COASTAL DEFENCE AND MARINE AGGREGATE DREDGING OFF THE UK

Dr ANDREW BELLAMY

British Marine Aggregate Producers Association (BMAPA)

SUMMARY

Marine dredged sands and gravels play a major role in UK coastal defence schemes. Demand for this purpose has increased in recent years. Dredging for these resources takes place well offshore and the deposits are not linked to the coastline. The use of marine aggregates in coastal defence is therefore environmentally beneficial. There are sufficient resource volumes in existing licence areas and in new licence application areas to satisfy the demands of both coastal defence and construction for many years to come provided new licences continue to be granted.

INTRODUCTION

The use of marine sand and gravel for UK coastal defence peaked at 6.2 million tonnes in 1996. Over the past 5 years landings for this purpose have averaged over 3.5 million tonnes per year. Marine aggregates clearly have a major role in the execution of coastal defence schemes and this paper examines the nature of these offshore resources, their distribution, availability and the associated environmental issues. Marine aggregates can be selected to closely resemble the pre-existing coastal sediments and can meet a variety of grading specifications in line with design concepts for robust coastal defences. Provided resources of the appropriate quality and quantity are available, large volumes can be transported ashore in relatively short time periods using dredgers with capacities in excess of 2500 m^3 (Figure 1). This avoids the need for increases in terrestrial quarrying and lorry convoys to coastal locations. The Environment Agency's Combined Beach Management Package (1999) indicates that demand for marine sand and gravel for coastal defence and beach replenishment will continue to be strong over the next 5 years. There is therefore a need to ensure that sufficient resources are available in the correct locations to meet this demand.

NATURE OF THE RESOURCES

Origins

Marine sands and gravels originated recently in geological terms. Their distribution is a product of major global climatic and hence sea level changes that have affected the British Isles and adjoining continental shelf over about the past 2 million years (the Quatemary Period). During repeated cold (glacial) phases ocean water was locked into ice sheets leaving the southern North Sea basin, English Channel and Bristol Channel regions largely exposed as land while ice sheets developed in the north and north-west of Britain. Conversely, intervening periods of warmer climate (interglacials) led to melting and retreat of ice sheets and the return of marine conditions over the continental shelf, as at present.

Sands and gravels are the products of the erosion of rocks and sediments on the land. Rivers and glaciers were the main agents of transport and deposition both on land and on the shelf Marine and terrestrial sands and gravels therefore share the same origins. With the continental shelf exposed as land in a cold climate, rivers sourced on the present landmass extended across the shelf and transported large volumes of sand and gravel in their valleys. Off SE Britain, these infilled valleys, river channels and river terraces represent the major source of sand and gravel. The thickness of the deposits ranges from about 3 m to over 1 0 m, occasionally over areas of several square kilometres. The submerged valleys commonly have little or no bathymetric expression, being completely or partly infilled.

Examples, of extensive submerged, infilled valleys are found west and east of the Isle of Wight, in the mid eastern English Channel, in the Thames Estuary and east of Great Yarmouth (Figure 2). The infills also include finer-grained sediments, peat, silt and clay, from deposition in lower energy environments like estuaries and tidal inlets during postglacial sea level rises.

Within glaciated areas such as the region off the Humber estuary and in the Irish Sea, sands and gravels are the products of a combination of glacial and glacial meltwater deposition together with marine reworking of pre-existing sediments.

Climatic warming at the end of the last glaciation led to sea level rise and the reworking of surface sediments to form coastal features such as beaches, spits and sediment veneers. Survey data from licensed areas indicates that submerged coastal features are uncommon, suggesting that their preservation potential since marine submergence is low. Geological evidence suggests that the continental shelf has been eroded by marine action during sea level rise. This erosion would have removed traces of coastal sediments, reworking them to form scattered veneers, widespread across the inner shelf However there are some examples of deposits which may represent submerged coastal features, for example west of the Isle of Wight.

Submerged coastal deposits, river valley infills and glacial deposits are termed relict, having been deposited in environments and by processes no longer present on the continental shelf They are immobile in the present marine environment, having remained undisturbed since their formation. Consequently structures suggesting a fluvial origin remain preserved within such deposits. These relict sediments are unrelated to present day coastal sediment budgets or sediment movements on the sea bed.

Composition

The composition of marine aggregates is similar to the composition of those quarried on land. Since rivers from the present land surface extended across the shelf, sands and gravels quarried in present river valleys are simply the upstream equivalents of those deposits now submerged offshore. Off SE Britain, flint constitutes the main component of the gravel fraction, being a product of the erosion of the chalk in southern and eastern England and possibly northern France. Off the Humber, gravel composition is more varied, reflecting the glacial origins ofthe deposits. Sands are quartz dominated in most areas.

