MERSEY TIDAL POWER

FEASIBILITY STUDY: STAGE 3

Marine Ecology Report

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Project Sponsors:

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Project Background

In the face of current and anticipated issues of security of supply and climate change, the need to find local sources of renewable energy has never been more urgent.

The Mersey Estuary has one of the largest tidal ranges in the UK, making it one of the best locations for a tidal power generation scheme. It has the potential to make a significant contribution to the Government's target to secure 15% of UK energy from renewable sources by 2020.

A large scheme could deliver enough renewable electricity to meet the needs of a significant proportion of the homes within the Liverpool City Region, as well as beyond. Any scheme put forward will need to take into account the ecological diversity of the Estuary, which supports internationally important bird habitats.

Phase 1 Pre-Feasibility Study - 'Power from the Mersey'

Peel, in partnership with the NWDA set out to explore the potential, the impacts and the implications of utilising the Mersey Estuary's renewable energy potential for the benefit of the Northwest region.

The Mersey Basin Campaign gave its full backing to the work and a consortium of consultants led by Buro Happold was commissioned in July 2006 to undertake a 'pre-feasibility' Phase 1 Study.

The primary objective of the Phase 1 Study was to undertake a full and open assessment of the options available for the generation of renewable energy and to undertake a preliminary assessment of viability.

A number of potentially viable schemes were identified. The continued development of marine power technology means that others may also need to be considered as the project moves into the next phase.

Meeting 2020 Renewable Energy Targets

An overall timetable was defined to ensure the project supports the policy objective of contributing to 2020 renewable energy targets. The key milestones of the project include submission of applications for planning or other statutory consents by 2012 and commissioning of the scheme by 2020.

Phase 2 Feasibility Study

Peel Energy and the Northwest Development Agency are progressing the project in line with the principles for sustainable development. A feasibility study has been commissioned to assess the options and identify a preferred scheme to take forward for submission of a planning application.

The feasibility study has been led by URS Scott Wilson, EDF and Drivers Jonas Deloitte, and supported by RSK, APEM, HR Wallingford, Regeneris, Turner and Townsend, University of Liverpool, Proudman and Global Maritime.

The feasibility study has been undertaken in three stages as follows:

- Stage 1: Definition of project strategies, data gathering and gap analysis, and selection of long list of suitable technologies
- Stage 2: Appraisal of the long list of technologies and formulation and appraisal of scheme options to identify a shortlist
- Stage 3: Further refinement and appraisal of the short list of scheme options and selection of the preferred scheme.

The project has been pursued in an open and transparent manner, building on the consultation and stakeholder engagement started in the Phase 1 study. An extensive programme of stakeholder engagement has taken place through project advisory groups, consultation with statutory and non-statutory consultees and public consultation targeted during appropriate stages of the project.

Mersey Tidal Power Scheme Objectives

The objectives of the Mersey Tidal Power scheme are:

(a) To deliver the maximum amount of affordable energy (and maximum contribution to Carbon reduction targets) from the tidal resource in the Mersey Estuary with acceptable impacts on environment, shipping, business and the community either by limiting direct impact in the Mersey Estuary or providing acceptable mitigation and/or compensation;

and in doing so,

(b) To maximise social, economic and environmental benefits from the development and operation of a renewable energy scheme, including where appropriate:

   (i) the development of internationally significant facilities and skills to support the advancement of renewable energy technologies and their supply chains,
   (ii) improvements to local utility and transport infrastructure,
   (iii) improvements to green infrastructure and environmental assets,
   (iv) the development of a leisure opportunity and tourist attraction.

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1 Introduction

1.1.1 There is the potential for all aspects of the ecological community of the Mersey Estuary and potentially further afield to be affected by a tidal power scheme in the Estuary, in which there are a number of nationally and internationally designated sites. The primary aims of these legislative drivers are to maintain or enhance the ecology of the Estuary in particular in relation to the diversity and numbers of waders and wildfowl and meeting the conservation requirements of the Mersey Estuary Special Protection Area (SPA). The first objective of the Mersey Tidal Power scheme is “to deliver the maximum amount of affordable energy (and maximum contribution to carbon reduction targets) from the tidal resource in the Mersey Estuary with acceptable effects on the environment, shipping, business and the community either by limiting direct effects on the Mersey Estuary or providing acceptable mitigation and/or compensation”. Where significant ecological effects are identified for a scheme, measures will be identified to firstly prevent harm where possible through alterations to scheme design and/or operation. Where residual effects remain, feasible and acceptable mitigation measures will be identified, and where effects cannot be fully mitigated compensation measures will be proposed. Many of the lessons learnt from the Stage 2 assessment have indeed been applied to the schemes being assessed at this stage as prevent harm measures aimed at reducing effects and resultant potential ecological consenting risk.

1.1.2 During this stage of the assessment the focus of the study area is upon the immediate proximity of the proposed scheme bands, in particular the Mersey Estuary SPA. The basis for this approach is that nearfield effects will be of greater magnitude than far-field effects. As such, during the optioneering phase of this study as detailed within this document, the focus will be upon assessing the relative effects of the proposed options upon the Mersey Estuary marine ecology receptors and overall integrity of the SPA, and on requirements of the Water Framework Directive (WFD).

1.1.3 It is considered that schemes deemed to have a greater effect upon the nearfield area will also have the greatest effects upon areas further afield. The same decision will be made upon the ecological consenting acceptability of the schemes upon consideration of the Mersey Estuary alone as opposed to a wider geographical area.

1.1.4 The Mersey Estuary SPA was designated under the Habitats Directive (Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora) for its assemblage of passage and wintering water birds in excess of 20,000 individuals and because of its nationally and internationally significant number of six bird species. The criteria for designation are therefore the sizes of the populations of individual species as well as the size of the bird assemblage as a whole. The most direct quantities to evaluate are the demographic rates of mortality and reproduction, the interaction between which determines population size (Goss-Custard 1993). But often, these rates are very difficult to measure and it is difficult to predict the effect of any proposed scheme upon them. So instead, attention usually tends to focus on the extent and quality of the habitats that support the populations. Accordingly, this assessment focuses on how each scheme would affect the extent and quality of the habitats that support the birds and on the time that they would have available for feeding on them.

1.1.5 The SPA also has conservation requirements for three habitats considered to be sub-features of the protected site; intertidal sediments, rocky shores and saltmarsh, all of which could be influenced by the scheme.

1.1.6 In addition, the WFD requires that all inland and coastal waters within defined river basin districts must reach at least Good status (or Good potential if considering a heavily modified water body (HMWB)) by 2015, based on criteria for a range of biological and ecological elements.

1.1.7 All SPA features and sub-features and WFD biological elements within the Estuary which could potentially be affected by a tidal power scheme have therefore been considered within this assessment. The status of chemical and physicochemical quality elements and hydromorphological quality elements also contribute to overall ecological status under the WFD but are outside the scope of this report and are covered by other assessment topics.

1.1.8 The assessment has been undertaken taking into account a number of conservation requirements and has included application of Habitat Regulations Assessment (HRA), WFD and Environmental Impact Assessment (EIA) Scoping criteria.

1.1.9 Prevent harm, mitigation and compensation measures to reduce the overall environmental impact of a scheme are also identified with an indication of high level costs amongst other factors associated with undertaking these works.

2 Methodology

2.1 Specialist Assessments

Schemes Under Assessment

2.1.1 Assessments have been undertaken for three schemes IBv2, VLHBv2 and VLHBv3. A summary of the key aspects of the three schemes assessed is provided in Table 2.1. Further details are available in the Civil engineering technical report (URS Scott Wilson 2011a).

Study Area

2.1.2 During this stage of the assessment the focus of the study area is upon the Mersey Estuary, in particular the Mersey Estuary SPA (Figure 2.1). Initial hydrodynamic modelling has been conducted to examine the potential effects of a worst case scenario impounding barrage scheme on water levels at locations within the Irish Sea, Liverpool Bay and the Mersey Estuary for the baseline scenario and with the scheme in place. Overall, far-field effects were limited to areas within, and local to, the Estuary mouth. The model indicated that when far-field effects were evident at a particular site the water level at low water would be higher than under baseline conditions under spring and neap tides. The differences in water level ranged from a few centimetres at most sites to ~80 – 130 cm at Gladstone dock, Liverpool (with the values varying in relation to the scheme considered). Modelling indicated that the high water level would be lower than baseline (generally <10 cm difference for each site with the exception of Liverpool where spring high water would be ~30 cm lower). Effects on the tidal range would be smaller for neap tides than for spring tides (see Appendix 1: Far-Field effects on water levels for further details).

2.1.3 These changes have the potential to affect the intertidal habitats between Hilbre and Formby point (See Appendix 1). The effects of these changes in tidal range could reduce feeding time and area for the bird species which over-winter or spend time in passage at these sites, as well as affecting the availability of the invertebrate food resource.

2.1.4 During the optioneering phase of this study as detailed within this document, however, the focus is on assessing the relative effects of the proposed options upon the Mersey Estuary marine ecology receptors and overall integrity of the SPA. Potential impacts on the Mersey Estuary SPA site have been considered as a ‘proxy’ for impacts on other nationally and internationally designated sites, on the basis that nearfield effects will be greater than far-field effects. Bird usage and the intertidal invertebrate assemblages present within intertidal habitats between Hilbre and Formby point would need to be considered as part of the detailed environmental assessment undertaken for the preferred scheme. Effects on water levels in the Dee and Ribble estuaries will be carried out once the preferred scheme is established, if required.

Table 2.1 Summary of the three schemes for which potential effects have been assessed

Scheme variant	Technology	Design			Operation
		Generating plant	Installed capacity	Sluice gates	
IBv2	Impounding barrage designed for unrestricted head operation	28 bulb turbines with a runner diameter of 8 m housed in 75 m long caissons (four turbines per caisson), at -5.7 mCD centreline setting	700 MW	18 sluice gates, each 12 m long, with 4 waterways per caisson	Unrestricted head ebb tide generation with low tide sluicing and hold period
VLHBv2	Impounding barrage designed for low (< 3 m) head operation	44 bulb turbines with a runner diameter of 8 m housed in 75 m long caissons (four turbines per caisson) at -8.5 mCD centreline setting	660 MW	As above	Restricted head ebb tide generation (typically < 3 m)
VLHBv3	Impounding barrage designed for low (< 3 m) head operation	44 reversible bulb turbines with a runner diameter of 8 m housed in 75 m long caissons (four turbines per caisson) at -8.5 mCD centreline setting	660 MW	As above	Restricted head ebb and flood generation (typically < 3 m)

2.1.5 Within the vicinity of the Mersey Estuary are a number of sites of conservation importance including Natura 2000 sites (e.g. Special Areas of Conservation (SACs), SPAs, Ramsar sites and Sites of Special Scientific Interest (SSSI) (Figure 2.1). The geographical extent for consideration, however, will gradually be refined through an iterative process as more information regarding the potential extent of hydrodynamic effects becomes available, further refined by sediment transport modelling.

2.1.6 In order to define the freshwater extent of the assessment, legislation such as the WFD was considered which defines waterbodies in terms of ecological status/potential (see APEM 2011a for further details). Migratory fish (e.g. salmonids, eel and lamprey) were considered to be the only WFD element contributing to the ecological status/potential of freshwater bodies in the Mersey catchment which could potentially be affected by a tidal power scheme in the Estuary. This is due to their passage through the Estuary during their life cycle. Maps from the EA were examined indicating areas in which salmonids (juveniles), eel and lamprey have been found historically or may potentially be found in the future within the Mersey catchment. These maps did not indicate migratory routes and the EA surveys only cover a small number of all of the tributaries in the catchment, however, it was assumed that migratory fish could be found downstream of any site at which they have been recorded or could be potentially present as long as there was a connection to the Mersey Estuary. When considering migratory fish together as one group, therefore, it was considered that they could potentially be present at all sites within the Mersey catchment. This defined the freshwater extent of the study area (see Figure 2.1).

2.1.7 The focus at this stage will be upon the Natura 2000 sites within immediate proximity of the proposed scheme bands in particular the Mersey Estuary SPA. The basis for this approach is that nearfield effects will be of greater magnitude than far field effects. As such the focus will be upon assessing the relative effects of the proposed options upon the Mersey Estuary SPA features and WFD elements and overall measures to prevent/reduce and mitigate for identified potential effects. Additional Natura 2000 sites will be considered in detail at later stages.

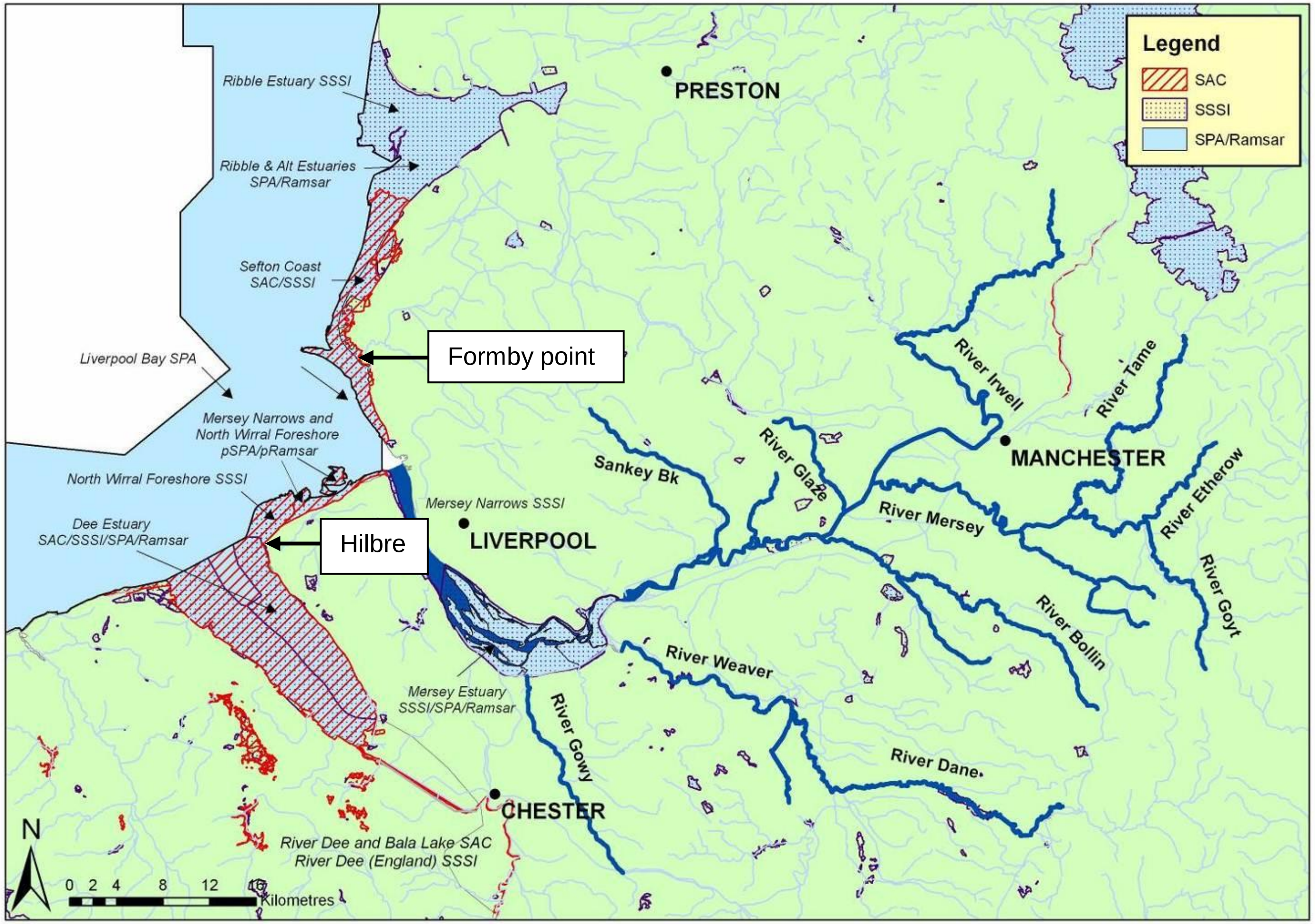


Figure 2.1 Map indicating location of Natura 2000 sites within the vicinity of the proposed development (also highlighting Ramsar and SSSI sites) and the main waterbodies within the Mersey catchment. Contains Ordnance Survey Data © Crown Copyright and database right 2011.

Attributes Examined for Assessment

2.1.8 A Shadow Habitat Regulations Assessment (SHRA) methodology has been produced to inform the options appraisal process for the Mersey Tidal Power project (APEM. 2011b). As it progresses, the SHRA will provide the relevant competent authority with information required to undertake a formal Habitat Regulations Assessment (HRA) as required under The Conservation of Habitats and Species Regulations 2010 (see APEM 2011b for more details).

2.1.9 The specialist assessments have largely been directed by SHRA methodology and follows assessment of specific indicators which are based upon the Mersey Estuary SPA attributes and targets (APEM 2011b).

2.1.10 In addition assessments have been conducted in relation to the requirements of the Water Framework Directive as described below.

Shadow Habitat Regulation Assessment

2.1.11 A brief qualitative assessment of potential effects which could have a significant effect upon the integrity of the Mersey Estuary SPA its interest and sub-features following the screening methodology has been undertaken from which it was determined that a number of effects should be considered further. As such further investigation has been undertaken and reported on within this document following the proposed SHRA methodology for this study stage.

2.1.12 The SHRA appropriate assessment methodology has been followed within this stage 3 assessment through the utilisation of the conservation sub-feature attribute targets (Table 2.2) as key impact assessors. Where quantitative assessments have been indicated for this stage of the study the assessment criteria have largely dictated the specialist assessments undertaken and reported on within this document. Data collected as part of the suite of aquatic ecology and bird surveys and collated through the data gap analysis exercise has informed the assessment where appropriate. Where assessments have been indicated as for future study stages only, qualitative expert judgement assessments have been undertaken where possible.

2.1.13 A key consideration of the assessment has been the potential of any effects to influence the structure and function of the Mersey Estuary SPA which contribute to site integrity. Consequently, adverse effects on structure and/or function have the potential to be considered as an adverse effect on integrity of the SPA which could result in ecological consenting risk for tidal power development in the Mersey Estuary.

Water Framework Directive

2.1.14 The WFD requires that all inland and coastal waters within defined river basin districts must reach at least Good status (or Good potential if considering a heavily modified water body (HMWB)) by 2015 and defines how this should be achieved through the establishment of environmental objectives and ecological and chemical targets for surface waters.

2.1.15 The approach for the WFD assessment has been defined in 'Stage 2 Water Framework Directive Scoping Study: Scoping report' (APEM 2011a). For the purposes of this project, as outlined in the WFD Scoping report, the main biological consideration for freshwater watercourses is the status of migratory fish species. For coastal waters WFD biological elements which have been considered within this assessment are phytoplankton, macroalgae, angiosperms (saltmarsh), benthic invertebrate fauna and fish fauna. These elements also apply to coastal waters with the exception of fish fauna which is not one of the WFD biological elements considered within coastal waters.

2.1.16 The assessment undertaken within this document has concentrated at this stage upon the potential for each of the schemes to result in a change to the ecological status of each of the WFD biological elements following the status definition tables detailed within the WFD scoping document (APEM 2011a). The assessment has primarily followed a qualitative expert judgement approach utilising available data sources from the MTP surveys and data gap analysis where appropriate.

Table 2.2 Condition assessment attributes and indicators for the Mersey Estuary SPA and the proposed criteria used to assess them at this and future stages.

SPA Sub-feature	Attribute	Indicator	Assessment criteria	Feasibility study (at Stages 2 & 3 of the project)
Intertidal sediments	Extent and distribution	Change in area of habitat exposed as a result of changes in tidal regime	Area (ha)	Quantitative
		Change in exposure time of habitat as a result of changes in tidal regime	Exposure time	Quantitative
		Change in area of habitat exposed as a result of changes in sediment transport	Area (ha)	Future Stage
		Change in sediment character/biotopes (habitat quality)	Area (ha)	Future Stage
	Food availability	Change in invertebrate prey biomass	Invertebrate biomass	Quantitative
		Change in plant/algae food sources (Habitat quality)	Algal abundance and distribution	Future Stage
Saltmarsh	Extent and distribution	Change in area of saltmarsh	Area (ha)	Quantitative
	Food availability	Change in food sources for bird species	Presence and abundance of soft-leaved and seed bearing plants	Future Stage
	Vegetation Characteristics	Change in vegetation height	Area (ha) of areas of vegetation with: <10cm height -wader roost sites <5cm height – wigeon feeding sites	Future Stage
Rocky shores	Extent and distribution	Change in extent of rocky shore habitats as a result of changes in tidal range and flows	Area (ha)	Quantitative
	Food availability	Change in invertebrate prey species assemblage	Species richness Invertebrate abundance Cover of green algae (%)	Future Stage

Area of Habitat Exposed

2.1.17 For the indicator 'area of habitat exposed', modelling has been undertaken to assess changes in the extent of intertidal sediments, saltmarsh and rocky shore within the Estuary from baseline under each of the scheme scenarios.

2.1.18 The first step was to classify the habitat types in the Estuary and estimate their relative areas under baseline conditions. In the absence of available historical data on habitat classifications within the Estuary, analysis was undertaken of an existing satellite image at low water. This image was downloaded from the Global Land Cover Facility (GLCF - http://ftp.glcf.umd.edu/index.shtml). The most recent image available for low water was from 2002 and as such is likely to differ from the present distribution of habitat although it does correlate well with the bathymetric data used for the hydrodynamic modelling which was also derived from data from 2002. The image was taken just after low tide (tide height was 0.93 metres when the image was taken whereas at low tide an hour earlier it was 0.43 metres). As the image does not represent a maximum low tide scenario and all intertidal habitat may not be exposed or accounted for there are areas of intertidal soft sediment which could not be characterised using the satellite image analysis approach. For the purposes of analysis it has currently been assumed that these areas consist of the same sediment type as neighbouring areas.

2.1.19 An initial unsupervised habitat classification with data clustering based on the brightness of the satellite image was undertaken to identify and categorise the exposed intertidal habitat areas into rocky habitat, saltmarsh and a number of sediment types (mud, sand, muddy sand, sandy mud). In order to ground-truth the results of the image analysis, sediment samples were taken in the field at 40 sites within the Estuary in spring 2010 and 54 sites in autumn 2010 as part of the Mersey Tidal Power suite of Aquatic Ecology Surveys. These samples were subjected to Particle Size Analysis (PSA). The PSA results from sediment sampling conducted in autumn 2010 were then incorporated by ERDAS Imagine Pro to perform a supervised classification of the image (autumn 2010 results were used as these represented the most complete sample set and it was anticipated that there would have been little change in PSA between spring and autumn of the same year). The final classification was, therefore, based on environmental data collected in the field and analysis of the image data. Each of the classes generated in the imagery were related directly to the results of the sediment sampling and the classified map was converted to an ESRI shapefile. The extent of rocky shore was informed by both GIS map data and rocky shore surveys conducted for the Mersey Tidal Power project.

2.1.20 Hydrodynamic modelling was conducted for 2010, 2030 and 2060 baseline scenarios. The 2010 scenario represented present day baseline, 2030 and 2060 scenarios integrated the effects of climate change on water levels with 2030 being an intermediate timeframe for the operational phase of the scheme and the 2060 scenario including longer term effects. Sea level rise due to climate change within the study area is expected to be close to the average predicted UK sea level rise, based on the medium emissions scenario. For the purposes of this project the UK absolute sea level rise value of +36.9 cm by 2100 has been used, which equates to approximately 3.4 mm/year (added to the published 2010 levels).

This equates to a 17 cm rise for the period between 2010 and 2060 (H R Wallingford 2009).

2.1.21 The baseline 2010, 2030 and 2060 hydrodynamic results were then combined with the habitat map in GIS to determine the area of rocky shore, saltmarsh and each sediment type exposed for low and high water for neap, intermediate and spring tides. This process was then repeated using the hydrodynamic modelling results for each scheme (for 2010, 2030 and 2060), tidal stage (spring, intermediate and neap) and for each tidal state (00 to 24 hour time series).

2.1.22 The scheme results were then compared in turn to those obtained for the baseline scenario to determine any changes in the area of each of the habitat types exposed under each of the scheme scenarios. In the absence of predictions for morphology and sediments for 2060, the model used the distribution of topography, habitat types and soft sediments on day one of operation. No consideration of changes to sediment transport and hydrodynamic processes was made.

2.1.23 Modelling was undertaken covering the entire Estuary and then for the SPA which allowed figures to be generated for both areas separately. The site boundary for the Mersey Estuary SSSI was used as a proxy for that of the SPA.

2.1.24 It should be noted that some of the area exposed in the hydrodynamic model but was not on the satellite imagery used to generate the sediment maps. This has been described as unclassified sediment in the results provided in Sections 5 and 6.

2.1.25 The assessed changes can be considered as relative only for this current assessment due to a number of factors including: the historic nature of the satellite image, the fact it was taken an hour after low water, the required extrapolation of sediment type area, the fact that there was no consideration of sediment transport and changes to hydrodynamic processes, the historic nature of the hydrodynamic baseline bathymetry map and absence of a defined SPA baseline for sub-features (which makes it difficult to assess potential changes since designation). The assessment technique will necessarily be refined in future assessment stages.

2.1.26 The process described above provided the information required to assess potential changes in the extent of intertidal sediments, rocky shores and saltmarsh within the Mersey Estuary. These habitats are sub-features of the SPA and are associated with specific sub-feature attribute targets as described in Section 5.2.

Invertebrate Prey Biomass

2.1.27 One of the SPA sub-feature attributes is associated with the availability of food for SPA bird features within intertidal sediments. It was necessary, therefore, to be able to associate changes in sediment exposure under the difference schemes with changes in food biomass for the SPA bird interest features.

2.1.28 As part of the Mersey Tidal Power aquatic ecology survey programme, intertidal sampling of invertebrates was conducted in autumn 2009, spring 2010 and autumn 2010. Surveys conducted in spring 2010 and autumn 2010 (40 and 54 sites, respectively) were more extensive than the initial autumn 2009 survey (14 sites). Analysis of samples involved assessments of invertebrate biomass as well as counts of individuals and sizing of invertebrates of key importance for birds. In addition to recording biomass for the sample as a whole, the biomass of seven individual prey items of SPA bird features was also recorded and the size of invertebrate individuals was noted. This is because different bird species consume preferred size ranges of prey items and therefore overall biomass may not necessarily represent the consumable biomass for a given bird species. These data are used qualitatively within the current assessment and will be utilised further at a later stage of the project when more detail is required for a preferred scheme. The results provided here are based on the overall biomass of samples.

2.1.29 The feeding conditions of shorebirds in the northern temperate zone are generally much more favourable in autumn than later in the winter and early spring as their energy demands are not usually elevated by low ambient temperatures in autumn, whereas in winter low air temperatures frequently raise energy demands. In autumn, the food supply is also usually at its most abundant, following the summer's period of reproduction and growth which was supported by the results of the sampling (mean biomass of invertebrates in autumn 2010 was found to be slightly greater than in spring 2009). Not only are the prey numerically abundant and so easier to find in autumn, but they often reach their maximum body size and mass and this has a decisive influence on the rate at which shorebirds can feed: the energy consumption rate of shorebirds increases as the mean mass of their prey increases. So, in autumn, not only are the birds' energy demands lower than later in the non-breeding season but they can also collect energy at a faster rate. For this reason the wintering period (October to March in terms of waders) was considered to be the most important time of year for bird feeding. Invertebrate data were collected across a wide spatial scale in spring (April) and autumn (October) 2010. The autumn data were used to consider the food supply, however, as they represent the food resources at the beginning of the non-breeding season when the wintering birds arrive at the estuary and are not influenced by any impact the birds might subsequently have upon the food resources.

2.1.30 Invertebrate biomass values were calculated for each sample site and the PSA analysis was used to determine the sediment type at each site. Using a combination of these data and consideration of site locations, each area on the sediment GIS map was assigned an equivalent biomass. For the unclassified sediment the GIS biomass map was used to identify sediment type and biomass values at sites nearest the unclassified locations and these values were used to generate a biomass estimate for the unclassified sections of the intertidal zone.

2.1.31 The change from intertidal to subtidal sediment types, as a result of a decrease in exposure, could then be associated with a respective loss of invertebrate biomass available for bird feeding which was taken forward to the assessment. The analysis was conducted for baseline and the three scheme scenarios for high and low tide during neap, intermediate and spring tide scenarios in 2060. Assessments were conducted for the Estuary as a whole and within just the SPA.

Exposure Time of Habitat

2.1.32 The length of time for which the intertidal habitats are exposed determines for how long the birds can feed on the intertidal flats, and is referred to here as ‘foraging time’. Foraging time was measured from curves showing the area of soft sediment exposed at half-hourly intervals through the tidal cycle. The beginning and end of the foraging period was measured as the time elapsed between when 200 ha or 400 ha of suitable soft sediment had been exposed on the receding tide and the point at which only 200 ha or 400 ha remained on the advancing tide. These criteria were chosen because, when birds are forced into high densities when only a small area of mudflats is exposed, their foraging efficiency decreases through competition either because dominant individuals steal prey items found by sub-dominants or because the prey have anti-predator responses, such as withdrawing into a burrow. The values of 200 ha and 400 ha were chosen because, with 40,000 birds (the peak count of all species combined in winter 2008/09) feeding at the beginning and end of the exposure period, the density of foraging birds would be 200 birds ha^{-1} or 100 birds ha^{-1} respectively in areas of that size. Forty thousand birds is approximately the peak count of all species combined in 2008/09. Were all 40,000 to be feeding in an area of 400 ha, the density would be 100 birds ha-1, the lowest density of shorebirds at which certain widespread forms of competition just begin to come into effect (Stillman and Goss-Custard 2010).section

2.1.33 Although more birds (>100 000) were recorded on peak counts on the Mersey Estuary at the time of its designation, the value of 40,000 (rather than 100 000) was chosen because (i) some species, such as golden plover, feed little, if at all, when they on the Estuary; (ii) many of the birds that do feed do not start feeding at the very moment the flats are exposed but wait until the tide has gone some way out; (iii) as different species may start to be affected by interference (if they are affected at all) at different bird densities, it is very likely that many birds are able to feed at a profitable rate when less than 200 ha or 100 ha is exposed; (iv) at designation, dunlin comprised almost half of the total bird assemblage but are very probably one of the species least prone to interference because of the small size of their prey (and thus rapid rate of handling them which gives other birds little chance to steal from them) and/or the absence of anti-predator responses in the prey (eg. the gastropod *Hydrobia ulvae*); (v) birds must still benefit from foraging even if interference is reducing their intake rate, as can be seen in many British estuaries when birds forage at very high densities on the small areas of mudflats exposed at the beginning and end of the exposure period, and (vi) the site designation was based on peak winter counts and was therefore a maximum estimate for the winter as a whole. Without extensive modelling it is not possible to estimate the area of exposed foraging space below which intake rate is reduced sufficiently at the beginning and end of the exposure period to threaten bird survival. On the other hand, the criteria are believed to provide realistic, clear-cut and biologically meaningful alternative points during the exposure period at which to begin and end the foraging period and are considered adequate to compare effects between schemes as the precise number of birds used would be very unlikely to affect the outcome.

2.1.34 During wintering and passage surveys carried out across the Estuary, observations have been made on the particular activities of the different bird species present. From that information a picture has been built up of the main areas used for feeding by the species upon which the SPA was designated. The changes to the feeding areas used by each species as a result of either of the schemes being implemented have been referred to in the scheme assessments (Section 5), and will be the focus of more detailed studies in later stages of the project.

Exposed Flats and Wetted Perimeter

2.1.35 Data on the predicted length of the tide edge over each sediment type at each half-hour interval were also used, this being the 'wetted perimeter' along which many shorebirds feed. Between them, the area of exposed sediment and the wetted perimeter length define the intertidal foraging space available to shorebirds under each scheme. The soft sediment categories were mud, muddy sand, sandy mud and sand. The exposed areas of saltmarsh and intertidal rocks were also predicted.

2.1.36 Baseline simulations were run for the year 2060 to allow for medium-term rise in sea level. The exposed areas and lengths of the wetted perimeter over each habitat type and category of soft sediment were then predicted for 2060 for each scheme. In the absence of predictions for morphology and sediments for 2060 at present, the model used the present-day topography, habitat types and distribution of soft sediments.

2.1.37 The foraging space at each half-hourly point through the modelled spring, intermediate and neap tides was measured (ha) as the total exposed surface area of each soft sediment category and habitat type in the SPA. The length of the wetted perimeter was measured (m) as the total length of the tide line at each half-hourly point over each soft sediment category and habitat type in the entire SPA.

2.2 Standards and Guidance

2.2.1 As indicated in Section 2.1 the requirements of the assessment have largely been driven by standards and guidance relating to the Habitats Regulations Assessment (HRA) process, the Water Framework Directive and in addition, general Environmental Impact Assessment guidance has been followed. A list of some of the documentation referred to is indicated below:

- Defra. 2006. Shoreline Management Plan Guidance. Volume 1: Aims and Requirements. DEFRA, London.
- Defra. 2009. The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2009.
- Davies, J., Baxter, J., Bradley, M., Connor, D., Khan, J., Murray, E., Sanderson, W., Turnbull, C. & Vincent, M. (2001) Marine Monitoring Handbook. JNCC
- Environment Agency. 2009. River Basin Management Plan North West River Basin District.

- European Commission. 2007. Guidance Document on Article 6(4) of the 'Habitats Directive' 92/43/EE

- European Commission. 2001. Assessment of plans and projects significantly affecting Natura 2000 sites. Methodological guidance on the provisions of Article 6(3) and (4) of the Habitats Directive 92/43/EEC.

- European Commission. 2003. Common Implementation Strategy for the Water Framework Directive (2000/60/EC), Guidance Document no. 7: Monitoring under the Water Framework Directive.

- European Communities. 2000. Managing Natura 2000 sites; The provisions of Article 6 of the 'Habitats' Directive 92/43/EEC. 2000

- European Communities. 2002. Assessment of plans and projects significantly affecting Natura 2000 sites; Methodological guidance on the provisions of Article 6(3) and (4) of the Habitats Directive 92/43/EEC

- European Communities. 2005. Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance Document No. 13. Overall approach to the classification of ecological status and ecological potential. Produced by Working Group 2A.

- European Communities. 2009a. Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance Document 24: River Basin Management in a Changing Climate

- European Communities. 2009b. Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance Document 3: Analysis of pressures and impacts

- European Communities. 2009c. Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance Document 10: Rivers and lakes – Typology, reference conditions and classification systems

- European Communities. 2009d. Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance Document 5: Transitional and Coastal Waters – Typology, reference conditions and classification systems

- Institute of Ecology and Environmental Management (2006) Guidelines for Ecological Impact Assessment in the United Kingdom: Marine and Coastal

- Joint Nature Conservation Committee. 2004. Common Standard Monitoring Guidance for Littoral Sediment Habitats. JNCC, Peterborough, UK.

- Office of the Deputy Prime Minister (ODPM). 2005. Government circular: Biodiversity and geological conservation – statutory obligations and their impact within the planning system

- Tyldesley, D. and Hoskin, R. 2008. Assessing projects under the Habitats Directive: guidance for competent authorities. Report to the Countryside for Wales, Bangor.

- UK Technical Advisory Group on the Water Framework Directive. 2009. UKTAG Transitional Water Assessment Methods Macroalgae: Fucoid Extent.

- WFD-UKTAG. 2008. UKTAG Rivers Assessment Methods: Fish Fauna. Water Framework Directive – United Kingdom Technical Advisory Group, Edinburgh, 11pp.

2.3 Sources of Information

2.3.1 A brief summary of the data sources identified for the analysis of the ecological receptors and groups in the region of interest is provided below.

Phytoplankton

2.3.2 The data sources identified for phytoplankton assemblages within the area of interest includes previous APEM sampling (e.g. sampling within the Middle Deep and Eastham Channel areas, APEM 2007 & 2008a), data and knowledge held by academic and research institutions (e.g. Proudman Oceanographic Laboratory, University of Liverpool, Hull University, CEFAS) and published and grey literature (e.g. Mersey Barrage Stage III Environmental Studies, ERL 1992a).

2.3.3 Data sources include APEM's recent surveys undertaken specifically for the current study (e.g. APEM 2010ab & 2011c) and others APEM studies conducted in the Mersey Estuary (e.g. APEM 2008a), as well as information on phytoplankton assemblages from the late 1970s (e.g. Voltalina 1983) and cover both the Mersey Estuary and surrounding areas, including Liverpool Bay and the Sefton Coast. The information sources indicate that phytoplankton assemblages in the Mersey Estuary are dominated by diatom taxa. Such assemblages are typical of estuarine environments.

Benthic Flora

2.3.4 The data sources identified for benthic flora in the area of interest includes survey work carried out specifically for the current work and other projects by APEM (2008a, 2010ab & 2011c), grey literature, such as the Mersey Barrage Stage III Environmental Studies reports (ERL 1992b) and information on benthic flora from surrounding areas, including the Dee Estuary (Round 1960). Benthic floral assemblages in the Mersey Estuary are dominated by diatom taxa typical of estuarine benthic floral assemblages.

Benthic Invertebrates

2.3.5 Data sources for benthic invertebrate assemblages in the area of interest include APEM's surveys of intertidal and subtidal invertebrates undertaken for this study, other work conducted by APEM in the Mersey Estuary, grey literature and peer-reviewed published literature. Data range from recent surveys (e.g. APEM 2008ab, 2010ab & 2011c) to those carried out in the early 1930s (Bassindale 1938).

2.3.6 The data sources include information on the invertebrate fauna within the Mersey Estuary and surrounding areas and incorporate a number of environmental impact assessments for developments within the North West England and North Wales region, including the Port of Mostyn and offshore windfarm EIAs (Burbo, North Hoyle, Gwynt y Môr).

2.3.7 Overall, it is considered that the benthic invertebrate assemblages in the Mersey Estuary and Liverpool Bay are typical of those in estuarine and coastal habitats. No records of nationally rare or unusual benthic invertebrate taxa have been reported.

Fish (Non-Migratory)

2.3.8 Data sources relating to fish assemblages within the area of interest include APEM's surveys conducted for the current project in addition to previous APEM survey work, published literature and grey literature. The data covers fish data from the early 1980s to the late 1990s (e.g. ERL 1992cd, Hering 1998) and repeated annual survey work carried out by APEM in the upper Estuary (APEM 2007, 2010ab & 2011c).

2.3.9 The data includes information on fish assemblages within the Mersey Estuary as well as surrounding water bodies, including the Dee and Ribble Estuaries (e.g. Potts and Swaby 1993).

2.3.10 Generally, the fish taxa recorded within the Mersey are typical of estuarine assemblages in the UK, with assemblages containing a high proportion of juvenile individuals. Some taxa present are UK Biodiversity Action Plan (BAP) species, including cod, herring, plaice, sole and whiting.

Migratory Fish

2.3.11 Several studies have investigated the migratory fish assemblages of the Mersey Estuary and rivers associated with the River Mersey and Mersey Estuary. These studies range from freshwater electric fishing to designated fish traps (such as that at Woolston Weir).

2.3.12 The data cover a number of years from 1978 up to 2005 and includes a number of freshwater courses within the Mersey catchment and Mersey Estuary (EA unpublished data). The Mersey Estuary acts as a migratory corridor for a number of species, including salmon and river lamprey protected under Annex II of the Habitats Directive and European eel and sea trout *Salmo trutta*, which are designated UK-BAP species. European eel are also protected under an Eel Management Plan for the Mersey Estuary (Defra 2010) and the Eels (Wales and England) Regulations. Sea lamprey could also potentially use the Mersey Estuary as a migratory corridor and this species has been recorded in the Mersey Estuary and the nearby Dee Estuary (EA unpublished data).

Estuarine Habitats

2.3.13 Data sources identified for estuarine habitats within the Mersey Estuary are relatively limited. Aerial or satellite data is considered an important source of information relating to the extent and location of habitat types and the most recently available data dates back to

2002. Other data sources include published peer-reviewed literature, technical reports and grey literature.

2.3.14 Data on the location and extent of habitats range from ongoing research at University of Salford (since April 2010) to surveys carried out in the late 1980s and early 1990s (e.g. ERL 1992b). Available data include a Mersey Estuary National Vegetation Classification (NVC) survey from 2002 and a 2009 Environment Agency survey of national saltmarsh coverage. Natural England are also currently undertaking a condition assessment of the SPA.

Rocky Shores

2.3.15 Russell *et al.* (1999) provide a review of macroalgal diversity throughout the Mersey Estuary since the late nineteenth century and Langston (1986) records the distribution of the macroalgae *Fucus vesiculosus* within the Estuary. APEM have also undertaken surveys of the rocky shore habitat within the Estuary during 2010 as part of the Mersey Tidal Power suite of aquatic ecology surveys (APEM 2010c).

2.4 Impact Assessment

2.4.1 The Stage 3 assessment has been undertaken based principally on the methodology detailed within the Shadow Habitat Regulations Assessment (SHRA), the Water Framework Directive (WFD) and the Environmental Assessment Scoping documents. Further details of the methods used are provided in Appendix 2.

2.4.2 The assessment has considered among other aspects the likely effects of each scheme upon the attribute targets for the different features of the SPA, which in the case of birds are:

- No significant reduction in numbers or displacement of birds from an established baseline, subject to natural change
- No increase in obstructions to existing bird view lines, subject to natural change

2.4.3 The assessment was made for bird numbers using predictions for the amount of foraging space and foraging time during which the density of birds is low enough for competition to be reduced that would be removed by each of the schemes and by using expert knowledge to interpret the findings. On sight lines, it is likely that a barrage would provide opportunities for birds of prey to use barrage structures as cover for attacks on shorebirds with all three schemes.

2.4.4 The amount of foraging space (*i.e.* suitable soft sediment, habitat types and length of the wetted perimeter) and the duration of the intertidal feeding period, the foraging time during which the density of birds is low enough for competition to be reduced, are two of the most important characteristics of the foraging environment for shorebirds (Stillman and Goss-Custard 2010). Clearly, a large reduction in either is more likely to cause an increased proportion of birds to have difficulty in meeting their food requirements than is a small one in either or both. And since there is some evidence to suggest that the substantial decline in the Mersey bird populations may be due to a reduction in their food supply perhaps associated with a recent reduction in the organic and nutrient input into the estuary, it is assumed that any additional deterioration due to a loss of foraging space or foraging time would be likely to cause numbers to decline still further.

2.4.5 Without modelling, however, difficulties of interpretation can arise if a scheme is predicted to decrease foraging space but to increase foraging time. Modelling of a similar situation with redshank, one of the Mersey SPA designated species, suggests, however, that a given percentage reduction in the time as has been defined here available for feeding is likely to reduce bird fitness by much more than would the equivalent percentage reduction in the amount of feeding space (Goss-Custard *et al.* 2006a).

2.4.6 Of perhaps comparable importance to foraging space and time to shorebird survival is the 'quality' of the feeding grounds. This depends largely on the size, and therefore energy content, of the prey (Goss-Custard *et al.* 2006b). The sizes of prey taken differ between the species for which the Mersey was designated an SPA; for instance, whereas dunlin take worms between 10 mm and 60 mm long, redshank eat ones 90 mm long, and sometimes even longer; shelduck eat bivalves up to 10mm long while black-tailed godwits take them up to 20 mm. Changes in the hydrodynamics of the Estuary upstream of a tidal power scheme could change the hydrology of the Estuary in ways that could increase prey size – although this is far from certain in the case of the Mersey (indeed, if the food supply has decreased in recent years following a reduction in nutrient and organic inputs, it may have been linked to a reduction in the average body size, and therefore energy content, of important prey species as the total biomass of invertebrates may not have changed).

2.4.7 A tidal power scheme will have structures such as sluice gate gantries that could provide perches for birds of prey ('raptors') to attack foraging shorebirds, particularly those of small body size, such as dunlin and redshank, both of which are SPA designation species. It was assumed here that the risk from such attacks would be the same for each scheme. The same assumption was made for the remaining two factors that could affect bird fitness – the presence of safe roost sites and the amount of onshore and intertidal disturbance from people.

2.4.8 A brief summary of the key requirements of the WFD assessment and the SHRA methodologies are provided below (further information is available in the 'Water Framework Directive Scoping Study: Scoping report', APEM 2011a and 'Briefing Note – Shadow Habitat Regulations Assessment Methodology', APEM 2011b).

2.4.9 Few marine mammals including cetaceans have been observed within the Mersey Estuary and in general the coastal waters of Liverpool Bay are also rarely visited by cetaceans (Sea Watch Foundation 2010, Evans & Shepherd 2001). In addition, marine mammals are not a sub-feature of Natura 2000 sites in the study area and are not biological elements which are considered under the WFD to assess ecological status. Potential impacts of a tidal power scheme on marine mammals include effects of underwater noise generated during construction, disruption and visual disturbance and restricted movement of individuals along the estuary with the scheme in place. As these impacts would be common to each scheme they are not discussed individually within the scheme assessment sections and, in terms of ecological effects, it is considered that the potential effects on marine mammals would be unlikely to be a differentiator among schemes.

2.4.10 Across all aspects of the specialist assessment a qualitative, professional judgement-based assessment was used when quantitative information was not available.

2.5 Summary of Consultation Undertaken

2.5.1 Consultation in relation to aquatic and avian ecology has been undertaken with various stakeholders throughout the project. A summary of consultations undertaken is provided in Table 2.3 below.

Table 2.3 Summary of consultations undertaken during the project.

Date	Attendees/Report	Consultee discussion/comments
Meetings		
17/02/2011	APEM, NE, RSK	Discussion of conditions assessment of Mersey SPA bird population.
09/12/2010	Environmental Technical Group: North West Coastal Forum, CEFAS, Cheshire Wildlife Trust, Environment Agency, Lancashire Wildlife Trust, Natural England, Merseyside Environmental Advisory Service, NWDA, Peel Energy, Scott Wilson, APEM, RSK	Project update, options being carried into Stage 3, Environmental Scoping, Ecological surveys update
03/08/2010	Peel Energy, Natural England, APEM, RSK	WFD Scoping meeting. Current project status and look ahead, NE's role and information provision
03/06/2010	Environmental Technical Group: Peel Energy, Scott Wilson, RSBP, CEFAS, Merseyside Environmental Advisory Service, Environment Agency, Natural England, Cheshire Wildlife Trust, Lancashire Wildlife Trust, NWDA, APEM, RSK	Project update, Overview of Ecological Assessment Process, Application of Shadow HRA Methodology
21/05/2010	Environment Agency, Peel Energy, APEM	Fisheries, intertidal and migratory fish, marine mammals, shellfisheries
22/04/2010	Environmental Technical Group: Peel Energy, Merseyside Environmental Advisory Service, RSPB, Environment Agency, Natural England, Cheshire Wildlife Trust, Lancashire Wildlife Trust, Marine Management Organisation, Scott Wilson, APEM, RSK	Project Progress Update, Water Framework Directive, Hydrodynamic Modelling,
18/03/2010	Environmental Technical Group: Peel Energy, CEFAS, Merseyside Environmental Advisory Service, RSPB, Environment Agency, NWDA, Natural England, Cheshire Wildlife Trust, Lancashire Wildlife Trust, Scott Wilson, APEM, RSK	Project Progress Update, Shadow Habitat Regulations Assessment (SHRA), Scope of Ecological Surveys
09/10/2009	Scott Wilson, Natural England, APEM, RSK	Ecology Start up meeting, Passage bird survey methodology, Mersey Estuary Conservation objectives, Mitigation measures, Ongoing projects
Written Consultations		
January 2011	WFD Scoping Study	NA
February 2011	SHRA Methodology	NA
February 2011	Environmental Scoping report	NA

3 Baseline Characteristics

3.1.1 Relevant policy and legislation was identified and considered during the assessment with particular emphasis on the Habitats Directive and WFD. The assessment required initial collation of baseline information for receptors of interest and collection of further baseline data where required (summarised below in the context of relevant policy/legislation). Specialist assessments were then carried out to provide the specific information required to inform the overall impact assessment.

3.1.2 Both the habitats and species of the Mersey Estuary are currently protected under national and international legislation. The primary aims of these legislative drivers are to maintain or enhance the ecology of the Estuary. To achieve these aims the relevant statutory authorities for each designation have defined conservation objectives or management actions. The actions implemented by the statutory authorities to comply with these directives will in part dictate the future state of the Estuary.

3.1.3 The Mersey Estuary is however a naturally changing environment which will be influenced by natural processes including climate change that will influence its future state. The ecology of the Estuary is typical of a dynamic fluctuating Estuary and will undoubtedly be adapted to this variable state. Shifts in the environmental state of the Estuary will likely represent improved conditions for some receptors and reduced for others. To maintain or enhance its current state each habitat and species within the Estuary will have a set of ecological requirements on which it depends or by which it is influenced.

3.1.4 The following section gives an overview of the current and future state of the Estuary and outlines the requirements of the ecological features to maintain or enhance its current state (as defined by various legislative instruments). It should be noted, however, that although targets have been set it may not be possible to meet future legislative requirements for the ecology of the Estuary even under baseline conditions (i.e. with no tidal power scheme in place) due to other influences on ecological populations.

3.2 Habitats Directive

3.2.1 The European Union Habitats and Birds Directives[1] strive to promote the maintenance of biodiversity and establish measures to maintain or restore natural habitats and species of European interest at 'Favourable Conservation Status' (FCS). A habitat or species is defined as being at favourable conservation status when (subject to natural change) its natural range and the areas it covers within that range are stable or increasing and the specific structure and functions which are necessary for its long term maintenance exist and are likely to continue to exist for the foreseeable future (English Nature,2001).

3.2.2 Under Article 4.2 of the Birds Directive, the Mersey Estuary has European marine site status as an SPA (gained on 20th December 1995) based on the fact that it supports:

[1] Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora

- Internationally important bird populations of regularly occurring migratory species.
- An internationally important assemblage of waterfowl.

3.2.3 Within the Mersey Estuary SPA, key habitats have been identified as important 'sub-features' which are required to support the birds that qualify the site as an SPA; these bird populations require a functioning estuarine ecosystem with sufficient intertidal habitat to support both feeding and roosting activities. The three sub-features are:

- Intertidal sediments
- Saltmarsh
- Rocky shores.

SPA Interest Features

3.2.4 The Mersey Estuary supports large numbers of passage and overwintering shorebirds. This is largely due to the extensive area of intertidal mudflats (and associated large wetted perimeter) and exposure time, the abundance of suitable invertebrate prey items (species and body sizes), the amount of terrestrial feeding space, the availability of roosting areas and the absence of excessive disturbance from people.

3.2.5 These resources enable the birds to maintain high rates of survival during the non-breeding season and to migrate in spring and to breed successfully, often overseas. Their energy demands are met by feeding (mainly at the wetted perimeter) when the intertidal flats are exposed at low tide during both the day and night, as required.

3.2.6 There is currently evidence that birds may now be wintering further to the east and north, nearer their breeding areas, and continuation of this trend could potentially decrease competition among shorebirds in the Mersey Estuary by reducing the overall densities of birds present.

3.2.7 The Mersey was classified on 20 Dec 1995, with the New Ferry extension on 23 June 2004, for the following birds: *Annex 1*: Golden plover *Pluvialis apricaria* (wintering) – 1.2% of GB population. *Regularly occurring migratory species*: redshank *Tringa totanus* (passage) – 3.5%*;* shelduck *Tadorna tadorna* (wintering) – 2.2% NW Europe (breeding); teal *Anas crecca* (wintering) – 2.9% NW Europe (non-breeding); pintail *Anas acuta* (wintering) – 1.9% NW Europe (non-breeding); dunlin *Calidris alpina* (wintering) – 3.7% *alpine*, W Europe (non-breeding) and black-tailed godwit *Limosa limosa* (wintering) – 2.8% *islandica*.

3.2.8 The assemblage figure at initial designation was *circa* 105,000 individual waterbirds over the non-breeding season (1993/94-1997/98). Within this assemblage, there were also nationally important populations of individual species; wigeon (3.6% of British population), grey plover (4.1%), black-tailed godwit (2.2%) and curlew (1.6%). However, several populations seem to have decreased substantially since designation according to a provisional analysis by Dixon & Kind (2011). The most recent Wetland Birds Report (Calbrade *et al.* 2010) also identifies the Mersey Estuary as one of the three estuaries that has experienced the greatest decreases in bird numbers in recent years, having declined by >50% over the last 5 years alone. The situation in the Mersey fits into a general pattern of change in the numbers of some species in west coast estuaries, which appear to be increasingly using estuaries and coasts to the north and east of the UK. Nonetheless, the site remains of international importance for shelduck, teal, dunlin, black-tailed godwit and redshank. In contrast to both the Mersey, and the general trend, it should be noted that the nearby Ribble Estuary attained second place for waterbirds in the UK, which might suggest that the decline on the Mersey is associated with factors local to the Mersey itself rather than to the north-west region as a whole. Whatever the cause, the peak numbers of waders and wildfowl wintering on the Mersey Estuary have decreased to *circa* 53,500 averaged over the last five years, with only 42,500 being counted during the last reported winter of 2008/09 (annual peak mean for 2008/09 from WeBS counts).

3.2.9 As the designation of the SPA is based on the numbers of birds, the effect of any scheme should be assessed in terms of its effect on bird numbers. Since bird numbers in turn are determined by the interaction between the two demographic rates of mortality and reproductive output, the appropriate means of making an assessment would be to predict its effect on whichever of these rates applies. In the case of the Mersey birds, this would certainly be the mortality over the non-breeding season; if the mortality rate were predicted to increase, population size would go down in most circumstances (Goss-Custard 1993). The Habitats Directive recognises the fundamental importance of demographic rates for making proper assessments, but realises that predictions for these rates may not be available. Accordingly, it focuses on quantities which are likely to affect the demographic rates (although usually to an unknown extent), such as the extent of the habitat and its condition and the amount of disturbance. Such factors are thought to affect the carrying capacity of a site.

