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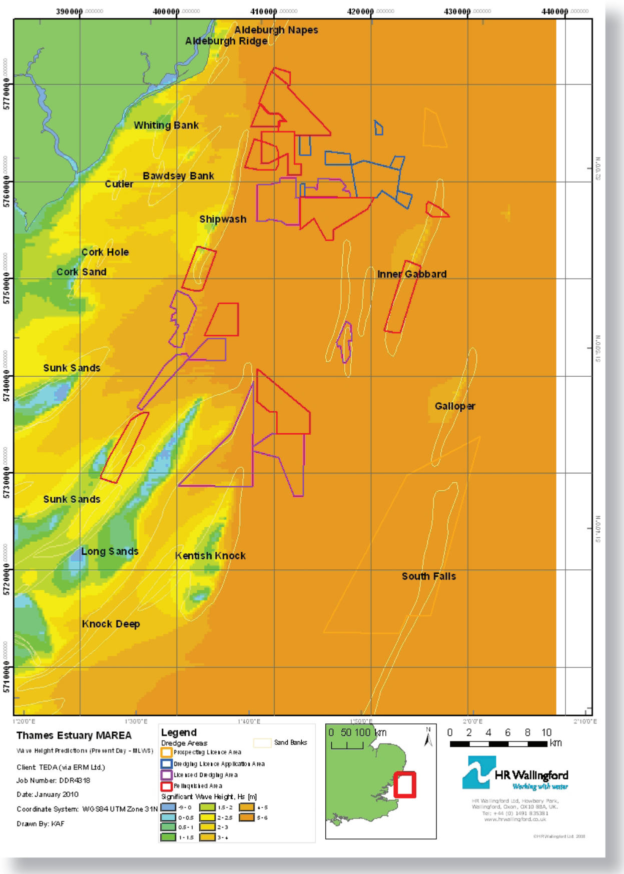
Thames Estuary Dredging Association

MAREA: Summary Report



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Summary

Thames Estuary Dredging Association

MAREA: Summary Report

Report EX6213
April 2010

This report summarises a number of related investigations into the effects of aggregate dredging on the physical environment of the outer Thames Estuary. These studies were carried out for the Thames Estuary Dredging Association (TEDA) and formed part of a wider-ranging Marine Aggregate Regional Environmental Assessment (MAREA) being managed by ERM Ltd. This overall assessment was designed to help answer a fundamental question relating to offshore aggregate dredging (Cefas, 2008), namely:

"Should existing dredging continue and new areas be dredged within the REA area?"

The important aspects of the physical environment considered in this project were the hydrodynamic regime of the region, i.e. tidal and wave conditions, the movements of sediment and the morphology of the coastline and the seabed.

The five studies summarised in this report were:

(1) a review of past reports and of available data characterising the physical environment of the region;
(2) a characterisation of the coastline of the region, identifying its sediment transport regime, coastal defences and management and its connections with the nearshore seabed;
(3) a preliminary assessment of the dispersal of turbid plumes and of the transport of fine-grained sand created during dredging operations;
(4) a regional assessment of changes in waves conditions as a result of seabed lowering within the dredging areas, and finally;
(5) a similar regional assessment of the effects of that seabed lowering on tidal flows and associated sediment transport.

The potential effects of dredging were estimated using a deliberately conservative approach that maximised the predicted spatial extents and magnitudes of possible changes to the physical environment. As a result, where these broad-scale assessments indicate no changes are likely, then it is safe to assume that in reality there will be no noticeable effects on the environment.

As a general observation, where these assessments did predict substantial changes, i.e. larger than the expected margins of inaccuracy in the modelling, these only occurred within and just outside the dredging areas themselves. As a simple rule of thumb based on this modelling carried out in this study, any physical changes caused by aggregate dredging that are large enough to have a pontetially significant effect on the environment have generally been predicted not to extend further from the boundary of any dredged area than the maximum dimension of that area. Since the dredging areas within this study region lie further offshore than their maximum dimension, it was consistent with this rule of thumb that neither past nor future dredging was predicted to have any effect on the coastline of the study region.

Summary continued

Where some noticeable change in the physical environment is predicted, then its broader environmental significance will generally need to be assessed in more detail, bearing in mind the sensitivities of the features of interest to that change. In many cases, the results of this regional assessment both provide a context for site-specific (EIAs) for individual dredging licence applications within the study region, and a preliminary indication of the spatial extent and the magnitude of changes that aggregate dredging may cause.

Contents

Contents continued

Appendices

1. Introduction

1.1 BACKGROUND TO STUDIES

In south-eastern England, sand and gravel dredged from the offshore seabed makes an important contribution to the aggregate needs of the construction industry. It has also been used in recharge schemes to improve beaches in Kent, Essex and Suffolk. There are numerous licensed dredging areas lying offshore of the coastline between North Foreland, Kent and Dunwich, Suffolk and these are shown, together with the boundary of the region considered in this report, in the Inset in Figure 1.

Extraction from each individual seabed area is licensed by the Crown Estate, but only after permission for such dredging is obtained from the Government. Such permissions are considered, in England, under the Environmental Impact Assessment and Natural Habitats (Extraction of Minerals by Marine Dredging) (England and Northern Ireland) Regulations 2007, which transposed into English law the requirements of the EIA Directive (Directive 85/337/EEC) and Habitats Directive (Directive 92/43/EEC) relating to marine aggregate dredging. In England, these regulations are supported by two policy guidance notes, namely Marine Mineral Guidance Notes 1 and 2 (CLG, 2002 and MFA, 2008). These set out the Government’s policies on the extraction of marine aggregates to ensure that dredging is consistent with sustainable development and explain the statutory procedures for the controls of such dredging activities. Obtaining permission for aggregate dredging almost always requires a full, formal assessment of the effects on the environment of those operations.

It has long been recognised that, in carrying out such environmental assessments, it is important to consider the cumulative effects of multiple aggregate dredging operations. To carry out this important but challenging task, it is not only necessary to consider the incremental effects of extraction from a single area over the duration of several licence periods, but also the possible additional effects caused by dredging in several areas in the same region of seabed. Regional Environmental Assessments help to meet these needs, and a framework for carrying out such assessments in the context of marine mineral extraction has been published by Cefas (2008).

1.2 SCOPE OF STUDIES CARRIED OUT

This report summarises a number of studies carried out by HR Wallingford that investigate the effects of aggregate dredging on the physical environment of the large study region (see Figure 1) that extends over and well offshore from the Outer Thames Estuary.

The studies described in this report contribute to a Marine Aggregate Regional Environmental Assessment (MAREA) being carried out for the Thames Estuary Dredging Association (TEDA), and being managed by ERM Ltd. TEDA comprises aggregate dredging companies working in this region, namely Britannia Aggregates Ltd, CEMEX UK Marine Ltd, Hanson Aggregates Marine Ltd, United Marine Dredging Ltd and Volker Dredging Ltd, and represents all the companies with marine aggregate licence interests in the study region.

The principal questions to be addressed within this MAREA are defined by Cefas (2008) and are:

"Should existing dredging continue and new areas be dredged within the REA areas? (i.e. are the current levels of dredging activity environmentally acceptable and if so can they be increased without causing significant environmental impact?)"

The extraction of large volumes of sand and gravel will inevitably disturb the environment locally, and will usually result in a permanent lowering of the seabed. These effects on the physical environment have the potential to affect other environmental aspects, for example marine plants and animals, man-made structures such as pipelines or wind-turbines and the historic environment including prehistoric geomorphological features and wrecks. Effects of dredging on the physical environment can therefore influence other aspects of the overall MAREA.

The studies described in this report consider the hydrodynamic, sediment transport and morphodynamic regimes of the study region, including its coastline, and assess any changes in these caused by past and/ or future aggregate dredging. Throughout these studies, a deliberately conservative approach has been adopted, to err on the side of caution and hence to over-estimate the spatial extent and magnitude of changes to the natural physical environment.

2. *Preliminary studies*

Within this project, two initial pieces of work were carried out to set the context and prepare for the computational modelling used to predict and assess the changes that have been, or may in the future be caused by aggregate dredging. These are described next.

2.1 REVIEW OF DATA AND PREVIOUS REPORTS

The first study was mainly a review of the available data on the hydrodynamic regime, i.e. on tidal levels, currents and waves, and on the bathymetry of the study region. This review concentrated on measurements of these parameters, which could be useful in the later studies reported here, for example to calibrate the numerical models that were used to predict the effects of marine aggregate dredging on the physical environment of the study region. In addition, this review identified measurements that might prove valuable in future, more detailed studies that might be needed in connection with applications for individual dredging areas. As well as identifying useful measurements of the physical environment of the region, this review also included a summary of past reports that might prove useful in the MAREA, for example those dealing with aggregate dredging and its effects, and presented information on computational models of the hydrodynamic region of the region. This preliminary work was reported in an interim report (Technical Note DDR4318-01) which also made recommendations for carrying out the further studies described later in this summary report. This review also contained tables with an extensive listing of metadata summarising the available measurements of waves and tides in the region. For convenience, a selection of the information contained in this interim report is provided in Appendix 1 of this report.

2.2 COASTAL CHARACTERISATION

The second preliminary element of the overall study program was a review of the coastlines of the study region, and this is included as Appendix 2 to this report. It has long been recognised that adverse changes to the coast arising from marine aggregate dredging would be unacceptable, so the assessment of potential physical effects on coastlines forms a key part of the Environmental Impact Assessment of marine aggregate dredging proposals. Marine Mineral Guidance 1 (CLG, 2002) requires that a Coastal Impact Study (CIS) is always carried out to comprehensively assess the possible coastal effects of dredging applications by considering potential changes in waves, currents and sediment transport. As well as reviewing previous CIS reports, therefore, an up-to-date assessment of the shoreline of the study region was undertaken, with the main objective of informing future EIAs of likely sensitivities at the coast. This assessment was largely based on existing sources of information such as Shoreline Management Plans, FutureCoast (Halcrow 2004), Coastal Impact Assessments for previous aggregate extraction applications, and coastal defence strategy studies. This desk review was been supplemented by dedicated site visits by an experienced engineer.

