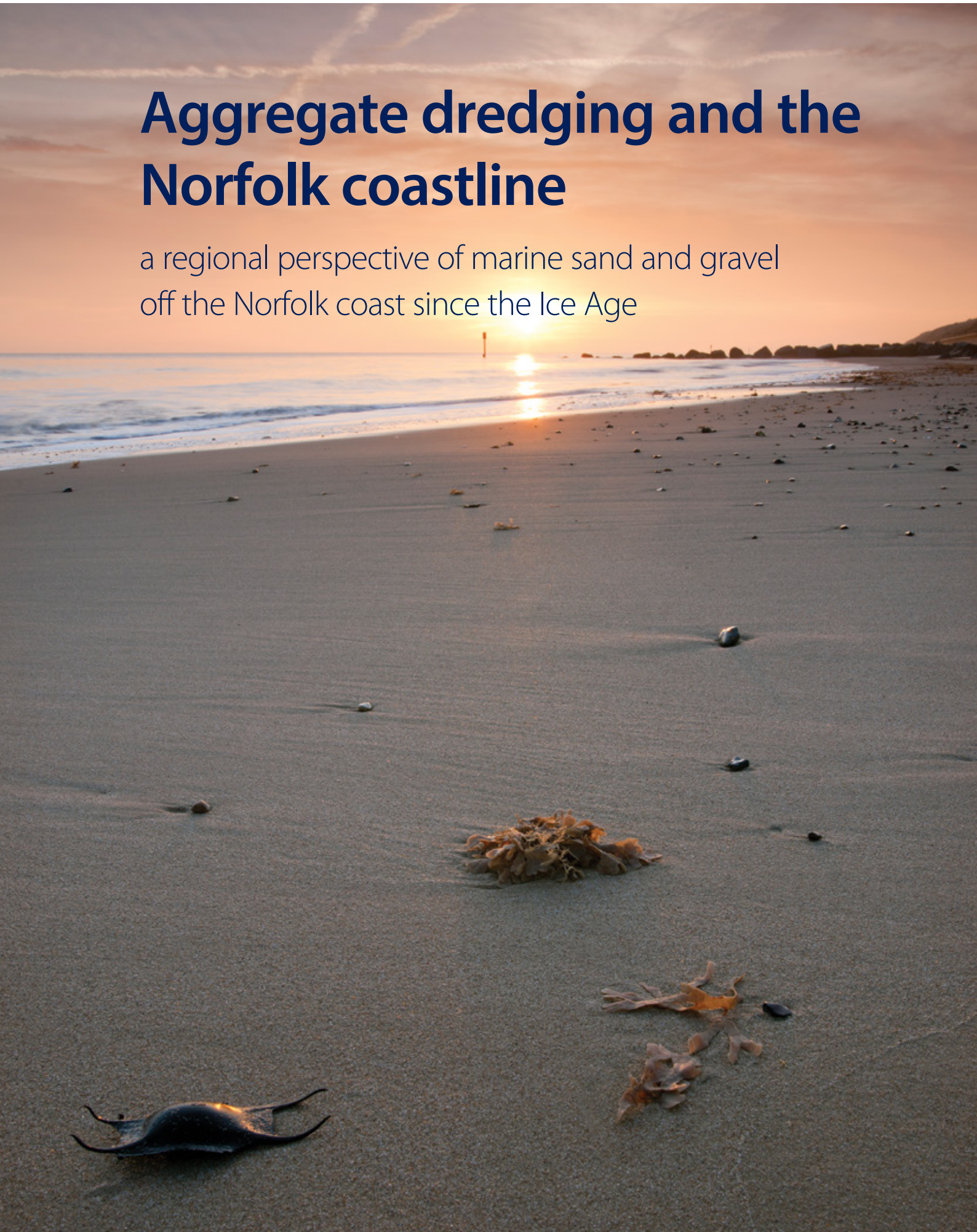


Aggregate dredging and the Norfolk coastline

a regional perspective of marine sand and gravel
off the Norfolk coast since the Ice Age



Perceptions about erosion and dredging

This pamphlet has been produced by the British Marine Aggregate Producers Association and The Crown Estate in response to perceptions that dredging off Norfolk may be contributing to impacts on the coastline. Modern aggregate extraction takes place well offshore and this report provides information to show there are no physical processes that link it to the natural erosion of the coastline that has been occurring since prehistory.

The UK marine aggregates industry is highly regulated, and coastal impacts are amongst a range of environmental issues that have to be thoroughly assessed before dredging is licensed. Dredging will only be permitted to take place in precisely defined licence areas if no significant environmental impacts are predicted. Once dredging is permitted, the environmental effects will be continually monitored and reviewed throughout the lifetime of any licence. To ensure that dredging activity only takes place where it has been licensed, all dredging vessels operating in UK waters are required to have a 'black box' electronic monitoring system that uses GPS positions to record their activities.

Whether undertaken for aggregates or for other purposes, dredging has the potential to result in changes to the physical processes which interact with the coastline – but only if it is allowed to take place in an inappropriate location such as in shallow water or too close to the shoreline. Such changes could be in the wave climate, tidal streams or interactions with sediment transport processes.

The most commonly cited example of this is at Hallsands in Devon where, following the dredging of beach sediments for use in constructing Devonport Naval Dockyard in the late 19th century, the village was tragically destroyed during storms in 1917. This remains the only example in the UK where aggregate dredging resulted in an impact on the coastline.

In contrast, modern marine aggregate extraction takes place much further offshore. This document explains the relationship between the offshore dredging areas and the coastline of Norfolk.

Information is presented on the evolution of the coast of Norfolk, the geological origins of the sand and gravel deposits that are being extracted and the influence of the modern day waves and tides on both these deposits and the coastline.

