


Department for Environment Food & Rural Affairs (DEFRA)

Lappel Bank and Fagbury Flats Compensatory Measures: Phase 2 - Detailed Hydrodynamic Modelling of Proposed Wallasea Island North Bank Realignment Scheme.

Non Technical Summary

Date: November 2004

Project Ref: R/3286/9

Report No: R.1115a

ABP mer marine environmental research

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Abbreviations

ABPmer	ABP Marine Environmental Research
BSS	Bed Shear Stress
BTO	British Trust for Ornithology
DEFRA	Department of Environment Food and Rural Affairs
EA	Environment Agency
EIA	Environmental Impact Assessment
EN	English Nature
GTENA	Greater Thames Estuary Natural Area
HW	High Water
LiDAR	Light Detection And Ranging
LW	Low Water
NTS	Non Technical Summary
PMG	Lappel Bank and Fagbury Flats Project Management Group
RSPB	Royal Society for the Protection of Birds
SSC	Suspended Sediment Concentration

Acknowledgements

We would like to thank the Environment Agency (EA) who provided us with a range of data to support the construction of the numerical model including: Light Detection And Ranging (LiDAR) images, maps, bathymetry survey information, water level measurements, current readings and physico-chemical data for the Crouch and Roach. We would also like to thank INTERMAP for the supply of radar-derived Digital Surface Model Images (DSM) which were used to describe the topography of the estuary in those areas not covered by the LiDAR images.

We would also like to thank John Hesp (Hesp Associates), Robert Bache (Wallasea Farms Ltd.) and Philip McLoughlin (Bullen Consultants) for supplying details about the proposed realignment scheme design. We are also particularly grateful to Mark Dixon (DEFRA Project manager for the Lappel Bank and Fagbury Flats Compensation Measures Project) for his advice on all aspects of the work especially the development of the preliminary scheme designs; the review of the different revised options that were modelled here and the selection of the final preferred scheme. Finally, our biggest thanks go to Ron Pipe for the hire of his boat during our surveys for his expert advice during the scheme design stage. He was an invaluable source of information.

Lappel Bank and Fagbury Flats Compensatory Measures: Phase 1 - Second Review of Short-listed Sites

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Project Background

Following a judgement by the European Court of Justice, the UK Government is committed to providing compensation measures to offset the environmental impacts arising from port developments at Lappel Bank in the Medway Estuary (Kent) and at Fagbury Flats in the Orwell Estuary (Suffolk). These port developments resulted in the loss of 22ha of mudflat at Lappel Bank and 32ha of both mudflat and saltmarsh at Fagbury Flats, both within sites of international conservation importance. The preferred option for compensating for these losses is to create suitable areas of new mudflat and saltmarsh (in particular to provide feeding habitats for birds) through the realignment of flood defences at a location within the Greater Thames Estuary Natural Area (GTENA). The GTENA is an environmental management area that covers the coastal areas and low-lying hinterland between the mouth of the Stour Estuary and the Swale Estuary in North Kent.

The Government's drive to pursue these compensation measures is being overseen by the Lappel Bank and Fagbury Flats Project Management Group (PMG) and the first phase of this process involved an extensive review of flood plain areas across the GTENA and southern Suffolk, to identify potentially suitable locations for this realignment. This 'Phase 1' site selection process was undertaken in a series of four stages as follows:

(1) Stage 1 (Nov 1996 to Jan 1998): An initial site selection process by both English Nature (EN) and the Environment Agency (EA) following which nine candidate sites were identified.

(2) Stage 2 (Oct 1998 to Oct 2002): A detailed comparative review, by ABPmer and the British Trust for Ornithology (BTO), of the nine candidate sites identified in Stage 1. Following this review Weymarks (on the Blackwater) was identified as the preferred site going forward.

(3) Stage 3 (Nov 2002 to April 2003): To identify whether there were any other suitable candidate sites, a further extended site selection process was undertaken by ABPmer. This involved a comprehensive review of the potential sites throughout the GTENA flood plain area. Following this review a second shortlist of five sites was identified.

(4) Stage 4 (April to August 2003): A second detailed comparative review (using the same methods as for Stage 2) of the five candidate sites identified in Stage 3 was then undertaken jointly by ABPmer and BTO.

Following completion of this Phase 1 site selection process, three potentially viable realignment sites were identified. These sites were at Weymarks in the Outer Blackwater Estuary and at two locations on Wallasea Island in the Crouch and Roach Estuaries system. A further preliminary hydrodynamic modelling study was then carried out to characterise the physical effects of realignment and evaluate the efficacy of the proposed coastal realignment at each site. Other methods of evaluation were i) public consultations; ii) risk assessments and iii) reviews of other key considerations (including the standard of existing coastal defences; the currently proposed coastal management measures; land ownership issues etc.)

As a consequence of these investigations, the PMG selected the Wallasea Island North Bank site as the preferred site for delivering the required compensation habitats. Based on this decision, on the 4th March 2004, the Minister for Nature Conservation announced that this would be the Government's proposed approach to the compensation requirements.

Objectives of This Modelling Study

Following the confirmed selection of the Wallasea Island North Bank site, DEFRA commissioned ABPmer to undertake a series of computer-based modelling studies to describe the effects of the realignment on the physical conditions in Crouch and Roach estuaries (i.e. water levels, flow speeds, channel depth etc.). This detailed modelling work was undertaken to support the accompanying Environmental Impact Assessment which is being undertaken separately for this study.

There are three broad questions that this detailed modelling is designed to answer. These questions are as follows: -

(1) What physical effects will the scheme have on the Crouch and Roach estuaries immediately after realignment;

(2) What physical effects will the scheme have on the Crouch and Roach estuaries in the longer-term (i.e. after periods of 10s to 100s of years);

(3) How the site will function and will it meet a series of pre-determined site design criteria identified by the PMG to ensure that viable coastal habitats are created

The results obtained were also used to make an initial judgment about the potential effects of the scheme on the main features of environmental and socio-economic importance within the Crouch and Roach (e.g. coastal defences, intertidal habitats, oyster beds, yacht/shipping moorings and vessel navigation). This report reviews the approach and findings of this detailed modelling work.

Methods

To answer the questions listed above, the modelling work was undertaken in four stages as summarised below:

Stage 1: A review of existing datasets and bathymetric survey

Available data describing the present physical characteristics of the Crouch and Roach estuaries were collated. A bathymetric survey was then undertaken to fill any identified gaps in these data in order to obtain a comprehensive description of the morphology (size and shape) of both estuaries. This survey, undertaken in March 2004, involved measurements of the water depths throughout the two main estuary channels. It also included sampling work to describe the composition of the seabed sediments and water quality conditions (i.e. suspended solid loads) in the estuaries.

