DECC

SEVERN TIDAL POWER

Feasibility of Large Scale Managed Realignment

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EXECUTIVE SUMMARY

Executive Summary

The Department of Energy and Climate Change (DECC) has undertaken a study of the feasibility of tidal power generation in the Severn Estuary. As part of this study, a Strategic Environmental Assessment (SEA) was prepared together with information to inform a Strategic Appropriate Assessment. This study is one strand of work within the feasibility study. The driver for this particular study is the concern that there could be insufficient habitat compensation opportunities around the Severn Estuary to meet the needs of the STP alternatives if such schemes were to go ahead. As such, the provision of large scale intertidal habitat could be required outside the Severn Estuary.

This re-alignment study provides part of the evidence base informing the identification of a toolkit of possible measures that might be applied to provide compensation for the effects of a STP scheme. This study has two separate components; the first considers the feasibility of delivering substantial areas of managed realignment (MR) by focusing on the feasibility and associated costs of scaling up the size of individual realignment sites. The second component is a small GIS assessment to identify the potential scope for MR within the Severn Estuary taking account of predicted water level changes arising from the STP alternatives. This second, smaller component contributes to other STP studies focusing on the Severn Estuary and is reported separately as Appendix 3.

In advance any decision on STP alternatives being made or HRA compensation package being developed, this stand alone study therefore investigates the feasibility of creating large scale intertidal habitat (mudflat and saltmarsh) in sites greater than 500ha; it does not assess their applicability as compensation for any tidal power alternative.

This is based on advice that a ‘large sites’ approach may be the most practical way of meeting large overall habitat creation targets should they be required as compensation for a STP option. It is also assumed that larger sites will provide greater provision and diversity of habitat with associated ornithological benefits, than a number of smaller, unconnected sites. The geographical scope of the study is England and Wales where there is potential availability of suitable sites.

The methodology follows a desk based approach focusing upon developing high level costs using three case studies. It has been compiled using Government held or public available datasets, no site visits have been made or site specific data collected as part of this investigation. The output of this study is this stand alone report which provides costs per hectare for large scale MR.

Case studies have been used as a representative sample to test the implications of scaling up MR. This was not a site selection process and the study was not designed to select sites for MR; all reference to the particular case study areas has been removed.

The study has found that it is possible to create large scale intertidal habitat with limited engineering intervention. It has also found that there are no *new* technical barriers associated with “large scale” MR other than those already encountered in MR schemes completed to date. However, the scale of the “large” projects would be such that the engineering costs would be higher and the risk of encountering unforeseen issues is greater and mitigation likely to be more costly than for existing MR. The study has found that it would be beneficial for large scale MR to follow a low-intervention approach which works with natural processes.

Site specific issues and considerations are seen to be the most important driver for the cost of large scale MR schemes and the cost of the case studies per hectare of habitat created has not shown any correlation with scale. Therefore it can be concluded that effective site selection is the most important factor affecting cost.

Issues associated with land acquisition will be much greater than experienced with MR schemes to date and this is due to the scale of land required. Statutory delivery routes may be required such as an Act of Parliament or compulsory purchase and effective public communication and engagement will be a vital component in managing costs and programme.

The baseline average cost per hectare of habitat created is approximately £53,000. This cost rises by approximately £2,000 and reduces by over £8,000 to under £45,000 per hectare different cost scenarios. These figures are quoted without optimism bias. With optimism bias the baseline cost rises to £85,000 per hectare. The study has followed a conservative approach to project costs, particularly with respect to the design of the rear embankment (including a 1:200 standard of protection, 1.5m freeboard and import of fill material) and the 50% rather than 30% allowance for design, consultancy and consenting. This approach is reflected further in the additional 60% optimism bias and as such could be an over-estimate. The Steering Group has noted that the cost estimates appear high, particularly when reviewed against the more recently completed projects. Therefore the low scenario costs with optimism bias of £71,500 may be applicable.

Large scale MR will affect the sediment transport and flow patterns outside the site which could result in significant environmental impacts. However, the case studies have shown that such changes may be manageable depending upon the nature and location of the realignment. There will be significant risks associated with proximity to designated sites and/or economic assets but these could be managed through site selection.

The programme and resource benefit of promoting a small number of large schemes is likely to greatly outweigh the alternative of developing many smaller schemes. The final approach will depend upon the scale of the compensation required by any STP alternative. There remain a significant number of key risks of taking forward such schemes and a number of these are listed below but the list is not exhaustive:

- Proximity to designated sites;
- Land purchase;
- Public acceptability;
- Implications of changes to hydrodynamic and geomorphological system for sensitive economic assets;
- Effective communication and engagement strategies;
- Presence of protected species;
- Site design and construction methodology; and
- Contribution to any habitat compensation package.

SECTION 1

INTRODUCTION

1 INTRODUCTION

1.1 Project Context

The Department of Energy and Climate Change (DECC) has undertaken a study of the feasibility of tidal power generation in the Severn Estuary. As part of this study, a Strategic Environmental Assessment (SEA) was prepared together with information to inform a Strategic Appropriate Assessment.

The Severn Estuary is internationally important for ecology and biodiversity and protected under international, European and national nature conservation legislation. The Conservation of Habitats and Species Regulations 2010 (the 'Habitats Regulations') transpose the European Habitats and Birds Directives into national legislation. These Habitats Regulations lay down strict procedures that must be followed for plans and projects within or adjacent to sites designated under the Directives.

A preliminary investigation (Severn Tidal Power – Preliminary Review of Possible Mitigation and Compensation Requirements under the Habitats Directive, ABPmer, September 2008) concluded that any tidal power development in the Severn Estuary is likely to have significant impacts on these sites, particularly including the following;

- Severn Estuary Special Area of Conservation (SAC) designated under the Habitats Directive;
- Severn Estuary Special Protection Area (SPA) designated under the Birds Directive;
- Severn Estuary Ramsar site (designated under the international Ramsar Convention); and
- Certain features in adjacent river SACs.

The Sustainable Development Commission (SDC) in its report 'Tidal Power in the UK' identified compliance with the Habitats and Birds Directives as a fundamental pre-requisite for any tidal power option in the Severn Estuary. If it is considered through the SEA, EIA and Habitat Regulations Assessment that the proposals would have an adverse affect on the features for which these sites are designated then appropriate 'compensation' would be required. The extent and type of compensation which would be required will depend upon the effect identified.

This study provides part of the evidence base informing the consideration of possible compensatory measures within the Severn Tidal Power feasibility study and focuses upon the feasibility of large scale intertidal habitat provision outside of the Severn Estuary. It has also reviewed the potential extent of areas suitable for mudflat and saltmarsh habitat behind existing sea walls within the Severn Estuary. Issues associated with the potential effects on specific habitats, bird or other protected species interests are outside the scope of this project and are being investigated through other studies.

Earlier investigations indicated the likelihood of habitat losses of 14,000ha to 20,000ha for the STP Cardiff-Weston Barrage option (DECC, 2009; Sustainable Development Commission, 2007). ABPmer (2008) estimated a 'plausible' area of 110,000ha around the UK within which coastal re-alignment may be possible, with limited engineering intervention, to create new intertidal habitat. This was a very high level first approximation working to broad assumptions. The 'plausible' area is not proven as a technically feasible area but should be seen as a theoretically possible area.

The scale of compensation required for some options could therefore be significantly larger than previous habitat creation interventions such as those being implemented as part of Flood Risk Management Strategies for the Humber, Thames and Severn Estuaries. As such, a new approach will be required.

Large scale can be considered in terms of the total extent of compensatory habitat provision and the scale of individual sites. A key issue for this investigation is the feasibility of scaling up the size of typical coastal re-alignment sites of a few hundred hectares to multi-thousand hectare blocks. Such sites are outside UK experience not just in terms of area but in terms of length of coastal frontage and depth of re-alignment.

1.2 Project Overview

The driver for this study is the concern that there could be insufficient habitat compensation opportunities around the Severn Estuary to meet the needs of the STP options if such schemes were to go ahead. As such, the provision of large scale intertidal habitat could be required outside the Severn Estuary.

Intertidal habitat includes two Severn Estuary SAC features, Atlantic saltmeadow and sandflats, and mudflats not covered by water at low tide. These habitats are also significant as supporting habitat for the Severn Estuary SPA bird populations. The study considers the feasibility of creating large areas of intertidal habitat but does not address their potential function as supporting habitat for birds[1].

This re-alignment study is therefore one project to inform the potential application of managed re-alignment within a toolkit of possible compensatory measures that might be provided. Any habitat provision would need to be made within the context of ecological coherence and be part of a specific compensation proposal should a project be taken forward.

This study has two separate components; the first considers the feasibility of scaling up individual MR sites using case study areas greater than 500ha. The second component is a small GIS assessment to identify the potential scope for MR within the Severn Estuary taking account of predicted water level changes arising from the STP options. This second, smaller component contributes to other STP studies and is reported separately as Annex 3.

[1] Having established that scaling up is a feasible measure to create intertidal habitat, the extent to which habitat could be targeted to deliver the required ecological function for SPA bird populations would require separate consideration.

In summary, in advance any decision on STP being made and HRA compensation package being developed, this stand alone study has investigated the feasibility of creating large scale intertidal habitat (mudflat and saltmarsh) in sites greater than 500ha.

This was based on advice that a 'large sites' approach may be the most practical way of meeting large habitat creation targets should they be required as compensation for a STP alternative. It also assumes that larger sites will provide greater provision and diversity of habitat with associated ornithological benefits, than a number of smaller, unconnected sites. The geographical scope of the study is England and Wales where there is potential availability of suitable sites.

The focus of this study is to investigate the feasibility of large scale managed realignment outside of the Severn Estuary. The study does not include assessment of habitat suitability with respect to requirements for compensation under Article 6 of the Habitats Directive arising from any STP alternative. The study is designed to test the feasibility of scaling up managed re-alignment and sites are included as a sample to test the implications of scaling up managed re-alignment. Their inclusion does not mean that they are the most likely sites or priority areas of site selection should a project be developed.

The methodology followed a desk based approach focusing upon the development of high level costs. It has been compiled using Government held or publicly available datasets such as OS Mastermap data, conservation data from the Natural England website and the Environment Agency's Unit Cost Database and Light Detection and Ranging (LiDAR) datasets. No site visits have been made or site specific data collected as part of this investigation. The study will be used as one of many strands of evidence to inform the feasibility of compensatory measures.

The project tasks were to:

- Review previous work and supporting literature and screen sites for suitability as case study areas.
- Investigate the three selected case study areas (environmental and technical constraints, habitat creation predictions) and associated sub-schemes and provide cost estimates for the case study scenarios.
- Review the wider issues and impacts associated with the realignment of large scale sites, in particular:
    - Criteria for promoting technically suitable compensation sites.
    - Appropriate levels of intervention and management of re-alignment and effects on timeline for delivery of ecologically functional habitat. Linked to this is the discussion of timeline and steps to develop a strategic level compensatory habitat proposal.
    - Measures that could be adopted to reduce risk and speed up delivery of compensatory habitat.
    - Identification of factors affecting cost.

- Risk based assessment of appropriate compensation ratios for large re-alignment sites/large areas of compensation.

- Any further studies that might be required to enable a project to be developed.

- The project has also considered the wider benefits of MR.

The primary output of the study is the production of indicative cost estimates on a per hectare basis and identification of the main factors influencing cost when implementing large scale managed realignment schemes.

A GIS re-calculation of the plausible area for habitat creation in the Severn Estuary using LiDAR data has also been supplied. This task was undertaken to support other STP SEA Studies and reporting the implications of the identified plausible area is outside the remit of this study. As such this aspect is reported as Annex C of this report and not discussed within the main report.

The project has been directly managed by DECC with audit and quality assurance provided by a Steering Group and technical experts. The Steering Group comprised representatives from the following organisations:

- DECC;
- Welsh Assembly Government;
- Department for Food and Rural Affairs (Defra);
- Countryside Council for Wales (CCW);
- Natural England (NE);
- Environment Agency; and
- Sustainable Development Commission.

Results of the case study screening and details of the proposed approach were submitted and discussed with the Steering Group. The locations of the three case study areas were agreed at a meeting in August 2009.

The study approach and preliminary results were presented at a Technical Workshop comprising of the Steering Group and technical experts from the Environment Agency, CCW, NE and Royal Society for the Protection of Birds (RSPB) in January 2010. These initial results were specific to the case study areas. The Technical Group provided comment and advice on the approach and the results and these have been incorporated into this report.

The most important outcomes of the Technical Workshop were:

- The cost of large scale MR should be based upon low-intervention scenarios (i.e. working with nature); ecological objectives should be set at the site selection stage to ensure the appropriate sites are chosen and promoted.

- Off-site costs are too uncertain to be included at this stage but an assessment of the risk of off-site costs should be included in the site selection process.

As a result, it was agreed that the inclusion of a high intervention scenario with significant land modification was not appropriate.

The Steering Group and workshop delegates have also commented on a previous draft of this report. Due to the nature and sensitivity of the study, all references to the case study areas have been removed.

1.3 Case Studies

This investigation has used three case study areas to develop the costs associated with large scale managed realignments. The purpose of the case study approach is to generate an understanding of the issues, costs, benefits and general feasibility of large scale MR.

The case studies were identified by undertaking a two phased review of those sites identified in the previous investigation. A short list of 14 sites was submitted to the Steering Group for discussion and three case study areas were chosen. These provided a geographical and geomorphological cross section of potential study areas and sought to capture a range of issues which may arise around England and Wales.

The case studies were also of suitable size to allow the creation of sub-sites each being a minimum of 500ha, totalling nine scenarios. A further two sub-scenarios were identified, one due to its location being straightforward to develop as a separate scenario and the second as an amendment to the back line. The number of sites are summarised below:

- Site 1: Full site and two sub-sites (labelled as Scenarios A-C);
- Site 2: Full site and three sub-sites (labelled as Scenarios A-D);
- Site 3: Full site and three sub-sites (labelled as Scenarios A-D).

Indicative costs of implementing these sites were then developed. Where possible the project has used standard data sources such as agricultural land prices and construction costs from the Environment Agency's Unit Cost Database.

To provide a broader understanding of whether it is technically feasible to undertake managed realignment on such a large scale, the project team undertook some basic computer modelling of the case study areas using existing hydrodynamic models to determine if the sites could function as intertidal. The results were interpreted to provide a high level geomorphological and hydrodynamic understanding of how the sites could function and the potential effects on the wider system. These wider costs have been included within the discussion sections of the report but have not been monetised within the cost estimations due to the high level of associated uncertainty.

The case study analysis was discussed with the Steering Group and key experts at a Technical Workshop on the 15 January 2010.

1.4 Document Format

This document provides a summary of the project methodology and outcomes and is the second and final deliverable associated with this study. Case study locations have been omitted as these are not relevant to the purpose of this study which is concerned with understanding the feasibility of scaling up managed re-alignment and not site selection. Hence the case studies are only relevant as sources of data to inform general principles and do not imply that they are in any way preferred locations.

The Severn Estuary Reassessment has been undertaken as a stand alone task which is not directly relevant to this investigation but contributes to other workstreams. This task has therefore been reported separately in Annex C.

SECTION 2

METHODOLOGY

2 METHODOLOGY

The objective of this study is to identify the likely costs of implementing large scale MR through the use of case studies. The long list of potential case studies used the results of a preliminary review of possible mitigation and compensation requirements undertaken in support of the Phase 1 SEA investigations (ABPmer, 2008). These sites were reviewed and assessed to identify sites which represented different geographical locations and could provide a cross section of issues to be investigated and costed. A short list of sites was presented to the Steering Group and three case study sites were chosen.

The study identifies the potential for creating intertidal saltmarsh and mudflat and is intended to inform a judgement about the extent to which MR could be used as a compensatory measure by providing strategic level information about environmental and engineering feasibility, costs, impacts and potential benefits. It is recognised that habitat creation would require more detailed investigation if an STP option were to proceed. The study does not address issues concerning the sustainability of the potential habitats as compensation for impacts arising from any STP alternative.

Further detail on the cases study selection process is provided below. Although this is not a site selection process it is recognised that the assessments contain sensitive information. The matrices were drafted for internal use only and have not been finalised or included in this report.

2.1 Case Study Selection

The previous investigation identified 83 large scale sites around England and Wales. These criteria follow a similar approach to that undertaken by Bray & Cottle (2003) and the Coastal Habitat Management Plans (CHaMP) for the Greater Thames (ABPmer, 2007), Severn Estuary (ABPmer, 2009) and subsequent Severn Estuary Flood Risk Management Strategy (unpublished). These criteria were:

- Sites larger than 500ha;
- Tidal flood zone 3 data cut to 5km of coastline;
- Excludes urban areas as classed under the OS Strategic data;
- Excludes International and European (Natura 2000) sites (but includes sites adjacent to designated open coast and estuaries);
- All sites non-continuous (i.e. hydraulically stand alone); and
- Excludes railways and A roads.

To prepare for an assessment of the potential sites for suitability for case study areas a number of additional criteria were used to reduce the number of potential sites. The sites upstream of the proposed STP alternatives were excluded as the objective of the study is to investigate large scale MR outside of the Severn Estuary. Sites were also excluded if a significant proportion of the sites was already realigned or has substantial proposals for realignment (e.g. Bowers Marsh in the Thames estuary and

Medmerry near Pagham Harbour). To allow the case study areas to be sub-divided but still allowing the investigation of 'large sites' a number of smaller adjacent sites were combined to provide larger potential case study areas where appropriate and unconnected sites smaller than 1,000ha were removed.

The remaining sites were then assessed and scored as high, medium or low on the following criteria.

- Size of the site;
- Potential to achieve saltmarsh or mudflat habitat; and
- Level of technical and economic complexity/difficulty and thus a primary driver of cost.

The size of the site has been an important driver for the study which has a key objective of understanding the costs and issues associated with implementing large scale managed realignment. To generate the maximum amount of information the project team has developed smaller realignment options within each of the three case study areas enabling the project to consider a total of eleven realignment scenarios. The main habitat types to be sought comprise mudflat, sandflat and saltmarsh and the project team identified the likely habitat composition based on expert judgement with respect to the known elevation, location with respect to tidal processes, exposure and adjacent habitat distribution.

The third criterion - level of difficulty, had four sub-criteria; the likely level of positive and negative interactions with extant infrastructure (housing, utilities); the likelihood of negligible effect on adjacent estuarine/coastal system; the likelihood of negligible effect on protected species/habitats (adjacent & within site); and the likelihood of lower defence requirements (length, height).The four sub-criteria were drawn together to give an overall understanding of the difficulty/complexity at each site.

The analysis was submitted to the Steering Group and 14 sites put forward as case study options. The three case study areas were chosen to represent different geomorphological conditions and different levels of complexity.

2.2 Case Study Investigations

The case study investigations have three components; high level computer modelling to provide indicative information on the technical feasibility of realigning large scale sites; provide cost estimates for the implementing MR on those sites; discussion of the wider issues associated with large scale MR.