The review provides a summary of the main physical characteristics of each stretch of the coastline including a description of its geomorphology, of its past and present management, e.g. its coastal defences, and of the main issues of concern or vulnerabilities.

Particular attention was paid to information on the movements of sediment both parallel to the coast (longshore transport) and perpendicular to it (cross-shore transport), the latter helping to identify any evidence for onshore transport to the coast from the seabed or vice versa. This part of the study also included analysis of cross-sectional surveys to determine the offshore limit of the beaches, i.e. the water depth where the mobile beach sediments met the nearly-horizontal shore platform. This analysis demonstrated that, along many frontages, beaches do not extend down more than a few metres below lowest tidal levels, and nowhere to the depths at which aggregate dredging is carried out. Typical results from the comparison of beach cross-sectional surveys, to a distance of 500m offshore, are presented in Figures 2 and 3.

The main outputs from this study were a series of maps that characterised the main characteristics and sensitivities of the coastlines of the region, and these are intended to provide information both for other parts of the current MAREA and for later EIA studies carried out for individual dredging licence applications.

These maps were produced in a GIS (Geographic Information System) and the files were provided to ERM Ltd to use within their overall assessment of the effects of aggregate dredging on the environment.

3. *Computational modelling studies*

3.1 REGIONAL MODELLING AIMS

As stated above, the principal purpose of this project was to assess the changes that have been, or may in future be caused by marine aggregate dredging to the hydrodynamic, sediment transport and morphodynamic regimes of the study region. The presence of numerous dredging areas within the study region, and the need to consider the cumulative effects of past and proposed future dredging in all of these, means that it is both necessary and appropriate to use computational modelling methods to produce a regional overview of the changes caused by aggregate dredging.

The broad-scale modelling and assessments carried out during this project are intended, first of all, to predict the spatial extent of any noticeable changes in the physical environment around each dredging area, or around a cluster of such areas. These zones of possible change are different in shape and extent depending on the particular topic being considered, for example waves or tidal currents. If some particular feature of interest, whether natural or man-made, lies outside these zones, then it can reasonably be concluded from this regional study that there is no need to further investigate any changes to that feature when carrying out an Environmental Impact Assessment (EIA) for the licence application for any individual dredging area. However, if this study indicates that dredging in one or more areas may affect the physical environment in the vicinity of that feature, then this may well need further study at an appropriate time in the future. In this situation, therefore, the results of this regional assessment, both provide a context for site-specific (EIAs) within the relevant study region and help to identify site-specific issues which such EIAs may need to focus on more specifically (see Cefas, 2008).

3.2 INTERPRETATION OF REGIONAL MODELLING RESULTS

We emphasize that care needs to be taken in interpreting the results from any of the three modelling studies presented below, particularly when using these in assessing the significance of changes to the environment. Some of the environmental changes caused by dredging can be quantified with a good degree of confidence and expressed in numerical terms, for example the change in the peak tidal current speed at some location within or close to a dredging area. The results from such models can be quoted to very high precision, i.e. too many significant figures, but this precision should not be confused with the accuracy of the calculations. As an example, numerical modelling of changes in wave conditions as a result of dredging produces estimates of changes in significant wave height that are probably only accurate to ±5% in many cases. In this situation, it is unlikely that a predicted change in wave height of less than 2% could be reasonably regarded as being significantly different to zero, i.e. to there being no change at all. Such a small change could reasonably be concluded as most unlikely to have any significant environmental effect.

If, however, there are locations where the magnitude of predicted changes in wave conditions is larger, for example greater than ±10%, then there is clearly a possibility that this is likely to be a genuine change. This in turn might affect some aspects of the environment that are of interest (i.e. receptors). However, there cannot be a general rule that links the magnitude of such changes to their environmental significance. Take for example the situation where, at some point close inshore, the post-dredging wave height might be predicted to increase by 20% during exceptionally severe wave conditions following seabed lowering by aggregate dredging.

This “headline” figure may well cause alarm, for example to those concerned about the capacity of coastal defences to prevent flooding in such severe events. However, the effect of this predicted change may be totally insignificant in this context, for example because the tidal level assumed in the modelling is very low or because the change in wave height is only from 50mm to 60mm. In this same vein, the effects on beaches of what is a large change in wave height may be insignificant because the duration and frequency of such an event is small, so that it will not alter the net annual longshore drift rate during that year by anything approaching the variations that occur naturally from year to year.

As will be seen later, as a general rule any predicted changes in waves or tidal flows greater than about 5% are restricted to within or to limited areas just outside the dredging areas themselves, although for some areas the changes do extend rather further afield. These changes are only likely to be a concern if there are natural or man-made features of interest within these areas, for example an unusual habitat, or structures such as pipelines or wind turbines. The potential effects on those features of the changes predicted in the present broad-scale modelling study would need to be considered carefully as part of the scoping of the more detailed EIA for the particular dredging area(s) involved, and if appropriate considered again as part of that assessment. This would allow a more detailed representation of the seabed bathymetry, the hydrodynamics and sediment transport regime than possible in this regional study, and hence provide more reliable guidance on the significance of any changes to the environment.

In summary, therefore, the computational modelling described below will provide reliable guidance on where changes in the physical environment are **not** likely to be significant. Further, they provide initial indications of where the changes might be of concern, thus contributing to the scope of the more detailed studies needed to inform the Environmental Impact Assessment for individual dredging licence applications.

The three computational modelling studies carried out as part of the MAREA are now described in turn.

3.3 TURBID PLUME AND FINE SAND DISPERSION

As part of this MAREA, HR Wallingford provided a high-level assessment of the footprint of potential impacts resulting from the dispersion of dredging plumes arising from dredging in each of the existing and proposed licensed aggregate extraction areas in the study region.

This work considered both the dispersion of fine sediment plumes and the longer term dispersion of sand released into the water column during the dredging process. In both cases, the extents and intensity of these effects were predicted using published scientific papers on field studies. The results of the reference studies have been re-interpreted for the physical conditions of the individual dredging areas within the study region, and where there was uncertainty in this procedure an emphasis was placed on a providing a conservative and precautionary assessment of the extent of the footprints around each area.

The approach adopted therefore is a *high-level* assessment, designed to identify areas where sediment plumes arising from aggregate dredging could *potentially* occur and, importantly to demonstrate areas where such plumes are unlikely to occur. This study therefore allowed, at this early strategic stage, a better understanding of how and where such potential impacts from proposed dredging will occur, without recourse to more detailed area-specific modelling.

This approach has required a number of simplifying but conservative assumptions, reflecting for example the sizes and pumping rates of the dredgers likely to be employed and the percentage of fine-grained sediments within the deposits being extracted. In addition, the spatial extents (footprints) of the turbid plumes and of movements of fine sand caused by dredging operations are based on:

- Predictions of the peak concentrations that are likely to be experienced (and which typically occur at any location for a few hours a day at most and only then during dredging of the relevant part of the Licence Area);
- An over-estimation of the distance over which the plume disperses. Most of the literature details excursion of plumes relative to the dredger location at the time of

measurement, rather than their excursion from the position of the dredger when the plume was initially released. This causes the distance of movement of the plume to be over-estimated (since the dredger moves away from the measurement location while the plume is travelling). The methodology of this study overlooked this aspect for the sake of simplicity. However, as a result of this the predicted footprints of the fine sediment in this study will over-estimate (spatially) the actual footprints.

A full description of the modelling of the turbid plumes and dispersion of fine sand is provided in Appendix 3 of this report, together with a review of previous studies and associated scientific literature.

Typical results from this study are presented in Figures 4 and 5, showing the predicted maximum extent of turbid (i.e. fine sediment) plumes and of the dispersion of fine sand respectively. These footprints have been supplied to ERM as GIS shape files on CD. However, 'peak concentration' figures can give the reader the impression that such footprints represent the plume itself and not the 'envelope' of the plume through throughout the dredging process. Therefore to set Figures 4 and 5 in context, a snapshot impression of the plumes from dredging in three areas during the ebb tide is presented in Figure 6.

Similar presentations of the predicted extent of the deposition of fine-grained sand to those shown for the sediment plumes in Figures 4 and 5 of this report were also produced during this same element of the overall study. These are presented in Appendix 3 as Figures 11a to 11c.

In summary, this high-level study has facilitated the targeting of any future and more detailed modelling to areas of possible concern, while allowing reduced emphasis in less sensitive areas. It is important to note that the footprints identified in this study *do not* necessarily correspond to areas where there will be a significant impact on the environment. They merely highlight areas where impacts may occur; the importance of the turbidity or the deposition of fine sand in such areas will depend on the sensitivity of any receptors in those areas, for example shellfish beds.

3.4 CHANGES IN WAVE CONDITIONS

Predicting possible changes in wave conditions, particularly near the coast, has long been an important component of studies into the environmental effects of proposed marine aggregate dredging. The present regional study provided an opportunity to review the cumulative effects on waves of all past aggregate dredging, and proposed future aggregate dredging, within the study region. This part of the project thus contributes to the overall MAREA by identifying potentially important changes in wave conditions within the study region before any formal application is made either to extend existing extraction licences, or for licences for new areas.

Because information was required on changes in wave conditions everywhere rather than just along coastlines and in nearshore areas, it was necessary to use a different computational model than that used in the previous Coastal Impact Studies carried out in connection with aggregate dredging. For this study, therefore, it was agreed that we should use the SWAN model, developed at the Technical University of Delft, since this is both widely used in coastal engineering and design studies and is available in the public domain.

To be able to assess the consequences of past aggregate dredging, and then predict the effects of proposed future aggregate dredging, it was necessary to produce three different representations of seabed levels across the whole study region. These are referred to as the pre-dredging, present-day and post-dredging bathymetries, and were used not only for the modelling of waves but also of tidal currents and associated sediment transport (see Section 3.5 below). Because the aim of this study was to predict just the effects of aggregate dredging on the physical environment, the three bathymetries only differed from one another within the past, present and proposed future dredging areas in the study region. Details of the changes in bed levels between each of these bathymetries are presented in Figures 7 and 8 for past and proposed future dredging respectively this is based on information provided by the TEDA members. Negative values indicate that some shallowing of the seabed has occurred while positive values indicate the seabed has become lower.

