer Thames Estuary

An area in the Outer Thames Estuary has been identified by the marine aggregate industry as consisting of localised sand and gravel but which is discontinuous and often obscured by sand banks. The deposits contained within production licence area 109 provide one such example. Located at the northern end of the Kentish Knock sand bank, license area 109 is worked by Tarmac Marine Dredging Ltd, CEMEX UK Marine Ltd and Britannia Aggregates Ltd. The licence lies just outside the English Channel and Thames Estuary map area but is typical of the geology in this region. Aggregate resources comprise sand and gravel deposited by a palaeo-river system that flowed across the area during times of lower sea level. As this type of deposit follows the course of river channels, they can often be anastomosing and complex. They can be discontinuous as they may have been be eroded away by subsequent fluvial or marine activity and grade into silt, clay and organic material as the environment of deposition changes. Many of these palaeo-river deposits have been buried by modern mobile sands in the form of sand waves and sand banks, which are common in this region.

Such palaeo-river deposits in this region, 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 at the western margin of the license area, these complex deposits are not indicated on the sand and gravel resource map. However, as is shown from detailed surveys undertaken by the industry, this area contains 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 complex, unpredictable deposits at a regional scale. As a result not all areas containing palaeo-river deposits have been resolved on the regional scale map.

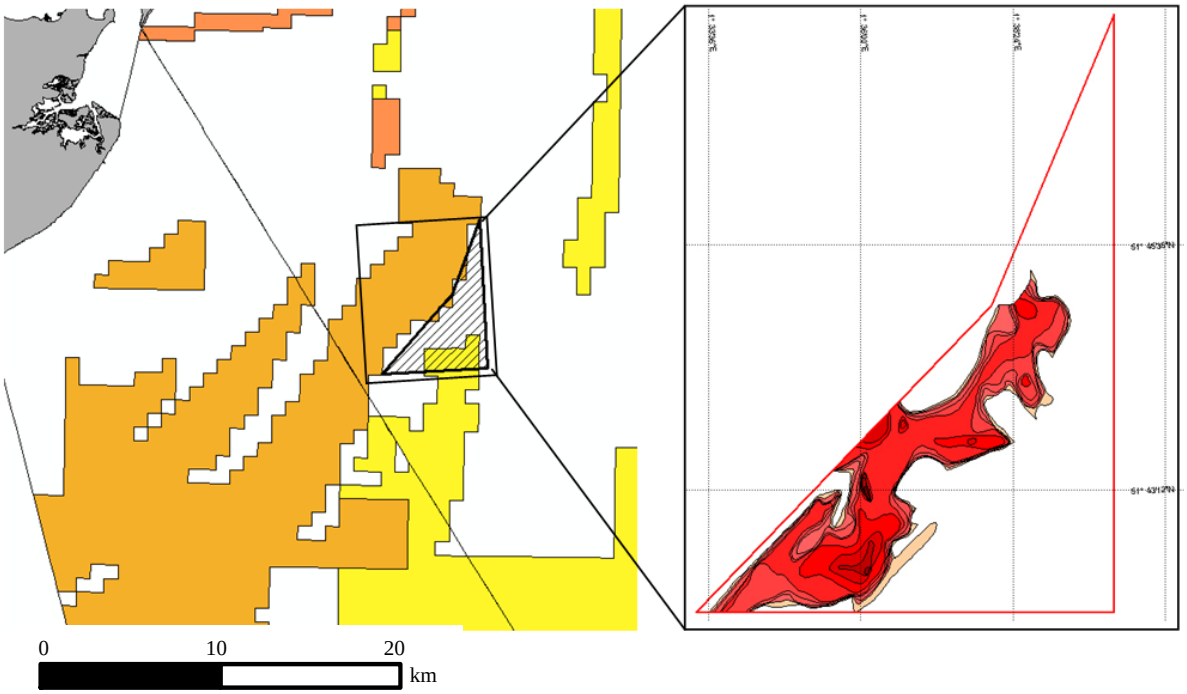


Figure 3. Resource isopachs compiled by a detailed site-specific survey for licence area 109, compared to the sand and gravel map (for resource isopachs darker shading indicates thicker resource).

3.2 REGIONAL REVIEW

Map coverage extends from the north Devon coast, around the Cornish peninsula to the inner Thames Estuary in the east, this includes the Western Approaches and East English Channel. This area includes several major embayments such as Mounts Bay, Whitsand Bay, Start Bay, Lyme Bay, Poole Bay, The Solent, and the Thames Estuary. Generally data coverage for these areas is poor and sediments are variable, and as such the major embayments of the Solent and the Inner Thames Estuary have not been included in this 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. Data coverage is also very sparse for the Western Approaches, as a result this area has been included as an inset map at a larger scale.