Stage 2: Model set-up and scheme design development

Using the detailed description of the estuary morphology as obtained from the data review and survey work, a hydrodynamic model was set up using the Delft-3D Software. This model was then used to test a range of different scheme design options and in total, ten different scheme designs were reviewed. These varied in terms of the breach locations and breach widths as well as the alignment and location of proposed island features within the site. The design which showed the best, and most even, water flows within the site was identified as the preferred final scheme and was subject to further investigation as part of the detailed modelling work.

Stage 3: Review of the immediate effects in the estuary

Once the preferred scheme design was established, the numerical model was run to test the initial effects of the realignment scheme. For this analysis the following two integrated models were used;

(1) A hydrodynamic model to describing the changes to the estuary tidal flow regime;

(2) A Sediment transport model to indicate the sediment behaviour within the realignment site and across the surrounding areas.

Stage 4: Review of long-term estuary development

To describe how the estuary might change in the long-term (over periods of 100s of years) in response to the proposed realignment, a system-wide tidal ‘regime model’ was developed separately to the above short-term models. For this analysis it was necessary to assume that the estuary has already fully responded to previous historical changes (i.e. reclamation of intertidal habitats, previous coastal realignment and the collapse of old seawalls) and can, therefore, be said to be in regime (i.e. there is a stable relationship between the various characteristics of the estuary including: cross-sectional area, tidal prism, sediment type etc.) However, there is evidence that the estuary is still responding to previous interventions and has not achieved a regime condition.

Results and Conclusions

The results of this work are considered here in four stages. Firstly, the final scheme design is described in outline terms; the immediate effects of the scheme are described; then the long-term effects on the estuary are predicted and finally, the conditions within the site itself are summarised.

Design of the realignment scheme

The proposed realignment scheme is illustrated in Figure NTS1 and its main components include the following: -

(1) **Construction of new seawalls**: – A new seawall (Wall A) has already been constructed on site by Wallasea Farms (in 2002) and a new wall (Wall B) is to be constructed (using suitable materials excavated on-site) that will link Wall A to the east bank of Wallasea Island.

(2) **Sediment Recharge:** – Along the seaward edge of Walls A and B sediment (dredgings) will be deposited to create an elevated strip of land fronting these walls. This is designed to provide habitat on which saltmarsh will develop but it will also increase the levels of coastal protection provided by the walls.

(3) **Breaches 1 to 6** (numbered from west to east): – Six breaches will be excavated through the existing seawall. Breach No. 4 will be the largest at 210m wide, the others will be either 60m or 100m wide and their total width will be 590m.

(4) **Islands 1 to 7** (numbered from west to east): – The mud, clay and seawall material that is excavated at the breaches will be deposited at selected locations in the site to create islands that will provide habitats for birds and other marine species.

Once the breaches have been excavated through the existing seawall, the tide will then flood the 108ha area in front of Walls A and B to create new coastal habitat. Given the existing ground height within the site, it will in future flood on each high tide and will be exposed on each low water. It will develop into mudflat habitat across much of its area although the sediment recharge area will develop into saltmarsh (as described above) since it occupies higher ground that is not always covered by water at high tide. This will provide a relatively large area of additional intertidal habitat within the Crouch and Roach estuary system. At present intertidal area has been calculated as 1,536ha so the proposed site will create an additional 7% of new mudflat and saltmarsh habitat.

On an average high tide following realignment, this area will be covered by around 1.2million m^3 sea water. This high tide volume will range over the course of the two-weekly Spring-Neap cycle from around 1.7m m^3 on the larger (Spring) tides to around 0.8m m^3 on the smaller (Neap) tides. These Spring and Neap high tide volumes represent about 2.5% and

1.2% respectively of the total volume of water entering and leaving the Crouch and Roach Estuary System as a whole (which is around 6.6 x $10^7 m^3$) over the course of a tide.

Modelling Results: Immediate effects of scheme

The modelling work has been used to compare the hydrodynamic conditions before and after realignment and has identified a number of changes that will take place as a result of the movement of the extra volume of water in the estuary. Within the model the 'before' or 'baseline' condition is based on real survey data and on scientific understanding about the conditions in the estuary at present. It is important to note that this scientific understanding includes, by necessity, a level of uncertainty (not least because of the variably that is inherent in natural processes), and that all the model predictions are contingent on that uncertainty and must be viewed in this context. These modelled changes are illustrated in Figures NTS2 to NTS5 and can be summarised as follows: -

(1) Water levels changes (Figure NTS2): For the majority of the tidal cycle, including at the top and bottom of the tide (i.e. at high and low water), there is no change in the water level. There are also no changes during any stage of the tide under Neap conditions. During the Spring tides, slight increases in water levels do occur during the times of maximum flow into and out of the realignment site (usually just +1cm although occasional increases of up to 2 to 3cm are observed). These increases occur as a result of the extra water flowing in and out of the estuary after realignment. They are transient events typically lasting for no more than 30 minutes. They do though, have a large spatial extent and at peak ebb periods on Spring tides are observed up most of the estuary (see Figure NTS2a). It occurs because at this peak ebb state the additional water leaving the realignment site causes a slight backing up of the ebbing tidal waters within in the main estuary. However, the changes are too small and transient to result in a perceptible change and no changes in water levels are likely to be observed. This is indicated in the water level variation plots in Figure NTS2b which show that the tidal curves for conditions before and after realignment are indistinguishable.

(2) Flow speed changes (Figure NTS3): For the majority of the tidal cycle, there are no changes in the flow speeds. During Spring tides though, flow speed increases of around 0.1-0.2 knot (or 5%-17% above baseline) occur during peak ebb and flood tide periods along the foreshore fronting the realignment site and also in patches extending across the channel to the east of Burnham-on-Crouch. These occur as relatively brief events lasting for 20 to 30 minutes. On Neap tides, similarly brief but much smaller increases of 0.07 knot (or 8-10%) are observed on peak ebb and flood periods. Similarly transient flow speed reductions are also observed in some areas (e.g. at the time of peak ebb at Wallasea Ness).

(3) Sediment erosion and accretion (Figure NTS4): The elevated flow speeds described above can cause equally small-scale and short-lived (typically no more than 30 minutes) increases in bed shear stress (i.e. the frictional forces exerted by water

flows on the sea bed). As with flow change they occur at peak ebb and are greater on Spring tides than on Neap tides. However, by taking account of the composition and stability of the seabed sediments, it is considered that bed shear stresses do not increase to levels that would result in a change to seabed erosion levels. Therefore, no discernable increases in sediment accretion were predicted for existing areas outside the realignment site.

(4) Suspend sediment concentrations: No discernable changes in turbidity levels (i.e. the amount of water-borne sediment) were predicted for areas outside the realignment site.

These results are also illustrated in Figure NTS5. This shows the water flow speeds and bed shear stress levels before and after realignment (once again for the worst-case condition of peak ebb and peak flood on a Spring tide). In each case the changes are shown to be relatively limited and the shear stress levels do not exceed the critical erosion thresholds.