*Front cover image courtesy of
North Norfolk District Council*

Eroding coastline at Hunstanton



Dredging off Norfolk

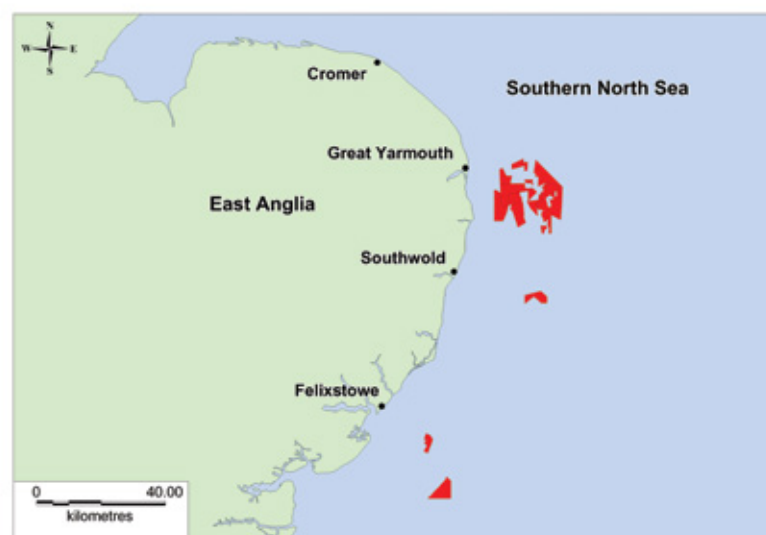
In 2013, a total of 739km² of seabed was licensed for marine aggregate extraction around the UK, of which 98.67km² was actually dredged. A total of 16.03 million tonnes of marine aggregate was extracted during 2013, of which 10.63 million tonnes was used for construction aggregate in England and Wales, 4.09 million tonnes was exported to the Continent for use as construction aggregate, and 1.31 million tonnes was used for beach replenishment and contract fill at locations across the UK.

Off the East Anglian coastline (Norfolk, Suffolk and Essex), 178.71km² of seabed area was licensed for marine aggregate extraction. Within this, dredging actually took place in 32.42km², producing 4.99 million tonnes of marine sand and gravel. Some 3.69 million tonnes of marine aggregate dredged from licensed areas in the Anglian region was landed at wharves in England for use as construction aggregate – mainly at sites along the Thames. A further 1.30 million tonnes was exported to the near Continent, also to be used as construction aggregate.

Marine aggregate is also commonly used to support beach nourishment schemes, providing benefits to communities, local economies and the environment. Since 1999, nearly four million tonnes of marine sand and gravel has been used to support schemes at Happisburgh, Southwold, Clacton and Southend.

The dredging process itself involves the dredger trailing a pipe along the seabed while moving slowly forwards (c.3 - 5 km/h). Powerful centrifugal electric pumps draw a mixture of sand, gravel and seawater through a draghead which rests on the seabed, up the dredge pipe and into the hold of the vessel. The sand and gravel settles into the base of the vessel's hold, while the excess water is returned to the sea via overflow spillways. The dredging process typically results in a cut of sediment 0.3m deep and 2m wide being removed as the vessel uses GPS positions to navigate within the licence area.

A key misconception about the marine aggregate dredging process is that it results in large holes in the seabed. By using the total tonnage dredged over a given period, together with the area of seabed where dredging takes place, it is possible to calculate the average lowering of the seabed that has resulted. In the case of the licences off Norfolk, Suffolk and Essex, over the 15-year period between 1998 and 2012, 134.9 million tonnes (81.1 million m³) was dredged from an area of 249km². This equates to the seabed across the area dredged being lowered by an average of 0.33m, although in reality the intensity of dredging activity will be more uneven.

