Appendix 1

Review of aggregate dredging and disposal activities in the study area

Southern North Sea Sediment Transport Study, Phase 2
Sediment Transport Report

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April 2001, updated July 2002

1. BACKGROUND

Dredging for sand and gravel[1] from the seabed off the eastern coast of England has been undertaken for many years. The origins of today's industry can be traced back to the mid-16th century when dredging in the Thames provided ballast for ships, a practice that increased to provide a significant revenue to Trinity House in the 18th century. Such dredging also served the purpose of increasing navigation depths in the vicinity of estuarine ports. Apparently, dredging for construction materials was a later development. A publication by RCHME (1996) notes that "In 1851, some 400 smacks were engaged daily in dredging stone for Portland cement off Harwich and Walton". Extraction of sand and gravel for the construction industry, mainly as aggregate for concrete, is now the main purpose of offshore dredging around the UK. Further details on the present dredging areas and extraction rates are presented below.

Other uses of dredged material include sand for general building work (e.g. mortar, plaster) and for hydraulically placed "fill" material for reclamation schemes. Since 1972, there has also been an increasing amount of sand and gravel dredged for use as beach recharge material, principally along the southern and eastern coasts of England. The two largest recharge operations so far carried out have both been on the East Anglian coast, between Mablethorpe and Skegness (Lincolnshire) and between Happisburgh and Winterton (Norfolk).

Whatever the use of the materials, large-scale offshore dredging operations inevitably have a range of effects on the seabed within and surrounding the extraction area, and on the seawater itself. The main concerns are possible effects on:

- Marine flora and fauna, particularly that living on or close to the seabed in the extraction area;
- Other legitimate users/ uses of the sea such as fishing, navigation, seabed pipelines and cables;
- Marine archaeology, e.g. the disturbance of wrecks or other historic materials on the seabed;
- Coastal geomorphological and hydrodynamic processes, e.g. on beaches and coastal defences.

Consideration of most of these concerns falls outside the scope of the present study, as does consideration of how they are assessed/ compared with other equivalent sand and gravel production methods. It is important here, however, to consider in detail the possible physical effects of offshore dredging with particular regard to how such operations might alter waves, tidal currents, sediment transport and morphological changes of the seabed and along the coast. The results from such an assessment can be used to determine the likely effect on beaches and coastal defences.

A further anthropogenic factor in the movement of seabed sediments, and changes in seabed morphology, arises as the result of the disposal of sediment dredged from ports, harbours and their approach channel. This topic is also briefly discussed in this Appendix.

2. DREDGING OFFSHORE FROM THE EAST COAST: PRESENT SITUATION

Commercial dredging off the eastern coast of England between Flamborough Head and North Kent is concentrated in three main regions. Using the nomenclature adopted by the Crown Estate, these regions are called, since 1995, the "Thames Region" (the northern part of the Outer Thames estuary), the "East Coast Region" (off Great Yarmouth) and the "Humber" Region (offshore from Lincolnshire and East

[1] Defined in the dredging industry as material with a diameter larger than 5 mm

Yorkshire). Prior to 1995, when there was much less dredging north of the coastline of north Norfolk, statistics on dredging are only available for the East Coast and Humber Regions combined. The exact position of individual extraction areas in 1999, and extent of dredging within them during that year, are both shown in a leaflet recently published by the Crown Estate and BMAPA (the British Marine Aggregate Producers Association). The part of this leaflet dealing with dredging within the present study area is reproduced as Figure 1 of this report. Since that time, there have been changes to these licensed areas, with some new areas being added and others being reduced in size or surrendered entirely (with generally a nett decrease (or no change) in the overall area licensed for dredging). More recent information on the boundaries of dredging areas is presented in Figures 49-56 of the main report, but these and any future changes do not affect the general discussion in this Appendix.

The Crown Estate also provides information on the total amounts of sand and gravel removed from the seabed around the UK. The annual amount of sand and gravel dredged from the seabed offshore from the coastline between North Foreland and Flamborough Head between 1989 and 2001 is summarised in Figure 2. The top line in this figure shows the total amount dredged from the seabed (all licensed areas) in each year between 1989 and 2001. This annual amount includes the contributions for the three "regions" described above (prior to 1994, extraction from the Humber Region was not separated from that in the "East Coast Region"). Dredging in the areas off Great Yarmouth (i.e. the so-called "East Coast Region" mainly lying seawards of the coastline between Caister Ness and Lowestoft) during 2001, for example, resulted in the extraction of over 9.6 million tonnes of sand and gravel. This region therefore contributed about 40% of the total tonnage dredged from around the UK coastline in 2001 (about 22 million tonnes in total).

The amounts removed from the seabed in the Humber Region have grown to be substantial since about 1994. The areas in the outer Thames estuary, i.e. lying offshore of the coastline between Orford Ness and the Blackwater estuary, were less heavily dredged. This region was one of the earliest used for the extraction of construction materials from the seabed but has now diminished in relative importance compared to the region off Great Yarmouth.

During the period 1989 to 2001, the tonnage dredged from the Thames Region has declined substantially. The tonnage removed from the Humber Region has increased, in no small part due to the requirements for the large beach recharge scheme in Lincolnshire.

Nationally, the amount of sand and gravel extracted from the seabed around the coastline of the UK has increased over the last 30 years. About 7-10 million tonnes were removed annually between 1965-1970, increasing to about 15 million tonnes/ year in the mid-1980's to the present levels of 20-25 million tonnes/ year. The amounts removed in any year reflect changes in demand from the construction industry, for example reducing during the downturn in the national economy (and hence in new building projects) in the early 1990's. They can also be significantly affected by large individual construction projects (for example the construction of the Cardiff Bay Barrage) or large beach recharge schemes such as those at Clacton, Mablethorpe to Skegness and Happisburgh to Winterton. For example, substantial volumes of material for beach recharge along the east coast were dredged in 1999 and 2000 (about 1.2 and 2.1M million tonnes respectively), but in 2001 there was much less, i.e. about 0.25M tonnes for continuing recharge at Skegness.

Much of the sand and gravel extracted from the "East Coast" and "Thames" Regions, as shown in Figure 2, has been delivered to wharves along the banks of the Thames estuary to serve construction projects in and around London. Similarly, material dredged from the area seaward of the mouth of the Humber has largely been delivered to quays within the Humber Estuary and along the Tyne and Tees rivers. Overall, about 30% of the aggregate dredged from UK waters in 2001 was exported to continental Europe.