3.2.10 Carrying capacity is a very useful term as it encapsulates the common sense notion that there must be a limit to how many birds a site can support over a defined period of time. But it means different things to different people, and the concept of carrying capacity underlying the assessment made in this report focuses on the demographic rate of most immediate concern; *i.e.* the mortality rate during the non-breeding season. If the mortality rate is predicted to increase, then according to this usage of the term, the carrying capacity is predicted to decrease. Models are now available for predicting the effect of many coastal schemes on carrying capacity, so defined (Stillman and Goss-Custard 2010), and will be used in later stages of the Mersey ecological assessment. Nonetheless, the focus on predicting the effect of a scheme on the mortality rate is the same as that which these models use, but quantitative predictions for mortality rate could not be made. Instead, qualitative arguments are used to evaluate the effect of a scheme on carrying capacity

SPA Key Sub-Features

3.2.11 For the sub-feature habitats of intertidal sediments, saltmarsh and rocky shores, the main conservation considerations are related to the extent and integrity of habitat and food availability for shorebirds. It must be noted however, that the Mersey Estuary is a naturally dynamic environment in which the physical habitat including the channels and intertidal habitat regularly fluctuate in size and position. All conditions are therefore subject to natural change which will influence baseline conditions over time. In addition there is no defined set of baseline conditions at designation for these sub-features.

3.2.12 Intertidal sediments are currently widespread throughout the Estuary. At present they support large numbers of intertidal invertebrates which are consumed by shorebirds. In highly dynamic and changeable habitats such as the estuarine intertidal, it is important to consider the natural variability in faunal assemblages. In addition to natural variability, faunal assemblages may also have been influenced by other factors, for example water quality within the Estuary. To this end, the mean densities of intertidal macrofaunal prey taxa recorded within the Mersey Estuary in November 1990 by ERL (1992e) and in winter 1990/1991 by the British Trust for Ornithology (BTO) (Rehfisch *et al.* 1991) were compared with APEM's November 2010 survey data (APEM 2011c). The mean densities of most of the recorded taxa showed much variability. For example, mean *Macoma* sp. density was 345 individuals m^{-2} in November 1990 (ERL 1992e) and 121 individuals m^{-2} in winter 1990/1991 (Rehfisch *et al.* 1991). The density recorded by APEM (2011c) in November 2010 fell within the range observed in the early 1990s at 170 individuals m^{-2}. This bivalve is an important prey item for a number of bird species including dunlin *Calidris alpina* and black-tailed godwit (*Limosa limosa*) (West *et al.* 2004). Mean densities of the amphipod *Corophium* spp. were 1,244 and 408 individuals m^{-2} in November 1990 and winter 1990/1991 respectively (Rehfisch *et al.* 1991, ERL 1992e). The density recorded in November 2010 was 1,180 individuals m^{-2} (APEM 2011c). This amphipod is fed upon by shore birds including dunlin and redshank.

3.2.13 Densities of some taxa however, were greater during the November 2010 survey. For example the gastropod genus *Hydrobia* was recorded at mean densities of 100 and 31 individuals m^{-2} in November 1990 and winter 1990/1991 respectively (Rehfisch *et al.* 1991, ERL 1992e). In November 2010, 400 individuals m^{-2} were observed (APEM 2011c). *Hydrobia* are an important prey item for some shorebird species including dunlin and redshank (West *et al.* 2004). In addition, oligochaete worms were recorded at mean densities of 4,004 and 2,778 individuals m^{-2} in November 1990 and winter 1990/1991 respectively (Rehfisch *et al.* 1991, ERL 1992e) and 4,528 individuals m^{-2} were recorded in November 2010 (APEM 2011c). Oligochaetes are preyed upon by a range of shorebirds including godwit and plover species.

3.2.14 Although these surveys represent temporal snapshots of the invertebrate assemblages their similarities suggest that they do not appear to have changed dramatically over this period. The differences that were observed are likely to be due to the natural variability inherent in intertidal assemblages and the composition of invertebrate communities within the Estuary may have remained relatively consistent over this period.

3.2.15 The observed consistency in the abundance of prey taxa is not reflected by bird assemblages within the Estuary. Bird populations have decreased substantially within the Mersey in recent years. This suggests therefore, that the density of intertidal invertebrate taxa is unlikely to represent a local limiting factor to birds i.e. it would be difficult to link decreases in bird populations to intertidal invertebrate abundance. It should be noted however, that the quality of a feeding area for birds can be related to the size of prey items in addition to density and high numerical densities of prey taxa can often indicate low mean prey sizes with associated low intake rates and thus a reduced feeding efficiency for birds.

3.2.16 The size-frequency of invertebrate prey taxa was recorded as part of the November 2010 MTP aquatic ecology baseline survey (APEM 2011c). Size-frequency data for two taxa (*M. balthica* and nereid polychaetes) are available from previous surveys, enabling a broad comparison of the size distribution of these taxa in the Mersey Estuary. ERL (1992e) recorded size-distributions of *M. balthica* in winter 1990/1991 and reported that ~58% of individuals (from a sample of 38 individuals) measured 11-15 mm in length. In November 2010, only 3.3% individuals (from a sample of 273 individuals) fell within this size category. The majority (57.1% of individuals) of *M. balthica* in November 2010 measured 2-5mm. It is possible therefore that the mean size of *M. balthica* has reduced since 1990/1991, however, a number of other factors may explain this observation. Aspects relating to recruitment for example can affect the size-distribution of an assemblage. A delayed reproductive season would result in a higher proportion of smaller (juvenile) individuals in November, with smaller individuals (i.e. 2-5mm) observed one or two months after successful recruitment. In addition, it is possible that in some years environmental conditions are amenable to larval and juvenile survival than other years. This would result in increased spatfall of juveniles and hence an increased proportion of smaller individuals within the assemblage.

3.2.17 Assemblages of nereid polychaetes in November 2010 and winter 1990/1991 were dominated by individuals <20 mm in length (65% of 465 individuals and 43% of 124 individuals, respectively; ERL 1992e, APEM 2011c). In winter 1990/1991, however, larger polychaetes >50 mm were also common (32% of individuals), and individuals of this size were uncommon in November 2010 (3% of individuals). There is not enough data, however, at this stage to confidently assess potential general trends in invertebrate body size over the last two decades.

3.2.18 With respect to the marine organism communities it supports, an intertidal mud/sand flat can be sub-divided into three distinct zones (Dyer *et al*., 2000):

- Lower tidal flats – 'lie between mean low water neap and mean low water spring tide levels and are often subjected to strong tidal currents';
- Middle flats – 'located between mean low water neaps and mean high water neaps',
- Upper flats – 'lie between the mean high water neap and mean high water springs'.

3.2.19 Although dependent upon tidal elevation and shore slope, it is generally considered that the middle tidal region (i.e. the middle flats) is the most productive in terms of the numerical abundance of invertebrates within the size range taken by shorebirds and their overall biomass. (Elliott *et al*. 1998). APEM's April 2010 survey (APEM 2010a) found that assemblages within the mid-tidal region generally had the greatest species richness, density of individuals and invertebrate biomass.

3.2.20 Lower shore habitats within the Mersey Estuary are generally characterised by more sandy sediments, with finer sediments (mud, sandy mud and muddy sand) common in mid and upper shore habitats (APEM 2010a, 2011c). Sandy sediment assemblages generally have reduced faunal diversity, density and biomass compared with muddy sediments (APEM 2010a, 2011c) (see Table 3.1).

Table 3.1 Mean values (± Standard Error) for assemblage parameters for different sediment types observed within the Mersey Estuary. n = number of sites characterised by a particular sediment type. From APEM (2011c).

Sediment type (n)	Mean number of taxa (m^{-2})	Density (m^{-2})	Biomass (g m^{-2})	Shannon Wiener[2]
Mud (5)	7.1 ± 0.7	28,360 ± 8,148	27.33 ± 9.2	1.212 ± 0.19
Sandy Mud (15)	6.4 ± 0.7	14,747 ± 4,906	28.74 ± 5.5	1.126 ± 0.08
Muddy Sand (4)	5 ± 1.3	2,992 ± 1,004	30.78 ± 12.1	1.203 ± 0.26
Sand (29)	2.6 ± 0.4	1,424 ± 506	6.9 ± 2.1	0.505 ± 0.08

3.2.21 The size distribution of prey items of SPA bird features are generally of similar sizes within different sediment types. The ragworm *Hediste diversicolor* was however, found to reach larger sizes in fine-grained sediments (mud, sandy mud and muddy sand) compared with those in sandy sediments (APEM 2011c).

3.2.22 The intertidal invertebrates which inhabit the sand- and mud-flats (intertidal sediments) of the Estuary are the principal food source of many of the resident and migratory bird populations afforded protection under the SPA designation. Surveys of this habitat by APEM (e.g. 2003, 2008a, 2010ab, 2011c) and others (Rehfisch *et al.* 1991) have shown that the middle of the Estuary (Silver Jubilee Bridge to Eastham), which comprises the SPA, contains high densities of invertebrate fauna, ranging from hundreds to thousands of individuals per square metre, especially compared with the more impoverished upper Estuary (tidal limit of the Mersey to the Silver Jubilee Bridge) (APEM 2008a). Major prey items of the qualifying bird species include the molluscs *Macoma balthica*, *Hydrobia ulvae* and *Cerastoderma edule*, the amphipod *Corophium* sp., the polychaetes *H. diversicolor* and *Nephtys* spp., and various oligochaete species (Environment Agency 2002, HBC, 2008). The numerical and biomass densities of these benthic invertebrate communities, and also the body size of individual prey animals should be maintained at a level at which they will continue to sustain the waterbird population of the Mersey Estuary SPA, particularly the qualifying species.

3.2.23 The saltmarsh areas provide a number of ecological roles including the supply of invertebrates and soft-leaved and seed-bearing plants which constitute important food sources for many bird species. For the saltmarsh habitats, vegetation characteristics are also important, with certain bird species requiring a minimum vegetation height for roosting which is currently suitable within the site for roosting birds. Juvenile fish can also reside in creeks and impounded areas within the intertidal saltmarsh.

[2] The Shannon-Wiener diversity index is a measure of species diversity and takes into account both the number of species within each sample and the proportion of individuals each species contributes to the total number of individuals within each sample (Magurran 2004).

3.2.24 The rocky shores were found to be dominated by the green alga *Ulva* sp., with brown fucoid algae also common across the sites surveyed (APEM 2010c). The faunal community was found to be dominated by barnacles, with dense mussel beds in the lower shore areas and littorinids increasing in abundance moving seawards along the Estuary. In general, macroalgae diversity was low and high percent coverage was recorded in some areas. The rocky shores provide roosting areas for birds in addition to supporting invertebrate and macroalgal species which are consumed by waders and wildfowl, respectively.

3.3 Water Framework Directive

3.3.1 The Mersey Estuary water body is classified under the WFD as Transitional Type 3. The general description for an estuary of this type is 'Type 3 transitional waters are fully mixed, predominantly polyhaline and are macrotidal. They are sheltered, with a sand or mud substratum and tend to have extensive intertidal areas.' (WFD-UKTAG, 2004). Type-specific conditions for benthic macroinvertebrates, fish, phytoplankton, macroalgae and angiosperms (saltmarsh) are indicated in Appendix 3.

3.3.2 The EC Water Framework Directive (WFD) requires that all inland and coastal waters within defined river basin districts must reach at least 'Good' status (or 'Good' potential if considering a heavily modified water body) by 2015. The overall status of the Estuary is dependent on the status of individual biological, chemical and hydromorphological elements. The status of general chemical and physicochemical quality elements, specific pollutants, priority substances and EU-level dangerous substances and hydromorphological quality elements also contribute to overall ecological status under the WFD however, these aspects are outside the scope of this report and are covered by other topic assessments. This report considers the biological elements which are assessed under the WFD for transitional water bodies which are invertebrates, fish, phytoplankton, macroalgae and angiosperms (saltmarsh flowering and seed-producing plants).

Invertebrates

3.3.3 Invertebrate assemblages in the Mersey Estuary are deemed to be of moderate ecological status and are predicted to remain so under baseline in 2015 and reach good status by 2027, however the confidence in this assessment is given within the RBMP as Uncertain (EA, 2009). Moderate status indicates that the level of diversity and abundance of invertebrate taxa is moderately outside the range associated with the type-specific conditions, taxa indicative of pollution are present and many sensitive taxa of the type-specific communities are absent. The WFD states that waters achieving a status below moderate are classified as poor or bad. To improve to good status it would be required for most of the sensitive taxa of type-specific communities to be present, and for high status all of the sensitive taxa associated with undisturbed conditions would need to be present.

3.3.4 The WFD includes consideration of both intertidal and subtidal invertebrates. Important factors influencing invertebrate assemblages include the type of substrate on the Estuary bed e.g. proportion of sand/mud sediments, morphology of the Estuary bed e.g. changes in channel position and areas of sediment accumulation, extent of suitable habitat, the relative proportion of intertidal and subtidal habitats and sediment load to the Estuary. In addition, suitable water quality conditions (e.g. temperature, dissolved oxygen, salinity) will be required along with an adequate food supply to support the invertebrate population.

3.3.5 Comparison of invertebrate assemblages in sedimentary habitats between intertidal and subtidal habitats in spring 2010 (APEM 2010a) shows that intertidal and subtidal habitats had similar species richness. Intertidal sites however, contained a significantly greater density of individuals and a greater total invertebrate biomass. Despite these differences, intertidal and subtidal assemblages showed considerable similarity in the identity of species present, with ~80% of polychaete and bivalve taxa found in both intertidal and subtidal habitats.

Fish

3.3.6 Fish assemblages within the Mersey Estuary are currently of Good Ecological Status and are predicted to remain Good in 2015 and 2027 (EA 2009). The boundary value for Good and Moderate, given under the WFD for fish in transitional waters, is based on a calculation in accordance with the "Transitional Fish Classification Index (TFCI)" (Defra 2009). The TFCI is based on the following parameters: species composition; presence of indicator species; species relative abundance; number of taxa that make up 90% of the abundance; number of estuarine resident taxa; number of estuarine-dependant marine taxa; functional guild composition; number of benthic invertebrate feeding taxa; and number of piscivorous taxa (Defra, 2009).

3.3.7 To attain Good status it must be considered that the abundance of the disturbance sensitive species show slight signs of distortion from type-specific conditions attributable to anthropogenic impacts on physicochemical or hydromorphological quality elements. For status to be reduced from the current Good status to Moderate it would need to be assessed that a moderate proportion of the type-specific disturbance–sensitive species were absent from the Estuary due to anthropogenic impacts on physicochemical or hydromorphological quality elements. Requirements to maintain some of the key TFCI score parameters into the future will be as follows:

- Presence of indicator species – the indicator species listed in the WFD guidance are all migratory species. A key requirement of these species will be safe fish passage through the Estuary in terms of both physical and chemical parameters. To maintain their status into the future they will require a route unimpeded by physical structures and chemical water quality parameters suitable for their physiological state during migration.

- Number of estuarine resident taxa – key requirements for estuarine resident taxa will be suitable resident, breeding, feeding and nursery areas which could include subtidal and intertidal habitats within the Estuary, a sufficient carrying capacity of food supply and suitable water quality conditions.

- Number of estuarine-dependent marine taxa – marine taxa dependent upon the Estuary will utilise it for either breeding, nursery or feeding grounds. The habitat, food supply and water quality characteristics will therefore, as above, be the primary requirements for the maintenance of their presence.

- Number of benthic invertebrate and piscivorous taxa – the ecological guilds represented by these two grouping will require sufficient food supply which will ultimately be dictated by the physical conditions of the Estuary including habitat availability and integrity, water quality and nutrient supply.

3.3.8 Fish recorded within the Estuary are characteristic of estuarine assemblages with a relatively small number of species dominating the catch and most species migrating into the Estuary from coastal waters, as opposed to being resident within the Estuary (APEM 2010a). In addition, a number of diadromous fish, such as eel, lamprey and salmon, are known to utilise the Estuary to reach habitats in the River Mersey and those further upstream. At the moment, fish passage up the Estuary is relatively unimpeded for these species, either physically (a small number of channels allowing passage at low tide), or chemically, as water quality has improved considerably over recent decades.

3.3.9 Due to the number of fish species under consideration within this assessment, an ecological guild approach has been adopted (Simberloff *et al.* 1991). This approach groups species by their expression of ecological traits or behaviours. In the current assessment, fish species were grouped in terms of their use of the Estuary and their diet.

3.3.10 The main functional groups for estuarine fish species have recently been refined (e.g. Elliott & Dewailly 1995, Potter & Hyndes 1999, and Elliott *et al*. 2007), and are summarised below based on the estuarine use functional group (EUFG) categories of Franco *et al*. (2008):

Estuarine Species: Can be resident (i.e. entire life cycle estuarine) or migrant (i.e. adults spawn in estuaries, marine larval phase, with juveniles returning to an estuary). Species with discrete populations in both estuarine and fully marine environments are included.

Marine Migrants: Adults live and spawn in marine environments, with juveniles frequently found in estuaries in large numbers. Juveniles can be opportunistic (i.e. can find suitable conditions within or outside estuaries), or dependant (i.e. require estuarine types of habitat).

Marine Stragglers: Live and breed in the marine environment. No estuarine habitat requirements but can enter lower reaches accidentally. Up-estuary movement is restricted by salinity as these stenohaline species generally avoid areas with salinities less than 35.

Anadromous: Most growth occurs at sea, adults migrate from coastal marine areas to freshwaters to spawn. Includes semi-anadromous species (migrate from sea to spawn within the upper extents of estuaries), and species which migrate from the sea to freshwater despite having no reproductive requirement for the migration.

Catadromous: Adults migrate from freshwaters to marine areas to spawn, but most growth occurs within freshwaters. Includes semi-catadromous species (migrate into lower estuarine waters to spawn but not out to sea), and species which migrate from freshwater to the sea despite having no reproductive requirement for the migration.

Anadromous and catadromous species are grouped together in this account as diadromous, i.e. migrating between marine and freshwater environments.

Freshwater Species: Those freshwater species found frequently and in moderate numbers in estuaries and whose distribution occasionally extends beyond the low salinity reach. Freshwater stragglers, species found in low numbers in estuaries that are restricted to areas of low salinity, are also included.

3.3.11 Marine and estuarine species have been further classified into feeding mode groups as defined below (from Franco *et al*. 2008):

Microbenthivores: Feed mainly on small benthic, epibenthic and hyperbenthic animals (<1 cm size).

Macrobenthivores: Feed mainly on larger benthic, epibenthic and hyperbenthic animals (>1 cm size).

Planktivores: Mainly consume zooplankton and occasionally phytoplankton.

Hyperbenthivorous-zooplanktivores: Feed principally on small mobile invertebrates found on or just above the sediment, and zooplankton.

Hyperbenthivorous-piscivores: Feed principally on larger mobile invertebrates on or just over the sediment, and other fish.

Detritivore: Predominantly consume detritus and/or microphytobenthos.

Herbivore: Consume living macroalgae and macrophyte material or phytoplankton.

Omnivore: Ingest a combination of plant and animal material.

3.3.12 A summary of the range of species expected to be found in the Mersey Estuary is provided in Table 3.2.

Table 3.2 Species list of fish recorded in the Mersey Estuary (data collated from ERL 1992d, Hering 1998, APEM 2008a, APEM 2011d). See abbreviations list for explanation of abbreviations (species list taken from Franco *et al.* 2008 and updated from Henderson *pers.comm*). Codes are provided in the accompanying table below.

Common name	Scientific name	EUFG	FMFG
Bass	*Dicentrarchus labrax*	MM	HZ, HP
Bib	*Trisopterus luscus*	MM	Bmi, BMa, HP
Brill	*Scophthalmus rhombus*	MM, MS	HP
Butterfish	*Pholis gunnellus*	ES, MS	Bmi, BMa
Chub	*Leuciscus cephalus*	F	HP, PL
Cod	*Gadus morhua*	MM	HZ, HP
Common bream	*Abramis brama*	F	Bmi, DV, HZ, HP, PL
Common goby	*Pomatoschistus microps*	ES	Bmi
Common sand eel	*Ammodytes tobianus*	MS	PL
Dab	*Limanda limanda*	MS	Bmi, BMa
Dover sole	*Solea solea*	MM	Bmi, BMa
European Eel	*Anguilla anguilla*	C	Bmi, BMa, HP, PL
Fifteen-spined stickleback	*Spinachia spinachia*	ES, MS	HZ
Five-bearded rockling	*Ciliata mustela*	MM	Bmi, BMa
Flounder	*Platichthys flesus*	MM	Bmi, BMa
Greater pipefish	*Syngnathus acus*	MS	Bmi
Grey gurnard	*Eutriglia gurnardus*	MS	Bmi, BMa
Herring	*Clupea harengus*	MM	PL
Lesser weaver	*Trachinus vipera*	MS	Bmi, BMa, HP
Long spined sea scorpion	*Taurulus bubalis*	MS	HP
Lumpsucker	*Cyclopterus lumpus*	ES, MS	Bmi, BMa
Nillson’s pipefish	*Syngnathus rostellatus*	MM	HZ
Plaice	*Pleuronectes platessa*	MM	Bmi, BMa
Pogge	*Agonus cataphractus*	ES, MS	Bmi, BMa
Poor cod	*Trisopterus minutus*	MM	Bmi, BMa, HP
River lamprey	*Lampetra fluviatilis*	A	HP
Roach	*Rutilus rutilus*	F	Bmi, BMa, PL, DV
Salmon	*Salmo salar*	A	Bmi, BMa, HP
Sand goby	*Pomatoschistus minutus*	ES	Bmi
Sea lamprey	*Petromyzon marinus*	A	HP
Sea trout	*Salmo trutta*	A,F	Bmi, BMa, HP
Short spined sea scorpion	*Myoxocephalus scorpius*	ES, MS	HP
Solonette	*Buglossidium luteum*	MS	Bmi, BMa
Sprat	*Sprattus sprattus*	MM	PL
Thicklipped grey mullet	*Chelon labrosus*	MM	DV
Thinlipped grey-mullet	*Liza ramada*	MM	DV
Thornback Ray	*Raja clavata*	MS	Bmi, BMa, HP
Three-spined stickleback	*Gasterosteus aculeatus*	ES, F	HZ
Whiting	*Merlangius merlangus*	MM	HP

Codes for Table 3.2

Estuarine Use Functional Group (EUFG)	**A**	Anadromous
	C	Catadromous
	ES	Estuarine species
	FS	Freshwater stragglers
	FW	Freshwater
	MM	Marine migrants
	MS	Marine stragglers
Feeding Mode Functional Group (FMFG)	**BMa**	Macrobenthivores
	Bmi	Microbenthivores
	DV	Detritivore
	HP	Hyperbenthivorous-piscivores
	HZ	Hyperbenthivorous-zooplanktivores
	PL	Planktivores

3.3.13 A number of these species are of conservation importance and as such are protected as features of site designations or under specific management plans. In particular migratory fish species within the Mersey Estuary with the exception of sea trout are of European importance (river lamprey, sea lamprey, salmon, European eel) and are protected under a range of policy and legislation (see Table 3.3). These species are present within the Estuary during periods of migration although for some species (e.g. potentially eel and salmon) some individuals may also reside within the Estuary outside these periods. A number of marine migrants entering the Estuary are UK BAP species. Periods of transit/residence for protected species have been predicted based on information currently available and are indicated in Table 3.3.

Table 3.3 Summary of the seasonal time of passage or residency of migratory species in the Mersey Estuary. Green cells indicate periods of fish passage and blue cells indicate periods of potential residency within the Mersey Estuary.

Receptor	Is the species/functional group a component of a designated site or protected under a plan?	Value of receptor	Population status in the Mersey Estuary	Species distribution	Residence and/or transit times												
Atlantic salmon	An Annex II species protected under the European Habitat and Species Directive (92/43/EEC) but this species is not protected by conservation site designations in the Mersey Estuary. The potential movement of fish from the Dee Estuary/Aber Dyfrdwy SAC into the Mersey must however be considered in terms of coherence of Natura 2000 sites.	European	Recovering	Across the UK - 88 designations (including 35 SAC/cSAC/SCI/pSAC) for this species	Transit	J	F	M	A	M	J	J	A	S	O	N	D
					Smolts d/s												
					Adults u/s												
River lamprey	An Annex II species protected under the European Habitat and Species Directive (92/43/EEC) but this species is not protected by conservation site designations in the Mersey Estuary. The potential movement of fish from the Dee Estuary/Aber Dyfrdwy SAC into the Mersey must however be considered in terms of coherence of Natura 2000 sites.	European	Unknown	Across the UK - 35 designations (including 21 SAC/cSAC/SCI/pSAC) for this species	Transit/resides												
					Newly metamorphosed adults d/s												
					Adults u/s												
Sea lamprey	An Annex II species protected under the European Habitat and Species Directive (92/43/EEC) but this species is not protected by conservation site designations in the Mersey Estuary. The potential movement of fish from the Dee Estuary/Aber Dyfrdwy SAC into the Mersey must however be considered in terms of coherence of Natura 2000 sites.	European	Unknown	Across the UK - 37 designations (including 23 SAC/cSAC/SCI/pSAC designations) for this species	Transit												
					Newly metamorphosed adults d/s												
					Adults u/s												
Eel	Protected under European eel management plan legislation (Eel Recovery Plan, Council Regulation No 110/2007 implemented under The Eels (Wales and England) Regulations 2009. The North West River Basin District Eel Management Plan affords Eel protection within the Mersey Estuary.	European	Currently meeting escapement target under Eel Management Plan - Stable	Across the UK	Transit/resides												
					Glass eel u/s												
					Silver eel d/s												
Sea trout	Nationally protected species under the UK Biodiversity Action Plan (UKBAP) list of priority species	National	Stable/ increasing	Across the UK	Transit/resides												
					Smolts d/s												
					Adults u/s												
Marine migrants																	
- Cod	Protected under a Species Action Plan as part of the UK BAP	National	Stable	Across the UK	Reside/nursery												
- Herring	Protected under a Species Action Plan as part of the UK BAP	National	Stable	Across the UK	Reside/nursery												
- Plaice	Protected under a Species Action Plan as part of the UK BAP	National	Stable	Across the UK	Reside/nursery												
- Sole	Protected under a Species Action Plan as part of the UK BAP	National	Stable	Across the UK	Reside/nursery												
- Whiting	Protected under a Species Action Plan as part of the UK BAP	National	Stable	Across the UK	Reside/nursery												
Marine stragglers	No	Local	Stable	Across the UK	Reside/nursery												
Freshwater stragglers	No	Local	Stable	Across the UK	Resides												
Estuarine residents	No	Local	Stable	Across the UK	Resides												

Phytoplankton

3.3.14 The Estuary supports benthic algae and phytoplankton which are important for primary productivity. Assemblage composition and biomass of these algae change considerably on a seasonal basis which is typical of dynamic environments such as the Estuary.

3.3.15 There is no information on the current status of phytoplankton populations under WFD in the Mersey Estuary however it is assumed, based on the overall status of the Estuary as classified within the RBMP, that they currently exist at Moderate status, with the future status being Good by 2027 (EA 2009). Phytoplankton status under the WFD is based on the Phytoplankton Multi-metric Toolkit Index (PMTI) which is based on three parameters: phytoplankton biomass during the growing season (90-percentile March-October inclusive); bloom frequency in respect of chlorophyll, individual taxa, total taxa and *Phaeocystis* bloom frequency; and seasonal succession of phytoplankton functional groups (Defra 2009). For moderate status the composition and abundance of phytoplankton differ moderately from type-specific conditions, biomass is moderately disturbed and a moderate increase in frequency and intensity of blooms may occur. The WFD states that waters achieving a status below moderate are classified as poor or bad. To attain good status there would be a slight change in composition, abundance and biomass compared with type-specific conditions and no evidence of accelerated growth of phytoplankton.

Macroalgae

3.3.16 Macroalgae require solid substrates for colonisation and are restricted to rocky shore areas and man-made hard structures within the Estuary with some fucoid species and green filamentous algae providing a food source for wildfowl.

3.3.17 There is no information on the current WFD status of macroalgae in the Mersey Estuary. As such, it is assumed that it will be classified as Moderate status which reflects the status for the Estuary as a whole at present, improving to Good by 2027 (EA, 2009). Moderate status indicates that the composition of macroalgal taxa differs moderately from type-specific conditions, moderate changes are observed in macroalgal abundance which may cause an undesirable change to the balance of organisms in the water body. Under the WFD waters achieving a status below moderate are classified as poor or bad. To improve this status to good it would be required for there to only be slight changes in the composition and abundance of macroalgal taxa compared to the type-specific conditions with no evidence of accelerated growth of phytobenthos or higher forms of plant life resulting in an undesirable disturbance of the balance of organisms in the water body. The status of macroalgae is calculated using information on the three fucoid species. The calculation depends on the presence or absence of any of these species in addition to the presence or absence of any other macroalgal species (Defra 2009). The reference conditions applicable to transitional waters are that one of the three fucoid species (*Fucus ceranoides, Fucus spiralis* and *Fucus vesiculosus*) is expected to be present in upstream parts of transitional waters with salinities in the range zero to <5 (and the fucoid zone is unbroken in lower parts of the transitional water where appropriate habitat exists) (UKTAG 2009).

3.3.18 There are a number of aspects of the chemistry and ecology of the Estuary which are expected to improve over time following recent trends. For example, the water quality would be expected to continue to improve due to management actions, including regular reviews of consents for discharges. Measures to limit dredging activity and a sediment management framework are expected to limit disturbance to benthos and reduce levels of sediment resuspension. Overall, there is potential for continued improvement in water quality and of the status of ecological assemblages in the Estuary including invertebrates, phytoplankton and macroalgae.

Angiosperms

3.3.19 The only angiosperms present within the Mersey Estuary are flowering and seed-producing plants within saltmarsh habitats, a habitat which can be utilised by birds and fish. There are currently no guidelines for WFD monitoring for saltmarsh habitats although key attributes to be considered include abundance, composition and saltmarsh spatial extent.

3.3.20 There is no information on the current WFD status of saltmarsh populations in the Mersey Estuary. As such it is assumed that as it forms part of the general ecology of the Estuary that it will be classified under the more generic moderate status at present, improving to good by 2027 (EA 2009). For moderate status it is considered that the composition of angiosperm taxa differ moderately from the type-specific communities and is significantly more distorted than at good quality. To attain good status it is required that any changes to angiosperm taxa in relation to type-specific communities is slight.

3.4 The Wildlife and Countryside Act 1981

3.4.1 The Mersey Estuary has been notified as a SSSI (Site of Special Scientific Interest) under the Wildlife and Countryside Act 1981 as the Estuary is an internationally important site for wildfowl and consists of large areas of intertidal sand and mudflats. The site designation covers a total area of 6,702.14 ha and incorporates both intertidal and subtidal habitat types. The site also incorporates reclaimed marshland, saltmarshes, brackish marshes and boulder clay cliffs with freshwater seepages. The site provides important feeding areas and a migrating staging post for internationally important numbers of wildfowl and waders.

3.4.2 Latest data on the current condition of the 12 Mersey Estuary SSSI units (December, 2010) indicate that 3 units comprising littoral sediment, supralittoral rock and standing open water and canals are considered to be of favourable condition. With reference to specific bird species a number of units within the Mersey Estuary SSSI are considered to be unfavourable due to declines in teal, pintail, widgeon and golden plover. The specific reason for the declines is uncertain. Within the SSSI assessment, Natural England indicate that declines in pintail and teal could potentially be attributable to improvements in water quality which have affected the abundance of their prey species. The reduction in wigeon may be attributable to the management of the salt marsh. Golden Plover are known to favour areas on the fringes and outside of the designated site i.e. the Hale end of units 1 and 7 and the Frodsham sludge lagoons. For most of the units experiencing unfavourable status, the salt marsh extent is decreasing which has been attributed to natural changes. The role on anthropogenic influences i.e. shipping is uncertain and is recognised by Natural England as potentially requiring investigation.

3.5 Other Legislative and Policy Drivers

3.5.1 There are a number of other legislative drivers which have the potential to influence the management of the Mersey Estuary and its ecological features which could influence the current and future state of the Estuary. As with the Habitats Directive and WFD, deviations from the requirements or standards set by these directives could influence the consenting of a tidal power scheme in the Mersey Estuary. The level of risk posed by each directive however, will be dictated by its derivation in UK or European law and will not necessarily be equal. These drivers include:

- **Eel Recovery Plan, Council Regulation No. 110/2007 -** The main requirement of this legislation with respect to the future state of the Estuary would be to ensure the escapement of silver eels out of the Estuary, a key component of which is to provide free passage of eel throughout the catchment.

- **Salmon and Freshwater Fisheries Act (Department for Environment, Food and Rural Affairs, 1975) (SFFA) –** The main requirement of this legislation with respect to the future state of the Estuary would be to achieve or maintain migratory salmonid fish passage through rivers and estuaries.

- **Modernisation of salmon and freshwater fisheries legislation; new regulatory order to address the passage of fish (for WFD and EU Eel Regulation) –** The main requirement of this legislation with respect to the future state of the Estuary would be to achieve or maintain migratory fish passage through rivers and estuaries**.**

- **Conservation of Natural Habitats and Wild Flora and Fauna, The Habitats Directive. Directive 92/43/EEC** – The main requirement of this legislation with respect to the future state of the Estuary would be to achieve or maintain migratory fish passage through rivers and estuaries**.**

- **UK Biodiversity Action Plan** - Of the 45 priority habitats under UK BAP, many are present in the Mersey Estuary including: estuarine rocky habitats, intertidal mudflats, saltmarsh, and subtidal sands and gravels. The UKBAP affords protection to the UK fish stocks of the following migratory species which could frequent the Mersey Estuary: eel, river lamprey, smelt, sea lamprey, salmon, and sea trout, as well as a number of marine fish species (e.g. herring, plaice, whiting).

- **UK Marine and Coastal Access Act 2009** – The main requirement of this legislation with respect to the future state of the Estuary would be to achieve or maintain migratory fish passage through the Estuary.

- **Land Drainage Act 1991 (and Water Resources Act 1991)** – The main requirement of this legislation with respect to the future state of the Estuary would be to achieve or maintain migratory fish passage through the Estuary.

3.6 Summary of Marine Ecology Receptors of Conservation Importance

3.6.1 An overview of the marine ecology receptors and groups in the region of interest is provided in Table 3.4. The value of the receptors given has been determined based on geographical context (e.g. international, national, designation) and conservation designations.

Table 3.4 Summary of marine ecology receptors and value

Receptor	Level of protection	Value
Migratory birds and wildfowl	European: Feature of SPA and Ramsar	**High**
Phytoplankton	European: Used to assess ecological status under the Water Framework Directive	**Medium**
Benthic flora	European: Used to assess ecological status under the Water Framework Directive	**Medium**
Benthic invertebrates	European: Used to assess ecological status under the Water Framework Directive and intertidal invertebrates a sub-feature of the SPA and Ramsar	**High (as sub-feature of SPA)**
Fish (non-migratory)	European: Used to assess ecological status under the Water Framework Directive, some UK BAP species	**Medium**
Migratory fish (eel, lamprey, salmon, sea trout)	European: Range of policy and legislation e.g. EU Habitats Directive, Salmon and Freshwater Fisheries Act, Eels (Wales and England) Regulations, UK BAP	**High**
Intertidal sediments	European: sub feature under SPA, Ramsar and listed as priority habitats under the UKBAP	**High**
Saltmarsh	European: sub feature under SPA, Ramsar and listed as priority habitats under the UKBAP	**High**
Rocky shores	European: sub-feature habitat under SPA, Ramsar and listed as priority habitats under the UKBAP	**High**

3.6.2 It is envisaged that changes in ecological features could occur in the future due to climate change. A report on the future morphology of the Estuary (H R Wallingford 2010) indicated that climate change and associated increases in sea level rise could lead to increased erosion of the shoreline leading to more rapid coastal retreat. The soft sediment shores and saltmarsh, and the ecological communities they support, are most likely to be influenced by these changes. In addition, the rocky shore habitats and other intertidal environments support assemblages of plants and animals adapted to a range of tidal inundation regimes. Increases in tidal height and higher waves associated with climate change could alter this regime range which could affect organisms within these habitats. Depending on the potential to extend the current habitat landward extents, however, changes may not result in detrimental effects.

4 Lessons Learnt from Stage 2

4.1.1 A number of key points were identified during Stage 2 of the project which have helped inform the work conducted at Stage 3. This was following an assessment at the end of Stage 2 to review criteria for marine ecology and consider potential measures for preventing harm, mitigation and compensation. These key points are indicated below:

- Initial modelling indicated that there was very little difference in terms of habitat loss when comparing schemes on Band A and on Band B due to scheme position alone (as opposed to scheme design). It was found that Band B was not the most suitable scheme location in terms of ecological effects for reasons including the following:
- The initial choice for the shallower water of Band B involved a large number of relatively small turbines with high rotation speeds. It was identified that these turbines would increase the risk of fish strike and potential mortality or injury to fish when compared with the larger turbines which could be effective on Band A schemes.
- If an impounding barrage or Very Low Head Barrage (VLHB) with large turbines was to operate effectively at Band B it would require extensive dredging within the SPA to increase the water depth, which would lead to considerable disturbance of the protected site. Depending on the navigation options selected for a scheme on Band A some local dredging would be required, however, the area to be dredged would be far smaller than for a Band B option using larger turbines.
- Band A overlaps some of the marginal habtats of the SPA but largely lies outside the SPA. Band B, however, is located further to the east within the SPA boundary where the Estuary widens and the majority of the Estuary channel consists of protected intertidal habitat. The length of a scheme at Band B would also be considerably greater than at Band A. The footprint of a scheme at Band B would consequently be greater than at Band A leading to greater direct loss of SPA intertidal habitat and would result in greater disturbance of the SPA during construction when compared to a development at Band A.
- Consequently an option on Band B offered very little ecological advantage overall to an option located on Band A.

4.1.2 Fish friendly turbines: It was determined during Stage 2 that fish have the potential to be injured/killed during turbine passage. As such a range of turbine technologies were investigated to reduce potential injury and mortality of fish during turbine passage. It was found that there were no suitable technologies available for the environmental conditions in the Mersey Estuary or which could be feasibly operated in a tidal power scheme.

4.1.3 Fish screening: The efficiency of physical screening to act as a successful protection measure to limit fish passing through turbines remains to be confirmed however indications from Stage 2 are that they may not be effective for the scheme. Although potentially offering greater efficiency the deflection rate of behavioural screening solutions was also identified as requiring further investigation. The inclusion of fish passage routes in scheme design was found to be the most likely successful mitigation measure to limit fish mortality due to turbine passage and as such was carried through to the Stage 3 scheme designs.

4.1.4 Generating energy at different head differences: An impounding barrage scheme would operate at a water level head difference of up to 4 m. It was considered that a very low head barrage option could also be investigated during the optioneering process with a smaller difference of 3 m or less. It was predicted that this would be beneficial for estuarine ecology as the lower the head difference the closer the tidal cycle would remain to the natural regime. It was considered that flexibility with the scheme operation enabling it to operate at a range of head differences could be investigated.

4.1.5 Ebb and flood generation: In addition to ebb only generation, as investigated at Stage 2, operation on both the ebb and flood tides was identified as potentially offering environmental benefit for marine ecology and as such was taken forward for investigation within Stage 3. It was predicted that the natural tidal cycle could be more closely replicated with an ebb and flood scheme which would be beneficial from an estuarine ecology point of view.

4.1.6 Low tide sluicing: The schemes assessed at Stage 2 were found to result in an increase in low tide water levels upstream of the structure. In order to increase the potential area of intertidal habitat exposed at low tide it was considered that, at the end of the generating cycle, sluices could be opened to allow more water to leave the basin to reduce low water levels further. It was predicted that this would be beneficial for estuarine ecology providing an increase in intertidal area exposed and more time for birds to feed.

4.1.7 Low tide pumping: Another option considered for lowering water levels in the basin at low tide was to actively pump water out of the basin to downstream of the structure at the end of the generating cycle.

4.1.8 High tide pumping: It was found that one of the potential effects of a scheme would be to decrease high water levels upstream of the structure. Saltmarsh relies on regular inundation to maintain its characteristics and function and when it is not inundated it can be encroached by terrestrial vegetation reducing the area of saltmarsh. Pumping of water from downstream of the structure to upstream to raise water levels in the basin before the turbines started generation was considered a possibility to increase water level at high tide. It was considered that this could potentially limit ingress of intertidal sediment areas by saltmarsh, and encroachment of the saltmarsh by terrestrial plants. Limitations include engineering considerations and the energy requirements for the pumping, however, the potential for high tide pumping may be explored further.

4.1.9 Seasonal variations in operation: Scheme designs which allow flexibility of operation in terms of effects on the tidal regime were investigated and were predicted to be potentially beneficial from an ecological viewpoint. During a time of year which is of particular significance in terms of bird feeding, flexibility in operation could allow each of the proposed options to be operated in a way which optimises area of intertidal habitat exposed and/or the length of time it is exposed for, benefitting the birds during that period.

5 Stage 3 Scheme Assessment

5.1 Potential Effects of a Tidal Power Scheme Without Consideration of Prevent Harm or Mitigation Measures

5.1.1 Potential effects of a tidal power scheme in the Mersey Estuary on estuarine ecology include the following:

Changes to Physical State of Estuary

5.1.2 The physical structure of a tidal power scheme in the Mersey Estuary and the potential alterations to the tidal regime that will result from its presence and operation, are predicted to potentially lead to a number of hydrodynamic and geomorphological changes which could have effects upon the physical state of the Estuary and ultimately the ecology it supports. The type and extent of these changes would be dependent upon the scheme being considered but can generally be split into the following broad categories;

Loss of Tidal Prism Upstream of a Scheme Due to Higher Mean Water Levels

5.1.3 The creation of a basin upstream of a scheme and its subsequent operation may result in higher low water levels and a longer high water stand in the mid and upper Estuary within the region of the main intertidal mud and sand flats and saltmarsh and within the boundaries of the SPA and SSSI.

5.1.4 The physical changes to the habitat may result in reductions to exposed area and wetted perimeter as well as the length of time it is exposed and could result in the submergence of the lower tidal flats altering these areas from intertidal littoral habitat to sublittoral. This could have an effect on benthic invertebrate communities and could reduce the total intertidal feeding area available for foraging shorebirds, reducing food supply areas and potentially increasing competition among birds.

5.1.5 Intertidal habitats act as valuable nurseries and over-wintering locations for a number of fish species (Elliott & Hemingway 2002, McLusky & Elliott 2004) and may be utilised temporarily by diadromous species (e.g. eel, river lamprey). Accordingly loss of this habitat and associated food sources could potentially have an effect on fish populations within the Estuary (particularly juvenile fish), or they may need to adapt.

5.1.6 A reduced wetting regime for saltmarsh at high tide has the potential to result in terrestrial vegetation encroachment into current saltmarsh areas reducing the overall area of saltmarsh habitat within the Estuary. This could have consequences for the juvenile fish which use areas of saltmarsh as feeding and nursery grounds (Colclough *et al*. 2005) and for birds feeding in saltmarsh habitats. Similarly, saltmarsh could encroach into intertidal sediment areas lower on the shore if the water level at high tide is reduced which could cause a decrease in the extent of exposed intertidal sediments.

Reduction in Tidal Currents and Changes to Siltation

5.1.7 A reduction in tidal currents has the potential to result in a tendency for conditions of increased deposition initially and a significant reduction in channel meandering. Morphological evolution is, however, likely to ultimately result in a long-term reduction in siltation and a loss of intertidal area (HR Wallingford 2010).

5.1.8 Reduced tidal flows as a consequence of a tidal power scheme could promote a more homogenous and stable environment for benthic invertebrates. This could result in an increase in the mean size of individuals which are a very good source of food for juvenile fish. While increased size of prey items may be beneficial to adult fish and to most shorebirds, juvenile fish may face reduced prey availability and therefore ultimately this could affect the nursery capability of the Estuary.

Alterations to the Channels Within the Estuary

5.1.9 Depending upon the configuration of the structure of each scheme there is the potential for the channel structures within the Estuary to change as a result of re-distributed channelling of flow. This may lead to the intertidal banks and channels in the Inner and Upper Estuary becoming fixed and accrete and potentially lead to changes in the extent of subtidal and intertidal habitats with the potential for resultant negative and positive effects upon the communities these habitats support respectively.

5.1.10 The alteration of the channel structure within the Estuary may additionally result in changes to the route of passage of fish through the Estuary in particular for migratory species which through a means of selective tidal stream transport have a tendency to follow the main flow lines to move around the Estuary.

Alterations to the Wave Profile

5.1.11 Changes to hydrodynamic regime within the Estuary could result in increased wave heights (H.R. Wallingford 2010). This has the potential to increase the erosion of intertidal sedimentary habitats within the Estuary. Erosion of saltmarshes can lead to cliffing of sediments which could lead to a reduction in saltmarsh extent. In addition, contaminants can become concentrated in saltmarsh sediments and when erosion occurs there is potential for the release of these contaminants. The ability of saltmarsh sediments to concentrate contaminants is well known and assessments examining concentrations of pollutants in saltmarsh sediments have been undertaken in the upper Mersey Estuary (Gifford 2008). Increased erosion of intertidal benthic habitats could also affect the suitability of such habitats for macrofaunal communities and potentially lead to an overall reduction in extent.

Physical Habitat Loss from the Scheme Footprint or Dredging Activities

5.1.12 The construction of a tidal power scheme would likely result in the loss of extent of benthic habitat as a result of the footprint of the scheme. The benthic habitats lost would result in a direct loss of habitat for invertebrates leading to an equivalent loss in food resources for taxa further up the food chain, including fish and birds.

5.1.13 Dredging required for each scheme to maintain shipping channels is likely to result in an unstable benthic environment, with deleterious effects upon the infaunal communities present and with associated implications further up the food chain.

Fish Turbine Passage

5.1.14 Fish may be injured or killed during turbine passage due to the following mechanisms: mechanical (including strike, abrasion and grinding), pressure, shear and turbulence and cavitation. The greatest risk will be whilst passing on the generating tide. Additionally fish may be indirectly killed or suffer from non-lethal effects, as a result of disorientation, increased predation, delay to migration and sub-lethal stressors. The timing of reproduction in most species is critical, therefore, a delay to migration could prevent fish from reaching spawning grounds on time or decrease their spawning success. A key aspect for consideration for a tidal power scheme is whether the fish species being assessed reside within the Estuary, use it periodically for feeding, breeding or as a nursery ground or migrates through the Estuary once or more during its lifetime. The type of turbine selected and the way in which it is operated will be key to determining these potential effects. As a result of the tidal exchange in the Estuary fish moving in either direction may also fallback once or numerous times leading to multiple passages through the turbines including for those species moving in a landward direction. All fish species moving around the Estuary may therefore be at risk of injury/mortality from turbine passage.

Increased Predation

5.1.15 A tidal power scheme will have structures such as sluice gate gantries,that could provide nest sites and perches for birds of prey situated at the edge of the main feeding grounds of the shorebirds and thereby increase the risk of predation on foraging SPA bird features. Also, as modelling has shown, even frequent unsuccessful attacks by raptors can cause significant disturbance for shorebirds (Goss-Custard *et al*. 2006). Were migratory fish to be delayed by a Mersey Tidal Power scheme there is also the potential for congregations of migrating individuals upstream or downstream of the structure. This may increase predation rates by piscivorous birds, fish and potentially marine mammals if present, upstream of the structure in the tailrace and at bypass entrance and outfall locations.

Disturbance

5.1.16 The tidal power scheme structure itself would attract many visitors to the area due to improved access, viewpoints and a proposed visitor centre and this could increase onshore disturbance at bird roost sites and feeding areas.

Obstruction to View Lines

5.1.17 Some birds of prey could use the tidal power scheme and its associated structures as cover as they approach shorebirds in order to launch a surprise attack. It is thought that this is why many shorebirds seem reluctant to feed close to high sea walls.

Changes to Water Quality

5.1.18 Any tidal power scheme is likely to affect the hydrodynamic properties of the Estuary with potential resultant implications for water quality. Changes to water quality would primarily be related to the potential for a tidal power scheme to affect water column mixing and water velocity, in addition to changes to the retention time of water within the Estuary. The key parameters likely to be affected which could have an effect on marine ecology are suspended solids concentration, salinity, temperature, dissolved oxygen, nutrients and concentrations of pollutants such as heavy metals and trace pollutants such as organochlorides and radioactive material. Changes in these parameters could have subsequent effects on estuarine ecology.

5.2 Impounding Barrage v2 (IBv2)

5.2.1 For details of this scheme, see Table 2.1 and URS Scott Wilson (2011a).

5.2.2 The significance of these effects have all been assessed before consideration of the application of prevent harm and/or mitigation measures.

5.2.3 It should be noted that even if the significance of an effect is considered to be moderate or major for a specific receptor, it does not necessarily represent an ecological consenting risk under the Habitats Directive if it is not expected to have an adverse effect on the principal interest features of the site (e.g. birds), or on the integrity (i.e. structure and function) of the site.

5.2.4 The footprint of the scheme would be 49 ha which would result in a direct loss of intertidal and subtidal habitat. The intertidal sediment predicted to be lost includes areas of rocky shore (~0.5 ha), sandy mud (~1.5 ha), sand (~0.3 ha) and muddy sand (~0.1 ha) (these losses of intertidal sediment are the same for all three schemes so will only be detailed here), the rest of the habitat lost would be subtidal.

5.2.5 Tide curves based on the area of water present at different stages of the tide illustrate differences in the tidal regime with the baseline scenario and with a scheme in place. These have been provided for spring, intermediate and neap tides (Figure 5.1).