Long-term estuary development

The regime modelling work indicates that over the longer term (period of 100s rather than 10s of years) the estuary will widen and deepen slightly across an area extending from the realignment site eastwards to the estuary mouth. Similar trends are predicted for the outer Roach. However, even over this period of time the expected losses of intertidal area are low (approximately 2ha in the Crouch and 0.5 hectares in the Roach).

Such changes are a consequence of the large habitat gains (an extra 108ha) provided by the proposed scheme and, when considering these losses, it should be borne in mind that erosion is currently progressing in the estuary at the present anyway and the realignment will help to mitigate for these losses. And also, after realignment, the estuary will have a more ‘sustainable shape’ (i.e. it will have a greater capacity to accommodate sea level rise and limit the impacts associated with coastal squeeze). These 2.5ha losses are also negligible when compared with the much larger losses in the Crouch that would occur if no managed realignment scheme was pursued and instead the Wallasea island defences were left to breach in an unmanaged way (with widespread flooding of the island and much larger volumes of water then passing through the estuary).

Development of the realignment site

Modelled observations of the flow speeds and tidal conditions within the realignment site itself indicate that there will be modest levels of sediment accretion due to the natural movements of suspended sediments in shallow areas. Over a Spring tide the rate of sediment accretion has been calculated to be around 0.1mm on each tide and if this occurred on all tides then the accretion rate over a year would be 7cm. However, over a Neap tide the modelling shows no change in sedimentation. Therefore, across the full range of tidal conditions the estimated upper limit for annual accretion would be around 3.5cm/year (i.e. midway between the zero change on a Neap and the 7cm change on a Spring). The model inherently assumes that there is an infinite source of sediment but on-site measurements and observations indicate that sediment availability is relatively low and in view if these findings the rate of accretion is not expected be between 1 and 3cm/year. Within the site, this sediment deposition will preferentially occur in the still waters of flooded land drains, borrow dykes and scrape areas. Flow speeds within the realignment site are relatively weak and there is no indication from the modelling that the site will erode or export sediment into the estuary. In view of the limited accretion, and the characteristics of the within-site flow regime, is expected to be sustainable over the long term.

Conclusions and Recommendations

The modelling work has indicated that the proposed realignment is likely to meet the PMG design criteria for the scheme. One of these criteria is that the site itself will provide the required coastal habitats for at least 50 years and this is indicated by the results, which show that the area will not be subject to high levels of erosion or accretion. There is also a need to show that the wider estuary will not be significantly affected. In this respect, the findings of the modelling work show that the changes which will occur in the estuary after realignment (as a response to the extra water in the system on each tide) are relatively small. There is no indication that the morphology of either the Crouch or the Roach estuaries or the main features or environmental and socio-economic value within them will be significantly affected by this scheme. The results of the short-term modelling effects for instance indicate that there will there no water level changes at high water to compromise coastal defences (especially Burnham-on Crouch) and there is no indication of erosion or accretion that could affect the Baltic Wharf, marina sites or shellfisheries. The lack of any accretion or erosion within the channel will also mean that navigable channels will not be adversely affected by this scheme.

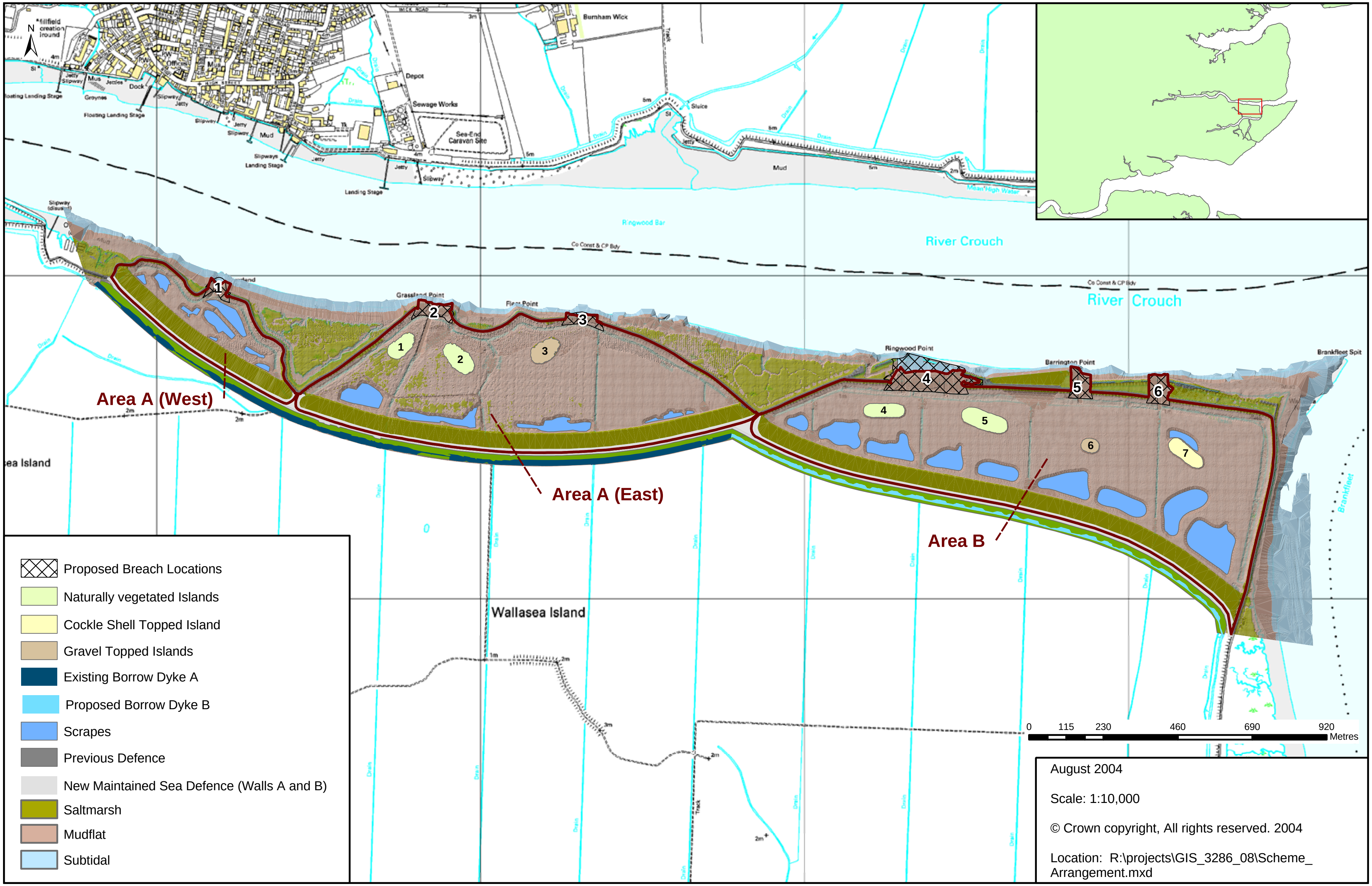
Although elevated flow speeds are predicted to occur for 20 to 30 minutes during ebbing and flooding tide periods, these will have no perceptible effect on the navigation of smaller vessels and recreational craft in the estuary over these periods. This is because they are of a negligible scale (0.2 knot maximum increase) and is unlikely even to be measurable in the context of the natural variability of flows speeds over a tidal cycle (on the Neap tides the increases would be much less at around 0.04m/s). These aspects will all be considered in greater detail within the impact assessment that is being conducted for this scheme.