Until about 1930, aggregate extraction was largely confined to the sheltered waters of estuaries, and typically carried out using cranes mounted on pontoons. More recently, dredgers have been equipped with centrifugal pumps. From about 1960 onwards, dredgers that worked "at anchor" excavating a relatively deep but localised depression in the seafloor have been replaced by "trailer suction" dredgers that excavate long, narrow and shallow "furrows" in a single pass over the seabed. This latter type of vessel was

developed for navigational dredging, e.g. removing sand that accumulates within an approach channel to a harbour, and is used throughout the world for this purpose.
A large, modern "trailer suction" dredger used in the extraction of sand and gravel from the southern North Sea can carry a cargo of up to 8,000 tonnes. If this is delivered to a wharf in the centre of a town or city on the banks of an estuary, the economic and environmental advantages of this mode of supply compared to road transport can be readily appreciated. Similar comments apply to the delivery of beach recharge material or fill material for an estuarial or coastal reclamation project.

A notable feature of the marine aggregate industry in the UK is that dredgers have been adapted to not only collect both sand and gravel, but to allow "sorting" of the material dredged. This latter adaptation involves passing the material entering the vessel over "screens" that prevent unwanted small or large diameter particles being added to the cargo. This enables a "desired" mixture of sand and gravel to be loaded and delivered by the dredger. Typical examples of the use of "screening" are:

- To reduce the percentage of sand in a cargo to obtain a 60% gravel, 40% sand to meet concreting market requirements;

- To eliminate gravel particles from a cargo of sand to meet specifications for the production of mortar, plaster or for fill for a reclamation;

- To produce a cargo of well-sorted gravel or sand to match the design specification for a beach recharge schemes.

Such "screening" capabilities are necessary from an economic viewpoint to meet market requirements. However, there is obviously a greater effect on the environment of such operations compared to direct loading of whatever material is dredged. By allowing screened material to fall back through the water to the seabed, for example, the extraction operations produce greater turbidity of the seawater. This typically results in a "turbid plume" that can persist for a few hours and be seen well beyond the limits of the actual dredging area. Where screening is used repetitively, over a long period, then the character of the sediments on the seabed within the dredging area will also change. In the southern North Sea, dredging for aggregates has often involved the use of screening, since the natural seabed sediment had a lower percentage of gravel than ideally desired for use in the production of concrete. Consequently, screening removed some of the sand, returning it to the seabed and so gradually decreasing still further the percentage of gravel in the remaining deposits of sediment. In some cases, the continued dredging of an area for aggregate becomes uneconomic because the percentage of gravel becomes too low.

It is also worth making the point that licensed dredging off the eastern coast of the UK is very largely confined to so-called "relict" deposits of sand and gravel. These were deposited in river valleys, estuaries or old coastlines that have subsequently been "drowned" by the increase in sea levels following the end of the last Ice Age (15,000 to 20,000 years ago). In many cases the gravel deposits, and the sand mixed within them, were brought to the area by glaciers or rivers draining glaciers, in the millennia before the North Sea existed. The geological context is discussed in Appendix 10 of the main report. The deposits of interest to the marine aggregate industry have been those that have not been subsequently covered by sand or mud, which would have both reduced the quality and increased the cost of extraction.

3. PHYSICAL EFFECTS OF DREDGING THE SEABED

As pointed out previously, the extraction of large quantities of sand and gravel from the seabed is likely to have a range of environmental effects, principally on the biological and physical characteristics of the sea and seabed. Before such dredging is authorised, in UK waters, a study of such effects has to be carried out, and presented in an Environmental Statement.

For the present study, the main interests are in the physical character and processes of the seabed and its sediments, and in the interaction between these and the coastline. The various studies of the physical effects of dredging the seabed, both of a fundamental research or site-specific nature, can therefore be

usefully employed to help achieve these objectives. The following section of this Appendix presents a review of general considerations when studying the physical effects of any proposed dredging. This is followed by a description of the procedures followed before such dredging is permitted, and a brief history of the specific studies undertaken of aggregate dredging within the study area.

3.1 General Considerations

The potential for dredging to have an adverse effect on a coast has been recognised for many years. A salutary example was provided by the extraction of gravel from the seabed offshore from Hallsands in Start Bay, south Devon in the 1890's. This resulted in erosion of the beaches and subsequent abandonment of the coastal village in the early 1900's. The main mechanism involved was probably "beach drawdown"; this can occur when extraction takes place so close to a beach that, during storms, the beach sediments are combed down into the dredged depression. This sediment is then not able to return to higher levels on the beach profile during subsequent calmer wave conditions, so resulting in a net loss to the beach. At Hallsands, dredging was apparently permitted up to the low water mark, so there may also have been direct extraction of gravel from the underwater part of the beach profile as well. Research into the "beach drawdown" effect was undertaken at Wallingford in the late 1960's (Amarsinghe, 1970). Generally speaking, the lowest limit of beaches is about –7m to –8m below lowest tidal level along the East Coast of England (Halcrow, 1991), while aggregate dredging rarely takes place in depths less than about 18m below lowest tidal level. Hence there is now no chance of beach drawdown occurring, although the issue is routinely addressed for each extraction application.

The depressions left by dredging can also indirectly affect a coastline, and its beaches, by altering the hydrodynamic motions of the sea both locally and further afield. The greatest danger is that the "refraction" pattern of the waves as they approach a shoreline is altered; this effect too has been demonstrated by bad experiences. Examples include the erosion of Lady Robinson's Beach, Sydney (HR Wallingford, 1972), caused by dredging for a reclamation, and both erosion and accretion of beaches on Grand Isle, Louisiana following dredging to provide beach recharge material for that same coastline (Combe & Soileau, 1987). As described later, checks are always carried out to ensure this type of effect will not alter wave heights along a coastline, or on a nearshore sandbank, as a result of offshore dredging.

Other possible effects of dredging on a coastline have also been postulated, although with apparently no clear-cut demonstrations that they have caused any noticeable effects. The most frequent concern is that dredging will affect the transport of sediment between a coast and the seabed in and around the vicinity of the extraction area. This might arise if the material extracted would otherwise have travelled to a coast, or if the depression in the seabed caused by dredging intercepted and trapped other sediments travelling through the area on route to the coast.