In each area, the changes in bed levels caused by past dredging were determined by a combination of the latest and previous bathymetric surveys, for example before dredging started if available, and using information on patterns and intensity of dredging together with the overall volumes of aggregate that have been removed. Future changes in bed levels in each area were based on the dredging plans submitted by the dredging companies.

Because the dates on which dredging started, the date of the latest bathymetric survey and the estimated date when any proposed future dredging will be completed all vary from area to area, it is not possible to ascribe a date to any of the three bathymetries used in this modelling study. For example, the present-day bathymetry in any area may now be several years out-of-date, depending on when the most recent survey that area was carried out.

It is also important to emphasise that no attempt has been made to account for the effects on waves of other changes in the seabed levels in the region, whether these were natural, e.g. caused by migrating sandbanks, or man-made e.g. the deepening of a navigation channel.

In common with the conservative approach adopted in this project for assessing other environmental changes, the wave modelling was mainly carried out using extremely severe approaching wave conditions. These conditions are expected to only have a 0.5% of occurrence in any year, i.e. a return period of 200 years, and are therefore the same as would be used to design flood defences for a low-lying coastal town. Such extreme conditions, by virtue of their long wave period, will be more strongly altered by changes in bed levels in the dredging areas than would more frequently occurring and smaller waves.

In addition, while the greatest concerns will be about changes in severe waves at the coastline when tidal levels are high, the effects of aggregate dredging will be greater at low tide levels. At low tide, the increase in water depths caused by dredging is proportionately greater, and the generally shallower water results in stronger wave refraction and frictional dissipation. The wave modelling was therefore carried out for two tidal levels, namely those of Mean High Water and Mean Low Water of Spring tides (MWHS and MLWS).

For each wave condition and bathymetry considered, the computer modelling predicted wave heights, periods and directions on a regular 250m square grid across the whole study region. These results were made available within a GIS system, as were the changes in wave heights caused by past dredging alone, by the proposed future dredging alone and for the combined effects of both past and future dredging.

In general, the modelling has demonstrated that the lowering of the seabed within any individual dredging area in the study region only alters wave heights within or very close to the boundaries of that area. However, in those areas where dredging, typically proposed future dredging, lowers the seabed by more than 2 to 3 metres, the changes in wave conditions can be larger and extend over a greater area beyond the boundaries of those particular areas.

As an example of the results obtained, Figure 9 shows the predicted changes in wave heights caused by both past and proposed future dredging in these same areas, i.e. as a result of the differences in bed level between the post-dredging and pre-dredging bathymetries, at the lower tidal level considered, i.e. MLWS. The spatial extent and magnitude of the changes in wave heights were both, in general, demonstrated to be smaller for this condition at MHWS, which is when coastal defences would be subject to a much greater test of their performance and structural stability.

Figure 9 also shows that when extreme waves approach from 60°N, the SWAN model predicts that changes in wave heights of more than 3% will to occur well beyond the boundaries of some of the dredging areas, in particular, Area 257 and the Long Sand Head area (licences 108/3, 109/1 and 113/1). Wave heights to the south of these areas are predicted to increase, while those just to the west of them heights are slightly decreased. This pattern of change is partly a result of reflection of the incoming wave energy where it encounters the deepened area of seabed. More commonly, the increase in water depths within the dredging areas slightly reduces the frictional dissipation at the seabed of these extremely large waves, leading to larger wave heights within and to landward, i.e. “down wave” of the dredging areas. However, this effect is rapidly reduced as the waves travel on towards the coast by the processes of wave diffraction and the further interaction between the waves and the winds particularly where the wave heights have been changed by the lowering of the seabed.

At this low tide level (MLWS), Figure 9 shows that the extremely severe waves considered may be changed by over 10% for up to 7 km beyond the boundary of the extraction area for some of the incident wave directions combinations considered, and changes of 2% might be expected at twice this distance away from the southern edge of the Long Sand Head area (licences 108/3, 109/1 and 113/1).

Similar results are presented for all dredging areas, and for a wider range of wave conditions, in the detailed description of the wave modelling exercise presented in Appendix 4 to this report.

In summary, this wave modelling exercise has shown that even by considering a worst case scenario, i.e. extremely severe waves arriving at the time of a low tidal level, the changes in wave conditions anywhere close inshore are so small in percentage terms as not to be significantly greater than the expected accuracy of the SWAN model itself.

Closer to and within the dredging areas, however, changes in extreme wave conditions may well be sufficient to need careful consideration if there are features of interest, particularly man-made structures such as pipelines or offshore wind turbines, within those same areas. The significance of such changes in wave conditions would need to be investigated in more detail as part of the EIA for the extraction licence applications for a particular area, and such a study may also need to consider dredging in other nearby areas, where they are clustered close together.

3.5 CHANGES IN TIDAL FLOWS AND SEDIMENT TRANSPORT

In the Coastal Impact Studies carried out previously for aggregate dredging areas within this study region, the assessment of changes in tidal currents caused by the lowering of the seabed was empirical rather than involving specific computational modelling for each application. This approach relied on a number of previous studies predicting changes to tidal flows where there were concerns about impacts on pipelines on the seabed close to proposed dredging areas. In these previous assessments, it was found that such flows were not altered by more than a few percent except within an area roughly twice the size of, and centred on, the dredging area itself.

Aggregate dredging areas almost always lie much further offshore from any coastline than their own diameter. It has generally been concluded, therefore, that dredging in these areas would not affect tidal currents close to the coastline.

In the present regional study, however, it is necessary to consider the changes in tidal currents, and hence in the way that they transport sediments, over the whole study region. This was achieved by using two linked computational models, first to represent the tidal currents and then to calculate the rates and directions of sediment transport caused by these currents.

As for the wave modelling (see Section 3.4 above), the main aim of the modelling of tidal flows was to identify where, and to what extent, there might be changes to the environment that could be significant, either directly, for example leading to changes in the seabed outside the dredging area or indirectly, e.g. affecting marine plants and animals using that part of the seabed. Based on the results obtained in the earlier wave modelling study, and bearing in mind the likely use of the results from this modelling, it was decided to concentrate on predicting just the cumulative effects of both past and proposed future dredging on tidal flows and sediment transport. The effects on these of past dredging alone will be smaller and of less concern than of the combination of past and future extraction, and of less importance when assessing whether to continue dredging from existing areas or to licence new areas.

By repeating the modelling for two of the same three bathymetries used in the assessment of changes in wave conditions, i.e. for the pre-dredging and post-dredging bed levels, we predicted the spatial extent and magnitude of changes in both tidal flows and the associated sediment transport that would be caused by all past and planned future dredging in the study region. A summary of this modelling follows, with a more detailed description presented in Appendix 5.

The computational technique used to simulate tidal flows in this study was TELEMAC, a finite element model, originally created by LNH-EDF of France. This software has been both developed at HR Wallingford over recent years and used for many comparable applications. TELEMAC has the significant benefit of being able to simulate flows over a very large area while allowing a fine grid resolution in specified sub-areas of particular complexity or interest. This allows a more detailed representation of the flow fields in these particular parts of the overall model domain.

For this particular study, it was possible to build upon a previous successful modelling exercise (HR Wallingford *et. al*, 2002) in which the TELEMAC model was used to simulate tidal propagation in the Southern North Sea. This existing and well-calibrated model was adjusted to better suit the needs of the present project by refining its computational grid to allow a more detailed and accurate representation of bed levels in and close to the dredging areas. Once its grid had been adjusted in this way, the pre-dredging and post dredging bathymetries were used to produce pre- and post dredging bathymetries for the TELEMAC model.

The flow model was run over both bathymetries for a mean Spring tide, and the instantaneous flow speeds and directions output at closely-spaced time intervals at all locations within the study region. As an example of the results, Figure 10 shows (interpolated) flow vectors during the flood tide, output at a single time-step when these flows were strongest. It is, however, the changes in the current speed that are of interest in assessing the effects of aggregate dredging, and Figure 11 shows, at the same stage in the tidal cycle as used in Figure 10, the predicted changes in current speeds due to both past and proposed future aggregate dredging.

Although changes as small as ±2% are shown in this figure, changes less than ±5% can be regarded as within the expected accuracy of the flow modelling and hence are unlikely to have any noticeable effects on the physical environment of the region.

Changes in current speed of greater than ±5% are very largely restricted to the dredging areas themselves or to limited zones close to their boundaries. However, changes of up to 15% due extend a considerable distance to both the west and south of Area 257 and the Long Sand Head area (licences 108/3, 109/1 and 113/1). As with the interpretation of the wave modelling results, if there are features of particular interest or sensitivity within parts of the seabed adjacent to aggregate extraction areas, then this broad-scale modelling provides an indication that more detailed consideration of changes in tidal currents and their consequences may be needed in the EIA for each specific dredging area. However, if this modelling shows no changes in tidal flows in an area of particular interest, then it can be assumed that there would be no need for further investigation of such effects as part of the licence application process.

The tidal flow modelling described above provides information on the changes in currents caused by dredging at any particular instant during the tidal cycle. By using information on these instantaneous current speeds, the water depth at that time, and then assuming the presence of a uniform-sized bed sediment, we were able to also calculate the instantaneous rate of transport of that sediment, and how that would be altered by the changes in bed levels caused by aggregate extraction. The seabed sediments in the dredging areas in this study region vary in size, but typically can be described as sandy gravel or gravelly sand. These deposits may be almost immobile for much of the time, depending on the details of the grain size distribution. However, in this regional study, it was not possible to include detailed information on the sediment deposits. Therefore a simpler approach has to be adopted to investigate possible changes in sediment transport patterns as a result of aggregate dredging.

To provide a broad-scale appreciation of the potential for such changes, therefore, we assumed that the whole seabed in the region was covered by a layer of medium-sized sand with a median grain diameter of 0.3mm. This will exaggerate the amounts of sediment transport that actually occur, and the changes in sediment transport rates caused by aggregate dredging.