3.3 AGGREGATE RESOURCES OF THE ENGLISH CHANNEL AND THAMES ESTUARY

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 and sorting different size fractions. Most economic sand and gravel is composed of particles that are durable and rich in silica (quartz, quartzite and flint). The sand and gravel resources of The English Channel and Thames Estuary are shown in Figure 4 and Figure 5

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. Glacial sediments are rare in the English Channel and Thames Estuary area. Quaternary ice sheets are known to have extended to the North Devon and Cornish coasts in the west but the precise limits are not well defined and there are no thick sequences of potential sand and gravel-bearing glacial sediments in this area as there is for most other areas of the UKCS. However, palaeo-river systems have had a major effect on the sand and gravel resources of this area. Throughout the Pleistocene period major river systems flowed out across the English Channel area, which at that time was intermittently exposed above sea level. These rivers created numerous terrace deposits, rich in sand and gravel. Terraces formed as tectonic uplift of the land and changes in sea level raised coarse sand and gravel deposits that had formed on river banks and floodplains. Palaeo-river systems also formed deep channels, which were subsequently infilled with sand and gravel resources. The largest palaeo-rivers systems associated with offshore sand and gravel resources are the palaeo-Solent, palaeo-Arun, palaeo-Thames and the channel system of the Northern Palaeovalley. Sediments from these palaeo-river systems have also been re-worked by marine processes to form thick sand sheets in the around Dungeness and Boulogne. To date these deposits have been the main focus of the extractive industry in the English Channel and Thames Estuary area.

More modern marine sand deposits (gravel is generally only mobilised by the most extreme sea bed currents in the modern marine environment) are formed by tidal currents and wave action re-working and sorting sand into semi-mobile banks and sand waves. There are extensive sand wave fields as well as numerous sand banks present. Significant sand wave fields occur in the far west of the area, around Little Sole Bank (Figure 4), off the south coast of Devon and Dorset and in the Thames Estuary and its approaches. Sand waves and banks in the far west of the area are significant in size but have high carbonate contents and occur in areas of relatively deep water. The large sand wave field, almost 100 km across, which occurs off the south Devon and

Dorset coast is associated with high carbonate contents. Although sand waves are prevalent here they are often directly on bedrock or have large wavelengths, limiting their potential for extraction. Sand waves and sand banks in the Thames Estuary are better constrained and contain significant volumes of sand, although generally fine-grained, especially in the thick sand bodies of Sunk Sand, Long Sand and Kentish Knock as well as the sand banks of the Goodwin Sands, South Falls and Sandettie (Figure 5) .

Shell content of sand is high in the west of the English Channel and Thames Estuary area, especially in areas far offshore in deep waters which have little clastic sediment input. Sediment composition varies with sandstone, siltstone, igneous and metamorphic rock types all represented although the most predominant lithologies are quartz, flint and quartzite.

Figure 4. Sand and gravel resources of the English Channel and Thames Estuary based on *the marine sand and gravel resources of the English Channel and Thames Estuary***.**