The above two possible problems had been recognised in the UK by about 1968. Indeed, fundamental research was being carried out in the late 1960's and early 1970's with the specific intention of improving knowledge of the mobility of seabed sediments and on possible effects of dredging on the wave refraction respectively. The first of these research projects was carried out off the coast at Worthing (South Coast UK) between September 1969 and May 1971 (Crickmore, Waters & Price, 1972). The introductory paragraph of this paper states: "The Hydraulics Research Station is often approached to assess the likely physical consequences on nearby coastlines that could arise from the commercial dredging of offshore banks of sand and shingle". (In fact, dredging of "offshore banks" was rarely considered, since the deposits were normally on flat areas of the seabed, or indeed within ancient and in-filled river valleys below the general level of the seabed.) The paper then goes on to describe the use of radioactive "tracer" particles to directly measure the movements of gravel over a period of two winters. This led to the conclusion that, at this site, there was no detectable movement of gravel at a depth of 18m below lowest tidal level.

This same paper mentions potential problems caused by changes in wave refraction following dredging, and these were being studied at Wallingford in the early 1970's using early computer models of wave transformation. This research concluded that, in south-east England, it was unlikely that dredging would have significant effects on wave refraction provided extraction was in water depths greater than 14m below

lowest tidal level (Motyka & Willis, 1974). These two research projects were used, over about the next 10 years, as a basis for assessing possible effects on a coast of offshore dredging of sand and gravel.
In addition to the above, there is sometimes a concern that dredging could lower the crest levels of a sandbank or similar seabed feature that provides shelter to a coast. This could conceivably occur either directly, i.e. by dredging on the bank itself, or indirectly by dredging too close to a bank provoking an equivalent of beach drawdown.

The dredged depression could also alter tidal currents, at least locally, with the possibility of altering natural sediment transport processes on the seabed or even along a nearby coast.

Finally, the actual process of dredging, particularly if it involves screening, will affect the sediment content of the seawater, causing increased turbidity and also affecting the natural sediment transport processes in and around the extraction area.

These various possibilities are all considered in a modern-day environmental assessment of any proposed marine aggregate dredging (see CIRIA, 1998). They are also used, in some cases, in similar assessments for other dredging or disposal operations, e.g. when deepening or maintaining depths in navigation channels.

3.2 UK Licensing Procedures for, and Policy on, Marine Aggregate Extraction

Dredging the seabed for sand and gravel will have effects on the environment, particularly on physical and biological conditions in and around the extraction site. In view of this, the UK Government has developed both a national policy for such dredging and a set of procedures to be followed before such dredging is allowed.

3.2.1 UK licensing procedures for marine aggregate extraction

Originally, because the seabed generally lies outside the limits of statutory planning legislation, decisions about any activities and development on the seabed were largely made by the landowners, normally the Crown Estate. By about 1970, however, a non-statutory equivalent to a planning process was introduced, and this has become known as the "Government View". This process has been revised periodically, and likely to become a statutory process during 2002, or shortly afterwards. In order to allow a smooth transition to this process, a set of "Interim Procedures" was introduced in 1998 and these define the way the "Government View" presently operates. The process, at present is described below.

Broadly speaking, the Crown Estate owns the seabed out to the 12-mile territorial limit, including the right to explore and exploit the natural resources of the UK Continental Shelf. Hence it has the right to issue dredging licences, and collect royalties on the basis of the amounts dredged, out to the limits of UK territorial waters. (There are some areas of the seabed, where aggregate dredging is carried out, that are not owned by the Crown Estate. These are typically within estuaries, but no such areas exist along the east coast of England.)

The Crown Estate issues licences to developers who wish to exploit marine resources. In the case of marine aggregates, two types of licences are currently required, namely a prospecting licence and a production licence.

A prospecting licence allows a developer to carry out the necessary studies (geological and geophysical) to inform an assessment of the nature of the seabed and likely sub-seabed resource. If this survey information indicates that the resource is suitable for exploitation as marine aggregate, then the developer will apply for a production licence.

The production licence allows the extraction of material from the seabed, typically sand and gravel although in the past coal has also been dredged under such a licence. At present, aggregate production licences issued by the Crown Estate typically have a duration of 10 years, and specify the maximum amount that can be dredged in any year. However, the Government View procedure now assumes that dredging will continue for up to 15 years, and is compiled on that basis. The Government View for any area is also now generally subject to a 5-yearly review.

However, the Crown Estate will only issue a production licence following receipt by the Crown Estate of a favourable "Government View" from the Minerals and Land Reclamation Division of the DTLR. Assembling the "Government View" is, in essence, a non-statutory planning procedure, used to determine an application to dredge materials from the seabed. It requires the applicants to undertake wide-ranging consultations about potential environmental impacts, and to commission an Environmental Impact Assessment (or Environmental Statement) and a Coastal Impact Study that consider these effects. The separate and specialised Coastal Impact Study is an extension to the normal requirements for a study of environmental effects, and reflects the concerns of many coastal communities about the potential effects of offshore dredging.

These study reports are widely circulated, both to statutory bodies such as local councils and the Environment Agency, other government departments and conservation organisations such as English Nature, and to other non-statutory organisations, e.g. the RSPB.

DTLR will then consider the responses from the consultees, and make a decision on the application. Often, if the Secretary of State for DTLR is "minded to approve" the application, the final favourable "Government View" will be dependent on conditions on the dredging activities. These, for example, may relate to the times of year when extraction is allowed, the methods used to extract the material and the requirements for any monitoring of the seabed and adjacent areas. Provided the applicant and the Crown Estate agree to these conditions, and they are incorporated in the agreement between those two parties, then the final favourable "Government View" will be issued, and the extraction licence granted.

The "Government View" procedure is presently carried out according to the Interim Procedures set out in 'Government View: New Arrangements for the Licensing of Minerals Dredging' published by DETR (now the DTLR) in 1998.

3.2.2 UK policy on marine aggregate extraction (Draft Marine Minerals Guidance Note 2)

The proposed 'Environmental Impact Assessment and Habitats (Extraction of Minerals by Marine Dredging) Regulations' will replace the current Interim Procedures (described above) and incorporate the requirements of both the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999 and Conservation (Natural Habitats, & C.) Regulations 1994 ("The Habitats Regulations"). Anticipating the new, statutory approach to determining applications for extraction licences, DTLR have also been revising existing policy regarding dredging for aggregate around the coastline of England and Wales.