The long-term morphological modelling indicates that the there may be a widening and deepening of downstream sections of the Crouch and Roach over periods of 100s of years. The predicted losses of intertidal habitats over this period are very low and this effect should be seen in the context of the large gains of such habitat that will arise from the proposed scheme. Also, any consideration of these changes should take account of the fact that, should realignment not be pursued in a managed way, the seawalls will breach 'naturally' in the future leading to widespread flooding of the low lying Wallasea Island and to significant effects on the estuary. This latter point was made in the Environment Agency's Roach and Crouch Flood Management Strategy as part of its recommendation for managed realignment along the north bank. The Strategy also notes that the estuary will be more sustainable as a result of this realignment work. All these findings are summarised in Table NTS1.

Table NTS1. Summary review of the physical changes occurring following realignment (as predicted by the numerical models used in the study)

Parameter	Baseline Conditions in Crouch and Roach Estuaries	Changes Following Realignment on Spring Tides	Changes Following Realignment on Neap Tides	What Impacts do These Changes Have?
Water Volume	Across the whole of the Crouch and Roach Estuaries the water volume difference between low water and high (called the Tidal Prism) is 66 million m^3.	The tidal prism of the two estuaries will be increased on Spring tide by 1.7 million m^3 due to the extra water held within the realignment site at high water during these bigger tides. This represents an extra 2.5%.	The tidal prism will be increased on Neap tide by 0.8 million m^3 due to the extra water held within the realignment site at high water during these smaller tides. This represents an extra 1.2%.	These estuaries accommodate the extra volume of water moving on each tide by increasing water level and flow speeds during periods of maximum tidal flow. These effects of these changes are as described below.
Water Level	The tidal heights in meters above ordnance datum (ODN) at key stages of the tide in the estuaries are as follows: - HAT = 3.3m ODN MHWS = 2.9m ODN MHWN = 1.9m ODN MLWN = -1.4m ODN MLWS = -2.2m ODN LAT = -2.7m ODN	For the majority of the tidal cycle, there is no change in the water level. Slight increases occur during the times of maximum flow in and out of the realignment site (i.e. on flooding and ebbing tides). These changes are small (usually just ±1cm) however, short-lived (typically no more than 30 minutes) increases of up to 2-3cm are occasionally observed. These minor and transient changes do have a large spatial extent, especially on the ebb tide when they are observed along the length of the estuaries. See Figure NTS2	The changes predicted following realignment are negligible throughout the whole tidal cycle and do not exceed ±1cm. In both modelling and practical terms this represents no discernible change.	The modelling shows that there will be no discernible change over the majority of the tidal cycle including periods of high water and low water. Any predicted changes are minor and transient on Spring tides and do not occur at all tidal states (e.g. not on Neap tides). Therefore, the impact on coastal defences will be insignificant.
Flow Speed	The part of the Crouch estuary in front of the proposed realignment site exhibits maximum flows during Spring tides of around 0.6m/s (1.2 Knot) on the flood tide and are slightly stronger on the ebb at around 1m/s (2 knot). On a Neap tide the peak flows during ebbing and flooding periods are around 0.4-0.5m/s (or 1 knot).	No changes in flow are observed over the majority of the tidal cycle but transient, small-scale increases occur at times of highest flow in and out of the realignment site (i.e. on flooding and ebbing tides). The increases are around 0.05-0.1m/s (0.1-0.2 knot) and typically last for 20-30 minutes and no more than 1 hour. These represents 5-17% increase above baseline. These effects mainly occur in front of the eastern half of the site east and are mainly observed during flooding periods and to a lesser degree on the ebbing tides. See Figure NTS3. Smaller changes (±0.1 knot) are observed in some parts of the upper Crouch for brief periods and mainly at times of peak flood.	As with Spring tides, changes are observed at times of highest flow in and out of the realignment site but these changes are lower because there is a less water being moved on a Neap tide. Near the breaches increases in flow are observed during flood and ebb periods of up to 0.04m/s (or 0.07 knot) that last for 20-30 minutes. These represent an 8-10% increase above baseline. In the middle of the channel, no changes are observed on the flood but on the ebb there are maximum changes of 0.03m/s (or 0.06 knot) that again last for 20-30 minutes. Across the rest of the estuary any changes are negligible.	As with the water levels changes, the changes in flow speeds are transient events occurring only during periods of maximum flow). These represent minor changes that will not be discernible in the estuary. They also occur away from the main moorings and marinas in the estuary. Therefore, no significant adverse effects on navigation or moorings are predicted. See Figure NTS5
Seabed Accretion and Erosion in the Estuaries	Recent Studies (Halcrow/EA 2003, Posford Haskoning 2002) and site observations Ron Pipe (pers. comm.) indicate that the channel, shoreline and saltmarshes near the realignment site are eroding. Subtidal accretion is taking place in other areas of the Crouch (at the mouth and upper estuary). These changes are thought to be occurring as the estuary responds to previous reclamation and coastal squeeze but may also reflect the variation in the 18.6-year lunar nodal cycle. At present the Bed Shear Stress (BSS) levels (which describe the frictional force exerted by flowing water on the seabed) on Wallasea's north bank foreshore are around: 0.5-0.8N/m^2 on peak Spring flows and 0.2-0.4N/m^2 on a peak Neap flows. In the estuary channel they range from 1.4-1.9N/m^2 under ebbing and flooding periods. The sediment model also indicates that erosion and accretion occur at around ±0.15-0.75mm/tide on a Spring tide.	The flow speed increase occurring after realignment results in BSS increases and, as they are coincident with the flow changes, they occur as transient events typically lasting for around 30 minutes and in estuarine areas fronting the eastern half of the realignment site. The increases in the estuary range from 0-0.17N/m^2 (i.e. an increase above baseline levels of around 9%). See Figure NTS4. The sediment model shows both erosion and accretion across the intertidal with typical changes on a Spring tide of around ±0.01-0.05mm (i.e. an increase above baseline levels of up to 34%) on each tide and maximum changes of ±0.26mm/tide. In the channel it shows erosion on a similar scale (i.e. ±0.01-0.05mm each tide).	The BSS increases that accompany the Neap tide flow changes range in the estuary channel from 0-0.05N/m^2 (i.e. an increase above baseline levels of around 10-13%). The sediment model shows no discernible erosion occurring in the estuary and describes accretion patterns of <0.04mm/tide. The low velocities occurring on a Neap tide result in a significant reduction in the mobility of sediment.	The minor and transient increases in BSS levels are not considered to be sufficient to cause erosion of the seabed because they do not exceed 1.83N/m^2 which is the identified critical erosion threshold. While the sediment modelling has indicated some change in sediment erosion/accretion in the estuary, the findings from fieldwork and historic changes in the estuary suggest that sediment availability and mobility is low and that changes will only occur on the largest tides. Hence these results represent a conservative estimate of change due to the assumptions used within the model. On this evidence therefore, no significant effects on the erosion or accretion effects are predicted that could affect shellfish beds or estuary morphology predicted. See Figure NTS5. However, significant effects would occur if realignment was not pursued in a managed way but instead the Wallasea Island defences were left to breach naturally (leading to widespread flooding of the island and significant water volume inverses in the estuary).
Suspended Sediment	Suspended Sediment loads are typically 100-1000mg/l in Essex estuaries. The ABPmer field survey (March 2004) recorded levels of 12-163mg/l in the Crouch and Outer Roach. Environment Agency survey in 2001 recorded a maximum of 1274mg/l in the Outer Roach although these data indicate that turbidity levels were generally lower in the Crouch and a maximum of 74mg/l was recorded at North Fambridge (Halcrow/EA 2003).	The model indicates that there will be no discernible change to suspended sediment loads even under Spring tide flow periods.	No discernible change is predicted on Neap tides.	As the model indicates that there will be no change to the existing suspended sediment concentration no significant adverse effect on ecology of shellfisheries are predicted.
Conditions in the Realignment Site	Only relevant after breaching	Modelled observations indicate that there will be modest levels of sediment accretion in the site. Under Spring tidal conditions an accretion rate of 0.1mm/tide was predicted. Such accretion will preferentially occur in the still deeper waters of flooded land drains, borrow dykes and scrapes.	Over Neap tides no discernible sedimentation is predicted within the realignment site.	As there is no movement on Neap tides, the maximum levels of accretion within the site are 3.5cm/year (i.e. mid-way between the zero change on a Neap and a theoretical 7cm annual change for only Spring tides). There is evidence that sediment availability may be relatively low and thus it is estimated that accretion be between 1-3cm/year. Given the flow conditions in the site no erosion and export of sediment from the site is expected.
Long Term Estuary Development	The estuary is believed to be still responding to previous interventions and changes (reclamation, realignment and seawall failures). It is eroding in parts and accreting in other and will take more than 100 years to achieve equilibrium form (Halcrow/EA 2003).	Over a period of centuries the estuary will widen and deepen slightly across an area extending from the realignment site to the estuary mouth. Similar trends are predicted for the outer Roach. Over this time period, the expected losses of intertidal area are 2ha and 0.5ha in the Crouch and Roach, respectively. This is a negligible change over this extended and indefinite time-scale		In view of the low level of impact (2.5ha of intertidal habitat lost) and the long duration of the effects (100s of years), the impact on the estuary will be minor. Also realignment at Wallasea will enhance the long-term sustainability of the estuaries (i.e. their ability to cope with sea level rise and impacts associate with coastal squeeze). This is why it is recommended in the EA Flood Management Strategy (Halcrow/EA 2003).
NB	All predictions are based on both survey data and scientific understanding about existing conditions in the estuary at present. The scientific understanding includes, by necessity, a level of uncertainty (not least because of the variably that is inherent in natural processes), and therefore all the model predictions are contingent on that uncertainty and must be viewed in this context.			