The computer modelling used existing hydrodynamic models (Mike21 and Delft3D) to provide information on the water levels and flows which are likely to result if the sites were breached. The models were not updated and no new data was collected or calibration undertaken. The objective of the modelling was to provide a high level understanding of how the sites would function rather than a detailed assessment. The modelling approach is robust for this high level feasibility study but it is recognised that significant detailed modelling and investigations would be required if such realignments were to be promoted. Allowance has been made in the case study costs for such investigations as part of the design, consultancy and consenting process.

This component of the Compensatory Measures work programme has sought to ensure linkages with the flood defence components of the STP SEA and the current flood risk management guidance for operating authorities. The project has used a base year of 2020, taken to be the first year of operation. The climate change and flood risk parameters used in the assessment are listed below:

- Baseline date of 2020;
- Standard of protection to a 1:200;
- 50 years of climate change for standard of protection (2070 for defence height);
- 100 years of climate change for habitat predictions (end year 2120);
- Defra sea level rise guidelines; and
- No other climate change parameters included.

Available extreme surge levels have been used with an appropriate Defra sea level rise allowance (no modelling required). More details on the engineering assumptions are provided in section 2.2.3 below.

The habitat creation predictions have been based upon water level projections over a digital terrain model. Input water levels have been drawn from the nearest available tide gauge to the case study areas. The habitat mapping has been calculated using proxy water levels as listed in the table below and assumes that the water levels at the rear of the site are the same as the entrance.

It should be remembered that this stand alone study is investigating the feasibility of large scale realignment and NOT the suitability of sites as part of any STP Compensation Package. As such, the use of proxy water levels is a robust assumption and follows a similar approach to that of the Environment Agency when predicting the likely habitat composition of potential MR sites. It is also recognised that if such sites were promoted, a review of the most applicable climate change parameters would be needed in support of the outline and detailed design investigations.

Table 1: Proxy water levels and associated habitats

Tidal Elevation	Habitat
MLWS-MHWN	mudflat
MHWN-MHW	pioneer/low saltmarsh
MHW-MHWS	mid/upper saltmarsh
MHWS-HAT	high saltmarsh
HAT+1	transitional grassland

2.2.1 Technical Feasibility

Basic hydrodynamic modelling has been undertaken for the case study sites to determine the hydraulic functioning of these large scale sites. This combined both the wetting and drying of the areas created and the wider effects of water levels and flows in the adjacent estuarine and/or coastal system. This was a high level investigation and used existing computer models for the relevant areas. No additional data was collected and no new calibration or validation of the models was undertaken. For case study area two, two existing computer models were linked together to provide suitable model coverage of the estuary complex.

The baseline costs have been developed based upon an assumption of limited site intervention. The modelling showed the need for the creation of a creek network to ensure tidal inundation across the site. The size and number of breaches and the extent of the creek network was estimated through the computer modelling and the costs for elements included within the construction costs. The baseline did not include any costs for additional land modifications which may be necessary to meet specific design parameters of the site and/or habitat required.

It should be noted that no LiDAR data was available for a large area of the case study two. Therefore, in order to fill the gaps left in the LiDAR data with an approximate value of the land elevation were taken from Google Earth. Owing to the large extent which needed to be covered by this method, a spacing of 500m to 1000m was used for the spot heights which were extracted from Google Earth and used in the numerical model. These values were relative to mean sea level and were corrected to the same datum (ODN). However, they are only given to the nearest metre and so must be considered as approximate values. As this is a high level investigation of the potential realignments this approach provides a sufficient representation of the topography within the site.

The key tasks undertaken were:

- Creation of Digital Terrain Models for three case study areas using LiDAR as the base dataset;
- Review rear extent of site;
- Tidal prism assessment;
- Breach assessment;
- Identification of breach locations and sub-scenarios (expert judgement);
- Complete model runs for two day spring tidal cycles;
- Production of rough model outputs for internal discussion and analysis;
- Habitat mapping (2020 and 2120); and
- Review of onsite and off-site changes.

2.3 Estimating Costs of Large Scale MR

The focus of the investigation has been the development of cost estimates for the eleven scenarios. An example of the spreadsheets is included as Annex A. The costs have been developed using industry standard cost estimates where applicable and expert judgement where standard data is lacking. More details on the source data is provided below.

The costs have been developed under the following headings:

- Land purchase (agricultural, residential and commercial);
- Construction; and
- Design, consultancy and consenting.

The costs have been provided with and without an additional 60% optimism bias. This reflects recent experience of planning and delivering smaller schemes. Although RSPB has noted that some of its projects have not fully realised this additional cost.

The construction costs have been developed assuming work is carried out in a single phase. However it is likely that such schemes would need to be designed and implemented following a phased approach to manage the risks such as those to protected species, a potentially limited construction window as well as managing the scale of construction equipment required to breach such large sites.

The methodology for developing the design, consultancy and consenting costs are provided in section 2.4 below. This has used expert judgement based upon knowledge of existing MR and similar schemes and the implications for the scale of these elements when 'going large'.

2.3.1 Land Purchase

This has been divided into agricultural land, residential property and commercial properties. The National Property Database (NPD) (version 3, 2008) was used to obtain land classifications in the sites. The land values used for costing purposes were current market values from the Royal Institute of Chartered Surveyors (RICS) Rural Market Survey H2 2009 (RICS, 2009) These were divided into pasture and arable land and were divided into regions across the country. The arable costs ranged from £9,884/ha to £14,827/ha and the pasture land costs ranged from £6,178/ha to £12,664/ha.

For residential properties the numbers and house type (detached, semi-detached, terraced and flat) were again taken from the NPD. The latest available market values were obtained from the Land Registry website (www.landreg.gov.uk/houseprices) where for example detached properties in the study areas ranged from £201,858 to £285,787.

Prices for commercial properties were developed based on individual properties from NPD data. A rateable value was obtained from the 'Valuation Office Agency' website (www.2010.voa.gov.uk) and a yield value was obtained from the Multicoloured Manual (MCM) (Middlesex University, 2005). From this the capital value was calculated.

It has become apparent however that the NPD does not make farms very easy to value. Farm houses are listed as residential properties (they are not specifically identified as farms in NPD) so have been valued by same means as residential properties. Some other properties are listed which share the same postcode as farm houses and could be outbuildings but no information is provided in NPD to enable a value to be determined easily. This means that the commercial valuations could be an underestimate of the true value.

2.3.2 Embankment Construction

Where the land at the back of the habitat site was not sufficiently high to act as a flood defence the cost of constructing an earth embankment has been calculated. Outline design was carried out to define the crest level of the embankment and its profile. The profile selected had a crest with a width of 4m to allow access and maintenance to be easily carried out. The sides had a 1 in 3 slope.

The crest height of the embankment was determined by adding 50 years of sea level rise to the extreme water level for a 1 in 200 year flood event calculated for the base year of 2020, providing an estimated water level in 2070. An allowance for free board was also added to this level, this was 1.5m. Such a considerable freeboard was required due to the large size of the habitat creation sites. Their size means that waves have a large fetch length to develop over. To cater for settlement an additional 5% of the required embankment height was added to the total height to be constructed.

LiDAR data was used to determine the height of the land at the back of the site. Points at 2m intervals were extracted and the volume of fill required calculated for each 2m length and was totalled for the entire embankment length. The embankment costs assume that the fill is imported and not sourced on site. The costs assume haulage of a reasonable distance but below the figures in the Environment Agency Flood Risk Management Estimating Guide. The cost of the construction was calculated using rates from the above Guide.

It is recognised that in many cases fill material could be sourced from site and as such it provides a conservative approach (overestimate).

To ensure the flood defence does not erode, rock armour was deemed to be necessary on the front face of the embankment. The portion of the embankment over which it was to be included varied along each site according to the vulnerability of the site to wave action and whether or not there are properties or infrastructure immediately behind it. The proportion of the embankment length over which the rock was required varied between a half and two thirds. An allowance was also made for a geotextile underlayer.

Outline design of the rock armour was undertaken and determined that the armouring would be made up from 2 layers. The underlayer is to be of a thickness of 0.35m (containing rock with a nominal diameter of 0.2m) and the top layer to be of a thickness of 0.85m (containing rock with a nominal diameter of 0.5m). The density of the rock was assumed to be 1.9T per m^3. A cost for the rock armouring using the total weight of rock required was developed based on other projects with input from a specialist Contractor.

The cost of excavating the breaches and channels within the sites was based on current charge rates for labour and plant and their outputs. The volumes to be excavated were calculated to build up this cost.

2.3.3 Road Diversions

There were very few road diversions that would be required within the case study areas. Most of the roads provided access to areas within the site itself rather than through routes. For the minor roads that would require diverting a rate for the work was obtained from the Spon's Civil Engineering and Highways price book (Langdon, 2007).

2.3.4 Service Diversions

A cost for decommissioning and removal of services for properties was estimated based per property. As a service search for the sites had not been undertaken a nominal cost was assumed for the diversion of unknown services that might be required.

Information on the location of electricity pylons was available from the OS MasterMap data set and expert judgement was used to provide a realistic diversion/decommissioning scenario. A cost for the diversion of these was estimated based on a rate provided by an independent power transmission specialist.

2.3.5 Surface Water Pumping Stations, Sluices and Outfalls

Due to the high level nature of this study the location of any pumping stations, sluices and outfalls were determined using OS maps and aerial views on the Google Website. It was assumed that those present would have to be reconstructed at the site of the new embankment. An estimated cost for the construction of a pumping station was £1.5M and that of a sluice or outfall was £250,000.

2.3.6 Demolition Costs

It was assumed that properties within the habitat site would have to be demolished after disconnection of services. A cost for this was assumed which varied according to the size of the property. Due to the difficulties in accurately determining details about commercial properties a nominal cost for each site was assumed. For example the cost of demolition of a detached house was assumed to be £10,000. A nominal cost was also used for the removal of roads within the site.

2.3.7 Contaminated Land

Relatively little is known about the previous use of the case study areas and it is therefore not possible to know the exact extent of contaminated land. It has therefore been assumed that a percentage of the old embankment which is to be breached contains material which is considered hazardous from a disposal point of view. A cost has been added to cover this. The percentage assumed ranges from 1 to 10 % where 10% has only been used for sites where there is known to be some kind of contaminant present.

The Environment Agency has noted that an allocation of 10% for removal of contaminated material is low and an estimate of 50% could also be considered to low. However, the assumption of 10% has been retained for the purpose of this study but it is recommended that any site screening process should include a contaminated land assessment and liaison with the Environment Agency to identify the risk of the presence of contaminated land.

2.4 Design, Consultancy and Consenting

To provide an understanding of the levels of uncertainty associated with developing costs at this stage, two methodologies were investigated to identify the potential costs associated with all other elements of the project excluding construction or land purchase.

Methodology A assumed the standard approximation for such elements of 30% of construction costs. This 30% includes all design, environmental impact assessment (EIA), surveys, investigations, consultations and all other aspects required to implement the scheme as a stand alone project (i.e. excluding any wider strategy costs). Within this study the 30% also includes fees for planning and other consents, legal fees and judicial review.

The Methodology B sought to identify costs for each element required for each case study on a case by case basis. The cost elements have been listed below and more information is provided in the blank cost spreadsheet provided as Annex A:

- Engineering design;
- Computer modelling;
- EIA Investigation/production;
- Consultation;
- Planning and consent fees:
    - FEPA (construction and/or dredging);
    - Coast Protection Act;
    - Harbour Works;
    - Flood Defence;
    - Abstraction/discharge;
    - Footpath diversions etc;
- Specific Investigations:
    - Ground Investigations;
    - Archaeological surveys/heritage mitigation;
    - Ecological surveys;
    - Unexploded Ordnance (UXO);

- o Dredging (including off-site);
- o Site Monitoring (including off-site monitoring);
- o Other (additional 10% of above surveys);
- o Protected species mitigation;
- o SSSI mitigation/compensation costs;

- Legal Fees:
  - o Compulsory purchase costs (legal fees and allowance for potential compensation);
  - o Judicial review or public enquiry;
  - o Allowance for risk of compensation to commercial interests e.g. navigation, fisheries (where identified); and

- Client costs.

It is recognised that the legal fees associated with land purchase and consenting could be significant. Allowances have been made within the cost breakdown for legal fees including £5m for Judicial Review or Public Inquiry. An allocation of 5% of total land purchase cost has also been added as an allowance for any compensation claims arising from the compulsory purchase or land purchase negotiations.

It is also recognised that other site specific issues which could require additional investigations or mitigation such as archaeology and unexploded ordnance pose a significant area of uncertainty. For this assessment an indicative allowance of £445/ha has been made for archaeology. For unexploded ordnance it has been assumed that 10% of the site may require survey unless specific knowledge of the site is known. An indicative cost of £810/ha has been allowed for unexploded ordnance surveys.

Costs were initially developed using both Methodology A and Methodology B following the spreadsheet format in Annex A. The case study specific costs (Methodology B) where then compared to the construction costs as illustrated in Table 2 below and a summary of the Methodology A and B costs are provided in Annex B.

Table 2: Methodology B % of construction costs

% of Total Construction Cost for Methodology B				
Scenario	**A**	**B**	**C**	**D**
Case Study 1	50	59	63	
Case Study 2	50	104	56	111
Case Study 3	32	33	32	14
Average	55	%		
Removing highest and lowest	53	%		

Table 2 shows that the average cost of all the design, consultancy and all other non land purchase and construction costs is 55%, removing the highest and lowest percentages gave a figure of 53% of the construction costs. This is a significantly greater cost than the standard 30%. When compared to other complex engineering project such as the STP project, buildings and other infrastructure, the construction elements for MR are relatively straightforward. However, the supporting environmental studies which will need to accompany such schemes will be detailed and complex in comparison. Furthermore, the area of land which will be inundated from MR is significantly greater than more traditional development schemes and therefore the survey costs for protected species, archaeology and other environmental factors are also likely to be greater.

The EIA, computer modelling and site monitoring costs will also be greater than recent MR schemes. This is due to the scale of such sites and the risk of off-site impacts (particularly in case studies one and two) and the detailed and robust investigations which would be required to support stakeholder consultation and the consenting process.

It should also be noted that all three case study areas are on coasts and estuaries adjacent to European nature conservation designated sites.

From the analysis of the case study site specific costs it is believed that the following factors are significant contributors to the design, engineering and consenting costs:

- The allocation of £1,000 per hectare for protected species;
- The presence of SSSI and the allowance of £20,000 per hectare for SSSI mitigation (particularly in Case Study 2)[2];
- Allowance of 5% of total land value for compulsory purchase compensation costs;
- The allowance of £5m for Judicial Review/Public Enquiry; and
- The allowance of £455 per hectare for site monitoring plus an indicative cost for off-site monitoring where it is known there will are economic assets which could be affected.

Based on the factors above it is considered that 50% of construction costs is a representative approximation for such sites and this figure has been used in the case study costs and sensitivity tests reported in this document.

2.5 Sensitivity Tests

To provide a greater understanding of the importance of specific line items, a number of sensitivity tests have been undertaken in discussion with the attendees at the Technical Workshop. The sensitivity tests undertaken are:

[2] SSSIs were not an exclusion criteria in the case study selection process and measures to mitigate or offset effects on SSSIs are included.

- Medium intervention scenario;
- Construction savings (reduction in construction costs of 20%);
- Construction savings (no rock armour required); and
- Property purchase.

2.5.1 Medium Intervention

The current STP SEA investigations (unpublished) have identified that mudflat is the most desired habitat for large scale MR. Discussion with the Steering Group has highlighted that for sites of this scale a pragmatic approach is likely to be the best approach with minimal engineering intervention and maximising the use of natural processes. The risk of the need for additional land modification, for example, to seek to engineer particular habitat types, has therefore been included as a sensitivity test. This sensitivity test reflects a medium intervention scenario and the costs for a high intervention scenario have not been included as it was concluded this would be a disproportionately high and not reflect the discussions on pragmatism and sustainability.

The medium sensitivity test assumes that an additional 10% of the total site area requires modification i.e. large scale land raising across a site would not be appropriate and any land lowering would be restricted in scale. Based upon information from the RSPB an indicative cost of £2,500 per hectare has been used for land modification.

For the creation of mudflat it is could be beneficial for the whole sea wall to be removed, thereby reducing the potential for site accretion. The medium intervention scenario therefore also includes an indicative cost of five times the cost of originally breaching the site for removal of the sea wall.

2.5.2 Construction Savings

The second and third sensitivity tests relate to construction costs. The project team has taken a precautionary approach to developing the engineering costs. As discussed above, the new rear wall alignments have been costed for protection against an extreme event in 2070 based upon Defra sea level rise predictions. An additional freeboard of 1.5m has also been added and the provision of rock revetment along sections of the rear alignment has been included. There are a number of uncertainties associated with these different elements, for example, the inland line may not require such a high standard of protection (depending upon the area benefiting from the defences), sea level rise predictions may be reduced, the level of freeboard would be reduced as more information supports the outline/detailed design process, and the extent and form of new intertidal may negate the need for rock armour protection.

The development of the creek network has also used standard estimates for excavating volumes of material. Cost savings are likely to be recognised if the scale or approach to creek excavation follows a minimal intervention approach although lower levels of intervention may reduce the certainty of resultant habitat creation or speed of habitat development.

Two sensitivity tests have therefore been included to explore construction uncertainties, a 20% reduction in construction costs and the removal of rock armour costs have been provided as sensitivity tests.

2.5.3 Property Purchase

Discussions at the Technical Workshop identified the sensitivity associated with land and property purchase. It was agreed that the study should not be identifying costs which may be over and above market prices. However, the costs have been derived from the NPD and ELM Consulting highlighted that from recent experience the NPD had underestimated property costs by approximately 50%. Therefore a property purchase sensitivity test has been included for property prices. No additional costs have been included to address agricultural land price or commercial estimation uncertainties.

2.6 Maintenance Costs

There will be ongoing maintenance costs associated with the MR sites, principally maintenance of the new rear walls and breaches, monitoring of the old walls as well as habitat management costs. The costs for these elements have been identified as:

- £100 per hectare per annum for intertidal habitat[3] (excluding mudflat which has no management costs associated with it); and

- £2.40 per metre per annum for sea wall maintenance[4].

The annual maintenance costs based on 2009 prices have assumed a flat annual spend profile for both the flood defence maintenance and habitat management. These maintenance costs are considered to be an overestimation in the short term as the new sea defences should not need any significant maintenance for 10-20 years. However as the sea defences age over time the maintenance costs will increase accordingly. The above costs are therefore an annual estimate over time. No costs have been included for any significant upgrade or the replacement of the defences after the 50 years design life of such structures.

No costs for further habitat mitigation or remediation have been included nor maintenance estimates (e.g. if the scheme fails to meet its ecological objectives). This assumption follows the standard approach for MR costings and it is expected that the risk would be identified, costed and managed through the scheme's Risk Register as the project is developed, designed and implemented.

The maintenance costs are provided in Tables 7, 11 and 15. The tables also give the annual maintenance costs as a percentage of the overall scheme cost to provide an indication of the significance of future expenditure.