In 2001, the Department issued a Guidance Note on the extraction of sand and gravel from the seabed. This Note, known as Marine Minerals Guidance Note 2, sets out Government policy and the proposals for the statutory regulation of marine dredging in the future.

Government recognises the important contribution marine derived aggregate makes to the UK construction industry, however, there is also a need to protect the marine environment. The concept of sustainable development has been embraced by the UK and incorporated into the aims of Government policy. The key policy aims relating to marine aggregate extraction are:

- To conserve minerals as far as possible whilst ensuring an adequate supply of newly extracted material to meet unavoidable needs.

- To ensure that the environmental impacts caused by mineral operations and the transport of minerals are kept, as far as possible, to a minimum.

- To minimise the production of waste and to encourage the efficient use of material including appropriate use of high quality materials, and to maximise the use of recycled and mineral waste materials.
- To encourage responsible working.

- To protect coastal and marine areas designated for their national or international nature conservation value, other than in exceptional circumstances and where it has been demonstrated that development is in the public interest.
- To prevent the unnecessary sterilisation of mineral resources.

The Government believes that the policy aims described above can be achieved through several measures, including:

- The careful location of new dredging areas.

- Considering new applications for Dredging Permissions in relation to the findings of an Environmental Impact Assessment.

- Minimising the overall impact of dredging by:

  Reducing the risk of cumulative impacts from multiple dredging operations and other human activities;
  Minimising the area being dredged at any one time; and
  Minimising the total area licensed for dredging.

- Controlling dredging operations through the use of legally enforceable conditions attached to Dredging Permissions.

- Requiring operators to monitor, as appropriate, the environmental impacts of their activities during, and on completion of, dredging.

The proposed statutory Regulations place great emphasis on the need for the environmental impacts of a marine dredging project to be considered as part of an EIA. This is of particular importance when identifying the location of new dredging areas. An EIA will be expected to present mitigation measures for any potential impacts and, significantly, to assess the likely cumulative impacts of dredging proposals.

The Government is promoting the concept of minimising the area affected by dredging at any one time and is encouraging the Industry to develop voluntary schemes for zoning dredging activities. The aim is to restrict the active dredging area to the smallest necessary area whilst still providing the Industry with the flexibility needed to satisfy their commercial requirements.

3.3 Review of Studies of Proposed Aggregate Dredging in the Study Area

Having described the procedures for licensing aggregate dredging from the seabed, and present Government policy on such operations, this section briefly describes the history of assessments of dredging applications for areas off the eastern coast of England between Flamborough Head, Yorkshire and North Foreland, Kent.

In order to provide this review, correspondence files and reports regarding proposed marine aggregate dredging have been examined at HR Wallingford. The correspondence files contain details of work carried out for the Crown Estate by the (then) Hydraulics Research Station from as early as 1965. Even at this time, applications were being made for significant extraction rates. These were up to 6M tonnes/year for the "cluster" of dredging areas off Great Yarmouth, and up to 0.6M tonnes/y from individual areas off the mouth of the Humber and in the Outer Thames Estuary. The earlier letters giving an opinion on the possible effects of proposed dredging were extremely short, often giving no indication of the methods used to arrive at a conclusion. This was partly due to the style of response required by the Crown Estate at that time, but prior to about 1970, the evidence suggests only a brief study was undertaken. The danger of beach drawdown, as at Hallsands, were well understood by this time, but the areas being applied for, in any event, were generally too far offshore for this to be considered a risk. One application, however, was received in 1970, for dredging close inshore, in the mouth of the Deben Estuary. It was considered that this "would undoubtedly result in erosion of the beaches immediately to the north and south". The reply to

the Crown Estate went on to recommended that only the minimum amount of material be removed as necessary to improve navigation.

By the early 1970's, the correspondence shows that more detailed consideration was by then being given to applications. This followed the fundamental research carried out in the late 1960's and early 1970's described previously, which provided rather general guidelines on the likelihood of seabed sediment mobility and changes in wave refraction patterns. An example of the use of these guidelines is provided by a letter, written in 1973 to the Crown Estate, regarding proposed dredging seawards of Spurn Head. This stated that it was unlikely that there would be any problem resulting from changes in wave refraction. However, HRS was concerned that dredging might affect sediment transport on the seabed, and perhaps a supply of sand/ gravel to the coast.

At about this time, concerns from coastal authorities regarding offshore dredging were beginning to feature in the correspondence between the Crown Estate and HRS. For example, in 1975, a HRS letter regarding dredging offshore from Spurn Head "supported the view of the East Lincolnshire Joint Advisory Committee given in 1972 on the restriction of the licence period". This suggested restriction was to 10 years rather than the then more usual indefinite period for such licences. Further south, the Anglian Water Authority were also becoming concerned about the effects of dredging. In 1975, they asked HRS to comment on offshore dredging proposed by Harwich Harbour Board for a reclamation scheme in Bathside Bay. In the following year, AWA wrote of their concerns about the "generally scant information with which to form our opinions when dealing with proposed dredging licences".

Undoubtedly, this latter concern arose principally because there was very little information available to such authorities, let alone the public, that explained the methods used and the conclusions reached when the physical effects of a proposed dredging licence were assessed. Indeed such studies, and their conclusions were still being summarised in a single brief letter, often of less that one page in length. This very brief form of reporting continued until the early to mid 1980's, although for some extraction applications, the standards of the studies of possible physical effects continued to improve. For example, in 1976, site-specific modelling of wave refraction was carried out to assess proposed dredging in Area 294 off Great Yarmouth, although this was about 13km offshore and in water depths of about 25m.

By this time, information was also being passed to HRS on the sediments on and below the sea floor, and sometimes on indications of sediment transport, from the dredging companies own "prospecting surveys". This provided a more detailed basis on which to predict the likely changes in the water depths resulting from dredging. Previously, a uniform increase in water depth was assumed, based on the surface area of the application area and the quantity of sediment that might be removed.