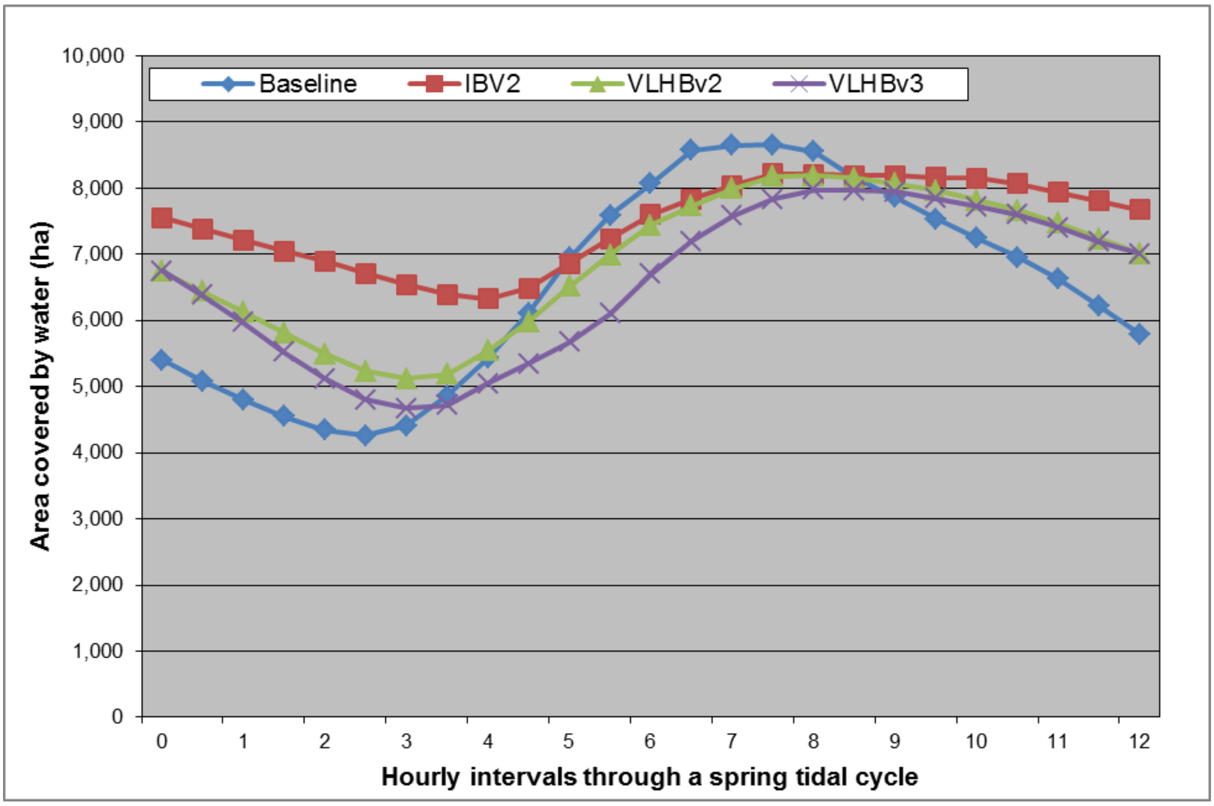


Figure 5.1a Tidal curve over a spring 2060 tidal cycle

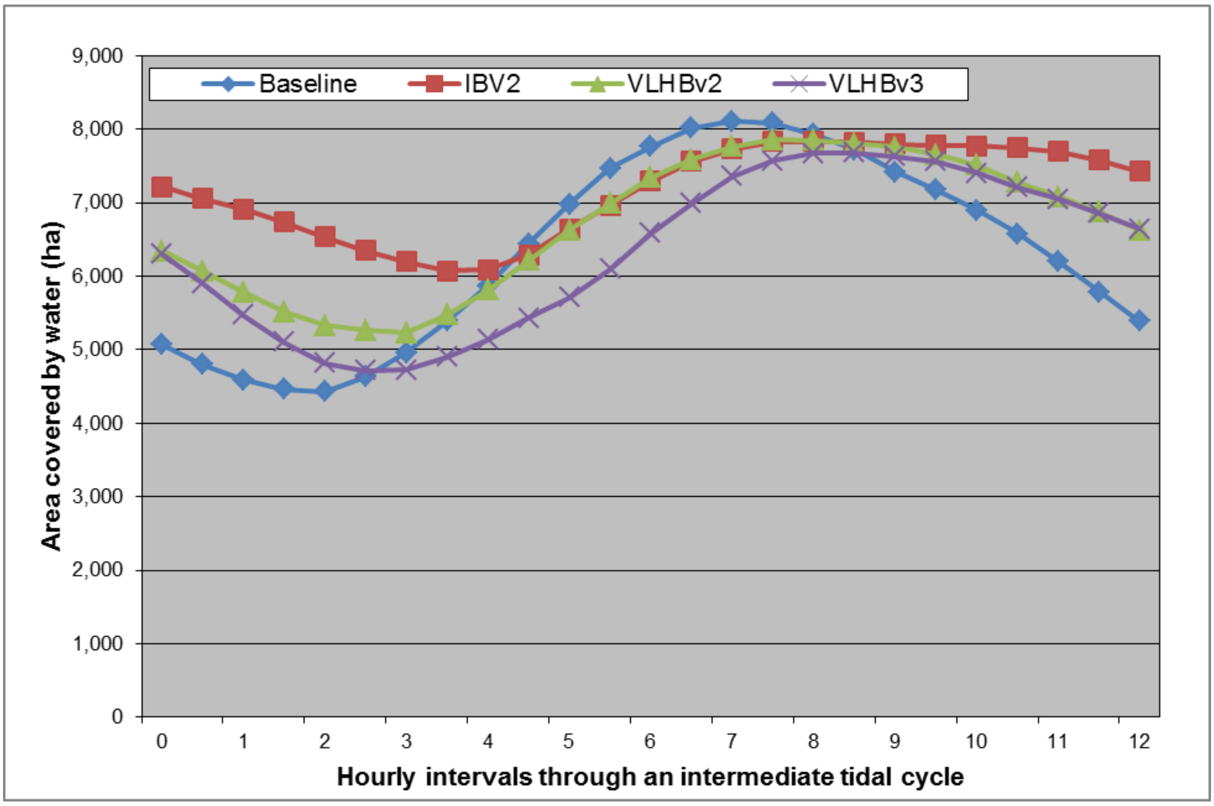


Figure 5.1b Tidal curve over an intermediate 2060 tidal cycle

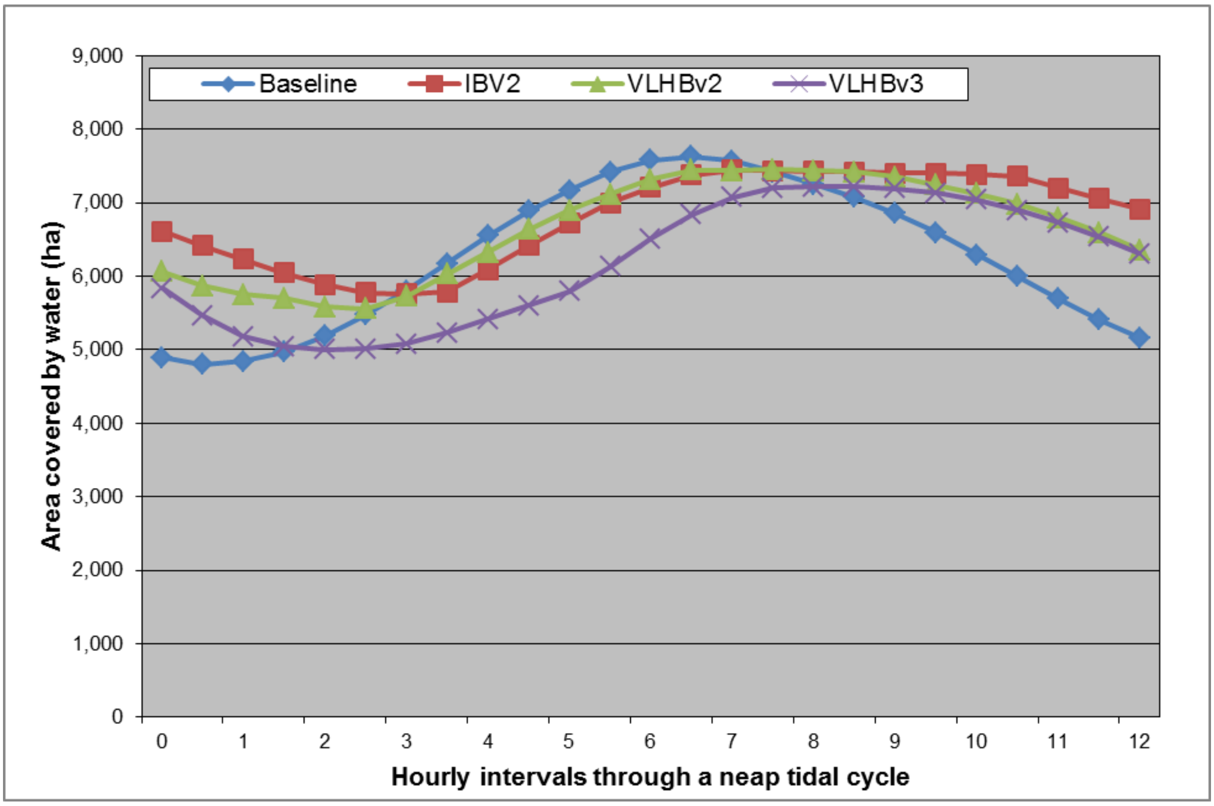


Figure 5.1c Tidal curve over a neap 2060 tidal cycle

Area of Habitat Exposed

5.2.6 A visual representation of change to areas of habitat exposed at spring low and high tide when comparing the baseline scenario with the scheme scenario for 2060, is provided in Figure 5.2 and Figure 5.3. These figures have been presented to illustrate the worst case scenario (i.e. the scenario for which the greatest decrease in intertidal area exposed was observed), however, tables indicating the results obtained for intermediate and neap tide scenarios are also provided. It should be noted that modelling was conducted for 30 minute time-steps throughout the tidal cycle. Presentation of results for high and low tide is considered to provide an overview of the extremes in terms of the magnitude of changes observed across the tidal cycle.

5.2.7 Under a baseline scenario with no scheme in place the lowest water level is observed, as would be expected, at low water on a spring tide, as opposed to a neap tide. Under the IBv2 scheme, however, due to changes in the tidal regime it was found that at low water more intertidal area would be exposed on the neap tide than on a spring tide (i.e. lowest low water with the scheme in place would be during neap tides and highest low water would be on spring tides, which is opposite to the baseline scenario), this is caused by interactions between a number of factors which are influenced by the operational strategy modelled for this scheme.

5.2.8 Changes in the timing of low and high tides is also evident upstream of the scheme. For baseline spring tides in 2060, low tide is 1.5 hours later than baseline with the scheme in place. Similar changes are also evident during neap and intermediate tides with low tide shifting to 2.5 and 1.5 hours later, respectively when compared with the baseline scenario. At high water there is shift of +0.5 hours during spring, intermediate and neap tides (Figure 5.1).

Intertidal Sediment

5.2.9 The results indicate that at low water during a spring tide there is a decrease in area of exposed intertidal sediment of 2,104 ha (55% of Estuary baseline) within the Estuary as a whole (of which 1,928 ha are in the SPA (56% of SPA baseline)) (Figure 5.2). Of the classified sediments the greatest decrease is in the area of intertidal sand exposed (737 ha (53%) in Estuary and 708 ha (56%) SPA) and the smallest decrease is for mud sediments (84 ha (19%) of baseline in the Estuary and 78 ha (19%) in the SPA).

5.2.10 The decrease in area exposed is lower at intermediate tides and lower still on neap tides. During the neap scenario the reduction in total area of exposed intertidal sediment is 1,034 ha within the Estuary (31% of Estuary baseline) and 962 ha in the SPA (33% of SPA baseline) with the greatest change being observed for sand habitats and the smallest change for mud habitat.

5.2.11 At high water, changes from baseline are smaller with evidence of an increase in the area of habitat exposed during spring, intermediate and neap tides (Figure 5.3). This is as a result of the high water level with a scheme in place being lower than for the baseline scenario. One of the reasons for this is that the scheme presents a barrier to water entering the Estuary on the flood tide, therefore, lower volumes of water can enter the basin on the flood tide when compared to the baseline scenario before the ebb tide commences emptying the basin once more. The extent of the differences modelled, between high water with a scheme in place and the baseline scenario, however, is mainly related to the operational strategy employed. With a decrease in high water level there is the possibility for saltmarsh to encroach areas of intertidal sediment, this could have the adverse effect of decreasing the extent of intertidal sediment habitat.

5.2.12 The SPA sub-feature attribute target for the attribute ‘Extent and distribution of intertidal sediment’ is:

- No decrease in extent of intertidal sediment habitat from an established baseline, subject to natural change.

In terms of change in area of habitat exposed as a result of changes in tidal regime there is a notable difference under this scheme and it is considered that there would be an adverse effect on this sub-feature. Further information is required in relation to changes to the sedimentation regime within the Estuary and the potential for sediment accretion/erosion within the Estuary to more accurately evaluate this change. The value/sensitivity is considered to be **high** as intertidal sediments form a sub-feature of the SPA which is a site of international importance. Effects are predicted to be **direct** and **temporary** with a duration of the operational lifetime of the scheme. A natural tidal regime is expected to resume following decommissioning and removal of the scheme which means that effects could potentially be reversible. Due to the decrease in the area of exposure of intertidal sediment with the scheme in place the magnitude of effect is predicted to be **high**. Consequently, it is assessed that there would be an adverse effect of **major** significance. An important consideration of the assessment, however, is whether there would be an adverse effect on the principal interest features of the site (e.g. birds) (discussed further in Section 2.4) or on the integrity (structure and function) of the site. Definitions for the terms used in the assessment text are provided in Appendix 2.

5.2.13 Changes in sediment character/biotopes and variation in area exposed as a result of changes in sediment transport are aspects which require further investigation through sediment transport modelling. These aspects would need to be examined in more detail for a preferred scheme at a future stage of the project.

Rocky Shore Habitat

5.2.14 The decrease in exposed areas of rocky shore habitat at spring tide low water equates to 17 ha within the Estuary (61% of Estuary baseline), 14 ha of which are in the SPA (64% of the SPA baseline).

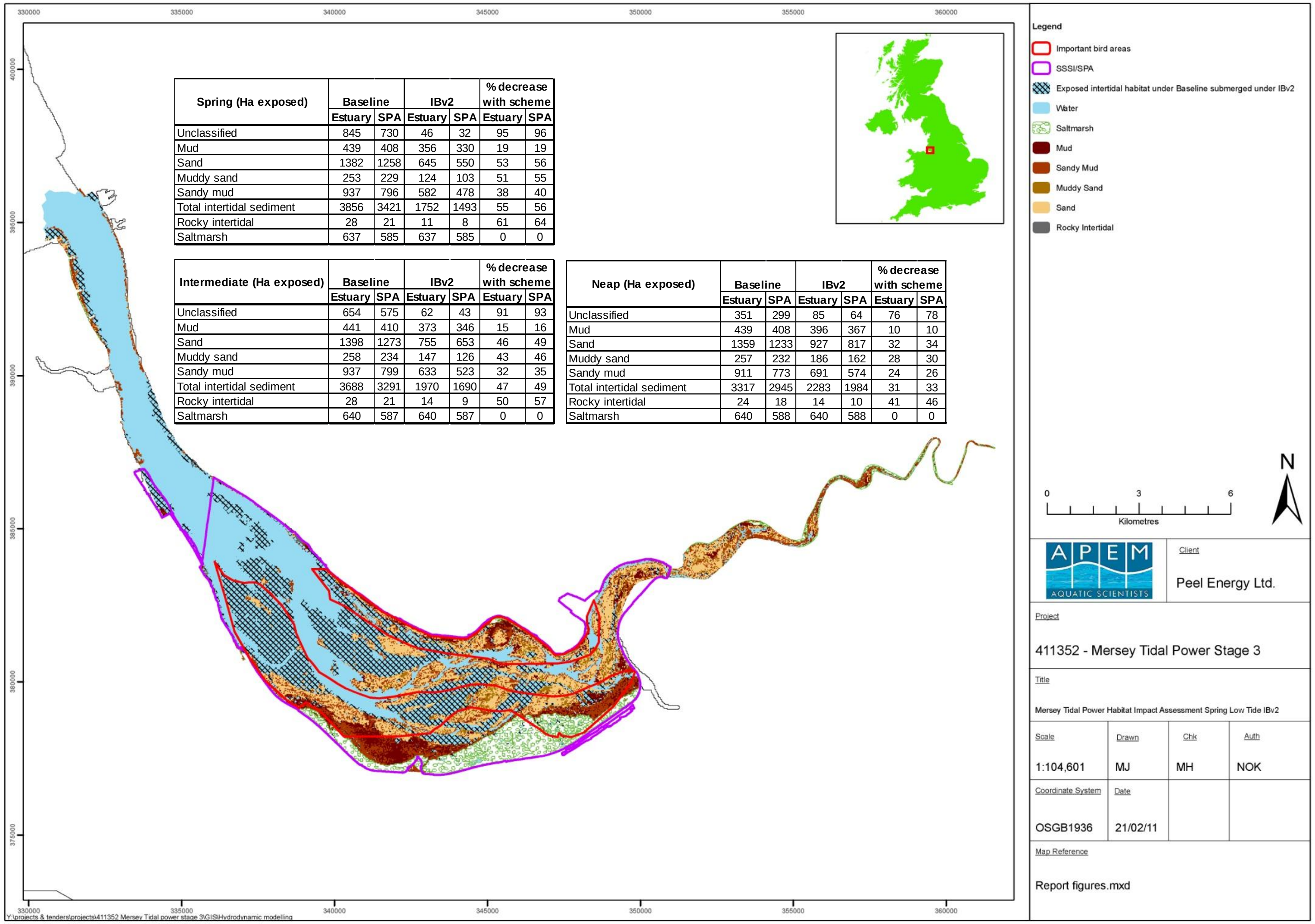
5.2.15 With the scheme in place for neap tide low water, rocky shore intertidal area is indicated to be reduced from 24 ha to 14 ha within the Estuary as a whole (41% reduction when compared to the Estuary baseline), and from 18 ha to 10 ha in the SPA (46% reduction).

5.2.16 At high water changes in the exposed area of rocky shore with the scheme in place when compared to baseline are very small (generally <1 ha).

5.2.17 The SPA sub-feature attribute targets for the rocky shore habitat attributes ‘Extent and distribution of habitat’ and ‘Food availability’ are, respectively:

- No decrease in extent of rocky shore habitat from an established baseline, subject to natural change.
- Presence and abundance of intertidal invertebrate and green algal prey species in rocky shore habitats should not deviate significantly from an established baseline, subject to natural change.

5.2.18 Areas of rocky shore are relatively small within the Estuary, however, the results of the assessment indicate that under this scheme there is a decrease in the exposure of rocky shore habitat. Value/sensitivity of this receptor is considered to be **high** as rocky shores form a sub-feature of the SPA which is a site of international importance. Effects are predicted to be **direct** and **temporary** with a duration of the operational lifetime of the scheme, with a natural tidal regime resuming following decommissioning and removal of the scheme. Due to the decrease in the area of exposed rocky shore habitat with the scheme in place, the magnitude of effect is predicted to be **high**. Consequently, it is assessed that there would be an adverse effect of **major** significance.

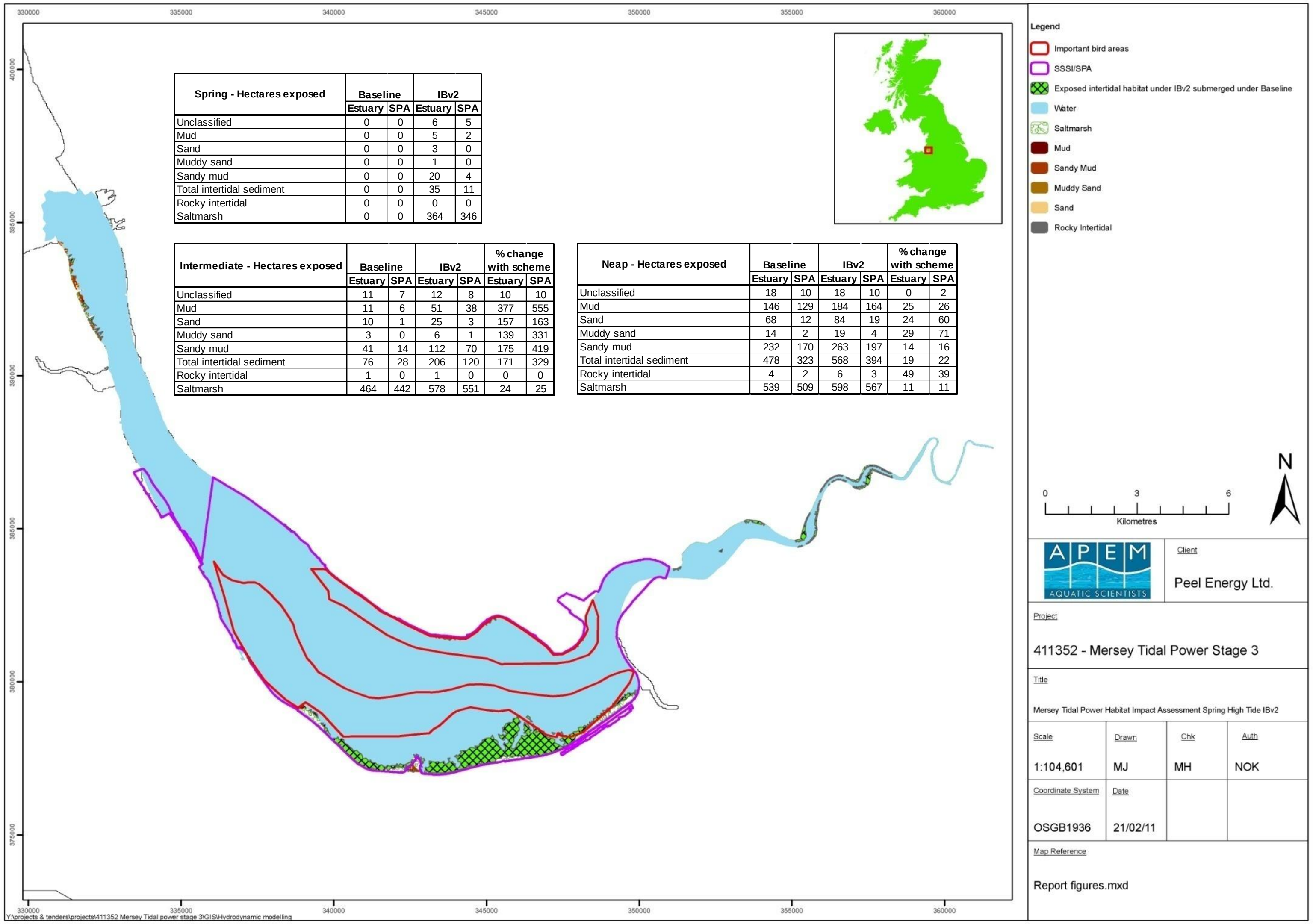


Spring (Ha exposed)	Baseline		IBv2		% decrease with scheme	
	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified	845	730	46	32	95	96
Mud	439	408	356	330	19	19
Sand	1382	1258	645	550	53	56
Muddy sand	253	229	124	103	51	55
Sandy mud	937	796	582	478	38	40
Total intertidal sediment	3856	3421	1752	1493	55	56
Rocky intertidal	28	21	11	8	61	64
Saltmarsh	637	585	637	585	0	0

Intermediate (Ha exposed)	Baseline		IBv2		% decrease with scheme	
	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified	654	575	62	43	91	93
Mud	441	410	373	346	15	16
Sand	1398	1273	755	653	46	49
Muddy sand	258	234	147	126	43	46
Sandy mud	937	799	633	523	32	35
Total intertidal sediment	3688	3291	1970	1690	47	49
Rocky intertidal	28	21	14	9	50	57
Saltmarsh	640	587	640	587	0	0

Neap (Ha exposed)	Baseline		IBv2		% decrease with scheme	
	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified	351	299	85	64	76	78
Mud	439	408	396	367	10	10
Sand	1359	1233	927	817	32	34
Muddy sand	257	232	186	162	28	30
Sandy mud	911	773	691	574	24	26
Total intertidal sediment	3317	2945	2283	1984	31	33
Rocky intertidal	24	18	14	10	41	46
Saltmarsh	640	588	640	588	0	0

Figure 5.2 Exposed habitat comparing baseline with IBv2 scenario at spring low tide.



Spring - Hectares exposed	Baseline		IBv2	
	Estuary	SPA	Estuary	SPA
Unclassified	0	0	6	5
Mud	0	0	5	2
Sand	0	0	3	0
Muddy sand	0	0	1	0
Sandy mud	0	0	20	4
Total intertidal sediment	0	0	35	11
Rocky intertidal	0	0	0	0
Saltmarsh	0	0	364	346

Intermediate - Hectares exposed	Baseline		IBv2		% change with scheme	
	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified	11	7	12	8	10	10
Mud	11	6	51	38	377	555
Sand	10	1	25	3	157	163
Muddy sand	3	0	6	1	139	331
Sandy mud	41	14	112	70	175	419
Total intertidal sediment	76	28	206	120	171	329
Rocky intertidal	1	0	1	0	0	0
Saltmarsh	464	442	578	551	24	25

Neap - Hectares exposed	Baseline		IBv2		% change with scheme	
	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified	18	10	18	10	0	2
Mud	146	129	184	164	25	26
Sand	68	12	84	19	24	60
Muddy sand	14	2	19	4	29	71
Sandy mud	232	170	263	197	14	16
Total intertidal sediment	478	323	568	394	19	22
Rocky intertidal	4	2	6	3	49	39
Saltmarsh	539	509	598	567	11	11

Figure 5.3 Exposed habitat comparing baseline with IBv2 scenario at spring high tide.

5.2.19 A survey was conducted during autumn 2010 examining distribution of algae and invertebrates on the intertidal rocky shore habitats in the Mersey Estuary and a reduction in extent of exposed area is considered likely to result in a reduction in the number of invertebrates on intertidal rocky habitats within the Estuary and SPA. Value/sensitivity of this receptor is considered to be **high** as rocky shores and their invertebrate communities form a sub-feature of the SPA which is a site of international importance. Effects are predicted to be **direct** and **temporary** with a duration of the operational lifetime of the scheme and invertebrates would colonise subtidal rocky habitats but these individuals would not be available to birds. A natural tidal regime would resume following decommissioning of the scheme and invertebrates would be expected to recolonise new intertidal areas of rocky shore. The abundance of invertebrates on rocky shores is considered to be relatively low in comparison with intertidal sediments and it is considered that rocky shores are of lesser importance for feeding birds, therefore, the magnitude of effect is considered to be **medium** and it is assessed that there would be an adverse effect of **moderate** significance.

Saltmarsh

5.2.20 There is no predicted change in the exposure of saltmarsh under the scheme at low water.

5.2.21 An increase in saltmarsh exposure is evident at high water under spring, intermediate and neap scenarios. The greatest change is during spring tides as area of saltmarsh exposed increases from 91 ha to 455 ha within the Estuary (72 to 418 ha within the SPA) when comparing the baseline scenario to the scheme scenario.

5.2.22 The SPA sub-feature attribute targets for the saltmarsh habitat attributes 'Extent and distribution of habitat', 'Food availability' and 'Vegetation characteristics' are, respectively:

- No decrease in extent of saltmarsh habitat from an established baseline, subject to natural change
- Presence and abundance of prey species in saltmarsh should not deviate significantly from an established baseline, subject to natural change
- Presence and abundance of soft-leaved and seed-bearing plants in saltmarsh habitats should not deviate significantly from an established baseline, subject to natural change
- Vegetation height throughout areas used for feeding and roosting should not deviate significantly from an established baseline, subject to natural change

5.2.23 It is evident from the results that there would not necessarily be a decrease in saltmarsh extent at low tide due to the presence of a scheme. At high tide, however, the increased exposure of saltmarsh which was previously inundated could result in encroachment by terrestrial vegetation and subsequent reduction in saltmarsh extent. In turn the saltmarsh itself could encroach intertidal habitats which may counter this change although further investigation is required to clarify this. Value/sensitivity of the receptor is considered to be **high** as saltmarsh forms a sub-feature of the SPA which is a site of international importance. Effects are predicted to be **direct** and **temporary** with a duration of the operational lifetime of the scheme with a more natural tidal regime returning following decommissioning and removal of the scheme. The encroachment of saltmarsh by terrestrial vegetation and the potential for saltmarsh to colonise areas lower on the shore, coupled with possible erosion caused by wave action suggests that magnitude of changes with the scheme in place is likely to be **high**. Consequently, it is assessed that there would be an adverse effect of **major** significance.

5.2.24 Further data are required to fully assess the types of change that may result in terms of presence and abundance of prey species. It is clear that the overall availability of prey could be reduced due a reduction in the extent of intertidal saltmarsh. The change in extent, however, has been assessed above and in terms of localised changes to invertebrate prey species within the saltmarsh habitat it is considered that prey species composition and density would not necessarily change within the remaining areas of intertidal saltmarsh while the scheme is operating. Value/sensitivity of the receptor is considered to be **high** as saltmarsh forms a sub-feature of the SPA which is a site of international importance. Effects are predicted to be **direct** and **temporary** lasting the operational lifetime of the scheme with effects potentially reversible following decommissioning and removal of the scheme. It is considered that the magnitude of change would be **very low** in local diversity and density of prey species within areas of intertidal saltmarsh and there would be an adverse effect of **minor** significance. It is important to note also that although a sub-feature of the SPA designation, the saltmarsh is not considered to be a major feeding resource for SPA bird features. The main SPA bird feature which has been observed to utilise saltmarsh is common shelduck, and even at times of peak counts of this species on the saltmarsh the percentage in comparison to the numbers using the Estuary as a whole are low. The shelduck observed on saltmarsh are mainly roosting birds which have been moved from their favoured areas of mud on high spring tides. Other birds such as whooper and Bewick's swan do feed on the saltmarsh but this does not appear to be the case for the SPA bird features. Taking this into consideration changes to prey composition on the saltmarsh may not have an adverse effect on birds or affect the conservation status of the SPA.

5.2.25 The type of soft-leaved and seed-bearing plants on the saltmarsh requires further investigation, however, it is unlikely that within the areas of intertidal saltmarsh which remain there would be considerable changes to composition of the saltmarsh vegetation, or the density of saltmarsh plants. Value/sensitivity of the receptor is considered to be **high** as saltmarsh forms a sub-feature of the SPA which is a site of international importance. Effects are predicted to be **direct** and **temporary** with a duration of the operational lifetime of the scheme, with effects potentially reversible following decommissioning and removal of the scheme. It is considered that the effect would have a magnitude of **very low** and an adverse effect of **minor** significance.

5.2.26 Although the extent of saltmarsh may change, based on information currently available the height of vegetation is not expected to change. Value/sensitivity of the receptor is considered to be **high** as saltmarsh forms a sub-feature of the SPA which is a site of international importance. Effects are predicted to be **direct** and **temporary** with a duration of the operational lifetime of the scheme with effects potentially reversible following decommissioning and removal of the scheme. Overall, the magnitude of this effect is therefore considered to be **very low** and there would be an adverse effect of **minor** significance.

Invertebrate Prey Biomass (Within Sediments)

5.2.27 Changes in exposed invertebrate biomass in relation to change in the exposure of different sediment types are summarised in Table 5.1 below. Only low water changes in biomass have been considered as low water is the important feeding period for birds. Under the spring tide scenario within the Estuary as a whole there is a reduction in exposed intertidal invertebrate biomass from ~585 to ~345 tonnes, this represents a ~41% reduction in biomass (Table 5.1). For the intermediate tide scenario this figure is ~35% and for the neap tide scenario there is a ~25% reduction in invertebrate biomass. Within the SPA there is a similar change with a reduction under the spring tide scenario of ~563 to ~352 tonnes (~38% of the SPA biomass), and similar percent reductions for the other scenarios when comparing against changes in the Estuary as a whole.

5.2.28 These values are based on the area of habitat reduced at low tide i.e. the reduction in area based on difference in the low water mark for baseline and under the scheme. It should be noted, however, that as the high water mark is reduced with the scheme in place there would be a drying out of the section of the upper intertidal zone which was submerged under baseline spring tides but is exposed at all times under the highest tides with the scheme in place. As this section of the shore would be dry at all times it would not be colonised by intertidal invertebrates which would result in a further reduction of the biomass of prey items which is not accounted for in the tables below. These tables, therefore, represent underestimates of the reductions in biomass expected under the schemes although this rationale only applies to the spring tide scenarios.

Table 5.1 Estimated potential change in invertebrate biomass exposed at low tide comparing baseline with the IBv2 scheme scenario under spring, intermediate and neap scenarios (to the nearest tonne).

Spring - Invertebrate biomass (tonnes)	Baseline		IBv2		Actual decrease		% decrease	
	Estuary	SPA	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified intertidal sediment	26	22	1	1	25	21	95	94
Mud	158	157	124	126	35	30	22	19
Sand	87	83	36	36	51	47	59	56
Muddy sand	87	87	41	42	45	44	52	51
Sandy mud	227	215	143	146	84	69	37	32
Total	585	563	345	352	240	211	41	38
Intermediate - Invertebrate biomass (tonnes)	**Baseline**		**IBv2**		**Actual decrease**		**% decrease**	
	Estuary	SPA	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified intertidal sediment	20	18	2	1	18	16	91	93
Mud	159	157	129	128	30	30	19	19
Sand	88	85	43	41	45	43	51	51
Muddy sand	89	89	50	50	39	38	44	43
Sandy mud	228	217	157	151	71	66	31	30
Total	584	566	381	371	203	193	35	34

Neap - Invertebrate biomass (tonnes)	Baseline		IBv2		Actual decrease		% decrease	
	Estuary	SPA	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified intertidal sediment	11	9	2	2	8	7	78	79
Mud	157	156	136	135	21	21	14	13
Sand	86	83	54	53	32	30	37	36
Muddy sand	89	89	64	64	25	25	28	28
Sandy mud	224	214	171	165	53	48	24	23
Total	**567**	**551**	**427**	**419**	139	131	25	24

5.2.29 The SPA sub-feature attribute target for the intertidal sediment attribute ‘Food availability’ in relation to intertidal invertebrates is:

- Presence and abundance of prey species in intertidal sediments should not deviate significantly from an established baseline, subject to natural change

5.2.30 As mentioned in Section 3.2 the invertebrate densities recorded within the Mersey Estuary in 1991 were similar to those which were recorded during Stage 2 surveys in 2010. There was variability in terms of the numbers of individuals of different species with some species having greater density during the 2010 survey. Size data suggests that there is some potential for mean size of invertebrates to have varied between surveys conducted in 1991 and those conducted in 2010 for the Mersey tidal power scheme, with a greater proportion of larger individuals of two key prey taxa recorded in 1991. This could simply reflect recruitment patterns, however, and is not necessarily indicative of a decline in mean prey size over this period, further information would be required to clarify any potential trends in prey size. Although the limited number of studies does not allow for a detailed comparison over a number of years this provides some indication that the baseline invertebrate assemblage within the Estuary appears to have remained relatively consistent over this time in some respects such as density and the types of species present, and there is some potential for variation in other attributes such as body size of prey items although this remains to be clarified.

5.2.31 As indicated in the above assessment the presence of the scheme would likely result in a reduction of exposed intertidal sediment at low water. The majority of habitat which would decrease in area is intertidal sand, however, and muddy habitat tends to be more important in terms of numbers of invertebrate individuals and biomass. Nevertheless, overall there was an estimated potential 38% reduction in exposed invertebrate biomass at low tide within the SPA under the spring tide scenario (Table 5.1). Value/sensitivity of the receptor is considered to be **high**. Effects are predicted to be **direct** and **temporary** with a duration of the operational lifetime of the scheme, when a natural tidal regime returns following decommissioning and removal of the scheme there is potential for the effects to be reversed. Due to the predicted decrease in the biomass (which would be representative in general of changes in number of individuals), the magnitude of effect is predicted to be **high**. Consequently, it is assessed that there would be an adverse effect of **major** significance.

Mud-Surface Plants and Green Algae

5.2.32 A further sub-feature attribute target for the intertidal sediment attribute 'Food availability' relates to intertidal algae:

- Presence and abundance of mud-surface plant and green algal prey species should not deviate significantly from an established baseline, subject to natural change.

5.2.33 Surveys have been conducted in autumn 2009, and spring and autumn 2010 to assess the assemblages of benthic algae and their biomass within the Mersey Estuary. It was evident from these surveys that density and diversity of intertidal benthic algae in the Mersey Estuary is relatively high. A reduction in intertidal sediment area exposed under this scheme would result in a decrease in the exposed biomass of benthic algae within the intertidal zone. The changes in intertidal sediment exposure indicated above therefore have the potential to have an adverse effect on this sub-feature attribute target. Value/sensitivity of the receptor is considered to be **high** as intertidal sediments form a sub-feature of the SPA which is a site of international importance. Effects are predicted to be **direct** and **temporary** with a duration of the operational lifetime of the scheme and would likely be reversible following decommissioning and removal of the scheme. Due to the decrease in the area of exposure of intertidal sediment with the scheme in place, the magnitude of effect is predicted to be **medium**. Consequently, it is assessed that there would be an adverse effect of **moderate** significance. This does not necessarily represent an ecological consenting risk in its own right, however it may create an adverse effect on a limited number of species within the overall bird assemblage on the site (affecting those species which are herbivorous).

Bird Foraging Space and Time

Exposed Surface Area

5.2.34 Table 5.2 and Table 5.3 show the predicted exposed area within the SPA of each category of soft sediment and of each habitat type for the baseline scenario and for each scheme over low tide and high tide respectively.

5.2.35 For scheme IBv2, the area of soft sediment foraging space for shorebirds at low water would be reduced to 64%, 69% and 78% of baseline on spring, intermediate and neap tides respectively (Table 5.2 & Figure 5.4), (this includes consideration of mud, muddy sand and sandy mud but not sand which is considered to be the sediment type of least importance for birds in terms of foraging activity). The area available at high tide would be comparable to baseline on spring tides and increase by 21% on neap tides (Table 5.3). The increase on the intermediate tide is probably a result of the high water level during intermediate tides being slightly lower when a scheme is in place than during baseline conditions. Passage and wintering bird surveys have identified the main feeding areas on the exposed intertidal flats for the bird species upon which the Mersey Estuary SPA has been designated. Changes in the percentage of these feeding areas which will still be available at spring low water if IBv2 is constructed vary for the different species (Appendix 4), with the greatest reduction being for pintail (to 19%), and the least affected species which feeds within the SPA being teal (with 87% remaining).

5.2.36 During spring tides the area exposed is predicted to increase substantially from 0 to 346 ha (Table 5.3). Increases in saltmarsh area exposed are also predicted for high water on neap and intermediate tides (~60-110ha).

Table 5.2 Surface areas of the intertidal habitats exposed at the low tide baseline of 2060 and under the three schemes in the SPA. NA = not applicable

Sediment	Baseline (ha)	IBv2 (ha)	VLHBv2 (ha)	VLHBv3 (ha)
SPRING TIDES				
Mud	408	330	392	397
Muddy sand	229	103	202	209
Sandy mud	796	478	715	759
Total	1,433	911	1,309	1,365
Percentage of baseline		***64%***	***91%***	***95%***
Unclassified	730	32	193	468
Sand	1,258	550	1,089	1,151
Saltmarsh	585	585	585	585
Intertidal rock	21	8	15	21
INTERMEDIATE TIDES				
Mud	410	346	390	403
Muddy sand	234	126	210	213
Sandy mud	799	523	688	764
Total	1,443	995	1,288	1,380
Percentage of baseline		***69%***	***89%***	***96%***
Unclassified	575	43	132	382
Sand	1,273	653	1,070	1,166
Saltmarsh	587	587	587	587
Intertidal rock	21	9	12	19
NEAP TIDES				
Mud	408	367	379	401
Muddy sand	232	162	190	218
Sandy mud	773	574	605	731
Total	1,413	1,103	1,174	1,350
Percentage of baseline		***78%***	***83%***	***96%***
Unclassified	299	64	82	186
Sand	1,233	817	908	1,149
Saltmarsh	588	588	588	588
Intertidal rock	18	10	9	14

NB. The modelling which has been carried out for the project, and the assessment of the satellite image of the Estuary (taken an hour after low water on a spring tide) appear to indicate that the total exposed intertidal sediments cover an area of 4027 ha within the boundary of the SPA. It should be noted that the SPA designation is for a total intertidal area of 5033 ha. During later stages of the project this discrepancy will be investigated.

Table 5.3 Surface areas of the intertidal habitats exposed at the high tide baseline of 2060 and under the three schemes in the SPA. NA = not applicable

Sediment	Baseline (ha)	IBv2 (ha)	VLHBv2 (ha)	VLHBv3 (ha)
SPRING TIDES				
Mud	0	2	2	10
Muddy sand	0	0	0	0
Sandy mud	0	4	6	21
Total rows 1 - 3	0	6	8	31
Percentage of baseline		***NA***	***NA***	***NA***
Unclassified	0	5	5	7
Sand	0	0	0	1
Saltmarsh	0	346	380	513
Intertidal rock	0	0	0	0
INTERMEDIATE TIDES				
Mud	6	38	34	87
Muddy sand	0	1	1	1
Sandy mud	14	70	62	127
Total rows 1 - 3	20	119	97	215
Percentage of baseline		***545***	***485***	***1075***
Unclassified	7	8	8	8
Sand	1	3	3	5
Saltmarsh	442	551	551	580
Intertidal rock	0	0	0	0
NEAP TIDES				
Mud	129	164	169	221
Muddy sand	2	4	5	10
Sandy mud	170	197	201	261
Total rows 1 - 3	301	365	375	492
Percentage of baseline		***121***	***125***	***164***
Unclassified	10	10	10	13
Sand	12	19	22	72
Saltmarsh	509	567	570	587
Intertidal rock	2	3	3	4

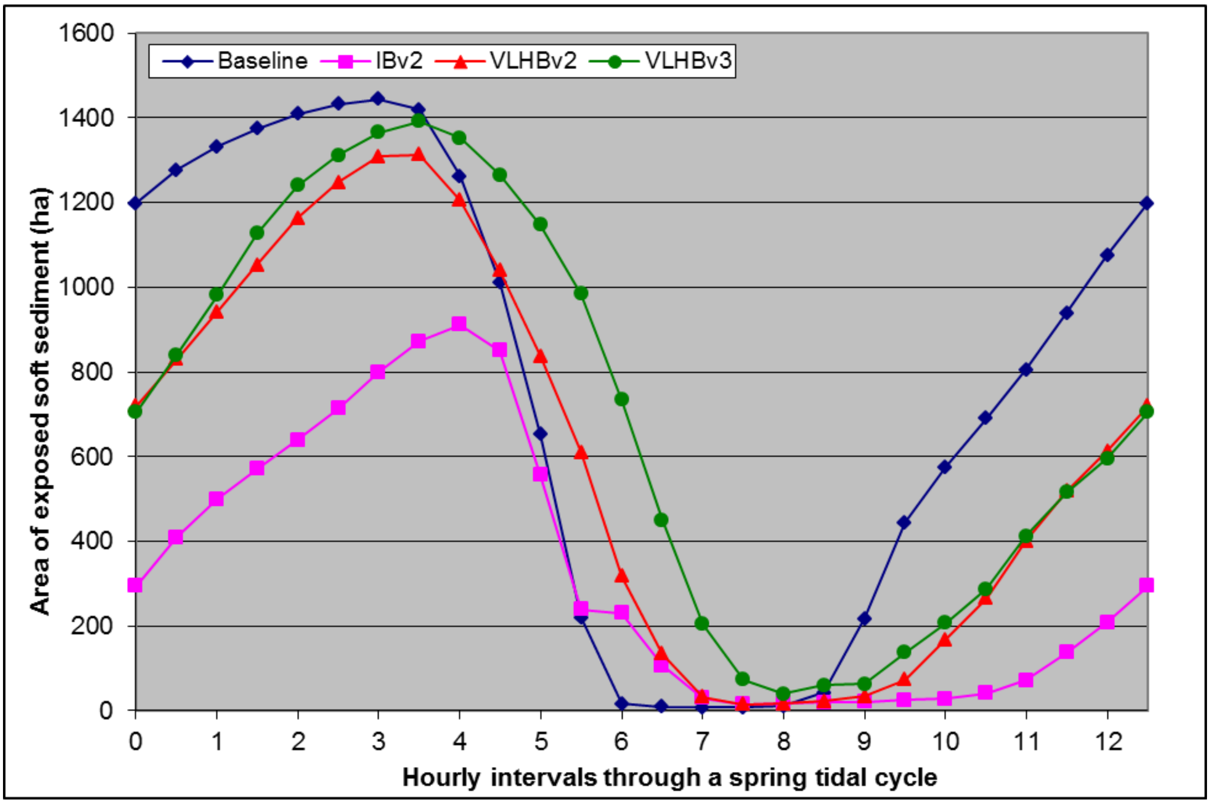


Figure 5.4a Soft sediment area exposed for foraging over a spring 2060 tidal cycle (does not include sand)

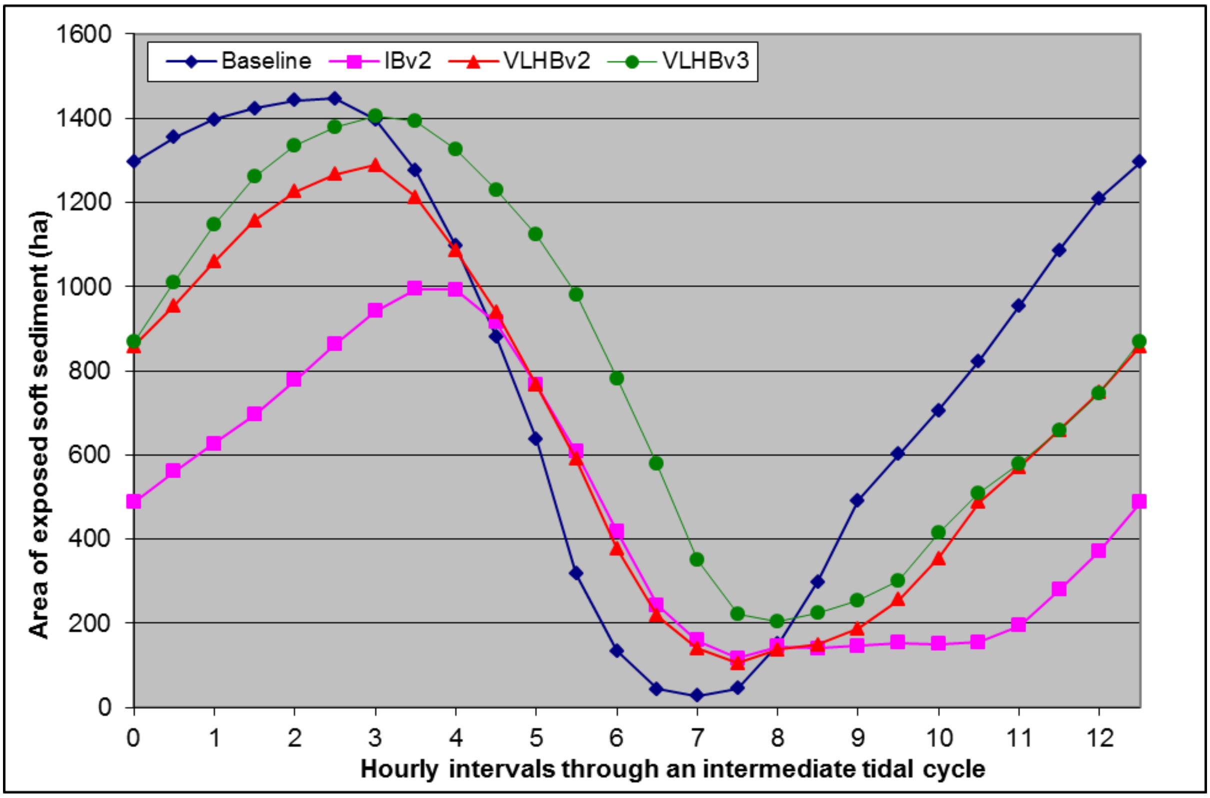


Figure 5.4b Soft sediment area exposed for foraging over an intermediate 2060 tidal cycle (does not include sand)

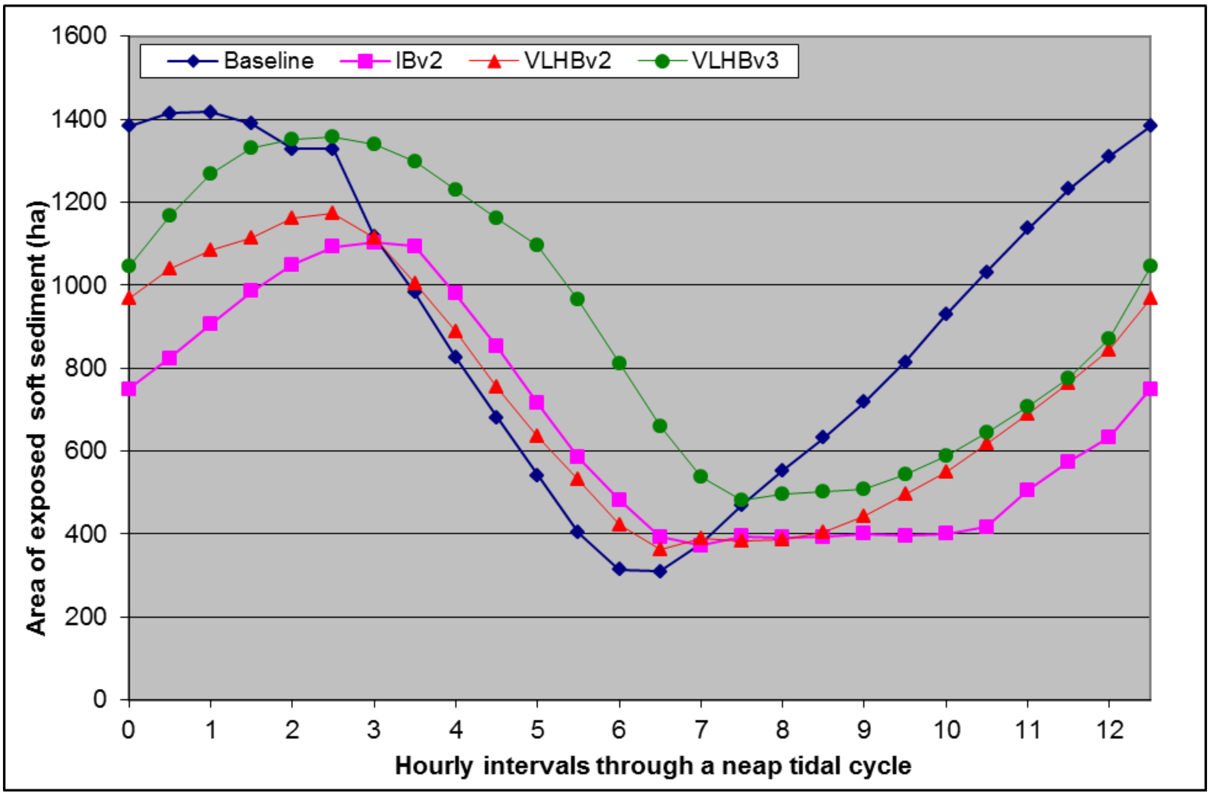


Figure 5.4c Soft sediment area exposed for foraging over a neap 2060 tidal cycle (does not include sand)

Wetted Perimeter

5.2.37 As feeding along the wetted perimeter is only common amongst shorebirds that take prey from the soft sediments, only its length across mud, muddy sand and sandy mud is considered, expressed as a percentage of the length at baseline. Table 5.4 and 5.5 indicate the predicted lengths of the wetted perimeter within the SPA of each category of soft sediment, singly and combined.

5.2.38 In scheme IBv2, the estimated length of the wetted perimeter over soft sediment at low water would be changed to ~95%, ~110% and ~101% of baseline on spring, intermediate and neap tides respectively (Table 5.4). The average value of ~102% means that, overall, the wetted perimeter length over the soft sediments most used by shorebirds at low water is not predicted to change. However, its length at high tide would be slightly increased to ~116% and ~107% on intermediate and neap tides respectively, and to ~326% on spring tides (Table 5.5). This large increase is an artefact of the modelling which predicts that many small water bodies would appear close to the high water mark when either of the schemes is in place, each of the water bodies having its own wetted perimeter. As these small water bodies have been identified from the modelling as the main reason for the predicted increase, it is considered likely that the length of the wetted perimeter at spring high tide would also be relatively unchanged.

Table 5.4 Estimated length of the wetted perimeter of the main soft sediment categories, at the low tide baseline of 2060 and under the three schemes.

Sediment	Baseline (km)	IBv2 (km)	VLHBv2 (km)	VLHBv3 (km)
SPRING TIDES				
Mud	18.5	20.5	19.3	18.6
Muddy sand	13.5	9.1	15.7	14.9
Sandy mud	38.5	37.6	42.9	41.3
Total rows 1 - 3	70.5	67.1	78.0	74.9
Percentage of baseline		***95.2%***	***110.5%***	***106.2%***
INTERMEDIATE TIDES				
Mud	18.5	19.8	19.8	17.6
Muddy sand	13.4	15.1	9.8	16.1
Sandy mud	38.6	42.8	38.4	40.4
Total rows 1 - 3	70.4	77.7	68.0	74.1
Percentage of baseline		***110.3%***	***96.5%***	***105.2%***
NEAP TIDES				
Mud	18.0	20.4	19.5	18.0
Muddy sand	13.9	13.5	15.6	16.5
Sandy mud	41.7	40.4	42.2	40.8
Total rows 1 - 3	73.7	74.2	77.3	75.3
Percentage of baseline		***100.8%***	***104.9%***	***102.2%***

Table 5.5 Estimated length of the wetted perimeter of the main soft sediment categories, at the high tide baseline of 2060 and under the three schemes.

Sediment	Baseline (km)	IBv2 (km)	VLHBv2 (km)	VLHBv3 (km)
SPRING TIDES				
Mud	3.1	12.2	13.6	19.4
Muddy sand	0.4	1.1	2.0	7.9
Sandy mud	7.8	23.5	24.7	32.2
Total rows 1 - 3	11.3	36.8	40.3	59.6
Percentage of baseline	***NA***	***326%***	***357%***	***528%***
INTERMEDIATE TIDES				
Mud	10.0	14.4	15.9	19.0
Muddy sand	7.8	2.5	2.6	8.4
Sandy mud	18.7	25.3	26.5	32.7
Total rows 1 - 3	36.4	42.2	45.0	60.0
Percentage of baseline	***NA***	***116%***	***123%***	***165%***
NEAP TIDES				
Mud	13.1	16.5	15.9	18.3
Muddy sand	7.2	3.1	2.6	8.4
Sandy mud	25.1	29.0	28.1	33.8
Total rows 1 - 3	45.3	48.6	46.6	60.4
Percentage of baseline	***NA***	***107%***	***103%***	***133%***

Invertebrate Prey

5.2.39 In scheme IBv2, the biomass of the invertebrates in the soft sediment exposed at low water would be reduced to ~69%, ~71% and ~79% of baseline on spring, intermediate and neap tides respectively (Table 5.6), closely following the changes in the areas of the soft sediments. Due to the position of the mud, sandy mud and muddy sand on the intertidal, the reduction in biomass availability is lower (ie. ~31% for spring tides) than is the case for all sediment types considered together (Table 5.1 indicates a ~38% reduction during spring tides across all sediment types within the SPA).

Table 5.6 Estimated potential change in invertebrate biomass exposed within the SPA at low tide in the main sediment categories (mud, muddy sand, sandy mud) combined for baseline 2060 and under the three schemes.

	Baseline (tonnes)	IBv2 (tonnes)	VLHBv2 (tonnes)	VLHBv3 (tonnes)
SPRING TIDES				
Total	458	314	417	426
Percentage of baseline	NA	***69%***	***91%***	***93%***
INTERMEDIATE TIDES				
Total	462	329	421	421
Percentage of baseline		***71%***	***91%***	***91%***
NEAP TIDES				
Total	459	365	389	431
Percentage of baseline	NA	***79%***	***85%***	***94%***

Foraging Time

5.2.40 The area of soft suitable sediment (mud, muddy sand and sandy mud combined) exposed through the tidal cycle is shown for spring, intermediate and neap tides in Figure 5.4. Compared with baseline, IBv2 is predicted to delay the time at which the area remaining on the advancing tide is reduced to 400 ha or 200 ha (see Paragraph 2.1.32 for the rationale behind the consideration of these areas). It would also delay by a greater extent the time at which such areas become exposed on the receding tide on both spring and intermediate tides. On spring tides and intermediate tides only, the duration of the foraging period during which the density of birds is low enough for competition to be reduced, is considerably reduced compared with baseline (these changes for spring and intermediate tides are indicated in Table 5.7). The exposed area is hardly reduced at all below 400 ha at high tide on neap tides.

5.2.41 During neap tides for the 2060 baseline and for all schemes in place there is always more than 200 ha of foraging area available. For baseline, IBv2, VLHBv2 and VLHBv3 the minimum areas of soft sediment exposed during neap tides are estimated to be 318, 365, 375 and 465 ha, respectively.

5.2.42 The area criteria used in Paragraphs 2.1.32 and the conclusion derived, relate to the reduced feeding time available for the general bird population. Different species in the

SPA, however, require different periods to obtain their daily food requirements, with this period being inversely related to body size; i.e. small-sized species generally feed for a greater proportion of the available foraging time than large-sized species. Within a species, it varies between individuals and over the non-breeding season, generally being greatest in mid/late-winter and just before migration in spring. When birds are having difficulty in acquiring their energy demands in the time available, however, they will feed for almost all the time for which intertidal flats that contain prey are exposed. These factors, which relate to bird fitness will be further investigated in later stages of the project.

Table 5.7 Estimated length of the foraging period on spring and intermediate tides when there is more than 200 ha or more than 400 ha of soft sediments exposed.

	LENGTH OF FEEDING PERIOD (mins)	
	at <200 ha	at <400 ha
SPRING TIDE		
Baseline	522	488
IBv2	382	281
VLHBv2	502	415
VLHBv3	548	468
INTERMEDIATE TIDE		
Baseline	595	535
IBv2	482	368
VLHBv2	582	482
VLHBv3	735	555

5.2.43 Sub-feature attribute targets for the attributes ‘Disturbance in bird feeding and roosting areas’ and ‘Absence of obstruction to view lines’ are, respectively:

- No significant reduction in numbers or displacement of birds from an established baseline, subject to natural change, and:
- No increase in obstructions to existing bird flight lines, subject to natural change.