The most important aspect of any changes in sediment transport rates in the context of an environmental assessment of aggregate dredging is likely to be the possibility of changes being caused to the morphology of the seabed outside the dredging areas. In some cases, the concern may be a rapid accumulation of sediment covering features of interest on the seabed, for example shellfish beds. Elsewhere problems may arise as a consequence of sediment being removed, for example causing scour around wrecks or pipelines. To indicate the potential extent and magnitude of such change to the seabed morphology, it is most useful to examine the net, or residual, sediment transport rate over a complete tidal cycle, and how this might change as a result of both past and proposed future dredging. This has been done and the results of the modelling are summarised in Figure 12. As for the changes to waves and to tidal currents, it is again the case that predicted changes in sediment transport rates of any substantial magnitude are usually limited to the dredging areas themselves or to reasonably restricted areas outside them, i.e. extending perhaps as far away as the maximum dimension of the dredging area itself. The spatial extent of changes in net sediment transport rates is greatest in the area surrounding Area 257 and the Long Sand Head area (licences 108/3, 109/1 and 113/1).

Because of the very conservative assumptions used in this modelling, it is safe to conclude that in reality any changes caused by aggregate dredging to sediment transport patterns, and hence to the morphology of the seabed, will be too small for any concern if not identified in this broad-scale modelling exercise. Even if this modelling does indicate an area of potential change in net sediment transport rates at some location of interest close to a dredging area, however, the results presented in Figure 12 should only be used to indicate a need for caution and perhaps for more detailed investigation at a later stage in the licence application process. At such a time, more detailed analysis of the quantities and characteristics of the seabed sediments in and around any particular area would be needed to provide a more reliable prediction of the changes in sediment transport rates and seabed morphology changes that might occur.

4. Conclusions

This report describes a number of inter-related studies that have been carried out to investigate the characteristics of a large area lying offshore over and seawards of the Outer Thames Estuary. As part of a much wider-ranging Regional Environmental Assessment, a broad-scale assessment of the effects of past and proposed future dredging on the physical environment of this region has been carried out using reviews of both data and previous scientific papers and reports, together with computational modelling.

In the computational modelling studies, a conservative approach was deliberately adopted to maximise the predictions of the spatial extents and magnitude of the possible changes to the physical environment that would be caused by aggregate dredging. As a result, where these broad-scale assessments indicate no changes are likely, then it is safe to assume that in reality there will be no noticeable effects on the environment.

Where these assessments did predict substantial changes, i.e. larger than the expected margins of inaccuracy in the modelling, these were restricted to the dredging areas themselves and to a restricted area of the region around these areas. As a simple guide, any changes likely to have a significant effect on the environment were predicted not to extend further from the edge of any dredged area than the maximum dimension of that area. Neither past nor future dredging was predicted to have any effect on the coastline of the study region.

Where any noticeable change in the physical environment is predicted, then its significance to the environment will generally need to be assessed in more detail, bearing in mind the sensitivities of the features of interest to that change. In many cases, the results of this regional assessment both provide a context for site-specific (EIAs) for individual dredging licence applications within the study region, and a preliminary indication of the spatial extent and the magnitude of changes that aggregate dredging may cause.

The results from the study have been produced in a GIS and the files proved to ERM Ltd to use within their overall assessment of the effects of aggregate dredging on the environment of the study region.

5. Technical Appendices

This final report contains five technical appendices based on Technical Notes produced by HR Wallingford during the Thames Estuary Marine Aggregate Regional Environmental Assessment (MAREA) for the Thames Estuary Dredging Association (TEDA).

The five technical notes are listed in Table 1, and have generally been reproduced in full in Appendices 1 to 5 respectively. (Some of the interim recommendations made in the first of these reports were acted upon later in this project. Those sections of that report have therefore been excised to avoid confusion).

Table 1 Technical reports included in EX6213

Study Component	Current Revision
Technical Note DDR4318/01 – Data Review	1.0
Technical Note DDR4318/02 – Coastal Characterisation	3.0
Technical Note DDR4318/03 – High-level Plume Study	5.0
Technical Note DDR4318/04 – Wave Modelling	5.0
Technical Note DDR4318/05 – Tidal Flows and Sediment Transport	3.0

6. References

CEFAS (Centre for Environment, Aquaculture and Fisheries Science), 2008. “Regional Environmental Assessment: A Framework for the Marine Minerals Sector”, 19pp.

CLG (Communities and Local Government), 2002. “Marine Minerals Guidance Note 1 (MMG1): Extraction by dredging from the English seabed”, Published by DETR. *http://www.communities.gov.uk/publications/planningandbuilding/marinemineralsguidance*

Halcrow, 2004. “Futurecoast”, on CD-ROM, produced for Department for Environment, Food & Rural Affairs. Halcrow, Swindon, UK.

HR Wallingford, CEFAS/UEA, Posford Haskoning and Dr Brian D’Olier 2002. “Southern North Sea Sediment Transport Study Phase 2, Sediment Transport Report”, Report produced for Great Yarmouth Borough Council, HR Wallingford Report EX4526, August 2002.

MFA (Marine and Fisheries Agency), 2008. “Marine Minerals Guidance Note 2 (MMG2): The control of marine minerals dredging from the British seabed”. *http://www.mfa.gov.uk/environment/documents/mmg-2-08.pdf*