In the early 1980's, the marine aggregate industry was becoming interested in new extraction areas in the Shipway channel, off the Suffolk coast. These areas lie to the landwards of the 18m contour, and therefore were not considered acceptable using the simple guideline on sediment mobility derived from the experiments off Worthing. This resulted in a new research project, funded by the Department of the Environment with some financial support from the dredging industry. Two main aspects of hypothetical dredging in the Shipway channel were considered, namely an experimental study into the mobility of seabed sediments (both sand and gravel) and the consequences of reducing the height of offshore banks. These two aspects of the research were reported separately (HR Wallingford 1984 and 1983 respectively). The first of these reports is particularly relevant to the present study of seabed sediment transport in the southern North Sea. As at Worthing, direct long-term measurements of the movement of sediment particles were made using radioactive tracers. The experiment lasted for one year, (mid August 1982 to mid-August 1983) and three different sizes of tracer sediments were used, representing gravel, coarse sand and fine sand. In brief, neither the gravel nor the coarse sand moved. The fine sand dispersed parallel to the axis of the Shipway channel (and to the direction of the tidal flows) but with no evidence of a "bulk displacement" in any direction. This experiment off the coast of East Anglia coastline therefore supported, perhaps strengthened, the conclusions reached during the earlier experiments off Worthing.
Following privatisation of the Hydraulics Research Station in 1982, the new company continued to act as advisor to the Department of the Environment on the effects on the coast of offshore dredging. However, studies now had to be carried out on a commercial basis, rather than as a duty of the Station, a part of that

Department. Until very recently, all such work was commissioned by the Crown Estate on behalf of the dredging company making the application. With the exception of applications for Scottish waters, this arrangement has now been replaced by the applicants commissioning studies directly (not necessarily by HR Wallingford). At about the same time, i.e. in the mid 1980's, there was a significant change in the general approach taken by the Crown Estate in making information available about offshore dredging. This resulted in the assessments of proposed dredging areas being explained in more detail, with the production of bound reports on each application. These were submitted to the Department of the Environment as part of the non-statutory planning process known as the Government View procedure (see CIRIA, 1998 for more details).

On checking through the Library at Wallingford, it appears that the first report (as opposed to a confidential letter to the Crown Estate) on proposed dredging off the eastern coast of England was produced in 1986. This was produced in connection with an application to dredge sediment for a beach recharge at Clacton. The next appeared in 1990, reflecting a lull in applications for new areas. Since that time, there have been 27 further reports on the possible effects on the coast of proposed dredging, mainly for aggregate. Four reports, however, deal with proposed dredging concerning the recharge scheme for the beaches between Mablethorpe and Skegness.

Initially, these more detailed reports were only given limited distribution by the Crown Estate, but in recent years, this situation has changed. Under the latest arrangements for the Government View, a dredging licence application has to be accompanied by both an Environmental Statement/ Assessment and a "Coastal Impact Study" and both documents are widely distributed.

The scientific standard of the studies assessing the possible physical effects of dredging has also improved significantly over the last 10 years. Of particular relevance to the present study are the reports concerning extraction of sand for recharging beaches in Lincolnshire. The National Rivers Authority applied for such an extraction licence, seeking to secure the supply of sand for a considerable period into the future. The desired material was sand, rather than the mixture of sand and gravel typically sought by the marine aggregate producers. Thus, the natural mobility and transport of sediment within the proposed extraction areas was a greater concern than for most dredging areas. To address this concern, the relevant "Coastal Impact Studies" were carried out jointly by HR Wallingford and the Coastal Geology Group of BGS, at Keyworth, Notts. In these reports, both a "geophysical" approach and numerical modelling were used to assess the likely consequences on the sediment transport of the proposed dredging. The information collated in, and the results of, these studies provided the best understanding thus far on the seabed sediment mobility in this area of the North Sea and will also be incorporated into the present study at a later stage.

Concerns have also been expressed by local authorities in recent years about the "cumulative effects" of dredging in multiple areas. This point had been made to the Crown Estate by HRS as early as 1973, and resulted years later in new licences being assessed in combination with those already in existence. In 1994, for example, two "Coastal Impact Study" reports were produced concerning further dredging areas in the Great Yarmouth "block" (HR Wallingford, 1995 and HR Wallingford, 1996). Both these studies considered cumulative effects of dredging in both new areas and continued dredging in all existing licensed areas, independent of the current applicant, offshore from the coast between Lowestoft and Caister Ness. Together, these reports can be considered as providing a retrospective assessment of the existing dredging areas to much higher standards than used when those areas were first applied for (some prior to the involvement of HRS from about 1965).

Similar "cumulative effects" studies have subsequently been carried out for proposed new and the existing licensed areas off the Lincolnshire/ Humber mouth coastline, (HR Wallingford, 1999a and 1999b) and similarly for proposed new and existing areas in the Outer Thames estuary region (HR Wallingford, 1999c). These areas are shown in Figure 3.

Because of this, therefore, it is true to say that the physical effects of virtually all of the existing offshore dredging areas in the study area have been investigated in the last 10 years, together with a number of proposed new extraction areas. The recent "Coastal Impact Study" reports provide a considerable amount

of information relevant to the mobility and transport of sediments in the southern North Sea as well as directly addressing concerns about the interactions between dredging and the coastline.

Finally, since about 1990, reports on the physical effects of aggregate dredging have usually made the recommendation that, if extraction is allowed, then monitoring of seabed levels in and around the extraction area should be carried out. Given that few new licences have been granted since 1996, and that even when a licence is issued then dredging may not start immediately, the information from such monitoring is only just beginning to accumulate. In due course, however, the information obtained will be useful in not only checking that existing dredging is not causing unexpected effects, but also in improving assessments of possible future extraction.

3.4 Reviews of the Effects on the Coastline of Licensed Aggregate Dredging

The aim of the existing process of assessing the environmental effects of dredging before it is licensed is to ensure that environmental effects are minimised in general, and that effects on the coastline, in particular, are insignificant. Because of this, and given the very conservative methods used to predict effects on the coastline when an application is considered, it is not surprising that no convincing evidence of any changes along the coastline following such extraction has been presented. Nevertheless, since much of the coastline of eastern England continues to erode, and aggregate dredging also takes place, there are still some individuals and organisations that link the two processes and claim a "cause and effect" relationship.