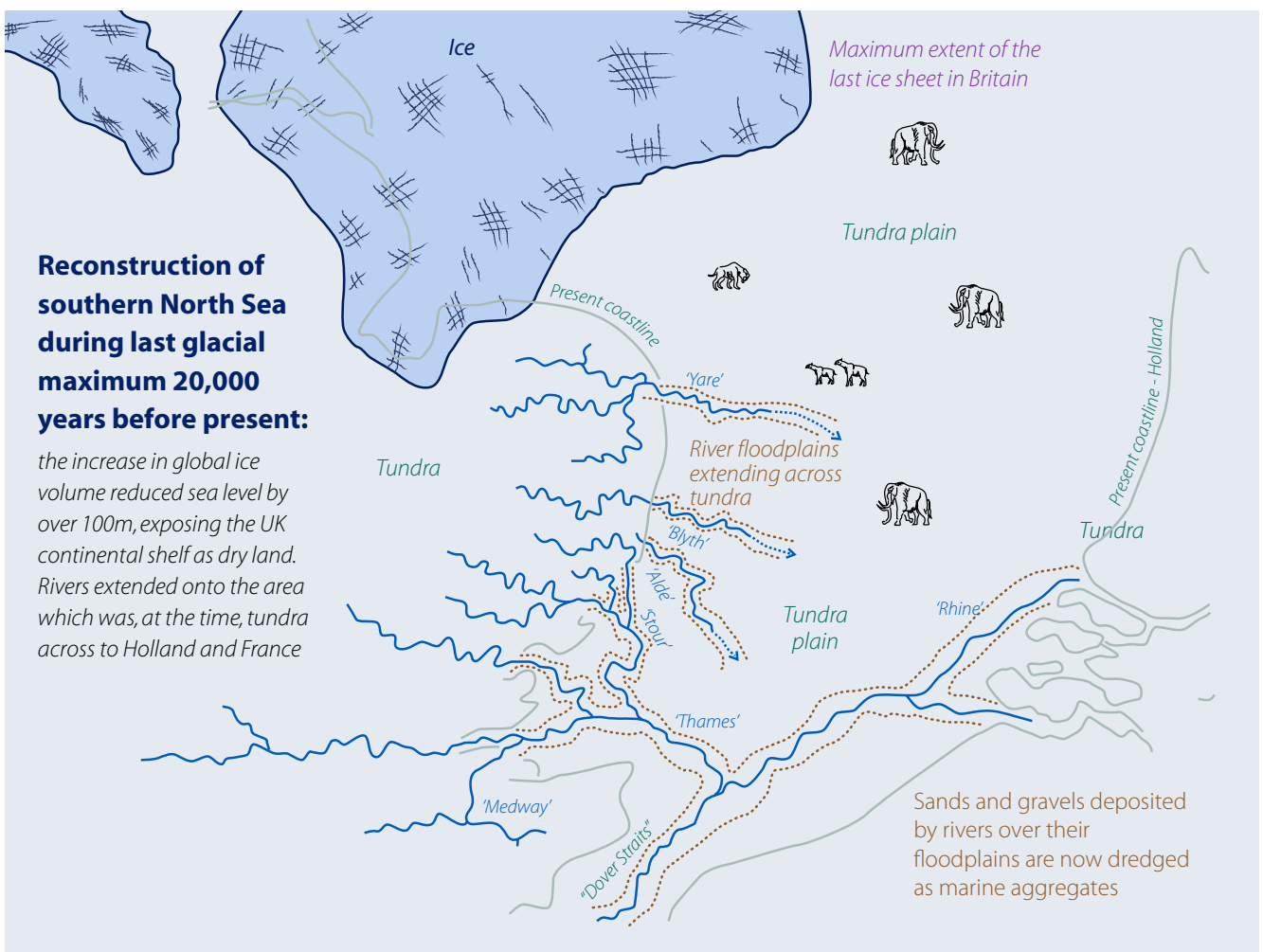


Licence areas off the Norfolk, Suffolk and Essex coast.

Evolution of the Norfolk coast: from continental tundra to island margin

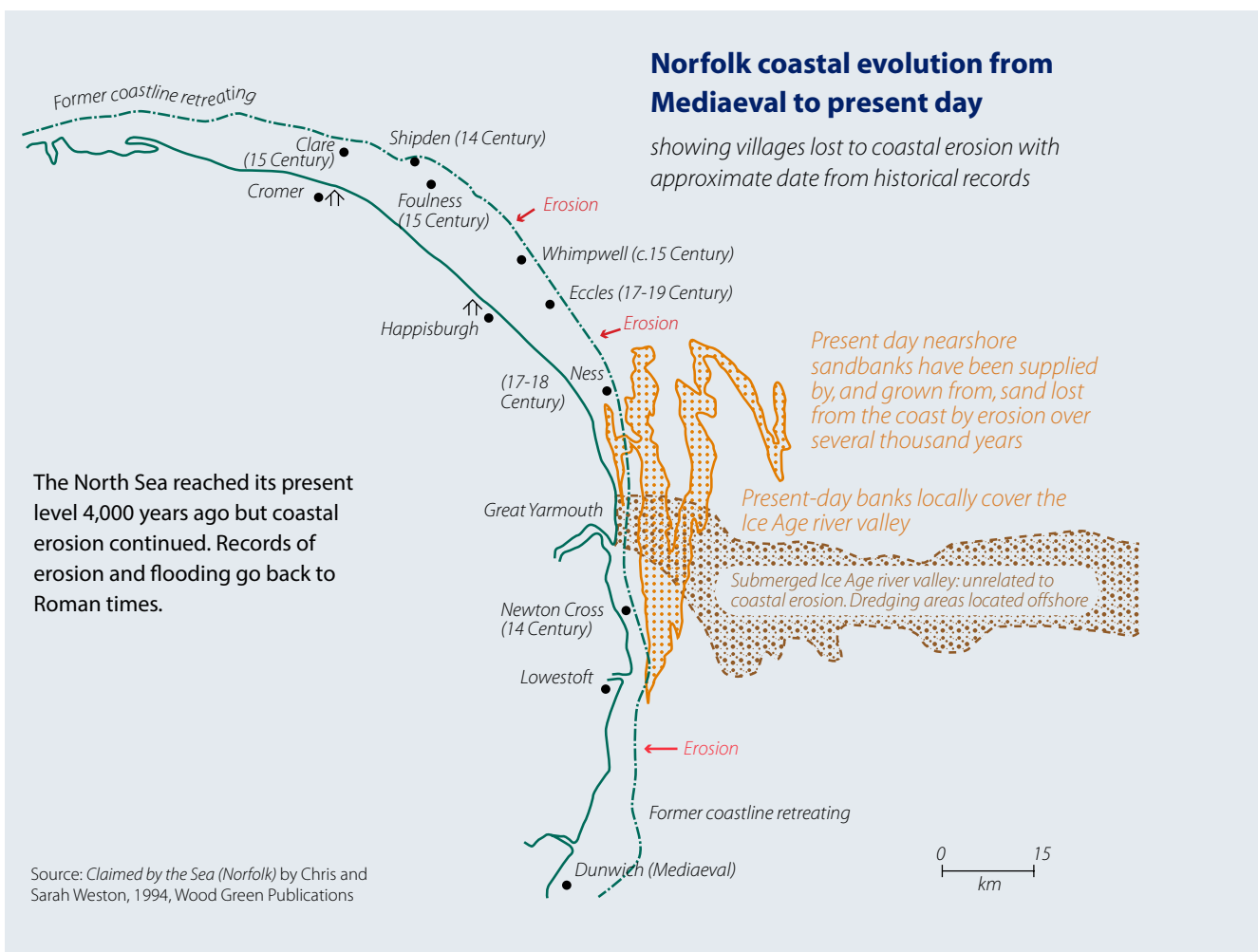
In the Ice Age, the area we now know as Norfolk was Arctic tundra crossed by rivers like the Yare which deposited sand and gravel. As sea levels rose, this now valuable aggregate resource was submerged and separated from the new shoreline by sand banks created from sediments from the still eroding coastline.