Figures

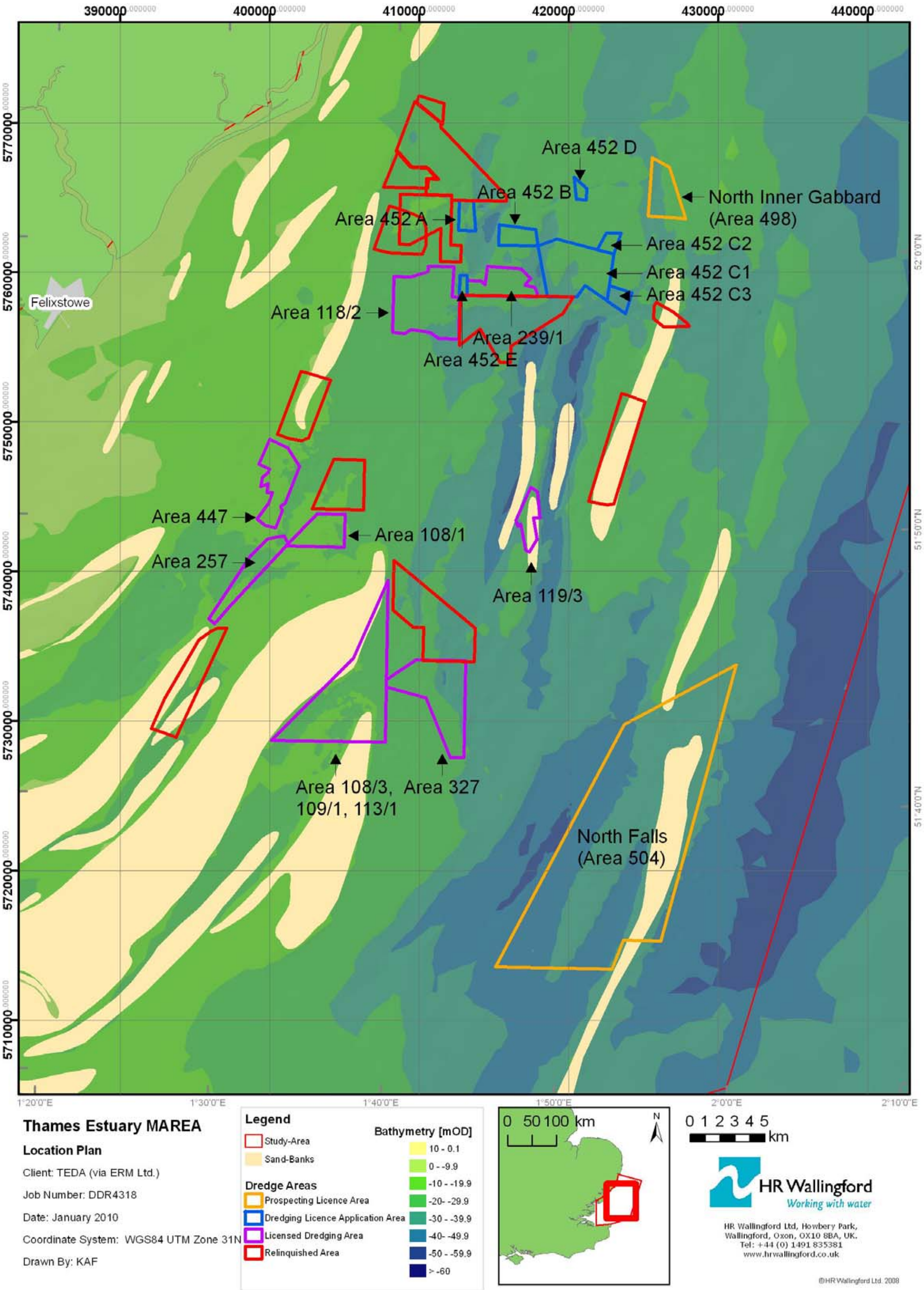

Figure 1 Location plan, showing study region boundary and dredging areas

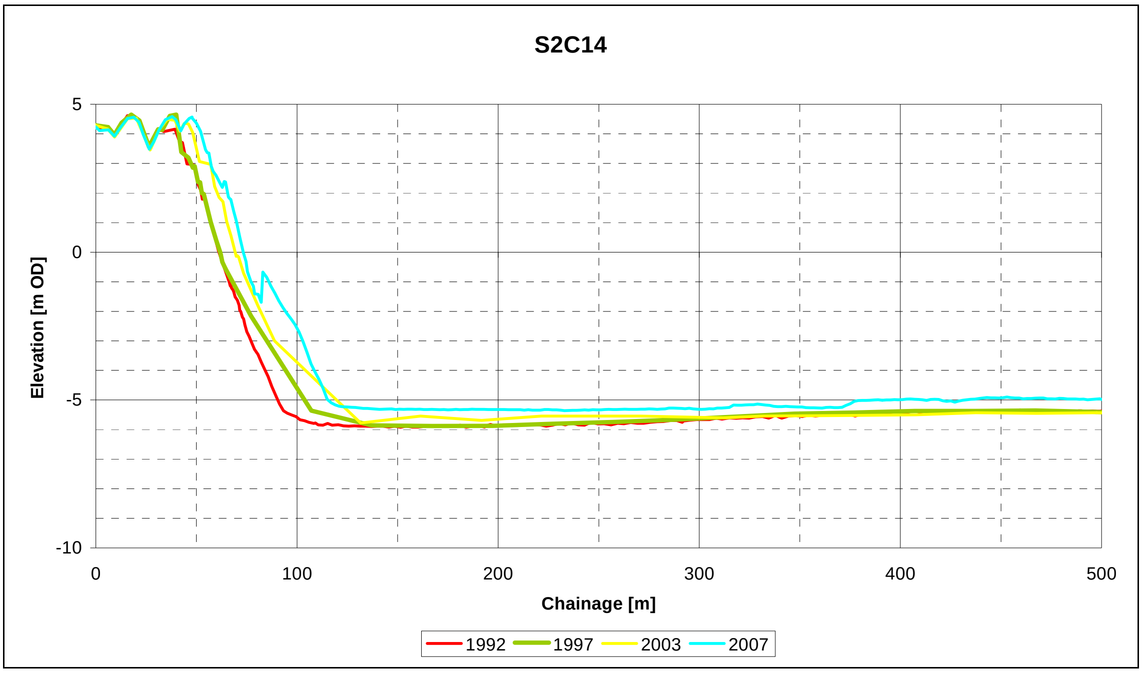

Figure 2 Beach cross-sectional survey comparison – Orford Ness spit (Source: Environment Agency)

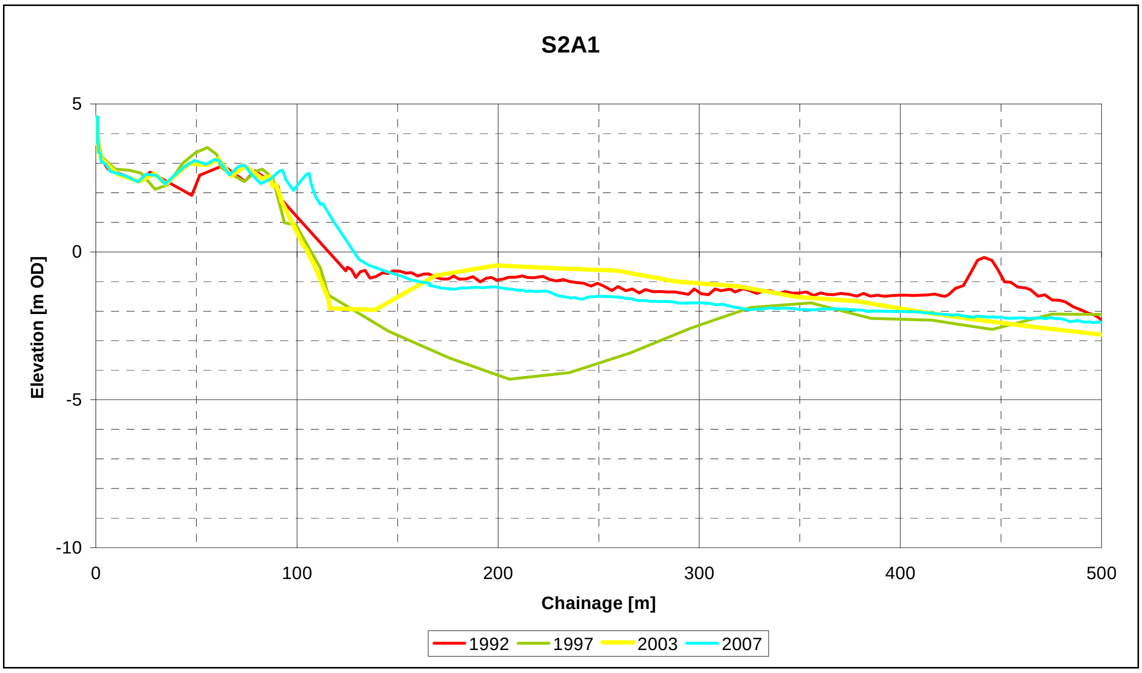

Figure 3 Beach cross sectional survey comparison – Felixstowe (Source: Environment Agency)

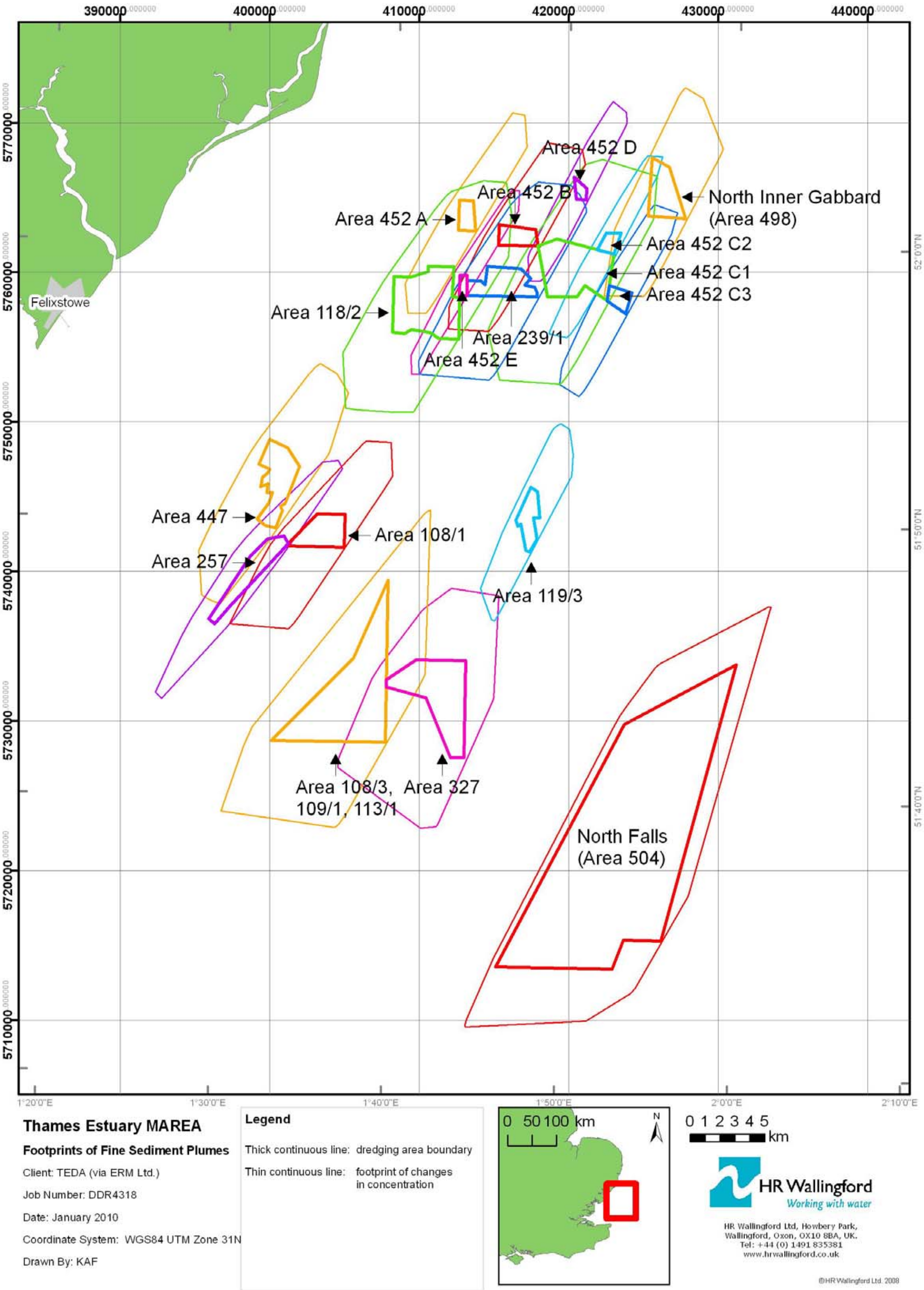

Figure 4 Maximum extent of fine-sediment plumes (east of the Isle of Wight)