[3] Based upon research undertaken by RSPB on its reserve management costs (unpublished).
[4] Based upon maintenance costs developed by the team in support of the Humber Estuary Management Plan (uprated from 2005 data).

2.7 Determining Price/Hectare of Habitat Created

The project is seeking to understand the likely cost per hectare of habitat created. However it is recognised that the MR itself may result in losses of existing intertidal area seaward of the case study areas through increased water levels. In some cases small areas within the case study areas have already been subject to habitat creation or already sustain intertidal habitats.

To provide a cost per hectare of habitat created these two components have been deducted from the original site area.

The predicted loss of existing intertidal habitats through changing water levels has been undertaken by using the Inverse Distance Weighted surface creation method in GIS (spatial interpolation) to calculate the areas of potential loss.

During project inception it was thought that the composition of intertidal habitat would be important in determining price per hectare and two scenarios were proposed; all saltmarsh/transitional grassland is acceptable and only mudflat and low/mid and upper saltmarsh is acceptable. However, as the project has progressed it has been concluded that this would significantly and unnecessarily inflate the cost of the schemes. Discussions with the steering Group have indicated that the focus for such sites should not be on providing like-for-like habitats in perpetuity but should focus on the delivery of large scale, sustainable intertidal habitat. Furthermore, when searching for suitable MR sites in reality, an assessment of likely habitat provision would be undertaken and only those sites which could provide the necessary habitat would be progressed as part of the site selection and decision-making processes. Therefore these scenarios have been omitted from this study.

2.8 Off-site Factors

It was originally proposed that off-site costs would be specifically included within cost estimations at a very high level and developed as a function of size and uncertainty using weighted estimations. Such off-site costs could result from:

- Changing water levels resulting in potential benefits/adverse effects on flood risk;
- Changing maintenance requirements for navigational channels;
- Changing maintenance requirements for existing coastal defences or waterside developments (harbour walls etc);
- Potential exposure of buried infrastructure (pipes, cables, training walls etc) or archaeology;
- Coastal/estuarine habitat change (habitat gains and losses);
- Potential risks to fishing and shellfisheries (water quality and flows); and
- Potential risks to other users (water levels and flows).

However, it has been significantly more difficult to determine the offsite factors than originally estimated. The offsite issues and other complicating factors are therefore included in the discussion section of this report. These include the opportunities and constraints associated with MR, land acquisition and compensation as well as benefits such as linkages with the shoreline management process.

SECTION 3

REVIEW OF MANAGED REALIGNMENT

3 REVIEW OF MANAGED REALIGNMENT EXPERIENCE

3.1 Introduction

To support the case study analysis the study has also undertaken a review of large scale MR across the world. From a review of available information it appears that there is little national or global experience of MR at the scale being investigated in this study. Of the 95 MR projects contained within the Online Managed Realignment (OMREG) database (www.abpmer.net/omreg) only two are of the size comparable with this study (i.e. over 500ha), both in Germany. One is a regulated tidal exchange[5] (RTE) scheme (850ha) and the second is a breach into a secondary dike (not for defence or people) to allow more effective water removal from the site following overwashing[6] (1750ha) (http://www.abpmer.net/omreg). The breach site has little or no saline influence. Little is known about either project although there appears to be an erosion issue at the RTE scheme due to the volumes and hence flow speed of the of water flowing through one of two sluices. Neither project appears to be directly applicable to this investigation.

3.2 Managed Realignment in the USA

ABPmer has undertaken a literature review of managed realignment in the USA and identified that there "are numerous regional initiatives concerned with wetland restoration which emerged during the late 1990s and hundreds of individual restoration projects have either been implemented or are currently being considered[7]. The restoration techniques applied range widely depending on local circumstances; the Louisiana Coastal Wetlands Conservation and Restoration Task Force's projects, for example, heavily favour the beneficial use of dredged material (essentially land claim) and vegetation planting (no MR projects per se could be found amongst the Task Force's projects) (Raynie *et al*., 2000). The Long Island Sound Estuarine Restoration Project (and a myriad of other smaller scale restoration projects) on the other hand seems to focus on hydrologic restoration through the installation of larger diameter pipes or culverts, where the tidal flow had been restricted through undersized structures (Long Island Sound Habitat Restoration Initiative, 2003 cited in ABPmer, 2009a)."

Crooks & Sharpe (2007) emphasised the similarity of Californian and British coastal systems (i.e. comparable meso-tidal setting, similar marsh inundation and colonisation patterns) and concluded that lessons from the San Francisco Bay restoration experience would be valuable to British practitioners. The Bay has either completed or in the progress of constructing over 11,300ha of wetland restoration

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[5] The regulated exchange of sea water to an area behind fixed flood defences, through engineered structures such as sluices, tide-gates or pipes, to create saline or brackish habitats (http://www.essex-estuaries.co.uk/glossary.htm)

[6] Overwash is the flow of water and/or sediment over the crest of the beach or bank (either through run-up or inundation) that does not directly return to the water body where it originated after water level fluctuations return to normal.

[7] See, amongst others, the Southern California Wetlands Recovery Project, the San Francisco Bay Habitat Goals Project, the Louisiana Coastal Wetlands Conservation and Restoration Task Force (cited in Callaway, 2005), the Delaware Bay Estuary Enhancement Program (Weishar *et al*., 2005), the Rhode Island Habitat Restoration Collaboration and the Long Island Sound Initiative (Long Island Sound Habitat Restoration Initiative, 2003).

with another 12,500ha planned (http://www.sfestuary.org/pages/home.php). The approach for implementing this scale of habitat creation appears to have been through estuary management (San Francisco Estuary Project began in 1987) with an associated management plan. The habitat projects range in size from less than one hectare to approximately 500ha (http://www.wetlandtracker.org) and therefore do not provide the necessary analogues for this investigation. In the Bay, restricted tidal exchange, limited sediment supply, and internally generated wind waves were described as the three most important physical process which can retard or prevent the ideal physical evolution of a realignment site (in combination, or isolation) (ABPmer 2009a).

This coordinated approach to MR appears successful and follows a similar approach to examples in the UK including the Humber Estuary Flood Risk Management Strategy and the Environment Agency's Regional Habitat Creation Programmes.

3.3 Managed Realignment in the UK

The difficulties associated with any managed realignment were identified by Defra (2002) which reviewed all MR in the UK and investigated experience overseas through literature reviews, questionnaires and workshops. The research identified the following key constraints to MR. "Major obstacles that were clearly identified by questionnaire respondents are the lack of financial compensation to land-owners, the need to provide compensatory habitats under the Habitats Regulations when terrestrial or freshwater sites are lost, and lack of public support. The issues, ranked in order of importance, which are relevant to this study, are:

- Insufficient financial compensation to land owners;
- Habitats Regulations;
- Potential loss of land with high property value;
- Lack of support from public opinion;
- Insufficient consultation;
- Potential high cost of Managed Realignment;
- Potential loss of terrestrial and freshwater habitats;
- Managed realignment is ineffective if carried out on a piecemeal basis;
- Lack of access to or information about suitable funding; and
- Difficulty of recreating an environmentally diverse habitat."

Due to the scale of the realignments the issues associated with land acquisition will be a very significant issue for such schemes. Historically the issues have focused around agricultural land purchase but in these instances the issues of residential and commercial properties will be at a scale not previously encountered, with small clusters of properties or entire hamlets being affected. The need for compulsory purchase is likely to be a very significant issue. The Defra research identified that one reason why the communities at Thorngumbald and Brancaster were broadly supportive of the realignment schemes is that the landowners directly affected were perceived to have been dealt with fairly, in that their land had been acquired by agreement (Defra, 2002). At such a scale the public and stakeholder consultation and engagement process will be a vital element for success.

A key driver for a number of the schemes will have been as habitat compensation due to coastal squeeze losses by the maintenance of existing sea defences. However, the consenting issues, particularly the timeline for consenting is likely to be much more complicated for any STP habitat compensation due to the scale of habitat that may be required.

Therefore there are a number of key steps which are recommended in support of any large scale MR proposals. These can be summarised as:

- Setting objectives for any compensation package;
- Define site selection criteria based on compensation objectives;
- Apply site selection criteria to develop options;
- Stakeholder and public engagement;
- Option selection; and
- Feasibility studies and site design.

3.4 Consents, Licences and Approvals

All realignments are subject to a number of licences, consents and approvals and the scale of the case study sites would require a wide variety and number of different such authorisations. Due to the nature and scale of the case study sites the most significant consent is likely to be the agreement of the relevant Minister for Compulsory Purchase for agricultural, residential and/or commercial properties. The two most commonly used powers of compulsory purchase are i) Compulsory Purchase Order (CPO), based on a specific Act of Parliament or ii) an Order under the Transport and Works Act 1992. Such case study sites are likely to require powers under a specific Act identified in i). Alternatively an Act of Parliament has been identified as a potential route for land purchase. The other likely consents, licenses, approvals and other authorisations which would be required include those under the following acts and regulations:

- Town and Country Planning Act (the sites could straddle different Parish/local administrations which could further complicate the issue;
- Coast Protection Act;
- Food and Environmental Protection Act;
- Water Resources Act;
- Land Drainage Act;

- Flood Defence (Land Drainage) Bylaws and Sea Defence Bylaws;
- Harbour Works Act;
- Highways Acts;
- Listed Buildings Consent;
- Wildlife and Countryside Act 1981 (as amended) (depending upon proximity to SSSI);
- Habitats Regulations (proximity to SPA/SAC designated sites may require the need for Habitat Regulations Assessment[8]);
- There may also be local arrangements in place that provide a legal basis for protection;
- Possibility for local bylaws, ancient rights or legally binding agreements for protection of land and property;
- Waste Management Licence Exemption; and
- Abstraction Licence Exemption.

The MR sites will require planning permission and be subject to EIA. Therefore other legislation and designations (e.g. Water Framework Directive, Areas of Outstanding Natural Beauty) and planning policies may represent a constraint.

The consenting route for a STP alternative and subsequent compensation package could affect the delivery of a MR. The issues are likely to be complex, particularly where realignment is being introduced to create compensatory habitat as part of a multi-site programme and/or if the development and the compensation sites are located in different areas of jurisdiction. This will be further complicated if the MR is adjacent or in the vicinity of a site subject to the Habitat Regulations.

[8] Also known as Appropriate Assessment.

SECTION 4

RESULTS

4 RESULTS

4.1 Habitat Creation Estimates

Table 3 presents an estimate of the likely habitats which could be created if realignment were to take place on the case study sites. The assessment is based upon the assumption that the schemes have been designed effectively. It also assumes that the water levels at the back of the site are the same as the front of the site. If water levels were constrained then the composition would reflect habitats higher in the tidal frame (i.e. more upper saltmarsh and transitional grassland). The predictions have used LiDAR data for the base topography along with water levels from the nearest available tide gauge to the site and climate change allowances using Defra (2006) sea level predictions. 2020 has been taken as the base year, reflecting the proposed implementation year for a Severn Estuary Tidal Power option.

Table 3: Habitat predictions

Habitat Predictions									
Scenario		A	B	C	D	A	B	C	D
Case Study 1									
	Year	2020				2120			
MHWN	Mudflat	1742	589	314	N/A	7953	3871	730	N/A
MHWS	Low/mid saltmarsh	6405	3382	491	N/A	485	146	294	N/A
HAT	Upper saltmarsh	178	49	130	N/A	186	18	103	N/A
HAT+1	Transitional grassland	288	18	176	N/A	82	6	53	N/A
Other	Grassland	150	15	74	N/A	57	9	12	N/A
Case Study 2									
	Year	2020				2120			
MHWN	Mudflat	8458	6546	3889	2657	9267	6893	3870	2730
MHWS	Low/mid saltmarsh	718	321	248	73	644	278	42	-
HAT	Upper saltmarsh	383	87	87	-	220	81	4	-
HAT+1	Transitional grassland	533	250	250	-	146	42	7	-
Other	Grassland	315	110	110	-	109	20	8	-
Case Study 3									
	Year	2020				2120			
MHWN	Mudflat	150	132	46	18	368	339	192	90
MHWS	Low/mid saltmarsh	1080	1060	870	260	1625	1604	1131	391
HAT	Upper saltmarsh	855	838	426	215	255	238	70	33
HAT+1	Transitional grassland	196	181	52	27	158	139	42	28
Other	Grassland	211	154	40	22	84	45	2	-

The table also presents predictions for 2120. However, these are based on predicted changes in water levels alone and do not take account of the possible accretion of the sites over the time period. The level of site accretion with respect to the pace of sea level rise will depend upon the local hydrodynamic conditions and sediment availability. This has not been investigated as part of this study but it is likely that there will be accretion in the short term but the rates may not keep pace with sea level rise in the long term when Defra sea level rise predictions are between 13 and 15mm per annum (Defra, 2006).

The results show that site one will provide low/mid saltmarsh as the primary habitat in combination with mudflat and limited high elevation habitats in comparison to the size of the site. Site two has a lower elevation with respect to tide levels and will predominantly provide mudflat habitat. The third case study area is higher in the tidal frame and will provide low/mid and upper saltmarsh as the predominant habitat types. Habitat distribution has also been assessed for 2120 taking account of sea level rise; the resulting habitat distributions show how the sites are subsequently lower in the tidal frame with the movement from saltmarsh to mudflat and low/mid saltmarsh.

The marine ecology chapter of the STP SEA has identified that the main inter-tidal habitat loss in the Severn Estuary as a result of the STP alternatives would be mudflat. Consideration of the case study sites shows that they have different potential for supporting mudflat. Case study two could provide significant mudflat provision in the short term. Case studies one and three would need significant engineering intervention to lower land levels sufficient to create the significant areas of mudflat, although case study one could become more suitable in the future with sea level rise. Hence of the three case study sites only one would form mudflat with minimal levels of intervention.

4.2 Case Study One

The results of the case study analysis are provided in the summary Tables 4 to 7. The results have shown that there is significant variability between the scenarios and between the case study areas. Each scenario is sensitive to costs with respect to each of the three components (land purchase, construction and other costs) with the topography, number of properties and other criteria all playing an important component in the construction costs. The significance of particular cost elements are discussed where relevant.

The habitat predictions in Table 3 above show that the habitat composition of the site is approximately 20% mudflat and 73% low to mid saltmarsh. If mudflat was the target for habitat creation, this site would be unable to deliver sufficient habitat without significant engineering intervention in the short term. However, with sea level rise the composition of mudflat by 2120 is approximately 90% (assuming no site accretion).

4.2.1 Scheme Costs

Table 4 below shows that there are small areas of intertidal or existing MR schemes within the case study scenarios. This investigation has also identified that the changes in water levels which may result as a consequence of scenarios A and B could result in some loss of existing intertidal areas. This predicted loss has been deducted from the baseline site size for the purposes of the cost per area of habitat created. Therefore 218ha has been deducted from the scenario A but all the available land within the scenario C can be counted for habitat gain. Table 4 also shows that there is some existing SSSI within the site boundaries but this is relatively small when compared to the scale of the scenario sites.

Table 4: Case Study 1 - Area of habitat created

Site Area for Calculation: Case Study 1			
Scenario	**A**	**B**	**C**
Total Site Area	8,919	4,114	1,198
Predicted loss from MR	86	30	0
Existing MR/intertidal	132	54	0
Total Ha for calculation	**8,701**	**4,030**	**1,198**
Existing SSSI	87	9	78

Table 5 below summarises the costs associated with the case study one scenarios. The table shows that without optimism bias the cost per hectare is between £37,000 and £55,500 per hectare. With optimism bias of 60% this increases to between £59,000 and £89,000 per hectare, showing a trend of reducing cost per hectare. This shows as size of the site increases there is an associated reduction in costs. This is primarily due to the construction costs reducing from 44% to 32% of the total scheme costs. Other key points are listed below:

- Scenario A: Land purchase is characterised as 68% agricultural land purchase; 20% property and 12% commercial;
- Scenario A: Embankment costs are 78% of total construction costs;
- Scenario B: Land purchase is characterised as 80% agricultural land; 19% property and 1% commercial costs;
- Scenario B: Embankment construction 78% of total construction costs; and
- Scenario C: Land purchase is characterised as 65% agricultural land purchase; 32% property and 2% commercial. I.e. there are significantly increased property costs for scenario C which is also likely to result in greater effect on local communities.

Table 5: Case Study 1 - Summary statistics

Summary Statistics: Case Study 1						
Scenario	**A**	% of Total	**B**	% of Total	**C**	% of Total
Area for site calculations (Ha)	8,701		4,030		1,198	
Land Purchase	167,417,617	51	66,564,684	44	22,470,364	34
Construction	105,145,758	32	57,498,120	38	29,356,774	44
Design, Investigations and Consenting (50% of construction)	52,572,879	16	28,749,060	19	14,678,387	22
Total	325,136,254	100	152,811,864	100	66,505,524	100
Price per ha	**37,368**		**37,919**		**55,514**	
Total including 60% optimism bias	520,218,007		244,498,982		106,408,839	
Price per ha including optimism bias	**59,788**		**60,670**		**88,822**	

The sensitivity tests are provided in Table 6 below. These show that the need for rock armour is the most sensitive element of the scheme and could reduce costs by 20%. The property purchase sensitivity increases the total cost by 4-5%. There remains uncertainty associated with the representation of commercial costs and therefore the land purchase costs may be further increased.

Table 6: Case Study 1 - Sensitivity tests

Sensitivity Tests: Case Study 1						
Scenarios	**A**	% Difference from Baseline	**B**	% Difference from Baseline	**C**	% Difference from Baseline
Medium Intervention						
Additional Costs	3,330,000		1,427,500		497,500	
New Construction cost	108,475,758	3	58,925,620	2	29,854,274	2
New design, investigation and consenting cost (50%)	54,237,879		29,462,810		14,927,137	
Total Cost	330,131,254		154,953,114		67,251,774	
Price per ha	37,942		38,450		56,137	
Price per ha (60% optimism bias)	**60,707**	**2**	**61,520**	**1**	**89,819**	**1**
Reduction in Construction Costs (20%)						
Cost reduction	21,029,152		11,499,624		5,871,355	
New Construction cost	84,116,606		45,998,496		23,485,419	
New design, investigation and consenting cost (50%)	42,058,303		22,999,248		11,742,709	
Total Cost	293,592,527		135,562,428		57,698,492	
Price per ha	33,742		33,638		48,162	
Price per ha (60% optimism bias)	**53,988**	**-10**	**53,821**	**-11**	**77,060**	**-13**
Reduction in Construction Costs (no rock armour)						
Cost reduction	32,417,959		18,815,953		8,548,841	
New Construction cost	72,727,799	-31	38,682,167	-33	20,807,933	-29
New design, investigation and consenting cost (50%)	36,363,899		19,341,083		10,403,966	
Total Cost	276,509,315		124,587,934		53,682,263	
Price per ha	31,779		30,915		44,810	
Price per ha (60% optimism bias)	**50,846**	**-15**	**49,464**	**-18**	**71,696**	**-19**
Property Purchase (increase of 50%)						
Addtitional cost	16,795,778		6,377,091		3,649,128	
New Land Purchase Cost	184,213,395		72,941,774		26,119,491	
Total Cost	341,932,032		159,188,954		70,154,652	
Price per Ha	39,298		39,501		58,560	
Price per Ha (60% optimism bias)	**62,877**	**5**	**63,202**	**4**	**93,696**	**5**

4.2.2 Maintenance Costs

The maintenance costs have been developed for the case study as discussed in section 2.7 and provided in Table 7 below. The table shows the length of defences for each of the scheme which varies from 14km to 34.6km. To give an indication of the future maintenance commitment, the annual costs have been expressed as a percentage of the total capital commitment. This shows that the maintenance commitments will be less than 0.25% of the capital commitment and are therefore not thought to be significant.