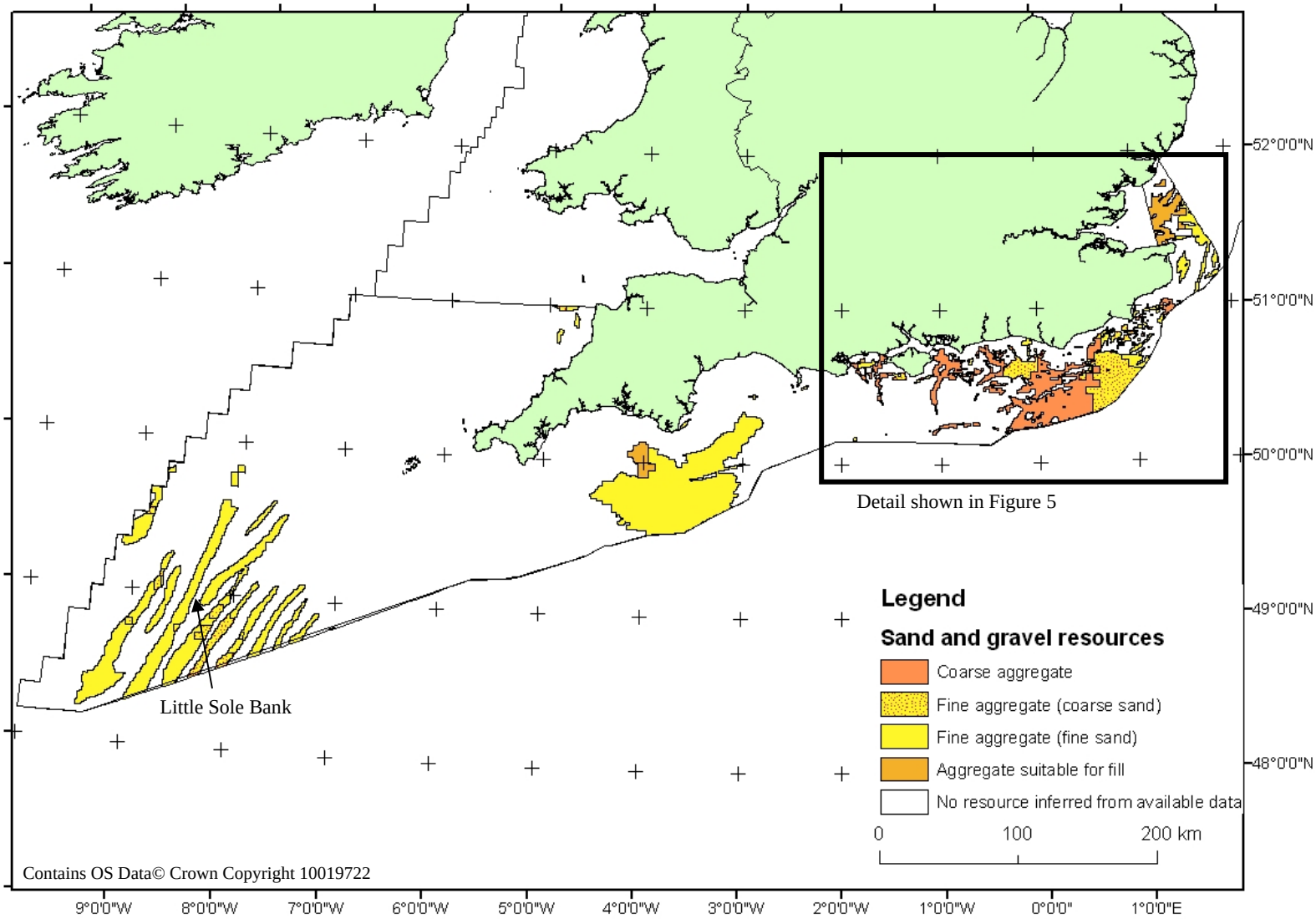
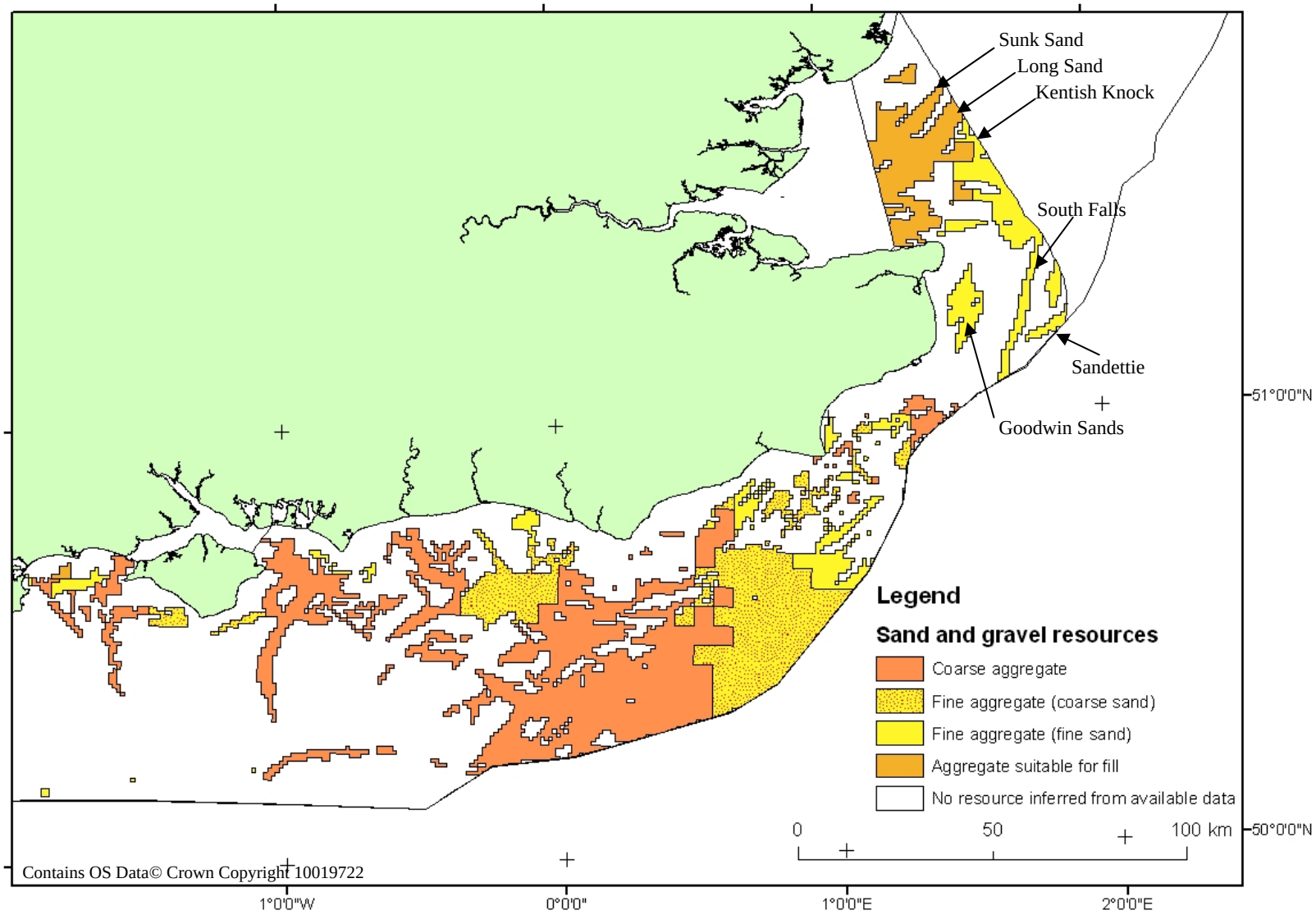