Because of these and other concerns, it is now standard practice to require dredging companies to carry out monitoring of their activities. For all recent extraction licences (i.e. those issued in the last 10 years or so) there is a requirement for:

1. The dredgers to be equipped with a "black box" recorder (Electronic Monitoring System) that records the position and activities of the dredger. The information from this system is returned to the Crown Estate who check that the dredging is taking place in the agreed area (and at the correct times of year in some circumstances). It is this data that allows the production of the very detailed information shown in Figure 1, showing where, and for how long, dredging operations have taken place;
2. The licence holders also undertakes regular (usually annual) bathymetric surveys of the seabed in and around the dredging area, at an agreed maximum spacing of survey lines. These and other surveys (see paragraph 3 below) are undertaken at the licence holder's expense by an independent surveying company, acceptable to all parties;
3. In addition, extra monitoring conditions are imposed on some licences, requiring, for example, surveys of the seabed sediments, benthic flora and fauna or side-scan sonar recording of the seabed. Such extra monitoring requirements are normally carried out after the extraction of a specified amount of aggregate, rather than at fixed time intervals;
4. As well as surveys carried out on behalf of the licence holders, some independent research projects investigating the effects of dredging have also been carried out. So far these have largely been related to the biological consequences of dredging, i.e. on recovery and re-colonisation rates of dredged areas, and on the effects of such dredging on adjacent areas of the seabed. Such studies have been commissioned both by the Crown Estate, and by DEFRA, and are often carried out by CEFAS, based in Burnham-on-Crouch and Lowestoft;
5. Finally, it is not uncommon for dredging companies to carry out, on a voluntary basis, their own surveys of the seabed. This is partly to manage the "resource", i.e. the remaining deposits of sand and gravel, partly to provide potential evidence for use in future studies, for example if they wish to apply for further dredging in the same or nearby areas. Such monitoring results, however, are normally commercially confidential and will not therefore necessary be available to other organisations.

Where monitoring surveys are required as a condition of the licence (reflecting the Government View) then the results are in the public domain. Copies of the surveys are sent to the Crown Estate, DTLR, DEFRA, English Nature and, for some areas, to the MOD (Hydrographic Office) and the Environment

Agency. Research reports, for example carried out by CEFAS on behalf of DEFRA, are also in the public domain.

It is sometimes a requirement of an extraction licence, however, for the licence holders to carry out or commission an independent review or interpretation of the survey results. It is possible that this will become a responsibility of DTLR when the present "government View" procedure is replaced by a statutory system. At present, therefore, there is not normally any routine interpretation or research into the results of the annual bathymetric surveys, for example.

However, from time to time, this survey information is reviewed, for example when new dredging licence applications are being considered in, or close to areas that have already been dredged. At present, a Coastal Impact Study for an extension of an existing licence for Area 254, off Great Yarmouth, is being prepared (for UMD Ltd.). As part of this study, UMD have made available two surveys of this area approximately ten years apart; analysis of the changes in bed levels in and around this area have shown that the total change in volumes of seabed sediments equates remarkably closely to the amount of sediment dredged. In addition, there is no evidence of bed changes outside the dredged area. This therefore indicates that there has been no infilling of the dredged depression, for example by sand, and that the changes to waves and tidal currents have not affected even the seabed immediately adjacent to the licensed area. Such observations lend weight to at least the conclusions of Coastal Impact Studies that dredging will not affect sediment transport over the seabed (or cause beach drawdown).

Further to this particular study, there has also been a more general review of dredging of Great Yarmouth carried out by the University of Southampton (Gao, Ke & Collins, 1993). This was largely based on an analysis of Admiralty charts and previous study reports. It concluded that the changes in bed levels in and around the dredging areas were not distinguishable from natural variations in level, and hence the dredging up to that time was not likely to have cause any adverse effects on the coast.

The review and analysis of surveys of the seabed that are carried out to fulfil one of the conditions under which a licence is issued may be an interesting area for further (academic) research.

This information may shed light into numerous aspects of seabed and coastal sediment processes, and any connections between the two. The research might complement similar research into the effects of dredging on the biological environment of the seabed, for example as undertaken by CEFAS.

4. DISPOSAL OF DREDGED MATERIAL IN THE SOUTHERN NORTH SEA

Material dredged from port approaches is dumped at various licensed sites within the Study Area. A review of the DEFRA RMED data base on returns for licensed disposal sites provides information relating to disposal activities. Disposal of capital and maintenance dredged material occurs at the sites listed in Table 1. This indicates the tonnage of material dumped and the variation in this quantity.

From this table it can be seen that main input of dredged material into the study area occurs as a result of the maintenance dredging at Felixstowe. Here approximately $2Mm^3$ of muddy material is taken from the mouth of the Stour and Orwell estuaries and placed offshore each year (equivalent to 2.8M tonnes). Within the study area the next largest regular maintenance disposal operation is at Lowestoft where about 120,000 tonnes of material are placed. This material is a mixture of muds and fine sands.

Very large quantities of material (up to $10Mm^3$) have been annually dredged in the Humber but all of this material is returned back into the estuary and therefore is outside of the study area.

Disposal of material arising from capital dredging occurs at many of the sites and contributes to year on year variability.

At present there is no disposal site near Harwich for the disposal of capital material. This follows the filling and capping of the Roughs Tower site during the 1999 completion of the Harwich Channel dredge.

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Table 1 Tonnages of capital and maintenance dredged material disposed to licensed sites in the study area. Source DEFRA database

Disposal Site Name	Site Code	Average Tonnage (1986 to 1999)	Range of Tonnage	Comment
Dover	DV010	490,000	Min 80,000 (1993) Max 1,300,000 (1991)	Capital + Maintenance
Pegwell Bay	TH140	120,000	Min 30,000 (1994) Max 220,000 (1991)	Capital + Maintenance
Port Ramsgate	TH145	10,000	Min 0 Max 60,000 (1997)	Maintenance only (Turning Basin)
Whitstable	TH073	5,000	Min 0 Max 12,000 (1995)	
South Falls	TH070	80,000	Min 0 Max 240,000 (1993)	
Inner Gabbard	TH052	2,750,000	Max 2,750,000 (1999)	Used 1999 only Maintenance only
Roughs Tower (Harwich)	TH038-45	2,880,000	Min 730,000 (1991) Max 10,000,000 (1999)*	Closed 2000 * Estimate of capital dredge by HRW
Lowestoft	HU160	120,000	Min 0 Max 245,000 (1992)	
Great Yarmouth	HU150	31,000	Min 0 Max 72,000 (1996)	
Breast Sand East	HU141	70,000	Min 25,000 (1995) Max 100,000 (1997)	Maintenance only
Breast Sand	HU140	70,000	Min 0 Max 125,000 (1987)	Capital + Maintenance
New Lynn Knock	HU125	1,000	Min 0 Max 1,000 (1990)	Used 1990 only Maintenance only