Figures



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Schematic description of the proposed realignment scheme at Wallasea showing the three hydrodynamic areas and key design features

Figure NTS1

Fig A) Map showing **maximum water level change (m)** in estuary after realignment site (occurring during periods of fastest flow out of the site)

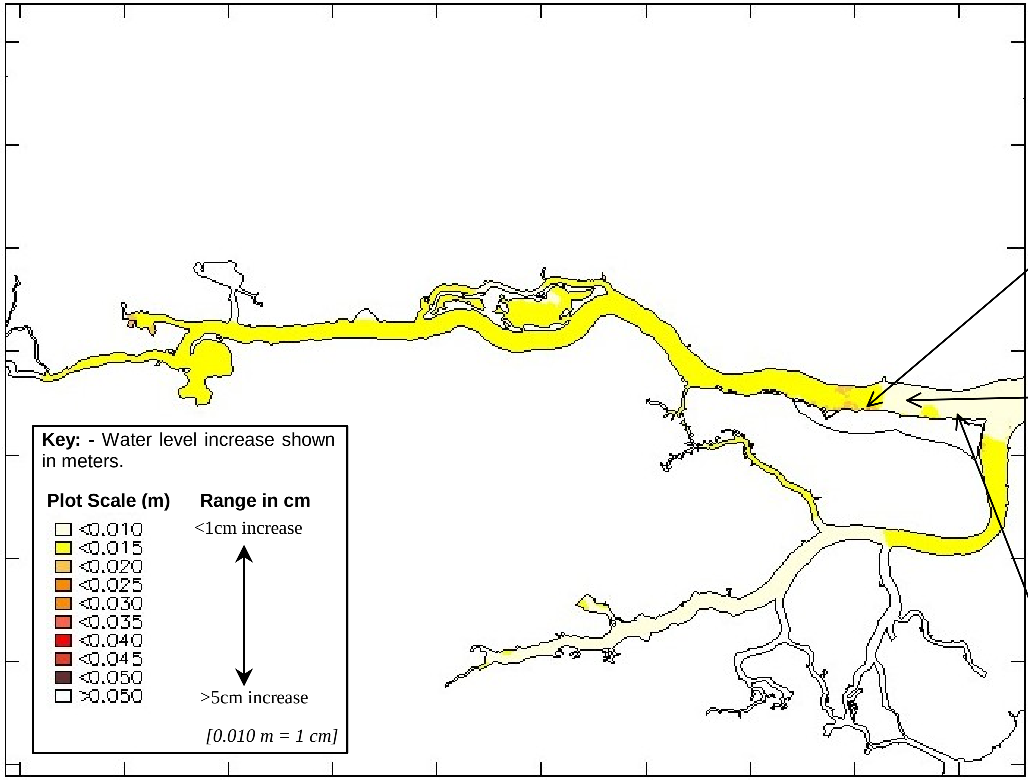
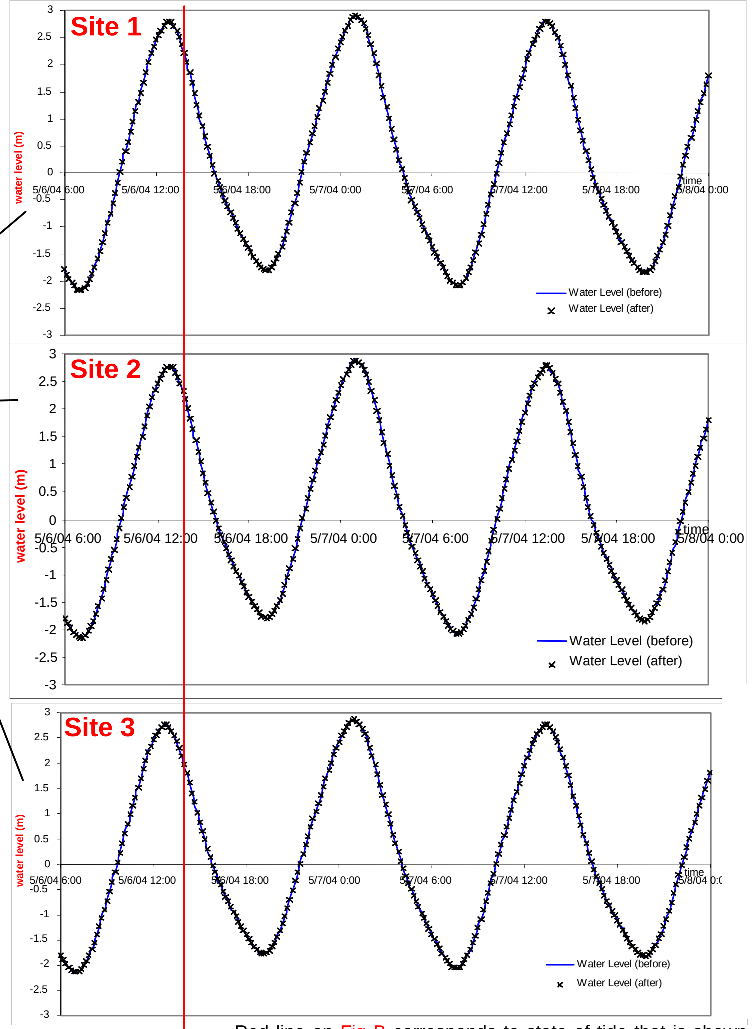