Figure 5. Detail of sand and gravel resources in the East English Channel and Thames Estuary based on *the marine sand and gravel resources of the English Channel and Thames Estuary*.



4 Other minerals

Coal, evaporite and metallic mineral resources are located on or beneath the sea bed. Metallic minerals have been worked from onshore deep mines which extend for limited distances under the sea in the English Channel and Thames Estuary area. 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 in Appendix 3 and the map depicting the extent of sub-sea evaporite-bearing geological formations (salt-bearing halite resources) is included in 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 underground 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.

In the English Channel and Thames Estuary area the only coal resources are those within the offshore extent of the Kent Coalfield (see Appendix 3). Carboniferous, coal-bearing strata extend offshore into the Central English Channel Basin, possibly as far as the north east French coast. The Westphalian-aged coal-bearing sequence is up to 884 metres thick onshore but reaches a maximum thickness of 1600 metres offshore (Hamblin *et al.*, 1992). Individual coal seams rarely reach thicknesses in excess of three metres. Coals of the Kent coalfield are of fairly high rank and calorific value, and have low sulphur and ash contents (Hamblin et al., 1992). Within the Central English Channel Basin Carboniferous coals occur at a depth of approximately 1000 metres at the edges of the coalfield, deepening to a maximum 2000 metres towards the centre (British Geological Survey, 1999).

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).

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.

Although there are extensive offshore evaporite resources on the UK Continental Shelf, their extraction may not 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.

Potential evaporite deposits occur in two major basins found at depth in the English Channel and Thames Estuary map area, the Melville Basin and Wessex Basin.

The Melville Basin is located in the Western Approaches Trough and contains the Melville Halite, a thick halite unit within the Mercia Mudstone Group with variable depths of burial, from near surface at the basin margins to nearly 2 km in the centre. Borehole data has shown a thickness of about 700 m on one of the major salt swells in the basin (Evans *et al*, 1990).

The Wessex Basin contains the Dorset Halite Formation. This is a saliferous unit underlying the Weston Mouth Sandstone Member of the Triassic Mercia Mudstone Group. The only borehole data for the unit recorded a thickness of about 350 metres. The offshore limits of this unit are poorly constrained and the depth of burial is variable across the basin.