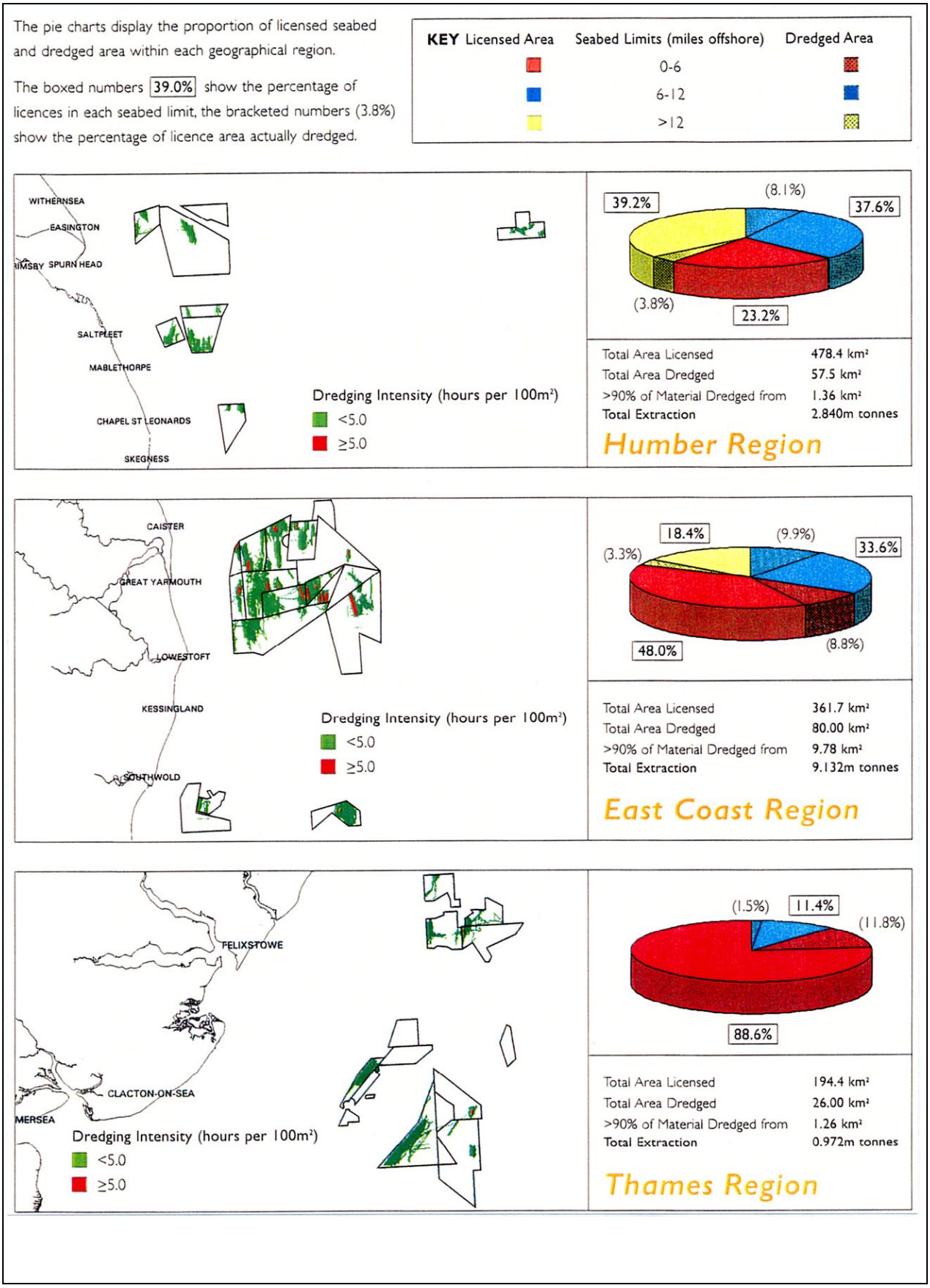

Figure 1 **Map showing dredging activity on the East Coast of England in 1999 (reproduced by kind permission of Crown Estate and BMAPA)**