Twenty thousand years ago, Norfolk was part of a vast expanse of Arctic tundra extending from the edge of an ice sheet across to present day Holland and beyond. Rivers like the Yare crossed this low-lying landscape and deposited sand and gravel over their floodplains. Mammoth and other Ice Age mammal bones, teeth and tusks are often found in dredged aggregates and in fishing nets from this now flooded area. When the climate warmed, the sea level rapidly rose and submerged the landscape, which became the bed of the southern North Sea. The coastline retreated as the sea rose, and cliffs made of older glacial sands formed, slowing but not stopping the advance of the sea.



Coastal erosion and the advance of the sea continues, and historical records show that many villages have been lost since Roman and Mediaeval times. The coast is prone to erosion due to the unstable sand-rich cliffs combined with easily scoured near-shore sediments. Indeed, the sand banks just off the coast of Great Yarmouth are largely formed from sediment released by this coastal erosion.

Aggregate dredging takes place offshore of these banks in one of the Ice Age river floodplains. Investigations and assessments of the effects of dredging demonstrate that it is not accelerating the natural process of coastal erosion in Norfolk.

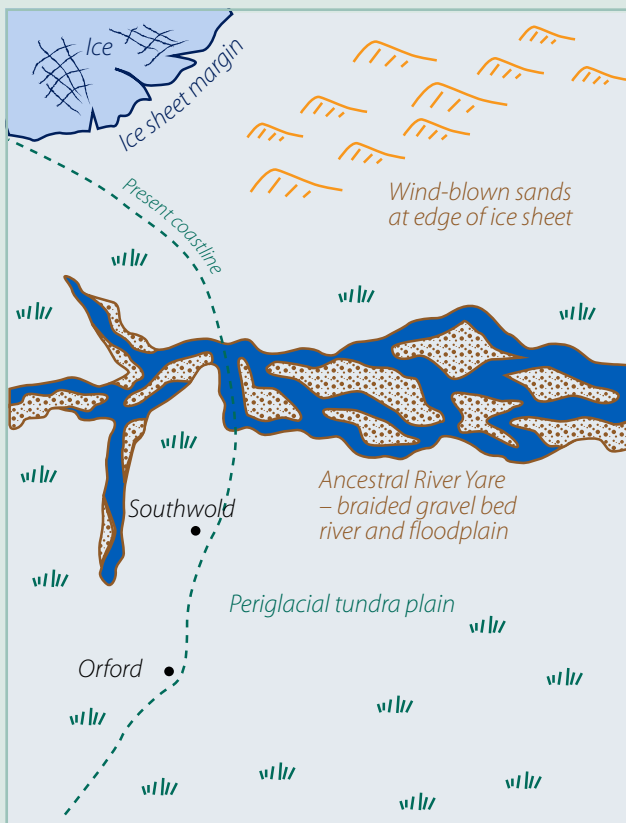


Geological origins:

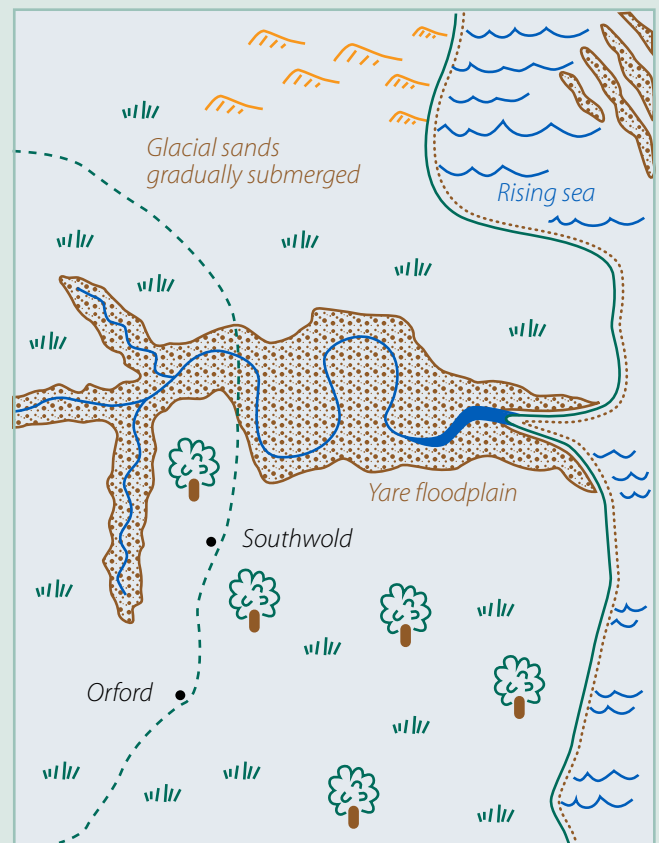
Arctic tundra, lost rivers and sand banks

The sand and gravel dredged off Norfolk originated in the Ice Age, or Pleistocene, covering the last two million years or so of geological time. The diagrams below illustrate the formation of the aggregate deposits in four stages, starting in the last glaciation in the region over 20,000 years ago.

A similar sequence of events has been repeated many times over the past two million years. The aggregate deposits were laid down in a river draining a cold tundra landscape that looked like parts of the modern-day Canadian or Siberian Arctic. River floods caused by snow and ground ice melting in the spring and summer over thousands of years brought down flint gravels and quartz sands, forming a wide braided river floodplain east of the present position of Great Yarmouth. Prehistoric flint hand axes made by our ancestors have recently been found in aggregate deposits in this area, dating back over 250,000 years when the North Sea was dry land, crossed by the ancestral River Yare.