Fig B) Water levels before and after realignment at three locations **over a two day Spring tide period**



Red line on Fig B corresponds to state of tide that is shown in Fig A (NOTE - at this point in the tide the water levels have dropped by nearly ½m before the 2cm increase is observed)

For the majority of the tidal cycle, there is no change in water level. Slight increases occur during times of maximum flows in and out of the realignment site (usually ±1cm although **occasional increases of 2 to 3cm** are observed) on Spring tides (no change is observed on Neap tides). These increases occur due to the extra water flowing in and out of the estuary and are short-lived events typically lasting for no more than 30 minutes. While they do have a large spatial extent (see Fig A above) they are too small and transient to result in a perceptible change. This is shown by the water level variation plots in Fig B which indicate that the tidal curves for conditions before and after realignment are indistinguishable.

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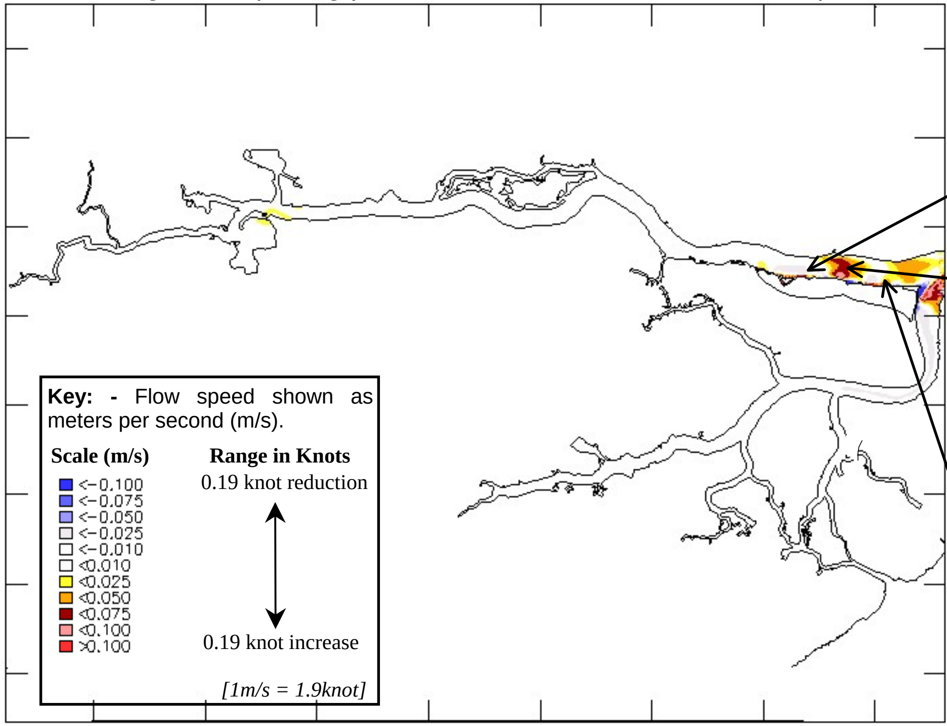
Water level changes as a result of the proposed realignment