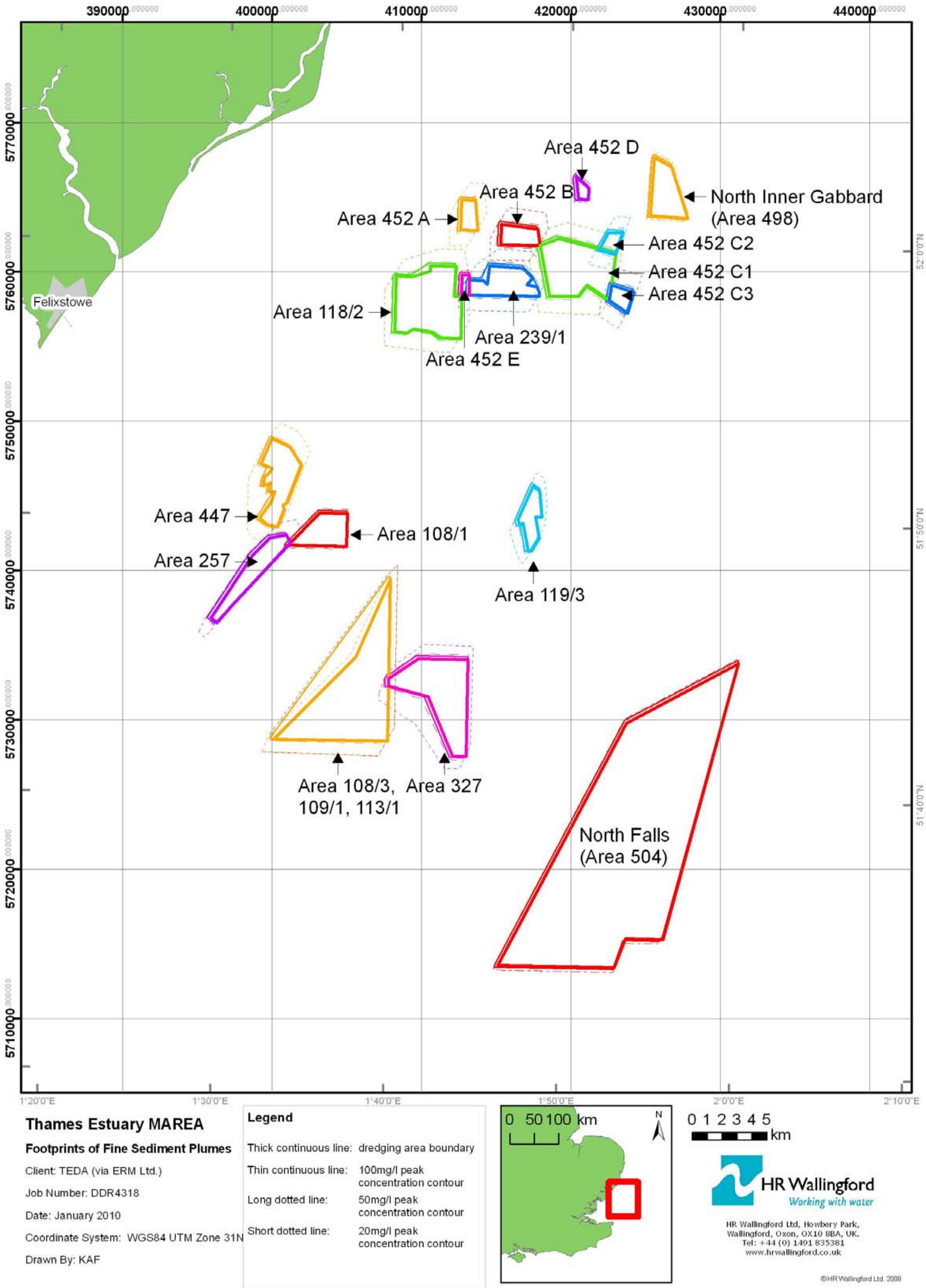

Figure 5 Maximum extent of fine sand dispersion

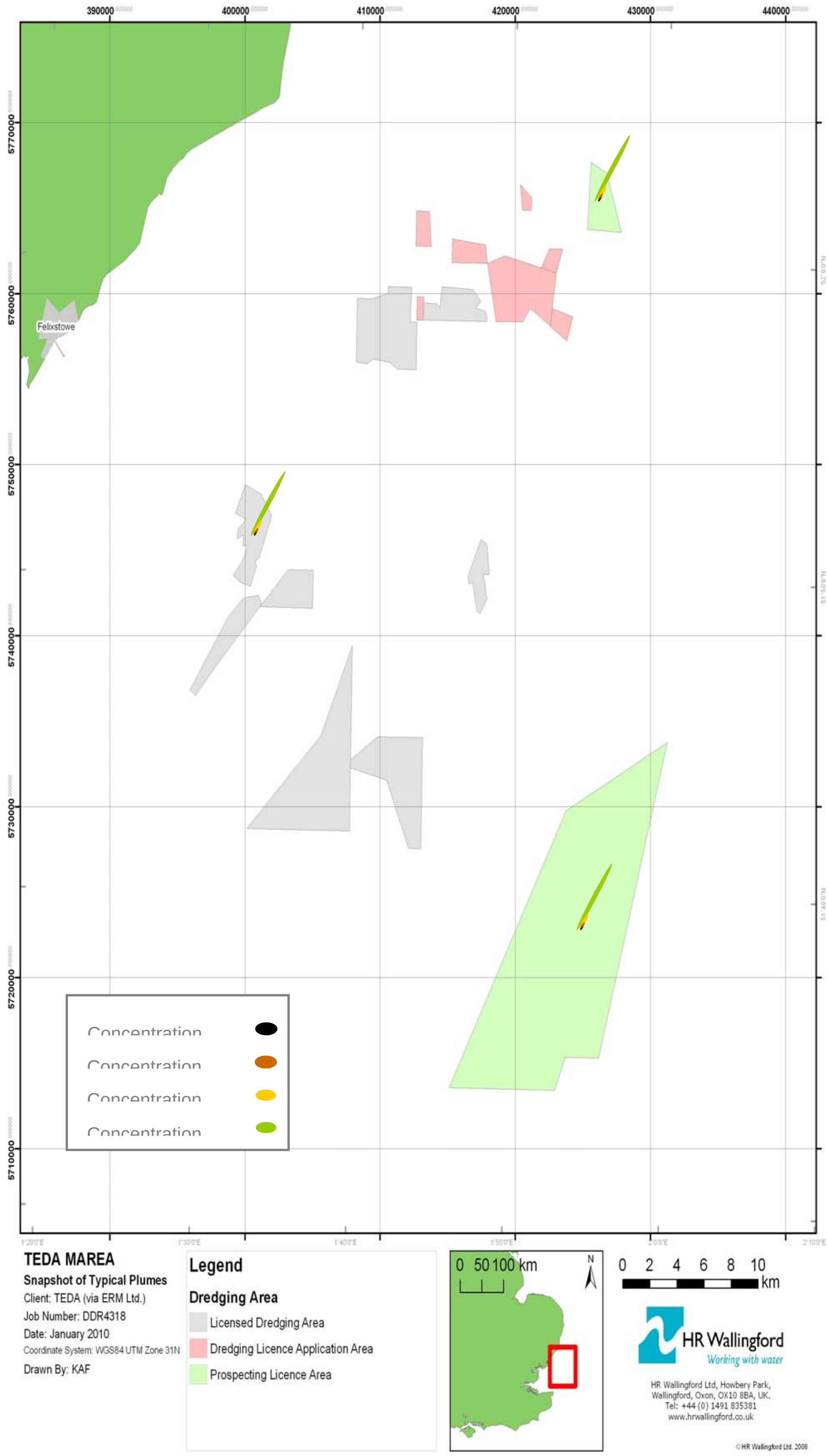

Figure 6 Snapshot of typical plumes from dredging in three areas on the ebb tide

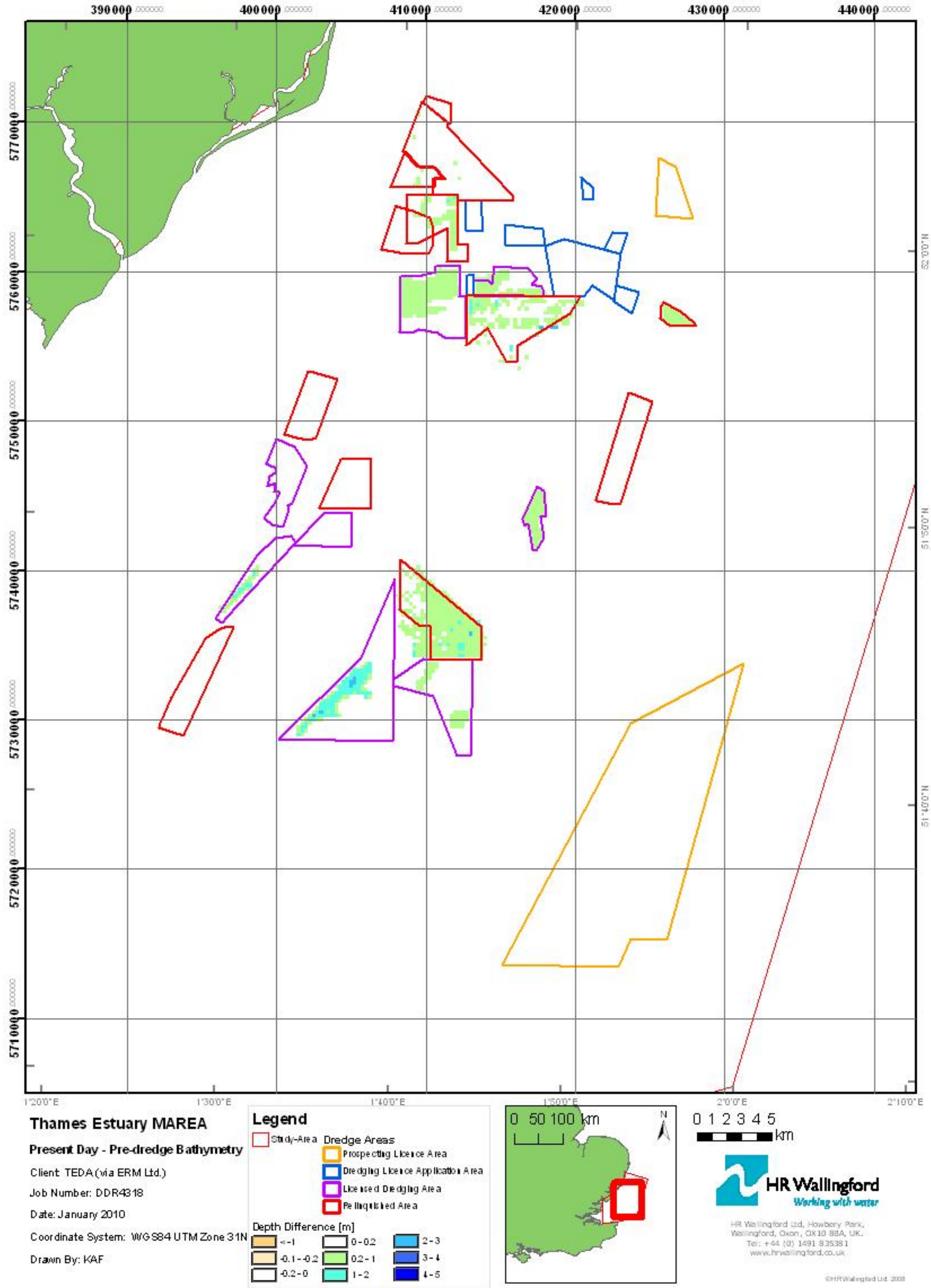

Figure 7 Past depth changes within existing licensed dredging areas