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

Currently there are no workings on or under the UKCS for metallic minerals. However, several types of mineral have been recorded in potentially economic concentrations and the working of some deposits has been considered in the past. Historically tin has been worked from vein deposits offshore from onshore mines around Cornwall which have extended under the sea.

Marine processes can lead to the concentration of metallic minerals in sea bed sediments. Dense (or 'heavy') minerals such as cassiterite and zircon are commonly concentrated in placer-type deposits. The formation of placer deposits is fundamentally a process of sorting heavy minerals from those of a lower density during sediment deposition. There are three main types of offshore placer: relict alluvial placers occupying submerged valleys or channels; relict beach placers formed by the migration of the shoreline; or contemporary marine placers formed in high-energy offshore and nearshore environments. The mineral assemblage of marine placer deposits will typically be dictated by the local onshore geology (Robb, 2005).

Tin (cassiterite)

Offshore tin accumulations on the sea bed off the Cornish coast are the result of both natural processes and the erosion and transport of man-made tailings from onshore workings (Evans, 1986). Previous exploration targets for offshore tin have been around the coast of Cornwall and have included: St Ives Bay, Porthtowan, Perranporth, St Austell Bay and Mounts Bay (Figure 6). Variable tin concentrations have been revealed in these sediments up to a maximum 2850 parts per million in St Ives Bay. Tin concentrations in beach sands and stream sediments in Cornwall are typically much higher at about 5000 to 20 000 parts per million respectively. Infilled submarine channels have been identified offshore of south-west England; however, these channels are often covered by up to 15 metres of sediment and the composition of the fill material is not well known (Evans et al., 1990, Banner, 1980).

A number of companies have attempted to recover tin from offshore sediments around the Cornish coast. In the 1960s a mining company acquired prospecting leases for 2600 square miles of sea bed off Cornwall for testing down to depths of 60 metres below sea level (Banner, 1980), although it is unclear to what extent investigations took place. During the late 1960s Coastal Prospecting Ltd undertook commercial dredging off the Red River Estuary in an area approximately 600 by 700 metres in which the upper 0.6 metres of sand averaged 0.2 per cent tin. Inadequate metallurgical recovery combined with poor weather and tidal conditions meant the venture was unsuccessful (Evans, 1986). In the mid-1980s licences were held by Marine Mining (Cornwall) Consortium off the northern Cornish coast. The company undertook pilot testing and began construction of an offshore pipeline and onshore concentrator to process tailings with an average of 0.15 per cent tin; however, it is unclear how successful this operation was (Evans, 1986). A survey into tin deposits was also conducted by Billiton, between 1982 and 1983 around the south coast of Devon, specifically Mounts Bay.

The potential to exploit offshore heavy mineral resources on the UKCS is likely to be dependent on a number of factors, such as the quality and quantity of material, water depth, sediment thickness, and tidal conditions. Previous work suggests that offshore tin deposits are less profitable when compared to onshore tin operations.