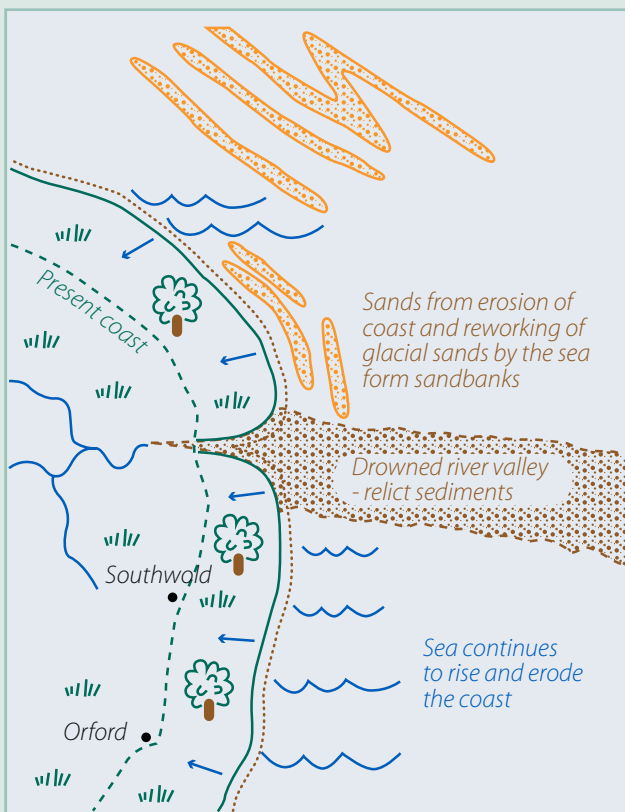


1: Last glaciation 20,000 years ago: sea level over 100m lower, present seabed exposed as land. Cold climate. Deposition of sand and gravel in Yare valley south of ice sheet. Strong winds off ice sheet cause accumulation of sands near ice margin.

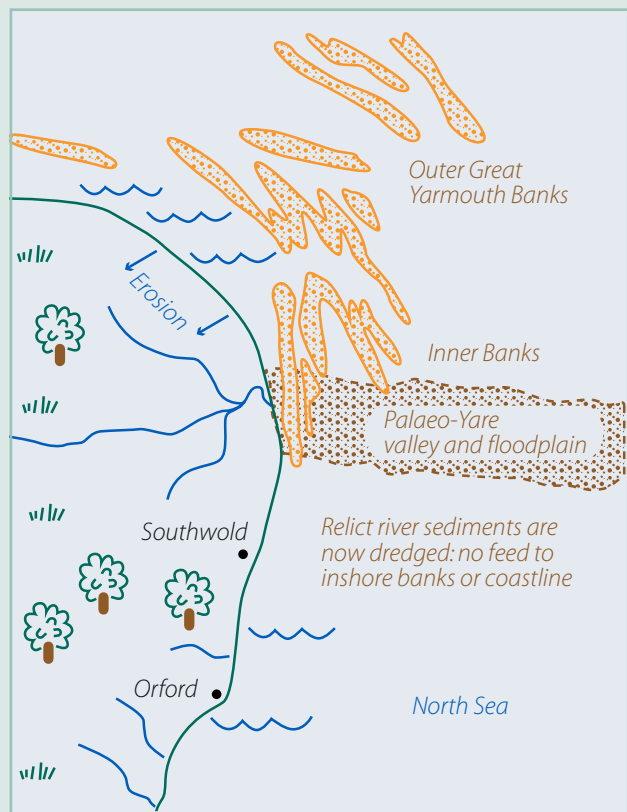


2: Rising sea as ice melts after last ice age 10-7,000 years ago. Warming climate. River Yare retreats as floodplain is submerged by the sea. Glacial sands are reworked by rising sea to form sandbanks.

The river floodplain was submerged by the rising sea at the end of the last Ice Age, becoming first an estuary and then fully marine by about 5,000 years ago. Marine geophysical and sampling surveys now show that the river's sand and gravel have remained in-situ within the ancient floodplain. Locally, the gravelly deposits are buried by the younger inshore sandbanks. Dredging of the old floodplain deposits far from the coast has no effect on coastal erosion because these sands and gravels are not part of the present coastal or sandbank sediment system.



3: Around 7-5,000 years ago, the Yare valley is drowned downstream of the present coastline. The river's sands and gravels are preserved on the seabed. Sandbanks form where sand is released from coastal erosion and where pre-existing glacial sands are reworked by the encroaching rising sea after the Ice Age.



4: Present day. Inner, nearshore banks are supplied by coastal erosion. Banks and coastline are not supplied by the now submerged, immobile and "fossil" Yare floodplain deposits which are now dredged for marine aggregate.

Today's marine processes:

North Sea waves, tides and sandbanks

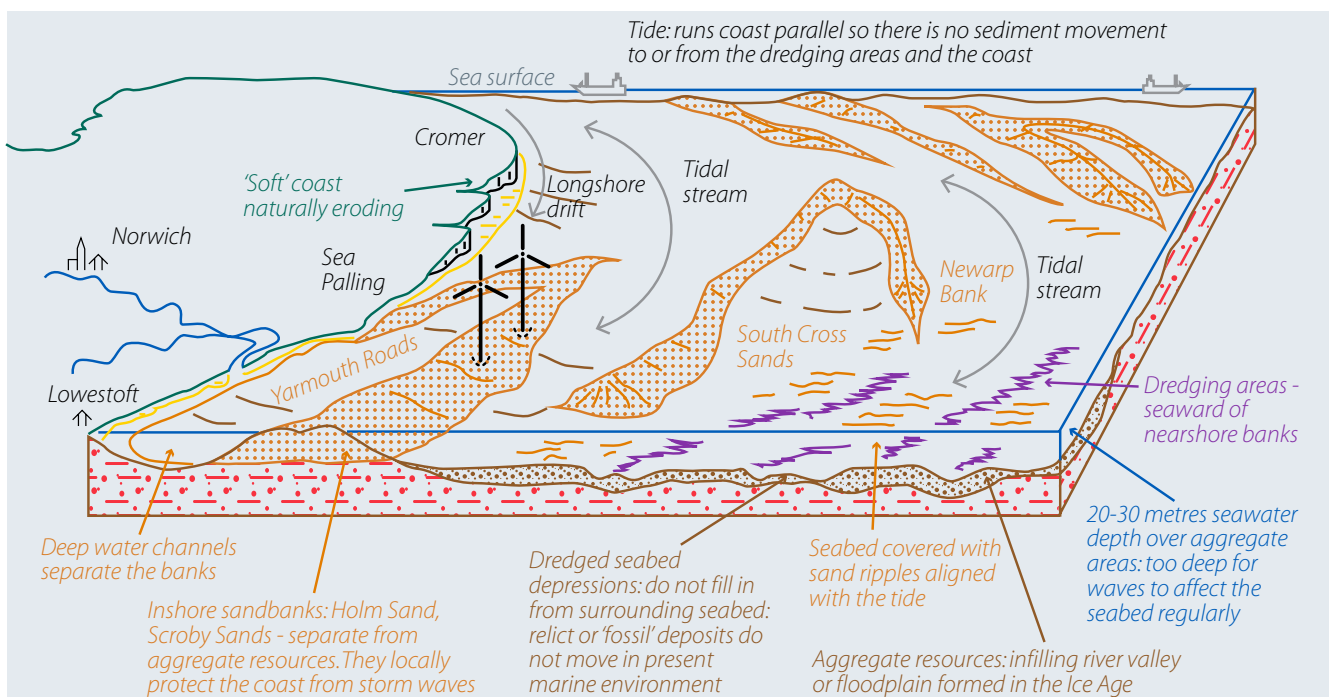
Near-shore sand banks play an essential role in defending Norfolk's coastline by absorbing wave energy. These features lie inshore of the dredging areas and remain unaffected by the shallow seabed depressions that are being created by sand and gravel extraction. There are no physical processes that link sediments along the coast, or in the near-shore, to the offshore seabed where dredging takes place.

The effects of wind, wave and tide have influenced the evolution of the Norfolk coast and the seabed features that lie offshore over many thousands of years. Today, these same processes continue to actively influence the transport and erosion of marine sediments.

Along the coast and in the shallow near-shore area immediately offshore, erosion and sediment transport are driven by the effects of wave energy, which are in turn influenced by the wind. Rather than moving sediment offshore, wave energy actually results in sediments being transported along the coastline through a process termed 'longshore drift'.

Further offshore, the water depths are too great for wave energy to influence seabed sediment transport on a regular basis. Here, the processes are driven by tidal energy which results in seabed sediments being transported parallel to the coast, not towards it. Evidence for these powerful processes can be seen in the orientation of the large sandbank features which are located off the coast of Norfolk, and the troughs and deeps that separate them.

These sandbanks play an essential role in defending the coastline that lies inshore, by absorbing wave energy before it is able to reach the coastline. In this respect, the sandbanks represent the nearest point of potential influence from the marine aggregate dredging that is taking place offshore. If there is no effect on the sandbanks from marine dredging, there can be no effect on the coast.



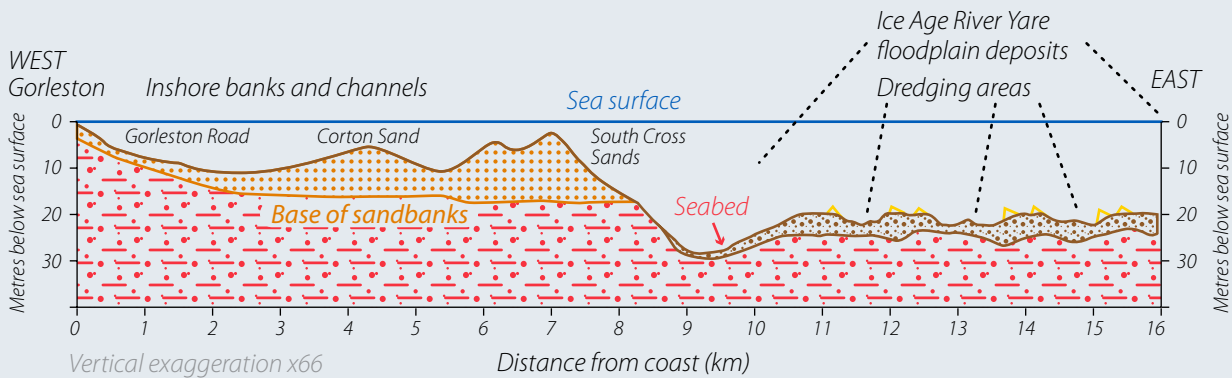
Relationship between Norfolk coast and offshore dredging areas:

the sand and gravel being removed from the dredging areas is not part of the modern sediment transport system or coast

Not to scale

Cross section from Gorleston to the offshore dredging grounds in the southern North Sea showing what lies beneath the seabed

The dredging areas are seaward of the near-shore banks and extraction of the ancient river deposits offshore will have no effect on either the banks or coastline: the submerged river deposits are "fossil" and immobile in the present marine environment and are unrelated to both the sands of the coastline and the nearshore banks



While the sediment processes that occur in and around the dredging areas are dominated by tides, the fossil sand and gravel resources being dredged remain unaffected. Modern sediments (mobile sand) will be transported across the surface of the seabed as sand waves and ripples by tides, in a coast-parallel direction. However, the marine aggregate resources remain immobile and in-situ as they have done for many thousands of years.

Over time, dredging results in shallow depressions being created (typically 2-4m deep over 1-2km) as the underlying fossil sand and gravel resource is removed. Monitoring data shows the modern sediment continuing to be transported by the tide. Rather than infilling these depressions, the modern sediment continues to be transported across and through them.

Similarly, the adjacent sandbank features which lie inshore of the dredging areas remain unaffected by the shallow depressions that are being created further offshore.

While the sandbank features provide a buffer to the wave energy coming from offshore, conversely, they also provide a natural barrier to sediment moving from the coastline. There can be a misperception that there is a gentle slope between coast and the dredge areas located further offshore, which allows sediment to be 'drawn down' into the dredged depressions.