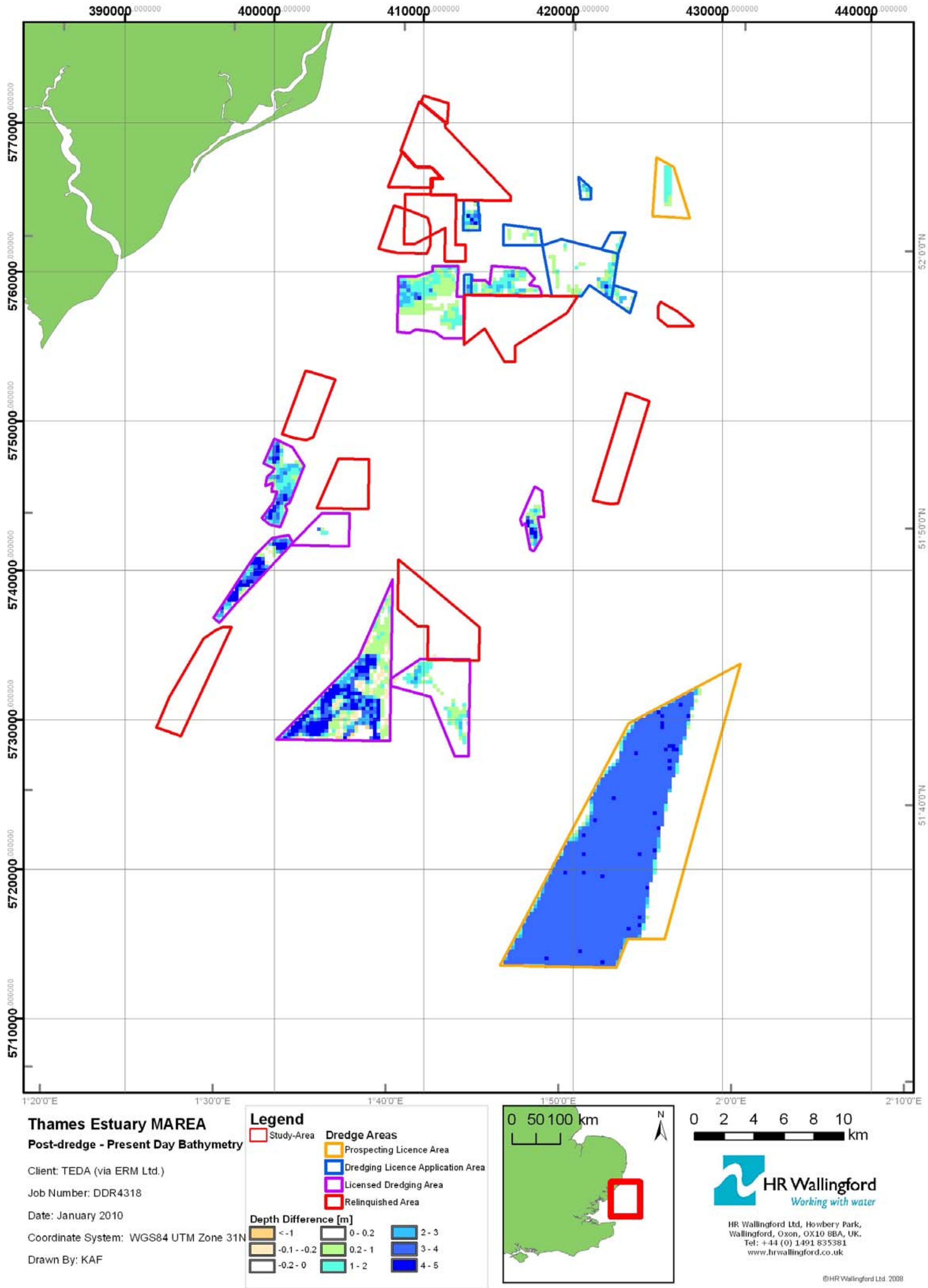

Figure 8 Plans for future depth changes in aggregate dredging areas

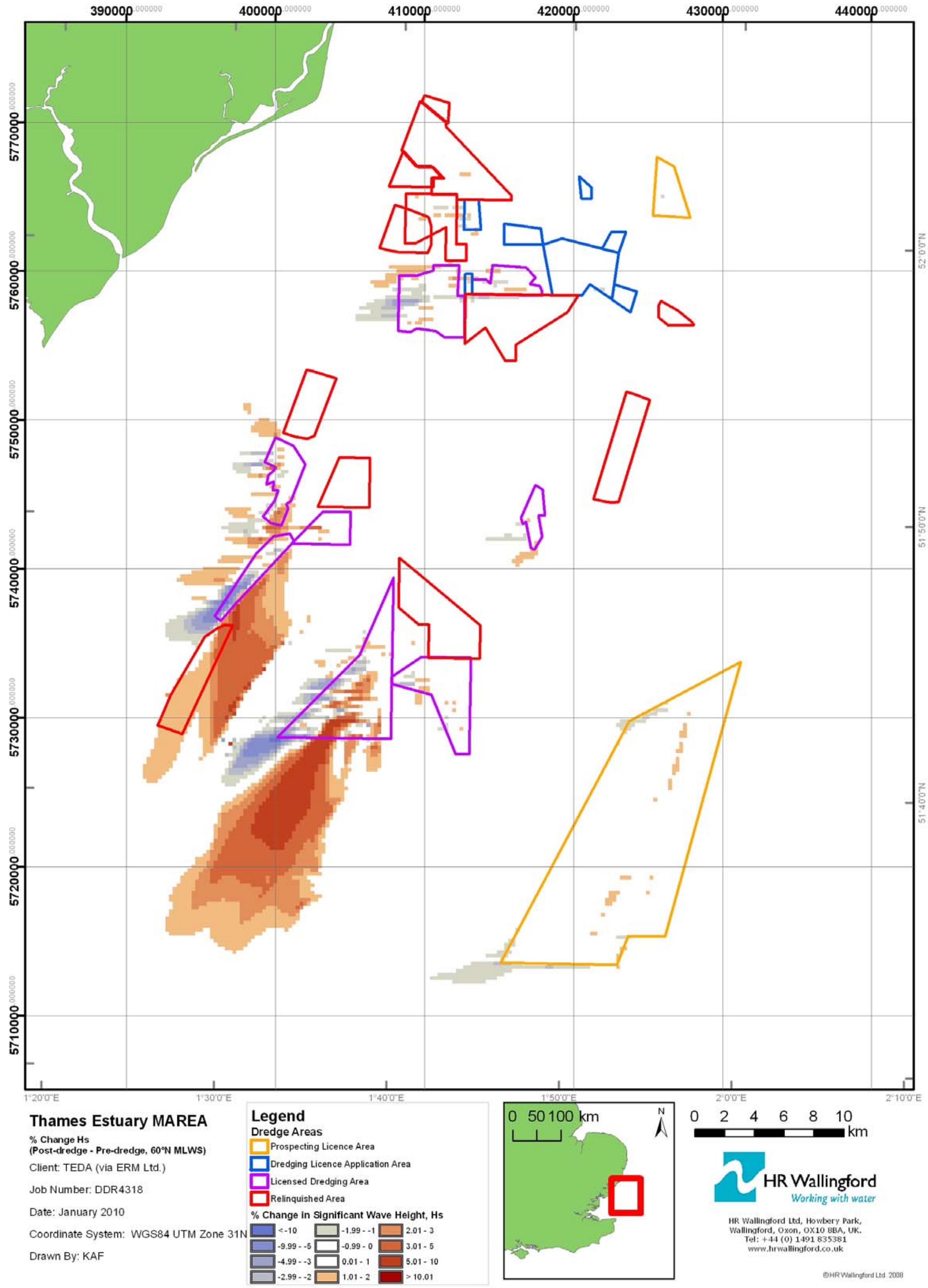

Figure 9 Wave height changes (%) for past and future dredging for 200 year return condition from 60ºN at MLWS