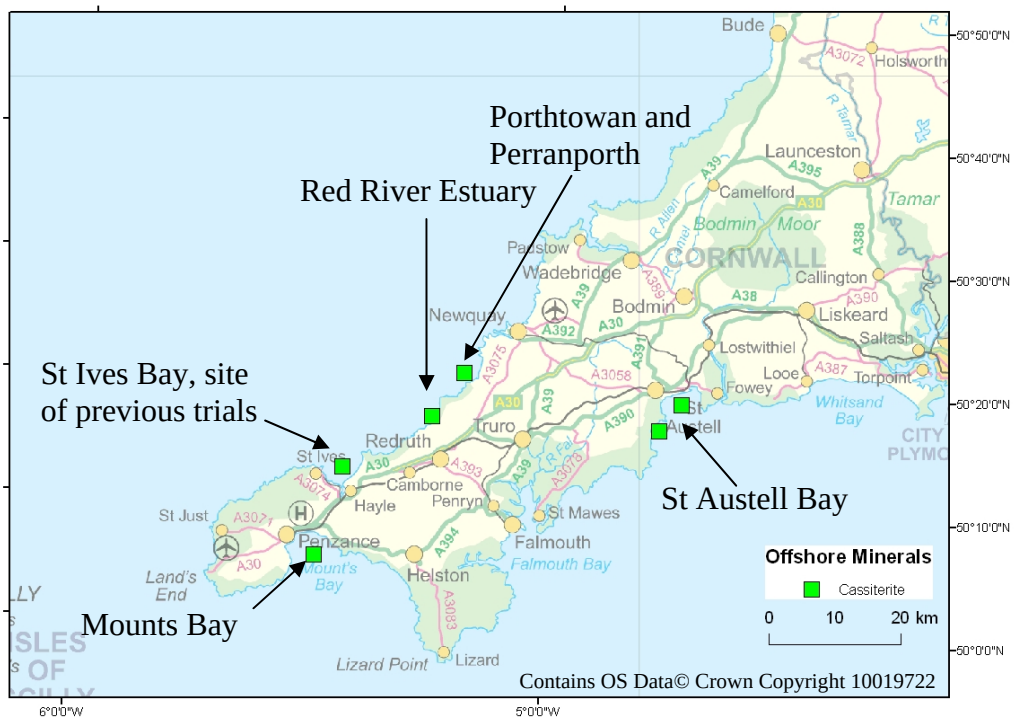


Figure 6. The location of offshore tin deposits around south west England.

Zircon

The majority of zircon occurrences are confined to onshore beach sands or shallow nearshore sands. However, limited offshore accumulations have also been identified. Small areas of zircon-rich sand have been identified on the western slopes of Long Sand in the Thames Estuary, (Figure 7). There has been no record of zircon-rich sands being exploited in the UK.

Figure 7. The location of known high concentrations of zircon in the Thames Estuary.

5 Limitations

The purpose of the maps described in this report is to show the broad distribution of mineral resources present in the English Channel and Thames Estuary 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: A siliceous mineral 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.

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

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

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.

Quaternary: An era of geological time from 2.58 million years ago to present.

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.

River terrace: Fluvial sediments that are located above the current coarse of the river that formed them due to downcutting.

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.

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

Tailings: Waste material left over from mining operations.