5.2.44 Based on the information available to date, in terms of the number of birds, there is likely to be a decrease because of the large reduction in the area of feeding grounds available over low tide and because of the large reduction in the amount of time for foraging in the intertidal zone at densities low enough for there to be a low risk of serious competition. Value/sensitivity of the receptor is considered to be **high** as birds are a feature of the SPA which is of international importance. Effects are predicted to be **indirect** and **temporary** with a duration of the operational lifetime of the scheme, with a more natural regime and following decommissioning and removal of the scheme (potentially resulting in increased bird numbers returning to the Estuary). Based on present information, the reductions in foraging space and foraging time are predicted to be large, therefore the magnitude of effect is predicted to be **high.** It is consequently assessed that there would be an adverse effect of **major** significance.

5.2.45 When considering flight lines, it is not only likely that the barrage would obscure sight lines and thus provide cover for approaching birds of prey, but it is also very likely that the barrage would provide perches from which birds of prey could launch attacks against shorebirds on the intertidal flats. It is recognised, however, that the position of the barrage will be some distance from the majority of the feeding grounds, and therefore sight lines for feeding shore birds will for the most part not be reduced. Value/sensitivity of the receptor is considered to be **high** as birds are a feature of the SPA which is of international importance. Effects are predicted to be **indirect** and **temporary** with a duration of the operational lifetime of the scheme, and would be removed following decommissioning and removal of the scheme. But as raptor predation on shorebirds generally seems to be quite low on large estuaries such as the Mersey, the magnitude of effect is predicted to be **very low**. It is consequently assessed that there would be an adverse effect of **minor** significance.

Water Framework Directive

Invertebrates

5.2.46 The WFD requirements are associated with both diversity and abundance of the overall assemblage. For the Transitional Type 3 Estuaries 'extensive intertidal habitat' is one of the characterising features and the assemblages of intertidal invertebrates are the main consideration. There would be a change in the abundance of intertidal invertebrates following a reduction in the extent of exposed areas of intertidal sediments, however, it is change in extent of intertidal sediments and subsequent effects on species abundance within the Estuary as a whole is a separate consideration to change in assemblage diversity and species abundance on a local scale due to presence of the scheme. Overall, taking this approach it is considered that invertebrate diversity and abundance is unlikely to fall below the current required status of 'moderately outside the range associated with type-specific conditions' (see Appendix 3). The scheme, is also unlikely to prevent attainment of future targets and it is considered, therefore, that it is possible that there would not be an ecological consenting risk under the WFD for this element.

5.2.47 Value/sensitivity of intertidal and subtidal invertebrates is considered to be **medium** as invertebrates are a biological element used for assessment of ecological status under the WFD and are, therefore, classed as being of national significance. Effects are predicted to be **direct** and **temporary** with a duration of the operational lifetime of the scheme, and would likely be reversible following decommissioning and removal of the scheme. The presence of the scheme would likely result in a decrease in the area of intertidal sediment at low water which is likely to be the main concern due to the Transitional Type 3 status of the Estuary. There would be changes in intertidal invertebrate numbers due to changes in the extent of the intertidal zone. In terms of changes to local density and diversity in a particular habitat type, however, it is considered that the effects would be small and the magnitude of effect is consequently predicted to be **very low** and it is assessed that there would be an adverse effect of **minor** significance.

Fish

5.2.48 For scheme IBv2 there would be 28 turbines of 8 m runner diameter, operating at ~60 rpm. Passage of fish, including migratory fish, could result in injury and mortality through operating turbines on the ebb tide and through sluices (potential contact with physical surfaces and shear, pressure change and turbulence effects) and free-wheeling turbines on the flood tide. There may also be incidence of 'fallback' of fish resulting in multiple passes through the turbines. Migratory fish species potentially passing through the turbines and sluices include Atlantic salmon, river and sea lamprey, European eel and sea trout all of which are protected by a range of legislation and management plans including the Habitats Directive, Eels (Wales and England) Regulations 2009 and the Salmon and Freshwater Fisheries Act (SAFFA)) and the UK BAP. In addition, a number of marine species which utilise the Estuary are protected under the UK BAP (Table 3.2). Three fish passage routes have been integrated into the IBv2 scheme design to limit the potential adverse effect during ebb generation.

5.2.49 Susceptibility of different species to injury or mortality may vary. For example fish species reaching larger body sizes may be more prone to strike by turbine blades than smaller fish species, however, smaller fish may be more at risk from other effects such as shear stress. Sparse data are available for non-migratory fish in terms of injury and mortality during turbine passage due to fish strike. When considering other risks, however, such as changes in pressure there may be effects such as rupturing of the swim bladder (although this is not the case for flatfish which do not have a swim bladder) or eye haemorrhaging.

5.2.50 The mechanisms by which fish are injured during turbine passage are generally grouped into four categories: mechanical (including strike, abrasion and gridding), pressure, shear and turbulence and cavitation. Not all fish species and life stage will suffer injuries from each of these mechanisms and the extent of injury will differ.

5.2.51 The most comparable assessment of potential mortality rates of fish due to blade strike during passage through generating turbines is the modelling conducted for the Severn Estuary Tidal Power Scheme (APEM 2010d). Assuming a similar turbine design with a rotation speed of 57.7 rpm modelled mortality rates are indicated below (APEM 2010d). No empirical data are yet available to confirm these values and these values only relate to mortality via blade strike and a range of other factors as indicated above can also lead to fish mortality. In addition, the values only correspond to one passage through the turbine and individuals may undergo multiple passages increasing the risk of mortality.

- Salmon: Smolts 2%, adults 15%
- Sea trout: Smolts 2%, adults 8%
- Eel: Elvers 0.04%, silver eel 8%
- Lamprey: River lamprey adults transformers 0.04%, adults 4%
- Marine migrants: 5%
- Marine stragglers: 19%
- Estuarine residents: 2%
- Freshwater stragglers: 5%

5.2.52 Potential effects are assessed below for the different functional groups of fish present within the Estuary as indicated in Table 3.2.

Marine Stragglers, Estuarine Residents and Freshwater Species

5.2.53 The main species which are likely to be resident within the Mersey Estuary are sand/common goby which are unlikely to be affected by the scheme (Table 3.2). Marine stragglers entering the Estuary are usually present in low numbers and may be killed or injured by the turbines/sluices, however, the main populations of these species are within the coastal and offshore waters and at the population level effects are expected to be limited. Freshwater species entering the Estuary are unlikely to move as far seawards as the scheme and the majority of individuals would not pass through the turbines/sluices.

5.2.54 The efficiency of fish passage routes for marine and estuarine fish species are largely unknown as there is no precedent for the requirement of fish passages within these environments or scientific studies examining these potential effects.

5.2.55 Receptor value/sensitivity for the functional groups of estuarine resident, marine stragglers and freshwater species is considered to be **medium** as fish are a biological element used for assessment of ecological status under the WFD. Effects are predicted to be **direct** and would be **temporary** with a duration of the operational lifetime of the scheme, but reversible following decommissioning and removal of the scheme, if there is no population collapse (as predicted). Overall the magnitude of effect is predicted to be **very low.** It is assessed, therefore, that there would be an adverse effect of **minor** significance.

Marine Migrants

5.2.56 Adults of these species generally reside in coastal or offshore waters but they may be dependent on the estuarine habitat as a nursery area to optimise survival of juveniles although there is potential for these species to utilise the Dee Estuary as well as the Mersey Estuary. The small body size of juvenile marine migrants entering the Estuary could reduce the risk of blade strike. If the loss of juveniles is still high, however, there is potential for an effect at the population level although individuals of these species would still be expected to be found within the Mersey Estuary (but likely in lower numbers) with the scheme in place. Focus here has been placed on the five UK BAP marine migrant species found within the Estuary; cod, herring, plaice, sole and whiting. Cod, herring and whiting can broadly be considered to be of similar body shape and size and the number of individuals lost is expected to be broadly proportional to the numbers of individuals passing through the turbines/sluices. Herring tend to shoal and are likely to pass through the turbines in groups whereas cod and whiting are more likely to pass through individually. Plaice and sole are both flatfish and due to their small size and flat shape may be less prone to blade strike and would be less affected by pressure change due to the absence of a swim bladder. Overall, there is little information available for these species and based on studies conducted to date.

5.2.57 Receptor value/sensitivity for cod, herring and whiting is considered to be **medium** as fish are a biological element used for assessment of ecological status under the WFD, they are also protected under the UK BAP. Effects are predicted to be **direct** and may be **temporary** with a duration of the operational lifetime of the scheme. There may be some potential for a reduction in population size within the Estuary and in surrounding coastal and offshore waters although following decommissioning and removal of the scheme there would be potential for the numbers in the Estuary to return to pre-scheme levels. A blade strike mortality rate of 5% per passage has been assumed, however, although there would be other sources of mortality during turbine passage, due to the ability of marine migrants to utilise environments other than the Mersey Estuary, including the Dee Estuary, the magnitude of effect is predicted to be **medium.** It is assessed, therefore, that there would be an adverse effect of **moderate** significance.

5.2.58 Receptor value/sensitivity for sole and plaice is considered to be **medium** as fish are a biological element used for assessment of ecological status under the WFD, they are also protected under the UK BAP. Effects are predicted to be **direct** and may be **temporary** with a duration of the operational lifetime of the scheme. There may be some potential for a reduction in population size within the Estuary and in surrounding coastal and offshore waters although following decommissioning and removal of the scheme there would be scope for the numbers in the Estuary to return to pre-scheme levels. A blade strike mortality rate of 5% per passage has been assumed, however, although there would be other sources of mortality during turbine passage, due to the ability of marine migrants to utilise environments other than the Mersey Estuary, including the Dee Estuary, the magnitude of effect is predicted to be **medium.** It is assessed, therefore, that there would be an adverse effect of **moderate** significance.

Diadromous Fish

5.2.59 Diadromous fish passing through the Estuary are indicated in Table 3.2. They include Atlantic salmon, river and sea lamprey, European eel and sea trout. Atlantic salmon and river/sea lamprey are Annex II species of European importance protected under the Habitats Directive. Numbers of Atlantic salmon passing through the Mersey Estuary are relatively low but have been increasing over the past decade, there is currently sparse information available for the lamprey populations in the Mersey catchment and the numbers passing through the Estuary. The European eel population is considered to be stable and the sea trout population is also expected to be stable/increasing.

5.2.60 Receptor value/sensitivity for Atlantic salmon is considered to be **high** as these species are Annex II species of European importance (although they do not contribute to conservation designations within the Mersey Estuary). Effects are predicted to be **direct** and may be **temporary** with a duration of the operational lifetime of the scheme. Salmon are natal homers returning to their natal waters to spawn and there may be some potential for population collapse within the Estuary and in surrounding coastal and offshore waters. If this was the case, following decommissioning and removal of the scheme, it would be possible that these species would not return to the Estuary. Overall, assuming a mortality rate of 15% per passage due to blade strike, and considering other potential sources of mortality during turbine passage, the magnitude of effect is predicted to be **high** and it is assessed, therefore, that there would be an adverse effect of **major** significance.

5.2.61 Receptor value/sensitivity for river and sea lamprey is considered to be **high** as these species are Annex II species of European importance (although they do not contribute to conservation designations within the Mersey Estuary). Effects are predicted to be **direct** and may be **temporary** with a duration of the operational lifetime of the scheme. Lamprey are not natal homers, therefore there is not likely to be population collapse, however, there may be some potential for a reduction in population size within the Estuary and in surrounding coastal and offshore waters although following decommissioning and removal of the scheme there would be scope for these species to return to the Estuary in increased numbers. Overall, assuming a mortality rate of up to 4% per passage due to blade strike, and considering other potential sources of mortality during turbine passage, the magnitude of effect is predicted to be **high** and it is assessed, therefore, that there would be an adverse effect of **major** significance.

5.2.62 Receptor value/sensitivity for European eel is considered to be **high** as this species is protected under a European eel management plan. Effects are predicted to be **direct** and may be **temporary** with a duration of the operational lifetime of the scheme. Eel are panmictic and do not return to a specific estuary/river as adults, therefore, there may be some potential for a reduction in population size within the Estuary and in surrounding coastal and offshore waters although following decommissioning and removal of the scheme there would be scope for this species to return to the Estuary in increased numbers. Overall, assuming a mortality rate of up to 8% per passage due to blade strike, and considering other potential sources of mortality during turbine passage, the magnitude of effect is predicted to be **high** and it is assessed, therefore, that there would be an adverse effect of **major** significance.

5.2.63 Receptor value/sensitivity for sea trout is considered to be **medium** as this species is protected under a UK BAP and is of national importance. Effects are predicted to be **direct** and may be **temporary** with a duration of the operational lifetime of the scheme. Sea trout are natal homers and there may be some potential for population collapse within the Estuary and in surrounding coastal and offshore waters and if this was the case, following decommissioning and removal of the scheme, it would be possible that these species would not return to the Estuary, Overall, assuming a mortality rate of 8% per passage due to blade strike, and considering other potential sources of mortality during turbine passage, the magnitude of effect is predicted to be **high** and it is assessed, therefore, that there would be an adverse effect of **major** significance.

Phytoplankton

5.2.64 Water quality is an important determinant of phytoplankton community composition. For example increased turbidity of the water column can limit photosynthesis and inhibit phytoplankton growth. Phytoplankton will be transported from the sea to the Estuary on every tide. Effects of a scheme could be related to changes in salinity and water quality and there is some potential for impoundment of water to lead to increased likelihood of phytoplankton blooms if thermal stratification of the water column occurs (which can happen if water is slow moving and surface water temperatures are elevated). There is currently limited information available regarding these factors under the different scheme scenarios and further modelling is required to assess changes in these parameters. A flushing study has been conducted, however, to indicate the ability of the Estuary to allow pollutants contained in the Estuary to discharge to sea. It was concluded that with the scheme in place the ability of the Estuary to flush was reduced from removal of 25% of a tracer in 2.4 days to removal in 4.5 days. This could have implications in terms of potential for build up of contaminants and potential for eutrophication (although this is limited due to the current turbidity within the Estuary) (URS Scott Wilson 2011b). There is evidence that some of the phytoplankton recorded within the mid Estuary (e.g. *Thalassiosira* sp. and *Skeletonema* sp.) are likely to originate from the open sea and changes in salinity could potentially influence the phytoplankton assemblage present. The presence of *Paralia sulcata* and *Navicula* sp. and *Nitzschia* sp. in the phytoplankton gives some indication of a benthic contribution to the phytoplanktonic community as these taxa are typically found in sediment on the Estuary bed and may be more susceptible to changes in water quality (APEM 2010ab). There is not enough information currently available to predict potential changes in salinity with the different schemes in place to assess this aspect of change.

5.2.65 Although further modelling is required it is considered likely that the presence of the scheme would not noticeably change the current baseline status of the phytoplankton community of the Estuary or prevent attainment of future targets, therefore it is considered possible that there would not be an ecological consenting risk under the WFD in relation to this feature.

5.2.66 Receptor value/sensitivity is considered to be **medium** as phytoplankton are a biological element used for assessment of ecological status under the WFD. Effects on phytoplankton are predicted to be **indirect** and **temporary** during the period of operation as the environmental conditions in the basin will have changed during operation, and would not return to their natural state until decommissioning and removal of the scheme. Overall, however, the magnitude of effect is predicted to be **very low.** It is assessed, therefore, that there would be an adverse effect of **minor** significance. This assessment is based on current knowledge of the Estuary and will be informed and potentially modified following consideration of any water quality modelling conducted at future project stages.

Macroalgae

5.2.67 Surveys conducted to assess macroalgal cover of rocky shores identified areas of cover of *F. spiralis* and *F. vesiculosus* within the mid to lower sections of the Estuary (macroalgae is sparse or absent in the upper Mersey Estuary). Due to a decrease in the extent of intertidal areas of rocky shore under the scheme it is considered that there would be a likely adverse effect on macroalgae extent. Cover of *F. spiralis* and *F. vesiculosus* was patchy within the Estuary, *F. spiralis* had a mean coverage of 12.5 % reaching a maximum coverage of 28 %, *F. vesiculosus* had mean coverage of 9 % with a maximum coverage of 37 %. In terms of WFD requirement, it is considered that the diversity of macroalgae present is not likely to change due to the presence of the scheme but the extent of the fucoid zone may change, however, at least one of the three fucoid species assessed are expected to continue to be present along with the other macroalgal species recorded during rocky shore surveys conducted for the assessment (APEM 2010c). Overall it is considered that the presence of the scheme would not noticeably change the current baseline status of the macroalgal community (especially in terms of diversity) or prevent attainment of future targets, therefore, it is possible that there would be no ecological consenting risk under the WFD.

5.2.68 Receptor value/sensitivity is considered to be **medium** as macroalgae are a biological element used for assessment of ecological status under the WFD. Effects are predicted to be **direct** and **temporary** with a duration of the operational lifetime of the scheme, and would likely be reversible following decommissioning and removal of the scheme. Fucoids cannot anchor themselves to soft sediment habitats and are largely restricted to solid structures. With a reduction in exposed rocky shore habitat of 41-61% at low water across neap to spring scenarios it is likely that the fucoid zone could become reduced in extent, however, it is considered that changes in the composition of algal taxa may not differ greatly with the scheme in place. In addition, some of the structures of the scheme could potentially provide habitat which could be colonised by macroalgae. Overall, the magnitude of effect is considered to be **very low.** It is assessed, therefore, that there would be an adverse effect of **minor** significance.

Angiosperms (Saltmarsh)

5.2.69 There is predicted to be no reduction in the area of saltmarsh habitat under low tide scenarios. Due to the reduction in the water height at high tide, however, some large areas of saltmarsh which would be submerged under baseline at high tide are predicted to remain exposed with the scheme in place. This is most notable for spring tides with an increase in exposed area within the Estuary of 91 ha to 455 ha. Without regular inundation saltmarsh higher up the shoreline can become encroached by terrestrial vegetation and no longer function as saltmarsh habitat. There are currently no guidelines for WFD monitoring for saltmarsh habitats although key attributes to be considered include abundance, composition and saltmarsh spatial extent, indeed a consideration under the WFD is that type specific conditions for saltmarsh indicate that it would be expected to cover at least 75% of suitable habitat and not show significant decline in aerial extent over a 5 year rolling mean (Appendix 3). It is considered that the presence of a scheme would be unlikely to changes plant density or species composition but it could change abundance throughout the Estuary as a whole following a potential reduction in saltmarsh extent. Overall, it is considered that the assessment above relating to saltmarsh extent as a sub-feature attribute target is applicable to consideration of this element under the WFD and it is assessed that there would be an adverse effect of **major** significance.

Summary

5.2.70 The various sub-feature attribute targets of the SPA and ecological status elements of the WFD have been considered above. When assessing possible risk of not attaining sub-feature attribute targets it is important to consider a range of aspects other than the reduction in exposed intertidal area. For example, numbers of a variety of SPA bird features have decreased since designation of the SPA, therefore the carrying capacity of the Estuary may be sufficient to support the new numbers of birds even with a reduction in exposed intertidal area at low tide. The change in area also needs to be related to changes in feeding time available for the birds and wetted perimeter. The implications of a reduction in exposed areas of intertidal habitat for birds is also related to the relative reductions of different sediment types under the scheme as, for example, mud habitat is the most important habitat for birds in terms of supply of potential prey items, and sand habitat is the least important. Overall, taking the above factors into account there may not necessarily be a change to the function of the SPA, however, the change in structure may be sufficient to have an adverse effect on the integrity of the site presenting an ecological consenting risk.

5.2.71 Data available at the end of Stage 3 indicate that although IBv2 is not predicted to decrease the length of the wetted perimeter along the tide edge that is used for feeding by many shorebirds on the Mersey, it is predicted to substantially reduce the amount of foraging space exposed and available prey biomass on the intertidal flats as a whole as well as the amount of time available for foraging there. If any of the declines in numbers of birds of the species upon which the Mersey was designated as a SPA are caused by deterioration in the feeding conditions, these decreases in foraging time and foraging space make it likely that survival, and therefore numbers, would be reduced by IBv2. This suggests further that there may be an adverse effect on the integrity of the site due to the presence of the scheme following changes in both structure and, in this instance, function of the site. Nor are the sight lines likely to be maintained as the impounding barrage itself could provide cover for approaching raptors and provide them with perches from which to launch their attacks, though this is likely to have a relatively minor effect on mortality rates given the distance of the barrage from the majority of the feeding areas.

5.2.72 Modelling in later stages of the project will help to predict the probable effect of the calculated changes in foraging space, length of the foraging time during which the density of birds is low enough for competition to be reduced, and quantity of prey, on the demographic rates and therefore carrying capacity of the Mersey Estuary.

5.2.73 Taking the results above into account the potential for there to be an ecological consenting risk with this scheme under the SHRA and WFD is indicated in Table 5.8 below. Overall, it is thought that without prevent harm/mitigation measures and under the operating regime modelled for this scheme, there could be an effect of major significance on numbers or displacement of birds, extent of intertidal sediments, presence and abundance of prey species in intertidal sediments, extent of rocky shores, saltmarsh extent (SPA sub-feature) and saltmarsh under WFD, and fish (including UK BAP species and those of European importance). Effects of moderate significance are predicted for mud-surface plants and green algae and invertebrates on rocky shores. It is considered that there may be an ecological consenting risk under WFD associated with fish and saltmarsh, and with each of the SPA sub-feature attribute targets under the HRA (with the exception of bird view lines, presence abundance of prey species in saltmarsh, presence and abundance of soft-leaved and seed bearing plants in saltmarsh habitats and saltmarsh vegetation height).

Table 5.8 Summary table of potential risk before application of prevent harm and mitigation measures in relation to SHRA assessment and WFD assessment for the IBv2 scheme. ✓ = possible ecological consent risk, × = not likely to be ecological consent risk. * = pending results of future water quality modelling data.

Feature	Potential for ecological consent risk	Potential significance of effect
SPA Sub-feature attribute measure		
Integrity of the SPA	✓	**Major**
Numbers of birds or bird displacement	✓	Major
Number of obstructions to existing bird view lines	×	Minor
Extent of intertidal sediments	✓	Major
Presence and abundance of prey species in intertidal sediments	✓	Major
Presence and abundance of mud-surface plants and green algae	✓	Moderate
Extent of rocky shore habitat	✓	Major
Presence and abundance of intertidal invertebrates in rocky shore habitats	✓	Moderate
Extent of saltmarsh habitat	✓	Major
Presence and abundance of prey species in saltmarsh	×	Minor
Presence and abundance of soft-leaved and seed-bearing plants in saltmarsh habitats	×	Minor
Vegetation height throughout areas used for feeding and roosting	×	Minor
WFD elements		
Overall ecological status	✓	**Major**
Invertebrates	×	Minor
Fish (based on consideration of the different groups below)	✓	Major
Diadromous fish:		
Atlantic salmon (European importance)	✓	Major
River/sea lamprey (European importance)	✓	Major
Eel (European importance)	✓	Major
Sea trout (National importance)	✓	Major
Marine migrants:		
Cod, herring, whiting (National importance)	✓	Moderate
Sole, plaice (National importance)	✓	Moderate
Marine stragglers, estuarine residents and freshwater species	×	Minor
Phytoplankton	×	Minor*
Macroalgae	×	Minor
Angiosperms (saltmarsh)	✓	Major

5.3 Very Low Head Barrage v2 (VLHBv2)

5.3.1 For details of this scheme, see Table 2.1 and URS Scott Wilson (2011a).

5.3.2 The significance of these effects have all been assessed before consideration of the application of prevent harm and/or mitigation measures.

5.3.3 It should be noted that an effect on a specific receptor of moderate or major significance is not necessarily an ecological consenting risk under the Habitats Directive in its own right. The assessment is based upon integrity (i.e. structure and function) of the SPA and consequently the main consideration of the assessment is whether there would be an adverse effect on the principal interest features of the site (e.g. birds) or on site integrity.

Area of Habitat Exposed

5.3.4 The construction of this scheme would likely result in the loss of approximately 63.4 ha of intertidal and subtidal habitat as a result of the footprint of the scheme. Specific details of the intertidal sediment which could potentially be lost are given in Section 5.2, Paragraph 5.2.4.

5.3.5 With the VLHBv2 scheme in place the lowest low water would be observed on spring tides and the highest low water would be on neap tides, as is the case with the baseline scenario.

5.3.6 Changes in the timing of low and high tides when compared to the baseline scenario are evident under the scheme. During spring tides there is a +0.5 hour shift in the timing of both low and high water under the scheme. During neap tides low water occurs 2 hours later under the scheme when compared to baseline whilst high water is 1 hour later. There is shift of +1 hour for low water under intermediate tides and high tide occurs 0.5 hours later under the scheme (Figure 5.1).

Intertidal Sediment

5.3.7 The results indicate that at low water during a spring tide there is an overall reduction of 910 ha (24% of Estuary baseline) of intertidal sediment exposed within the Estuary as a whole (of which 829 ha are in the SPA (24% of SPA baseline)) (Figure 5.5). Of the classified sediments the greatest decrease is observed for sand (174 ha (13%) in Estuary/169 ha (13%) in SPA) and the smallest reduction in area exposed is for mud sediments (17 ha (4%) in Estuary/16 ha (4%) in the SPA).

5.3.8 The decrease modelled was lower for intermediate tides and the smallest change in exposed area was evident for neap tides. During the neap tide scenario the decrease in total intertidal sediment exposed is 833 ha within the Estuary (25% of Estuary baseline) and 781 ha in the SPA (27% of SPA baseline). The sediment type with the greatest reduction in exposed area was sand and the smallest reduction was for areas of mud.

5.3.9 At high water there is an increase in exposed intertidal sediment during spring, intermediate and neap scenarios when compared with the baseline. The areas which were intertidal under baseline and exposed at all times under the scheme would dry out and no longer support an intertidal invertebrate assemblage. The increase is greatest during intermediate tides. For example within the Estuary as a whole, total intertidal sediment during intermediate tides is predicted to increase from 76 to 182 ha and when considering the SPA an increase from 28 to 108 ha is observed (Figure 5.6).

5.3.10 The SPA sub-feature attribute target for intertidal sediment extent and distribution is indicated in Section 5.2, Paragraph 5.2.12. In terms of change in area of habitat exposed as a result of changes in tidal regime there is a notable difference under this scheme at spring tide low water, with a quarter of the area exposed under baseline being submerged with the scheme in place. Further information is required in relation to changes to the sedimentation regime within the Estuary and the potential for sediment accretion/erosion within the Estuary to more accurately evaluate this change. The value/sensitivity is considered to be **high** as intertidal sediments form a sub-feature of the SPA which is a site of international importance. Effects are predicted to be **direct** and **temporary** with a duration of the operational lifetime of the scheme and a natural tidal regime would resume following decommissioning and removal of the scheme. Due to the decrease in the area of exposure of intertidal sediment with the scheme in place the magnitude of effect is predicted to be **high**. Consequently, it is assessed that there would be an adverse effect of **major** significance.

5.3.11 As is the case for each scheme, changes in sediment character/biotopes and variation in area exposed as a result of changes in sediment transport are aspects which require further investigation via sediment transport modelling.

Rocky Shore Habitat

5.3.12 At low water during a spring tide the reduction in exposed rocky shore habitat equates to 7 ha within the Estuary (28 to 21 ha; 25% of Estuary baseline), 6 ha of which are in the SPA (21 to 15 ha; 29% of the Estuary baseline).

5.3.13 During the neap tide scenario, rocky shore intertidal area exposed would be reduced from 24 ha to 13 ha within the Estuary as a whole, and from 18 ha to 9 ha when considering the SPA only.

5.3.14 At high water, changes in the exposed area of rocky shore with the scheme in place when compared to baseline are almost negligible on spring and intermediate tides and slightly greater on neap tides (a 2 ha increase in exposed area within the Estuary).

5.3.15 SPA sub-feature attribute targets for rocky shore habitats are indicated in Section 5.2, Paragraph 5.2.17. Areas of rocky shore are relatively small within the Estuary, however, the results of the assessment indicate that under this scheme at low tide there is a considerable decrease in the exposure of intertidal rocky shore habitat (see Table 5.2 and Figure 5.5). In many instances the assessment for scheme VLHBv2 is the same as for the IBv2 scheme, in these instances instead of repeating the full assessment it has been stated that the assessment is as indicated for the IBv2 scheme. This means that the assessment was exactly the same in terms of duration (permanent or temporary), whether the effect would be direct or indirect and the magnitude of the effect, the significance of the effect has then been provided.

5.3.16 Value/sensitivity of this receptor is considered to be **high** as rocky shores form a sub-feature of the SPA which is a site of international importance. Effects are predicted to be **direct** and **temporary** with a duration of the operational lifetime of the scheme with a natural tidal regime resuming following decommissioning and removal of the scheme. Due to the decrease in the area of exposed rocky shore habitat with the scheme in place, the magnitude of effect is predicted to be **medium**. Consequently, it is assessed that there would be an adverse effect of **moderate** significance.

5.3.17 A survey was conducted in autumn 2010 examining distribution of algae and invertebrates on the intertidal rocky shore habitats in the Mersey Estuary and a reduction in extent is considered likely to result in a reduction in the presence of intertidal invertebrates within the Estuary and SPA. The assessment of effect is as indicated for the IBv2 scheme and it is assessed that there would be an adverse effect of **moderate** significance.

Saltmarsh

5.3.18 There is no predicted change in the exposure of saltmarsh under the scheme at low water.

5.3.19 An increase in the area of saltmarsh habitat exposed is evident at high water under spring, intermediate and neap scenarios. Under spring tides the area of saltmarsh exposed increases from 0 to 394 ha within the Estuary (380 ha within the SPA). The increased exposure of saltmarsh which was previously inundated could result in encroachment by terrestrial vegetation reducing its extent. In turn the saltmarsh itself could encroach intertidal habitats which may counter this change although further investigation is required to clarify this.

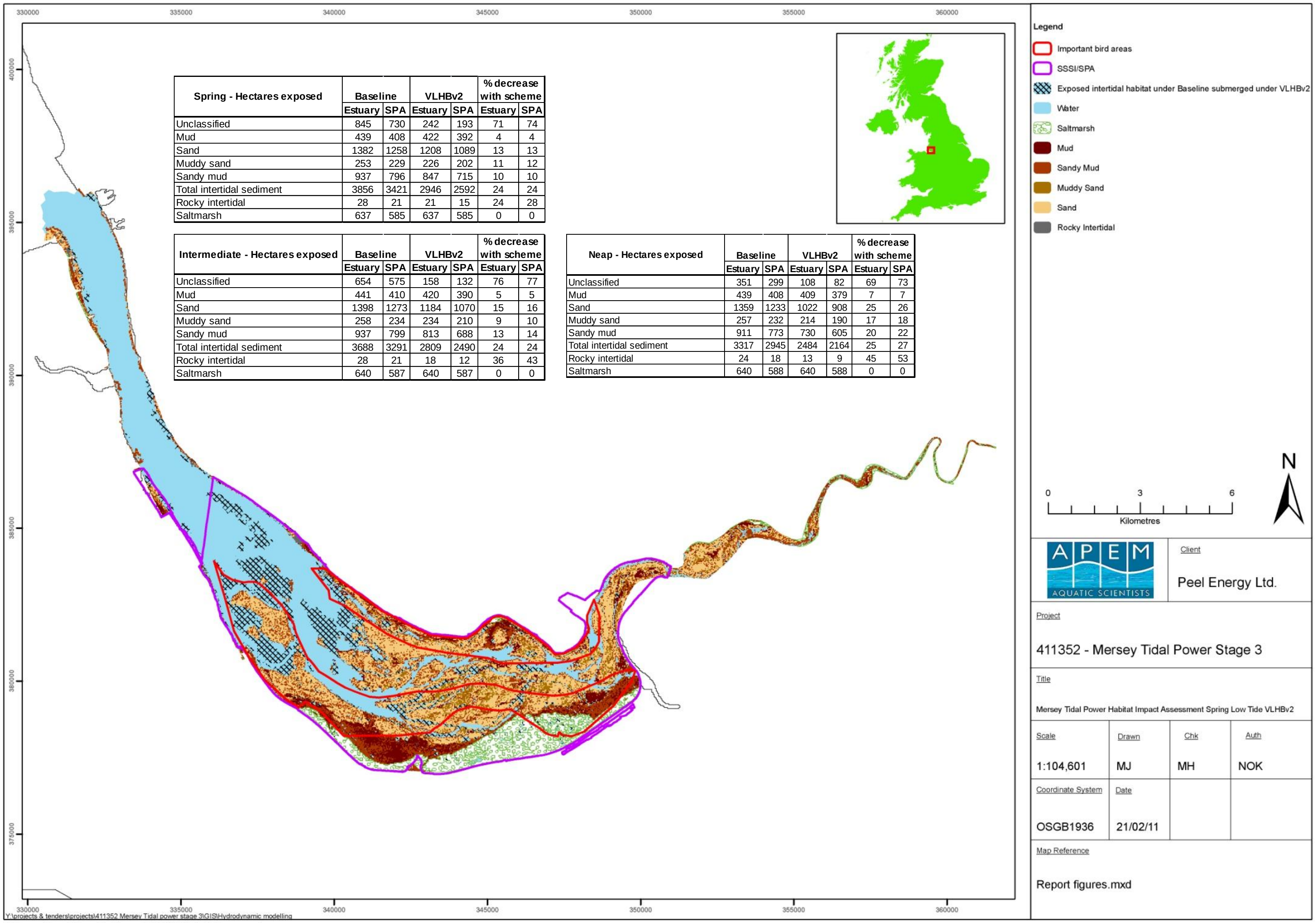
5.3.20 SPA sub-feature attribute targets for saltmarsh habitat are indicated in Section 5.2, Paragraph 5.2.22.

5.3.21 The assessment relating the change in the extent of saltmarsh is as indicated for the IBv2 scheme and it is assessed that there would be an adverse effect of **major** significance.

5.3.22 Further data are required to assess the types of change that may result in terms of presence and abundance of prey species. Prey species composition would not necessarily change but the overall availability of prey could be reduced if the extent of intertidal saltmarsh decreased. The assessment is as indicated for the IBv2 scheme and it is assessed that there would be an adverse effect of **moderate** significance.

5.3.23 The type of soft-leaved and seed-bearing plants on the saltmarsh requires further investigation, however, there may be some changes to composition if the upper shore assemblages differ from the lower shore saltmarsh although overall it is thought that a similar plant community would remain. The assessment is as indicated for the IBv2 scheme and it is assessed that there would be an adverse effect of **moderate** significance.

5.3.24 Although the extent of saltmarsh may change, based on information currently available the height of vegetation is not considered to be likely to change. The assessment of effect is as indicated for the IBv2 scheme and it is assessed that there would be an adverse effect of **minor** significance.

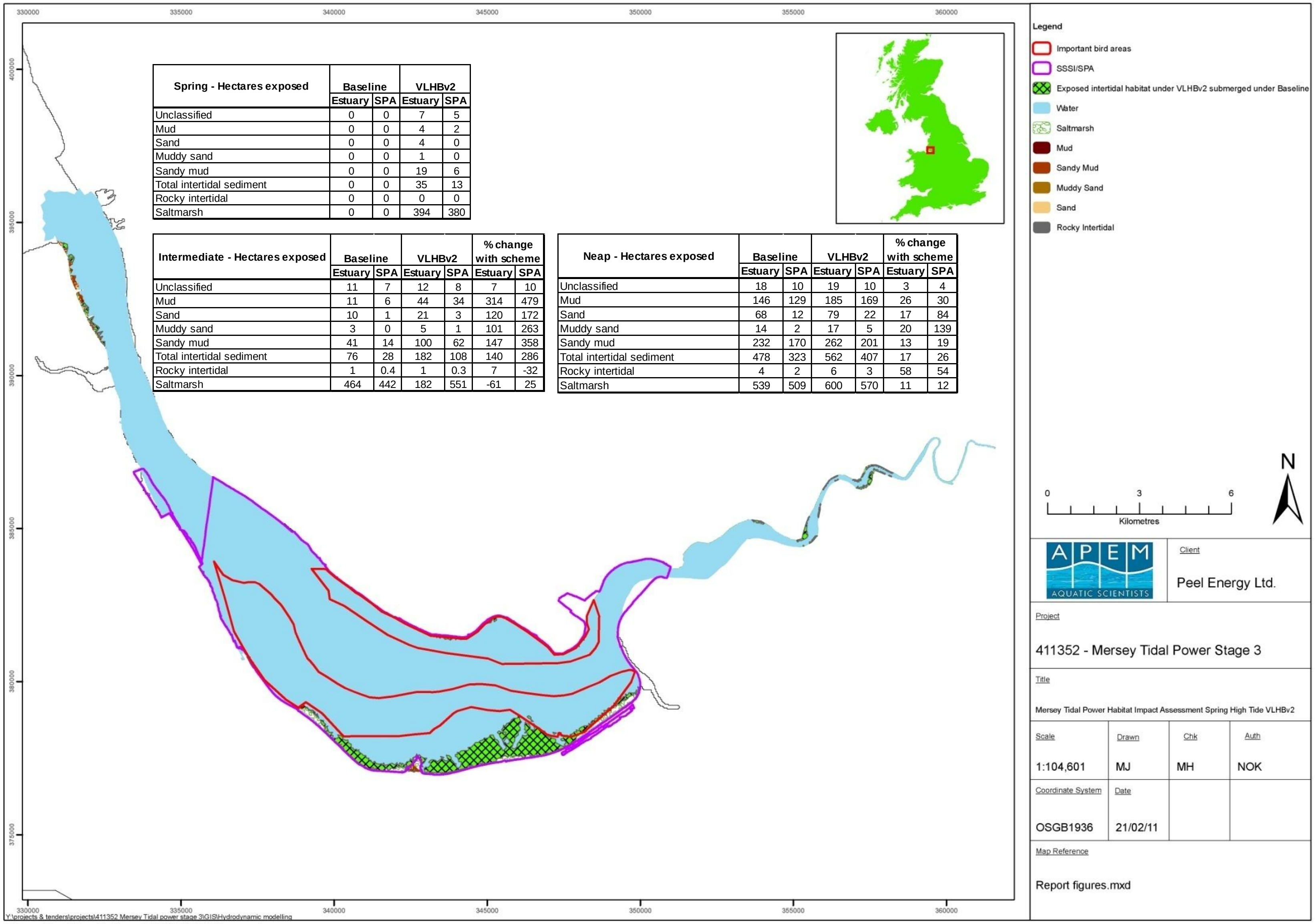


Spring - Hectares exposed	Baseline		VLHBv2		% decrease with scheme	
	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified	845	730	242	193	71	74
Mud	439	408	422	392	4	4
Sand	1382	1258	1208	1089	13	13
Muddy sand	253	229	226	202	11	12
Sandy mud	937	796	847	715	10	10
Total intertidal sediment	3856	3421	2946	2592	24	24
Rocky intertidal	28	21	21	15	24	28
Saltmarsh	637	585	637	585	0	0

Intermediate - Hectares exposed	Baseline		VLHBv2		% decrease with scheme	
	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified	654	575	158	132	76	77
Mud	441	410	420	390	5	5
Sand	1398	1273	1184	1070	15	16
Muddy sand	258	234	234	210	9	10
Sandy mud	937	799	813	688	13	14
Total intertidal sediment	3688	3291	2809	2490	24	24
Rocky intertidal	28	21	18	12	36	43
Saltmarsh	640	587	640	587	0	0

Neap - Hectares exposed	Baseline		VLHBv2		% decrease with scheme	
	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified	351	299	108	82	69	73
Mud	439	408	409	379	7	7
Sand	1359	1233	1022	908	25	26
Muddy sand	257	232	214	190	17	18
Sandy mud	911	773	730	605	20	22
Total intertidal sediment	3317	2945	2484	2164	25	27
Rocky intertidal	24	18	13	9	45	53
Saltmarsh	640	588	640	588	0	0

Figure 5.5 Exposed habitat comparing baseline with VLHBv2 scenario at spring low tide.



Spring - Hectares exposed	Baseline		VLHBv2	
	Estuary	SPA	Estuary	SPA
Unclassified	0	0	7	5
Mud	0	0	4	2
Sand	0	0	4	0
Muddy sand	0	0	1	0
Sandy mud	0	0	19	6
Total intertidal sediment	0	0	35	13
Rocky intertidal	0	0	0	0
Saltmarsh	0	0	394	380

Intermediate - Hectares exposed	Baseline		VLHBv2		% change with scheme	
	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified	11	7	12	8	7	10
Mud	11	6	44	34	314	479
Sand	10	1	21	3	120	172
Muddy sand	3	0	5	1	101	263
Sandy mud	41	14	100	62	147	358
Total intertidal sediment	76	28	182	108	140	286
Rocky intertidal	1	0.4	1	0.3	7	-32
Saltmarsh	464	442	182	551	-61	25

Neap - Hectares exposed	Baseline		VLHBv2		% change with scheme	
	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified	18	10	19	10	3	4
Mud	146	129	185	169	26	30
Sand	68	12	79	22	17	84
Muddy sand	14	2	17	5	20	139
Sandy mud	232	170	262	201	13	19
Total intertidal sediment	478	323	562	407	17	26
Rocky intertidal	4	2	6	3	58	54
Saltmarsh	539	509	600	570	11	12

Figure 5.6 Exposed habitat comparing baseline with VLHBv2 scenario at spring high tide.

Invertebrate Prey Biomass (Within Sediments)

5.3.25 Changes in invertebrate biomass in relation to change in the exposure of different sediment types are summarised in the table below (Table 5.9). In terms of invertebrate biomass, when considering the spring tide scenario within the Estuary as a whole there is a reduction from ~585 to ~506 tonnes this represents a ~13% reduction in biomass (Table 5.9). For the intermediate tide scenario this figure is ~13% and for the neap tide scenario ~19%. Within the SPA there are reductions in extent of exposed area of ~12-18 % depending on the type of tide (spring to neap).

5.3.26 As described in Section 5.2, in addition to the reductions in biomass indicated in the tables below there would be a further reduction in biomass due to the drying out of the uppermost shore with the scheme in place as it would then no longer be colonised by intertidal invertebrates. Therefore, the values in the tables below represent an underestimate of reductions in biomass due to the scheme.

Table 5.9 Estimated potential change in invertebrate biomass availability comparing baseline with the VLHBv2 scheme scenario under spring, intermediate and neap scenarios (to the nearest tonne).

Spring - Invertebrate biomass (tonnes)	Baseline		VLHBv2		Predicted decrease		% decrease	
	Estuary	SPA	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified intertidal sediment	26	22	7	6	19	17	73	74
Mud	158	156	148	146	10	10	7	6
Sand	87	83	71	68	16	15	18	18
Muddy sand	87	87	76	76	10	10	12	12
Sandy mud	227	215	204	194	23	20	10	9
Total	585	563	506	490	78	72	13	13

Intermediate - Invertebrate biomass (tonnes)	Baseline		VLHBv2		Predicted decrease		% decrease	
	Estuary	SPA	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified intertidal sediment	20	18	4	4	16	14	78	78
Mud	159	157	146	145	12	12	8	8
Sand	88	85	73	71	15	13	17	16
Muddy sand	89	88	80	80	9	8	10	10
Sandy mud	228	217	203	195	24	21	11	10
Total	584	565	506	495	76	68	13	12

Neap - Invertebrate biomass (tonnes)	Baseline		VLHBv2		Predicted decrease		% decrease	
	Estuary	SPA	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified intertidal sediment	11	9	3	2	8	7	73	75
Mud	157	156	141	140	16	16	10	10
Sand	86	83	62	60	24	22	28	27
Muddy sand	89	89	74	74	15	15	17	17
Sandy mud	224	214	182	175	42	39	19	18
Total	567	551	462	451	105	99	19	18

5.3.27 The sub-feature attribute target for invertebrate prey biomass is provided in Section 5.2, Paragraph 5.2.29. As indicated in the above assessment the presence of the scheme would likely result in a decrease in intertidal sediment exposed at low water. The majority of habitat which would decrease in extent is, however sand, and muddy habitat tends to be more important in terms of numbers of invertebrate individuals and biomass. Nevertheless, overall there is a ~12-18% reduction in invertebrate biomass within the SPA. The assessment of effect is the same as that indicated for the IBv2 scheme and it is assessed that there would be an adverse effect of **major** significance.

Mud-Surface Plants and Green Algae

5.3.28 The sub-feature attribute target for mud-surface plants and green algae is provided in Section 5.2. A reduction in intertidal sediment area exposed under this scheme would likely result in a decrease in the intertidal area available for benthic algae. The changes in intertidal sediment exposure indicated above therefore have the potential to have an adverse effect on this sub-feature attribute. The assessment of effect is as indicated for the IBv2 scheme and it is assessed that there would be an adverse effect of **moderate** significance.

Bird Foraging Space and Time

Exposed Surface Area

5.3.29 In scheme VLHBv2, the area of soft sediment foraging space for shorebirds at low water would be reduced to 91%, 89% and 83% of baseline on spring, intermediate and neap tides respectively (Table 5.2). The area available at high tide would be comparable to baseline on spring tides and increase (by approximately 25%) on neap tides (Table 5.3). The increase on the intermediate tide is probably a result of the high water level during intermediate tides being slightly lower when a scheme is in place than during baseline conditions. Passage and wintering bird surveys have identified the main feeding areas on the exposed intertidal flats for the bird species upon which the Mersey Estuary SPA has been designated. Changes in the percentage of these feeding areas which will still be available at spring low water if VLHBv2 is constructed vary for the different species (Appendix 4), with the greatest reduction being for pintail (to 72%), and the least affected species which feeds within the SPA being teal (with 99% remaining).

5.3.30 Increases in saltmarsh area (~60-110 ha) are predicted for high water over neap and intermediate tides. On spring tides the area is predicted to increase substantially from 0 to 380 ha (Table 5.3).

5.3.31 At low tide, the area of intertidal rock is predicted to be reduced by approximately 30-50% on all tides from 18-21 ha down to 9-15 ha (Table 5.2).

Wetted Perimeter

5.3.32 In scheme VLHBv2, the length of the wetted perimeter over soft sediment at low water would be ~111%, ~97% and ~105% of baseline on spring, intermediate and neap tides respectively (Table 5.4). The average value of ~104% means that, overall, the wetted perimeter length over the soft sediments most used by shorebirds at low water is not predicted to change. However, its length at high tide would be slightly increased to ~123% and ~103% on intermediate and neap tides respectively, and to ~357% on spring tides (Table 5.5). This large increase is an artefact of the modelling which predicts that many small water bodies would appear close to the high water mark with either of the schemes in place (each of the water bodies having its own wetted perimeter). As these small water bodies have been identified from the modelling as the main reason for the predicted increase, it is considered likely that the length of the wetted perimeter at spring high tide would also be relatively unchanged.

Invertebrate Prey

5.3.33 In scheme VLHBv2, the biomass of the invertebrates in the soft sediment exposed at low water would be reduced to ~91%, ~91% and ~85% of baseline on spring, intermediate and neap tides respectively (Table 5.6), closely following the changes in the areas of the sediments.

Foraging Time

5.3.34 The area of soft suitable sediment (mud, muddy sand and sandy mud combined) exposed through the tidal cycle is shown for spring, intermediate and neap tides in Figure 5.4. Compared with baseline, VLHBv2 is predicted to delay by 40-45 minutes the time at which the area remaining on the advancing spring and intermediate tides is reduced to 400 ha or 200 ha and, by 40-80 minutes the time at which such areas become exposed on the receding spring and intermediate tides. The exposed area is hardly reduced below 400 ha at high water on neap tides. On spring tides and intermediate tides only, therefore, the duration of the foraging period is reduced respectively compared with baseline by 20 and 13 minutes for the <200 ha criterion and by 73 and 53 minutes for the <400 ha criterion (Table 5.7).

5.3.35 Sub-feature attribute targets for birds are indicated in Section 5.2, Paragraph 5.2.43.

5.3.36 Based on the information available to date, in terms of the number of birds, there is likely to be a decrease because of the reduction in the area of feeding grounds available over low tide and because of the reduction in the amount of time for foraging in the intertidal zone at densities low enough for there to be a low risk of serious competition. Value/sensitivity is considered to be **high** as birds are a feature of the SPA which is of international importance. Effects are predicted to be **indirect** and **temporary** with a duration of the operational lifetime of the scheme, with a more natural regime and bird numbers returning following decommissioning and removal of the scheme. Based on present information, the reductions in foraging space and foraging time are predicted to be moderately large, therefore the magnitude of effect is predicted to be **moderate**. It is consequently assessed that there would be an adverse effect of **moderate** significance.

5.3.37 When considering flight lines, it is not only likely that the barrage would obscure sight lines and so provide cover for approaching birds of prey, but it is also very likely that the barrage would provide perches from which birds of prey could launch attacks against shorebirds on the intertidal flats. It is recognised, however, that the position of the barrage will be some distance from the majority of the feeding grounds, and therefore sight lines for feeding shore birds will for the most part not be reduced. Value/sensitivity is considered to be **high** as birds are a feature of the SPA which is of international importance. Effects are predicted to be **indirect** and **temporary** with a duration of the operational lifetime of the scheme, and would be removed following decommissioning and removal of the scheme. But as raptor predation on shorebirds generally seems to be quite low on large estuaries such as the Mersey, the magnitude of effect is predicted to be **very low**. It is consequently assessed that there would be an adverse effect of **minor** significance.

Water Framework Directive

5.3.38 As indicated in Section 3.3 the Mersey Estuary water body is classified under the WFD as transitional type 3. Type-specific conditions for benthic macroinvertebrates, fish, phytoplankton, macroalgae and angiosperms (saltmarsh) are indicated in Appendix 3.

Invertebrates

5.3.39 Requirements for assessment under the WFD are summarised in Section 3.3 as are considerations of the assessment in relation to this element. In terms of WFD requirements it is considered that local diversity and abundance within specific habitat types is unlikely to fall below the current required status of 'moderately outside the range associated with type-specific conditions' and the scheme is unlikely to prevent attainment of future targets, therefore it is considered that it is possible that there would not be an ecological consenting risk under the WFD for this element. The assessment of effect is as indicated for the IBv2 scheme and overall it is considered that there would be an adverse effect of **minor** significance.

Fish

5.3.40 Requirements for assessment under the WFD are summarised in Section 3.3. Scheme VLHBv2 would involve the operation of 44 turbines, of 8 m runner diameter turning at ~60 rpm. Passage of fish, including migratory fish, could result in injury and mortality through operating turbines on the ebb tide and through sluices and free-wheeling turbines on the flood tide.

There may also be incidence of ‘fallback’ of fish resulting in multiple passes through the turbines. A total of four fish passage routes have been incorporated into the scheme to limit injury and mortality of fish.

5.3.41 Information relating to the potential effects of turbine/sluice passage is provided in Section 5.2. Potential effects are assessed below for the different functional groups of fish present within the Estuary as indicated in Table 3.2.

Marine Stragglers, Estuarine Residents and Freshwater Species

5.3.42 The assessment is as indicated for the IBv2 scheme and it is considered that there would be an adverse effect of **minor** significance for fish species belonging to these functional groups.

Marine Migrants

5.3.43 For cod, herring, whiting, sole and plaice the assessment of effect is as indicated for the IBv2 scheme and it is considered that there would be an adverse effect of **moderate** significance.

Diadromous Fish

5.3.44 For Atlantic salmon, river and sea lamprey, European eel and sea trout the assessment of effect is as indicated for the IBv2 scheme and it is considered that there would be an adverse effect of **major** significance for each of these species.

Phytoplankton

5.3.45 Requirements for assessment under the WFD are summarised in Section 3.3. A flushing study has been conducted to indicate the ability of the Estuary to allow pollutants contained in the Estuary to discharge to sea, it was concluded that with the scheme in place the ability of the Estuary to flush was reduced from removal of 25% of a tracer in 2.4 days to removal in 4.4 days. This could have implications in terms of potential for build up of contaminants and potential for eutrophication (although this is limited due to the current turbidity within the Estuary) (URS Scott Wilson 2011b). Overall, the assessment of effect is the same as that for the IBv2 scheme and it is assessed that there would be an adverse effect of **minor** significance.

Macroalgae

5.3.46 Requirements for assessment under the WFD are summarised in Section 3.3. With a loss of rocky shore habitat of 24-45% at low water across neap to spring scenarios the results of the assessment of effect are the same as those for IBv2 and it is assessed that there would be an adverse effect of **minor** significance.

Angiosperms (Saltmarsh)

5.3.47 Requirements for assessment under the WFD are summarised in Section 3.3. The assessment of effect is the same as that for Scheme IBv2 and it is assessed that there would be an adverse effect of **major** significance.

Summary

5.3.48 The various sub-feature attribute targets of the SPA and ecological status elements of the WFD have been considered above.

5.3.49 Data available at the end of Stage 3 indicate that although VLHBv2 is not predicted to decrease the length of the wetted perimeter along the tide edge that is used for feeding by many shorebirds on the Mersey, it is predicted to somewhat reduce (9-17% by comparison with baseline, depending upon the type of tide) the amount of foraging space and prey biomass on the intertidal flats as a whole. There would also be small decreases in the amount of time available for foraging at densities at which competition is reduced. If any of the declines in numbers of birds of the species upon which the Mersey was designated as a SPA are caused by deterioration in the feeding conditions, these decreases in foraging time and foraging space may reduce survival levels, such that population numbers could be reduced by VLHBv2. Overall, there may be a change in the structure and function of the SPA, and consequently an adverse effect on site integrity. Sight lines for birds are not likely to be maintained as the impounding barrage itself could provide cover for approaching raptors and provide them with perches from which to launch their attacks, though this is likely to have a relatively minor effect on mortality rates given the distance of the barrage from the majority of the feeding areas.

5.3.50 Taking the results above into account the potential for there to be an ecological consenting risk with this scheme under the SHRA and WFD is indicated in Table 5.10. Overall, it is thought that without prevent harm/mitigation measures, under the operating regime modelled for this scheme, there could be an effect of major significance on the extent of intertidal sediments, presence and abundance of prey species in intertidal sediments, saltmarsh extent (SPA sub-feature) and saltmarsh under WFD, and fish (including UK BAP species and those of European importance). It is considered there could be effects of moderate significance for numbers or displacement of birds, mud-surface plants and green algae, extent of rocky shores and presence and abundance of invertebrates on rocky shores. It is considered that there may be an ecological consenting risk under WFD associated with fish and saltmarsh, and with each of the SPA sub-feature attribute targets under the SHRA (with the exception of bird view lines, presence abundance of prey species in saltmarsh, presence and abundance of soft-leaved and seed bearing plants in saltmarsh habitats and saltmarsh vegetation height).