Table 7: Case Study 1 – Maintenance costs

Maintenance Cost: Case Study 1			
Scenario	**A**	**B**	**C**
Length of defences (m)	34,650	15,860	14,040
Maintenance cost metre/pa (£)	2.40	2.40	2.40
Cost per annum (£)	83,160	38,064	33,696
Saltmarsh/grassland area (ha)	7,021	3,464	871
Cost per ha per annum (£)	100	100	100
Cost per annum (£)	702,100	346,400	87,100
Total maintanance cost per annum (£)	785,260	384,464	120,796
Total capital cost (£)	325,136,254	152,811,864	66,505,524
Annual maintenance costs as a percentage of capital cost (£)	0.24%	0.25%	0.18%

4.2.3 Hydrodynamic and Geomorphological Changes

The following section provides a summary of the hydrodynamic and geomorphological changes which could result from the Scenarios. The associated off-site implications of these changes are discussed separately in section 5.2.

Modelling of the maximum proposed realignment has a net effect of raising the estuary tidal prism by about 5.7%, with proportionally smaller changes associated with the other schemes. Due to the location of the realignments these increases will occur in the wider, open estuary section.

Analysis of water levels shows that whilst flow fills the realignment water levels in the estuary are reduced, particularly towards high water when the effects of the realignment are proportionately greater. For Scenario A, this results in an overall reduction of HW levels of 0.3cm to 10cm depending on location in the estuary. At low water changes to water levels are negligible.

During the ebb tide, the lag in water levels between the case study realignments and the estuary means that additional flow is provided from the realignments at the time maximum flows normally occur in the estuary, increasing peak ebb flows by about 7% for Scenario A. Just as importantly, the duration it occurs is increased because of the lag caused by the realignment draining. The peak ebb flows in the main channels is already higher than during the flood, therefore the ebb flow speed dominance is considerably increased.

The dynamic nature of the estuary makes it difficult to reliably predict sediment transport and long-term morphological changes, particularly given the limited modelling information available. Based on expert judgment, the indicative hydrodynamic changes may give rise to a number of potential changes to estuary sediment transport and long-term morphology:

- The increase in ebb flow speed dominance will increase erosion potential. This could result in erosion of the main channel and some intertidal areas in a region of the estuary adjacent to and slightly upstream of the realignment;

- Any eroded sediment would be expected to be transported down estuary and deposited around the mouth or lost to the open coast;

- Over time the potential for increased volume of sediment in the lower estuary could change the existing regime for bank and channel movements;

- Predicted minor reductions in flow speeds in the inner estuary will reduce the potential for sediment transport and therefore the mobility of the existing bank and channel system, and could potentially increase accretion; and

- The MR sites would be expected to impose an additional sediment demand on the estuary. It is unclear whether the long-term sediment supply to the estuary is sufficient to meet this demand.

These potential changes would be expected to be further modified by long term changes in SLR. In particular, accelerated sea level rise in the longer term would be expected to increase sediment demand within the estuary. If this demand cannot be met, this would be expected to lead to reductions in sediment deposition and/or increases in erosion.

4.3 Case Study Two

As with case study one, the results of the analysis is provided in the Tables 8 to 11 below. The results have again shown that there is significant variability between the scenarios. Each Scenario is sensitive to costs with respect to each of the three components (land purchase, construction and other costs) with the topography, number of properties, contaminated land and other criteria all playing an important component in the construction costs. The protected species and SSSI mitigation costs are the largest element of the 'other costs', particularly with respect to Scenario D. The significance of particular cost elements are discussed where relevant.

The habitat predictions for Case Study two are provided in Table 3. It is predicted that this site would be more suitable for mudflat creation with over 80% of the area of Scenario A providing mudflat habitat following a breach. This rises to nearly 90% with sea level rise.

The scenarios vary in size from nearly 4,000ha to 11,500ha. The predicted loss of existing intertidal area through changes in water levels predicted by the scenarios is limited to Scenario A. Of particular note for this case study is the significant area of SSSI within Scenario D, the nominal cost of £20,000 per hectare for SSSI mitigation in combination with the protected species costs could add £14.5m to the costs of Scenario D. Although this cost is not directly reflected in Table 9 it has been costed within Methodology B and therefore a component of the 50% design, consultancy and consenting provision.

The figures used to calculate cost per hectare are outlined in Table 8 below.

Table 8: Case Study 2 – Site area for calculation

Site Area for Calculation: Case Study 2				
Scenario	**A**	**B**	**C**	**D**
Total Site Area	11,419	8,519	4,584	3,935
Predicted loss from MR	29	-	-	-
Existing MR/intertidal	900	-	-	-
Total Ha for calculation	**10,490**	**8,519**	**4,584**	**3,935**
Area of existing terrestrial/freshwater SSSI	807	622	29	593

Table 9 below provides a summary of the cost estimates for Case Study 2. The table shows that the cost per hectare for the different sites range from approximately £22,500 to £40,000 without optimism bias and from £36,000 to £64,000 with optimism bias. It can be seen that there is no correlation between site size and cost. This is due to the site specific aspects; in particular scenario D does not have any associated embankment costs and its location means that additional off-site monitoring has not been included. Scenario C includes construction costs for 19km of earth embankment which has increased the construction cost of this scenario from £22m to £48m; and hence design, consultancy and consenting costs have increased accordingly. Other key aspects include:

- Scenario A: land purchase can be categorised as 71% agricultural land purchase; 25% property purchase and 4% commercial;
- Scenario A: Embankment costs are 60% of total construction, this is a smaller percentage than Case Study 1 costs;
- Scenario A: Removal of contaminated material contributes 21% of construction costs and diversion of roads a further 6%;
- Scenario B: land purchase can be categorised as 78% agricultural land purchase; 21% property purchase and 1% commercial;
- Scenario B: Embankment costs are only 50% of total construction with the diversion of roads and other services contributing to 40% of the construction costs;
- Scenario C: land purchased is broken down to 89% agricultural land and 11% property purchase (small property purchase element);
- Scenario C: Embankment costs are 54% of the total construction cost with pumping stations, outfalls, contaminated land and creek excavation all contributing significantly to total construction;
- Scenario D: Land purchase broken down into 64% agricultural land purchase, 33% property purchase (significant when compared to scenario C) and 3% commercial; and
- Scenario D: There are no embankment costs but there is over £17m of costs associated with the removal of contaminated land (54% of construction) and £10m for the diversion of roads (30% of construction).

It can be seen that there is significant variability in the cost base between the scenarios. The high cost associated with Scenario A is primarily due to the 31km of rear embankment needed and the land purchase price. Scenario A has approximately 250 properties identified within its boundaries and associated demolition costs are also included, this is twice the number of properties than scenario B and seven times the properties in scenario D.

Table 9: Case Study 2 – Summary statistics

Summary Statistics: Case Study 2								
Scenarios	**A**	% of Total	**B**	% of Total	**C**	% of Total	**D**	% of Total
Site Area for calculations (Ha)	10490		8519		4584		3935	
Land Purchase	193,879,215	46	114,683,149	59	63,985,986	47	50,697,163	51
Construction	151,920,076	36	52,072,862	27	48,028,327	35	32,678,570	33
Design, Investigations and Consenting (50% of construction)	75,960,038	18	26,036,431	14	24,014,163	18	16,339,285	16
Total	421,759,329	100	192,792,442	100	136,028,476	100	99,715,018	100
Price per ha	**40,206**		**22,631**		**29,675**		**25,341**	
Total (60% optimism bias)	674,814,926		308,467,907		217,645,562		159,544,028	
Price per ha (60% optimism bias)	**64,329**		**36,209**		**47,479**		**40,545**	

Table 10 provides a summary of the sensitivity tests for case study two. The medium intervention sensitivity shows that this scale of intervention would not substantially affect cost where as the construction sensitivities again can influence by approximately 10% and changes in the estimates of property prices can add a further 8% to the total cost.

Table 10: Case Study 2 - Sensitivity tests

Sensitivity Tests: Case Study 2								
Scenarios	**A**	**% Difference from Baseline**	**B**	**% Difference from Baseline**	**C**	**% Difference from Baseline**	**D**	**% Difference from Baseline**
Medium Intervention								
Additional Costs	5,855,000		4,755,000		2,350,000		1,382,500	
New Construction cost	157,775,076	4	56,827,862	9	50,378,327	5	34,061,070	4
New design, investigation and consenting cost (50%)	78,887,538		28,413,931		25,189,163		17,030,535	
Total Cost	430,541,829		199,924,942		139,553,476		101,788,768	
Price per ha	41,043		23,468		30,444		25,868	
Price per ha (60% optimism bias)	**65,669**	**2**	**37,549**	**4**	**48,710**	**3**	**41,388**	**2**
Reduction in construction costs (20%)								
Cost reduction	30,384,015		10,414,572		9,605,665		6,535,714	
New Construction cost	121,536,061		41,658,289		38,422,661		26,142,856	
New design, investigation and consenting cost (50%)	60,768,030		20,829,145		19,211,331		13,071,428	
Total Cost	376,183,306		177,170,583		121,619,978		89,911,447	
Price per ha	35,861		20,797		26,531		22,849	
Price per ha (60% optimism bias)	**57,378**	**-11**	**33,275**	**-8**	**42,450**	**-11**	**36,559**	**-10**
Reduction in construction costs (no rock armour)								
Cost reduction	33,242,345		6,169,706		6,169,706		0	
New Construction cost	118,677,731	-22	45,903,155	-12	41,858,620	-13	32,678,570	0
New design, investigation and consenting cost (50%)	59,338,866		22,951,578		20,929,310		16,339,285	
Total Cost	371,895,812		183,537,882		126,773,917		99,715,018	
Price per ha	35,452		21,545		27,656		25,341	
Price per ha (60% optimism bias)	**56,724**	**-12**	**34,471**	**-5**	**44,249**	**-7**	**40,545**	**0**
Property Purchase (increase of 50%)								
Additional cost	24,481,057		12,053,273		3,679,219		8,374,054	
New Land Purchase Cost	218,360,272		126,736,422		67,665,205		59,071,217	
Total Cost	446,240,386		204,845,715		139,707,695		108,089,072	
Price per ha	42,540		24,046		30,477		27,469	
Price per ha (60% optimism bias)	**68,063**	**6**	**38,473**	**6**	**48,764**	**3**	**43,950**	**8**

4.3.1 Maintenance Costs

The maintenance costs have been developed for the case study as discussed in section 2.7 and provided in Table 11 below. The table shows the length of defences for each of the scheme which varies from no defence requirements at all to 51km. Provision for habitat management has also been provided. To give an indication of the future annual maintenance commitment costs have been expressed as a percentage of the total capital commitment. This shows that maintenance expenditure will be less than 1% of the capital commitment and are therefore not thought to be significant.

Table 11: Case Study 2 – Maintenance costs

Maintenance Cost: Case Study 2				
	A	B	C	D
Length of defences (m)	51,050	19,130	19,130	0
Cost per metre per annum (£)	2.40	2.40	2.40	2.40
Cost per annum (£)	122,520	45,912	45,912	0
Saltmarsh / Grassland area (ha)	1,949	768	695	73
Cost per ha per annum (£)	100	100	100	100
Cost per annum (£)	194,900	76,800	69,500	7,300
Total maintenance cost per annum	**317,420**	**122,712**	**115,412**	**7,300**
Total capital cost	421,759,329	192,792,442	136,028,476	99,715,018
Annual maintenance costs as a percentage of capital cost	**0.08%**	**0.06%**	**0.08%**	**0.01%**

4.3.2 Hydrodynamic and Geomorphological Changes

The following section provides a summary of the hydrodynamic and geomorphological changes which could result from the Scenarios. The associated off-site implications of these changes are discussed separately in section 5.2.

The case study area is located adjacent to an estuary complex which is designated under international, European and national nature conservation legislation and has wide intertidal flats.

MR under Scenario A which is either side of the main estuary entrance will increase the area of the estuary by 260% and the tidal prism by 190%, assuming each site can fully inundate and drain to the same level as the estuary. Scenarios B-D approximately double the size of the estuary tidal prism and the scale of hydrodynamic effect is approximately proportional to the volume of inundation.

Scenario A changes the tidal propagation and hydrodynamics throughout the estuary system. The tidal range is reduced by about 10% throughout the estuary length, created by a rise in the level of low water in the order of 0.25m and a similar reduction at high water. Within the realignments, water levels increase to similar levels to those that occur in the adjacent estuary or open coast. However, an insufficient channel network and general resistance to flow across the realignments impedes drainage, therefore not all areas are able to drain to the breach level. The modelling therefore showed the full volumetric potential of the proposed realignments was not achieved.

The overall increase in tidal prism increases flow speeds on both the flood and ebb tide, with the greatest change increasing with distance towards the mouth. Up estuary beyond the extent of the realignment hydrodynamic effects were negligible. The largest changes in flow speeds at the lower end of the constricted section were on average increased by about 45% (0.65m/s) on both the flood and ebb. On the ebb, not only are the peak flow speeds increased but the duration of higher flows is also increased due to the lag in drainage from the realignment sites.

Assessment of the likely sedimentary effect on the system as a whole from the results of the hydrodynamic modelling is difficult to determine, as it is dependant on the supply of sediment entering with the tidal prism. However, the sites will still be fronted by wide open expanses of intertidal, which will still be susceptible to wave disturbance. It is therefore envisaged that suspended sediment concentration levels will not change from those at present.

As sea levels rise, water levels over these foreshore areas will increase and therefore be subject to greater wave activity. This increase in wave disturbance has the scope to maintain the supply, despite the greater sediment demand from the accretion that is likely to occur in the realignments. On this basis the infill of the realignment could have scope to keep pace with sea level rise, particularly as the areas will be protected from the erosion effects of the offshore wave activity. The sites are however large so a greater level of internal wave disturbance compared to smaller existing sites could result. This however, is not expected to offset the accretionary nature of the realignments.

Based on the changes identified from the hydrodynamic modelling and expert judgment, a number of potential changes to the sediment transport regime of the existing estuary are likely to result:

- Throughout the main channel, the estuary will change from one of weak peak flow speed ebb dominance to one of stronger ebb dominance. In addition absolute flow speeds are considerably increased on both flood and ebb, increasing the potential for scour of the main channel in both directions. The duration of the ebb flows is also increased, therefore the time at which the flows can erode or transport material is also increased;

- The changes to the flow patterns substantially increase the potential for the estuary to scour, thus enabling the cross section to enlarge relative to the change in total prism passing, therefore the erosion will be potentially more towards the mouth of the constricted section. As sea levels rise, the tidal prism increases further; therefore increased erosion is likely until water depths begin to reduce the channel flow speeds as a new dynamic equilibrium develops. The actual amount of scour will depend on the composition and geology of the channel bed and side slopes;

- The approach through the wide intertidal to the constricted section of the estuary is also likely to widen and deepen, at all levels, therefore a lowering of the intertidal adjacent to the channel could be expected until a new equilibrium forms, which could take 10s to 100s of years; and

- Net sediment transport will be in the down estuary direction, however the potential for erosion to occur on the flood, could also increase suspended sediment concentration levels entering the realignments. Initially this could cause greater rates of realignment infill (should appropriable material exist on the bed) than would occur in areas where there is little increase in flood flows. As this could only occur at the higher water levels, the predominant effect would still be a tendency to increase the volume of the estuary due to deepening/widening of the low water channel.

As noted above the rate of these changes would be further modified by sea level rise. This could significantly affect the time scale over which a new equilibrium profile and hydrodynamic regime for the estuary would develop. Influencing factors would be the rate of deepening relative to the rate of sea level rise along with the composition of the bed and offshore wave disturbance affecting the potential supply of material to the estuary as a whole.

4.4 Case Study Three

As with previous case studies, the results of the analysis are provided in Tables 12 to 15 below. The results have again shown that there is significant variability between the scenarios and between the case study areas. Each scenario is sensitive to costs with respect to each of the three components (land purchase, construction and other costs) with the topography, number of properties, contaminated land and other criteria all playing an important component in the construction costs. The significance of particular cost elements are discussed where relevant.

The habitat predictions in Table 3 show that this site is high in the tidal frame with only 6% of the site predicted to provide mudflat habitat, rising to only 14% by 2120. This shows that the case study location is inappropriate if it were to be investigated for offsetting mudflat habitat. These results show the importance of screening the sites against defined ecological criteria.

This case study is smaller in size than case studies one and two with the scenarios ranging from 542ha to 2,664ha. Table 12 below shows that a proportion of the site is already subject to MR. Furthermore, the prediction of existing intertidal habitat loss through changes in water level as a result of scenarios A and B is 237ha and 131 for scenario C. These figures have been removed from the cost per hectare estimation for habitat created which further reduces the size of the sites.

Table 12: Case Study 3 – Area of habitat created

Site Area for Calculation: Case Study 3				
Scenario	**A**	**B**	**C**	**D**
Total Site Area	2,664	2,539	1,604	542
Predicted loss from MR	237	237	131	9
Existing MR/intertidal	167	167	167	0
Total Ha for calculation	**2,260**	**2,135**	**1,306**	**533**
Area of SSSI	131	131	15	9

Table 13 below provides a summary of the estimated costs for case study three. It can be seen that the cost estimates per hectare are substantially higher than case studies one and two. The case study estimates range from £74,000 per hectare to £109,500 without optimism bias and this price increases further to between £118,500 and £175,200 with optimism bias.

Table 13: Case Study 3 – Summary statistics

Summary Statistics: Case Study 3								
Scenario	**A**	% of Total	**B**	% of Total	**C**	% of Total	**D**	% of Total
Area of land for calculation	2260		2135		1306		533	
Land Purchase	52,558,758	31	50,567,923	31	27,367,482	27	6,930,384	12
Construction	76,680,676	46	73,333,388	46	48,828,367	49	34,291,017	59
Design, Investigations and Consenting (50% of construction)	38,340,338	23	36,666,694	23	24,414,184	24	17,145,509	29
Total	167,579,772	100	160,568,005	100	100,610,033	100	58,366,910	100
Price per ha	**74,150**		**75,207**		**77,037**		**109,506**	
Total including 60% optimism bias	268,127,635		256,908,808		160,976,053		93,387,056	
Price per ha including optimism bias	**118,641**		**120,332**		**123,259**		**175,210**	

These higher costs are due to the high embankment costs as a proportion of site size; it is a relatively long, thin site not extending far inland. For example, the construction cost for scenario A is approximately £76m for 2,200ha with 114 buildings/properties identified. The construction costs for case study two, Scenario B is approximately £52m for a return of 8,500ha and 120 properties identified. Key points include:

- Scenario A: Land purchase costs are broken down as agricultural land 62%, property 36% and commercial 3%;
- Scenario A: Embankment 81% of construction costs;
- Scenario B: increases the cost/ha of potential habitat rather than reducing the cost;
- Scenario C: Property purchase is the most significant element of the land purchase costs at 60% with 37% agricultural and land and 3% commercial;
- Scenario C: The embankment costs consist of 86% of total construction;
- Scenario D: Agricultural land purchase consists of 96% of the total land purchase costs, 4% commercial and no property purchase;
- Scenario D: Embankment consists of 82% of construction; and
- All sites: it is believed that commercial property values are an underestimate.