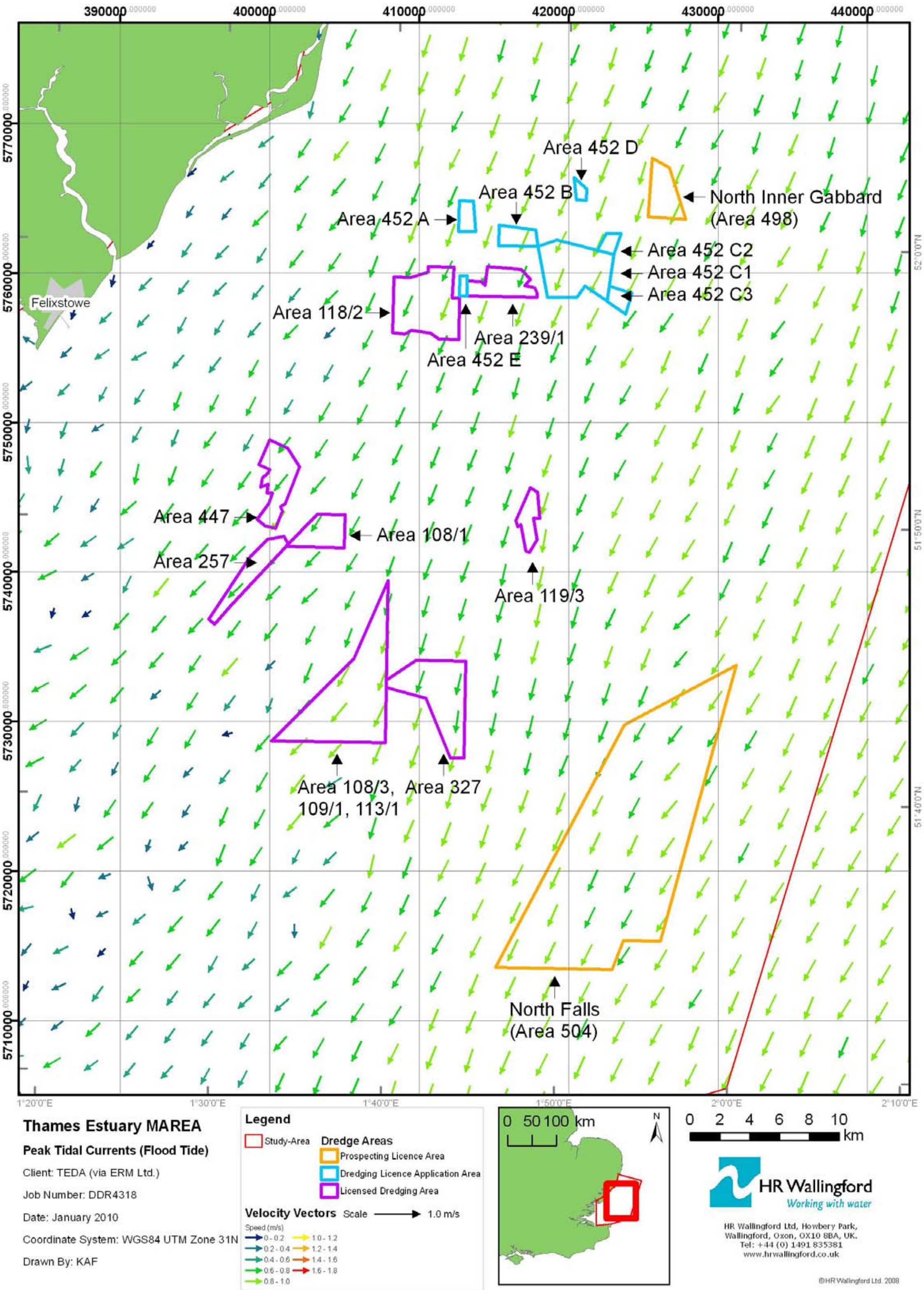

Figure 10 Peak tidal currents during flood tide

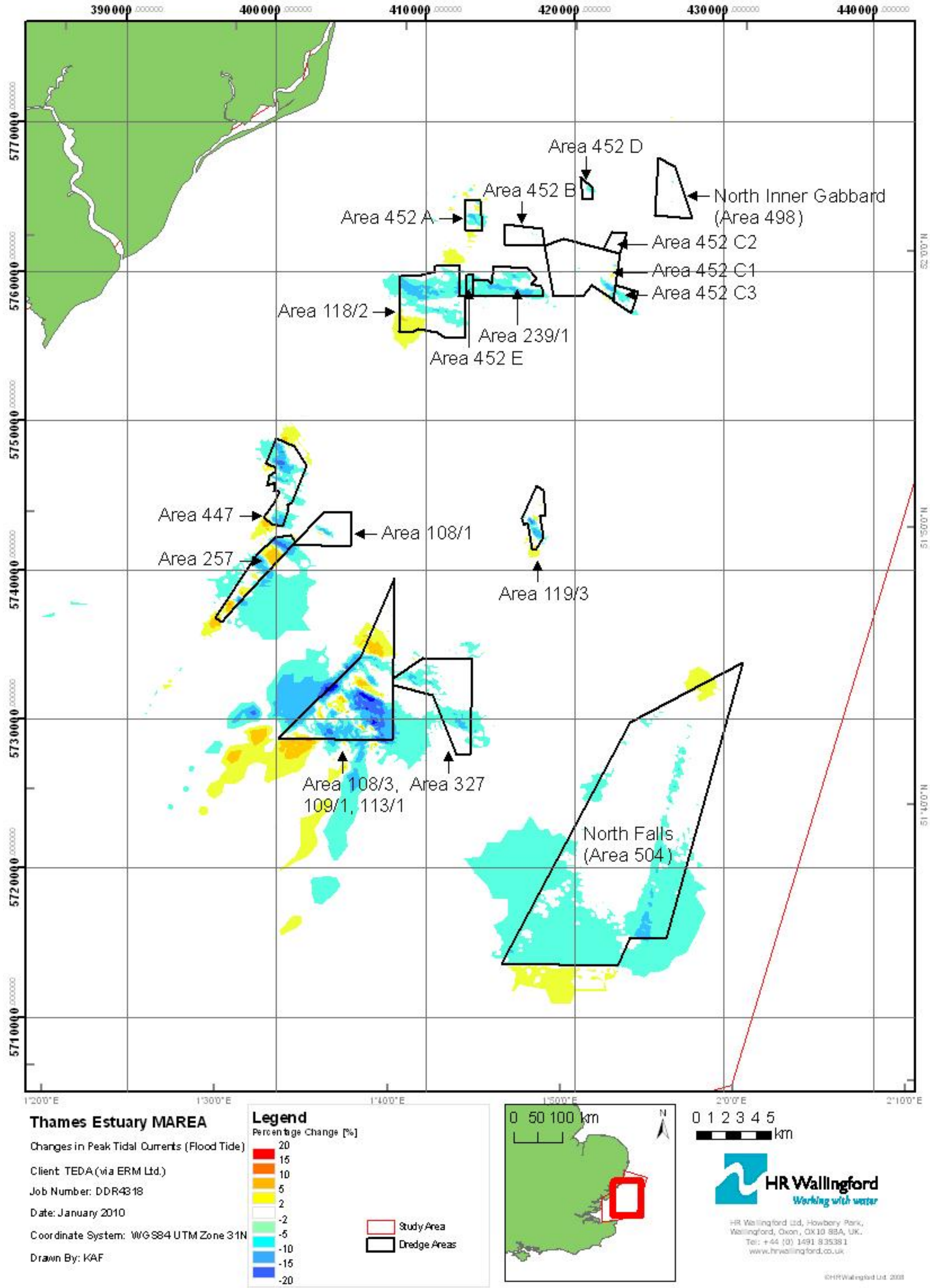

Figure 11 Changes in peak tide currents during flood tide (post-dredge – pre-dredge)

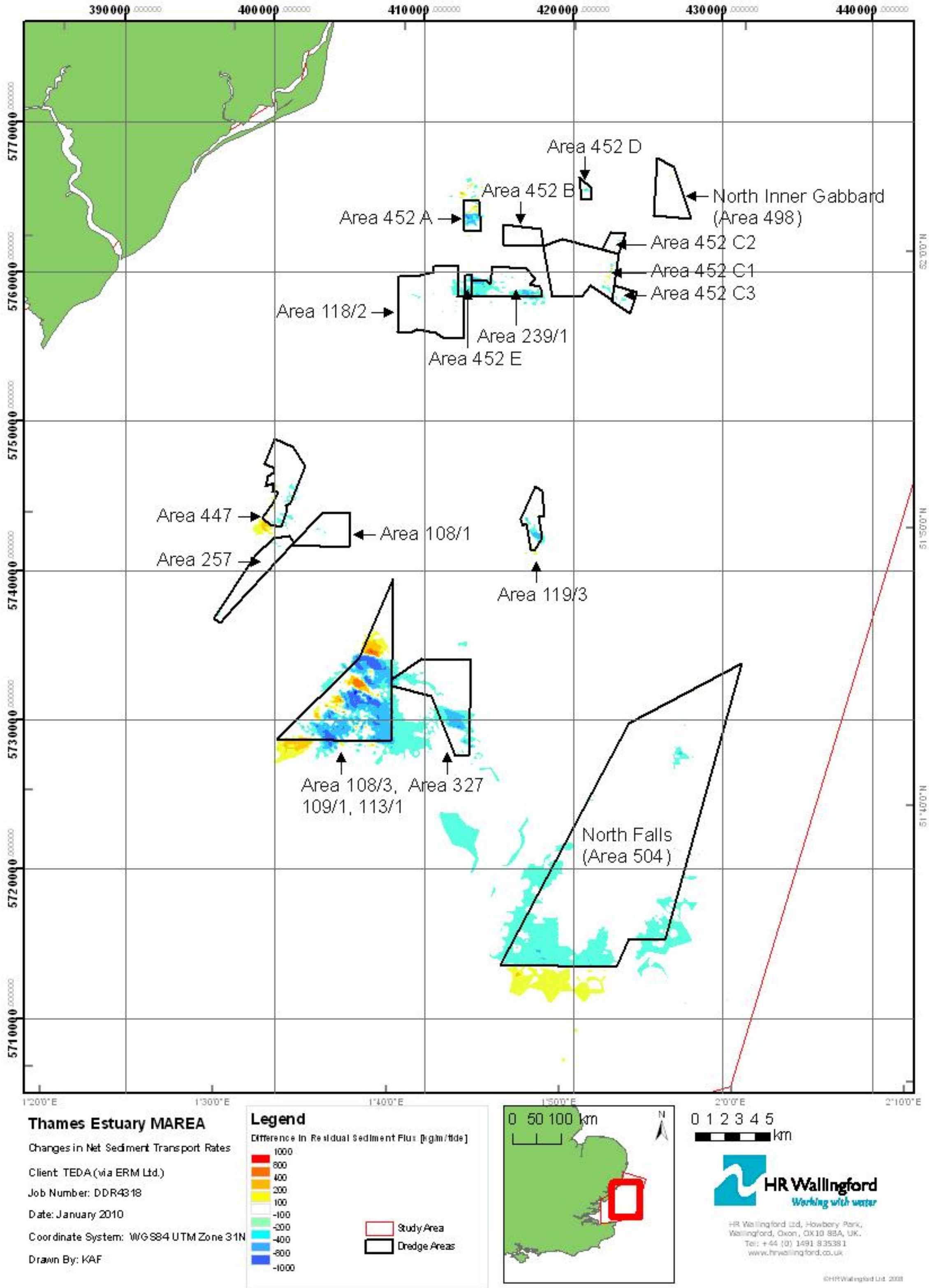

Figure 12 Changes in net sediment transport rates (post-dredge – pre-dredge) (0.3mm sand)

Appendices

Appendix 1 Extracts from Technical Note DDR4318-01: MAREA: Data Review

Appendix 2 Technical Note DDR4318-02: MAREA: Coastal characterisation

Appendix 3 Technical Note DDR4318-03: MAREA: High-level Plume Study

Appendix 4 Technical Note DDR4318-04: MAREA: Wave Study

Appendix 5 Technical Note DDR4318-05: MAREA Flows and Sediment Transport Study