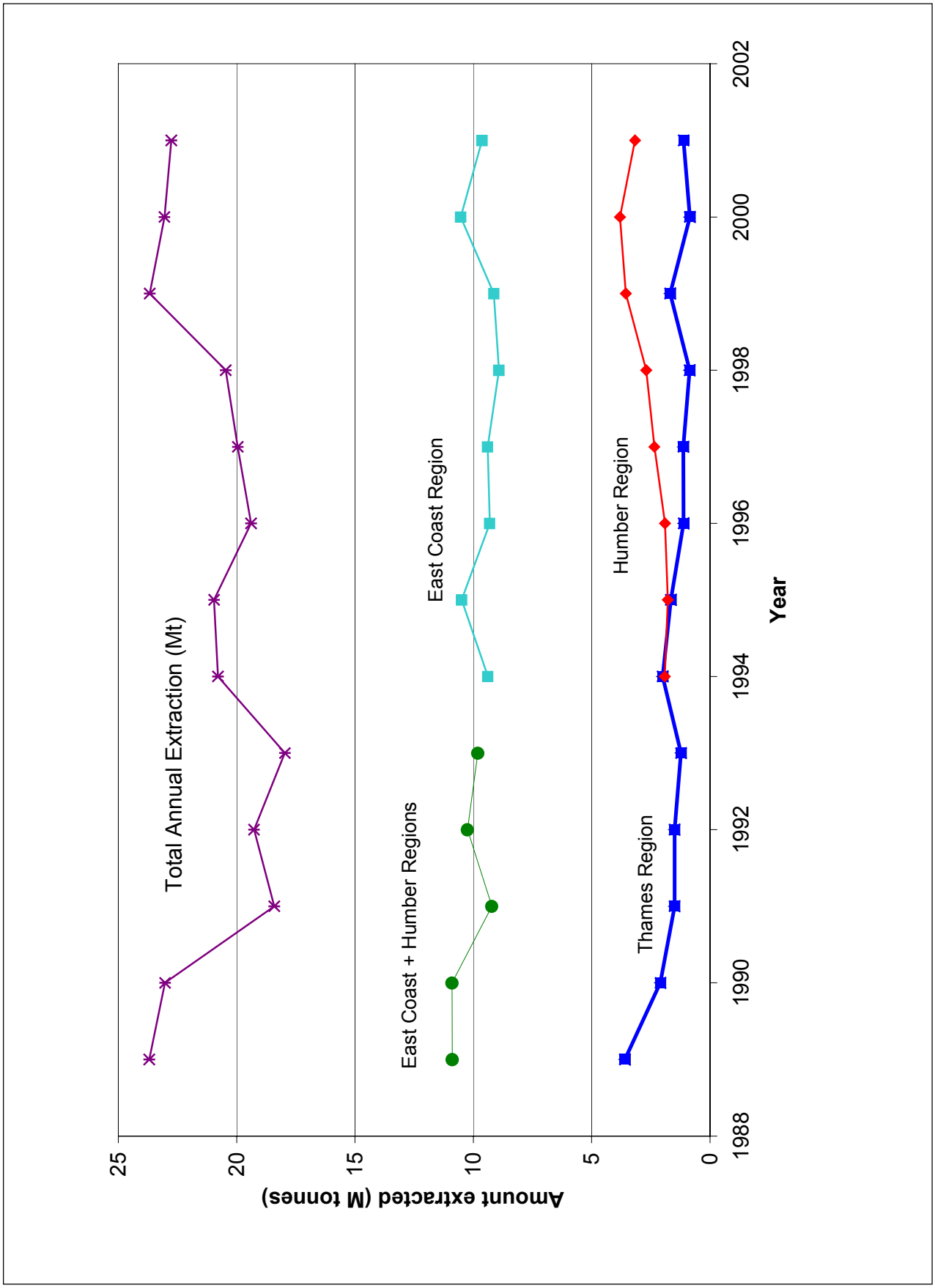

Figure 2 **Amounts dredged off eastern coast of England (1989 - 2001) compared with total annual extraction in the same period, from Crown Estates database**

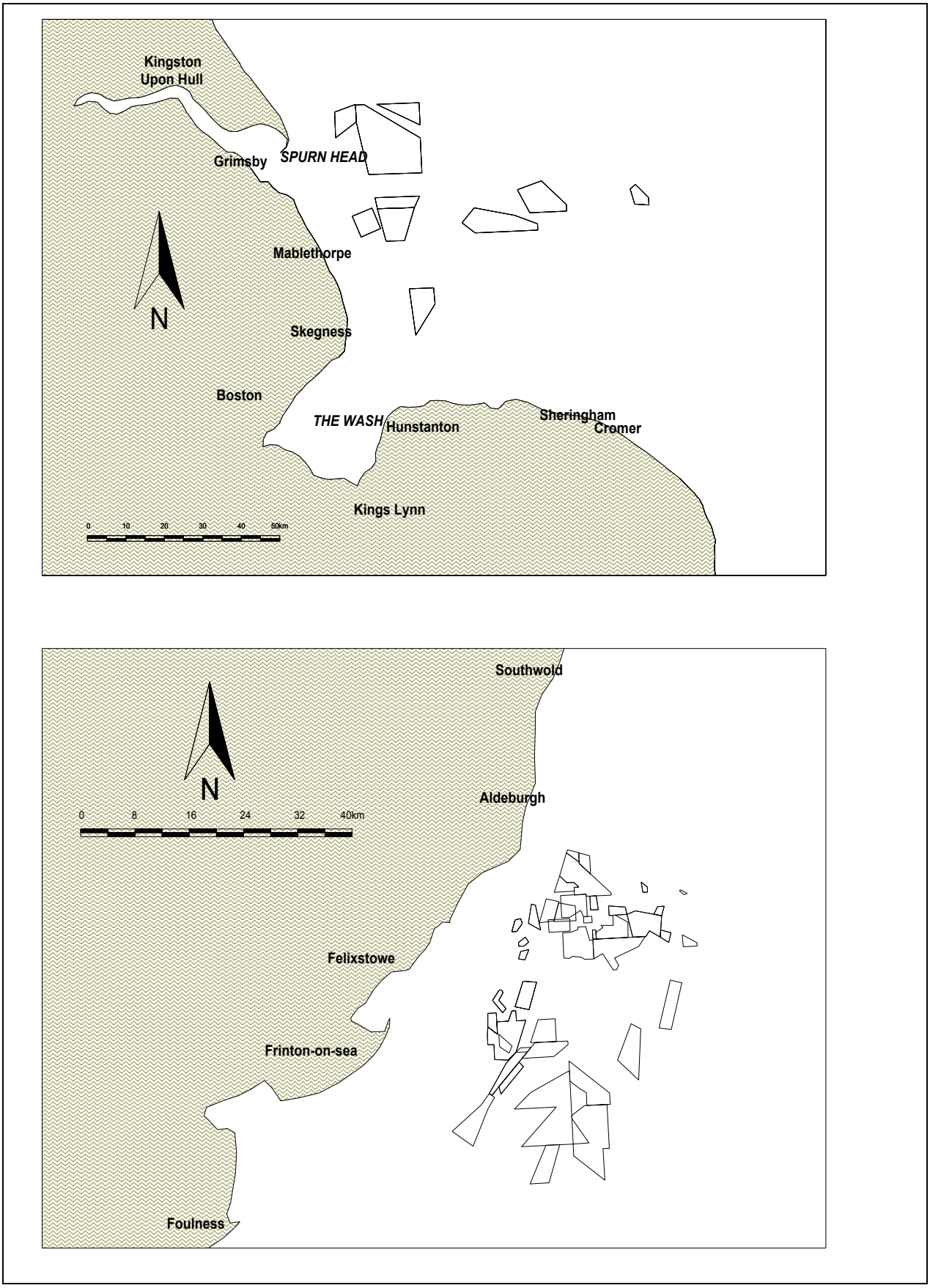

Figure 3 Maps showing the areas considered by HR Wallingford in recent "cumulative effects" studies for proposed new and existing aggregate dredging licences (see Section 3)