Shell fragment content is generally low in marine aggregates, reflecting their non-marine origins. Local concentrations of shelly sediments can occur in marine reworked sea bed veneers.

AVAILABILITY OF RESOURCES

Licences

There are over *50* licensed dredging areas located generally between 5 and 35 km offshore in water depths of between 10 and 40 m (Figure 3). These are licensed to 1 1 operating companies. In 1 993 the Crown Estate introduced competitive tendering for exclusive prospecting rights for potential licence areas. Tenders are based on the offer of a guaranteed minimum tonnage ofitake and guaranteed royalty rate per tonne. The Crown Estate also takes the location and environmental characteristics of an area into account. Should the Crown Estate decide to make an award, then a prospecting licence is issued with the option to the operator of applying for a production licence.

Prospecting and locating resources

Prospecting involves detailed surveying to locate sand and gravel deposits. A survey vessel is chartered together with high resolution shallow seismic profilers, side scan sonar, echo sounders and core and grab samplers. Vessel positioning is highly accurate, commonly using satellite navigation systems. Seismic surveys involve steaming over predetermined survey lines to generate a grid pattern, commonly with a line spacing of 100 - 500 m. Seismic profiles are an acoustically generated section through the sea bed providing information on the type, thickness and extent of deposits. Side scan sonar records show an acoustic image of the sea bed in plan view and reveal sea bed features such as bedforms and rock outcrops. Different sea bed sediment types can be inferred from data interpretation.

Sea bed sample sites are normally chosen from interpretation of seismic data and sample density is determined by the complexity of the geological structures, sediment types and the data requirement. Core samples are obtained using 3 - 6 m long vibrocorers capable of penetrating and recovering samples in coarse-grained sediments. Such samples assist the interpretation of seismic data by revealing sediment characteristics at depths of up to 6 m below the sea bed. Grab samples provide information on the range of grain sizes in the surface sediments and assist interpretation of side scan sonar data. They are also used to obtain data for benthic biological assessments ofdredging areas.

Geological data and its interpretation is therefore essential in deciding whether or not to persue a licence application. Accurate assessments of resource quality and volume are made to guide decision-making. Such data is also used once dredging begins to precisely locate deposits ofthe required quality and quantity for different end uses, including coastal defence.

Licence applications

Assuming a viable deposit is located, an application for a Government Permission is made to the DETR in England, the National Assembly for Wales or the Scottish Parliament. All applications must involve the production of an environmental impact assessment coupled with rounds of consultation with relevant organisations.

Permissions are only granted after detailed studies and after taking into account the views of consultees. The Crown Estate will only issue licence if a favourable Government Permission is given. Recently granted new licences have taken between about 5 and 10 years to obtain. A variety of monitoring conditions may be attached to a permission including regular bathymetric surveying, sampling, data analysis and review. In view of the time lag and uncertainty between locating an extractable resource and obtaining a licence, companies plan well into the fliture for their own security to underpin substantial long term investments in specialised dredgers and to ensure continued availability of resources to meet demand.

Maintaining supplies of marine aggregates

It is the responsibility of operating companies to locate resources and obtain licences. Resources for coastal defence are therefore made available through the licensing process by the efforts ofthe dredging industry in obtaining new permissions.

Most companies have other markets to supply, mainly the construction industries of the UK and near continent and must balance the usage of their resources accordingly in terms of quality and quantity. However, the needs of construction and coastal defence are not considered to be in conflict given the natural volumes of resources on the sea bed. The main issues are'firstly obtaining licences to extract the resource and secondly accepting that longer transit distances may be necessary to supply aggregates of the required quality. Both factors apply equally to construction and coastal defence uses. There are sufficient resources to serve both uses for decades to come provided licences continue to be issued. Requirements of certain specifications may constrain what can be used but increasingly licence holders are consulted as to what is naturally available before any specification is designed.

POTENTIAL IMPACTS ON THE COASTLINE

Concerns, mainly by coastal local authorities, over shoreline erosion being caused or exacerbated by offshore aggregate dredging persist. All licence applications are accompanied by a coastal impact study carried out by specialist scientists, commonly HR Wallingford Ltd. Predictive wave and tidal modelling and sediment mobility calculations are designed using highly conservative or pessimistic assumptions to exaggerate any possible effects of dredging. A licence application will only proceed if the study concludes that the dredging will not affect coastal processes. In most cases the proposed dredging will be many kilometres offshore and in water depths below most wave bases. Nonetheless, each application is examined in an extremely rigorous fashion before recommendations are made.