As with the previous case studies, sensitivity tests have been undertaken. The tests show that due to the proportionate size of the construction costs the construction sensitivity test reduce the cost per ha by up to 26% but the medium intervention scenario has little effect (Table 14). Due to the high number of properties with respect to the size of the site when compared to case studies one and two this also affects the cost per hectare.

Table 14: Case Study 3 - Sensitivity tests

Sensitivity Tests: Case Study 3								
Scenario	**A**	**% Difference from Baseline**	**B**	**% Difference from Baseline**	**C**	**% Difference from Baseline**	**D**	**% Difference from Baseline**
Medium Intervention								
Additional Costs	1,265,000		1,165,000		700,000		397,500	
New Construction cost	77,945,676	2	74,498,388	2	49,528,367	1	34,688,517	1
New design, investigation and consenting cost (50%)	38,972,838		37,249,194		24,764,184		17,344,259	
Total Cost	169,477,272		162,315,505		101,660,033		58,963,160	
Price per ha	74,990		76,026		77,841		110,625	
Price per ha (60% optimism bias)	**119,984**	**1**	**121,642**	**1**	**124,545**	**1**	**177,000**	**1**
Reduction in construction costs (20%)								
Cost reduction	15,336,135		14,666,678		9,765,673		6,858,203	
New Construction cost	61,344,541		58,666,710		39,062,694		27,432,814	
New design, investigation and consenting cost (50%)	30,672,270		29,333,355		19,531,347		13,716,407	
Total Cost	144,575,569		138,567,989		85,961,523		48,079,605	
Price per ha	63,971		64,903		65,820		90,206	
Price per ha (60% optimism bias)	**102,354**	**-14**	**103,845**	**-14**	**105,313**	**-15**	**144,329**	**-18**
Reduction in construction costs (no rock armour)								
Cost reduction	16,321,455		24,748,311		16,477,943		10,051,267	
New Construction cost	60,359,221	-21	48,585,076	-34	32,350,424	-34	24,239,750	-29
New design, investigation and consenting cost (50%)	30,179,610		24,292,538		16,175,212		12,119,875	
Total Cost	143,097,589		123,445,538		75,893,118		43,290,009	
Price per ha	63,318		57,820		58,111		81,220	
Price per ha (60% optimism bias)	**101,308**	**-15**	**92,512**	**-23**	**92,978**	**-25**	**129,951**	**-26**
Property Purchase (increase of 50%)								
Addtitional cost	9,356,293		9,133,311		8,241,013		0	
New Land Purchase Cost	61,915,051		59,701,234		35,608,495		6,930,384	
Total Cost	176,936,064		169,701,316		108,851,046		58,366,910	
Price per ha	78,290		79,485		83,347		109,506	
Price per ha (60% optimism bias)	**125,264**	**6**	**127,177**	**6**	**133,355**	**8**	**175,210**	**0**

4.4.1 Maintenance Costs

The maintenance costs have been developed for the case study as discussed in section 2.7 and provided in Table 15 below. The table shows the length of defences for each of the scheme which vary from 7.4km to 32km. Provision for habitat management has also been provided. To give an indication of the future commitment the annual maintenance costs have been expressed as a percentage of the total capital commitment. This shows that the maintenance commitments will be less than 0.2% of the capital commitment and are therefore not thought to be significant.

Table 15: Case Study 3 – Maintenance Costs

Maintenance Costs: Case Study 3				
Scenario	**A**	**B**	**C**	**D**
Length of defences (m)	32010	25360	11410	7430
Cost per metre per annum (£)	2.4	2.4	2.4	2.4
Cost per per annum (£)	76824	60864	27384	17832
Saltmarsh area (ha)	2342	2233	1388	524
Cost per ha per annum (£)	100	100	100	100
Cost per annum (£)	234200	223300	138800	52400
Total maintanance cost per annum (£)	**311024**	**284164**	**166184**	**70232**
Total capital cost (£)	167,579,772	160,568,005	100,610,033	58,366,910
Annual maintenance costs as a percentage of capital cost	0.19%	0.18%	0.17%	0.12%

4.4.2 Hydrodynamic and Geomorphological Changes

The following section provides a summary of the hydrodynamic and geomorphological changes which could result from the Scenarios. The discussion focuses on the largest MR option, scenario A and B with smaller effects being realised for scenarios C and D. The associated off-site implications of these changes have been combined with those of case studies one and two and are discussed separately in section 5.2.

The proposed maximum realignment within the case study area takes place in the more fluvial 'up estuary' reaches of the Estuary. Within this section up estuary, based on hypsometry alone, the realignment increases the tidal prism by about 34%. The actual increase in in-flow and out-flow of the estuary is substantially less because the tidal propagation is affected throughout the estuary, with maximum levels reducing by over 0.5m in the upper reaches. Due to the restricted breaches, the maximum levels achieved within the area of the realignment were on average 0.5m below the estuary, giving a potential reduction in the tidal level in the realignment of 1.0m. The actual increase in tidal prism is therefore reduced considerably below the 34% theoretical value.

The high level of the bed of the realignment means that the majority of flood in-flow occurs when levels in the main river are above MHWN, therefore most effects will only occur on spring tides and then do not fill or drain to the same levels as occur in the main channel. Suspended sediment will be drawn in with the tidal prism and will settle to raise levels, except within the creek areas adjacent to the breaches. It is not clear whether there will be sufficient supply of sediment for the realignments to keep pace with sea level rise. This will depend on the type of material eroded on the ebb flows and whether this will be suspended to increase the suspended sediment concentrations to be returned on the flood tide. It is likely that once the surface layers of potentially finer material have been eroded, the sediments will become too coarse to be re-imported. This suggests there will be a lack of suspended sediment supply to allow the realignments to build up with sea level rise.

The shape of the area of the MR relative to the existing channel configuration means that the estuary can be divided into four sections which will be affected differently.

The main channel, up estuary of the tributary

This section of estuary is currently flood dominant with respect to peak flow speeds. With the realignment, the tidal prism will be reduced (by a reduction in high water level) which continues to fill for over 1.3 hours extra, thus reducing the peak flood flows. Conversely, the ebb is delayed compared to present and flows exit marginally faster, thus the flood flow speed dominance of the estuary is reduced. The tidal prism will reduce the supply of sediment but the reduction in flows, particularly over the extended high water, will be more conducive to settlement of sediment, albeit at lower levels over the existing intertidal. The increased ebb flows, particularly when confined to the channel will tend to marginally increase the flushing from the main channel. These changes tend to cancel each other out, however, morphologically, the lower tidal prism would suggest over time additional accretion would occur over the intertidal areas, with slight deepening of the low water channel. With sea level rise, the intertidal accretion is likely to increase when the effects of sea level rise overcome the effects of the realignments, assuming a suitable sediment supply exists. Whether deepening or widening of the channel occurs will depend on the nature of the underlying bed and the existing training walls; both which would restrict channel widening.

The constricted channel from the tributary towards the estuary mouth

Through this section there will be of the order of 30% increase in tidal flow on spring tides but no change in neap tides. Morphologically this can be considered an equivalent to about a 15% increased tidal prism. The estuary is presently considered to be in approximate equilibrium, therefore, over time, the cross-section of the estuary in this section could be expected to increase by 15%. This, however, could be considerably reduced or delayed in time by the training walls and any hard geology or highly compacted bed. This section of estuary is strongly ebb dominant with respect to peak flow speeds and already experiences high flow speeds up to 2.5m/s on the ebb.

The effect of the realignments causes negligible change on flood flow speeds but, due to the lag in draining the realignments and the constriction remaining from the unbreached sections of embankment, the ebb flow speed dominance is considerably increased with peak flows predicted to exceed 3.2 m/s and general ebb flows about 0.5m/s faster than present, as well as occurring for a significantly longer period of time. This will have the potential effect of significantly eroding the channel, both deepening and widening, with the sediments all transported into the wider sections down estuary. It should be noted, however, this is one of the shallowest sections of the existing estuary despite already high flows. This may suggest a resistant bed, therefore erosion may not be as large as the changes in flows would suggest. Again the training works would influence the pattern of erosion. With sea level rise, the further increase in total prism is only likely to increase the ebb flow speed dominance and erosion potential further. Should the erosion occur from the introduction of the realignments, the flow speeds are high enough for the cross section to increase very quickly, thus reducing the flow speeds and therefore the rate of erosion. Channel modification back to a more equilibrium form would be expected in perhaps less than 10 years.

Intertidal areas in the vicinity of the estuary mouth

Depending on the location of the breaches, flow speeds over the intertidal can be expected to increase by over 0.2m/s on the ebb tide as flow continues to drain through the breach. This flow, depending on the bed composition is likely to cause creeks over the intertidal emanating from breach. Flow speeds in these creeks could reach up to 1.4m/s. This flow will combine to increase flows in the main channel. The flow rate will, however be considerably slower than in the constriction up estuary, and although they will be enhanced following the realignment, it is suggested that, at least initially, this erosive energy will be used up in transporting the eroded material from up estuary. Initially it is possible some sedimentation will occur in the main channel until the up estuary supply reduces, then the channel will be able to clear to form a new equilibrium

4.5 Comparison and Summary of Case Study Costs

A considerable range of costs per hectare can be seen across the case studies and sensitivity tests with costs between £21,000 and £110,500 per hectare of habitat created. A summary of the case study statistics are provided below in Table 16.

The case studies have shown that there is substantial variability between the case study areas and within the case study scenarios and no patterns of costs can be identified. The only conclusion which can be stated with certainty is that the costs vary and are highly uncertain as site characteristics are their primary driver.

To provide a simpler indicator of cost, the four sensitivity tests have been combined into high and low scenarios as follows:

- High Scenario: Combination of the medium intervention and property purchase sensitivity tests; and

- Low Scenario: Combination of the 20% reduction in construction costs and removal of the rock armour component.

Table 16 shows the baseline average cost per hectare of habitat created of approximately £53,000, however there is a wide disparity in case study costs represented in the standard deviation of over £27,500.

The average cost per hectare rises by approximately £2,000 to nearly £55,000 under the high scenario and falls by over £8,000 to under £45,000 per hectare under the low scenario. These figures are quoted without optimism bias. With optimism bias the baseline cost rises to £85,000 per hectare.

When taking an average of all the case study areas and all the sensitivity tests below, the average cost per hectare of habitat created is approximately £51,000. With 60% optimism bias this increases to approximately £81,500.

The study has followed a conservative approach to project costs, particularly with respect to the design of the rear embankment (including a 1:200 standard of protection, 1.5m freeboard and import of fill material) and the 50% rather than 30% allowance for design, consultancy and consenting. This approach is reflected further in the additional 60% optimism bias and as such could be an over-estimate.

The Steering Group has noted that the cost estimates appear high, particularly when reviewed against the more recently completed projects. Therefore the low scenario costs with optimism bias may be the most applicable for further work. The low scenario with optimism bias gives a cost per hectare of approximately £71,500.

Table 16: Case Studies: Overall summary table

Average Cost per Hectare of Habitat Created					
Case Study Scenarios		**A**	**B**	**C**	**D**
Baseline Costs					
Case Study 1		£37,368	£37,919	£55,514	
Case Study 2		£40,206	£22,631	£29,675	£25,341
Case Study 3		£74,150	£75,207	£77,037	£109,506
Cost/Ha	£53,141		Standard Deviation	£27,540	
Cost/Ha (Optimism Bias)	£85,026				
High Scenario					
Case Study 1		£38,620	£38,975	£57,348	
Case Study 2		£41,791	£23,757	£30,460	£26,668
Case Study 3		£76,640	£77,756	£80,594	£110,066
Cost/Ha	£54,789		Standard Deviation	£27,855	
Cost/Ha (Optimism Bias)	£87,662				
Low Scenario					
Case Study 1		£32,761	£32,277	£46,486	
Case Study 2		£35,657	£21,171	£27,094	£24,095
Case Study 3		£63,645	£61,361	£61,966	£85,713
Cost/Ha	£44,748		Standard Deviation	£20,704	
Cost/Ha (Optimism Bias)	£71,596				
Average of Baseline, high and low scenarios					
Overall cost/Ha: without optimism bias	£50,893				
Overall Cost/Ha: with optimism bias	£81,428				

4.6 Assumptions and Uncertainty

This has been a high level study of the potential costs of large scale MR. The study has used national data sources and desk based analysis and no site visits or investigations have been undertaken. As such there is uncertainty associated with the statistics provided due to potential errors in the source data, including but not limited to:

- LiDAR: risk of error due to vegetation;
- LiDAR: use of Google Earth to overcome gaps in coverage;
- NFCDD: Length of assets identified significantly greater than shoreline length;
- NDP: accuracy of classification of farm buildings; and
- NPD: accuracy of commercial and residential property prices.

Whilst seeking to ensure a robust but cost–effective approach, the numerical modelling undertaken has used existing computer models which have not been recalibrated for this project and no new data has been sourced. The project has also been based upon a number of estimations and assumptions which are discussed in the methodology section.

There are also a number of other uncertainties which should be taken into consideration, the most important of these are:

- The 50% allocation for 'design, consultancy and consenting' includes sufficient allowance for survey and mitigation costs appropriate for this high level feasibility. Appropriate scoping and site feasibility studies should enable future provisions to be reduced;
- The scope of this project has been to understand the costs associated with creating saltmarsh and mudflat on a large scale. However, the actual costs will depend upon the ecological objectives of any site and the level of intervention which would be required to meet those objectives. This will be particularly relevant in the context of any Habitats Regulations Compensation Package; and
- Investigations and monitoring of off-site factors has been included in the 50% allocation, however mitigation or compensation for off-site effects is not included.

This methodology is considered robust for this high level assessment of potential costs associated with large scale MR. However, this is not a site selection process nor is it a robust assessment of the feasibility of these case studies for MR. Highly detailed investigations would be required in support of large scale MR and these costs are a key component of the case study estimates.

4.7 Comparison with Other MR Schemes

To support the understanding of how 'going large' could affect costs, the project has undertaken a review of other MR sites around the country. The previous investigation (ABPmer, 2008) concluded the average price of previous MR sites to be approximately £65,000 per hectare. However, this previous review included a large number of small schemes which it was thought may be disproportionately expensive when assessed on a cost/ha basis.

A summary review of more recently completed schemes has been undertaken. As shown in Table 17 the cost of schemes vary significantly from less than £15,000 per/ha to nearly £95,000 per/ha. This is likely to be a result of onsite factors. When averaged, the more recent schemes have resulted in an overall cost/ha of approximately £41,000, a reduction of £24,000 per hectare from the £65,000 previous estimation. However, the costs of delivering Hesketh Out Marsh were not much greater than agricultural land prices and opportunities for such cost effective schemes are unlikely to be frequent or possible for 'large' schemes. When removing this MR the average cost rises to approximately £46,000.

With optimism bias the projected costs developed for this study of large scale MR are significantly greater than recent projects and there are likely to be a number of reasons for the difference in these estimates. A number of these are listed below:

- All the sites have been identified through some form of Strategy, site screening process or as a result of specific opportunities;
- Costs for existing MR schemes may not include the full life-cycle of project costs;
- The development of the baseline scenario of 50% of construction costs for design, consultancy and consenting may be overestimates;
- Existing datasets may have overestimated the number of properties within the site boundaries;
- Construction estimates are conservative[9] due to levels of uncertainty;
- Design elements are conservative due to levels of uncertainty; and
- Cost savings and value engineering are likely to have been implemented during project development.

When simply reviewing the summary statistics of the large scale MR against Table 17 the initial conclusion would be that large scale MR is more expensive than the existing approach. However, it is likely that with a robust site selection process, the costs could be significantly reduced.

Table 17: Analogues recently completed MR schemes

Analogue MR Schemes	Wallasea Wild Coast	Frieston	Alkborough	Paull Holme Strays	Donna Nook	Hesketh Out Marsh
Site Area (ha)	650	81	370	78	138	168
Total Estimated Cost	27,535,000	2,130,000	8,431,500	7,400,600	6,159,500	2,500,000
Cost/ha	£42,362	£26,296	£22,788	£94,879	£44,634	£14,881
Average Cost/ha	£40,973					
Average cost (without Hesketh Out Marsh)	£46,192					

[9] These could be an over-estimate of costs

SECTION 5

DISCUSSION

5 DISCUSSION

This section discusses the key issues for large scale MR. The three case studies have formed the basis of the discussion and this has been supported by wider experience of MR from the project team, technical experts and Steering Group. The issues have been discussed under the headings of on-site impacts, off-site effects and technical and engineering feasibility. The key cost drivers are then discussed and potential benefits identified. The final discussion section focuses on how large scale MR might be taken forward.

5.1 Effects on Site Interests

The case study analyses have identified and costed for land purchase and removal or diversion of the existing infrastructure on site. This is discussed in the results section above. The following section discusses these issues where specifically relevant to large MR.

5.1.1 Existing Development and Community Interests

Due to the size of the proposed sites, even with careful site screening there will inevitably be existing developments and community interests within the proposed MR. This is likely to be the most complex on-site issue in terms of public acceptability, programme and cost.

The number of properties for the largest Scenario A sites vary between 114 and 249 and the smaller scenarios between zero and 85 properties (including flats/maisonettes). In addition, there are likely to be a number of different owners of agricultural land and complex arrangements of landowners, leaseholders and land rental. The costs have been developed based upon current market rates. However, a landowner that did not want to sell or sought a price above market rates could affect the feasibility of the MR. This could result in increased costs and delay to the project programme of months or more likely years.

Therefore it will be highly unlikely that any large MR will be possible without significant landowner consultation, engagement, and the availability of compulsory purchase powers, potentially through an Act of Parliament. There are other issues associated with land ownership including presence of significant infrastructure which could not be removed (e.g. roads, pipelines, pylons and other service infrastructure), or ownership by Government Departments which may not consider relocation. Site selection criteria should avoid those sites which are likely to pose additional programme risks.

5.1.2 Changes to Existing Land Characteristics

MR would result in significant environmental changes as agricultural land is converted to intertidal and coastal habitat. All the case study areas have substantial agricultural land within the site boundaries (over 8,600ha of primarily grade 1-3 in one case study) and the land characteristics are likely to be similar for any MR sites. The loss of productive farmland may be perceived as a concern in relation to food security, and objections have been made to a currently proposed (much smaller) MR on this basis.