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

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

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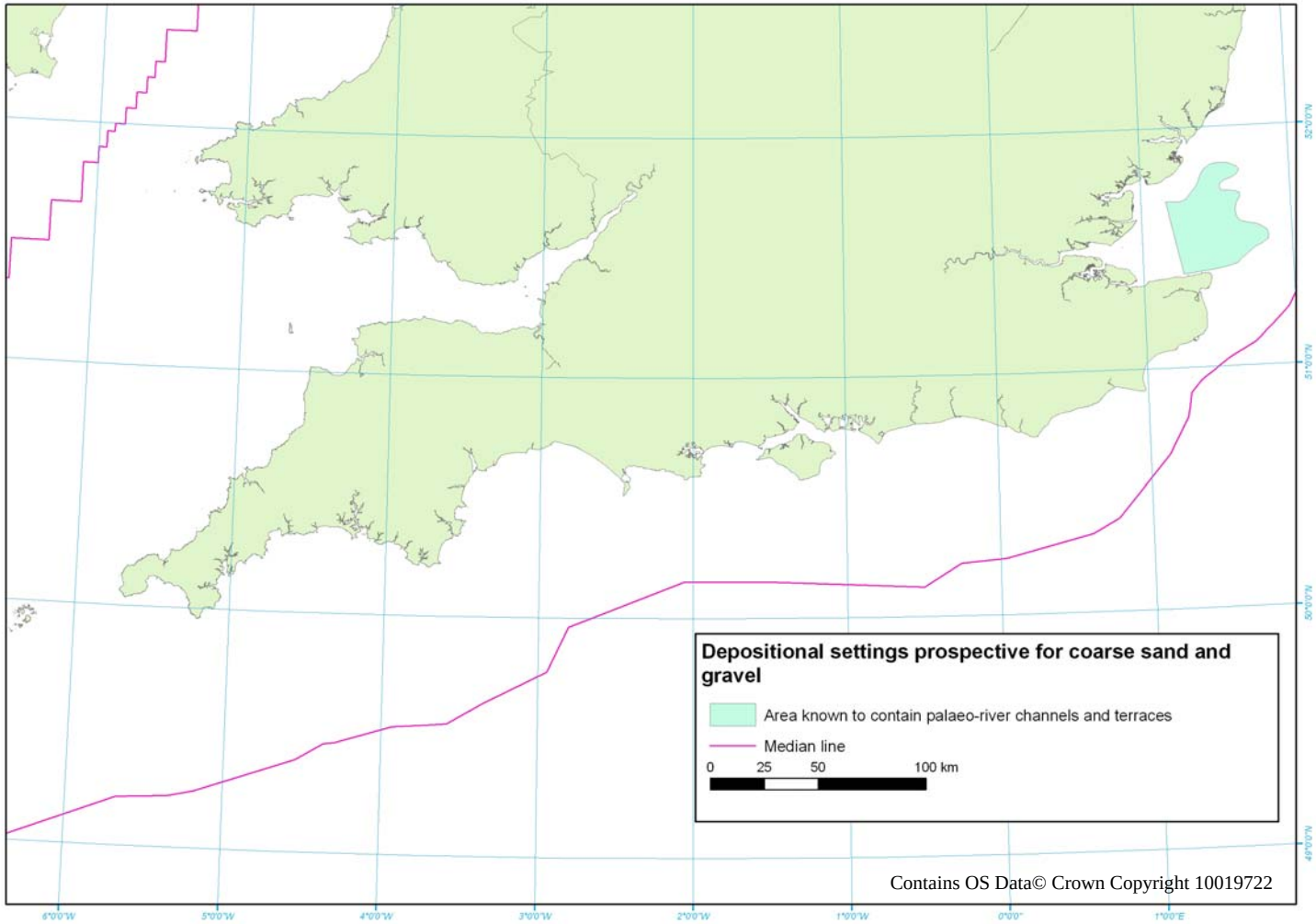
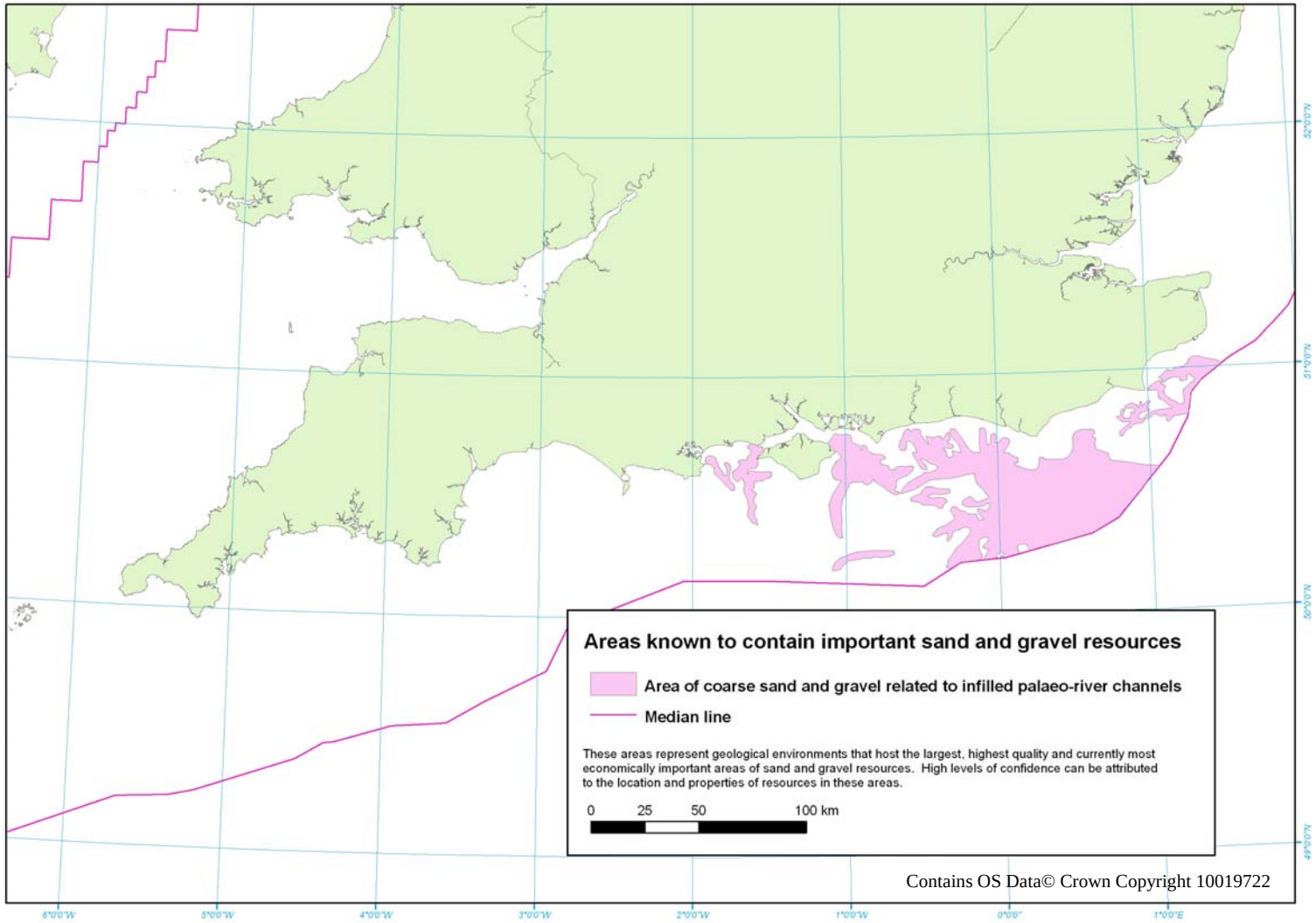