Table 5.10 Summary table of potential risk before application of prevent harm and mitigation measures in in relation to SHRA assessment and WFD assessment for the VLHBv2 scheme. ✓ = possible ecological consent risk. * = pending results of water quality modelling.

Feature	Potential for ecological consent risk	Potential significance of effect
SPA Sub-feature attribute measure		
Integrity of SPA	✓	**Moderate**
Numbers of birds or bird displacement	✓	Moderate
Number of obstructions to existing bird view lines	×	Minor
Extent of intertidal sediments	✓	Major
Presence and abundance of prey species in intertidal sediments	✓	Major
Presence and abundance of mud-surface plants and green algae	✓	Moderate
Extent of rocky shore habitat	✓	Moderate
Presence and abundance of intertidal invertebrates in rocky shore habitats	✓	Moderate
Extent of saltmarsh habitat	✓	Major
Presence and abundance of prey species in saltmarsh	×	Minor
Presence and abundance of soft-leaved and seed-bearing plants in saltmarsh habitats	×	Minor
Vegetation height throughout areas used for feeding and roosting	×	Minor
WFD elements		
Overall ecological status	✓	**Major**
invertebrates	×	Minor
Fish (based on consideration of the different groups below)	✓	Major
Diadromous fish:		
Atlantic salmon (European importance)	✓	Major
River/sea lamprey (European importance)	✓	Major
Eel (European importance)	✓	Major
Sea trout (National importance)	✓	Major
Marine migrants:		
Cod, herring, whiting (National importance)	✓	Moderate
Sole, plaice (National importance)	✓	Moderate
Marine stragglers, estuarine residents and freshwater species	×	Minor
Phytoplankton	×	Minor*
Macroalgae	×	Minor
Angiosperms (saltmarsh)	✓	Major

5.4 Very Low Head Barrage v3 (VLHBv3)

5.4.1 For details of this scheme, see Table 2.1 and URS Scott Wilson (2011a).

5.4.2 The significance of these effects have all been assessed before consideration of the application of prevent harm and/or mitigation measures.

5.4.3 It should be noted that even if the significance of an effect is considered to be moderate or major for a specific receptor, it does not necessarily represent an ecological consenting risk under the Habitats Directive if it is not expected to have an adverse effect on the principal interest features of the site (e.g. birds), or on the integrity (i.e. structure and function) of the site.

Area of Habitat Exposed

5.4.4 The construction of this scheme would likely result in the loss of approximately 63.4 ha of habitat as a result of the footprint of the scheme. Specific details of the intertidal sediment which could potentially be lost is given in Section 5.2.

5.4.5 With the VLHBv3 scheme in place the lowest low water would be observed on spring tides and the highest low water would be on neap tides, as is the case with the baseline scenario.

5.4.6 Under the scheme changes in the timing of low and high tides are also evident. Under spring tides both low and high water occur 0.5 hours later under the scheme when compared to baseline. During neap tides low water occurs 1.5 hours later under the scheme whilst high water is 2 hours later. Low water occurs 2 hours later under intermediate tides and high tide occurs 1.5 hours later with the scheme in place (Figure 5.1).

Intertidal Sediment

5.4.7 At spring tide low water there is an overall decrease in exposed area of 498 ha (13% of Estuary baseline) of intertidal sediment within the Estuary as a whole (of which 437 ha are in the SPA (11% of SPA baseline)) (Figure 5.7). The greatest reduction in exposure of a classified sediment category is observed for sand (110 ha (8%) in the Estuary/107 ha (9%) in the SPA) and the smallest decrease is apparent for mud sediments (11 ha in the Estuary, all of which is in the SPA).

5.4.8 The reduction in exposed area is smaller for intermediate tides and smaller still on neap tides. During the neap scenario the total reduction in area of exposed intertidal sediment lost is estimated to be 301 ha within the Estuary (9.1% of Estuary baseline) and 259 ha in the SPA (8.8% of SPA baseline) with sand habitats having the greatest decrease in exposure and mud having the smallest decrease in exposure (Figure 5.7).

5.4.9 At high water there is an increase in intertidal area exposed for the spring, intermediate and neap tide scenarios. The neap tide scenario indicates the greatest increase: total intertidal sediment within the Estuary as a whole is predicted to increase from 478 ha to 778 ha and when considering the SPA it represents an increase from 323 to 578 ha (Figure 5.8).

5.4.10 The SPA sub-feature attribute target for intertidal sediment extent and distribution is provided in Section 5.2, Paragraph 5.2.12. The reductions in total intertidal area under this scheme are relatively small (up to 13% for the Estuary as a whole), especially when considering mud which is likely the most important habitat for foraging birds (3% decrease in exposed area within the SPA). Further information is required in relation to changes to the sedimentation regime within the Estuary and the potential for sediment accretion/erosion within the Estuary to more accurately evaluate this change. The value/sensitivity is considered to be **high** as intertidal sediments form a sub-feature of the SPA which is a site of international importance. Effects are predicted to be **direct** and **temporary** with a duration of the operational lifetime of the scheme and a natural tidal regime would resume following decommissioning and removal of the scheme, therefore effects could potentially be reversible. Due to the decrease in the area of exposure of intertidal sediment with the scheme in place, the magnitude of effect is predicted to be **low**. Consequently, it is assessed that there would be an adverse effect of **moderate** significance.

5.4.11 As is the case for each scheme, changes in sediment character/biotopes and variation in area exposed as a result of changes in sediment transport are aspects which require further investigation via sediment transport modelling.

Rocky Shore Habitat

5.4.12 At spring tide low water the reduction of exposed rocky shore habitat is 1 ha within the Estuary (4% of Estuary baseline). At low water on a neap tide the rocky shore intertidal area exposed would be reduced from 24 ha to 19 ha within the Estuary as a whole, and from 18 ha to 14 ha when considering the SPA only.

5.4.13 At high water, changes in the exposed area of rocky shore with the scheme in place when compared to baseline are generally small (up to 4 ha increase within the Estuary).

5.4.14 SPA sub-feature attribute target for rocky shore habitats are provided in Section 5.2, Paragraph 5.2.17. Areas of rocky shore are relatively small within the Estuary, however, under this scheme the percent reductions in exposed area of rocky shore are also relatively small. Value/sensitivity is considered to be **high** as rocky shores form a sub-feature of the SPA which is a site of international importance. Effects are predicted to be **direct** and **temporary** with a duration of the operational lifetime of the scheme and a natural tidal regime would resume following decommissioning and removal of the scheme. Due to the relatively small decrease in the area of exposed rocky shore habitat with the scheme in place, the magnitude of effect is predicted to be **very low**. Consequently, it is assessed that there would be an adverse effect of **minor** significance.

5.4.15 A survey was conducted in autumn 2010 to record the distribution of algae and invertebrates on the intertidal rocky shore habitats in the Mersey Estuary and a reduction in extent is considered likely to result in a reduction in the presence of invertebrates on intertidal rocky habitats within the Estuary and SPA. Value/sensitivity is considered to be **high** as rocky shores and their invertebrate communities form a sub-feature of the SPA which is a site of international importance. Effects are predicted to be **direct** and **temporary** with a duration of the operational lifetime of the scheme, a natural tidal regime would resume following decommissioning of the scheme and intertidal invertebrates would be expected to recolonise new intertidal areas of rocky shore. The abundance of invertebrates on rocky shores is considered to be relatively low in comparison with intertidal sediments and it is considered that rocky shores are of lesser importance for feeding birds, therefore, the taking in consideration the relatively small reduction in extent of the shore magnitude of effect is considered to be **very low** and it is assessed that there would be an adverse effect of **minor** significance.

Saltmarsh

5.4.16 There is no predicted change in the exposure of saltmarsh under the scheme at low water.

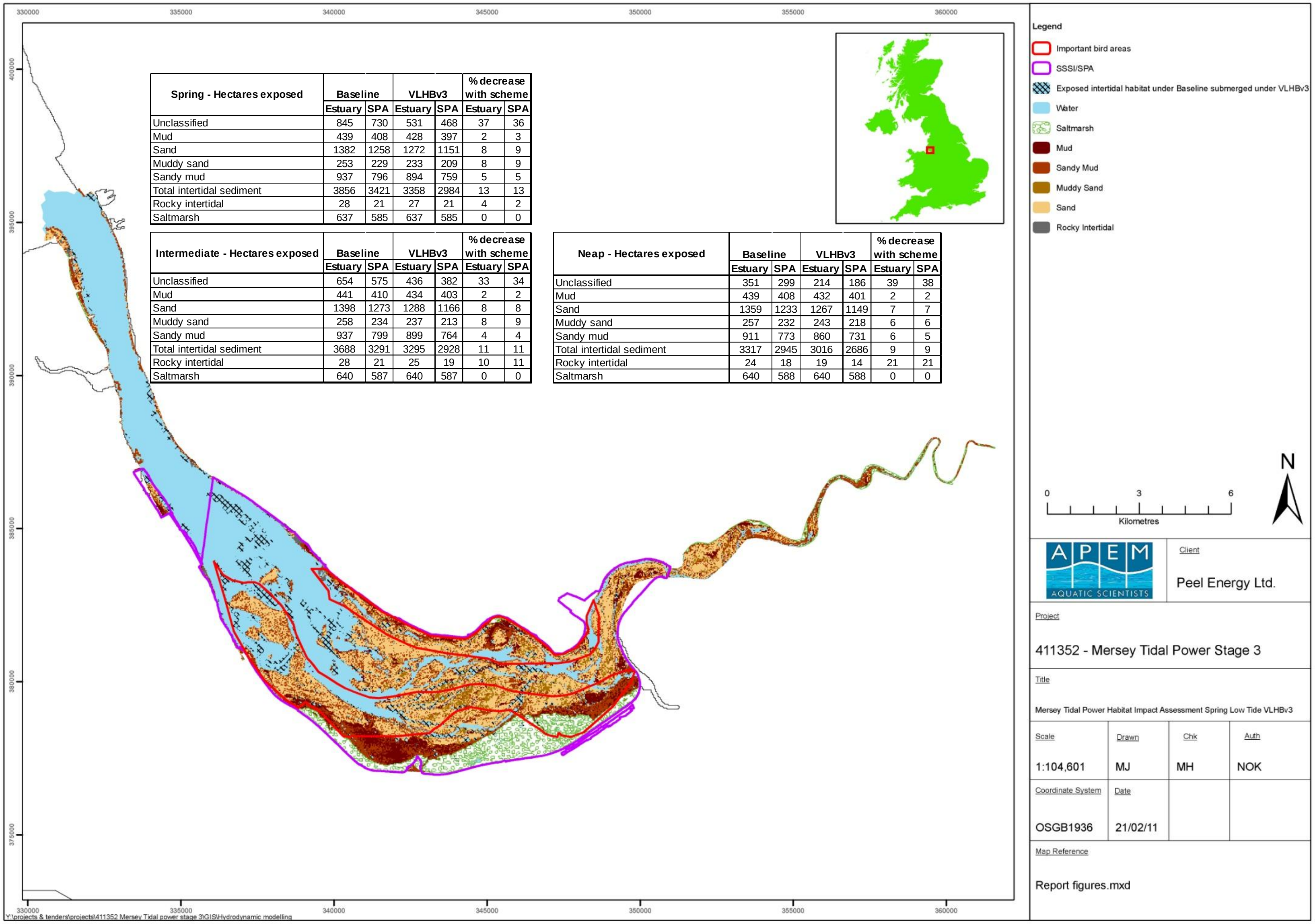
5.4.17 An increase in the area of saltmarsh habitat exposed is evident at high water under intermediate and neap scenarios with a particularly large increase apparent under the spring tide scenario (increase from 0 to 538 ha). The increased exposure of saltmarsh which was previously inundated could result in encroachment by terrestrial vegetation reducing its extent. In turn the saltmarsh itself could encroach intertidal habitats which may counter this change although further investigation is required to clarify this.

5.4.18 SPA sub-feature attribute targets for saltmarsh habitat are indicated in Section 5.2, Paragraph 5.2.22. Due to the relatively large increase in extent of saltmarsh and the potential for encroachment of the saltmarsh by terrestrial vegetation the assessment of effect is the same as that conducted for both schemes IBv2 and VLHBv2 and it is assessed that there would be an adverse effect of **major** significance.

5.4.19 Further data are required to fully assess the types of change that may result in terms of presence and abundance of prey species. It is likely, however, that prey species composition would not necessarily change but the overall availability of prey could be reduced if the extent of intertidal saltmarsh decreased. The assessment of effect is the same as that for the IBv2 and VLHBv2 schemes and it is considered that there would be an adverse effect of **moderate** significance.

5.4.20 The type of soft-leaved and seed-bearing plants on the saltmarsh requires further investigation, however, there may be some changes to composition if the upper shore assemblages differ from the lower shore saltmarsh although overall it is thought that a similar plant community would remain. The assessment of effect is the same as that for the IBv2 and VLHBv2 schemes and it is considered that there would be an adverse effect of **moderate** significance.

5.4.21 Although the extent of saltmarsh may change, based on information currently available the height of vegetation is not considered to be likely to change**.** The assessment of effect is the same as that for the IBv2 and VLHBv2 schemes and it is considered that there would be an adverse effect of **minor** significance.



Spring - Hectares exposed	Baseline		VLHBv3		% decrease with scheme	
	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified	845	730	531	468	37	36
Mud	439	408	428	397	2	3
Sand	1382	1258	1272	1151	8	9
Muddy sand	253	229	233	209	8	9
Sandy mud	937	796	894	759	5	5
Total intertidal sediment	3856	3421	3358	2984	13	13
Rocky intertidal	28	21	27	21	4	2
Saltmarsh	637	585	637	585	0	0

Intermediate - Hectares exposed	Baseline		VLHBv3		% decrease with scheme	
	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified	654	575	436	382	33	34
Mud	441	410	434	403	2	2
Sand	1398	1273	1288	1166	8	8
Muddy sand	258	234	237	213	8	9
Sandy mud	937	799	899	764	4	4
Total intertidal sediment	3688	3291	3295	2928	11	11
Rocky intertidal	28	21	25	19	10	11
Saltmarsh	640	587	640	587	0	0

Neap - Hectares exposed	Baseline		VLHBv3		% decrease with scheme	
	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified	351	299	214	186	39	38
Mud	439	408	432	401	2	2
Sand	1359	1233	1267	1149	7	7
Muddy sand	257	232	243	218	6	6
Sandy mud	911	773	860	731	6	5
Total intertidal sediment	3317	2945	3016	2686	9	9
Rocky intertidal	24	18	19	14	21	21
Saltmarsh	640	588	640	588	0	0

Figure 5.7 Exposed habitat comparing baseline with VLHBv3 scenario at spring low tide.

Spring - Hectares exposed	Baseline		VLHBv3	
	Estuary	SPA	Estuary	SPA
Unclassified	0	0	12	7
Mud	0	0	17	10
Sand	0	0	17	1
Muddy sand	0	0	4	0
Sandy mud	0	0	55	21
Total intertidal sediment	0	0	105	39
Rocky intertidal	0	0	1	0
Saltmarsh	0	0	538	513

Intermediate - Hectares exposed	Baseline		VLHBv3		% change with scheme	
	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified	11	7	15	8	40	19
Mud	11	6	100	87	846	1401
Sand	10	1	35	5	264	466
Muddy sand	3	0	7	1	186	833
Sandy mud	41	14	174	127	328	837
Total intertidal sediment	76	28	331	228	336	714
Rocky intertidal	1	0.4	3	0.3	137	-26
Saltmarsh	464	442	607	580	31	31

Neap - Hectares exposed	Baseline		VLHBv3		% change with scheme	
	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified	18	10	26	13	42	32
Mud	146	129	242	221	66	71
Sand	68	12	149	72	120	501
Muddy sand	14	2	27	10	89	388
Sandy mud	232	170	334	261	44	54
Total intertidal sediment	478	323	778	577	63	78
Rocky intertidal	4	2	8	4	90	101
Saltmarsh	539	509	618	587	15	15

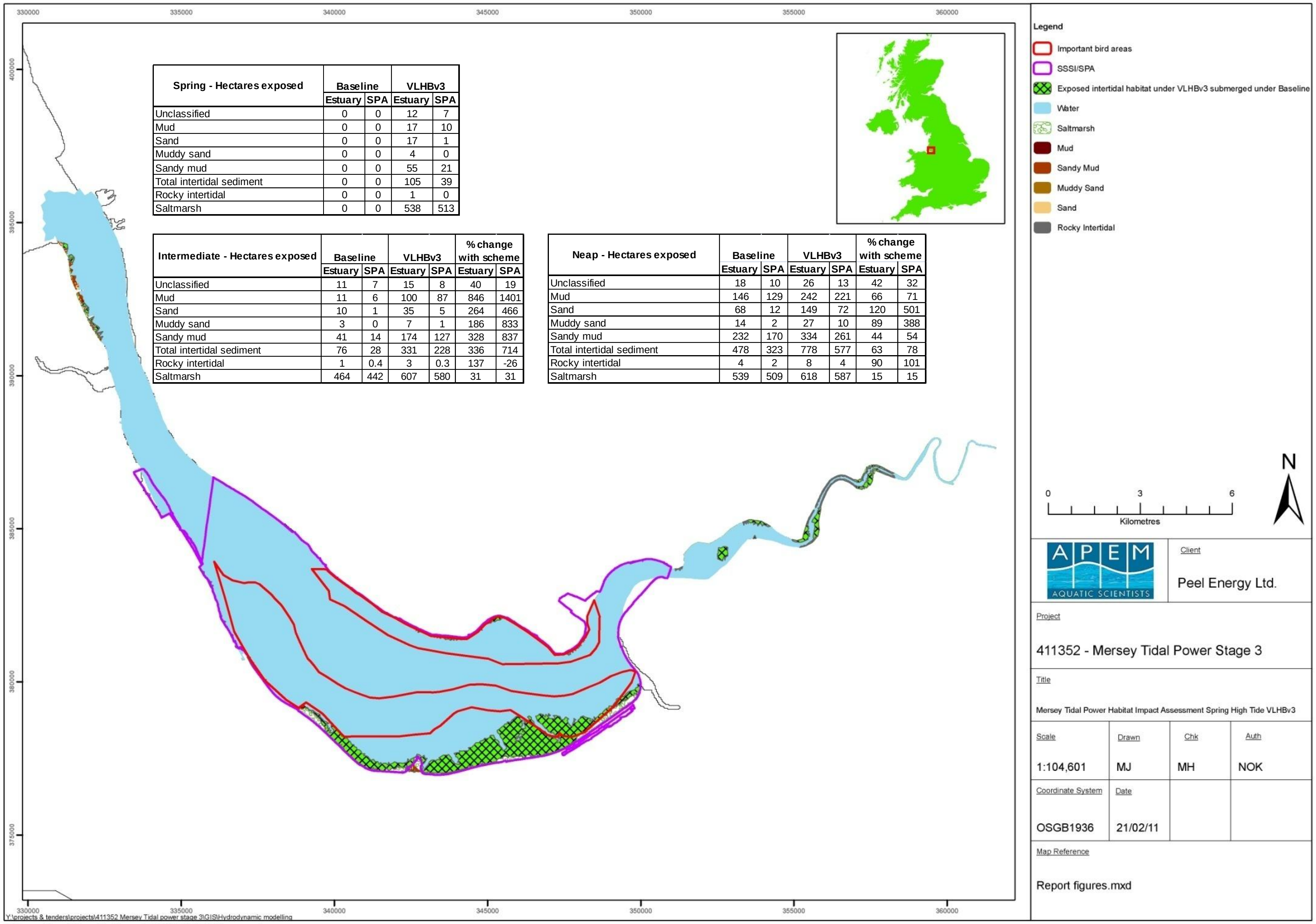


Figure 5.8 Exposed habitat comparing baseline with VLHBv3 scenario at spring high tide.

Invertebrate Prey Biomass (Within Sediments)

5.4.22 The sub-feature attribute target for invertebrate prey biomass is provided in Section 5.2, Paragraph 5.2.29.

5.4.23 It is predicted that the presence of the scheme would result in a reduction in the exposed area of intertidal sediment at low water. The majority of habitat which decreases in extent is sand, however, and muddy habitat tends to be more important in terms of numbers of invertebrate individuals and biomass. Nevertheless, under the spring tide scenario there is a predicted overall decrease in biomass availability of ~9% within the SPA (Table 5.11). There is potential for the change to have an adverse effect on the sub-feature attribute targets for this feature.

5.4.24 As described in Section 5.2, in addition to the reductions in biomass availability indicated in the tables below there would be a further reduction in biomass due to the drying out of the uppermost shore with the scheme in place as it would then no longer be colonised by intertidal invertebrates. Therefore, the values in the tables below represent an underestimate of reductions in biomass due to the scheme.

Table 5.11 Estimated potential change in invertebrate biomass availability comparing baseline with the VLHBv3 scheme scenario under spring, intermediate and neap scenarios.

Spring - Invertebrate biomass (tonnes)	Baseline		VLHBv3		Predicted loss		% decrease	
	Estuary	SPA	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified intertidal sediment	26	22	7	14	19	9	73	38
Mud	158	157	150	149	8	8	5	5
Sand	87	83	74	71	13	12	14	15
Muddy sand	87	87	78	78	9	9	10	10
Sandy mud	227	215	209	199	17	16	8	7
Total	585	564	519	510	66	53	11	9

Intermediate - Invertebrate biomass (tonnes)	Baseline		VLHBv3		Predicted loss		% decrease	
	Estuary	SPA	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified intertidal sediment	20	18	13	4	8	14	38	78
Mud	159	158	151	145	7	12	5	8
Sand	88	85	76	71	13	14	14	16
Muddy sand	89	89	80	80	9	9	10	10
Sandy mud	228	217	211	196	17	21	8	10
Total	584	565	530	496	54	69	9	12

Neap - Invertebrate biomass (tonnes)	Baseline		VLHBv3		Predicted loss		% decrease	
	Estuary	SPA	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified intertidal sediment	11	9	6	5	5	4	45	42
Mud	158	156	150	149	8	7	5	5
Sand	86	83	76	74	10	9	12	11
Muddy sand	89	89	82	82	7	7	8	8
Sandy mud	224	214	208	200	16	14	7	6
Total	568	551	523	511	45	41	8	7

5.4.25 Value/sensitivity is considered to be **high** as invertebrates provide food for the SPA bird features. Effects are predicted to be **direct** and **temporary** with a duration of the operational lifetime of the scheme, when a natural tidal regime returns following decommissioning and removal of the scheme there is potential for the effects to be reversed. Due to the relatively small predicted decrease in the biomass (which would be representative in general of changes in number of individuals), the magnitude of effect is predicted to be **low**. Consequently, it is assessed that there would be an adverse effect of **moderate** significance.

Mud-Surface Plants and Green Algae

5.4.26 The sub-feature attribute target for mud-surface plants and green algae is provided in Section 5.2, Paragraph 5.2.32. A reduction in intertidal sediment area exposed under this scheme would likely result in a small decrease in the intertidal area available for benthic algae. The changes in intertidal sediment exposure indicated above therefore have the potential to have an adverse effect on this sub-feature attribute. Value/sensitivity is considered to be **high** as intertidal sediments form a sub-feature of the SPA which is a site of international importance. Effects are predicted to be **direct** and **temporary** with a duration of the operational lifetime of the scheme and would likely be reversible following decommissioning and removal of the scheme. Due to the relatively small decrease in the area of exposure of intertidal sediment with the scheme in place, the magnitude of effect is predicted to be **very low**. Consequently, it is assessed that there would be an adverse effect of **minor** significance.

Bird Foraging Space and Time

Exposed Surface Area

5.4.27 In scheme VLHBv3, the area of soft sediment foraging space for shorebirds at low water would be reduced to 95%, 96% and 96% of baseline on spring, intermediate and neap tides respectively (Table 5.2). The area available at high tide would increase on spring, intermediate and neap tides under the scheme (Table 5.3). The increase on the intermediate tide is probably a result of the high water level during intermediate tides being slightly lower when a scheme is in place than during baseline conditions. Passage and wintering bird surveys have identified the main feeding areas on the exposed intertidal flats for the bird species upon which the Mersey Estuary SPA has been designated. Changes in the percentage of these feeding areas which will still be available at spring low water if VLHBv3 is constructed vary for the different species (Appendix 4), with the greatest reduction being for pintail (to 79%), and the least affected species which feeds within the SPA being teal, the whole of their feeding area still being available at low water.

5.4.28 Increases in saltmarsh area (513, 138 and 78 ha) are predicted for high water on spring, intermediate and neap tides (Table 5.3). This substantial increase is likely to be caused by the reduction in spring high water level with scheme VLHBv3 in place by comparison with the baseline situation. Furthermore, encroachment of the saltmarsh by terrestrial vegetation within the areas of saltmarsh which were inundated under baseline but not under the scheme could potentially result in a reduction in the overall extent of intertidal saltmarsh.

5.4.29 At low tide, the area of intertidal rock is predicted to be reduced only slightly to below baseline (Table 5.2).

Wetted Perimeter

5.4.30 In scheme VLHBv3, the length of the wetted perimeter over soft sediment at low water would be changed to ~106%, ~105% and ~102% of baseline on spring, intermediate and neap tides respectively (Table 5.4). The average value of 104% means that, overall, the wetted perimeter length over the soft sediments most used by shorebirds at low water is not predicted to change. However, its length at high tide would be increased to ~165% and ~133% on intermediate and neap tides respectively, and to ~528% on spring tides (Table 5.5). This large increase is an artefact of the modelling which predicts that many small water bodies would appear close to the high water mark when either of the schemes are in place (each of the water bodies having its own wetted perimeter). As these small water bodies have been identified from the modelling as the main reason for the predicted increase, it is considered likely that the length of the wetted perimeter at spring high tide would also be relatively unchanged.

Invertebrate Prey

5.4.31 In scheme VLHBv3, the biomass of the invertebrates in the soft sediment exposed at low water would be reduced to ~93%, ~91% and ~94% of baseline on spring, intermediate and neap tides respectively (Table 5.6), closely following the changes in the area of exposed sediments.

Foraging Time

5.4.32 The area of soft suitable sediment (mud, muddy sand and sandy mud combined) exposed through the tidal cycle is shown for spring, intermediate and neap tides in Figure 5.4. Compared with baseline, VLHBv3 is predicted to delay the time at which the area remaining on the advancing tide is reduced to 400 ha or 200 ha and, by a similar amount, the time at which such areas become exposed on the receding tide on both spring and intermediate tides. The exposed area does not fall below 465 ha at high tide on neap tides (compared with the baseline situation in which the minimum area of exposed soft intertidal sediment is 318 ha). The duration of the foraging period during which the density of birds is low enough for competition to be reduced is expected to mostly increase on spring and intermediate tides compared with baseline (on the intermediate tide with the criterion of 200 ha for assessing bird density, soft sediments are predicted to be exposed throughout the whole of the 735 minutes (6.25 hrs) of the tidal cycle), (Table 5.7).

5.4.33 Sub-feature attribute targets for birds are indicated in Section 5.2, Paragraph 5.2.43.

5.4.34 Based on the information available to date, in terms of the number of birds, there is likely to be, at the most, only a small decrease because of the predicted reduction in the area of feeding grounds available over low tide is so small and because the amount of time for foraging in the intertidal zone at densities low enough for there to be a low risk of serious competition is predicted to be likely to increase on the majority of tides. Value/sensitivity is considered to be **high** as birds are a feature of the SPA which is of international importance. Effects are predicted to be **indirect** and **temporary** with a duration of the operational lifetime of the scheme, with a more natural regime and bird numbers returning following decommissioning and removal of the scheme. Based on present information, as the reduction in foraging space is predicted to be small while foraging time is predicted often to increase, the magnitude of effect is predicted to be **very low**. It is consequently assessed that there would be an adverse effect of **minor** significance.

5.4.35 When considering flight lines, it is not only likely that the barrage would obscure sight lines and so provide cover for approaching birds of prey, but it is also very likely that the barrage would provide perches from which birds of prey could launch attacks against shorebirds on the intertidal flats. It is recognised, however, that the position of the barrage will be some distance from the majority of the feeding grounds, and therefore sight lines for feeding shore birds will for the most part not be reduced. Value/sensitivity is considered to be **high** as birds are a feature of the SPA which is of international importance. Effects are predicted to be **indirect** and **temporary** with a duration of the operational lifetime of the scheme, and would be removed following decommissioning and removal of the scheme. But as raptor predation on shorebirds generally seems to be quite low on large estuaries such as the Mersey, the magnitude of effect is predicted to be **very low**. It is consequently assessed that there would be an adverse effect of **minor** significance.

Water Framework Directive

5.4.36 As indicated in Section 5.2 the Mersey Estuary water body is classified under the WFD as transitional type 3. Type-specific conditions for benthic macroinvertebrates, fish, phytoplankton, macroalgae and angiosperms (saltmarsh) are indicated in Appendix 3.

Invertebrates

5.4.37 Requirements for assessment under the WFD are summarised in Section 5.2. As indicated in the above assessment, the presence of the scheme would likely result in a relatively small reduction of exposed intertidal sediment (especially for mud habitat) at low water. Receptor value/sensitivity is considered to be **medium** as invertebrates are a biological element used for assessment of ecological status under the WFD. Effects are predicted to be **direct** and **temporary** with a duration of the operational lifetime of the scheme, and would likely be reversible following decommissioning and removal of the scheme. The presence of the scheme would likely result in a decrease in the area of intertidal sediment at low water, however, it is not considered that there would be local changes in diversity of abundance within the remaining areas of intertidal habitat. The magnitude of effect is consequently predicted to be **very low** and it is assessed that there would be an adverse effect of **minor** significance.

Fish

5.4.38 Requirements for assessment under the WFD are summarised in Section 5.2. Scheme VLHBv3 would involve the operation of 44 number of turbines, of 8 m runner diameter turning at 60 rpm and there would be no sluices with this scheme. Passage of fish, including migratory fish, could result in injury and mortality through operating turbines on both the ebb tide and flood tides. There also may be incidence of ‘fallback’ of fish resulting in multiple passes through the turbines. A total of four fish passage routes have been incorporated into the scheme to limit injury and mortality of fish. It should be noted that with a scheme generating energy on both the ebb and flood tide the only routes of passage for the fish on both ebb and flood stages of the tidal cycle would be either through generating turbines (as opposed to potentially passing through sluices on the flood tide with the other schemes) or through the fish passage routes. As such this scheme represents the highest risk in terms of potential fish mortality or injury due to turbine strike of the schemes.

5.4.39 Information relating to the potential effects of turbine/sluice passage is provided in Section 5.2. Potential effects are assessed below for the different functional groups of fish present within the Estuary as indicated in Table 3.2.

Marine Stragglers, Estuarine Residents and Freshwater Species

5.4.40 For cod, herring, whiting, sole and plaice the assessment of effect is as indicated for the IBv2 and VLHBv2 scheme and it is considered that there would be an adverse effect of **moderate** significance.

Marine Migrants

5.4.41 The assessment of effect is as indicated for the IBv2 and VLHBv2 scheme and it is considered that there would be an adverse effect of **moderate** significance.

Diadromous Fish

5.4.42 For Atlantic salmon, river and sea lamprey, European eel and sea trout the assessment of effect is as indicated for the IBv2 and VLHBv2 scheme and it is considered that there would be an adverse effect of **major** significance for each of these species.

Phytoplankton

5.4.43 Requirements for assessment under the WFD are summarised in Section 3.3. Information relating to the potential influence of water quality on phytoplankton is provided in Section 4.2 A flushing study has been conducted to indicate the ability of the Estuary to allow pollutants contained in the Estuary to discharge to sea, it was concluded that with the scheme in place the ability of the Estuary to flush was reduced from removal of 25% of a tracer in 2.4 days to removal in 3.4 days. This could have implications in terms of potential for build up of dangerous substances and potential for eutrophication (although this is limited due to the current turbidity within the Estuary) (URS Scott Wilson 2011b). Overall, the assessment of effect is the same as that for the IBv2 and VLHBv2 schemes and it is assessed that there would be an adverse effect of **minor** significance.

Macroalgae

5.4.44 Requirements for assessment under the WFD are summarised in Section 3.3. With a loss of rocky shore habitat of 4-21% at low water across neap to spring scenarios it is likely that the fucoid zone could become more patchily distributed. Further information considered during the assessment is indicated in Section 5.2. Receptor value/sensitivity is considered to be **medium** as macroalgae are a biological element used for assessment of ecological status under the WFD. Effects are predicted to be **direct** and **temporary** with a duration of the operational lifetime of the scheme, and would likely be reversible following decommissioning and removal of the scheme. With the predicted reduction in exposed rocky shore habitat at low water across neap to spring scenarios the magnitude of effect is considered to be **very low**. It is assessed, therefore, that there would be an adverse effect of **minor** significance.

Angiosperms (Saltmarsh)

5.4.45 Requirements for assessment under the WFD are summarised in Section 3.3. The assessment of effect is the same as that for Scheme IBv2 and VLHBv2 and it is assessed that there would be an adverse effect of **major** significance.

Summary

5.4.46 The various sub-feature attribute targets of the SPA and ecological status elements of the WFD have been considered above.

5.4.47 Data available at the end of Stage 3 indicate that although VLHBv3 is not predicted to decrease the length of the wetted perimeter along the tide edge that is used for feeding by many shorebirds on the Mersey, it is predicted to lead to a small reduction in the amount of foraging space exposed and the available prey biomass on the intertidal flats as a whole. On the other hand, VLBHv3 is also expected to lead to a mostly small increase in the amount of time available on many tides for foraging when the density of birds is low enough for competition to be reduced. Thus VLHBv3 is predicted to have both small negative and small positive effects on the foraging environment and modelling would be required to predict the net effect of these contradictory changes on bird survival. The combination of a small increase in the length of foraging time during which the density of birds is low enough for competition to be reduced and a small reduction in one aspect of foraging space make it probable that survival, and therefore numbers, would be changed by only a small amount. Overall, it is not considered that there would be considerable change to the structure and function of the SPA, and consequently an adverse effect on site integrity is not expected and there is potential that there would not be an ecological consenting risk. The sight lines likely to be maintained as the impounding barrage itself could provide cover for approaching raptors and provide them with perches from which to launch their attacks. It is considered likely, however, that this would have a relatively minor effect on mortality rates given the distance of the tidal power scheme from the majority of the feeding areas.

5.4.48 A range of other considerations required during the assessment are indicated in the Summary of Section 5.2. Taking such factors into account the potential for there to be an ecological consenting risk under the SHRA and WFD is indicated in Table 5.12 below. Overall, it is thought that without prevent harm/mitigation measures under the operating regime modelled for this scheme there could be an effect of major significance on fish, saltmarsh extent (SPA sub-feature) and saltmarsh under WFD, and effects of moderate significance on extent of intertidal sediments and presence and abundance of prey species in intertidal sediments. It is considered that there may be ecological consenting risk under WFD associated with fish and saltmarsh, and with the following SPA sub-feature attribute targets under the SHRA (numbers or displacement of birds, extent of intertidal sediments, presence and abundance of prey species in intertidal sediments and saltmarsh habitat extent).

Table 5.12 Summary table of potential risk before application of prevent harm and mitigation measures in relation to SHRA assessment and WFD assessment for the VLHBv3 scheme. ✓ = possible ecological consent risk. * = pending water quality modelling results.

Feature	Potential for ecological consent risk	Potential significance of effect
SPA Sub-feature attribute measure		
Integrity of the SPA	✓	**Minor**
Numbers of birds or bird displacement	✓	Minor
Number of obstructions to existing bird view lines	×	Minor
Extent of intertidal sediments	✓	Moderate
Presence and abundance of prey species in intertidal sediments	✓	Moderate
Presence and abundance of mud-surface plants and green algae	×	Minor
Extent of rocky shore habitat	×	Minor
Presence and abundance of intertidal invertebrates in rocky shore habitats	×	Minor
Extent of saltmarsh habitat	✓	Major
Presence and abundance of prey species in saltmarsh	×	Minor
Presence and abundance of soft-leaved and seed-bearing plants in saltmarsh habitats	×	Minor
Vegetation height throughout areas used for feeding and roosting	×	Minor
WFD elements		
Overall ecological status	✓	**Major**
Invertebrates	×	Minor
Fish (based on consideration of the different groups below)	✓	Major
Diadromous fish:		
Atlantic salmon (European importance)	✓	Major
River/sea lamprey (European importance)	✓	Major
Eel (European importance)	✓	Major
Sea trout (National importance)	✓	Major
Marine migrants:		
Cod, herring, whiting (National importance)	✓	Moderate
Sole, plaice (National importance)	✓	Moderate
Marine stragglers, estuarine residents and freshwater species	×	Minor
Phytoplankton	×	Minor*
Macroalgae	×	Minor
Angiosperms (saltmarsh)	✓	Major

6 Comparison of Schemes

6.1 Area of Habitat Exposed

6.1.1 This comparison is based on assessments before consideration of the application of prevent harm and/or mitigation measures.

6.1.2 One of the key considerations for comparison of schemes from an ecological viewpoint is the change in the extent of intertidal habitat area exposed under each scheme.

6.1.3 Consideration has been given to the changes in area of intertidal habitat exposed throughout the tidal cycle for spring, intermediate and neap tides for the different schemes. To facilitate presentation of results, however, changes under low tide and high tide scenarios have been provided in this comparison for spring and neap tides only. The results under these tide scenarios are generally representative of the relative differences observed throughout the tidal cycle as a whole under the different schemes.

6.1.4 The relative importance of different sediment types for birds has been considered with birds likely to feed on mud, muddy sand and sandy mud habitats while generally avoiding sand areas. Of these habitats in which feeding occurs, mud is likely to provide the most abundant food supply. Consequently, changes in this habitat type have been highlighted below.

6.1.5 As discussed, the values for changes in area of intertidal sediment exposed have been calculated for the Estuary as a whole and for the SPA in isolation. For the purposes of this comparison values for the SPA have been discussed (the values for the Estuary as a whole generally closely reflect the changes within the SPA).

Spring Tide Scenarios

Low Water

6.1.6 Results of the assessment for the three schemes are provided in Table 6.1. When examining reduction in total intertidal sediment during a spring tide it is clear that IBv2 results in the greatest decrease (56% of intertidal habitat lost within the SPA (1928 ha) with a 19% decrease in mud habitat (78 ha)).

6.1.7 The decrease in total area of exposed intertidal sediment is greater than halved with the VLHBv2 scheme (24% of intertidal sediment lost within the SPA (829 ha) with a 4% loss in mud habitat (16 ha)).

6.1.8 The smallest decrease in the area of exposed intertidal habitat with a scheme in place is evident with the VLHBv3 scheme for which there is a 13% reduction in area of exposed intertidal sediment within the SPA (437 ha), with a 3% decrease in exposed areas of mud habitat (11 ha).

6.1.9 For the neap tide scenario the pattern is the same with the VLHBv3 scheme resulting in the smallest decrease in area of exposed intertidal sediment (259 ha, equivalent to 9% of the habitat within the SPA), and a 2% reduction in exposed mud habitat within the SPA (7 ha) (Table 6.2).

Table 6.1 Comparison of decreases in areas of exposed intertidal sediment for different schemes at spring low water

	IBv2				VLHBv2				VLHBv3			
Spring (ha exposed)	Decrease in area of intertidal habitat exposed with scheme		% decrease with scheme		Decrease in area of intertidal habitat exposed with scheme		% decrease with scheme		Decrease in area of intertidal habitat exposed with scheme		% decrease with scheme	
	Estuary	SPA	Estuary	SPA	Estuary	SPA	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified	800	698	95	96	603	537	71	74	314	262	37	36
Mud	84	78	19	19	17	16	4	4	11	11	2	3
Sand	737	708	53	56	174	169	13	13	110	107	8	9
Muddy sand	129	126	51	55	27	27	11	12	20	20	8	9
Sandy mud	355	318	38	40	90	81	10	10	43	37	5	5
Total intertidal sediment	2,104	1,928	55	56	910	829	24	24	498	437	13	13
Rocky intertidal	17	14	61	64	7	6	24	28	1	0	4	2
Saltmarsh	0	0	0	0	0	0	0	0	0	0	0	0

Table 6.2 Comparison of decreases in areas of exposed intertidal sediment for different schemes at neap low water

	IBv2				VLHBv2				VLHBv3			
Neap (ha exposed)	Decrease in area of intertidal habitat exposed with scheme		% decrease with scheme		Decrease in area of intertidal habitat exposed with scheme		% decrease with scheme		Decrease in area of intertidal habitat exposed with scheme		% decrease with scheme	
	Estuary	SPA	Estuary	SPA	Estuary	SPA	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified	266	234	76	78	243	216	69	73	137	113	39	38
Mud	44	41	10	10	30	29	7	7	8	7	2	2
Sand	432	416	32	34	337	325	25	26	92	84	7	7
Muddy sand	72	70	28	30	43	43	17	18	14	14	6	6
Sandy mud	220	200	24	26	181	168	20	22	51	42	6	5
Total intertidal sediment	1,034	962	31	33	833	781	25	27	302	259	9	9
Rocky intertidal	10	8	41	46	11	10	45	53	5	4	21	21
Saltmarsh	0	0	0	0	0	0	0	0	0	0	0	0

High Water

6.1.10 The main consideration for high water is exposure of saltmarsh under the scheme which was not exposed under the baseline scenario. This could lead to saltmarsh encroachment of intertidal sediment and terrestrial plant encroachment of the saltmarsh.

6.1.11 The greatest change in area of both exposed intertidal sediment and saltmarsh at spring high water is evident for the VLHBv3 scheme (513 ha change within the SPA), with the smallest change indicated for the IBv2 scheme (346 ha change) (Table 6.3). This suggests, that of the three schemes, VLHBv3 would result in the greatest risk in terms of encroachment.

6.1.12 For the neap tide scenario the differences noted are far smaller when considering change in saltmarsh area (e.g. 58-77 ha across the three schemes) with the VLHBv3 scheme again resulting in the greatest increase (Table 6.4). For the total intertidal sediment area, under neap tide the change in area for VLHBv3 (254 ha) is far greater than for VLHBv2 (84 ha) and IBv2 (70 ha). So under neap tides VLHBv3 again provides the greatest risk in terms of encroachment.

Table 6.3 Comparison of increases in areas of exposed intertidal sediment for different schemes at spring high water.

	IBv2		VLHBv2		VLHBv3	
Spring (ha exposed)	Increase in area of intertidal habitat exposed with scheme		Increase in area of intertidal habitat exposed with scheme		Increase in area of intertidal habitat exposed with scheme	
	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified	6	5	7	5	12	7
Mud	5	2	4	2	17	10
Sand	3	0	4	0	17	1
Muddy sand	1	0	1	0	4	0
Sandy mud	20	4	19	6	55	21
Total intertidal sediment	35	11	34	13	105	39
Rocky intertidal	0	0	0	0	1	0
Saltmarsh	364	346	394	380	538	513

Table 6.4 Comparison of increases in areas of exposed intertidal sediment for different schemes at neap high water.

	IBv2		VLHBv2		VLHBv3	
Neap (Ha exposed)	Increase in area of intertidal habitat exposed with scheme		Increase in area of intertidal habitat exposed with scheme		Increase in area of intertidal habitat exposed with scheme	
	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified	0	0	1	0	8	3
Mud	38	35	39	40	96	92
Sand	16	7	11	10	81	60
Muddy sand	6	2	3	3	13	8
Sandy mud	31	27	30	31	102	91
Total intertidal sediment	89	70	83	85	300	254
Rocky intertidal	1.9	0.8	2	1.1	4	2
Saltmarsh	59	58	61	61	79	77

Invertebrate Prey Biomass

6.1.13 It is predicted that the IBv2 scheme could result in reduction of ~38% of available invertebrate biomass within the SPA during the spring low tide (212 tonnes). This decrease is reduced considerably with the VLHBv2 scheme (to 13% of invertebrate biomass i.e. 73 tonnes). As would be expected from the results obtained for areas of exposed sediment, however, the smallest decrease in invertebrate biomass is evident for the VLHBv3 scheme (a 9% reduction in the SPA biomass) (Table 6.5).

6.1.14 As described in Section 5.2, however, in addition to the reductions in biomass indicated in the tables below there would be a further reduction in biomass due to the drying out of the uppermost shore with the scheme in place as it would then no longer be colonised by intertidal invertebrates. Therefore, the values in the tables below represent an underestimate of reductions in biomass due to the scheme.

6.1.15 Of the habitat types present, mud is considered to be the most important in terms of availability of invertebrate prey items for birds. The VLHBv3 scheme is predicted to result in just a 5% reduction in the biomass of invertebrates within this habitat (Table 6.5).

6.1.16 The results obtained for a neap tide are in line with the patterns observed under a spring tide scenario. The biomass reduction and percentages of SPA biomass decrease for total intertidal sediment are; IBv2 132 tonnes, 24% of SPA biomass, VLHBv2 100 tonnes 18% of SPA biomass, and VLHBv3 41 tonnes, 7% of SPA biomass. The changes in biomass for specific habitat types also generally follow these proportional changes.

Table 6.5 Comparison of estimated potential changes in available invertebrate biomass for different schemes at spring low water

Spring tide – Invertebrate biomass (tonnes)	IBv2				VLHBv2				VLHBv3			
	Biomass decrease with scheme		% decrease with scheme		Biomass decrease with scheme		% decrease with scheme		Biomass decrease with scheme		% decrease with scheme	
	Estuary	SPA	Estuary	SPA	Estuary	SPA	Estuary	SPA	Estuary	SPA	Estuary	SPA
Unclassified	25	21	95	94	19	17	73	74	19	9	73	38
Mud	35	30	22	19	10	10	7	6	8	8	5	5
Sand	51	57	59	56	16	15	18	18	13	12	14	15
Muddy sand	45	45	52	51	10	10	12	12	9	9	10	10
Sandy mud	84	69	37	32	23	20	10	9	18	16	8	7
Total intertidal sediment	240	212	41	38	78	73	13	13	66	53	11	9

Bird Foraging Space and Time

6.1.17 Relative to baseline 2060, all three schemes show important similarities. None of them significantly change the length of wetted perimeter over the soft sediments used by shorebirds at low tide, and all show some increases in wetted perimeter at high tide. As so many of the shorebirds forage in this zone, this is an important finding. All schemes will reduce the area of saltmarsh, and this may affect the feeding resource for herbivorous birds, additionally this assessment was not able to take into account the effect of changes in the height of high water on the extent of that habitat through invasion by terrestrial species.

6.1.18 All the schemes are predicted to decrease the total invertebrate biomass available for the birds and the area of intertidal rock exposed at low water. The main difference between the schemes is in the predicted magnitudes of their effects on foraging space, food supply and on the length of the foraging period during which the density of birds is low enough for competition to be reduced. These are summarised in Table 6.6. Percentage values are not given for predictions made for high tide because the values could be sensitive to the small sizes of the areas that are often involved. For the individual species for which the SPA is designated, percentage reductions in their feeding areas on the exposed intertidal flats within the Mersey SPA are shown in Table 6.7 for all three proposed schemes. It can be seen that there is a reduction in the areas lost moving from IBv2 to VLHBv2, with reductions in area being least under VLHBv3. Appendix 4 provides the information from which Table 6.7 has been produced.

6.1.19 On all measures, the predicted negative effect on the birds' feeding conditions decreases across the sequence IBv2 to VLHBv2 to VLHBv3. For the species upon which the SPA was designated, little feeding takes place on areas of intertidal rock and food tends to be less available in areas of sand, therefore the most important considerations after the unchanged length of the wetted perimeter are the area of soft sediments suitable for shorebirds (mud, muddy sand and sandy mud), the food supply they contain and the amount of foraging time during which the density of birds is low enough for competition to be reduced. On all three measures, VLHBv3 has less of an effect on the feeding conditions than IBv2 and, to a lesser degree VLHBv2. Indeed, VLHBv3 is predicted to increase the length of the foraging period by an amount that could offset the reduced foraging space over low tide by a significant amount (this is based on reference to the one other Estuary where the importance of foraging time has been studied (Goss-Custard et al. 2006a)).

6.1.20 The predicted effect on bird numbers therefore also decreases across the sequence IBv2 to VLHBv2 to VLHBv3. In VLHBv3, indeed, the loss in feeding space could be offset by the predicted increase on many tides in the duration of the foraging period when bird densities are low enough to reduce competition, although the magnitude of any resulting gain in bird survival has not yet been assessed. Further study will be required to verify the benefit of the increased foraging period, in particular the likely condition of the areas which will be exposed for an increased duration will need to be understood as they may suffer from a degree of change due to lower frequencies of tidal inundation. An impounding barrage is predicted to create a difference in the timing of low water between the impounded basin and the Estuary outside. This would allow birds in the impounded basin to cross the barrage and begin feeding on any mudflats by then exposed in the lower reaches of the Estuary, downstream of the barrage, and extend their the length of the period per tidal cycle when food was available somewhere for them to utilise by perhaps as much as 1-1.5 hours. If birds from the impounded basin flew out to the coasts as well, birds displaced by all three schemes could benefit from this difference in the time of the exposure of the flats within and out with the impoundment.

Water Framework Directive

6.1.21 Effects on the WFD elements invertebrates and macroalgae are considered to decrease across the sequence IBv2 to VLHBv2 to VLHBv3, although the effects are assessed as being of minor significance for all schemes.

6.1.22 Further information regarding water quality is required to fully assess potential effects on phytoplankton, however, at this stage it considered there would likely be an effect of minor significance for all schemes.

6.1.23 Modelling indicates that the areas of saltmarsh exposed at high water would be greater for VLHBv3 than for the other two schemes, therefore, a potential reduction in saltmarsh extent due to possible encroachment by terrestrial vegetation would likely be greatest with the VLHBv3 scheme. It should be noted, however, that a likely effect of major significance on saltmarsh extent is evident with each of the schemes in place.

6.1.24 In addition, the risks to fish would be greatest with the VLHBv3 scheme due to generating turbines operating on both the ebb and flood tide. An impact of major significance is assessed for diadromous fish (and hence fish overall), however, for each of the schemes.

Table 6.6 Comparison of schemes, based on Tables 5.2-5.7. All values are relative to Baseline 2060.

	IBv2	VLHBv2	VLHBv3
Area of soft sediments (mud, muddy sand and sandy mud combined) at:			
Low tide	Decreased by 22-36%	Decreased by 9-17%	Decreased by 4-5%
High tide	Similar or increased (depending on whether spring, intermediate or neap tide)	Similar or increased (depending on whether spring, intermediate or neap tide)	Increased
Area of saltmarsh	Similar or decreased	Similar or decreased	Similar or decreased
Area of intertidal rock at low tide	Decreased by 50-65%	Decreased by 30-50%	Decreased by 0-5%
Length of wetted perimeter ofsoft sediments (mud, muddy sand and sandy mud combined) at:			
Low tide	No change	No change	No change
High tide	Increased	Increased	Increased
Invertebrate biomass	Decreased by 20-30%	Decreased by 9-15%	Decreased by 6-9%
Duration of intertidal feeding time with bird densities <200 ha and <100 ha (NB. Baseline time for exposure of these areas ranges between 8.13 hrs and 9.92 hrs) for spring and intermediate tides	Decreases of between 3.45 and 1.88 hrs	Decreases of between 1.22 and 0.22 hrs	0.33 hr decrease to 2.33 hr increase

Table 6.7 Area in hectares (and percentage of baseline) of feeding area remaining for each species at low spring tide (2060) for the three modelled schemes by comparison with predicted baseline low spring tide (2060).

Species	Baseline (ha)	IBv2 (ha & % of baseline)	VLHBv2 (ha & % of baseline)	VLHBv3 (ha & % of baseline)
Redshank	559	348 (62)	505 (90)	522 (94)
Shelduck	573	398 (69)	518 (90)	533 (93)
Teal	136	118 (87)	135 (99)	136 (100)
Dunlin	732	446 (61)	656 (90)	674 (92)
Pintail	17	3.2 (19)	12.3 (72)	13.4 (79)
Golden Plover		n/a	n/a	N/a
Black-tailed Godwit	236	175 (74)	226 (96)	228 (97)
Curlew	965	659 (69.3)	888 (91.9)	908 (94)

Ecological Consent Risks

6.1.25 The potential effects of each of the schemes in terms of the significance of effect and potential ecological consent risk have been summarised in Table 5.8, 5.10 and 5.12.

SPA Sub-Features

6.1.26 For the IBv2 and VLHBv2 schemes the significance of effect for all sub-feature attribute targets is considered to be major or moderate with the exception of an increase in obstructions to existing bird view lines, presence and abundance of prey species and soft-leaved and seed-bearing plants in saltmarsh habitats and changes to saltmarsh vegetation height. It is considered there is potential for an adverse effect on site integrity (structure and function) for each of the sub-feature attributes assessed as having major or moderate significance, and hence there could be a potential ecological consenting risk to the development under this legislation.

6.1.27 When considering the VLHBv3 scheme it was identified that there were potential effects of major or moderate significance for the extent of intertidal sediments and the presence and abundance of prey species in intertidal sediments. Although the overall effect on integrity of the SPA is expected to be minor, it is considered that there could still be a potential ecological consenting risk to the development under this legislation.

Water Framework Directive

6.1.28 There is unlikely to be an ecological consenting risk associated with the ecological status of invertebrates and macroalgae for all schemes.

6.1.29 It is considered unlikely that there would be an ecological consenting risk in relation to phytoplankton and it is unlikely to be a differentiator among schemes.

6.1.30 There is a potential ecological consenting risk associated with the ecological status of saltmarsh and fish (in particular diadromous fish) for all schemes.