One of the issues investigated is beach drawdown, or the trapping of beach sediment in depressions offshore, preventing its return to the beach. This is a process that could occur if water depths immediately seaward of the beach deepened allowing sediment to be drawn down to fill them.

Aggregate dredging has occasionally been wrongly linked to beach drawdown with the perception that the dredged depressions are infilled with coastal sediments. This is an incorrect observation for the following reasons:

a) Aggregate dredging takes place in localities sufficiently distant from beach sediment accumulations such that the beach is not “aware” of depth changes in the dredged area. Indeed, in most cases, dredging takes place over 5 km from any beach.

b) There are commonly areas of deeper or much shallower water between the dredging area and the coast, making drawdown into dredged depressions impossible, for example off Great Yarmouth (Figure 4).

c) Sea bed gradients from nearshore to offshore in many areas are extremely low and the seaward transport of sediment from beaches to dredged areas would be highly unlikely in such circumstances. Furthermore, tidal cuffent directions are commonly coast parallel or subparallel, for example off eastern England, the south coast and in the Bristol Channel. This clearly suggests that offsho're sediment transport from coast to dredging areas is improbable.

d) Present day coastal sediments and the relict fluvial, glacial or submerged coastal deposits referred to above are completely unrelated to each other in the present marine environment. A removal of sediment from an infilled valley will not result in a corresponding loss of sediment from a beach (Figure 4).

Conversely, the perception that dredged depressions will trap sediment travelling to the coast also persists. This issue is always addressed in coastal impact studies which find that gravel is largely immobile at sea bed and sand, if mobile, will align with the tidal stream. Side scan sonar records are used to investigate sea bed sediment transport directions and commonly demonstrate that no sediment is being trapped in dredged areas that would otherwise reach the coast.

The use of marine aggregates for coastal defence therefore represents an environmentally beneficial and sensible solution to shoreline erosion because the offshore deposits would not otherwise be transported to the coast by natural processes. With appropriate environmental studies before permission is given for extraction, their continued use is ideal.

DEMAND FOR MARINE AGGREGATES IN COASTAL DEFENCE

A common issue with central and local government is whether there are sufficient resources to satisfy fliture demand for beach recharge. The discussion above has explained that there are sufficient resources for many decades to come provided these are licensed to allow their extraction. Furthermore, recent estimates of demand for both construction aggregates (Department ofthe Environment, 1994) and beach recharge material (Humphreys *et al,* 1996) appear to be high given evidence over the past 5 years and given new demand forecasts.

Humphreys *et al* (1996) estimate an annual demand for sand and gravel for beach recharge in England and Wales for the next 20 years of between 3 and *6.5* million m^3 per year (about *5.5* - 11.5 million tonnes). Using the Combined Beach Management Package of the Environment Agency (1 999) indicates a demand over the period 1 999 - 2002 of between 4 - *5.5* million m^3 for the Agency's Southern and Eastern Regions.

The Southern and Eastern Regions are likely to be the largest regional users of beach recharge resources. They require, according to Humphreys *et al* (1996), over 50% of the sand and 95% ofthe gravel for initial recharge and 45% ofthe sand and *65%* ofthe gravel for annual maintenance in England and Wales.

Using these figures for the period 1999 - 2002 indicates an annual demand of slightly less than 2 million m^3 instead of the 3 - *6.5* million m^3 from Humphreys *et al* (1996). Even allowing for additional local authority demand, it is difficult to see the annual demand over the next four years greatly exceeding 2 million m^3 in England and Wales.

Whilst it is difficult to predict whether demand will increase beyond 2002, an increase in demand to levels predicted by Humphreys *et al (* 1 996) would require:

1 . An increase in flinding for schemes
2. An increase in natural erosion problems forcing additional demand
3 . A growth in the trend towards beach recharge solutions at the expense of other techniques.

It is therefore suggested ' that the 1 996 estimates represent predictions of extremely high demand, which are "optimistic," at least on the basis of evidence for demand over the next 3-4 years.

CONCLUSION

Given likely levels of demand in fliture, there are sufficient volumes of marine aggregates of the appropriate quality in existing licences and in application areas to satisfy both the demands of coastal defence and other uses. Provided new licences are issued to replace depleted resources, then marine sand and gravel will continue to meet these strategic needs in an environmentally acceptable manner for many years to come.