Profiles of water depth (taken from Admiralty charts) from the coast out to the dredging areas clearly show a series of deeps and banks in between the two that beach sediments would have to somehow 'traverse' in order to get to the dredge area. Modern sediment transport processes, driven by either wave or tide, actually run coast-parallel (broadly north/south), so there is no transport mechanism for this to happen. Further evidence of this can be seen in monitoring data, which shows the dredged depressions are not being infilled.

In terms of modern sediments, there are no physical processes that link sediments along the coast or in the near-shore to the offshore area where dredging takes place. Furthermore, the fossil sediments being removed from the dredging areas do not form part of the modern sediment transport system, and are completely unrelated to the sediments present along the coast and the processes acting upon them.

In fact, the only way that the fossil sands and gravels being dredged will find their way to the coast is if they are deliberately placed there. In this respect, the marine aggregate industry fulfils an important role in helping to protect the coastline of Norfolk by supplying sand and gravel resources in support of beach replenishment.

Monitoring, assessment & regulation

Aggregate extraction is closely regulated to protect the environment. Expert studies are undertaken and extraction licences will be refused if there is any genuine concern about impacts on the coastline. Monitoring of the dredged seabed continues throughout the life of a licence – typically 15 years.

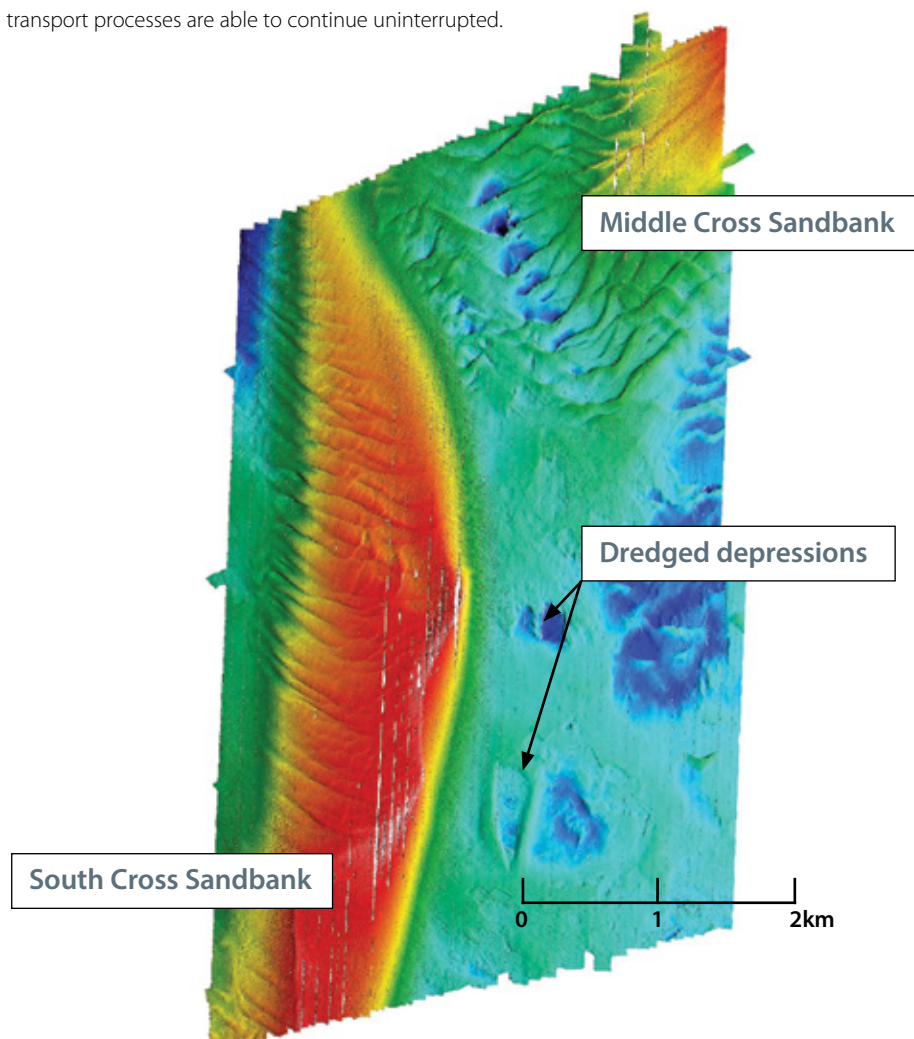
Marine aggregate dredging in English waters is regulated by the Marine Management Organisation through marine licences which are intended primarily to protect the environment. Before dredging can be licensed, dredging applications are subject to a rigorous assessment process which takes several years. Operators are responsible for commissioning detailed environmental impact studies, including coastal impact studies which consider the potential effects of the proposed dredging on waves and sediment mobility as well as coastal processes.

The outcomes of these studies are reviewed and scrutinised by government regulators and advisors as well as numerous other stakeholders, and if there is any remaining serious doubt over the potential for coastal impacts then dredging will not be permitted.

Licences for aggregate dredging always include a requirement for ongoing monitoring during the life of the licence (typically up to 15 years). Bathymetric monitoring surveys are used to record water depths across dredged areas. This enables the extent of the shallow depressions that result from the removal of fossil resources to be accurately measured. Bathymetric data provides regulators and their advisors with evidence, for example, that the dredged depressions do not infill with new sediment, and that the natural sediment transport processes are able to continue uninterrupted.

Bathymetric data gives industry and regulators a clear picture - in this case, sandbanks and dredging areas 10 km off Great Yarmouth.