7 Prevent Harm, Mitigation and Compensation

7.1 Approach to Prevent Harm, Mitigation and Compensation Measures

7.1.1 The first objective of the Mersey Tidal Power scheme is 'to deliver the maximum amount of affordable energy (and maximum contribution to carbon reduction targets) from the tidal resource in the Mersey Estuary with acceptable effects on the environment, shipping, business and the community either by limiting a direct effect on the Mersey Estuary or providing acceptable mitigation and/or compensation'. To this aim, where significant ecological effects arise from a scheme, measures have been proposed to firstly prevent harm where possible through alterations to scheme design and/or operation. Where residual effects remain, feasible and acceptable mitigation measures to reduce or prevent ecological consenting risk and adverse effects upon the ecology of the Estuary, and potential compensation measures, have also been proposed. Many of the lessons learnt from the Stage 2 assessment have been applied to the schemes being assessed at this stage as prevent harm measures aimed at reducing effects and resultant potential ecological consenting risk. Potential prevent harm, mitigation and compensation measures for a Mersey Tidal Power scheme as a whole is detailed within Appendix 5 of this document. This table provides a complete list of measures which may be considered but does not imply that all will be implemented at all or at the scale identified as potential.

7.1.2 There are issues of uncertainty in relation to ecological equivalence and coherence that need to be considered when assessing the measures to be implemented and their predicted efficiency. The level of uncertainty will also determine the area and type of habitat likely to be required to mitigate against, or compensate for, exposed intertidal habitat area reduction experienced during the development and/or operation of a scheme and the resultant effects upon the SPA bird interest features and the integrity of the Mersey Estuary Natura 2000 sites (and other local Natura 2000 sites yet to be assessed).

7.1.3 The level of confidence in the ecological equivalence and coherence of mitigation habitat contributes to the ratios applied to assess the area of habitat required. For example if a habitat identified as suitable for providing mitigation habitat is of a quality and standard similar to or of greater value than that which is predicted to experience a reduction in extent it is reasonable to assume that the ratio of mitigation to reduced habitat required is likely to be low i.e. a 1:1 ratio or less. Similarly, if the mitigation habitat is of a lesser quality than the habitat predicted to be reduced then it is reasonable to assume that the ratio of mitigation to reduced habitat is likely to be higher i.e. a 2:1 ratio or greater. Implementation of a higher ratio would aim to counter the uncertainty associated with the confidence in the ability of the mitigation habitat being able to perform the function for which it is being created.

7.1.4 Uncertainty may also arise where the measure is effectively unproven as it is not an established method or practice and/or has not been undertaken on the scale likely to be required for a Mersey Tidal Power scheme and as such is unprecedented. There may also be a requirement to apply a ratio of application if only in the short term where the measure may not be fully functional upon commencement of operation and the effect begins or if the effectiveness of the measure cannot be satisfactorily proven to the statutory authorities in advance of scheme commencement.

7.1.5 The ratio of compensatory to reduced habitat required is likely to depend on the nature of the predicted effect, ecological equivalence and coherence of compensatory habitat, the location of the compensatory habitat and geographical proximity to the predicted area of effect. Compensation ratios are not specified in the Habitats Directive; however, ratios between 1:1 and 100:1 are alluded to in some instances (Kramer, 2009). Ratios for specific measures will be individually assessed, however, there is potential that for habitat creation measures identified requirements for ratios higher than 3:1.may be unlikely.

7.1.6 The issue of site integrity is also an important factor for consideration in determining the approach to mitigation and compensation; for example in the case of an SPA if the carrying capacity of the protected area is demonstrable and a reasonable assumption can be made on the site being able to support a designated bird population with a smaller area than is currently designated, then it may not be necessary to replace all the habitat that is predicted to experience a reduction in extent. If the structure and function of the protected site is such that it can function effectively with a smaller area then it could be inferred that equivalent habitat is not likely to be required.

7.1.7 The survival rate of shorebirds, and therefore the sizes of their populations, is likely to be considerably influenced by the interaction between the amounts they have of foraging space and foraging time during which the density of birds is low enough for competition to be reduced. This interaction does not seem to be such that each factor is as important as the other. Although further work would be highly desirable to confirm this point, present evidence suggests that a given percentage reduction in foraging space has less of an effect on survival than does an equivalent percentage reduction in foraging time (Goss-Custard *et al.* 2006a). Or to put it another way, a small percentage increase in foraging time might be able to mitigate the effect on survival of a much larger percentage loss in foraging space.

7.1.8 Therefore, it would be worthwhile to explore mitigation and compensation measures that would extend the foraging time available to the birds as well as provide replacement foraging space. Possible techniques include tidal regulation devices that impede the inflow of Estuary water into saline lagoons beyond the seawall or porous barriers in the intertidal zone itself that would have the same effect.

7.1.9 Because of the apparently unequal interaction between foraging space and foraging time, caution should be applied when considering ratios of the size of replacement feeding areas to the reduction observed. In principle, it is possible that quite a small replacement mudflat, relative to the size of that lost, could maintain the survival rates of the birds if it prolonged the foraging time sufficiently. It has been calculated by individual-based modelling, for example, that a 25 ha lagoon would have compensated for the loss of the 250 ha of Cardiff Bay if it extended the foraging time on spring tides by under one hour per tidal cycle (Goss-Custard *et al.* 2006a).

7.1.10 If such measures are successful in maintaining the birds' survival rates and body conditions at their present-day SPA levels, the carrying capacity of the estuary would be said to have been unaffected and so the integrity of the site would be maintained because the Estuary would still be providing the function it does for these populations, just as well as it does now. Indeed, such measures might even increase survival rates above present-day levels.

7.1.11 To mitigate for any lost foraging space for the birds that feed in the Mersey Estuary itself, the measures would need to be provided locally, and may need to be species specific. The Mersey populations, however, contribute to the wider populations. Indeed, one of the purposes of SPAs such as the Mersey is to contribute to the Natura network of sites that allows these highly migratory animals to move around at a large geographic scale.

7.1.12 This means that one can consider compensation measures that are not local to the Mersey. If measures can be found to increase the survival rate of these bird species elsewhere in their passage and wintering range, the meta-population of which the Mersey birds are a part will be increased. Indeed, the same effect would be achieved by raising the reproductive rate of the birds because the size of a population is brought about by the interaction between survival and reproductive rates. In most circumstances, increasing the reproductive rate by, for example, increasing the limited area of breeding habitat (e.g. grazing rank saltmarsh to encourage breeding redshank) or reducing egg and chick losses through predator control, should increase population size (Goss-Custard 1993). Clearly, however, measures in the breeding season could only be applied to British-breeding birds but, then, several of the designated species in the Mersey Estuary do breed in Britain. In particular, redshank and shelduck (two of the designating species) breed locally and their breeding numbers and output might be increased by providing additional suitable habitats, for example, by managing appropriately the saltmarshes of the Mersey estuary.

7.1.13 Finally, there is the possibility that mitigation would not be necessary if one is concerned about the maintenance of the meta-population. Some evidence suggests that estuaries in south-west England and in Wales are losing shorebirds because, with climate change, they are more able to spend the winter in areas to the north and east that are nearer to their breeding grounds. This could mean that spare carrying capacity is currently being released which could accommodate any birds displaced from the Mersey.

7.1.14 With this idea in mind, a final step could be to provide compensation that does not necessarily benefit the species directly affected by any loss of feeding grounds on the Mersey, but 'does something' for conservation as a whole. For example, reed-bed wetlands are much valued and some might consider that a large extension somewhere in the UK in the area of this habitat to be an acceptable compensation for any loss of mudflats on the Mersey Estuary, especially if that loss is not predicted to have a large effect on bird numbers there. Indeed, any changes to the intertidal habitat which result from the installation and operation of a tidal power scheme could result in the establishment of conditions which are attractive to species which currently overwinter in estuaries to the south of the Mersey. If the general trend of species moving to the north and east continues, then these species could spend more time on intertidal areas within the Mersey Estuary in the future.

7.2 Application of Potential Measures to the Different Schemes

7.2.1 Prevent harm measures are measures which would be implemented as part of the design and operational regime of each of the schemes to limit direct and indirect effects on ecology (for further information on the schemes assessed see Table 2.1. Mitigation and/or compensation measures are not related to scheme design (i.e. structures integral to operation of the scheme) or operational regime and could contribute to offsetting any ecological effects. These items have a capital cost (and potential operational cost) but are not expected to have an effect of significance on energy output of the scheme. The cost for these items would likely be lower than the cost related to the energy output penalties when implementing the operational prevent harm measures indicated in Appendix 5.

7.2.2 As indicated above a range of prevent harm, mitigation and compensation measures have been identified which could potentially be applied to ameliorate adverse effects of the schemes on estuarine ecology. These measures are summarised in the table in Appendix 5. For each scheme the effects on the SPA sub-feature attribute targets and WFD elements have been addressed before and after application of the measures (Table 7.1, 7.2 and 7.3). The significance of effect following implementation of these measures is termed the residual significance of effect. Based on the information available to date, professional judgement has been used to estimate the likely benefits provided by the prevent harm and mitigation measures considered. It is expected that based on further information, these likely benefits will be clarified and where possible quantified more accurately, to refine the assessment for future options for a tidal power scheme.

IBv2 Scheme

7.2.3 Before implementation of prevent harm and mitigation measures it has been assessed that there would likely be effects of major significance on numbers or displacement of birds, extent of intertidal sediments, presence and abundance of prey species in intertidal sediments, extent of rocky shores and saltmarsh extent (SPA and WFD) and fish (including UK BAP species and those of European importance). Effects of moderate significance have been predicted for mud-surface plants and green algae and invertebrates on rocky shores.

7.2.4 For IBv2 with prevent harm and mitigation measures in place none of the effects are considered to be of major significance. There would be residual effects of moderate significance for seven of the potential effects identified in Table 7.1 (numbers or displacement of birds, extent and distribution of intertidal sediments, presence and abundance of prey species in intertidal sediments, extent and distribution of rocky shores and saltmarsh extent and distribution (SPA and WFD) and fish (diadromous species)) and it is considered that compensation would likely be required for six of these effects in addition to the prevent harm and mitigation package (it is considered unlikely that compensation would be required for extent and distribution of rocky shore habitat although it was assessed to be an effect of moderate significance due to the fact that changes to this sub-feature are not likely to have a considerable effect on birds). Given the extent of the sub-features lost due to the high-head (at all times) generation scheme proposed for IBv2 it is concluded that there may be ecological consenting risk when considering both SPA integrity and the WFD.

VLHBv2 Scheme

7.2.5 Before implementation of prevent harm and mitigation measures effects of major significance have been predicted for numbers or displacement of birds, extent of intertidal sediments, presence and abundance of prey species in intertidal sediments, extent of rocky shores, saltmarsh extent and fish (including UK BAP species and those of European importance), with effects of moderate significance on mud-surface plants and green algae and invertebrates on rocky shores.

7.2.6 Following application of prevent harm and mitigation measures none of the effects are considered to be of major significance for the VLHBv2 scheme (Table 7.2). There would be residual effects of moderate significance on five of the sub-feature attribute targets/WFD elements (extent and distribution of intertidal sediments, presence and abundance of prey species in intertidal sediments and saltmarsh extent and distribution (SPA and WFD) and fish (diadromous species)). It is considered that compensation could possibly be required for effects on six of these SPA sub-feature attributes/WFD elements in addition to the prevent harm and mitigation package (although effects on numbers or displacement of birds were predicted to be of minor significance it is considered that requirements for compensation would still be possible). It is considered, therefore that there may be ecological consenting risk when considering both SPA integrity (although effects on SPA integrity are predicted to be minor) and the WFD.

VLHBv3 Scheme

7.2.7 Prior to implementation of prevent harm and mitigation measures it has been assessed that there could be effects of major significance on numbers or displacement of birds, extent and distribution of saltmarsh habitat and fish (including UK BAP species and those of European importance), with effects of moderate significance on extent and distribution of intertidal sediments and presence and abundance of prey species in intertidal sediments.

7.2.8 If prevent harm and mitigation measures are applied with scheme VLHBv3 as indicated in Table 7.3 it has been assessed that none of the effects would be of major significance (Table 7.3). There would be residual effects of moderate significance for three of the sub-feature attribute targets/WFD elements (extent and distribution of saltmarsh habitat (SPA and WFD) and fish (diadromous species). Compensation may be required in addition to the prevent harm and mitigation measures for these effects and effects on three of the other SPA sub-feature attribute targets/WFD elements (numbers or displacement of birds, reduced extent and distribution of intertidal sediments and reduced presence and abundance of prey species in intertidal sediments), this is despite the fact that effects on these attributes were assessed to be of minor significance following the application of prevent harm/mitigation measures. It is considered, therefore that there may be ecological consenting risk when considering both SPA integrity (although effects on SPA integrity are predicted to be minor) and the WFD.

7.2.9 Based on this information, from an ecological point of view the VLHBv3 scheme would have least ecological effects of the three schemes following the use of prevent harm measures and mitigation. There are some specific approaches that could be applied to each of the three schemes to further reduce effects, and these will be explored in the following section in which the elements of a preferred scheme will be outlined.

Table 7.1 Potential significance of effects of scheme IBv2 before and after the implementation of both Prevent Harm measures and Mitigation measures.*=pending results of water quality modelling.

Impact	Estimated significance	Prevent Harm (PH) & Mitigation (M) Package	Estimated significance after measures	Compensation required?
SPA Sub-features				
Integrity of SPA	**Major**	**Encompasses all measures below**	**Moderate**	**Possible**
Significant reduction in numbers or displacement of birds from an established baseline	Major	**PH**: Alterations to operation and tidal flood regime, predator control, caisson placement for sediment deposition, accretion guide walls. **M:** creation of new lagoons, promoting recovery of unfavourable SSSI/SPA units, elevation of existing subtidal habitat, placement of artificial structures to enhance sedimentation.	Moderate	Possible
Increase in obstructions to existing bird view lines	Minor	Not required	Minor	Unlikely
Reduced extent of intertidal sediments	Major	**PH**: Alterations to operation and tidal flood regime, predator control, caisson placement for sediment deposition, accretion guide walls. **M**: creation of new lagoons, promoting recovery of unfavourable SSSI/SPA units, elevation of existing subtidal habitat, placement of artificial structures to enhance sedimentation.	Moderate	Possible
Reduced presence and abundance of prey species in intertidal sediments	Major	see package proposed for "Reduced extent and distribution of intertidal sediments"	Moderate	Possible
Reduced presence and abundance of mud-surface plants and green algae	Moderate	see package proposed for "Reduced extent and distribution of intertidal sediments"	Minor	Unlikely
Reduced extent of rocky shore habitat	Major	**PH**: Alterations to operation and tidal flood regime **M**: creation of artifical rock structures in the intertidal zone.	Moderate	Unlikely
Reduced presence and abundance of intertidal invertebrates in rocky shore habitats	Moderate	see package proposed for "Reduced extent and distribution of intertidal sediments"	Minor	Unlikely
Reduced extent of saltmarsh habitat	Major	**PH**: Alterations to operation and tidal flood regime (e.g. sluicing to increase flood flows, high tide pumping) **M**: promoting recovery of unfavourable SSSI/SPA units.	Moderate	Possible
Reduced presence and abundance of prey species in saltmarsh	Minor	Not required	Minor	Unlikely
Reduced presence and abundance of soft-leaved and seed-bearing plants in saltmarsh habitats	Minor	Not required	Minor	Unlikely
Reduction to vegetation height throughout areas used for feeding and roosting	Minor	Not required	Minor	Unlikely
WFD elements				
Overall ecological status	**Major**	**Encompasses all measures below**	**Moderate**	**Possible**
Change to ecological status of invertebrates (intertidal and subtidal)	Minor	Not required	Minor	Unlikely
Change to ecological status of fish	Major	**PH**: Fish-friendly turbines and passage routes, channel fixing, fish screening, noise effect reduction, predator control, timing of works **M**: Fish trapping, herding and stocking, fisheries buyout.	Moderate	Possible
Change to ecological status of phytoplankton	Minor*	Not required	Minor	Unlikely
Change to ecological status of macroalgae	Minor	Not required	Minor	Unlikely
Change to ecological status of saltmarsh	Major	see package proposed for "Reduced extent and distribution of saltmarsh habitats"	Moderate	Possible

Table 7.2 Potential significance of effects of scheme VLHBv2 before and after the implementation of both Prevent Harm (PH) measures and Mitigation (M) measures.*=pending results of water quality modelling.

Impact	Estimated significance	Prevent Harm & Mitigation Package	Estimated significance after measures	Compensation required?
SPA Sub-features				
Integrity of SPA	**Moderate**	**Encompasses all measures below**	**Minor**	**Possible**
Significant reduction in numbers or displacement of birds from an established baseline	Moderate	**PH**: Alterations to operation and tidal flood regime, predator control, caisson placement for sediment deposition, accretion guide walls. **M:** creation of new lagoons, promoting recovery of unfavourable SSSI/SPA units, elevation of existing subtidal habitat, placement of artificial structures to enhance sedimentation.	Minor	Possible
Increase in obstructions to existing bird view lines	Minor	Not required	Minor	Unlikely
Reduced extent of intertidal sediments	Major	**PH**: Alterations to operation and tidal flood regime, predator control, caisson placement for sediment deposition, accretion guide walls. **M**: creation of new lagoons, promoting recovery of unfavourable SSSI/SPA units, elevation of existing subtidal habitat, placement of artificial structures to enhance sedimentation.	Moderate	Possible
Reduced presence and abundance of prey species in intertidal sediments	Major	see package proposed for "Reduced extent and distribution of intertidal sediments"	Moderate	Possible
Reduced presence and abundance of mud-surface plants and green algae	Moderate	see package proposed for "Reduced extent and distribution of intertidal sediments"	Minor	Unlikely
Reduced extent of rocky shore habitat	Moderate	**PH**: Alterations to operation and tidal flood regime **M**: creation of artifical rock structures in the intertidal zone.	Minor	Unlikely
Reduced presence and abundance of intertidal invertebrates in rocky shore habitats	Moderate	see package proposed for "Reduced extent and distribution of rocky shore habitat"	Minor	Unlikely
Reduced extent of saltmarsh habitat	Major	**PH**: Alterations to operation and tidal flood regime (e.g. sluicing to increase flood flows, high tide pumping) **M**: promoting recovery of unfavourable SSSI/SPA units.	Moderate	Possible
Reduced presence and abundance of prey species in saltmarsh	Minor	Not required	Minor	Unlikely
Reduced presence and abundance of soft-leaved and seed-bearing plants in saltmarsh habitats	Minor	Not required	Minor	Unlikely
Reduction to vegetation height throughout areas used for feeding and roosting	Minor	Not required	Minor	Unlikely
WFD elements				
Overall ecological status	**Major**	**Encompasses all measures below**	**Moderate**	**Possible**
Change to ecological status of invertebrates	Minor	Not required	Minor	Unlikely
Change to ecological status of fish	Major	**PH**: Fish-friendly turbines and passage routes, channel fixing, fish screening, noise effect reduction, predator control, timing of works **M**: Fish trapping, herding and stocking, fisheries buyout.	Moderate	Possible
Change to ecological status of phytoplankton	Minor*	Not required	Minor	Unlikely
Change to ecological status of macroalgae	Minor	Not required	Minor	Unlikely
Change to ecological status of saltmarsh	Major	see package proposed for "Reduced extent and distribution of saltmarsh habitats"	Moderate	Possible

Table 7.3 Potential significance of effects of scheme VLHBv3 before and after the implementation of both Prevent Harm (PH) measures and Mitigation (M) measures.*=pending results of water quality modelling.

Impact	Estimated significance	Prevent Harm & Mitigation Package	Estimated significance after measures	Compensation required?
SPA Sub-features				
Integrity of SPA	**Moderate**	**Encompasses all measures below**	**Minor**	**Possible**
Significant reduction in numbers or displacement of birds from an established baseline	Minor	Not required	Minor	Possible
Increase in obstructions to existing bird view lines	Minor	Not required	Minor	Unlikely
Reduced extent of intertidal sediments	Moderate	**PH**: Alterations to operation and tidal flood regime, predator control, caisson placement for sediment deposition, accretion guide walls. **M**: creation of new lagoons, promoting recovery of unfavourable SSSI/SPA units, elevation of existing subtidal habitat, placement of artificial structures to enhance sedimentation.	Minor	Possible
Reduced presence and abundance of prey species in intertidal sediments	Moderate	see package proposed for "Reduced extent and distribution of intertidal sediments"	Minor	Possible
Reduced presence and abundance of mud-surface plants and green algae	Minor	Not required	Minor	Unlikely
Reduced extent of rocky shore habitat	Minor	Not required	Minor	Unlikely
Reduced presence and abundance of intertidal invertebrates in rocky shore habitats	Minor	Not required	Minor	Unlikely
Reduced extent of saltmarsh habitat	Major	**PH**: Alterations to operation and tidal flood regime (e.g. sluicing to increase flood flows, high tide pumping) **M**: promoting recovery of unfavourable SSSI/SPA units.	Moderate	Possible
Reduced presence and abundance of prey species in saltmarsh	Minor	Not required	Minor	Unlikely
Reduced presence and abundance of soft-leaved and seed-bearing plants in saltmarsh habitats	Minor	Not required	Minor	Unlikely
Reduction to vegetation height throughout areas used for feeding and roosting	Minor	Not required	Minor	Unlikely
WFD elements				
Overall ecological status	**Major**	**Encompasses all measures below**	**Moderate**	**Possible**
Change to ecological status of invertebrates	Minor	Not required	Minor	Unlikely
Change to ecological status of fish	Major	**PH**: Fish-friendly turbines and passage routes, channel fixing, fish screening, noise effect reduction, predator control, timing of works **M**: Fish trapping, herding and stocking, fisheries buyout.	Moderate	Possible
Change to ecological status of phytoplankton	Minor*	Not required	Minor	Unlikely
Change to ecological status of macroalgae	Minor	Not required	Minor	Unlikely
Change to ecological status of saltmarsh	Major	see package proposed for "Reduced extent and distribution of saltmarsh habitats"	Moderate	Possible

8 Recommendations for Final Scheme

8.1 Lessons From the Different Schemes

8.1.1 Based on the results of the modelling and for the operational regimes assessed it is evident from an ecological point of view that the VLHBv3 scheme would result in a tidal regime closest to that under baseline with the smallest change in exposed area of intertidal sediments at low tide. At high tide, however, the VLHBv3 scheme could result in the greatest reduction in saltmarsh habitat due to encroachment by terrestrial vegetation. Overall taking this consideration into account, however, it is considered that this scheme under this operational regime would pose the least risk to attainment of targets for sub-features of the SPA and to the structure and function (and thereby integrity) of the SPA.

8.1.2 When considering the results of the hydrodynamic/sediment exposure modelling it should be noted that they,have been undertaken without detailed modelling to indicate how the sediment transport regime in the Estuary may change with each of the different schemes in place. It could be that for each of the schemes areas of natural deposition of sediment could develop resulting in the formation of new areas of intertidal sediment which could counter some of the modelled decreases in intertidal area. Similarly, there may be areas of increased erosion which have not been incorporated into the model. Each scheme could have a different effect on the sedimentation regime within the Estuary and with this information the values provided for changes in intertidal area would likely be modified. In addition, the effects may change in relation to the layout of turbines/sluices. As such the assessment has been conducted assuming the potential situation on the first day after commencement of operation of the scheme and has not incorporated the modelling of future changes in sediment accretion/erosion at this stage.

8.1.3 To meet the targets of the WFD the main consideration with each of the schemes is the potential effect on fish. Due to the type and numbers of turbines involved and the potential for injury and mortality of fish during passage, there is a risk to WFD status of the Estuary for this element for each of the schemes. Of the three schemes assessed, the risks with VLHBv3 are expected to be the greatest as this scheme would generate energy on both the ebb and flood tide. There would be no sluices with this scheme Routes for passage for the fish on both ebb and flood stages of the tidal cycle would therefore be restricted to generating turbines (as opposed to potentially passing through sluices on the flood tide with the other schemes), free wheeling turbines at the end of the tidal cycle (when the head is not sufficient for turbines to be operational), or the fish passage routes.

8.1.4 During Stage 3 lessons have been learned in relation to the benefits of enabling a flexibility of scheme operation such as the use of ebb only or ebb and flood generation during different tidal states. Different operational regimes could potentially be applied to reduce the environmental effects of each scheme, in particular schemes IBv2 and VLHBv2. This refining of scheme design would be explored further at the next stage of the study with the aim of proposing a preferred scheme which could have reduced effects and present a reduced risk to the ecology of the Estuary. Some examples of changes to operational regime which could be beneficial are provided below for each scheme. These operational changes, however, have been derived for ecological consideration. To meet the aims of the study, consideration will also be required of the implications of the changes upon technical feasibility and the commercial viability of the development.

IBv2

8.1.5 Low tide sluicing and a hold period were considered as one option to potentially increase the extent of intertidal areas exposed at low tide, and as such were incorporated into the IBv2 operational regime assessed at this stage. The results of running the hydrodynamic modelling for the IBv2 scheme (which incorporates sluicing and a hold period) were compared with results obtained for the same scheme design assessed at Stage 2 (IBv1). It was found that in terms of area exposed there was very little difference between the schemes (i.e. 59 more hectares exposed with sluicing) which is unlikely to represent a significant difference, especially when taking into account the likely variability in the model outputs and model constraints.

8.1.6 One of the effects of scheme IBv2, in addition to a reduction in the area of exposed intertidal habitat at low tide, is that high water is lower than for the baseline scenario. This could potentially result in a reduction in saltmarsh area due to encroachment by terrestrial vegetation. Increasing the number of sluice gates for sluicing at high tide could help the recovery of basin water levels on the flood tide resulting in increased high water levels and reducing the area potentially affected by encroachment.

8.1.7 The most effective prevent harm measures for a scheme such as IBv2 would involve changes to operational regime to optimise area of the intertidal zone exposed, wetted perimeter and feeding time. For example, Stage 2 studies and the assessments within Section 5 of this document, have indicated that the greater the proportion of ebb and flood energy generation the better this is in terms of the areas of intertidal sediments exposed at low tide and the available feeding time for birds. It is important to consider, however, that results of the modelling indicate that ebb and flood generation results in the greatest reduction in water level at high tide and increased potential for saltmarsh encroachment by terrestrial vegetation when compared to ebb only generation.

8.1.8 The IBv2 scheme, as modelled for the assessment, only generates energy on the ebb tide. In light of the above points a scheme option enabling flexible operation (i.e. ebb and flood, and ebb only generation) would be preferential. The following variations to operating regime are considered in relation to the unrestricted head operation represented by IBv2 (as opposed to restricted head operation), although application of both ebb and flood generation would result in a different scheme to IBv2.

8.1.9 Within the Mersey Estuary the lower shore sediments exposed on the lowest spring tides are generally sandy substrates which are generally considered to be relatively poor in terms of value for feeding of SPA bird features. The muddier habitats which are found within the mid to upper intertidal areas provide richer food sources for the birds and are, therefore, of greater value ecologically. As described within the assessment section for the IBv2 scheme, under the operational regime modelled there would be a reversal in tide height with neap tides having the lowest low water and spring tides having the highest high water. Under this scenario, a scheme option which operates during ebb and flood on spring tides would have the greatest advantage in terms of exposure of the mid to upper reaches of the intertidal zone for longer periods of time. If this was not possible the next best option would be to utilise ebb and flood generation on lower than mean intermediate tides in order to increase the exposed area of mid to upper intertidal sediments and increase available bird feeding time.

8.1.10 One consideration with this approach is that it would create a different tidal regime for the organisms present within the Estuary with an unusual sequence of periods of low water when compared to baseline (i.e. without a scheme in place). Taking this approach it is considered that no new areas would become intertidal which were not intertidal under the baseline tidal regime and, as such, it is expected that the invertebrate assemblages present would be able to adapt to the new regime.

8.1.11 This approach would result in a scheme option with increased extent of key bird feeding habitats within the mid and upper intertidal zone on intermediate tides and the length of wetted perimeter and time of exposure would also be greatly improved on these tides when compared with IBv2. One disadvantage of ebb and flood generation is that the level of high water is reduced resulting in a greater risk of encroachment of saltmarsh by terrestrial vegetation which could potentially result in the upper shore becoming invertebrate impoverished as a result of continual exposure. Leaving the spring tide (highest high water under the scheme) as ebb generation only would, therefore, help maintain high water on these tides which would ensure periodic wetting of the saltmarsh and upper intertidal. This could be combined with increased flood tide sluicing at high tide as described above to augment water levels in the basin.

8.1.12 One consideration that has been explored is the potential to conduct ebb generation as the primary mode of operation but change to ebb and flood generation for a period of months during key ecological periods for birds (e.g the winter months). With this approach it is considered that some invertebrates may be within an intertidal area during ebb and flood generation but this would become subtidal when ebb only generation was conducted. There is a question, however, as to how rapidly individual organisms of a particular species would be able to adapt from being subtidal for most of the year to being intertidal for a few months when they would experience the stresses of intertidal conditions such as desiccation and an inability to filter feed while the tide is out. Consequently, such an approach would need to be managed in a more periodic manner such as utilising ebb and flood generation on lower than mean intermediate tides as described above.

8.1.13 Another aspect to examine is the potential for diurnal variation in ebb and flood and ebb only generation and whether this would be beneficial to waders and wildfowl. Ebb and flood generation would produce the most consistent supply of energy (as it is generated on the rising and falling ebb and flood tide as opposed to the generation of energy on ebb tides only) and this could be applied to coincide with periods of peak energy demand. It is considered that any opportunities to conduct ebb and flood generation would be beneficial in terms of increasing the exposure of intertidal habitats and the time available for bird feeding as many waders and wildfowl feed at night as well as during the day. This approach would be dependent on the timing of appropriate tides each day.

VLHBv2

8.1.14 The main differences between IBv2 and VLHBv2 are that IBv2 utilises a head of water of up to 5-6 m to generate energy whereas VLHBv2 utilises a restricted head of 3 m, and IBv2 would have fewer turbines (28) than VLHBv2 (44). The assessments conducted for the schemes indicate that overall effects would be reduced when generating energy with the restricted head (i.e. the VLHBv2 scheme).

8.1.15 The operational prevent harm measures indicated above for the IBv2 scheme are also applicable to the VLHBv2 scheme. For example, increased flood tide sluicing at high tide could be used to raise water levels within the basin and reduce the area of saltmarsh potentially encroached by terrestrial vegetation and limit reductions in terms of areas of exposed sediment in the upper intertidal zone. Utilising ebb and flood generation on certain tides (e.g. lower than the mean intermediate tides) and on a diurnal basis as discussed above, could be beneficial for ecology in terms of the area of intertidal sediments exposed and increases in the feeding time available for waders and wildfowl.

8.1.16 A consideration of VLHBv2 is that the assessment has indicated that the use of restricted head generation would be better in ecological terms than an unrestricted head scheme (e.g. IBv2), however, the requirement for 44 generating turbines for VLHBv2 may not be feasible. A potential variant would be a restricted head barrage with 28 generating turbines and a larger number of sluices. It has been found that using sluices at low water only at the end of the generating cycle would likely have a minor effect on areas of exposed soft sediments. By using sluices to manage basin water levels throughout the tidal cycle, however, it is considered by the Project team that using fewer turbines and more sluices could be used to closely replicate the tidal regime observed under the VLHBv2 scheme (i.e. resulting in similar reductions in areas of exposed intertidal sediments and invertebrate biomass as indicated in Section 5 of this document for VLHBv2). Although fish can be injured during sluice passage the risks are far lower than when passing through turbines One benefit of this proposed variant is that the reduced number of turbines (and as a result, a reduced water flow through the turbines) could therefore result in a lower risk of fish injury/mortality and a greater flow of water through the sluices would facilitate fish passage.

VLHBv3

8.1.17 As indicated in the assessment conducted in Section 5 of this document the VLHBv3 scheme has the least effect on ecology of the three schemes examined and under the operational regimes assessed. One of the main disadvantages of this scheme, however, is that high water is lower than for the other two schemes and that the expanse of saltmarsh which could potentially be encroached by terrestrial vegetation is greatest. As mentioned above for IBv2, sluicing at high tide and increasing the number of sluices used could be implemented to limit this effect under this scheme, modelling conducted to date suggests that sluicing at low tide only would likely have a limited effect on areas of exposed soft sediments.

8.2 Recommendations for Preferred Scheme

8.2.1 When assessing the potential effects of a Mersey Tidal Power scheme on ecology, focus has been placed on species and habitats of conservation importance. In particular, assessments have been made of potential effects on SPA interest and sub-features and WFD biological elements. Following assessment it was considered that each of the three schemes could have effects of minor significance on ecological status of three of the five WFD biological elements before application of prevent harm and mitigation measures (invertebrates, macroalgae and phytoplankton). They would, therefore, be unlikely to present an ecological consenting risk for these elements. The other two biological elements used to assess ecological status of the Estuary are fish and angiosperms (saltmarsh flowering and seeding plants) for which effects of moderate significance were predicted after the use of prevent harm and mitigation measures. As these elements could potentially present some ecological consenting risk under the WFD possible compensation measures would likely need to be explored. Overall, however, these potential effects on WFD biological elements (and overall ecological status of the Estuary under the WFD) are not expected to differentiate between schemes.

8.2.2 In addition, prior to the impact assessment it was considered that potential effects on marine mammals would be common to each of the three schemes assessed and would be unlikely to differentiate between them.

8.2.3 The main receptors for which the significance of effect varies, thereby differentiating schemes, are the SPA sub-feature attributes associated with extent of habitats, prey species presence and abundance (i.e. invertebrate biomass) and interest feature attributes associated with birds (which are reliant on habitat extent and prey availability).

8.2.4 The sample schemes developed and assessed during the feasibility study have tested the performance of a range of scheme parameters (technology, location, engineering design and operating regime) against the broad spectrum of technical, consenting and financial criteria summarised on the decision making framework.

8.2.5 The sample schemes assessed at Stage 3 represent the extremes of performance; of the three schemes assessed IBv2 represents the best energy scheme and VLHBv3 represents the best scheme in terms of limiting environmental impacts. By identifying the issues arising from these two extremes it is now possible to identify a preferred scheme that is considered to best meet the project objectives and be taken forward for further development.

8.2.6 It should be noted, however, that although VLHBv3 represents the best scheme in terms of limiting environmental impacts this was the worst scheme economically and is not considered to be financially viable (URS Scott Wilson 2011c).

8.2.7 A number of variables could be applied to the operating regime to develop a preferred scheme which considers both energy output and limits potential environmental effects. It may be considered appropriate to use a different operating regime at certain times of year, for example such that maximum intertidal habitat exposure is achieved when overwintering bird populations are present in the Estuary. A level of exposure would need to be maintained throughout the year for these intertidal habitats to maintain invertebrate populations to provide suitable feeding habitat for birds. A significant shift in operation between summer and winter has therefore not been recommended, but smaller seasonal shifts (or changes to operation in extreme weather conditions) may be beneficial.

8.2.8 The Stage 3 assessment has found that overall, without the use of prevent harm/mitigation measures, it is considered likely that the length of the soft sediment wetted perimeter (where birds tend to feed) at high tide would not decrease for any of the scheme variants assessed, and the same would be expected for the preferred scheme. This is important as birds tend to feed at the water's edge. Based on the 2D modelling outputs for IBv2 and VLHBv3, the impacts on the available duration of bird feeding time have been investigated to identify a preferred regime, for example, under one operating regime it has been found that at low water on spring tides, the preferred scheme could be expected to decrease the time available for birds to feed at appropriate densities by around 2.33-3.45 hours (based on the IBv2 model outputs, which could be improved by the use of additional sluice gates). However at low water on some intermediate tides (when the operating regime could be switched to restricted head ebb and flood operation) the preferred scheme could be expected to increase the time available for birds to feed by 0.33-2.3 hours (based on VLHBv3 model outputs, which could also be improved by the use of additional sluice gates). On neap tides, it is considered there would likely be no reduction in feeding time compared to baseline.

8.2.9 An initial representative operating regime for the preferred scheme design has been identified based on the conclusions of the studies undertaken to date. On the spring tide, when the volume of water passing the structure is greatest and the greatest amounts of renewable energy can be yielded, generation could use an unrestricted head and take place on the ebb tide only. This mode of operation could also be used on the neap tides when ebb and flood generation would be operationally more difficult (based on experience at La Rance, which has found the number of gate and turbine operations required for ebb and flood generation on restricted amplitude tides to be impractical). On smaller tides, however, when the potential energy yield is less, generation could take place on both ebb and flood tides, using a more restricted head, to enable the upper and mid intertidal habitats that are most important for birds' feeding to be exposed for more time and to a greater extent.

8.2.10 Consequently, the preferred scheme would employ a range of operational modes (use of unrestricted/restricted head and ebb only or ebb and flood generation) depending on the stage of the tidal cycle. There would still likely be effects of moderate significance on some of the SPA sub-features (mainly the sub-features which are based on extent and distribution) after application of prevent harm and mitigation measures. For example, use of the unrestricted head (and ebb only) operational mode during spring tides would likely produce an effect of moderate significance on the extent and distribution of intertidal sediments with these measures in place - however, during intermediate and neap tides the change in operational mode to a low head (with ebb and flood energy generation) would reduce the loss of exposed intertidal area. When employing the three modes of operation the lowest sections of intertidal shore would still be lost. It should be noted, however, that these sections of lower shore cover a relatively small area and are of lesser importance in terms of abundance of prey items for birds than areas in the mid to upper intertidal zone. A large percentage of the current intertidal area would therefore remain as intertidal and the presence and abundance of invertebrate species, which the overwintering and passage birds feed upon, should remain at levels which maintain the fitness of the birds, and hence the integrity of the SPA. Unrestricted head operation where possible would also maintain a high water level which would minimise the reduction in saltmarsh, another sub-feature of the SPA. Considering the levels of effect to the different sub-features which are likely to result from the operation of the preferred scheme, it is concluded that this scheme could potentially have a limited ecological consenting risk from a HRA perspective, although, there may be further ecological consenting risk in relation to ecological status of the Estuary under the WFD.

8.2.11 Optimisation of the initial representative operating regime described above would include:

- Assessment of the beneficial and potential adverse impacts of high tide pumping on some generating cycles;
- Identification of appropriate seasonal changes operation;
- Further modelling of potential impacts on bird populations (such as Individual Bird Modelling) to identify operational measures that prevent harm to be balanced with other measures to mitigate impacts (with consideration of impacts on the renewable energy output);
- Number and placement of turbines and sluices and operating sequence;
- Modelling of sediment transport, water quality, water resources, wave and flood risk impacts to study the effects of different operating regimes.

8.2.12 A package of measures to prevent harm and mitigate impacts on estuarine ecology features, including creation and enhancement of areas for SPA birds to feed, would reduce the overall impacts on the structure and function of the SPA. There may be residual effects, and these would be considered in formulating a package of compensation measures.

9 Assumptions and Limitations

9.1.1 A number of assumptions and limitations have been identified throughout the course of the assessment. There are risks associated with the assumptions made and the residual uncertainties, in particular with respect to aspects of modelling which have not yet been conducted (e.g. potential changes to water quality and sedimentation regime) and the fact that baseline scenarios for the extent of intertidal habitats and the distribution of different habitat types within the Estuary are based on historic data. Due to these factors absolute quantitative assessments of impacts and identification of mitigation and compensation requirements for all options are not possible at this stage and as such relative assessments have been conducted based on semi-quantitative information and professional judgment. A number of the key considerations are provided below.

9.2 Modelling

9.2.1 The Mersey Estuary is a highly dynamic environment and the locations of channels, intertidal sand/mudflats and locations of erosion/accretion can change over periods of a few weeks. The bathymetry used for the hydrodynamic modelling is from 2002 and is not expected to be consistent with the present day bathymetry.The satellite image used to generate the intertidal habitat maps to estimate potential changes in exposed areas of intertidal sediments and saltmarsh is also from 2002 and is not expected to represent the present day environment. In addition, the satellite image was taken an hour after low tide and therefore does not represent the lowest low water on a spring tide. As a consequence there are areas of intertidal soft sediment which could not be characterised using the satellite image analysis approach and for the purposes of analysis it has currently been assumed that these areas consist of the same sediment type as neighbouring areas.

9.2.2 To estimate reductions in biomass in relation to changes in the area of intertidal habitat exposed at low tide, extrapolations were required based on data from the intertidal invertebrate sampling conducted specifically for the Mersey Tidal Power scheme. Due to the expanse of intertidal sediments within the Mersey Estuary any sampling programme can only provide a limited record of the invertebrate assemblages at specific sites. The approach taken has assumed, therefore, that the biomass of invertebrates and other characteristics of invertebrate assemblages at a particular site are representative of other sediments within the vicinity with a similar composition (e.g. sand, muddy substrate etc.).

9.2.3 Hydrodynamic modelling was conducted to indicate changes in water level within the Estuary across a tidal cycle for neap, intermediate and spring tides. The water level modelling provided a time series across the tidal cycle with 30 minute time steps. With this separation of data it may be the case that highest and lowest water levels were not covered in estimates of area exposed and the lengths of the wetted perimeters. This may have resulted in a more pessimistic assessment of foraging time and wetter perimeter at the lowest low water if this period was missed by the 30 minute time step.

9.2.4 To accurately assess potential changes in the extent of intertidal it is important to understand how sediment transport would likely change with a scheme in place. Changes to the sediment transport regime could lead to new areas of sediment deposition and creation of new areas of intertidal habitat, which could counter some of the habitat lost. In addition, changes to hydrodynamic conditions and current within the Estuary could cause increased erosion within some areas. The assumption currently made is that conditions within the Estuary and changes in extent of exposed areas of intertidal habitat are as they would be on day one of operation of the scheme (while also considering that the distribution of intertidal habitats currently used for modelling is based on historic data as indicated in Paragraph 9.2.2 above). There is potential therefore, that if natural deposition of sediment occurred and created intertidal areas the current projected reductions in extent of exposed intertidal areas may be smaller than those currently predicted. In addition, there may be increased erosion in some areas which would also influence the results obtained. Further modelling of changes to sediment transport and hydrodynamics with the scheme in place are required to take this into consideration and inform more detailed assessments.

9.2.5 Ecology within the Estuary can be influenced by changes in water quality. Flushing studies have been conducted which give an idea of how quickly pollutants could be flushed out of the Estuary, however, no specific water quality modelling (e.g. predictions of changes in specific parameters) has been conducted at this stage. Professional judgement has, therefore, been used at this stage to provide estimates for potential changes to water quality and how they may affect ecological receptors. It has been assumed that water quality changes would generally not be sufficient to have a significant effect on ecology within the Estuary under the proposed schemes with the specific operational regimes modelled and, as such, it is considered likely that water quality changes would not be a differentiator between schemes. Further modelling is required to clarify whether or not this would likely be the case and to assess more accurately potential changes to water quality parameters.

9.2.6 No modelling has been conducted at this stage to assess injury/mortality rates of fish, the assessment has, therefore, been based on information from other studies and professional judgement. Modelling of this type would be required for future assessment stages.

9.3 Assessment of Effects

9.3.1 There is currently no information available regarding potential changes to the composition of intertidal sediments with a scheme in place. Sediment composition can be a principal factor in determining the types of invertebrate assemblages present. Modelling would, therefore, be required to conduct a more accurate assessment of changes in the relative proportions of different sediment types and subsequently the potential effects this could have on invertebrate assemblages.

9.3.2 Without information regarding potential changes in the composition of intertidal sediments it is difficult to predict likely changes in prey availability for birds beyond an assessment focussing solely on changes in the exposure of intertidal areas. In addition to the numbers and types of species present it is also important to consider prey size, which is one of the key points of consideration in terms of availability of a suitable food supply for birds. Prey size could also be related to the composition of intertidal sediments.

9.3.3 No predictions are currently available in terms of potential changes in turbidity of the water column and whether there could be a reduction in turbidity which could potentially promote growth of phytoplankton. Modelling would be required to assess the potential changes in turbidity with a scheme in place. If such a change occurred and resulted in increased primary productivity it could have a knock on effect on other components of the food chain and could possibly lead to an increase in productivity within the Estuary. There is potential, however, for a decrease in turbidity to increase the likelihood of phytoplankton blooms which would be detrimental to other ecological receptors. Decreased turbidity could also result in more suitable conditions for filter feeding organisms which could influence the assemblages of invertebrates present.

9.3.4 There are currently no baseline data available from regulatory bodies for SPA sub-features. Assessments have therefore been based on data collected in the field specifically for the Mersey Tidal Power scheme and the application of professional judgement.

9.3.5 No studies have been conducted to record the types of vegetation currently present on the saltmarsh, the density of plants and the height of vegetation, the assemblages of invertebrates present and their abundances. It is understood, however, that a condition assessment of all of the sub-features of the Estuary is currently being conducted by Natural England and could be available for later assessment stages.

9.3.6 There is currently little information to effectively assess the likelihood of saltmarsh extending to lower parts of the shore and how effectively this could counter any reductions in saltmarsh extent due to encroachment by terrestrial vegetation. It is expected that saltmarsh would be likely to extend into areas lower on the shore, however, such potential changes and the extent of these changes would require more detailed investigation at later stages of the project.

9.3.7 In future assessment stages, modelling may be used to determine the effects that changes in habitat and prey availability can have on the bird populations. Models now exist with which the effect on one of the demographic rates that determine population size (mortality rate during the non-breeding season) of proposed schemes can be predicted (Stillman and Goss-Custard 2010). As long as the required predictions for the food supply and its accessibility through the tidal cycle are available, these models, could also be used to help evaluate the optimum strategy for operating a scheme to the benefit of shorebird populations and also for testing the efficacy of many of the measures that might be proposed to prevent harm or to provide mitigation. As bird numbers fluctuate naturally between years, and as the mortality rate is likely to be influenced by the density of the birds on the feeding grounds which affects the intensity of competition, the appropriate way to do this is to compare the predicted mortality rates over a range of population sizes; i.e. to use predicted density-dependent mortality functions. Density-dependent mortality functions can easily be obtained by seeding the model with the range of population sizes recorded in the site over a specified period of years. If the predicted post-scheme function lies exactly over the predicted baseline function, the scheme would be predicted to have no effect on population size because, however many birds spent the winter on the Estuary, their mortality rate would have to be the same as that experienced by the same number of birds prior to the scheme being built. In such a case, it could be said that the carrying capacity has not been affected. But if the post-scheme density-dependent function was found to lie above the pre-scheme one, then mortality rate would be predicted to increase at a given population size and the scheme would be predicted to have a negative effect on carrying capacity and the supported bird populations.

9.4 Prevent Harm, Mitigation and Compensation

9.4.1 A number of assumptions and limitations are described in relation to the cost, effectiveness and risk associated with implementing measures proposed to prevent harm, mitigate and compensate for adverse effects of the proposed scheme. For some of the measures proposed there are no feasible technologies currently available or methods are untested in an environment similar to the Mersey Estuary or for the purpose and scale for which they are proposed. An indication of how frequently and effectively the proposed measures have been implemented for projects in the past, and consideration of the potential feasibility of applying different measures, is provided in Appendix 5.

9.4.2 Considerations in terms of the potential feasibility of applying different measures are outlined in Appendix 5.

9.4.3 It is recognised that further investigation is required into many of the prevent harm, mitigation or compensation measures proposed and additional detailed modelling is likely required for a number of specific scheme aspects.

9.4.4 The costs for implementation of various measures to minimise adverse impact are dependent on the area required to implement the measure, its location and also the design of the preferred option. Indicative costs for various measures are provided in Appendix 5, however, they are subject to change as the development of the preferred option progresses.

9.4.5 The assignment of risk/uncertainty to the prevent/harm, mitigation and compensation package measures is based on assumptions that the proposed measures will perform as effectively as predicted. This is based on the information currently available and would likely be modified as part of an iterative process as further data and results from modelling in relation to the Mersey Tidal Power scheme become available. Risk/uncertainty associated with the different measures proposed is indicated in Appendix 5.

9.4.6 It is considered that further investigation is required into many of the prevent harm, mitigation or compensation measures proposed and additional detailed modelling is likely required for a number of specific scheme aspects.

10 Summary

10.1.1 This report evaluates how three different Mersey Tidal Power scheme options could potentially affect the extent and quality of the habitats that support birds within the Mersey Estuary SPA by looking at SPA sub-features, the time that birds would have available for feeding within these habitats and the potential effects of the proposed schemes on WFD biological elements. This has been undertaken based on hydrodynamic modelling conducted for specific operational regimes for each of the schemes. Using specialist assessments and expert opinion, this report assesses potential effects on a range of ecological attributes used to assess the structure and function (and hence integrity) of the Mersey Estuary SPA.

10.2 Baseline Information

10.2.1 Field surveys were conducted specifically for the Mersey Tidal Power study to gather baseline information for birds, invertebrates, fish (including intertidal fish surveys), rocky shore assemblages (macroalgae and invertebrates), benthic algae and phytoplankton.

10.2.2 The Mersey Estuary is a dynamic ecosystem and supports a range of waders and wildfowl which utilise the Estuary for overwintering or on passage. Numbers of waders and wildfowl have decreased, however, since the site was designated as a SPA, perhaps due to a change in the Mersey Estuary environment. Invertebrate assemblages present are typical of estuarine environments, there is some evidence to suggest that density of invertebrates may not have changed considerably over the last two decades, however, it is possible that the mean size of individuals may have decreased although more data are required to confirm if this is the case.

10.2.3 Fish assemblages within the Mersey Estuary include a number of migratory (diadromous) taxa. Atlantic salmon and river/sea lamprey are protected under Annex II of the Habitats Directive. Sea trout and European eel are UK BAP species. European eel are also of European importance, protected under a European Recovery Plan which is implemented under the Eels (Wales and England) Regulations, in addition to having a Mersey Estuary Eel Management Plan. In addition to migratory species, a number of other non-migratory ecological guilds are supported (estuarine species, marine migrants, marine stragglers and freshwater species). Within the Mersey Estuary the marine migrant ecological guild includes five designated UK BAP species (cod, herring, plaice, sole and whiting).

10.2.4 Rocky shore assemblages are dominated by fucoid macroalgae which is patchily distributed throughout the Mersey Estuary and have limited distribution due to the small areas of rocky habitat available for colonisation. Invertebrates on rocky shores had relatively low abundances and the species present are typical of this habitat. Benthic floral and phytoplankton assemblages are both dominated by diatom taxa and the assemblages recorded during field surveys conducted for the Mersey Tidal Power scheme are typical of those within estuarine habitats.

10.3 Assessment of Ecological Effects

10.3.1 There are a number of assumptions and limitations that have been noted during the assessment and these are indicated in Section 9 of this document.

10.3.2 Effects were assessed on SPA sub-feature attribute targets described in the advice given under Regulation 35 of the Conservation of Habitats and Species Regulations 2010. These sub-feature attribute targets were associated with birds, intertidal sediments, rocky shore habitat and saltmarsh habitat.

10.3.3 In addition WFD guidance was considered to determine potential effects of the proposed schemes on the WFD elements which contribute to the ecological status of the Mersey Estuary (invertebrates, fish, angiosperms (saltmarsh), macroalgae and phytoplankton). WFD guidance and professional judgement were used to assess whether effects would pose a risk to maintaining ecological status of the Mersey Estuary or attaining future targets.

10.3.4 Quantitative specialist assessments of the potential effects of the scheme on habitat types were conducted by using GIS to overlay the results of hydrodynamic modelling on a sediment basemap produced for the study. The hydrodynamic modelling covered 30 minute time steps, across neap, spring and intermediate tides, for the years 2010, 2030 and 2060 for the baseline scenario and for each of the scheme scenarios (the 2010 scenario represented present day baseline, 2030 and 2060 scenarios integrated the effects of climate change on water levels with 2030 being an intermediate timeframe for the operational phase of the scheme and the 2060 scenario including longer term effects). Calculations were conducted to measure the changes in exposed areas of different types of intertidal sediments, saltmarsh and rocky shore throughout the tidal cycle for each of the different schemes for the 2060 scenario.

10.3.5 Data from the invertebrate surveys conducted for the Mersey Tidal Power project provided density and biomass information for invertebrates at a range of subtidal and intertidal sites. PSA samples were also taken at these sites to identify the types of sediment present (e.g. sand substrate or muddier substrates) as this can be a key determinant of the invertebrate assemblages present. The PSA information from intertidal sites was used to refine the mapping of the distribution of different sediment types in the Estuary.

10.3.6 Changes in invertebrate biomass at different stages of the tidal cycle for each of the schemes were assessed for each scheme by applying the invertebrate biomass data gathered from field surveys to the GIS sediment map and combining with the hydrodynamic modelling.

10.3.7 The assessment for bird numbers was made using predictions of potential changes in the amount of foraging space and foraging time under each of the schemes and by applying expert knowledge to interpret the findings. The assessment was based on peak counts of birds in the SPA designation, therefore, as numbers of birds have decreased the assessment may have resulted in "worst-case" impacts being identified.

10.3.8 If any of the declines in numbers of birds of the species upon which the Mersey was designated as a SPA are caused by deterioration in the feeding conditions it is assumed that any additional deterioration due to a reduction in foraging space or foraging time would be likely to cause numbers to decline still further. If the food supply has decreased, however, it may have been linked to a reduction in the average body size of invertebrate prey species, as opposed to reductions in numbers of individuals. If this was the case it would reduce the energy content of available invertebrates and, consequently, reduce their value to the birds even if the total biomass of invertebrates may not have changed.

10.3.9 Reductions in the extent of exposed areas of intertidal habitat and invertebrate biomass were found to be the greatest with the IBv2 scheme. IBv2 was not predicted to decrease the length of the wetted perimeter along the tide edge that is used for feeding by many shorebirds on the Mersey. It was predicted, however, to substantially reduce the amount of foraging space and available prey biomass on the intertidal flats as a whole (based on consideration of reduced area of exposed sediment and density of invertebrates in different sediment types), and the amount of time available for foraging there. Reductions in foraging time and foraging space make it likely that survival of SPA bird features, and therefore numbers, would be reduced by IBv2.

10.3.10 Reductions in the extent of exposed areas of intertidal habitat and invertebrate biomass were less with the VLHBv2 scheme, when compared to IBv2, although they still remained considerable. Although VLHBv2 is not predicted to decrease the length of the wetted perimeter, it is predicted to reduce the amount of foraging space and available prey biomass on the intertidal flats as a whole as well as the amount of time available for foraging. Reductions in foraging time and foraging space make it unlikely that survival, and therefore numbers, would not be reduced by VLHBv2.