There is also the potential for impacts on recreational value if there is a reduction in access to the coast, loss of navigational access or wider enjoyment of the area. The scale of the realignments would result in footpath diversion (or possibly extinguishment and creation) which requires consent from the local Highways Authority (County or Unitary Council). Public and private access routes have been identified as one of the most constraining factors (to date) on MR projects (Environment Agency, 2007). Experience has shown that the issues associated with loss or diversion of footpaths can be significant and can be illustrated through experience of a current small scale MR scheme which is being promoted by the Environment Agency which has been delayed for over a year due to footpath diversion legislation.

Issues of contaminated land have been identified both in terms of contaminated land within existing flood defences and existing flood defences protecting contaminated land or old land fill sites. It is likely that in some cases the volumes of potentially contaminated land could make MR unviable and such issues may need to be included in the site selection process.

Implications for archaeology and natural heritage have not been explicitly identified for the case study areas but such scheme will undoubtedly result in local impacts to known or unknown cultural heritage and archaeological resource.

With such large scale sites all the issues identified above will be greater in scale than encountered by MR schemes to date and likely to be more complex to address.

5.1.3 Flood Risk Management

Whether a MR project is led by national government or promoted by a private developer is significant in terms of the potential liability and ownership of any new flood defences associated with such a scheme.

If Government was to take a role, it would need to be determined whether to take on the responsibility for such defences after completion of a project or after a defined period of time. The rationale might depend on the flood risk management policy for the MR site and the assets that might be protected by a new alignment.

The case study sites have been reviewed against the current shoreline management plans and policies. The results have shown that for the vast majority of the frontages, the current policy is to hold the line but with the policy changing to no active intervention or MR in the long term (post 50 years). Government funding (through Defra and WAG to the Environment Agency) for flood management is limited and therefore schemes across the country are prioritised based upon a number of measures but primarily funding is directed to areas where it can provide most benefit. The areas identified as potential MR sites are in more rural areas and current flood defences are protecting limited assets in the context of national priorities. Depending on the policy, MR could be seen as delivering wider benefits and national governments may see opportunity in sharing responsibility with a developer and/or assuming full responsibility. Therefore there is opportunity for collaboration in the long term. In the short term there may be conflicts with existing shoreline management policy.

Linkages with flood risk management could provide flood risk management benefits and increase the acceptability of compensatory measures. Hypothetical case study alignments have significantly reduced the length of flood defences when compared to existing flood defence assets, in some cases potentially reducing existing asset lengths by over 100km[10].

The provision of new flood defences could reduce short and medium term maintenance costs. Using the second largest case study scenario as an example, maintenance savings in the order of £83,000 per year may be possible. In addition, the linkages and 'branding' of such MR schemes for integrated coastal management could support the consultation and consenting process for a STP compensation scheme i.e. as a mechanism for managing areas which might not otherwise receive funding.

Generally schemes promoted by private developers and associated assets would remain the liability of the developer and national governments would not adopt new assets unless there was sufficient public need. Different assumptions about the future ownership of risk, maintenance and replacement of flood defences have the potential to significantly affect treatment of costs of any scheme.

5.2 Off-site Effects

Large scale MR is likely to results in changing hydrodynamics and morphological changes to the wider estuary or coastal zone systems (off-site effects). The extent of influence on the wider environment will be dependant upon the location of the proposed sites within the system and the proximity to other developments, users and other sensitive receptors.

The additional investigations, surveys and monitoring required to assess such effects have been included in the development of the 50% design, consultancy and consenting costs. However, due to the levels of uncertainty at this stage, the costs for managing or mitigating such effects have been excluded from the calculations.

The case studies have investigated three sites and 11 scenarios in areas with different hydrodynamic and geomorphological characteristics and each scenario has resulted in some change to the hydrology and geomorphology of the wider coastal or estuarine system. The sites are in proximity to different types and scales of economic development which will be highly sensitive to such changes including navigation and fishing interests. The nature and extent of the off-site effects will be different for each site. The following off-site changes have been identified from the three case studies but the nature and scale are indicative only:

- Changes in hydrology and geomorphology potentially affecting adjacent designated sites;
- Minor reductions in water levels providing potential benefits for flood risk management;
- Minor reductions in water levels affecting navigation;
- Changing maintenance requirements for navigational channels;
- Changing maintenance requirements for existing coastal defences;

[10] Existing asset data obtained from the Environment Agency's NFCCD and likely to include secondary flood bunds and other flood risk management assets.

- Potential exposure of buried infrastructure (pipes, cables, training walls etc);
- Existing habitat change (habitat gains and losses);
- Potential risks to fishing and shellfisheries (water quality and flows); and
- Potential risks to other users (water levels and flows)

As with the case studies, any MR is likely to be adjacent to coastlines or estuaries designated under the Birds and/or Habitats Directives due to their distribution across England and Wales and therefore there is a significant risk that any large scale MR could affect designated sites. Detailed investigations would be required to determine if such changes constitute a significant adverse effect on the integrity of sites as part of any project appraisal. Such developments adjacent to designated sites are likely to be difficult and complex to implement.

The case studies have shown that sites on the open coast are less sensitive to potential off-site effects than those within estuaries. Generally the further up-estuary the site is located, the greater the change in water level and hydrodynamics as a result of the MR (these changes could be both adverse and beneficial). The sediment availability for such large scale sites is also uncertain and there is a risk that the reduced sediment load in the wider estuary from a MR could have knock-on effects on the wider sediment regime.

To manage the risks of off-site issues the screening criteria may seek to avoid areas of high economic infrastructure or design schemes which manage/minimise risks e.g. reducing the size of the schemes being promoted in particular areas.

5.3 Technical and Engineering Feasibility

The study has found that there are no *new* technical barriers to “large scale” MR other than those already encountered in the MR schemes completed to date. However, the scale of the “large” projects would be such that the engineering costs would be higher and the risk of encountering unforeseen issues is greater and mitigation for such risks likely to be more costly than for existing MR. For example, the risk and cost of addressing contaminated land over a site of 10,000 hectares with respect to previous MRs of 100 hectares.

The modelling has shown that it is possible to find large sites that could be breached and creek networks excavated sufficiently to allow regular inundation of water such that mudflat and saltmarsh could be created. Due to the size of the sites there are likely to be changes in hydrology and geomorphology in the surrounding area but the extent of the off-site effect would be site specific.

The site design will be critical to the successful delivery of the compensation and there are many aspects which need to be considered. For this high level assessment the following aspects were considered:

- Site hydrology and function (breach design and creek network);
- Size and cross section of the new defence line;

- Species and habitat mitigation; and
- Management of old defence line.

The computer modelling has shown that large scale MR is feasible for all three case studies. However, without the design and construction of a significant creek network, full inundation will not be possible particularly in the short term. The exact nature of the creek network would depend upon a number of factors including:

- The habitat compensation requirements (i.e. what habitats are required);
- The provision of accommodation space; and
- Presence and/or proximity to existing protected species/habitat.

The creek network could be engineered as part of the design or allowed to develop naturally. The decision on the engineering intervention of a creek network will depend upon the need for greater certainty in the habitat composition across the site and the timeline for habitat delivery.

Excavating the creek network could supply some/all of the material needed for a rear flood bund and this has been assumed within the costs, however, the extent of this opportunity would be dependant upon the nature of the material. It is also recognised that there could be significant contamination issues, for example there are known historic landfill sites in the vicinity of case study two and the costs of remediation would be significant.

Construction costs for all case studies are significant and greatly affect the overall cost of the scheme. The project has followed a precautionary approach to the design of the rear defence line and used an assumed crest height equivalent to a 1:200 year extreme event at 2070 (base year of 2020 plus climate change using Defra parameters) at each site. In addition to this, a freeboard allowance of 1.5m has been used and the project team has also been precautionary in the use of rock armour. As such, these costs may be an overestimate of the true embankment costs. However, refinement of the rear defence line would not be possible without an assessment of the potential flood risk arising from the development. To address this potential overestimation, additional sensitivity tests have been provided.

The case studies have been costed based upon an assumption that they would be implemented in a single phase. However schemes of this size may need to be implemented over a number of years and over a number of phases to ensure that existing species and habitats are mitigated sufficiently through the design. Knowledge gained from this phased approach, in combination with monitoring, would also benefit the design for subsequent phases.

Working with natural processes will be an important aspect in managing the risk of habitat delivery and the project costs. Whilst sites can be engineered to meet the required habitat objectives, this could be costly and unsustainable in the long term. The most effective approach to habitat delivery will be a robust site investigation and selection process to find sites which will cost-effectively match the habitat objectives, rather than working against nature. For example, if the required habitat is mudflat then the ecological objectives of the site selection should be to deliver that with minimum intervention.

The most appropriate way forward may be to undertake a high level assessment of the potential habitats which could be created on each site with minimal intervention as part of the site selection process. The subsequent investigations could then focus on designing sustainable schemes which maximise the use of natural processes to deliver that habitat; rather than designing high level interventions subject to higher cost and risk of failure.

5.4 Cost Drivers

This feasibility study has undertaken a high level assessment of potential costs affecting large scale MR and has identified that the most significant 'known' costs are land purchase and construction. This section discusses the other significant cost factors which will affect large scale MR.

It has been impossible to fully understand the off-site effects and potential impacts on economic assets in the vicinity of the case study areas and have therefore not been included. Therefore this assessment of 50% of construction fees should be taken as an estimate of costs to develop 'plausible' sites only.

The key issues affecting cost identified in this study include:

- The number of properties and extent of agricultural land which would need to be purchased;
- On-site criteria affecting construction costs (contaminated land, embankments etc);
- Risks of changes affecting adjacent Habitats Regulations protected sites;
- Risks of changes affecting off-site economic assets;
- Presence of protected species, SSSI habitats;
- Environmental site surveys (archaeology, UXO);
- Judicial review/public inquiry; and
- Consultation.

A number of these aspects are discussed in more detail below and would need to be investigated in detail as part of an EIA which would be required.

However, the development of specific ecological objectives in combination with a robust site selection process would be an effective mechanism to manage costs. Including a thorough assessment of the on site factors which could affect cost (e.g. thorough review of flood risk management requirements), and off-site risks.

5.4.1 Off-site Risks

The case study investigation has shown that such large scale MR will result in changes in the hydrodynamics and sediment transport of the wider estuarine or coastal system. The three case study sites are adjacent to designated sites and would be subject to HRA. The potential for off-site changes affecting the integrity of adjacent sites could be significant and detailed assessments of change in the context of the coherence of the designation would be required. The risk that such a project is unable to prove that it does not adversely affect site integrity could be substantial.

At a high level it can be concluded that the presence of significant economic assets which rely on the coast/estuary through navigation or fisheries interests will increase risk (as listed in section 5.2). The presence of such assets would require additional consultation, investigations and monitoring requirements in support of the MR. In addition, any changes which effect the operation of the industry could result in compensation claims against the project. Site selection criteria could be developed to take account of these factors and screen out areas which have too high a risk or too great a dis-benefit.

Cost estimates for investigating such risks were included in Methodology B and have been indirectly included in the study as part of the 50% design, consultancy and consenting costs. However, the costs for mitigation and/or compensation are impossible to quantify at this stage and have not been included in any of the scenario costs or optimism bias. Such risks would need to be understood and managed carefully and form an important part of the site selection process.

5.4.2 Consultation

To increase public understanding, maximise benefits and reduce the risks associated with land purchase, there would need to be substantial consultation with stakeholders and local communities, which is likely to be resource intensive. Using Wallasea Wildcoast Project as an analogue, costs of between £1m and £2m for the large and complex case study sites may not be unreasonable, particularly in support of land purchase negotiations. The approach to consultation may depend upon the land assembly route taken but the key aspects of the consultation could include but not be limited to:

- Establish partnerships involving STP constructors and operators, land owners, local and national Governments and their agencies to maximise benefits for UK plc;
- Promotion and 'branding' as integrated coastal management projects; and
- Development of a strategy for consultation and engagement for the whole life-cycle of the projects (site selection to post scheme monitoring) with specific, targeted programmes for different stakeholder interests.

Failure in the consultation strategy to engender support for such schemes is likely to result in additional issues for land purchase, planning and consenting and result in significant additional costs and delay to such projects. Conversely, consultation may identify opportunities for land assembly and delivering MR through working with willing landowners.

5.4.3 Public Liability

It has been shown that large scale MR, particularly in estuaries, will result in changes to the hydrodynamic regime. These changes could affect current economic interests in the vicinity such as fisheries (through water quality and hydrodynamic changes), commercial navigation, existing flood defences and infrastructure (through hydrodynamic and morphological changes). Such changes could result in economic losses to industry for which the project may have to compensate. There are a number of aspects to this issue and a few are highlighted below:

- Compensation claims against the scheme promoters for loss of earnings;
- Compensation claims against the scheme promoters for additional business costs (e.g. maintenance or dredging costs);
- Value of compensation paid (this may be significantly greater than the calculated losses or costs incurred);
- Insurance needs and premiums associated with such risks; and
- Monitoring and investigations associated with managing such risks.

5.4.4 Flood Management

The provision of new flood defences is significantly smaller than the existing flood defences as identified in NFCDD. However, the cost for new flood defences remains a substantial element of the construction costs in the majority of cases (although contaminated land and utility costs are significant in case study two). Therefore it would be beneficial to identify sites with landward boundaries on rising ground as part of the site screening criteria and/or subsequent option investigations.

There is a risk that changing hydrodynamics of the estuary or coastal zone could affect local processes around existing flood defences, resulting in higher maintenance costs or the need for additional flood defence provision. This risk would need to be investigated in detail as part of any scheme and supporting EIA and flood risk assessment.

There are likely to be further benefits if linked to wider flood risk management provision and these are discussed in section 5.1.3 above.

5.4.5 Working with Natural Processes

As discussed in other sections, working with natural processes will be the most cost effective approach to habitat delivery as opposed to designing 'like-for-like' habitats. Significant engineering interventions will increase construction and maintenance costs and increase the risk of the MR failing to achieve its ecological objectives. Therefore the site selection process should support the selection of sites that optimise the fit between natural processes and the desired objective (e.g. creating and maintaining intertidal mudflat).

5.4.6 Procurement Strategy

The Technical Workshop highlighted the importance of an effective procurement route for delivery and recommended the development of a procurement strategy which would need to take account of the risks, sensitivities and complexities of the projects it would be commissioning. Therefore the strategy would be minded to investigate the most appropriate assessment criteria, in particular the quality and cost ratios, to ensure that value for money is assessed against the whole-life-strategy cost and not necessarily procured on the lowest price per commission.

5.5 Benefits

Although not identified in the scope of works, the project team has noted that MR can deliver benefits through the provision of ecosystem goods and services (EGS) and wider public welfare. A summary of the potential benefits is provided below. It is recognised that if the MR was being promoted to offset losses of habitat elsewhere there could be a risk of double-counting and the benefits of such schemes may not be received by the communities where the original loss occurred.

English Nature (2006) has identified the EGS benefits associated with MR/intertidal habitats and EGS assessments have been undertaken by Eftec (Watts, *et al.,* 2009). The English Nature report identifies the following potential categories of ecosystem goods and services (EGS) that may be provided by marine intertidal habitats including mudflat and saltmarsh. There are other categorisations of ecosystem goods and services which have slightly different elements but the English Nature report can be used to provide an indication of potential EGS.

In addition to the benefits listed below, there are also non-use benefits which contribute to the total economic value which MR can provide. The EGS values largely relate to direct uses and indirect uses but information in support of these calculations is limited and information on non-use values even more limited.

A selection of the direct and indirect benefits has been reproduced below from the English Nature document (English Nature, 2006):

- Provisioning Services:
    - Food products (e.g. fish, shellfish); fibre and construction products (e.g. reeds for thatching); ornamental products and other products (e.g. white weed, shells, driftwood, bait); and other natural coastal products (e.g. samphire).
- Regulating Services:
    - Erosion control; flood risk management; detoxification of water and sediments; nutrient retention; carbon fixation and sequestration; global climate regulation; local climate regulation; and pollination.
- Cultural Services:
    - Recreation and tourism; education and scientific research resource; physical health benefits and promotion of personal well being; historical meanings and cultural importance and gene bank for research and development products.
- Supporting Services:

- o Oxygen production; Nutrient cycling; Habitats of conservation importance; association with species of conservation importance; high primary production and regenerative services.

Calculations of the economic benefits of intertidal habitats have been undertaken by Eftec (Watts *et al.,* 2009). This assessment calculated the ecosystem benefits of 5,734 Euros per hectare per year for saltmarsh (£5,197) and 4,112 Euros (£3,727[11]) per hectare per year for mudflat. Although these figures appear to illustrate the large scale benefits of MR, specific benefits assessment would need to be made with respect to the wider gains and losses associated with the implementation of a STP option.

5.6 Implications for Large Scale MR

The following sections discuss the wider issues associated with large scale MR as identified through the case study analysis and wider experience of the project team and Technical Workshop.

5.6.1 Ecological Functionality

The case study habitat predictions have shown that under a low intervention scenario (limited to breaching and excavation of a creek network), the site elevations with respect to the tidal frame, predict very different habitat compositions; case study one providing primarily low to mid saltmarsh, case study three providing low/mid and upper saltmarsh; and case study two providing primarily mudflat habitat. If the case studies were to be investigated as part of a site selection process for mudflat provision, case study two provides the greatest opportunity in the short term, providing over 80% mudflat, with case study three providing only 6%. To avoid progressing sites which cannot provide the necessary habitat potential it will be important to define the ecological criteria at the outset and undertake habitat prediction assessments as part of site screening unless significant intervention is the preferred option.

To minimise cost, site selection will be the most appropriate method for achieving the desired habitat and levels of engineering intervention should be minimal with respect to managing the risk of project delivery, timelines and costs associated with MR. Larger sites such as these could also provide the upper saltmarsh and transitional grassland habitats which are also Biodiversity Action Plan habitats and provide opportunities for a wider diversity of habitats and future accommodation space.

Where the objective is creation and long term maintenance of mudflat then the site selection process should direct investigations towards coastal or lower estuary sites with topography low in the tidal frame and interventions limited to aspects such as creek networks or removal of the existing sea defences (subject to detailed assessment and local conditions). However, there will continue to be uncertainty with long term habitat projections and the ability for a site to keep pace with sea level rise and it may be necessary to accept natural site evolution.

Conversely designing/engineering for an exact habitat replacement in perpetuity will result in increased costs and a greater risk of failure. For example, it would be inappropriate to promote a site high in the tidal frame to create long term mudflat. This would require substantial land lowering and continued dredging to keep levels low in the tidal frame to offset site accretion with the associated continued

[11] based on exchange rate of 0.9

maintenance costs and habitat/species impacts. This approach would not be sustainable.

Designing and implementing for specific habitats may also delay the timeline for implementation. The designing will be more technically challenging and require more modelling and investigations in consultation with stakeholders for agreement. The more complex designs would also extend the construction programme. In many areas there will be construction programme restrictions, for example, to mitigate potential construction impacts on breeding or over-wintering birds and an extended programme could mean construction over a number of years before breach.