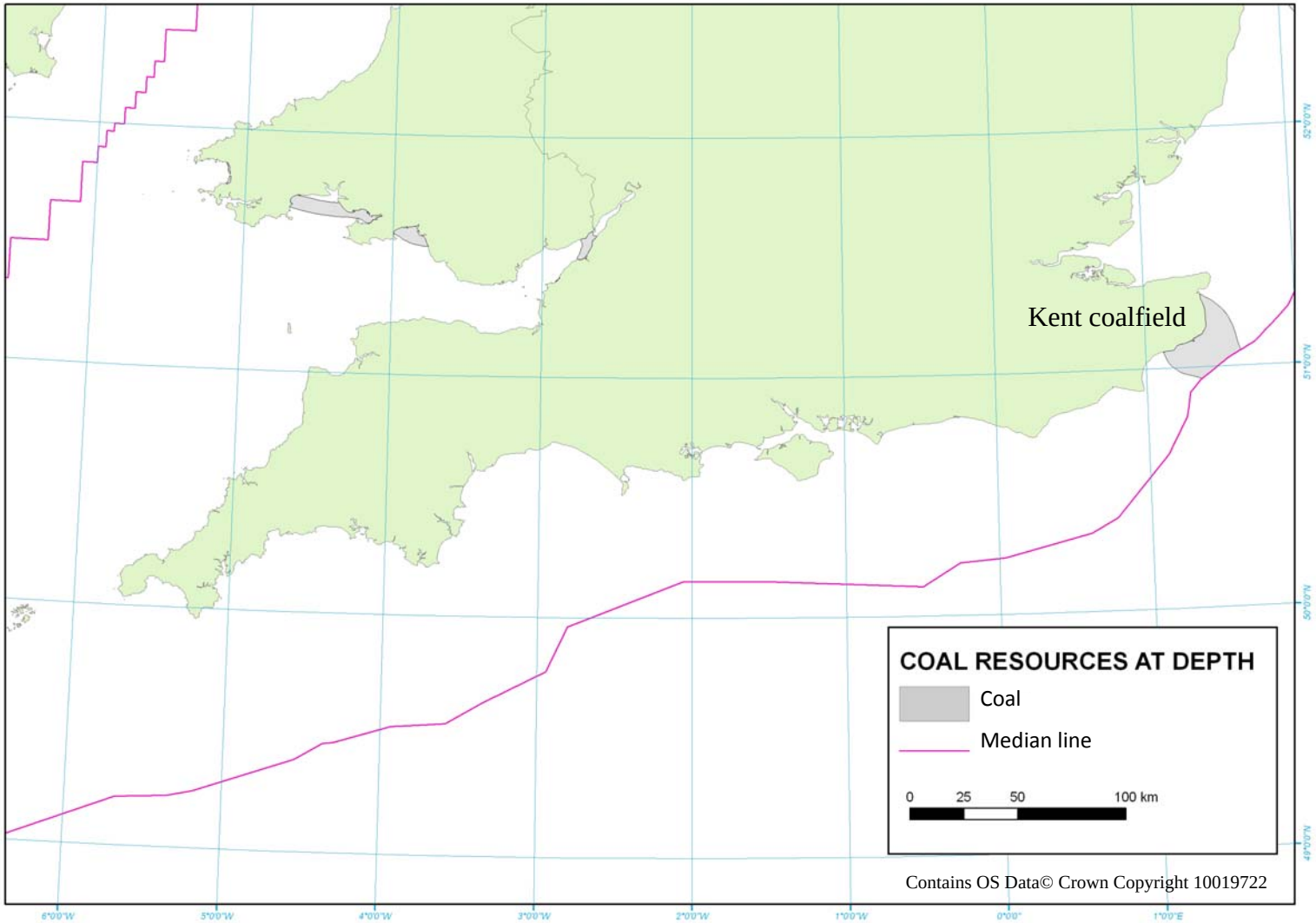
Appendix 1 Map depicting the geological features used to identify areas prospective for coarse sand and gravel



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