10.3.11 The smallest reductions in extent of exposed areas of the intertidal habitat and invertebrate biomass were evident with the VLHBv3 scheme. This scheme is not predicted to decrease the length of the wetted perimeter but it is predicted to lead to a small reduction in the amount of foraging space and prey biomass on the intertidal flats as a whole. On the other hand, VLBHv3 is also expected to lead to a small increase in the amount of time available for foraging on many tides (compared with the baseline, the range is a 20 minute decrease in time available when there is less than 400 ha available on spring tides, to 20 minutes more time being available for the same area on intermediate tides. When an area less than 200 ha is available on spring and intermediate tides the time available for foraging increases by 26 minutes and 2 hours 20 minutes respectively, in comparison with the baseline). Thus VLHBv3 is predicted to have variable effects on the foraging environment and modelling would be required to predict the net effect of these contradictory changes on bird survival. The combination of a small increase in foraging time during which the density of birds is low enough for competition to be reduced, and a small reduction in one aspect of foraging space, make it likely that risks to survival, and therefore numbers, would be lower for the VLHBv3 scheme than for the other two schemes.

10.3.12 The schemes are predicted to have potentially varying effects on WFD elements and the relative effects on invertebrates, phytoplankton and macroalgae were lower for VLHBv3 than for the other schemes although the assessed significance of the effects remains similar. The potential reduction in saltmarsh area due to increased encroachment of the saltmarsh by terrestrial vegetation was greatest for VLHBv3. The main WFD concern under each of the schemes, however, would be potential effects on fish (including migratory species which are of European conservation importance). The effect on fish would be greatest for VLHBv3 due to generation of energy on both the ebb and flood tides and the fact that fish passage would be restricted to generating turbines, free wheeling turbines at the end of the tidal cycle, or the fish passage routes (unlike the other schemes assessed no sluices would be present to provide an alternative route for fish passage).

10.3.13 The predicted negative effect on the birds' feeding conditions, and on their numbers, and on other aspects of estuarine ecology considered during this assessment decreases across the sequence IBv2 to VLHBv2 to VLHBv3. The exceptions were that the areas of saltmarsh exposed at high water has been assessed to be greater for VLHBv3 than for the other two schemes, therefore, a reduction in saltmarsh extent due to encroachment by terrestrial vegetation could potentially be greatest with the VLHBv3 scheme. In addition, the risks to fish would be greatest for the VLHBv3. It is concluded overall, however, that under the operational strategies assessed for each scheme VLHBv3 would be the scheme that would pose least risk to the condition of the Mersey Estuary as a passage and wintering area for shorebirds.

10.3.14 It should be noted that this assessment has been based purely on ecological considerations. To meet the aims of the study the Project team will also need to assess implications of each scheme on other aspects including the commercial viability of the development.

10.4 Prevent Harm Measures

10.4.1 The results of the assessments are based on the hydrodynamic modelling relating to specific operational regimes for each scheme. The intention was to learn from these regimes to determine a preferred scheme option, not constrained to the three modelled. Options for operational regimes for the different schemes to limit effects on ecological receptors have been suggested in Section 8 of this document.

10.4.2 A number of potential prevent harm measures are related to variations in operational regime to optimise the area of the intertidal zone exposed, the length of wetted perimeter and feeding time.

10.4.3 Sluicing at both low and high tide has been considered, with greater ecological benefits noted for high tide sluicing as it enables higher water levels to be maintained within the basin and reduces the area of saltmarsh which could be at risk from encroachment by terrestrial vegetation.

10.4.4 Ebb and flood generation has been found to be beneficial in terms of increasing the area of exposed intertidal sediments as it replicates most closely the natural baseline tidal conditions within the Estuary. The IBv2 and VLHBv2 scheme options utilise ebb only generation, these could be modified to develop new scheme options which utilise ebb generation only on certain tides and utilise ebb and flood generation where possible (most likely on intermediate tides). This would increase the areas of exposed intertidal sediment in the mid to lower sections of the shore (most important for bird feeding) and increase the feeding time available for birds within these areas whilst maintaining periodic high tide submersion of the upper shore.

10.4.5 In addition, investigations could be undertaken to assess the potential for changes on a daily basis. Utilisation of ebb and flood generation where possible could increase the exposure of intertidal habitats and the time for which it is exposed, both of which would be beneficial for feeding birds.

10.4.6 For the VLHBv2 scheme there could be potential to reduce the number of turbines from 44 to 28 and utilise sluicing throughout the tidal cycle to manage the tidal regime within the basin. It is considered that this variant would provide similar exposures of intertidal sediment to that assessed for the VLHBv2 operational regime within this document and would be beneficial for fish as the lower number of turbines and large number of sluices would increase the proportion of flow through the sluices facilitating fish passage.

10.4.7 With the VLHBv3 scheme a greater area of saltmarsh would be exposed at all times at high tide when compared with the other two schemes, increasing the potential for encroachment of saltmarsh by terrestrial vegetation and increasing the reduction in the wetted area of the upper intertidal sediments. Application of high tide sluicing could be advantageous in increased water levels within the basin at high water and reducing these effects.

10.5 Mitigation/Compensation

10.5.1 There are a variety of ways in which effects could be prevented or mitigated. These measures would increase the area of habitat available for intertidal invertebrates and the biomass of invertebrates available for birds. Measures that would extend the foraging time available to the birds as well as provide replacement foraging space are thought likely to be effective. Possible techniques to increase available foraging time include tidal regulation devices that impede the inflow of Estuary water into saline lagoons located in the intertidal zone beyond a porous barrier.

10.5.2 Compensation measures in other coastal areas and on the breeding grounds of species that breed in Britain could be implemented to increase the size of the regional and national populations of which the Mersey birds form a part and also help preserve the integrity of the Natura 2000 network of sites.

10.5.3 A wide range of potential prevent harm, mitigation and compensation measures have been proposed within Appendix 5 of this document. It is not expected that each of these would be deployed but they could potentially contribute to an overall package of prevent harm/mitigation/compensation measures to limit or compensate for effects on ecology.

10.6 Residual Effects

10.6.1 This Stage 3 assessment was based on the operational regime modelled for each of the schemes and does not take into account the prevent harm measures indicated above. With a package of prevent harm, mitigation and compensation measures in place an assessment has been made of the residual significance of effects on a range of SPA sub-feature attribute targets and WFD biological elements. This is based on professional judgement and it is acknowledged that the specific measures to be applied for each scheme are yet to be defined.

10.6.2 For IBv2 with prevent harm and mitigation measures in place none of the effects are considered to be of major significance. There would be residual effects of moderate significance for seven of the potential effects (numbers or displacement of birds, extent of intertidal sediments, presence and abundance of prey species in intertidal sediments, extent of rocky shores and saltmarsh extent (SPA and WFD) and fish) and it is considered that compensation would likely be required for six of these effects in addition to the prevent harm and mitigation package (it is considered unlikely that compensation would be required for extent and distribution of rocky shore habitat although it was assessed to be an effect of moderate significance due to the fact that changes to this sub-feature are not likely to have a considerable effect on birds).

10.6.3 Following application of prevent harm and mitigation measures none of the effects are considered to be of major significance for the VLHBv2 scheme. There would be residual effects of moderate significance for six of the potential effects identified (extent of intertidal sediments, presence and abundance of prey species in intertidal sediments, extent of rocky shores and saltmarsh extent (SPA and WFD) and fish) and it is considered that compensation would likely be required for six effects in addition to the prevent harm and mitigation package (although effects on numbers or displacement of birds were predicted to be of minor significance it is considered that compensation would still be likely, in contrast. it is considered unlikely that compensation would be required for extent and distribution of rocky shore habitat although it was assessed to be an effect of moderate significance due to the fact that changes to this sub-feature are not likely to have a considerable effect on birds).

10.6.4 If prevent harm and mitigation measures are applied with scheme VLHBv3, it has been assessed that none of the effects would be of major significance. There would be residual effects of moderate significance for three of the potential effects identified (extent of saltmarsh (SPA and WFD) and fish) and it is considered that compensation would likely be required for six of the effects in addition to the prevent harm and mitigation package (in addition to the three effects considered to be of moderate significance after mitigation, compensation is also considered likely in relation to the sub-feature attribute targets; numbers or displacement of birds, reduced extent and distribution of intertidal sediments and reduced presence and abundance of prey species in intertidal sediments although effects on these attributes were assessed to be of minor significance following the application of prevent harm/mitigation measures).

10.6.5 Based on this information, from an ecological point of view the VLHBv3 scheme would have least ecological effects of the three schemes following the use of prevent harm measures and mitigation. Compensation would likely be required to reduce ecological consenting risk for each of the schemes. As stated above, however, a range of considerations are required to identify a feasible scheme including requirement for energy generation and as such a variant of one of the assessed schemes is likely to form the preferred scheme.

10.7 Preferred Scheme

10.7.1 The sample schemes developed and assessed during the feasibility study have tested the performance of a range of scheme parameters (technology, location, engineering design and operating regime) against the broad spectrum of technical, consenting and financial criteria summarised on the decision making framework.

10.7.2 The principal variations of a preferred scheme in comparison to those modelled are likely to include:

- Having a flexible operational regime and utilising a different operating regime during certain periods (including use of an unrestricted or restricted head). For example, on the spring tide and neap tides, generation could use an unrestricted head and take place on the ebb tide only. On intermediate tides, however, generation could take place on both ebb and flood tides, using a more restricted head, to enable the upper and mid intertidal habitats that are most important for birds' feeding to be exposed for more time and to a greater extent.

- Increased number of sluices to increase the effectiveness of sluicing on the flood tide to limit the extent of the areas of saltmarsh potentially encroached by terrestrial vegetation. An increased number of sluices would also facilitate fish passage.

- Placement of turbines and sluices and operating sequence to limit effects on ecology

10.7.3 Considering the effects on the different sub-features which are likely to result from the operation of the preferred scheme, it is concluded that this scheme will likely have low ecological consenting risk from a HRA perspective. There may, however, be further ecological consenting risk in relation to ecological status of the Estuary under the WFD.

10.7.4 A package of measures to prevent harm and mitigate impacts on estuarine ecology features, including creation and enhancement of areas for SPA birds to feed, would reduce the overall impacts on the structure and function of the SPA. There may be residual effects, and these would be considered in formulating a package of compensation measures.

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Appendix 1: Hydrodynamic Modelling Technical Notes

Technical Note

Subject **Feasibility Study Stage 3: Estuary Morphology Technical Note**

1 Introduction

This note seeks to address issues raised by the ecology team in the course of their work in Stage 3 of the Feasibility Study and relate to the estuary morphology and associated processes. This Technical Note sets out some general responses with, where appropriate and possible, specific details.

Each of the questions below applies to any of the Stage 3 schemes that have been assessed (A1.02b, A2.01a and A2.02a) following installation of the scheme, and/or during construction (as appropriate):

1. What are the potential changes in sediment type within different areas of the Estuary?
2. What are the potential nature of changes in sediment input to the Estuary e.g. will there be a likely net gain or loss of sediment to the Estuary?
3. Where will sediment within the SPA and/or Estuary accrete, be eroded or remain unchanged at different locations within the Estuary, and can potential 'hotspots' for accretion/erosion be identified?
4. Will the position, number, depth and width of channels within the Estuary be likely change, and if so what will the changes be?
5. How feasible is it to fix channels as part of our mitigation proposals for fish?
6. Can intertidal habitats be created from areas which are currently sub-tidal, and can intertidal banks be elevated such that they are exposed at an earlier stage on an ebbing tide as part of our mitigation proposals?
7. Will the wave profile (e.g. wave height etc.) change within the Estuary and will this be likely to have any effects on erosion of intertidal habitats (e.g. salt marsh and mudflat)?
8. Will water quality within the Estuary change e.g. concentrations of ammonia, suspended solids, biological oxygen demand (BOD), dissolved oxygen, nutrient concentrations (e.g. total organic nitrogen (TON)), soluble reactive phosphorous (SRP), dissolved inorganic nitrogen (DIN)?
9. Will turbidity change within the Estuary?

These questions are all addressed in the following sections.

2 General Response

The Feasibility Study has not considered the sediment transport processes within the Estuary in detail. The Stage 2 work did consider the general sediment transport processes and the possible response of the Estuary to changes in the different forcing mechanisms (see Scott Wilson and HR Wallingford, 2010). Some of the possible responses that the Estuary would have to changes in the physical forcing of the Estuary as a result of the introduction of different schemes were identified.

Without detailed modelling of the sediment processes it is not possible to provide detailed assessments of the potential response of the Estuary to the different schemes and variants. It is reasonable to present some of the generic changes that are likely, however the quantification of these changes is not possible at this stage with any degree of certainty or confidence.

It should be noted that whilst some differences between schemes may be identified, the variation of the potential response of the Estuary is such that it may not be reasonable to use the different responses of the Estuary as a differentiator between schemes.

It should also be noted that the short-term response of the Estuary to a scheme may be different to the longer term response and also that these effects may be affected positively or negatively by the long-term changes in sea level or fluvial flows due to climate change. The prediction of these changes will require significant and careful study in future stages of the project to ascertain the important processes and the temporal and spatial scales of these changes in processes.

The imposition of a barrage on the Estuary (however it is operated) would result in some key changes to the Estuary's hydrodynamic and sedimentary processes. The changes to the water level and duration for which a certain water level is maintained would effect many processes including groundwater, sediment transport and water quality.

2.1 Tidal Prism

A barrage would be likely to lower the high water level and raise the low water level (assuming that no pumping is used). This would result in a decrease in the tidal prism (the volume of water between high and low water), resulting in a general reduction in the average current speed within the Estuary; however the peak current at some locations could increase. These changes in currents would result in changes to the distribution of the sediment.

The change in tidal prism would also result in a change in the flushing of the Estuary, although the duration of the ebb and flood tides is also important for this assessment.

2.2 Mean Water Level

The change in high and low water levels would also result in a change in the mean water level in the Estuary. This would have important consequences for groundwater. If the mean water level was raised significantly then the potential for further saline intrusion would be increased. Also the longer duration high water levels could result in extended flooding of disused landfills or other potentially contaminated land with the subsequent release of contaminants to the Estuary.

2.3 High or Low Water Stand

The high or low water stand periods would allow fine sediments a longer period of time to settle out of the water column. This could result in lower turbidity by the end of the standing time. Conversely the shorter period of time over which the flood and ebb tidal currents would be allowed to run could result in an increase in the current speed such that a higher suspended sediment concentration would be achieved during these periods of high currents. The spatial distribution of the water with a lower or higher suspended sediment concentrations is variable and cannot sensibly be predicted without extensive modelling, preferably calibrated against observed field data.

3 Responses to Ecology Team Questions

3.1 Sediment Type and Distribution

The distribution of sediment within the Estuary would change as a result in the changes to the currents. It is not possible to provide clear guidance on specifically how the distribution would change. It is likely that the Estuary would continue to have a net influx of sediment; however the distribution of this sediment may not be evenly distributed over the whole Estuary.

3.2 Channels

The locations of the channels within the Estuary are constantly changing for the existing baseline case. The range of these changes and the mechanism for the movements are well documented if not wholly understood and predictable. It is possible that the presence of a barrage could fix the locations of channels in the lower Estuary; however it is likely that the upper Estuary would continue to have a continually changing arrangement of channels.

In the Stage 3 schemes' designs, the distribution of the turbines and the sluices along the length of the barrage has been selected based on the most suitable ground conditions for the turbines. This would result in specific flow patterns being generated on the flood and the ebb tide for each of the schemes and this could result in the channels in the lower Estuary being 'fixed'. The potential for this to occur has been demonstrated by earlier studies of the Estuary at Stage 2.

It is likely that there would be a rapid response to the channel arrangement in the short-term, particularly the infilling of existing sub-tidal channels if the low water level was raised. If the low water level was significantly higher than the baseline case then the variability in the sub-tidal channels could decrease in the medium term. The meandering of the main channel in the upper Estuary is a consequence of the combined fluvial and ebb tide draining of the upper Estuary salt marshes and mud flats. This results in a fluvial system for the upper Estuary allowing the channel to meander and change alignment due to the comparatively soft sediment (when compared to a river flowing through a terrestrial environment). The erosion of the sediment that occurs to allow the continually changing alignment of the channels is an important process in the distribution and re-distribution of sediment within the Estuary.

In summary, there will be changes and these will affect the whole Estuary but they can not reasonably be predicted at this stage.

3.3 Creation of Habitat

It is possible that some of the dredge spoil could be used to raise the existing intertidal areas to ensure that they remain intertidal, but this would require careful consideration.

The fixing of channels is a more complex issue. It is possible that some of the channels in the lower Estuary would be more stable; however the sub-tidal and drainage channels in the upper Estuary would continue to meander and adjust naturally based on the modified tidal flows.

The Stage 2 study showed that fixing any main channel with training walls would actually increase the deposition outside of those training walls. If this occurred then the accretion rates could result in medium to long-term changes in the intertidal area including the creation of salt marsh and/or terrestrialisation of existing salt marsh. All of these would result in a decrease in the tidal prism and therefore potentially increase deposition and decrease power generation capability.

3.4 Wave Conditions

The wave conditions within the Estuary have not been modelled or considered in detail.

The wave conditions in the upper Estuary are locally generated and therefore the presence of a barrage would not significantly change the amount of wave energy entering the Estuary from the open sea. The wave conditions (height and period) that would be generated at a given water level would be likely to be similar for all schemes and the baseline. However the frequency of occurrence of these wave conditions would be altered by the frequency of occurrence of the water level. Specifically the high water stand period would result in the upper mudflat and salt marsh being exposed to the largest waves for a longer period of time. This could result in the drawdown of sediment from the upper intertidal area to the lower area; possibly infilling sub-tidal channels (see previous section).

The higher occurrence of the largest waves would affect the distribution of sediment within the Estuary. The effect however must be considered in combination with the available sediment within the water column. This will need to be carefully considered at a later stage within the project.

3.5 Water Quality

The turbidity in the Estuary would be likely to decrease during the periods of high or low water stands and increase during the ebb and/or flood tide. Potential changes to the peak and average turbidity are not able to be quantified or even qualified as the changes would be dependent on the detailed changes in current speed and distribution of the currents and sediments within the Estuary. It is therefore not possible to state with certainty what the turbidity would be compared to the baseline case for any particular state of the tide. This is because although the high and low water stand periods would provide an opportunity for sediment to settle down through the water column, if the turbidity was higher at the start of the stand than it would be in the baseline, then the average turbidity at the end of the stand period might not be lower than the average turbidity for the baseline at the end of a high or low water. It is probably reasonable to assume that at the end of a standing period the upper part of the water column would have a lower turbidity; however it is not reasonable to estimate the suspended sediment concentration throughout the water column at this time.

The potential changes to water quality parameters cannot reasonably be estimated at this stage. Whilst the flushing of the Estuary is likely to decrease with a barrage this does not mean that the changes in water quality are predictable. For example the high flow rates through the sluice gates could result in higher dissolved oxygen levels being achieved in the water entering the Estuary, particularly if the flow was super-critical and therefore turbulent. Water quality studies are required to establish the possible changes to water quality parameters within the Estuary.

4 References

Scott Wilson and HR Wallingford (2010) *Mersey Tidal Power Feasibility Study Stage 2: Future Morphological Evolution of Liverpool Bay and the Mersey Estuary*

Subject **Feasibility Study Stage 3: Far-Field Effects on Water Levels Technical Note**

1 Introduction

Identification of the geographical area potentially affected by a barrage has been achieved through the consideration of the predicted changes to the high and low water values for a neap and spring tide for the baseline scenario and with each of the Stage 3 schemes.

Water levels at 15 points (shown in Figure 1 and Figure 2) within the Irish Sea, Liverpool Bay and the Mersey Estuary for each of the scheme variants A1.02b, A2.01a and A2.02a and the baseline have been graphically compared to provide a general understanding of the geographical range of any changes in water levels, specifically the spring and neap high and low water levels.

The analysis undertaken in this technical note is intended to provide an indication of the likely geographical extent of changes in water levels as a result of each of the schemes. In future stages of the project, the ADCIRC model developed for the Joule project may be used to examine the possible effects of the scheme on the wider area. The Joule project model has boundaries that are off the continental shelf and as such the boundaries are very unlikely to be affected by the schemes. The analysis presented here assumes that the schemes do not have any significant affect on the boundaries. If this is not the case then a difference in water levels would be seen at sites away from the project site. The use of the Joule project's model would provide additional confidence that the scheme is not going to affect the water levels outside of the immediate area.

Note that this assessment has only considered water levels and not currents or sediment transport. These would be studied in more detail in a later stage of the project.

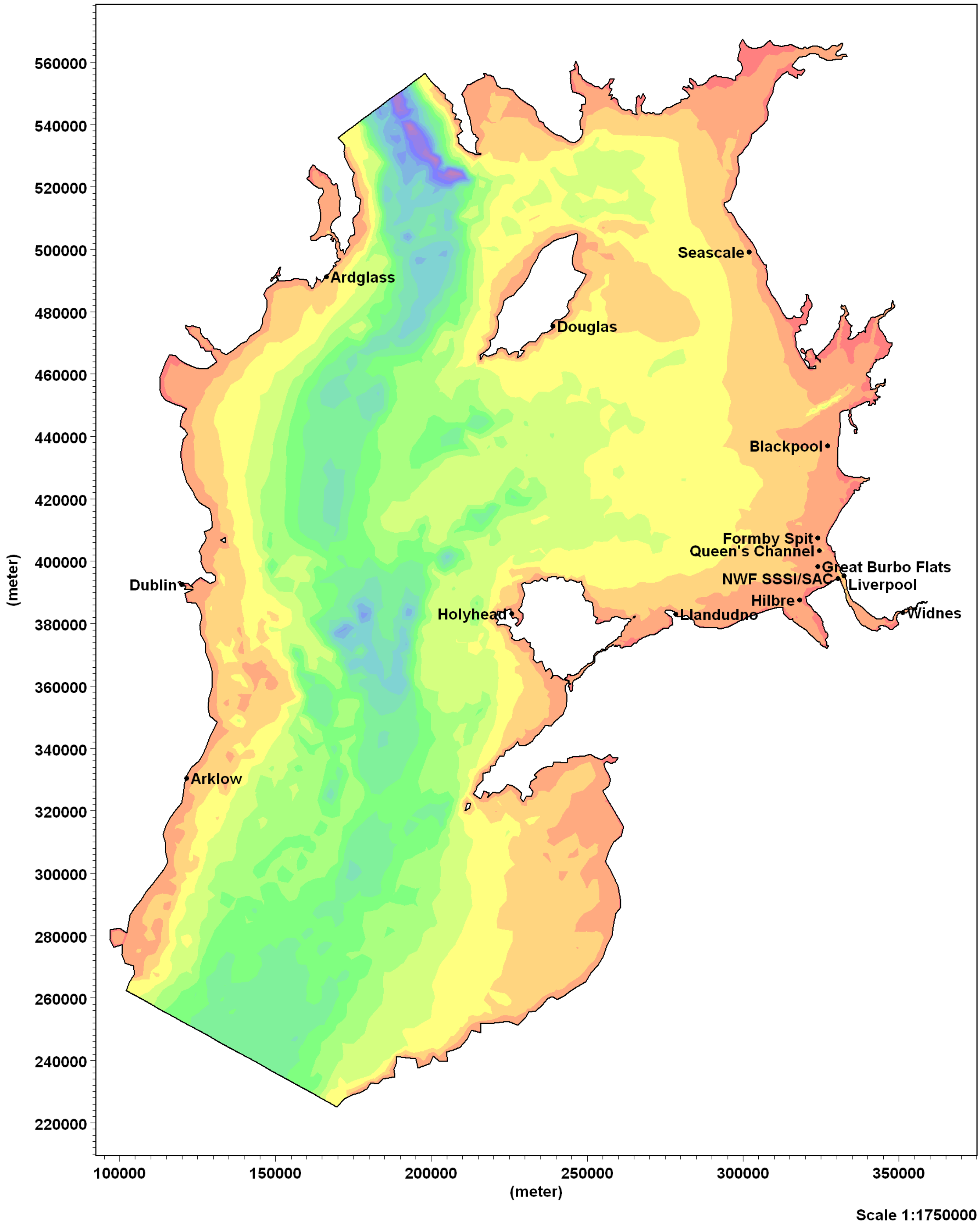


Figure 1. Location of points used for comparison in the Irish Sea, Liverpool Bay and the Mersey Estuary (a detailed map of Liverpool Bay and Mersey Estuary is provided in Figure 2).

Note: colours indicate water depth (increasing depth from red to orange to yellow to green to blue)

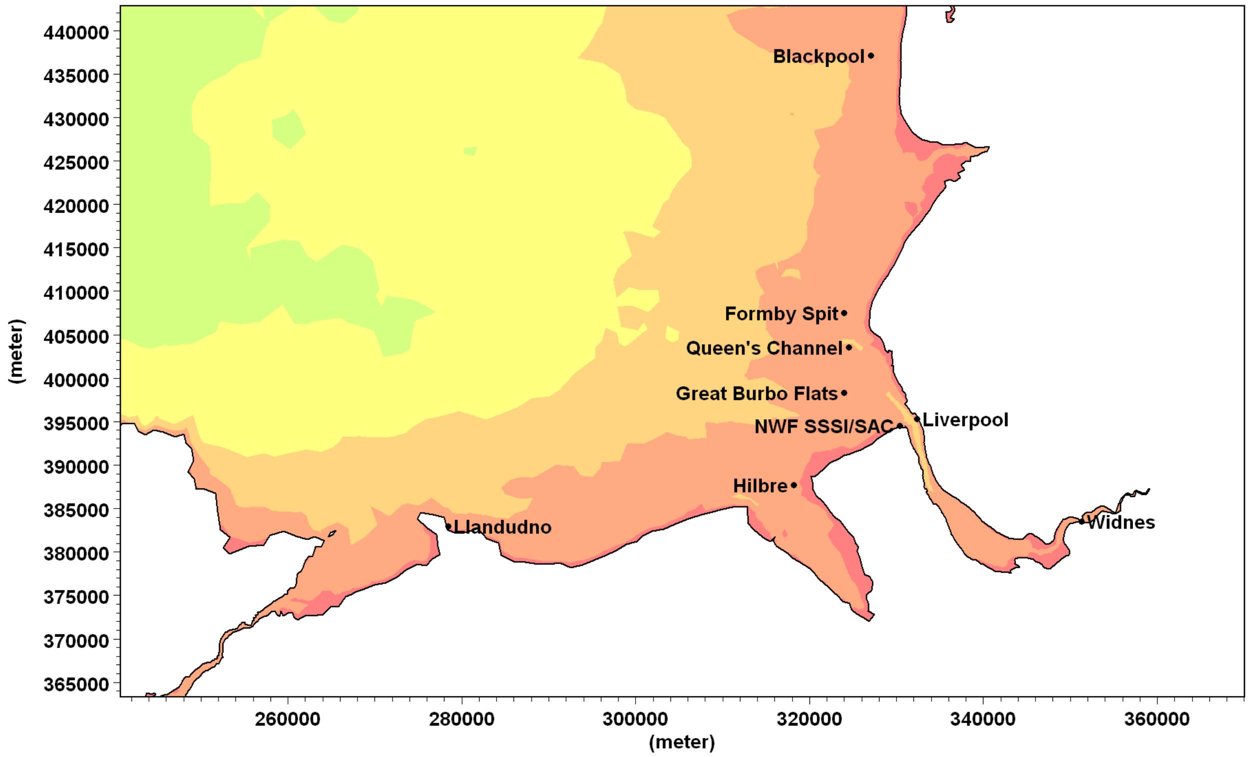


Figure 2. Location of points used for comparison in Liverpool Bay and the Mersey Estuary

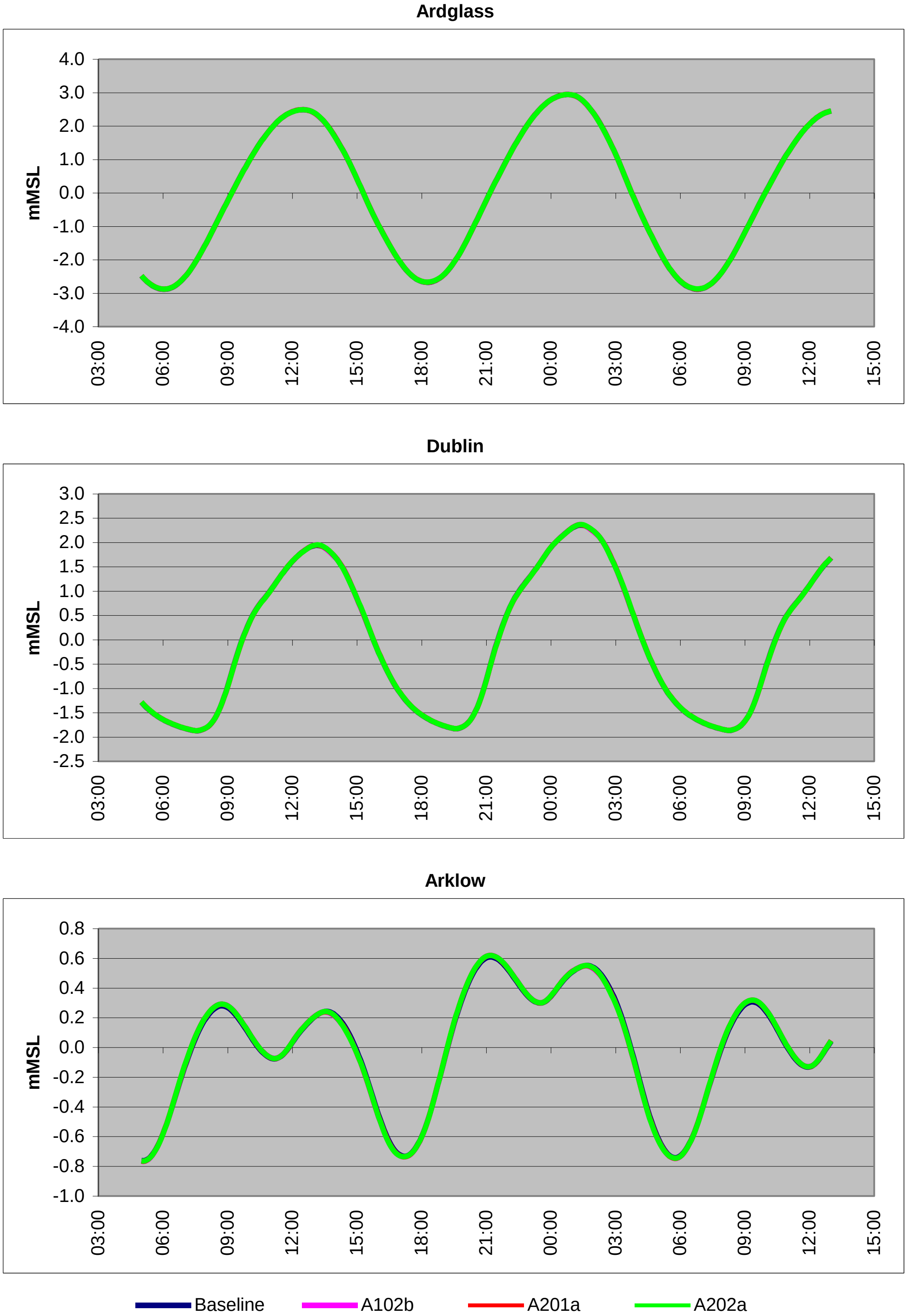
2 Results

The comparison of water levels for the spring and neap tides are shown in Figure 3 to Figure 7 and Figure 8 to Figure 12 respectively. For ease of comparison within a graph the vertical axis on each graph is modified for each location to represent the tidal range at that location; it is anticipated that comparison between graphs is not required.

For points outside of the Mersey Estuary the water levels are all measured to local mean sea level. Within the Estuary the datum is mean sea level at Alfred Dock. The analysis has been undertaken using water levels in 5 minute intervals.

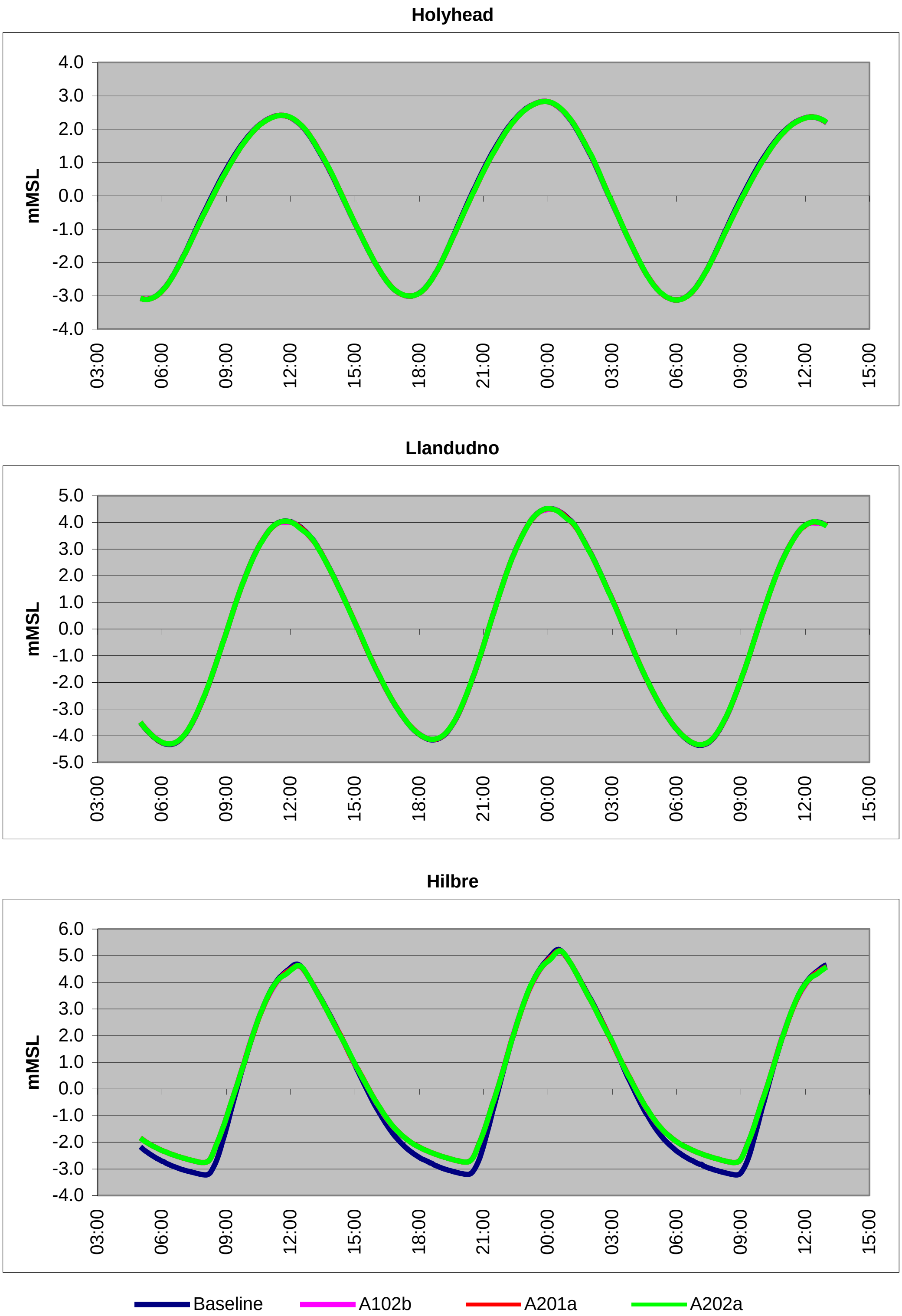
Most of the graphs show no differences in water levels between the baseline and with scheme scenarios, therefore only a single curve is visible. On some graphs it appears that data for one or more schemes has not been plotted - this is because the water levels for some schemes are similar and only one curve is visible.

A numerical analysis of the difference between the water levels for each scheme and the baseline has also been undertaken. The minimum, maximum and absolute maximum differences are shown in Table 1 to Table 3 (page 14). The difference is calculated as the scheme minus baseline water level for the corresponding spring/neap period shown in Figure 3 to Figure 12. The differences in high and low water levels for the spring and neap tide at each location are shown in Table 4 and Table 5 respectively (page 15).



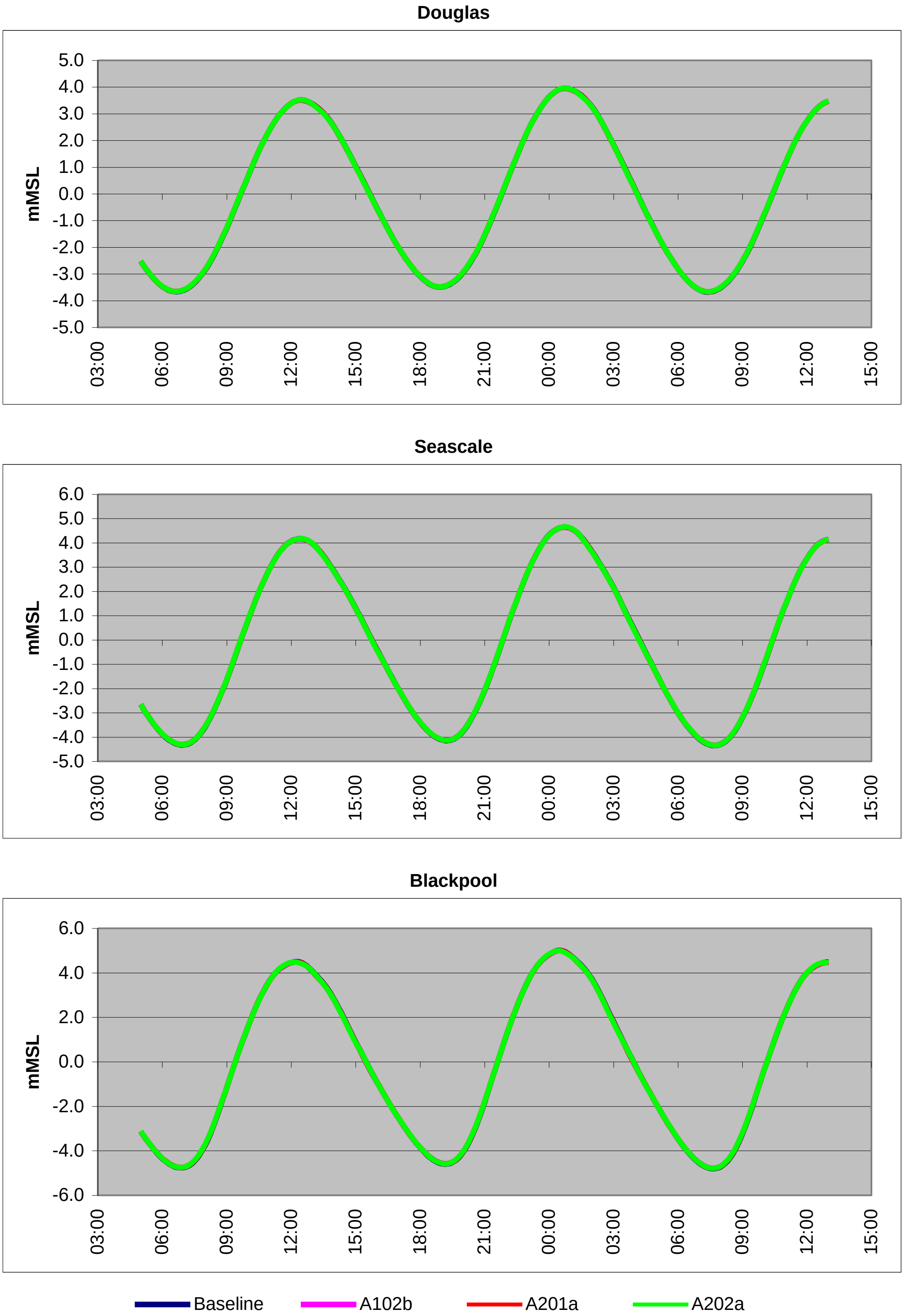
Note that if a curve is not visible then it is obscured by another; indicating the values are similar.

Figure 3. Comparison of spring tide water levels for Ardglass, Dublin and Arklow



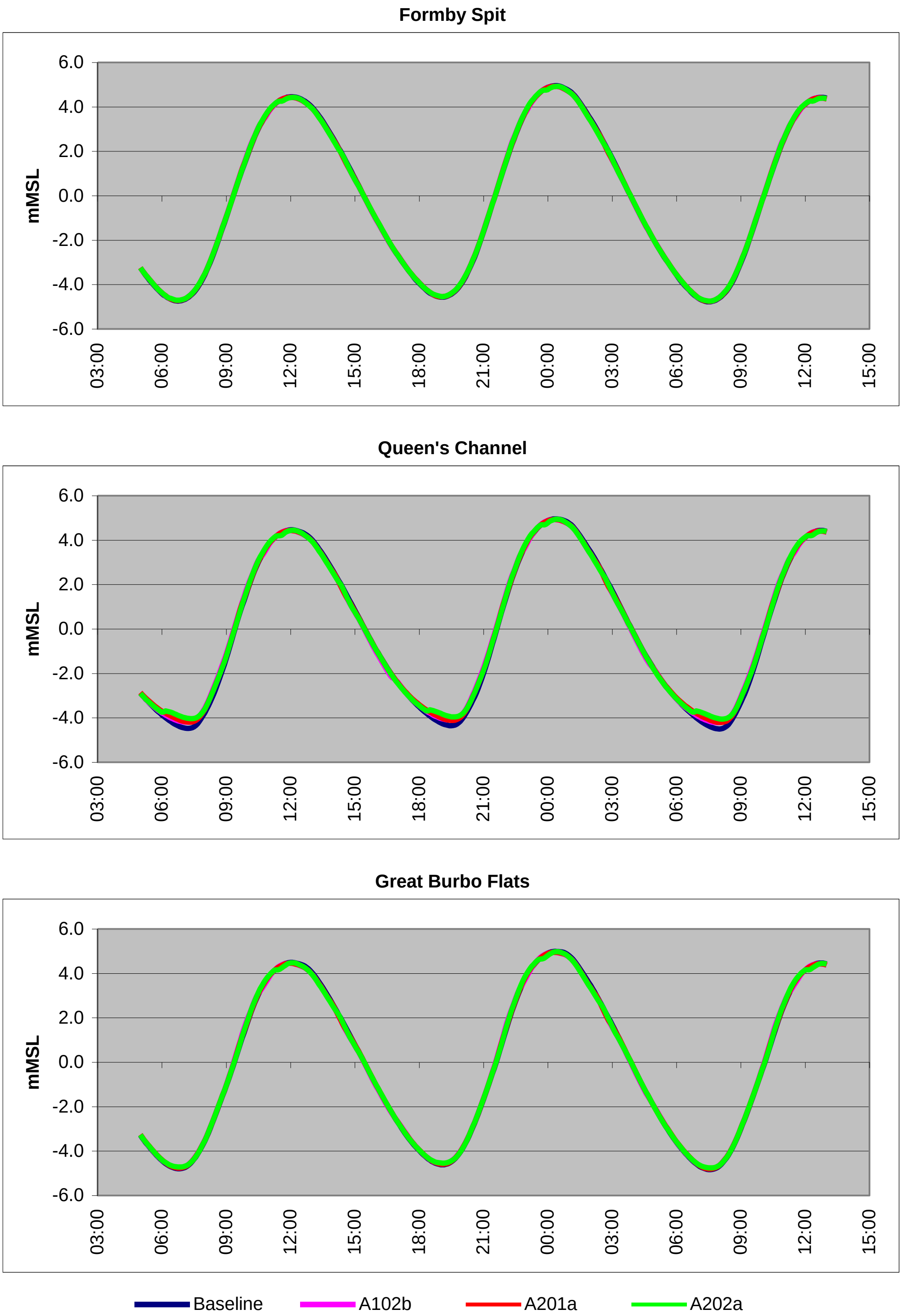
Note that if a curve is not visible then it is obscured by another; indicating the values are similar.

Figure 4. Comparison of spring tide water levels for Holyhead, Llandudno and Hilbre



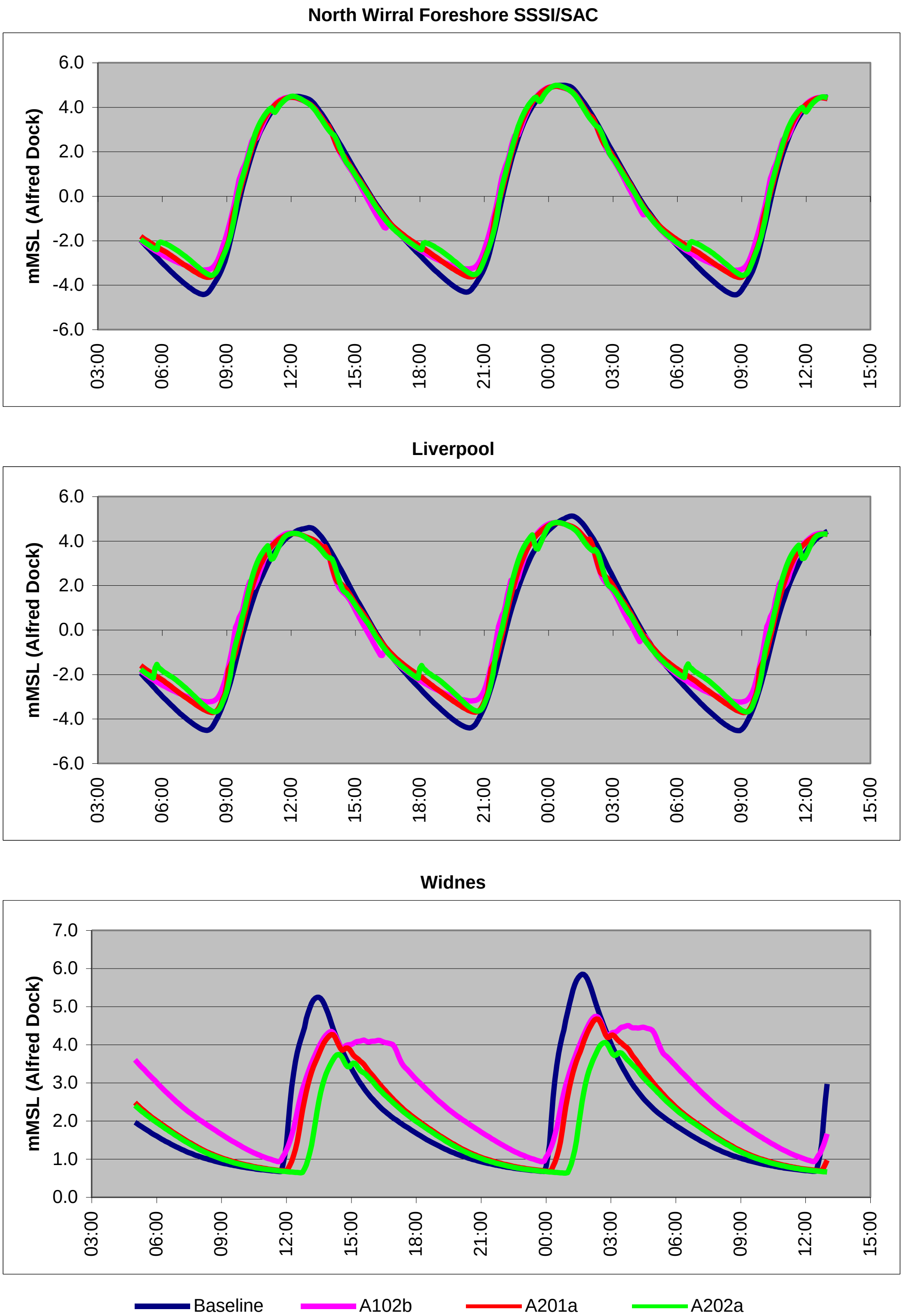
Note that if a curve is not visible then it is obscured by another; indicating the values are similar.

Figure 5. Comparison of spring tide water levels for Douglas, Seascale and Blackpool



Note that if a curve is not visible then it is obscured by another; indicating the values are similar.

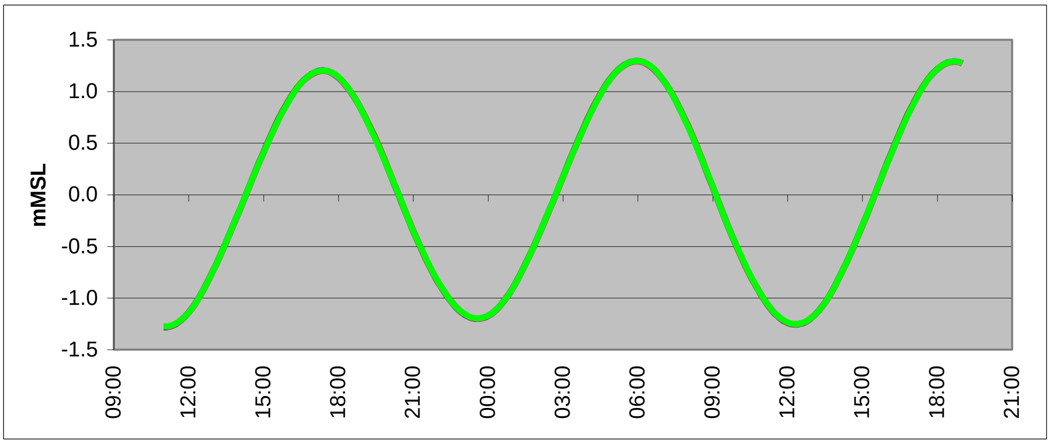
Figure 6. Comparison of spring tide water levels for Formby Spit, Queen's Channel and Great Burbo Flats



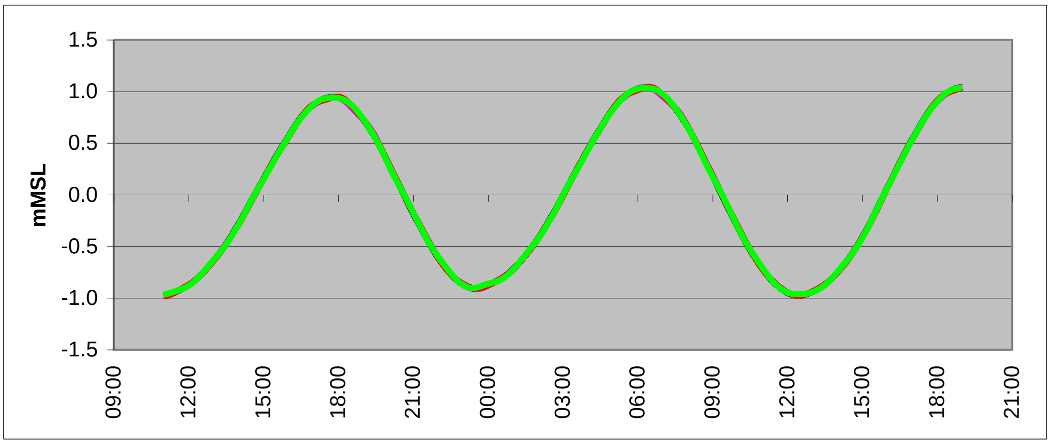
Note that if a curve is not visible then it is obscured by another; indicating the values are similar.