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BMAPA MEMBERS

Britannia Aggregates Limited
Hanson Aggregates Marine Limited
Kendall Brothers (Portsmouth) Limited
Northwood (Fareham) Limited
Norwest Sand and Ballast Company 1985
South Coast Shipping Company Limited
United Marine Dredging Limited

Figure 1 The dredger "Sand Harrier" pumping marine sand and gravel onto the beach at Folkestone in Kent. The sand and gravel was dredged from the Hastings Shingle Bank licence area

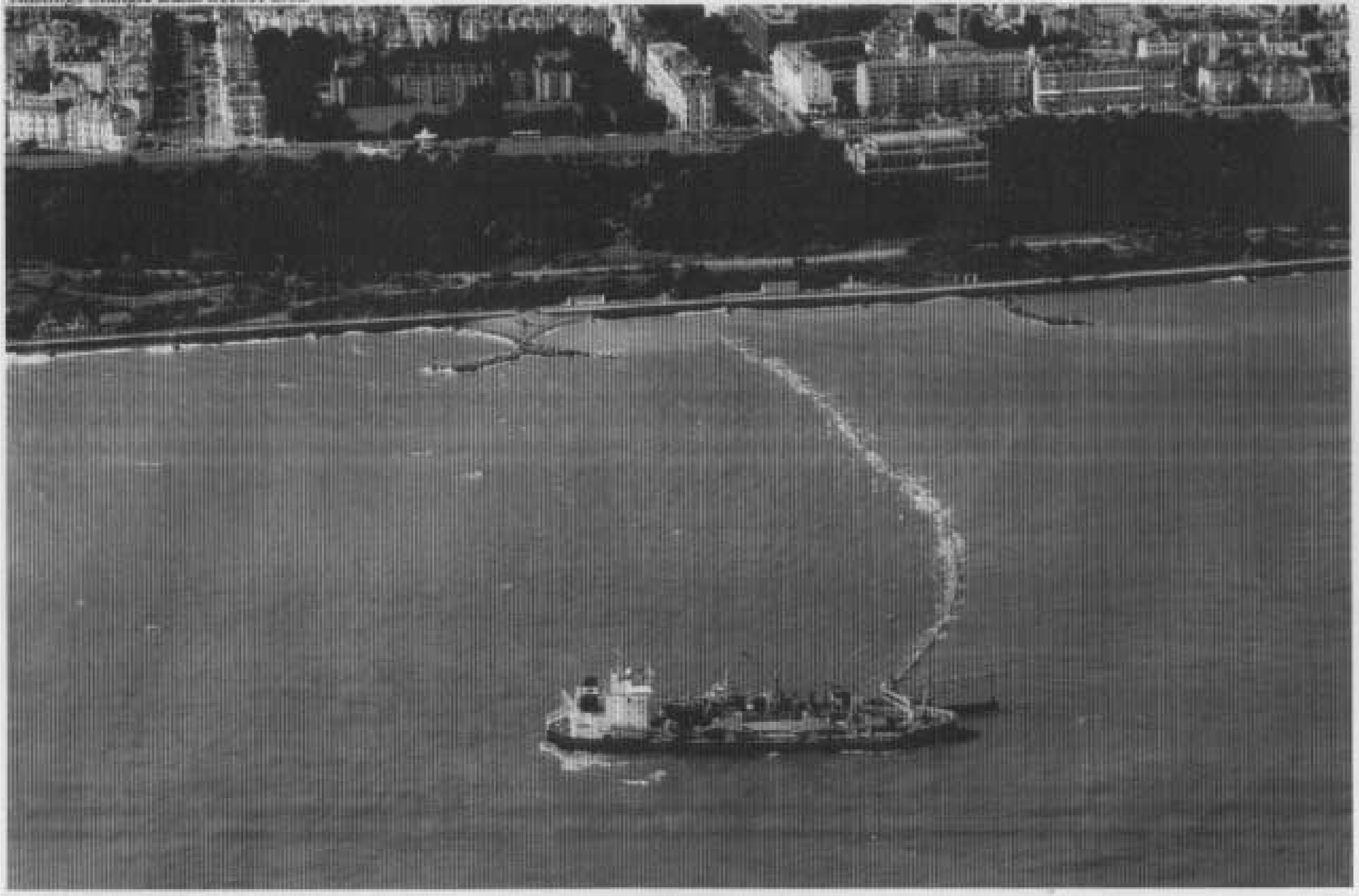
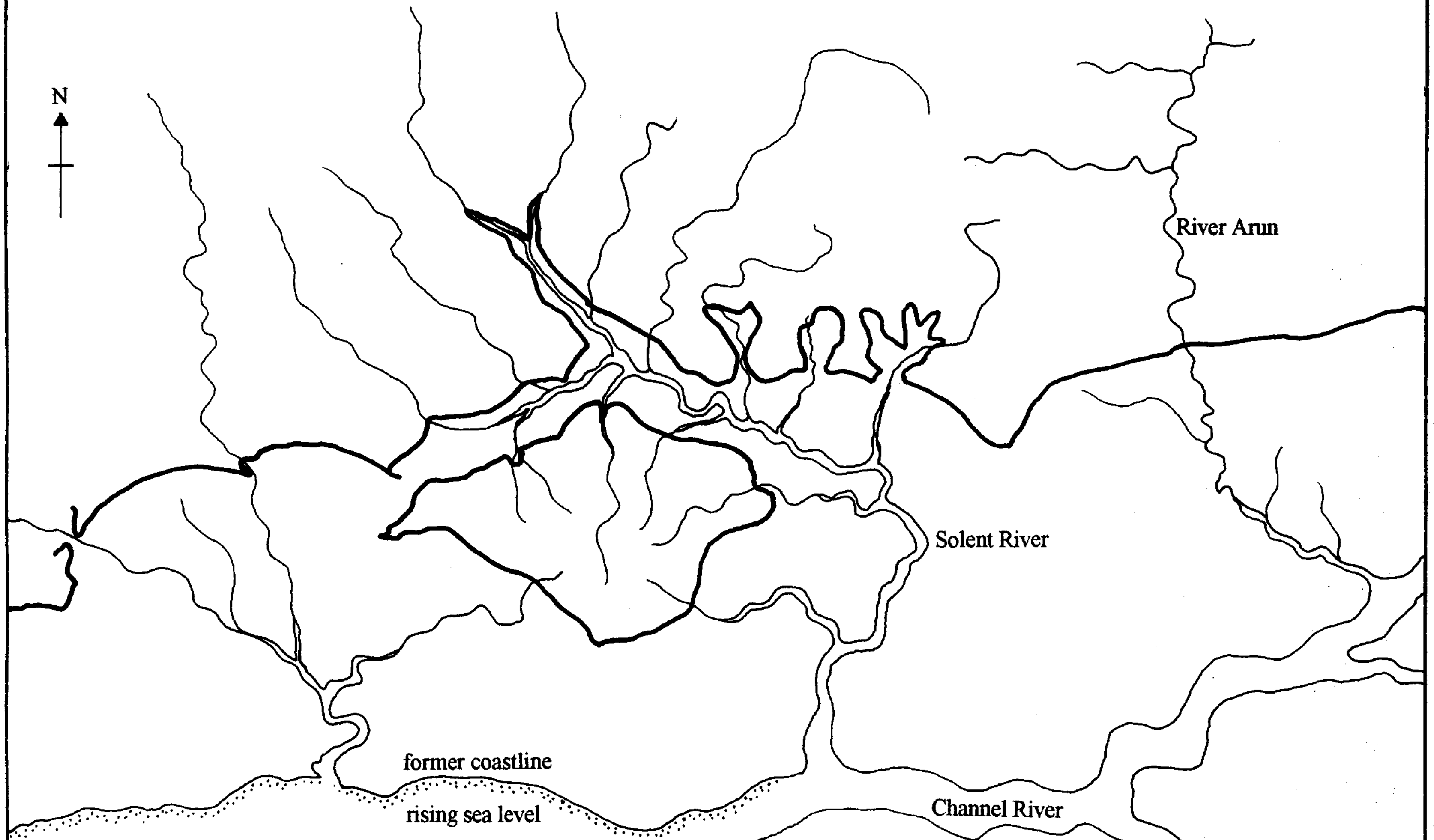


FIGURE 3. UK AGGREGATE DREDGING LICENCE AREAS

Figure 2



Hypothetical reconstruction of the rivers east and west of the Isle of Wight with sea level at about 35 m below present level at the end of the last glaciation

Assisted with reference to Velegrakis et al (1999), Bellamy (1995) and BMAPA offshore survey data

Marine sand and gravel resources are concentrated within parts of the now submerged valleys of these rivers. The Channel River was the trunk stream of the region and possibly included drainage from the ancestral Thames and Rhine catchments (Gibbard, 1988).

The present coastline is shown for reference.

Figure 4

Cross section of the sea bed from Great Yarmouth to the offshore dredging licence block

The dredging licences are seaward of the near shore banks. The deposits within the licence areas are largely relict and are unrelated to the coastline. Sediment thicknesses are approximate.