The engineering of a creek network could speed up delivery of intertidal habitat across the site by improving hydraulic function (wetting and drying) and ensuring the site achieves maximum potential for intertidal habitat creation. The material from the creek network could also contribute to the rear wall embankments where required and material appropriate.

Due to the size of the MR sites, the scale of engineering required even with minimal intervention, and the onsite mitigation required for protected habitats and species, such projects may need to be undertaken in phases over a number of years. Therefore the provision of the necessary habitat would be staggered over different timeframes.

Appropriate compensation ratios for large scale MR

One of the objectives of the study was to identify if there are any additional issues specifically relating to 'going large' which would mean that additional compensation ratios would be required to meet Article 6 of the Habitats Directive.

The study has shown, at a high level, that sites can be breached and water can inundate the site such that saltmarsh and mudflat habitat could form. This potential functionality of large sites leads to the conclusion that additional compensation increments specifically relating to the size of the sites may not be necessary in support of Article 6.

5.6.2 Possible Timeline and Steps for Large Scale MR

This section poses a timeline for a compensatory habitat but does not discuss the consequential implications for a STP option. The proposed timeline for delivering MR can be separated into four stages and indicative programme lengths have been assigned:

- Stage 1: Site Selection (2 years);
- Stage 2: Design, planning, land purchase and consenting (5 -7 years);
- Stage 3: Construction (3 years); and
- Stage 4: Ecosystem function (2-5 years).

Site selection includes establishing the project governance and approach and the development and agreement of high level habitat compensation objectives (ecological criteria for site selection). Site screening, assessment and short-listing undertaken and a short-list of options presented and agreed with the regulators and key stakeholders.

Stage two would be the design stage. This includes the development of the detailed design and associated investigations, land purchase and consenting. Land purchase would be the most complex element and the greatest risk to the project timeline. HRA investigations and studies of off-site effects are also likely to be a significant component of this stage as it is unlikely that a suitable MR site could be found that is not adjacent to, or in the vicinity of, a designated site.

The construction stage has been estimated as three years assuming a large scale site with a potentially limited construction window (e.g. avoiding overwintering or breeding seasons).

Stage four is the period from completion of construction to ecological function. Diverse intertidal benthos assemblage could develop in one or two years and assuming local seed supply, saltmarsh could colonise in a year with nearly 100% coverage by year five. Bird usage of the site is likely to be immediately following construction with respect to roosting and use as food supply from years two to three.

Variations in the Consenting Timeline

The actual timeline with respect to STP would be very complex. Consent cannot be given for any project which has an adverse effect on integrity (e.g. STP option) until it can be demonstrated that compensation could be secured. This requires a clear indication that all matters which could prevent habitat creation have been or are capable of being resolved (including any potential adverse effects from the MR).

It is therefore assumed that the timeline for such habitat provision would need to be initiated prior to project level STP investigations being completed and prior to any compensatory measures package being fully defined and agreed. To reduce the potential delay on the delivery of associated MR the ecological criteria could be set at a high level with a process of update and review as further information becomes available.

It may be possible to speed up the land acquisition process by working with devolved administrations and government departments which are significant landowners and developing schemes on these landholdings. Whilst it is recognised that there would remain issues associated with existing tenants there may be timeline opportunities. National governments and public bodies would include The Crown Estate, Ministry of Defence and others. A stock-take of such land holdings could be a useful input to the site selection process.

Coordinated Approach

It is recognised that there are a number of Government (UK and WAG) and public bodies which are also seeking to implement MR around the country and benefits could be gained by coordinating site selection and implementation of such schemes. Managing and monitoring losses and gains in a coordinated manner could streamline the timeline for delivery of intertidal habitat as well as cost savings for UK plc.

It is recognised that such an approach would need governmental and organisational assurances of delivery as well as annual monitoring and review of Natura 2000 coherence.

5.6.3 Screening for Large Scale MR

This section discusses the criteria which may be required to identify the most appropriate sites for large scale MR. The discussion refers to general criteria for identifying large scale MR options as well as the criteria required in support of any STP habitat compensation package. The weighting of each criteria and how each of these would contribute to site selection would need to be considered. The criteria for compensating for a STP option have been discussed separately to general MR site criteria.

The types of approach used in constructing this study could be applied to developing criteria for site selection[12].

Large scale MR

It is likely that an options appraisal process would be required to show appropriate cost-benefit. Therefore the initial screening process may benefit from following the same approach as this study; estimating land purchase, construction, and design, consultancy and consenting costs.

Within a given area, a number of permutations of options may be available giving rise to different unit costs (£/ha created) and off-site effects. To support options appraisal, it may be helpful if the site selection process considered a number of broad options for each location which can be refined through subsequent analysis.

In some locations, large scale MR may give rise to significant off-site changes which could affect flood risk, designated habitats or economic uses. Based on the initial modelling assessments undertaken for this study, it may be prudent to avoid very large realignments in estuaries with important commercial interests because of the potentially significant costs in mitigating or compensating such impacts.

In taking forward the identification and prioritisation of potentially suitable sites; it is therefore suggested that the following criteria should be applied:

- Desk based evaluation of the nature and extent of potential habitats created using LiDAR or other indicative elevation information;
- Estimation of unit costs of created habitat (£/ha) based on land purchase costs, construction costs and design, consultancy and consenting costs as per the methodology applied in this study; and
- A risk assessment of off-site issues to highlight possible sites and/or scales of development where off-site risks may affect viability/deliverability. This should include screening of potential assets and simple computer modelling of sites/areas where considered necessary.

[12] The study approach excluded main roads and rail infrastructure and this has been queried by the Steering Group. The re-routing of major infrastructure as part of any MR is likely to significantly raise the unit cost, therefore it is questionable whether such sites should be investigated on economic grounds but flexibility in the screening would be recommended.

When reviewing the previous screening outputs the area of potential MR should be landward to the extent of the Environment Agency's Flood Zone 3 mapping rather than 5km from the coastline.

Those sites which were considered to be most appropriate might then be taken forward for a more detailed pre-feasibility assessment including the statutory and legal issues, in particular.

- Suitability of potential habitats (habitat predictions reviewed against project objectives);
- Statutory and legal issues;
  - Land ownership (number of properties and landowners as well type of landowner (state owned, residential, commercial));
  - Potential cost of land purchase;
  - Proximity to commercial interests which could potentially be affected and likelihood of compensation being required;
  - Potential for objection; judicial review, public inquiry;
  - Level of environmental protection and need for further mitigation/compensation; and
  - From above, identification of liabilities against which the project may need to be insured.
- Flood risk management;
  - Scale of requirement for new flood defences;
  - Potential implications for off-site flood storage capacity; and
  - Linkages with flood risk management policies.
- Technical issues;
  - Requirements for road, rail, and infrastructure diversions;
  - Ability to function with limited intervention;
  - Scale of the off-site changes (hydrodynamics, geomorphology); and
  - Site sustainable with climate change against stated objectives.
- Environmental issues;
  - History of pollution or contamination;
  - Potential landscape impact/impact on visual amenity;
  - Potential impact on archaeology/cultural heritage; and
  - Exclusion of areas already subject to MR;

- Social and recreational issues;
    - Potential effects on rights of way/public access; and
    - Potential effects on navigation (non-commercial);

Linkages to STP

When defining the ecological criteria for large scale MR for a STP alternative the following considerations may be useful:

- For reasons of sustainability and cost, it would be beneficial to assess the suitability of sites in meeting the ecological objectives following a minimal intervention scenario;

- The importance of proximity has been raised by the Steering Group. The relative scarcity of potential large MR sites around England and Wales, makes it unachievable to apply this principal when selecting large sites and would need to be considered as part of the delivery of the overall habitat creation package of which a large scale MR site would be a component;

- It is highly likely that the MR site will be adjacent to another designated site and although this should not preclude the promotion of large scale MR in such areas this is likely to be a technically complex and costly issue; and

- Separate from technical issues, the site selection process would need to be integrated with the consenting programme for any STP scheme and seek opportunities to identify sites which have potential for early implementation

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SECTION 6

CONCLUSIONS AND RECOMMENDATIONS

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The most important conclusion to draw is that it is possible to create large scale intertidal habitat with limited engineering intervention. In addition, the study has found that there are no *new* technical barriers associated with “large scale” MR other than those already encountered in MR schemes completed to date. However, the scale of the “large” projects would be such that the engineering costs may be higher and the risk of encountering unforeseen issues is greater and mitigation for such risks likely to be more costly than for existing MRs. The study has found that it would be beneficial for large scale MR to follow a low-intervention approach which works with natural processes.

These conclusions are founded on the project assumptions set out in the methodology. The conclusions are valid with respect to the creation of mudflat and saltmarsh habitat. The project has not sought to determine the contribution of the case study areas to offsetting impacts on the Severn Estuary.

Site specific issues and considerations are seen to be the most important driver for the cost of large scale MR schemes and the cost of the case studies per hectare of habitat created has not shown any correlation with scale. Therefore it can be concluded that effective site selection is the most important factor affecting cost.

Issues associated with land purchase will be much greater than experienced with MR schemes to date and this is due to the scale of the large sites. Statutory delivery routes may be required such as an Act of Parliament or compulsory purchase and effective public communication and engagement will be a vital component in managing costs and programme.

The baseline average cost per hectare of habitat created of approximately £53,000. This cost rises by approximately £2,000 to nearly £55,000 under the high scenario and falls by over £8,000 to under £45,000 per hectare under the low scenario. These figures are quoted without optimism bias. With optimism bias the baseline cost rises to £85,000 per hectare. The study has followed a conservative approach to project costs, particularly with respect to the design of the rear embankment (including a 1:200 standard of protection, 1.5m freeboard and import of fill material) and the 50% rather than 30% allowance for design, consultancy and consenting. This approach is reflected further in the additional 60% optimism bias and as such could be an over-estimate. The Steering Group has noted that the cost estimates appear high, particularly when reviewed against the more recently completed projects. Therefore the low scenario costs with optimism bias of £71,500 may be applicable.

The case studies have shown that the hydrodynamic and sediment transport changes may be manageable depending upon the location of the realignment. However there are significant risks associated with proximity to designated sites and economic assets. The case study selection should take account of such risks and potential liabilities for a MR scheme.

The programme and resource benefits of promoting a small number of large schemes is likely to greatly outweigh the alternative of developing 50 or 60 smaller schemes. The final approach will depend upon the scale of the compensation required by any STP alternative.

There remain a significant number of key risks of taking forward such schemes and a number of these are listed below but the list is not exhaustive:

- Proximity to designated sites;
- Land purchase;
- Public acceptability;
- Implications of changes to hydrodynamic and geomorphological system to sensitive economic assets;
- Effective communication and engagement strategies;
- Presence of protected species;
- Site design and construction methodology; and
- Contribution to any habitat compensation package.

6.2 Recommendations

The timeline identified for delivering large scale compensatory habitat is estimated between 10 and 12 years for a scheme on the ground with a further period of between 2 and 5 years to develop ecological functionality. Therefore the lead in time for schemes that require large areas of compensation requires early planning, site selection, prioritisation and investigation, focusing on the ecological criteria, costs and offsite risks.

Site ecological selection criteria should reflect the compensatory requirement and where there are specific requirements it is recommended these are addressed through site selection rather than site engineering i.e. minimum intervention.

Land assembly has been identified as the most difficult aspect of the project and one of the greatest risks with respect to programme/timeline. A preferred procurement model would need to be identified.

It may be beneficial to establish partnerships involving STP constructors and operators, land owners, local and national Governments and their agencies to maximise benefits for UK plc and the benefits of such schemes could be identified and promoted as part of a coordinated approach for large scale MR.

6.3 Further Investigations

As recommended above, the lead in time for MR requires early planning and it would be beneficial to begin work on refining the criteria and the site selection and investigation as early as possible in the process. The next stages are recommended to develop and implement a Site Selection Strategy, in particular:

- Define the ecological objectives for compensatory package;
- Agree screening criteria and site selection strategy;
- Undertake site screening and prioritisation; and
- Agree prioritisation of sites and begin feasibility studies for those short-listed (including sub-options).

It is likely that the site selection process will be iterative as the sites are reviewed and monitored with respect to a habitat compensation package and ecological coherence.

In parallel to this the STP project could be working with key organisations to define the land procurement route (e.g. Act of Parliament), develop communication and consultant procurement strategies and begin seeking political support.

Investigation of the benefits associated with large scale MR may also be helpful.

SECTION 7

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7 REFERENCES

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SECTION 8

ACRONYMS AND ABBREVIATIONS

8 ACRONYMS AND ABBREVIATIONS

%	Percent
£	British Pound (Sterling)
ABPmer	ABP Marine Environmental Research Ltd
CCW	Countryside Council for Wales
CHaMP	Coastal Habitats Management Plan
cm	Centimetre(s)
CPO	Compulsory Purchase Order
DCLG	Department for Communities and Local Government
DECC	Department of Energy and Climate Change
Defra	Department of Environment Food and Rural Affairs
EGS	Ecosystem Goods and Services
EIA	Environmental Impact Assessment
FEPA	Food and Environment Protection Act
FHRC	Flood Hazard Research Centre
GIS	Geographical Information System
ha	Hectare(s)
HAT	Highest Astronomical Tide
HRA	Habitats Regulations Assessment
km	Kilometre(s)
LiDAR	Light Detection and Ranging
m	Metre(s)
M	Million
m/s	metre(s) per second
m^3	Metre(s) cubed
MCM	Multicoloured Manual
MHW	Mean High Water
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MR	Managed Realignment
NDP	National Property Database
NE	Natural England
NFCDD	National Flood and Coastal Defence Database
NPD	National Property Database
ODN	Ordnance Datum Newlyn
OMREG	On Line Managed Realignment Guide
OS	Ordnance Survey
RICS	Royal Institute of Chartered Surveyors
RoW	Rights of Way
RSPB	Royal Society for the Protection of Birds
RTE	Regulated Tidal Exchange
SAC	Special Area of Conservation
SDC	Sustainable Development Commission
SEA	Strategic Environmental Assessment
SLR	Sea Level Rise
SMP	Shoreline Management Plan
SPA	Special Protection Area
SSSI	Sites of Special Scientific Interest
STP	Severn Tidal Power

T	Tonne(s)
UK	United Kingdom
UKCIP	United Kingdom Climate Impacts Programme
UXO	Unexploded Ordnance
WQ	Water Quality

ANNEX A

EXAMPLE COSTING SPREADSHEET

Cost Item		Rate as from source	Base date	Uprating factor	Rate for cost calc	Units	Quantity	Cost	Totals	Comment/Source
Land purchase (See rate on sheet 3)										
	Acquisition Costs									
	Arable (Grades 1-3)		Jun-09	N/A	0	Ha		**0**		Example Rates: NPD classifications and values from RICS rural market survey H1 2009
	Pasture (grades 4-5)_		Jun-09	N/A	0	Ha		**0**		
Property purchase										
	Detached	201,858	Oct-09	1.00	201,858	No.		**0**		Example Rates: NPD Classifications and values from Land Registry Website
	Semi-detached	116,191	Oct-09	1.00	116,191	No.		**0**		
	Terraced	87,400	Oct-09	1.00	87,400	No.		**0**		
	Maisonette/flat	79,872	Oct-09	1.00	79,872	No.		**0**		
Commercial										
										Specific costs developed for each commercial property
Total Land Purchase									**0**	
Diversion of roads										
	Link Road (rural)	945	May-06	0.9931	938	m		**0**		Spon's Civil Engineering and Highways price book
	Single carriage way (rural)	1,311	May-06	0.9931	1,302	m		**0**		
	Dual carriage way (rural)	1,932	May-06	0.9931	1,919	m		**0**		
	Motorway (3 lane rural)	2,968	May-06	0.9931	2,948	m		**0**		
Diversion of railways										
						km	0	**0**		None in study sites
Diversion of footpaths										
	Temporary					km	0	**0**		
	Permanent					km	0	**0**		
Diversion of services										
	Nominal cost to divert unknown services									Nominal figure of between £1.5M and £500k used (expert judgement)
	Diversion of gas pipeline									
	Service removal / decommissioning				2,000		0	**0**		Nominal figure of £2k per property used (expert judgement)
Other costs										
	Pumping Stations				1,500,000	No.		0		
	Sluice/outfall				250,000	No.		0		
	Demolition Costs									Costs based on number of properties
	Detached				10,000		0	**0**		
	Semi-detached				8,000		0	**0**		
	Terraced				7,000		0	**0**		
	Maisonette/flat				5,000		0	**0**		
	Commercial									Nominal figure used per site based on site size
	Road removal									Nominal figure used per site based on site size and number of roads to be removed
Embankment costs										
	Embankment Length (km)									Env. Agency's Flood Risk Management Estimating Guide.
	Average height embankment (m)									
	Cost of embankment construction									£24 per m^3 fill volume
	Stone armouring Placement and delivery	50	Dec-09	n/a	50	T				Including delivery by boat to nearest Port, Haulage to site and placing of rock
	Geotextile underlayer	5	Dec-09	n/a	5	m^2				
	Total embankment cost									
Breach creation										
	On-site channels				4	m^3				Rate based on outputs of plant/labour and volumes of excavation required
	Breach excavation				20,000	per breach		**0**		
Assessment and Management of contaminated ground										
	Removal of contaminated material from old embankment				200	m^3		**0**		Professional judgement
Total Construction									**0**	
Other Costs										
Scenario A (% land/construction estimations)										
	Engineering Design and Management costs				25	%		0		25% of construction costs
	Client Costs				5	%		0		5% of construction costs
Total Design and Supporting Costs									**0**	
Total following Scenario A									**0**	
	Optimism Bias				60	%			0	
Grand Total following Scenario A									**0**	
	Price per Ha								**0**	
Scenario B (case study specific)										
Consultancy										
	Engineering Design							1,600,000		Assume that scheme would need to follow a phased approach for H&S and ecological purposes. Ecological and flood storage mitigation assumed to be included within design
	Computer Modelling							1,300,000		HD, Wave, Sediment and Flood Risk
	EIA Investigation/Production							1,200,000		Includes EIA investigations including Traffic; Noise; Landscape; WQ; Sustainability Appraisal; Habs. Reg. Assessment etc.
	Consultation							1,000,000		Professional judgement
Total Consultancy									**5,100,000**	
Consents										
	Planning							250,000		Changes by DCLG likely to reduce planning fees for MR. However due to the scale of these sites unlikely the lower costs of £1690 would be applicable
	FEPA/CPA Construction							25,000		Estimations
	FEPA Dredging							31,000		
	Abstraction/Discharge consents							12,000		
	Other (Harbour Works, RoW etc)							15,000		
Total Consents Fees									**333,000**	
Specific Investigations (Risks)										
	Ground Investigations							1,000,000		Assume required along back wall alignment
	Archaeological surveys/heritage mitigation	445	Jan-10		445		**8,919**	3,968,955		RSPB Experience from previous sites; Estimation of other sites divided to give a generic cost per ha
	Ecological Surveys	222	Jan-10		222		**8,919**	1,980,018		RSPB Experience from previous sites; Estimation of other sites divided to give a generic cost per ha
	UXO	810			810		**892**	722,520		Alkborough £300k for 370ha (£810ha) % of site dependant upon local knowledge
	Dredging							3,000,000		Potential need for additional maintenance dredging (navigational channel), site specific
	Site Monitoring	445	Jan-10		445		**8,919**	3,968,955		RSPB Experience from previous sites; Estimation of other sites divided to give a generic cost per ha
	Offsite Monitoring							2,000,000		Additional monitoring costs over and above estimate to address additional offsite risks. Case study specific
	Other				10	%		1,364,045		
Total Specific Investigations									**18,004,493**	
Legal Fees+ client costs										
	Compulsory Purchase				1000		**232**	232,000		Assume lawyers fees of £1,000 per property (exc. agri. land)
	Compulsory purchase compensation				5	%	**0**	0		Assume 5% of total land value
	Judicial Review							2,500,000		
	Client costs				5	%		0		5% of construction costs
Total Legal Fees + Client Costs									**2,732,000**	
Total following Scenario B									**26,169,493**	
	Optimism Bias				60	%			15,701,696	
Grand Total following Scenario B									**41,871,188**	
	Price per Ha								**4,695**	
High Scenario (Sensitivity Test)										
	Medium Intervention									
	Wall removal				0		5	0		Assume 5 times breach costs
	Site Landscaping				2,500	ha		0		RSPB Advice from experience at other sites: assume 10% of site
	Total Medium Intervention									
	New Construction cost									
	Scenario A New Design and client cost							0.00		Assume 30% of new construction total
	Price per Ha Scenario A with Habitat Intervention				60	%		0.00		Including optimism Bias
	Price per Ha Scenario B with Habitat Intervention				60	%		0.00		Including optimism Bias. Note that design costs have not been increased accordingly
	Property Purchase				50	%		0.00		50% of Property Purchase
Construction (Sensitivity Test)										
	20% Reduction in Construction Costs				20	%	**0**	0	0	New construction cost: Assume Value engineering results in 20% cost reduction
	Scenario A New Design and client cost				30	%		0.00		30% of new construction total
	Price per Ha Scenario A				60	%		0.00		Including optimism Bias
	Price per Ha Scenario B				60	%		0.00		Including optimism Bias. Note that Scenario B costs have not been decreased accordingly
	No Rock Armour Required						0.00		0.00	
	Scenario A New Design and client cost							0.00		30% of new construction total
	Price per Ha Scenario A with no rock armour required				60	%		0.00		Including optimism Bias
	Price per Ha Scenario B with no rock armour required				60	%		0.00		Including optimism Bias. Note that Scenario B costs have not been decreased accordingly