Image courtesy Hanson Aggregates Marine Ltd



Dredging in Europe

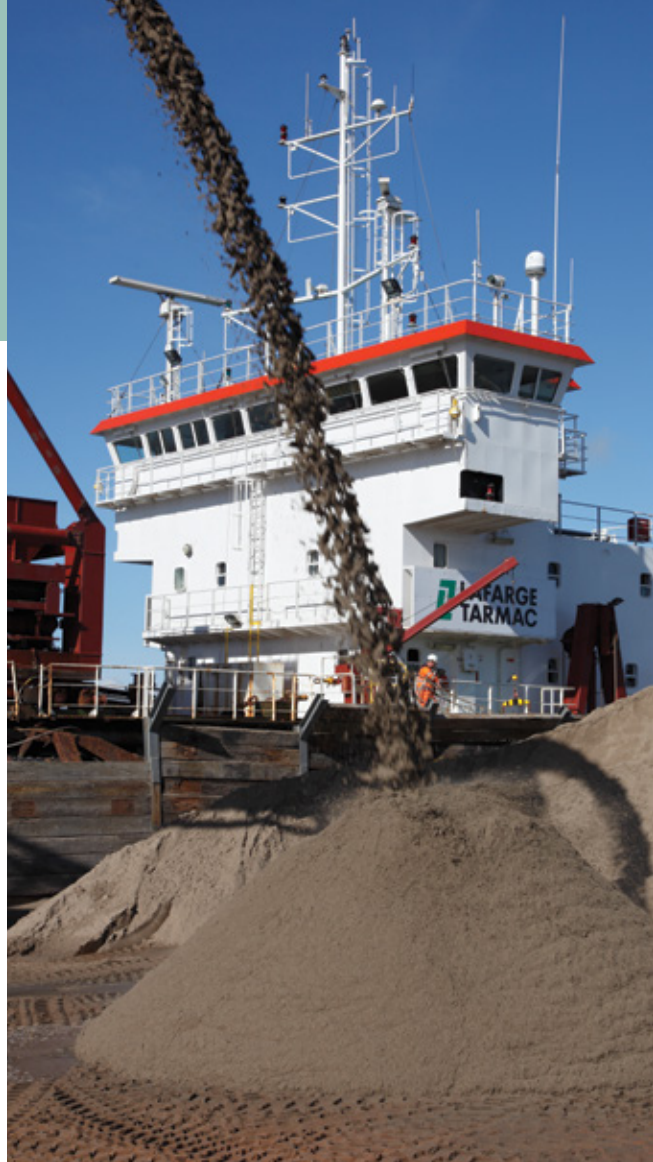
It has been suggested that UK marine aggregates are exported to Holland and Belgium because those Governments do not allow dredging in their own waters. The reality is that UK operators deliver construction aggregates to those countries as their continental shelves do not have deposits of coarse aggregate. Needs for fine and medium-grained sand for construction and beach replenishment are met in large quantities from local sources off Holland and Belgium.

Around 40 million tonnes of sand is dredged from licensed areas in Dutch waters each year, around double that dredged from all UK waters. A national environmental impact study undertaken by the Dutch government concluded that dredging in a depth of 20m or more on their continental shelf would not result in coastal impacts, subject to no more than

2m of sediment being removed. Consequently, operators are able to obtain a production licence to dredge in >20m of water by simply paying a licence fee, and without the need to undertake a site-specific impact assessment. This approach contrasts to regulation in English waters, where licence areas lie in water depths of between 10 – 50 m and detailed site specific assessments of dredging proposals have to be undertaken irrespective of the tonnage being dredged or the water depths involved.

For larger scale extraction requirements which require more than 2m of sediment to be removed from water depths of more than 20m, site-specific assessments are required before the activity is permitted. The Dutch authorities have recently permitted over 360 million tonnes of marine sand to be removed over a five-year period to support the extension of Rotterdam harbour¹. The dredging depths and volumes of sediment involved meant that a full Environmental Impact Assessment (EIA) was necessary before dredging began. This scale of dredging represents over 70 times that dredged off East Anglia in a single year.

Another example of this is the 'Sand Engine'² project in the province of Zuid Holland. During 2011, around 30 million tonnes of marine sand was dredged from licence areas 10km off the Dutch coast to create a new hook-shaped peninsula. This will naturally erode over 20 years to maintain and enhance beach levels, which in turn will ensure that the communities, infrastructure and environment located inland are protected.



¹Rotterdam harbour project: <http://www.maasvlakte2.com/en/index/>

²Sand Engine project: <http://www.dezandmotor.nl/en-GB/the-sand-motor/introduction/>

Marine aggregate facts

Marine aggregates are an essential part of our daily lives, satisfying around 20% of all the sand and gravel needed for construction in England and Wales. At a time when rising sea levels pose a growing threat, marine sand and gravel is also vital to coastal protection.

Construction aggregates influence every facet of modern life – from the homes we live in and the transport infrastructure we use to get around, to the energy and fresh water that we take for granted. In order to maintain and develop the built environment in which we live, every person in Britain indirectly generates demand for three tonnes of aggregates every year – equivalent to around 200 million tonnes each year.

The majority of this need is met by material from recycled or secondary sources (25%), sand, gravel or crushed rock quarried from the land. A proportion of the demand is, however, met by sand and gravel dredged from the sea. In England and Wales, marine aggregates represent around 20% of all the sand and gravel used in construction. In the south east of England, a third of all construction materials come from marine sources.



Marine dredged sand and gravel also have a strategic role in supplying large-scale coastal defence and beach replenishment projects – over 25 million tonnes being used for this purpose since the mid-1990s. With the growing threats posed by rises in sea levels and more frequent storms, the use of marine sand and gravel for coast protection purposes will become increasingly important.

The commercial rights to marine aggregates in English waters are administered by The Crown Estate. Operators are required to pay a royalty for every tonne of sand and gravel they dredge. In the financial year 2013/14, marine aggregate extraction generated royalty revenue of £15.6 million, the surplus of which was passed to HM Treasury.



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ISBN: 978-1-906410-56-8

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Aggregate Producers Association 2015

This document has been produced by BMAPA and The Crown Estate in consultation with members of the Local Government Association Coastal Special Interest Group. Local authorities around England acknowledge the importance of marine aggregate dredging for economic regeneration. They strongly support the use of a sound scientific evidence base with effective regulation and monitoring in determining from where material should be extracted.