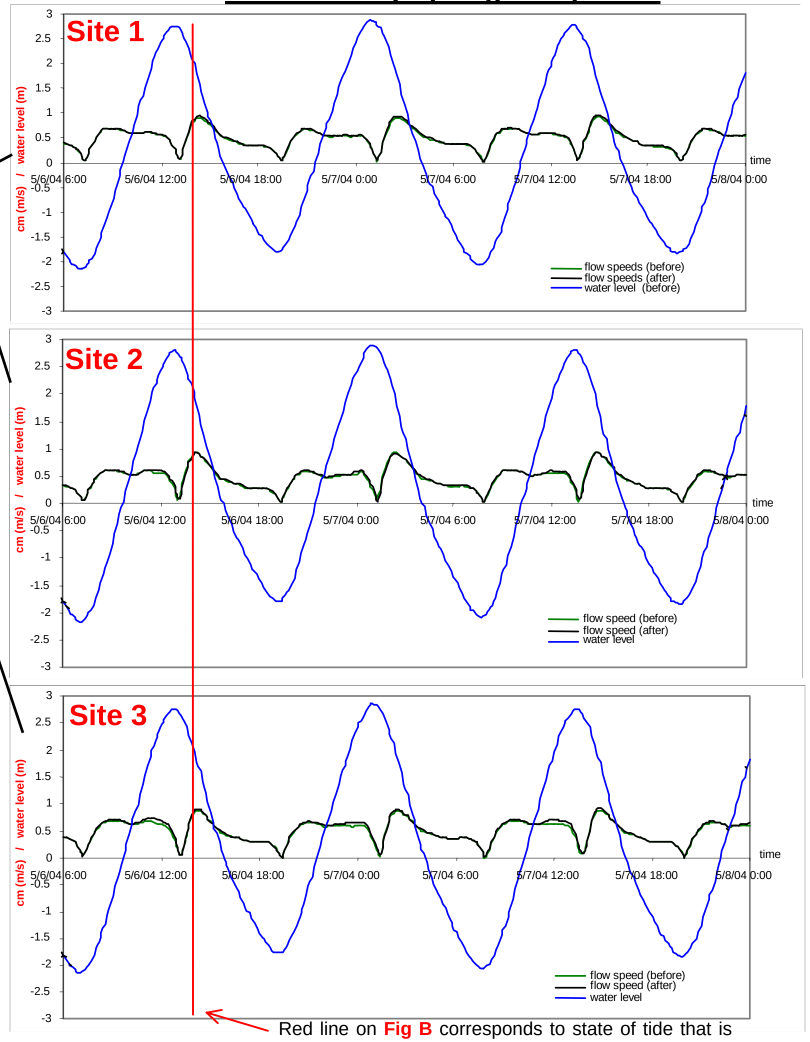
Figure NTS2

Fig A) Map showing **flow speed changes (m/s)** in the estuary after realignment (during periods of fastest flow out of the site).



For the majority of the tidal cycle, there are no changes in flow speeds. Transient small-scale increases do occur at the times of highest flow in and out of the realignment site. The maximum **increases are around 0.1 to 0.2 knot** (5%-17% above the existing flows) and are short-lived (typically lasting for 20-30 minutes and no more than 1 hour). These effects mainly occur in front of the eastern half of the site (**Fig A**). The duration of these changes is indicated in **Fig B** which also shows that it is only at the very most easterly location (**Site 3**) where changes to the flow are discernable. On Neap tides, similarly transient but much smaller increases of 4-7% (or an extra 0.07 knot) are observed on peak ebb and flood periods

Fig B) Flow speed before and after realignment at three locations **over two day spring tide period**



Red line on **Fig B** corresponds to state of tide that is shown in **Fig A**

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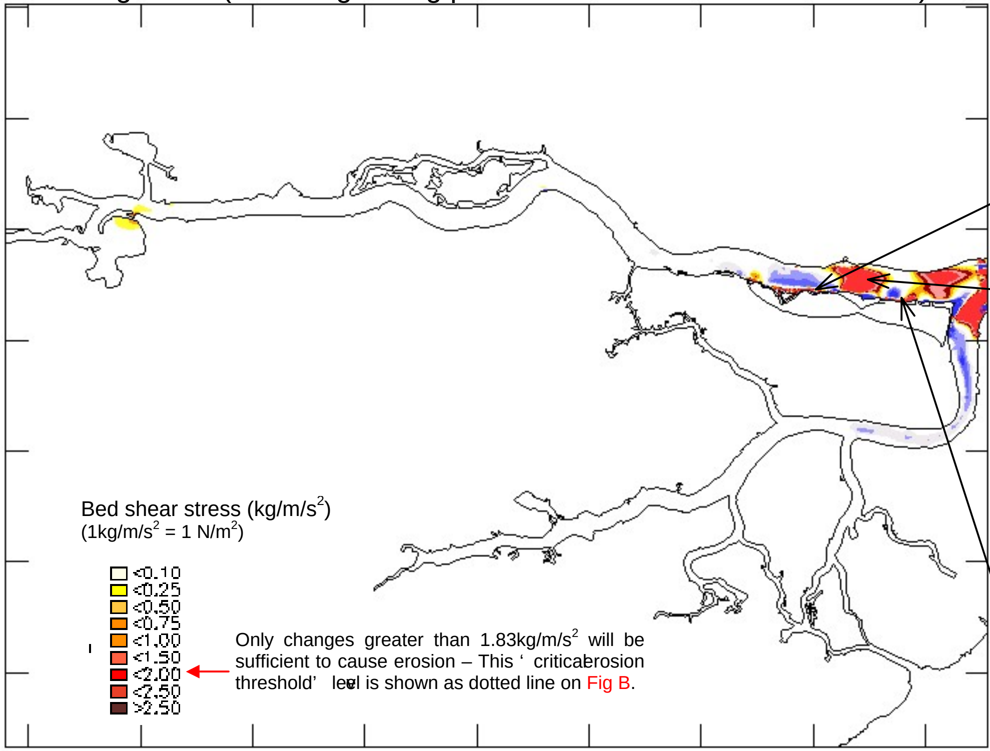
Flow speed changes as a result of the proposed realignment

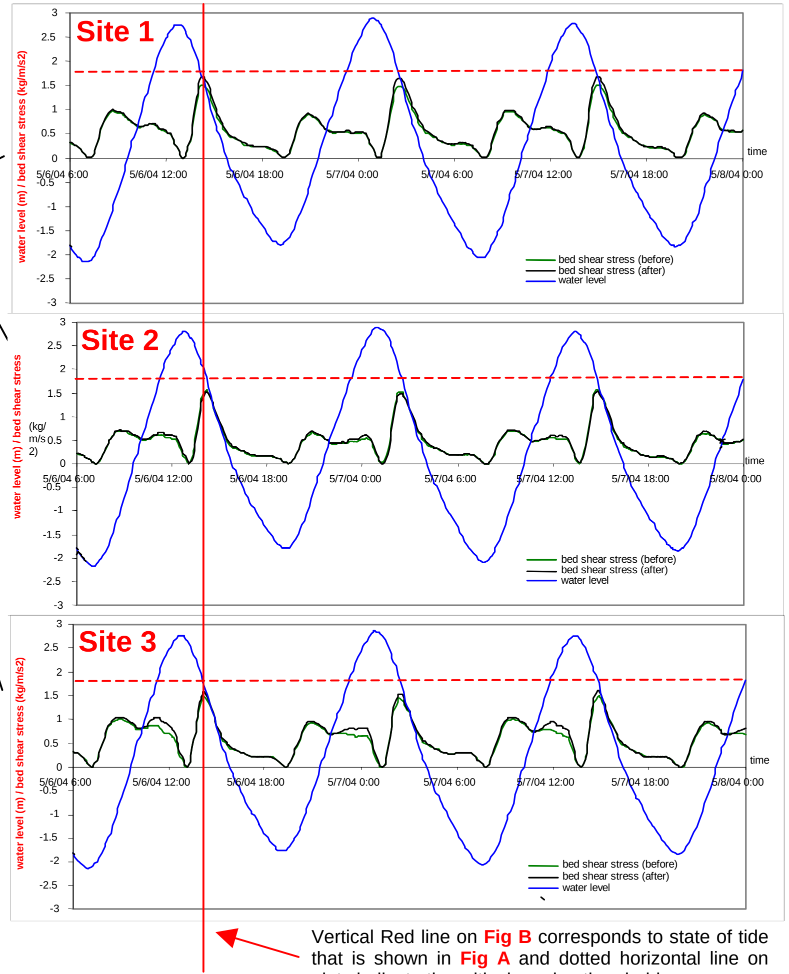
Figure NTS3

Fig A) Map showing **maximum bed shear stress (kg/m/s²)** in estuary after realignment (occurring during periods of fastest flow out of the site)



After realignment the transient flow increases described in **Fig NTS3** result in Bed Shear Stress (BSS) increases (BSS levels indicate the friction effects on the seabed). As with flow changes, they are short-lived events, typically occurring for no more than 30mins during peak ebb and flood periods in areas to the east of the site (**Fig A**). **Fig B** shows that there is limited change even during a Spring cycle when flows are fastest and that levels do not exceed 1.83kg/m/s² which is the critical erosion level. Therefore, these changes are considered to be insufficient to cause erosion of the sediments.