ANNEX B

RESULTS: DETERMINING APPROPRIATE CONTRIBUTION OF DESIGN, CONSULTANCY AND CONSENTING COSTS AS A PROPORTION OF TOTAL CONSTRUCTION

Costing Methodologies: Case Study 1						
Scenario	**A**	**% Difference from Baseline**	**B**	**% Difference from Baseline**	**C**	**% Difference from Baseline**
Methodology A						
Base cost	£31,543,727		£17,249,436		£8,807,032	
Total A (including optimism bias)	£486,571,364		£226,099,583		£97,014,671	
Cost/Ha A (including optimism bias)	£55,921	-6	£56,440	-8	£80,981	-9
Methodology B						
Base cost	£52,956,662		£33,959,282		£18,404,670	
Total B (including optimism bias)	£520,832,059		£252,835,338		£112,370,893	
Cost/Ha B (including optimism bias)	£59,859	0	£62,738	3	£93,799	6
Methodology B % of construction costs		50		59		63
Methodology B % of construction without SSSI costs		49		59		57

Costing Methodologies: Case Study 2								
Scenarios	**A**	**% Difference from Baseline**	**B**	**% Difference from Baseline**	**C**	**% Difference from Baseline**	**D**	**% Difference from Baseline**
Methodology A								
Base cost	£43,664,735		£13,972,550		£14,408,498		£9,803,571	
Total A (including optimism bias)	£623,142,441		£289,165,697		£202,276,497		£149,086,886	
Cost/Ha A (including optimism bias)	£59,403	-8	£39,536	9	£44,127	-7	£54,611	35
Methodology B								
Base cost	£75,770,785		£53,907,991		£26,819,414		£36,399,194	
Total B (including optimism bias)	£674,512,122		£353,062,404		£222,133,964		£191,639,883	
Cost/Ha B (including optimism bias)	£64,300	0	£48,272	33	£48,459	2	£70,198	73
Methodology B % of construction costs		50		104		56		111
Methodology B % of construction without SSSI costs		38		70		55		81

Costing Methodologies: Case Study 3								
Scenario	**A**	**% Difference from Baseline**	**B**	**% Difference from Baseline**	**C**	**% Difference from Baseline**	**D**	**% Difference from Baseline**
Methodology A								
Base cost	£23,004,203		£22,000,016		£14,648,510		£10,287,305	
Total A (including optimism bias)	£243,589,818	-9	£233,442,124	-9	£145,350,975	-10	£82,413,930	-12
Cost/Ha A (including optimism bias)	£107,783		£109,341		£111,295		£154,623	
Methodology B								
Base cost	£24,775,633		£24,383,727		£15,644,061		£4,788,113	
Total B (including optimism bias)	£246,424,108		£237,256,062		£146,943,857		£73,615,223	
Cost/Ha B (including optimism bias)	£109,037	-8	£111,127	-8	£112,514	-9	£138,115	-21
Methodology B % of construction costs		32		33		32		14
Methodology B % of construction without SSSI costs		29		30		31		15

ANNEX C

SEVERN ESTUARY: RE-ASSESSMENT OF PLAUSIBLE HABITAT

REASSESSMENT OF PLAUSIBLE LAND AVAILABLE IN THE SEVERN ESTUARY (BEHIND SEA WALLS)

Methodology

The study has reviewed the STP options which are being investigated within the SEA and are listed in the table below. The study has sought to investigate the area of land potentially available for intertidal habitat creation which is currently behind sea walls.

This GIS assessment is intended to be a screening of the theoretical area available in the Severn Estuary and provides an initial estimate of the potential land available under the different tidal power options. These options are listed in Table C1 below. Further work will be required to determine the applicability of such sites for MR, assessing each site against different ecological, hydrodynamic, policy and technical criteria all of which is outside the scope of this study.

Table C1: Severn Estuary Tidal Power options

SEA Phase 1	**SEA Phase 2**
Large barrage	B3 Cardiff-Weston barrage
Small barrage	B4 Shoots Barrage B5 Beachley Barrage
Lagoon	Lagoon L2 (Welsh Grounds) Lagoon L3 (Bridgwater).

MHWS and MHWN have been taken as proxies for the upper limited of saltmarsh and mudflat habitat respectively for this assessment, based on the following key assumptions:

- The existing sea walls would be breached; and
- There is sufficient water entering the site to effectively inundate the newly created area.

The base year for the investigation has been taken to be 2020, the assumed year of operation of a preferred option.

In line with the remainder of the managed realignment feasibility study and the flood risk components of the SEA, the Defra 2006 sea level rise guidelines have been used to determine the 2020 water levels. For the year 2020 this results in a sea level rise of 0.105m from the 1990 baseline against the UKCIP projection of 0.097m. Therefore there is a difference of only 8mm between the two predictions which is not significant in the calculation of areas that might be inundated.

The base topography for the assessment is a digital terrain model using a composite of different LiDAR datasets flown between 1998 and 2008 (Black and Veatch (2009)). As such there remains a risk of inaccuracies in the data due to distortion from vegetation inadvertently elevating land levels. Ground-truthing would be required in support of future investigations.

Water levels for MHWS, MHWN and Highest Astronomical Tide (HAT) have been taken from the ABPmer hydrodynamic modelling undertaken for the STP SEA and used as proxies to map the predicted distribution of mudflat, saltmarsh and coastal grazing marsh. The predictions were then reviewed against the STP SEA Phase 1 outputs and the Severn Estuary Coastal Habitat Management Plan (CHaMP) to update the loss predictions arising from the scheme options relative to the coastal floodplain. Consideration has been given to the likely threshold beyond which compensation outside the Severn Estuary may be required.

A review of the topography of the plausible habitat has shown that area landward of the sea walls is at a relatively high elevation in the tidal prism and the opportunities for mudflat creation are extremely limited. This has been determined by calculating the predicted MHWN tide levels derived from the hydrodynamic modelling for the baseline (no scheme). Less than 10ha of potential mudflat opportunity has been identified under the baseline (no scheme) case which is insignificant in the context of potential losses. It was therefore considered unnecessary to calculate mudflat opportunities under the different SEA options.

Due to the limited mudflat opportunities this technical note has therefore focused upon the use of MHWS to differentiate between saltmarsh and coastal grassland and calculations have been made for the intertidal area available landward of existing sea walls as follows:

- Baseline (no scheme in place); and
- The five SEA options.

These results have then been reviewed against the original area of plausible habitat identified and discussed in relation to the potential losses of intertidal habitat which are being identified by the SEA. The review has been limited to the predicted change in water levels arising from the STP options. No other construction or operational effects, such as dredging, have been taken into account.

Habitat Calculations

The GIS layers from the Phase 1 investigation were used as the basis for this study. They were clipped to the SSSI layer and all overlapping areas removed. This was used as a mask to create a raster of plausible managed realignment sites complete with elevation from the BV digital terrain model developed by Black and Veatch for the STP SEA investigations (BV, 2009). Plausible areas have been calculated with the inclusion and exclusion of SSSI. The area identified has therefore been based upon:

1. Environment Agency Flood Zone 3;
2. Within 5 km of the coast;

3. Exclusion of Natura 2000 sites;

4. Each site greater than 10ha in size; and

5. SSSI sites (scenarios for inclusion and exclusion).

Water levels were created based on the modelled changes in MHWS which would occur for each option. The MHWS and MHWN water levels were extracted from the two dimensional hydrodynamic modelling being undertaken in support of the current SEA investigations (BV/PB in development). The water level data were converted into GIS data layers by plotting XYZs and creating a raster from the points. The rasters were modified using Raster Calculator to take into account sea level rise using Defra 2006 sea level rise predictions to produce MHWS water levels for the assessment year of 2020 (year of operation). The Raster Calculator was used to determine how much of the managed realignment sites identified were less than the new MHWS.

The habitat calculations were based on water levels only and the functionality of the sites was not investigated. This approach differs from the CHaMP and Phase 1 investigation simply due to the water levels used. The CHaMP identified all the plausible area using parameters 1-3 above, i.e. capturing all the area which could have the potential for coastal habitats. This investigation has used all five criteria above and the MHWS and MHWN water levels (as proxies) to determine the opportunity for creating saltmarsh and mudflat habitat. This provided more specific estimations of intertidal habitat potential with and without any STP scheme.

Results

This GIS based assessment has been undertaken to provide an understanding of the likely land that could be theoretically suitable for creating intertidal habitat through MR. The assessment is intended to be used as an indicative screening study, using MHWS and MHWN as proxies for the upper limit of saltmarsh and mudflat habitat. It is recognised that the identification of areas through this approach is a first step in the process and that further investigations would be required to determine if/how the sites could function as intertidal habitat and if/how the sites would be suitable within a larger habitat compensation package.

It is also noted that many of the sites are adjacent or landward of existing SSSIs and further investigation would be needed to determine potential effects in liaison with CCW, NE and others. This study is also limited to the identification of mudflat and saltmarsh and separate studies are investigating issues associated with other species (particularly SPA bird interests) and specific features (including Atlantic Salt Meadow, intertidal rock etc.) which could be affected through the implementation of the Severn Estuary Tidal Power options. Finally it is recognised that any such habitat creation opportunities should be developed in collaboration with other plans and projects in the Severn Estuary, in particular the Shoreline Management Plan and forthcoming Severn Estuary Flood Risk Management Plan which may also be seeking and implementing habitat creation schemes along the Severn Estuary.

The results are provided in Table C2 and indicate the theoretical habitat availability for both the baseline (no scheme) and for each of the five short-listed options.

The headline conclusion from these results is that the potential realignment areas adjacent to the Severn Estuary are suitable for saltmarsh creation but the opportunities may be substantially limited under certain STP options. However there are no MR opportunities for developing sustainable mudflat habitat even without any STP options in place at 2020 based upon the current topographic data[13].

Baseline (No scheme)

The review has included an assessment of the MR opportunities within the CHaMP opportunity areas and has been reported as 'the baseline'. The CHaMP identified all potential areas for coastal MR within areas at risk of coastal flooding (i.e. could be inundated under a 1:200 extreme flood event). The baseline case for this study has used MHWS and MHWN as proxies for the upper limit of saltmarsh and mudflat habitat providing more detail on the 'intertidal' component of habitat creation opportunities. The results with respect to the baseline situation at 2020 are:

- Less than 10ha of mudflat would be available for mudflat creation landward of seawalls in the Severn Estuary;
- Only 66% of the area identified in the CHaMP could deliver intertidal habitat (below MHWS) at 2020 with the remainder providing coastal grassland habitat. This equates to approximately 7,600ha of the total 11,500ha; and
- The figures are similar for the total area of non-SSSI with the total area of plausible sites being approximately 5,580ha or 66% of the total.

STP Options

The potential for compensatory habitat through managed realignment within the Severn Estuary varies between options. Excluding SSSI habitat, there remains opportunity to create between 300ha (Cardiff-Weston barrage (B3) option) and nearly 5,000ha (Welsh Grounds Lagoon (L2) option) of intertidal habitat in the Severn Estuary. Within this there may be opportunities for regulated tidal exchange[14] (RTE) for mudflat creation but this would depend upon the site elevation within the tidal prism, it is anticipated that opportunities may remain limited.

If SSSI habitat was suitable for inclusion the opportunity for intertidal habitat creation landward of existing sea walls would increase to between 690ha (for Cardiff-Weston (B3) option) and 6940ha for the Welsh Ground Lagoon option (L2).

The Cardiff-Weston (B3) option has, as expected, the largest effect on the total area of plausible compensatory habitat available. This is because it reduces the predicted MHWS by approximately 0.5m – 0.7m and raises the low water level. This results in the area of intertidal habitat potentially available reducing from 5,580ha (excluding SSSI) to 300ha.

[13] It is noted that there may be opportunity to create intertidal mudflat within the Severn Estuary through topographic modification based on a preliminary investigation undertaken as part of the STP investigations (BV 2009 unpublished).
[14] The regulated exchange of sea water to an area behind flood defences, through engineered structures such as tide-gates, sluices or pipes, to create saline or brackish habitats.

Even with these relatively small reductions in water levels, it is predicted that only 5% of the potential compensatory habitat would remain available at 2020*, with the remaining area being above the predicted intertidal zone*. The other SEA options have less of an effect with between 55% and 90% of the baseline intertidal still available for potential habitat compensation.

The implications of the potential sites being located in the upper tidal range can be seen through the sensitivity test which has been undertaken for the Cardiff-Weston (B3) option. With an additional 0.5m added to MHWS, the plausible land available excluding SSSI habitat increased significantly to 1,720ha or 31% of the baseline plausible area. This sensitivity accounts for approximately 50 years of sea level rise (54 years based on Defra sea level rise predictions from a base year of 2020) and/or could account for the inclusion of transitional and coastal grassland as well as sea level rise.

Table C2: Potential habitat creation areas in the Severn Estuary

			Total area identified (Phase 1)	No Scheme (Baseline)	B3	B4	B5	L2	L3
Intertidal Habitat	Including SSSI	Area (Ha)	11580	7670	690	6620	6250	6940	4450
		% of total available area		66					
		% of baseline intertidal remaining			9	86	81	90	58
	Excluding SSSI		8500	5580	300	4390	3970	4960	3070
		% of total available area		66					
		% of baseline intertidal remaining			5	79	71	89	55
Mudflat	Excluding SSSI	Area (Ha)		9					
Sensitivity (+ 0.5m)	Including SSSI	Area (Ha)			2350				
		% of baseline intertidal remaining			31				
	Excluding SSSI	Area (Ha)			1720				
		% of baseline intertidal remaining			31				

Discussion

As discussed in the methodology and results sections above, this GIS assessment is intended to provide a theoretical maximum of the plausible area of intertidal habitat within the Severn Estuary. It is not intended to be used as a substitute for assessing individual sites for habitat creation potential or as part of the assessment/development of the any compensatory package.

This is a high level assessment and is subject to a wide variety of uncertainties, for example, reductions in sea level rise estimations; the accuracy of the LiDAR (no ground truthing has been undertaken); model tolerances and others. The assessment is therefore intended to be used as an indicator and it should be used as an indication of habitat availability without undue focus upon the specific numbers.

The assessment of the opportunity for mudflat creation under the baseline (no scheme) scenario has shown that less than 10ha would be suitable for mudflat creation. This is due to the vast majority of the 5,500ha of potentially available land being above the MHWN and therefore unlikely to create sustainable mudflat habitat. This means that even without any STP scheme being in place, there are no significant opportunities for mudflat creation in the Severn Estuary landward of sea walls without the need for significant engineering intervention.

The potential for compensatory habitat through MR within the Severn Estuary varies between options. Excluding SSSI habitat, there remains opportunity to create between 300ha (B3 Cardiff-Weston option) and nearly 5,000ha (L2 Welsh Lagoon option) of intertidal habitat within the Severn Estuary. Within this there may be opportunities for RTE for mudflat creation but this would depend upon the site elevation within the tidal prism, it is anticipated that opportunities may remain limited. If SSSI habitat was suitable for inclusion the opportunity for intertidal habitat creation landward of existing sea walls would increase to between 690ha for the B3 Cardiff-Weston option and 6940ha for option the L2 Welsh Lagoon option.

When reviewing the worst-case scenario of the Cardiff-Weston (B3) option (without SSSI), where 300ha of intertidal is theoretically available, it is unlikely that there is such potential in reality. The opportunities are limited to two areas on the Welsh coast. The first is situated behind a terrestrial/freshwater SSSI in the Caldicot Levels next to the M4. The second is in the upper reaches of the Severn Estuary near Gloucester.

There may be opportunities for using the existing wetland and terrestrial SSSI areas for intertidal compensation but consideration of the features for which they are designated and the potential to move them inland as part of climate adaptation measures would be needed as well as the potential for conflict with terrestrial mitigation opportunities. Any such measures would need further investigation with respect to the features of interest; the functionality of the scheme; the implications for the wider estuary as well other measures, plans and projects in the estuary.

It has been questioned whether the reduction in water levels as a result of the STP B3 Cardiff-Weston option could offset coastal squeeze in the estuary. Whilst this does reduce water levels by 0.5-0.7m there are issues associated with the loss of intertidal in the lower tidal frame. Therefore whilst it is a theoretical possibility, this would need to be discussed in the context of the wider habitat gains and losses in the Severn Estuary and is outside the scope of this investigation.