Fig B) Bed shear stress before and after realignment at three separate locations **over a spring tidal cycle**



Vertical Red line on **Fig B** corresponds to state of tide that is shown in **Fig A** and dotted horizontal line on plots indicate the critical erosion threshold.

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Bed shear stress changes as a result of the proposed realignment

Figure NTS4

Fig A) Water flows before (peak ebb)

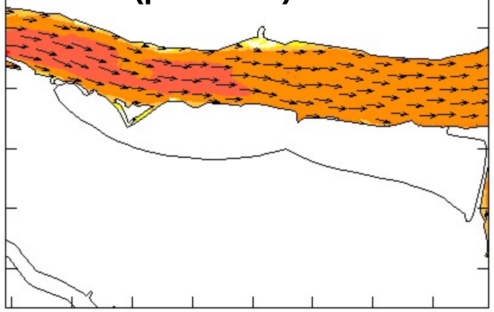


Fig C) Water flows before (peak flood)

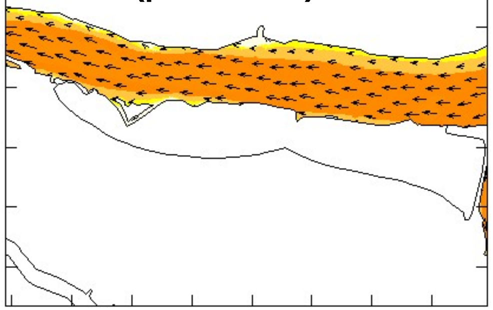


Fig E) Shear Stress before (peak ebb)

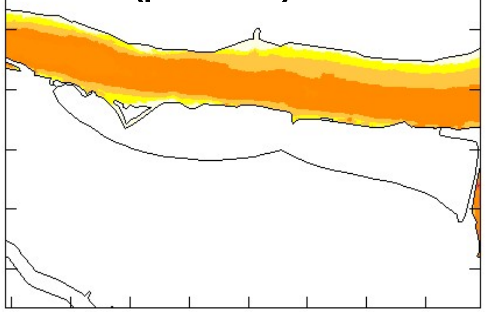


Fig G) Shear Stress before (peak ebb)

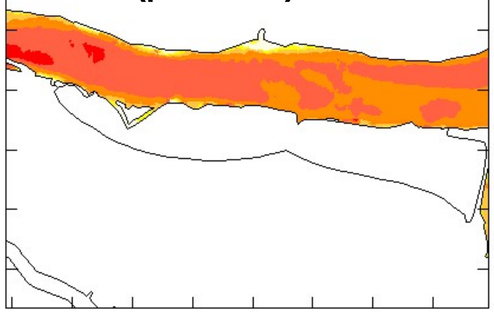


Fig B) Water flows after (peak ebb)

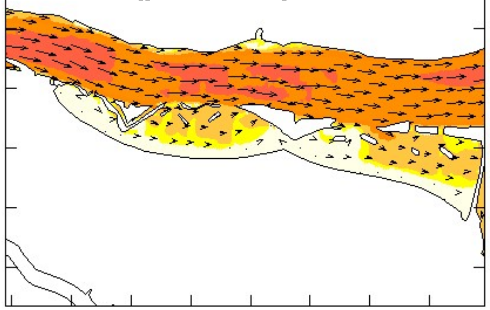


Fig D) Water flows after (peak flood)

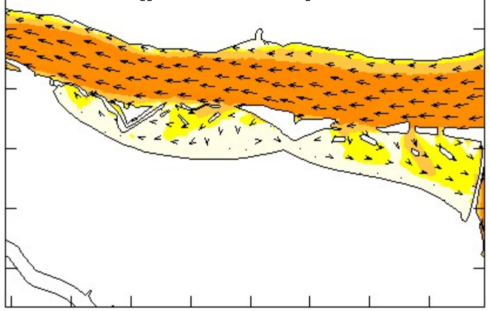


Fig F) Shear Stress after (peak ebb)

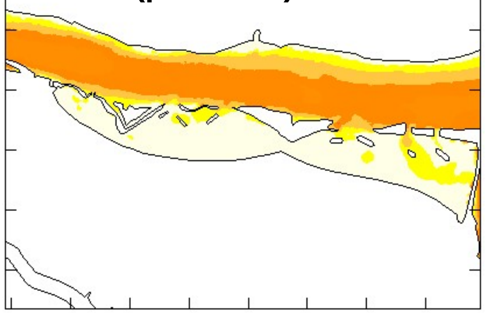
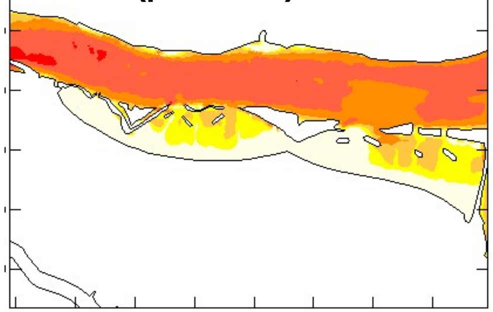


Fig H) Shear Stress after (peak ebb)



Scale (m/s)	Scale (Knots)
<0.1	<0.19 knot
<0.2	
<0.4	
<0.6	
<0.8	
<1.0	
>1.0	>1.9 knot
0.500	*[1m/s = 1.9knot]*

Figs A to D) Show **flow speeds** before and after realignment during 'worst-case' conditions of peak ebb and flood on Spring tides. Note the similarity of the conditions in the estuary before and after (as described in Fig NTS3).

Shear stress (kg/m/s^2)
(1kg/m/s^2 = 1 N/m^2)

- <0.10
- <0.25
- <0.50
- <0.75
- <1.00
- <1.50
- <2.00
- <2.50
- >2.50

Figs E to H) Show **Bed Shear Stress** levels before and after realignment during 'worst-case' conditions of peak ebb and flood on Spring tides. Note the similarity of the conditions before and after (as described in Fig NTS4) and also that levels after realigning don't exceed critical erosion level of 1.83 kg/m/s^2

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Comparison of water flow speeds and bed shear stress before and after the proposed realignment

Figure NTS5

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