Figure 7. Comparison of spring tide water levels North Wirral Foreshore SSSI/SAC, Liverpool and Widnes

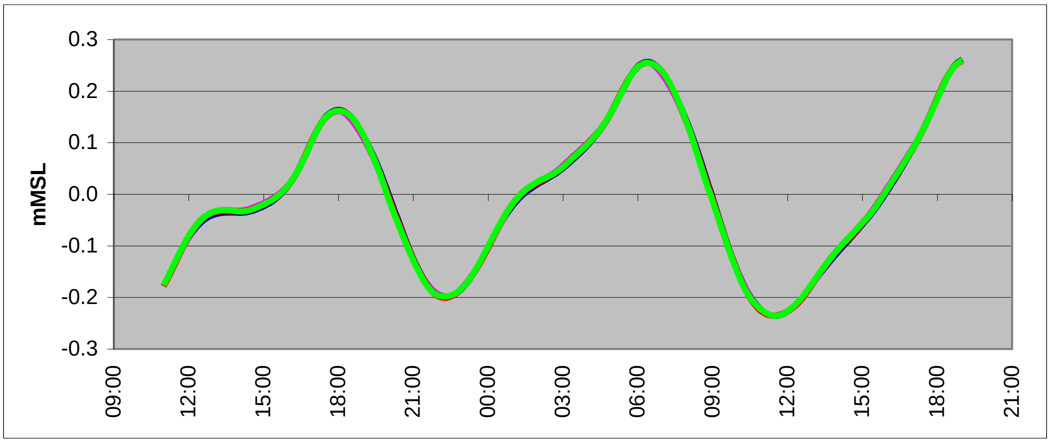
Ardglass



Dublin



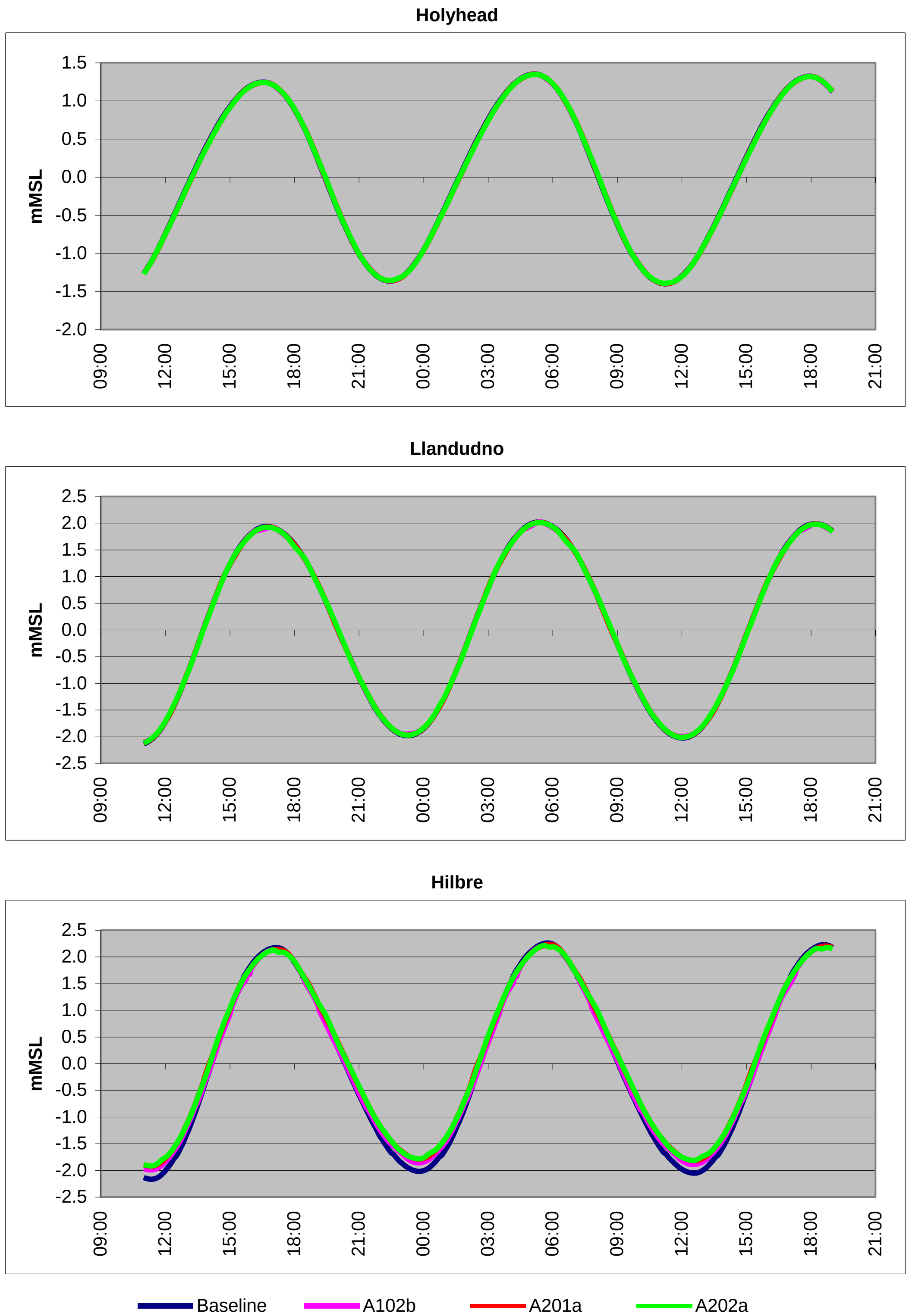
Arklow



Baseline A102b A201a A202a

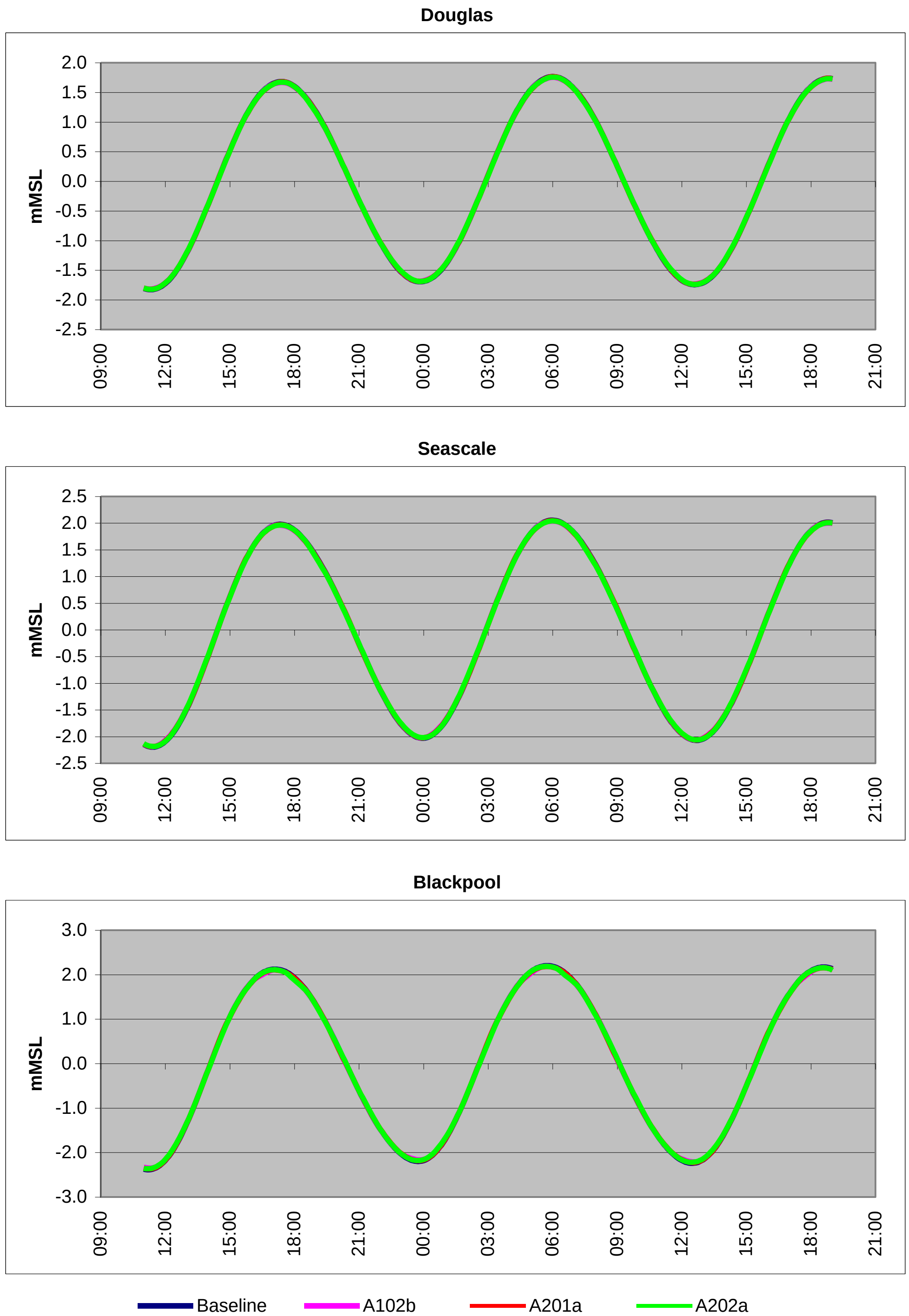
Note that if a curve is not visible then it is obscured by another; indicating the values are similar.

Figure 8. Comparison of Neap tide water levels for Ardglass, Dublin and Arklow



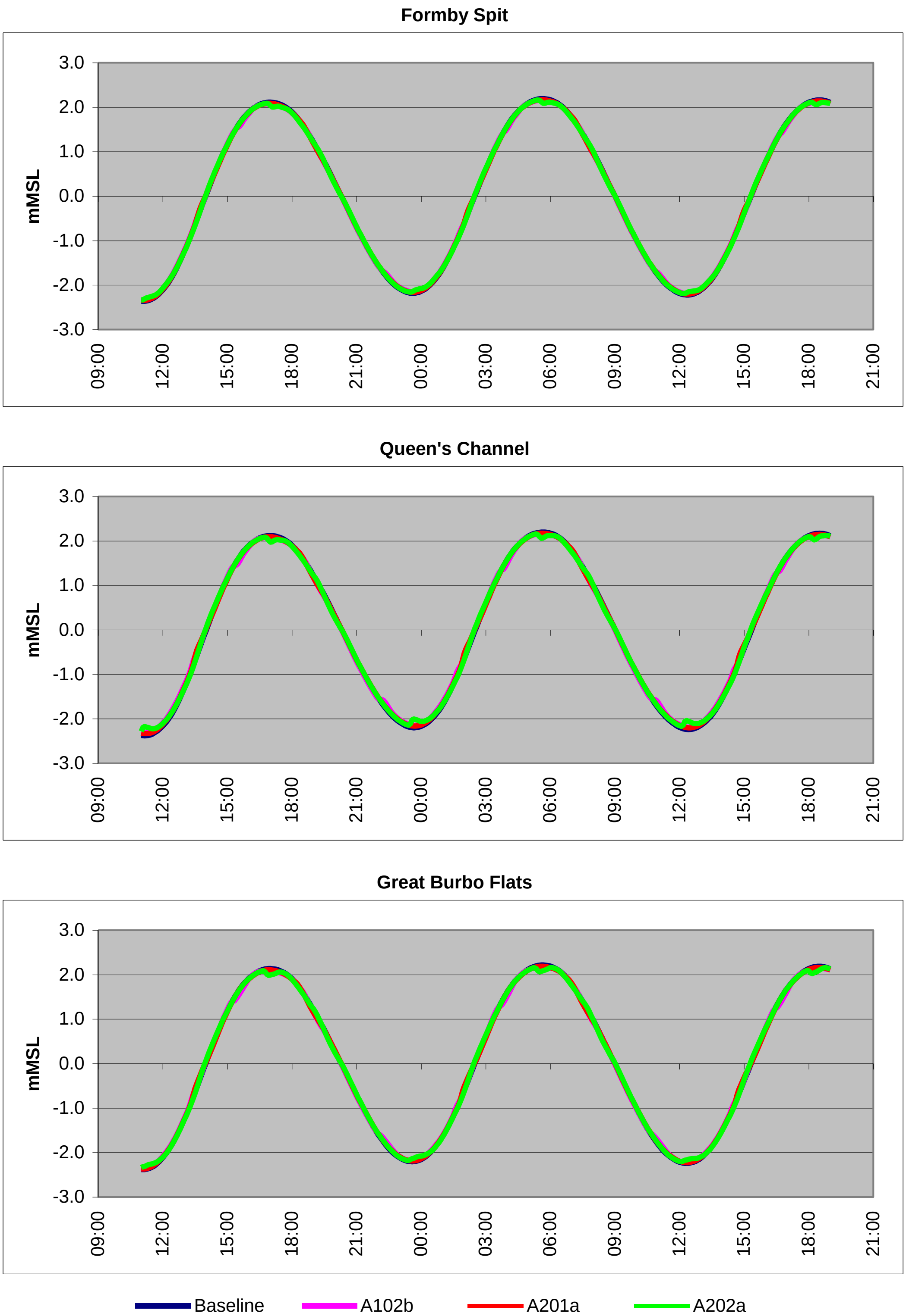
Note that if a curve is not visible then it is obscured by another; indicating the values are similar.

Figure 9. Comparison of Neap tide water levels for Holyhead, Llandudno and Hilbre



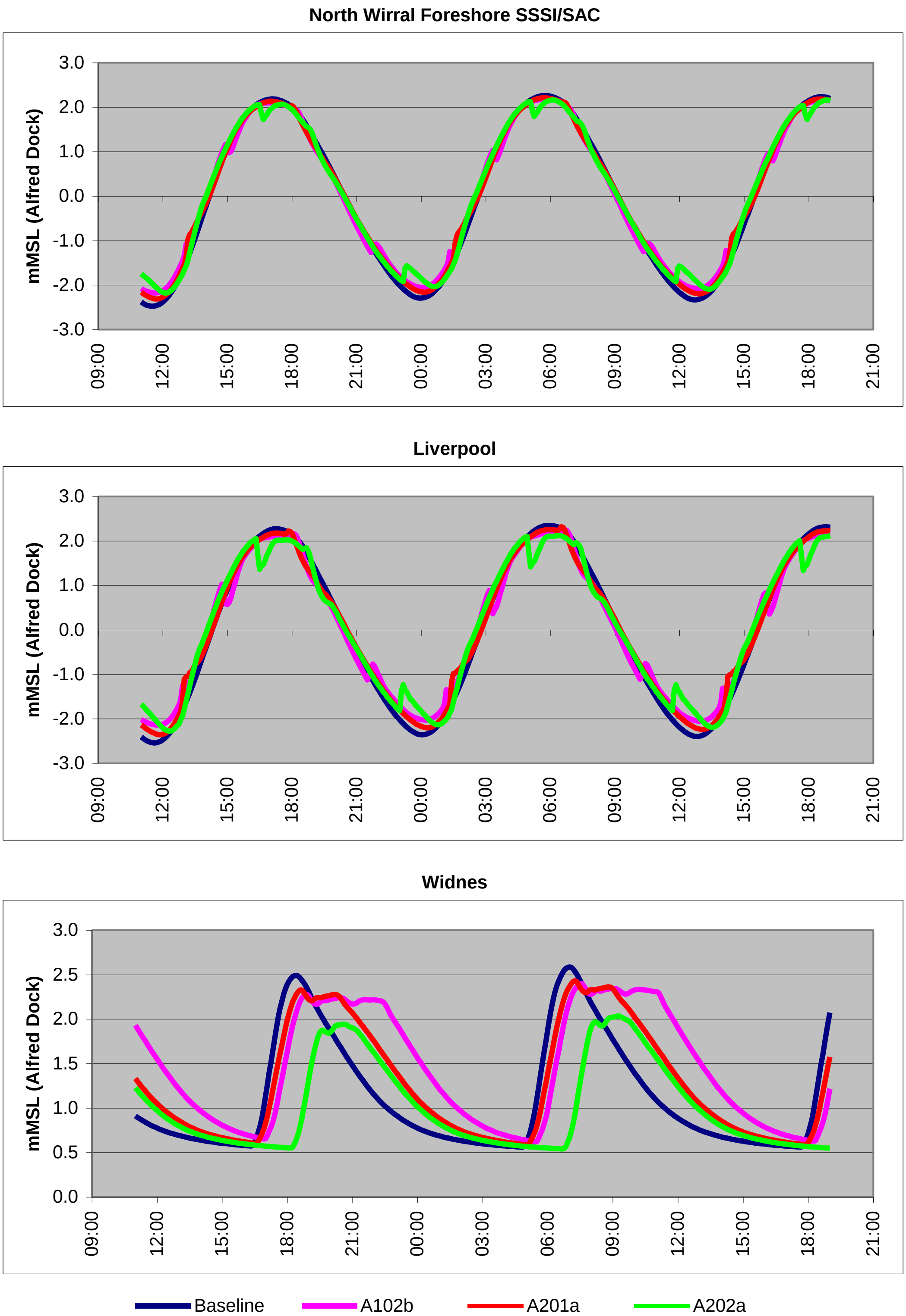
Note that if a curve is not visible then it is obscured by another; indicating the values are similar.

Figure 10. Comparison of Neap tide water levels for Douglas, Seascale and Blackpool



Note that if a curve is not visible then it is obscured by another; indicating the values are similar.

Figure 11. Comparison of Neap tide water levels for Formby Spit, Queen's Channel and Great Burbo Flats



Note that if a curve is not visible then it is obscured by another; indicating the values are similar.

Figure 12. Comparison of Neap tide water levels North Wirral Foreshore SSSI/SAC, Liverpool and Widnes

Table 1. Minimum values of differences in water levels calculated as difference = scheme – baseline; a negative value indicates that the scheme water level is lower than the baseline water level.

Location	Spring Tide			Neap Tide		
	A102b	A201a	A202a	A102b	A201a	A202a
Liverpool	-0.99	-0.92	-0.80	-0.38	-0.34	-0.75
Hilbre	-0.09	-0.09	-0.13	-0.13	-0.04	-0.08
Douglas	-0.03	-0.02	-0.03	-0.02	-0.01	-0.02
Llandudno	-0.05	-0.03	-0.06	-0.05	-0.03	-0.04
Holyhead	-0.06	-0.06	-0.06	-0.02	-0.02	-0.02
Arklow	-0.02	-0.02	-0.02	-0.01	-0.01	-0.01
Ardglass	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Dublin	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01
North_Wirral_Foreshore_SSSI_SAC	-0.55	-0.36	-0.33	-0.24	-0.16	-0.42
Blackpool	-0.05	-0.04	-0.06	-0.04	-0.02	-0.06
Seascale	-0.04	-0.03	-0.04	-0.02	-0.01	-0.03
Widnes	-1.91	-2.57	-4.39	-0.91	-0.53	-2.00
Formby Spit	-0.09	-0.08	-0.10	-0.08	-0.04	-0.10
Queen's Channel	-0.14	-0.13	-0.13	-0.11	-0.06	-0.14
Great Burbo Flats	-0.13	-0.11	-0.15	-0.11	-0.06	-0.15

Table 2. Maximum values of differences in water levels calculated as difference = scheme – baseline; a negative value indicates that the scheme water level is lower than the baseline water level.

Location	Spring Tide			Neap Tide		
	A102b	A201a	A202a	A102b	A201a	A202a
Liverpool	1.61	0.97	1.36	0.55	0.60	0.88
Hilbre	0.61	0.60	0.61	0.18	0.24	0.27
Douglas	0.03	0.02	0.02	0.02	0.01	0.02
Llandudno	0.03	0.02	0.03	0.03	0.02	0.03
Holyhead	0.03	0.03	0.04	0.02	0.02	0.02
Arklow	0.01	0.01	0.01	0.01	0.01	0.01
Ardglass	0.01	0.01	0.01	0.01	0.01	0.01
Dublin	0.01	0.01	0.01	0.02	0.01	0.02
North_Wirral_Foreshore_SSSI_SAC	1.11	0.89	1.26	0.41	0.43	0.63
Blackpool	0.05	0.04	0.05	0.05	0.02	0.03
Seascale	0.03	0.02	0.03	0.03	0.02	0.02
Widnes	2.03	0.76	0.55	1.23	0.63	0.51
Formby Spit	0.11	0.05	0.06	0.07	0.07	0.07
Queen's Channel	0.30	0.30	0.48	0.13	0.13	0.21
Great Burbo Flats	0.21	0.09	0.11	0.09	0.10	0.09

Table 3. Maximum absolute difference in water levels calculated as difference = scheme – baseline.

Location	Spring Tide			Neap Tide		
	A102b	A201a	A202a	A102b	A201a	A202a
Liverpool	1.61	0.97	1.36	0.55	0.60	0.88
Hilbre	0.61	0.60	0.61	0.18	0.24	0.27
Douglas	0.03	0.02	0.03	0.02	0.01	0.02
Llandudno	0.05	0.03	0.06	0.05	0.03	0.04
Holyhead	0.06	0.06	0.06	0.02	0.02	0.02
Arklow	0.02	0.02	0.02	0.01	0.01	0.01
Ardglass	0.01	0.01	0.01	0.01	0.01	0.01
Dublin	0.02	0.02	0.02	0.02	0.02	0.02
North_Wirral_Foreshore_SSSI_SAC	1.11	0.89	1.26	0.41	0.43	0.63
Blackpool	0.05	0.04	0.06	0.05	0.02	0.06
Seascale	0.04	0.03	0.04	0.03	0.02	0.03
Widnes	2.03	2.57	4.39	1.23	0.63	2.00
Formby Spit	0.11	0.08	0.10	0.08	0.07	0.10
Queen's Channel	0.30	0.30	0.48	0.13	0.13	0.21
Great Burbo Flats	0.21	0.11	0.15	0.11	0.10	0.15

Table 4. Difference in low water level calculated as difference = scheme – baseline; a negative value indicates that the scheme water level is lower than the baseline water level.

Location	Spring Tide			Neap Tide		
	A102b	A201a	A202a	A102b	A201a	A202a
Liverpool	1.29	0.81	0.85	0.40	0.19	0.26
Hilbre	0.46	0.46	0.46	0.18	0.24	0.25
Douglas	0.01	0.01	0.01	0.01	0.01	0.01
Llandudno	0.02	0.02	0.02	0.03	0.01	0.02
Holyhead	0.00	0.00	0.00	0.01	0.00	0.01
Arklow	-0.01	0.00	0.00	0.00	0.00	0.00
Ardglass	0.01	0.01	0.01	0.00	0.00	0.01
Dublin	0.00	0.00	0.00	0.00	0.00	0.01
North_Wirral_Foreshore_SSSI_SAC	1.10	0.78	0.88	0.30	0.16	0.30
Blackpool	0.02	0.02	0.02	0.04	0.02	0.02
Seascale	0.02	0.02	0.02	0.01	0.01	0.01
Widnes	0.25	0.00	-0.04	0.06	0.03	-0.02
Formby Spit	0.03	0.02	0.04	0.03	0.02	0.03
Queen's Channel	0.28	0.29	0.45	0.06	0.05	0.10
Great Burbo Flats	0.04	0.03	0.08	0.02	0.02	0.04

Table 5. Difference in high water level calculated as difference = scheme – baseline; a negative value indicates that the scheme water level is lower than the baseline water level.

Location	Spring Tide			Neap Tide		
	A102b	A201a	A202a	A102b	A201a	A202a
Liverpool	-0.29	-0.31	-0.29	-0.10	-0.03	-0.23
Hilbre	-0.06	-0.05	-0.06	-0.04	-0.03	-0.05
Douglas	-0.01	0.00	0.01	-0.01	0.00	-0.01
Llandudno	-0.02	-0.01	-0.01	0.00	-0.01	-0.01
Holyhead	0.00	0.00	0.00	0.00	0.00	-0.01
Arklow	0.01	0.01	0.01	0.00	0.00	0.00
Ardglass	0.00	0.00	0.00	0.00	0.00	0.00
Dublin	0.01	0.01	0.01	0.00	0.00	-0.01
North_Wirral_Foreshore_SSSI_SAC	-0.04	-0.04	0.00	-0.08	-0.05	-0.10
Blackpool	-0.01	-0.02	-0.02	-0.01	-0.02	-0.02
Seascale	-0.01	-0.01	0.00	-0.02	-0.01	-0.01
Widnes	-1.10	-1.17	-1.79	-0.19	-0.16	-0.55
Formby Spit	-0.03	-0.03	-0.03	-0.03	-0.02	-0.03
Queen's Channel	-0.03	-0.03	-0.02	-0.04	-0.03	-0.04
Great Burbo Flats	-0.04	-0.04	-0.01	-0.04	-0.03	-0.06

3 Conclusions

The predicted levels of low water (Table 4) for all sites on the Irish coast (Arklow, Dublin and Ardglass) the Isle of Man (Douglas), Welsh coast (Holyhead, Llandudno) and North West English coast (Seascale, Blackpool) are within 5 cm of the corresponding baseline low water level. Closer to the Estuary mouth the low water levels in the Queen's Channel are predicted to be higher than the baseline, with scheme A2.02a raising low water levels by as much as 45 cm. The corresponding predicted increase in water level water level at Formby Spit and Great Burbo Flats is less than 10 cm suggesting that the water would be flowing through the deep water channel. Within the Estuary downstream of the structure (Liverpool) the low water level is predicted to be raised significantly; this is because water would be discharging through the structure beyond the time of low water and the incoming flood tide would occur before the Estuary had emptied.

The predicted levels of high water (Table 5) on the Irish Coast (Arklow, Dublin and Ardglass) are within 1 cm of the baseline suggesting minimal or no change to high and low water levels on the Irish coast. Closer to the Estuary mouth (Formby Spit, Queen's Channel, Great Burbo Flats, North Wirral and Hilbre) there are small predicted differences in the levels of high water, with all schemes predicted to lower the level by less than 10 cm. Within the Estuary mouth (Liverpool) the spring high water level is predicted to be approximately 30 cm below the baseline level.

Overall the geographic area that would be directly affected by a scheme is considered to be comparatively local to the Estuary mouth and limited to the area between Hilbre and Formby Spit. The study to date has not however looked at the detailed water levels within the neighbouring estuaries such as the Dee and Ribble and this would require a more detailed appraisal at a later date.

This appraisal has shown that the far-field effects of the barrage would be limited to the Estuary mouth. Later scheme variants may be tested with an improved hydrodynamic model, which would include the neighbouring estuaries in more detail and allow a more robust assessment to be made. Additionally consideration would be given to using the ADCIRC model from the Joule project to evaluate the far-field impacts.

Appendix 2: Assessment Methodology

During the assessment reference has been made to a number of descriptors of potential effects.

A2.1 Identification of Potential Marine Ecological Effects

Descriptors of potential effect

A number of descriptors have been considered when making assessments of possible effects and when assessing their degree of significance. Reference has not necessarily been made to each of the aspects below but they are aspects which were considered as part of the assessment:

- whether effects were beneficial or adverse;
- whether a particular effect was direct or indirect. Direct effects are the original result of an option. Indirect effects are effects which are not a direct result of a tidal power scheme but occur away from the original effect or as a result of a complex pathway;
- the extent of the effect (geographical area and the size of the population);
- the magnitude of any effects (see below for more details);
- the duration of the effect and/or recoverability (short (1 year), medium (5 years to 10 years) or long term (>10 years));
- the reversibility i.e. permanent/temporary;
- the timing and frequency of effects in relation to key sensitivities;
- likelihood of effect occurring

Value and Sensitivity of receptor

A critical aspect of the assessment is to determine the value and sensitivity of the receptor being assessed. There is existing guidance on assessing value and sensitivity provided by IEEM (IEEM 2006 & 2008).

Overall, the value of the receptor was determined based on geographical context (e.g. international, national, regional etc, see below) and conservation designations (see Table A2.1). Criteria for assigning the sensitivity of receptors to potential effects based on these considerations is also indicated in Table A2.1. In instances for which value falls within one category and sensitivity falls within another the highest value category was taken forward to the significance matrix (see below).

Table A2.1 Site sensitivity and value matrix

Definition	Value and Sensitivity Guidelines
High	**Value** Feature / receptor possesses key characteristics which contribute considerably to the distinctiveness, rarity and character of the site / receptor e.g. Designated features of **International** designation / importance e.g. SAC, Ramsar, SPA etc. Feature / receptor possess **important** biodiversity, social/community value and / or economic value. Feature / receptor is **rarely** sighted. **Sensitivity** Receptor populations are identified as having very low capacity to adapt to, or recover from, proposed form of change i.e. population is **highly sensitive to change and/or currently unstable**.
Medium	**Value** Feature / receptor possesses key characteristics which contribute considerably to the distinctiveness, rarity and character of the site / receptor e.g. Designated features of **National/ Regional / County** designation / importance e.g. WFD, UK BAP, SSSI, Nature Reserves. Feature / receptor possess **moderate** biodiversity, social / community value and / or economic value. Feature / receptor is **occasionally** sighted. **Sensitivity** Receptor is identified as having low capacity to accommodate proposed form of change i.e. is **moderately sensitive**.
Low	**Value** Feature / receptor only possess characteristics which are of **District** or **Local** importance. Feature / receptor not designated or only designated at the district or local level e.g. LNR. Feature / receptor possess **some** biodiversity, social/community value and / or economic value. Feature / receptor is **relatively common**. **Sensitivity** Feature / receptor is identified as having some tolerance of the proposed change subject to design and mitigation etc i.e. is only **slightly sensitive**.

Magnitude of Effect

The magnitude of the effect is defined as;

The descriptors listed above can be used to describe the magnitude of an effect. For example, magnitude is a function of other aspects such as the extent of an effect (being the area over which the effect occurs), the duration (the time for which the effect is expected to last prior to recovery or replacement of the resource or feature), the likelihood (the chance of an effect occurring) and reversibility.

The criteria used to assign a magnitude of effect are shown in Table A2.2 below and incorporates all the descriptors listed above. The table presents generic criteria relating to each category and those specific to marine ecology. For this assessment the criteria relating to marine ecology has been used.

Assignment of significance

The overall significance of an effect is a function of the magnitude of effect and value/sensitivity of the receptor. Once these values were determined, the significance value was therefore allocated using the assessment matrix indicated in Table A2.3. The definitions of the significance ratings are shown in Table A2.4. These ratings are drawn from generic significance criteria in DCLG (2006).

Role of professional judgement

Professional judgement has been applied to qualitative or semi-qualitative assessments and to estimate descriptors as required i.e. magnitude.

Table A2.3 Magnitude of effect

Magnitude of effect	Criteria
High	**Generic description** Very significant, permanent / irreversible changes, over the whole development area and beyond (i.e. off site), to key characteristics or features of the particular environmental aspect's character or distinctiveness for more than 2 years. **Marine Ecology description** The quality and availability of habitats and species are degraded to the extent that protected species and habitats experience widespread change, such that the integrity of the ecosystem and the conservation status of a designation is compromised. Also applies to species and habitats not afforded statutory protection. Activities predicted to occur and affect receptors continuously over the long term, and during sensitive life stages. Effects likely to be irreversible or reversible, temporary or permanent.

	Effects not limited to areas within and adjacent to the development.
Medium	**Generic description** Significant, permanent / irreversible changes, over the majority of the development area, to key characteristics or features of the particular environmental aspect's character or distinctiveness for more than 2 years. **Marine Ecology description** The quality and availability of habitats and species are degraded to the extent that the population or habitat experiences reduction in number or range. Activities predicted to occur and affect receptors regularly and intermittently, over the medium to short term and during sensitive life stages. Effects likely to be irreversible or reversible, temporary or permanent. Effects limited to the areas within and adjacent to the development.
Low	**Generic description** Noticeable, but not significant changes for more than 2 years or significant changes for more than 6 months, but less than 2 years, over a partial area, to key characteristics or features of the particular environmental aspect's character or distinctiveness. **Marine Ecology description** The quality and availability of habitats and species experience some limited degradation. Disturbance to population size and occupied area within the range of natural variability. Activities predicted to occur intermittently and irregularly over the medium to short term. Effects likely to be reversible and not likely to coincide with sensitive life stages. Effects limited to the area within the development.
Very Low	**Generic description** Noticeable changes for less than 2 years i.e. temporary / irreversible, significant changes for less than 6 months, or barely discernible changes for any length of time, over a small area, to key characteristics or features of the particular environmental aspect's character or distinctiveness. **Marine Ecology description** Although there may be some effects on individuals it is considered that the quality and availability of habitats and species would experience little or no degradation. Any disturbance would be in the range of natural variability. Activities predicted to occur occasionally and for a short period. Effects likely to be reversible and not likely to coincide with sensitive life stages. Effects limited to the area within the development.

Table A2.4 Significance matrix

	Values and sensitivity of receptor		
Magnitude	**Low**	**Medium**	**High**
Very Low	Negligible-Minor	Minor	Minor-Moderate
Low	Minor	Minor-Moderate	Moderate
Medium	Minor-Moderate	Moderate	Moderate-Major
High	Moderate	Moderate-Major	Major

Table A2.5 Definitions of significance criteria for effects

Level of Significance	Description
Major	Very large or large change in environmental or socio-economic conditions. Effects, both adverse and beneficial, which are likely to be important considerations at a regional or district level because they contribute to achieving national, regional or local objectives, or, could result in exceedance of statutory objectives and/or breaches of legislation.
Moderate	Intermediate change in environmental or socio-economic conditions. Effects that are likely to be important considerations at a local level.
Minor	Small change in environmental or socio-economic conditions. These effects may be raised as local issues but are unlikely to be of importance in the decision making process.
Negligible	No discernable change in environmental or socio-economic conditions. An effect that is likely to have a negligible or neutral influence, irrespective of other effects.

The rating of the significance of the effect was used to assess whether mitigation was required and to determine whether mitigation measures would reduce the effect to an acceptable (residual) rating. The ability of mitigation to reduce a potential effect was evaluated according to professional judgement. Those effects which were assigned a significance level rating of moderate significance and above were considered to require mitigation. Consequently, in the above approach, effects rated as negligible or minor were considered to be acceptable without further mitigation required.

Appendix 3: Transitional Type 3 reference conditions

Type 3 transitional waters are fully mixed, predominantly polyhaline and are macrotidal. They are sheltered, with a sand or mud substratum and tend to have extensive intertidal areas.

Reference Conditions
Phytoplankton
Fully mixed, reduced salinity water column (A7.2, A7.5)
TWs prone to higher levels of production compared with CWs, though light availability, salinity and hydrological effects may naturally temper this. Patterns of seasonal growth and succession are similar to coastal dynamics but demonstrate greater variability, in peak duration and composition. Nuisance/toxic species are at persistently low levels compared with local background levels. Peaks in chlorophyll-a, used as a proxy for phytoplankton bloom biomass, are infrequent and inter-bloom periods are low compared with background levels.
Macroalgae
Littoral rock, sub-littoral rock and other hard sediment (A1.3, A3.3)
There is a graded distribution from mouth to head whereby species richness declines upstream due to naturally selective attenuation firstly of red and then of brown algae. The outer (or lower) zones consist of a reduced version of coastal shore flora and zonation, with general fucoid domination and species richness generally in the range of 10 – 50 species depending on position along the transitional water gradient. The inner (or upper) zones are dominated by mat forming green algae, *Vaucheria* and cyanobacteria, displaying local variations with around 10 species and the extent of fucoid penetration is likely to be dependent on the salinity regime. The sublittoral flora is naturally very reduced or absent. There should also be an absence of excessive opportunistic algal growth or the presence of macroalgal blooms.
Littoral and sub-littoral sediment (A2, A4)
No normal flora or zonation pattern (except where odd hard substrate outcrops are present). Opportunistic green, brown or red algae may occur on soft surfaces but there will be a general absence of opportunistic macroalgal blooms with total cover not exceeding 10%.
Marine Angiosperms
Seagrass beds on littoral and sublittoral sediments (A2.7, A4.5)
Clean, fine sedimentary littoral or sublittoral substrata, sheltered or extremely sheltered from strong tides and currents, variable salinity can support beds of seagrass. Littoral sediments support beds of *Zostera noltii* and/or *Zostera angustifolia* and sublittoral sediments support beds of *Ruppia* spp (extremely sheltered, weak tidal streams brackish muddy sand or mud).
In existent seagrass beds mean density of healthy shoots is high. There may be a naturally high percentage cover of epiphytic macroalgae, without compromising health of seagrass species. Sub-littoral species may exhibit no or low levels of Wasting Disease (leaf infection); mean leaf area affected < 15%. Stable seagrass bed area with no loss or loss of area attributable to natural environmental events. There may be temporal variation in the abundance of seagrass in intertidal areas as seagrass will die back during cold winters.

Saltmarsh
EUNIS Classification: A2 (A2.6)
Salt marshes form on the upper parts of intertidal mud flats on sheltered coastlines where fine sediment is deposited. Salt marshes are typically found on sheltered coasts such as estuaries, inlets and behind barriers such as islands and shingle spits. Where they occur they would be expected to cover at least 75% of suitable habitat and not show significant decline in aerial extent over a 5 year rolling mean.
Benthic Macroinvertebrates
A mosaic of habitats occur within transitional waters, influenced by tidal streams, sediment deposition and salinity ranges, and a wide variety of benthic invertebrate communities exist; within this mosaic typical habitats include:
Variable salinity mud and fine sand communities (A4.32, A2.23)
Intertidal and shallow subtidal mesohaline/polyhaline mud communities which extend from the extreme lower shore may support communities comprised of bivalves such as *Macoma*, *Mya*, *Cerastoderma* and the polychaete *Arenicola*, of these genera deposit feeders would dominate mud sediments, the suspension feeders favouring sandier conditions.
Muddy sand shores (A2.25)
The drier sediment of the upper shore is characterised by the amphipods *Bathyporeia* and *Corophium* with a limited abundance of polychaetes and bivalves. Sediment of the mid and lower shore remains saturated throughout the tidal cycle and supports a lower abundance of amphipods but a wide range of polychaetes commonly occur, including Nephtys hombergii, *Scoloplos armiger* and *Pygospio elegans*. The bivalves *Cerastoderma edule* and *Macoma balthica* may also be common.
Littoral muds (A2.3)
Littoral muds, which typically form extensive mudflats in variable salinity environments, are habitats characterised by abundant polychaetes, such as *Hediste*, *Eteone* and *Pygospio*. Oligochaetes such as Tubificoides, the clam *Macoma*, the spire shell *Hydrobia ulvae* and the furrow shell *Scrobicularia plana* can also be present. The biological community becomes increasingly impoverished in reduced salinity conditions.
Fish
EUNIS CLASSIFICATION – A1, A2, A3, A4, A7. Currently there is some data available to the fish team to take this classification further. Fish species will utilise a range of habitat types dependent upon state of tide, season and life stage. A full literature search is required in order to associate habitat type with fish species. Dominated by flatfish e.g. *Platichthys flesus*, *Pleuronectes platessa*, *Limanda limanda* & *Solea solea*. Tends to be a larger functional component of freshwater species, e.g. Leuciscus leuciscus & Osmerus eperlanus and estuarine resident species such as *Agonus cataphractus*, *Ammodytes tobianus*, *Pomatoschistus microps*, *Pomatoschistus minutus* & *Platichthys flesus*. Marine juveniles are common in winter e.g *Gadus morhua*, *Sprattus sprattus*, *Clupea harengus* & *Merlangius merlangus* with marine adventitious species becoming more prevalent in summer e.g. *Liza ramada*, *Chelon labrosus*, & *Dicentrarchus labrax*.

Appendix 4: Summary Information for each of the Bird Species upon which the Mersey Estuary has been Designated

Redshank (*Tringa totanus*)

International threshold:		2,800
National threshold:		1,200
Mean peaks: (WeBS)		
1993/94-1997/98	winter:	4,993
2004/05-2008/09	winter:	2,816
2008/09	winter	1,228
1993/94-1997/98	autumn:	4,513
2004/05-2008/09	autumn:	2,602
	spring:	984
2008/09	autumn:	1,228

When the Mersey SPA was extended in June 2004, it supported 3.8% of the wintering British population of *T. t. brittanica*. Wintering numbers have declined by approximately 50% since the SPA was first established in December 1995, but they have increased by more than 200% compared with 25 years ago. The downward trend over the last 15 years reduced wintering numbers from well above the international threshold to only just above national significance in the last winter for which WeBS data are available (2008/09). This decline on the Mersey matches the decline that has taken place nationally which itself may be linked to an eastwards shift in the distribution of wintering redshank in Western Europe, perhaps linked to climate change.

The number of redshanks on passage in autumn have also declined by approximately 50% since the SPA was established. The reduction has resulted in autumn numbers falling from well above the international threshold to only just above national significance in the last year for which data are available (2008/09). There are no data on the national numbers of autumn passage redshank with which to compare the downward trend on the Mersey.

The surveys by RSK Environment over the exposure period that were made during the winters of 2008/09 and 2009/10 show that, in both years, the numbers of wintering redshank in the SPA only ever exceeded the national threshold, this happening in just two months in both years: however, the national threshold was exceeded in the estuary as a whole in 2009/10 in an additional three winter months. Indeed, more than 50% of the estuary population was often not found in the Mersey SPA. Although sometimes this was mainly due to birds roosting in Frodsham, this was by no means always the case. Accordingly, it is likely that a significant amount of winter feeding in the Mersey estuary was sometimes done outside the SPA. Nonetheless, the majority of their winter feeding was carried out in the SPA.

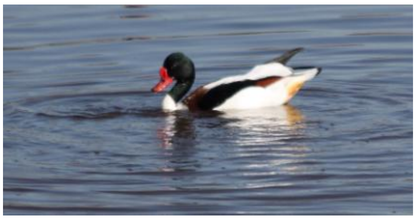
Both the graphic and the Figure 0.1 reveal that, in winter, foraging redshank were widely dispersed within the estuary. Across both winters, 11 sites occurred in the two most populated sites in a month, with Manisty, Eastham, New Ferry, Crosby and New Brighton occurring most frequently (3 to 5 times) in the top two.

The RSK surveys during the autumn passage periods (July-September) in 2009 and 2010 showed that the number of redshank in the SPA exceeded the national threshold regularly in both years, and sometimes also exceeded the international threshold: the pronounced peaks of redshank numbers during the autumn and spring passage show clearly in Figure 0.1. However, in comparison to winter, the majority of redshank on passage occurred in limited parts of the estuary, being found mainly the flats off Manisty and Eastham, and thus well within the boundary of the Mersey SPA.

On the intertidal flats of estuaries, redshank mainly eat medium-sized macro-invertebrates, particularly the ragworm *Hediste diversicolor* (10-100mm) and other polychaetes, but also crustaceans, particularly *Corophium volutator* (>3.5mm), gastropod molluscs, particularly *Hydrobia ulvae* (>1.5mm), and bivalve molluscs, particularly *Macoma balthica* and *Scrobicularia plana* (2.5-14.5mm). In mid-winter, redshank usually feed for a very high proportion of the time during which the intertidal flats are exposed. Many birds can be seen feeding as soon as the first mudflats are exposed on the receding tide and as the last flats are covered on the advancing tide. Redshank is generally regarded as one of the species most likely to have difficulty in obtaining its food requirements during difficult periods of the winter, and some major mortalities have occurred in this species during severe winter weather.

As the graphic shows, redshank were recorded by RSK mainly on mud, muddy-sand and sandy-mud although they also used the large sandy area off Oglet. Of their low tide feeding areas on Spring tides, scheme IBv2 would leave 62% remaining whereas VLHBv2 and v3 would leave remaining 90% and 94% respectively. But as so much feeding by redshank is done at the higher shore levels throughout Neap tides and on all tides as the tide first recedes and advances, a rather larger percentage of the flats they use throughout the exposure period as a whole on all tides would remain than these figures, which are limited to Spring tides, indicate.

Shelduck (*Tadorna tadorna*)



International threshold:		3,000
National threshold:		782
Mean peaks: (WeBS)		
1993/94-1997/98	winter	6,476
1994/95-1998/99	autumn	8,137
2004/05-2008/09	winter	2,901
	autumn	15,249
2008/09	winter	4,237

When the Mersey SPA was extended in June 2004, it supported in winter 2.2% of the north-west European breeding population of shelduck. Wintering numbers have declined by approximately 45% since the SPA was first established in December 1995 and by more than 50% over the last 10 years. On the other hand, the numbers in autumn have almost doubled over the same period. Whereas the significance of the Mersey for shelduck in the early 1990's was its role as a wintering site, peak numbers now occur in July and August, suggesting that the estuary is now functioning as a moulting ground.

The surveys by RSK Environment over the exposure period that were made during the winters of 2008/09 and 2009/10 show that the numbers of wintering shelduck in the Mersey SPA exceeded the national threshold in four and two months respectively. It was only in autumn that shelduck numbers exceeded the international threshold, in August 2009 and July 2010. The great majority of these ducks were recorded within the boundary of the SPA in both autumn and winter.

Both the graphic and Figure 0.2 reveal that, in winter, many foraging shelduck occurred on the south side of the estuary off Eastham, Ellesmere, Manisty, Stanlow and Weaver but also on the north side off Hale. Some also occurred towards the middle of the estuary off Oglet. In the peak autumn months of August 2009 and July 2010, the majority of shelduck occurred on the flats off Manisty, Eastham and Ellesmere, which may indicate a preference to form large flocks when moulting.

On the intertidal flats of estuaries, shelduck mainly eat molluscs, particularly the gastropod *Hydrobia ulvae* (probably >1.5mm), but may also take crustaceans, such as *Corophium volutator* and bivalve molluscs, such as *Macoma balthica*.

As the graphic shows, shelduck were recorded by RSK mainly on mud, muddy-sand and sandy-mud. Of their low tide feeding areas on Spring tides, scheme IBv2 would leaves 69% remaining whereas VLHBv2 and v3 would leave remaining 90% and 93% respectively. But as so much feeding by shelduck is done at the higher shore levels throughout Neap tides and on all tides as the tide first recedes and advances, a rather larger percentage of the flats they use throughout the exposure period as a whole on all tides would remain than these figures indicate.

Teal (*Anas crecca)*

International threshold:	5,000
National threshold:	1,920
Mean peaks: (WeBS)	
1993/94-1997/98	11,723
2004/05-2008/09	4,787
2008/09	2,000

When the Mersey SPA was extended in June 2004, the SPA supported 2.9% of the north-west European non-breeding population. By 2006/07, however, wintering numbers had declined by approximately 75% since the Mersey SPA was first established in December 1995. The latest WeBS counts suggest that the trend downwards is continuing and at a greater rate than the more gentle national decline.

The surveys by RSK Environment over the exposure period that were made during the winters (when teal are most numerous) of 2008/09 and 2009/10 show teal numbers exceeded the national threshold only in a single month, December 2009 (Figure 0.3). Often, a very high proportion of the birds were not found within the Mersey SPA but were mainly at Frodsham. This occurred particularly during the winter 2008/09 and during the autumn of 2009. Accordingly, it is not clear how much of their feeding was done inside the SPA.

Within the Mersey SPA, the largest concentrations of teal during the winter 2008/09 were recorded by RSK on several of the intertidal flats, mostly those off Hale, Weaver, Crosby and Oglet with smaller numbers off Ellesmere and New Ferry. During the winter of 2009/10, the greatest numbers of teal within the Mersey SPA consistently occurred off Manisty and Eastham, with the remainder occurring in several, widespread sites – Weaver, New Ferry, Garston, Ince, Stanlow, Ellesmere, Runcorn, Hale and Crosby.

Teal are omnivorous but little is known of their diet on estuaries. It is likely to include both vegetable matter – particularly, perhaps, the seeds of saltmarsh plants and some algae, such as *Enteromorpha* - and perhaps small macro-invertebrates, the gastropod *Hydrobia ulvae* being a likely component.

As the graphic shows, teal were recorded by RSK on mud, muddy-sand , sandy-mud and sandy areas, probably because they tend to feed at the edge of the tide and in watery depressions, on whatever the underlying sediment. Of their low tide feeding areas on Spring tides, scheme IBv2 would leaves 87% remaining whereas VLHBv2 and v3 would leave remaining 99% and 100% respectively. But as so much feeding is done at the tide edge, even IBv2 is likely to have a much lesser impact on their feeding areas than this calculation suggests.

Pintail (*Anas acuta*)

International threshold:	600
National threshold:	279
Mean peaks: (WeBS)	
1993/94-1997/98	1,169
2004/05-2008/09	103
2008/09	56

When the Mersey SPA was extended in June 2004, the SPA supported 1.9% of the north-west European non-breeding population of pintail. By 2006/07, however, wintering numbers had declined by approximately 95% since the SPA was first established in December 1995. The latest WeBS counts suggest that the trend downwards is continuing. In contrast, national numbers seem to have fluctuated over the period, without trend.

The surveys by RSK Environment over the exposure period that were made during the winters (when pintail are most numerous) of 2008/09 and 2009/10 show that their numbers did not reach even the national threshold in a single month (Figure 0.4). Indeed, only in January 2010 did their numbers reach half the national threshold. As so few pintail were recorded at Frodsham, most of the small number of birds present were found within the boundary of the SPA.

Within the Mersey SPA, the most consistently used site in both winters were the intertidal flats off New Ferry and, to a lesser extent during 2009/10, those off Manisty and Easthham. Very few pintail occurred elsewhere within the Mersey SPA.

Pintail are omnivorous but little is known of their diet on estuaries. It is likely to include both vegetable matter – particularly, perhaps, the seeds of saltmarsh plants and some algae, such as *Enteromorpha* - and perhaps small macro-invertebrates, the gastropod *Hydrobia ulvae* being a known constituent of their diet.

As the graphic shows, pintail were recorded by RSK on mud, muddy-sand and sandy-mud areas. Of their low tide feeding areas on Spring tides, scheme IBv2 would leave only 19% remaining whereas VLHBv2 and v3 would leave remaining 72% and 79% respectively.

Dunlin (*Calidris alpina*)

International threshold:	13,300
National threshold:	5,600
Mean peaks: (WeBS)	
1993/94-1997/98:	48,789
2004/05-2008/09	33.795
2008/09	23,115

When the SPA was extended in June 2004, the Mersey SPA supported 3.7% of the west Europe population. Although numbers have declined by approximately 40% since the SPA was first established in December 1995, they have increased compared with 25 years ago. The downward trend over the last 15 years or so matches the decline that has taken place nationally which itself may be linked to an eastwards shift in the distribution of wintering dunlin in Western Europe, perhaps linked to climate change.

The surveys by RSK Environment over the exposure period that were made during the winters of 2008/09 and 2009/10 show dunlin numbers were above both the international and national thresholds in both winters from November to February and also in March in the second winter. As Figure 0.5 shows, rather few dunlin occur on the estuary during the autumn and spring passage months. In winter, a high proportion of the birds were often not found within the Mersey SPA but were outside the boundary, mainly at Frodsham where they do not feed but roost over high tide. Accordingly, most of the feeding by dunlin in the Mersey estuary was done within the SPA, in the areas shown in the graphic.

The Frodsham peak counts of roosting birds exceeded either or both the international and national thresholds in most of the winter months in both years. The largest concentrations of foraging dunlin during the winter 2008/09 were recorded by RSK on the intertidal flats adjacent to Ellesmere and Stanlow, Hale, Ince and Weaver, with some use made of the flats off Oglet. During the winters 2009/10, the greatest numbers again occurred off Stanlow and Ellesmere but also off Manisty, with some use made of the flats off Hale, Weaver and Ince. Foraging dunlin were therefore distributed widely within the SPA during 2008/09 and 2009/10 with the Ellesmere and Stanlow areas being important in both but with the centre of gravity of their distribution shifting somewhat from Hale towards Ince in the second winter.

On the intertidal flats of estuaries, dunlin mainly eat small-sized macro-invertebrates, particularly the ragworm *Hediste diversicolor* (<50mm) and other small polychaetes and oligochaetes, but also gastropod molluscs, particularly *Hydrobia ulvae* (>1.5mm), bivalve molluscs, particularly *Macoma balthica* (<9.5mm) and crustaceans, such as *Corophium volutator* (>3.5mm). In mid-winter, dunlin usually feed for a very high proportion of the time for which the intertidal flats are exposed. Many birds can be seen feeding as soon as the first mudflats are exposed on the receding tide and as the last flats are covered on the advancing tide. Dunlin is generally regarded as one of the species most likely to have difficulty in obtaining its food requirements during difficult periods of the winter.

As the graphic shows, dunlin were recorded by RSK mainly on mud, muddy-sand and sandy-mud although they also used the large sandy area off Oglet. Of their low tide feeding areas on Spring tides, scheme IBv2 would leaves 61% remaining whereas VLHBv2 and v3 would leave remaining 90% and 92% respectively. But as so much feeding by dunlin is done at the higher shore levels throughout Neap tides and on all tides as the tide first recedes and advances, a rather larger percentage of the flats they use throughout the exposure period as a whole on all tides would remain than these figures indicate.

Golden plover (*Pluvialis apricaria*)

International threshold:	9,300
National threshold:	4,000
Mean peaks: (WeBS)	
1993/94-1997/98	3,040
2004/05-2008/09	625
2008/09	1,420

When the Mersey SPA was extended in June 2004, the SPA supported 1.2% of the British wintering population on peak counts. Although there has been an increase of well over 50% compared with 25 years ago, the numbers of golden plover have declined by almost 80% since the Mersey SPA was first established in December 1995 and by more than 50% over the last 5-10 years. In contrast, numbers have shown a steady increase in England from the early 1980's up until about 2005. But as this plover is primarily a bird of agricultural land, and occurs most often on estuaries when fields are frozen or snow-covered, the decline on the Mersey estuary may simply reflect a shift in their distribution between estuary and fields as winters have become generally less severe.

The surveys by RSK Environment over the exposure period that were made during the winters of 2008/09 and 2009/10 show that golden plover numbers were only ever above national thresholds during three months of the first winter and not subsequently (Figure 0.6). Often, a high proportion of the birds were not found within the Mersey SPA but were outside the boundary, mainly at Frodsham. When these birds were on the estuary within the Mersey SPA, they mostly occurred on the flats off Ince and Weaver, both of which are close to Frodsham, and occasionally on the other side of the estuary, off Garston.

In terrestrial habitats, golden plover take a wide variety of invertebrates, but principally beetles and earthworms. Very little is known of their diet when they visit estuaries, which they mainly do during severe winter spells, but it is likely to include a range of medium-sized macro-invertebrates. However, on the Mersey, very little feeding – if any – has been recorded on the intertidal flats by RSK. These plovers mainly use the estuary for roosting. Therefore, none of the schemes IBv2, VLHBv2 and v3 would have an impact on the feeding areas of this plover.

Black-tailed godwit (*Limosa limosa*)

International threshold:		470
National threshold:		150
Mean peaks: (WeBS)		
1993/94-1997/98	winter	976
1994/95-1998/99	autumn	1,140
2004/05-2008/09	winter	303
	autumn	2,730
2008/09		54

When the Mersey SPA was extended in June 2004, the SPA supported 2.8% of the west Europe wintering population of *L.l. islandica.* Winter numbers have declined by approximately 65% since the SPA was first established in December 1995. However, peak autumn numbers have approximately doubled over the same period, giving the estuary an increasing importance during the autumn passage.

The surveys by RSK Environment over the exposure period that were made during 2008/09 and 2009/10 show that black-tailed godwit numbers were usually above the international and national thresholds from August 2009 to September 2010 but were extremely low during the first winter, a substantial difference between years that has yet to be explained. In that second winter, the great majority of the godwits were found within the Mersey SPA.

As Figure 0.7 shows, the largest concentrations of black-tailed godwits during the second year were recorded by RSK on the intertidal flats on the south side of the estuary, adjacent to New Ferry, Manisty, Eastham, Ellesmere and Stanlow. Significant numbers also occurred on passage on the other side of the estuary off Garston.

On the intertidal flats of estuaries, black-tailed godwits mainly eat medium-sized macro-invertebrates, particularly the bivalve molluscs *Macoma balthica* and *Scrobicularia plana* (5.5-19.5mm) and polychaete worms, such as the ragworm *Hediste diversicolor,* lugworm *Arenicola marina* and *Scoloplos* spp.(>20mm). They also supplement their intertidal diet regularly by feeding on earthworms in fields.

As the graphic shows, black-tailed godwit were recorded by RSK mainly on mud, muddy-sand and sandy-mud. Of their low tide feeding areas on Spring tides, scheme IBv2 would leaves 74% remaining whereas VLHBv2 and v3 would leave remaining 96% and 97% respectively. But as so much feeding is likely to be done at the higher shore levels throughout Neap tides and on all tides as the tide first recedes and advances, a rather larger percentage of the flats they use throughout the exposure period as a whole on all tides would remain than these figures indicate.

Curlew (*Numenius arquata*)

International threshold	8,500
National threshold	1,500
Mean peaks: (WeBS)	
1993/94-1997/98	NA
2004/05-2008/09 winter	1,264
autumn	1,308
2008/09	1,038

Curlew was not cited in the Mersey SPA designation of December 1995 and the data on their abundance then are not available. However, there numbers according to the WeBS seem to have remained steady over the most recent six autumns and winters.

The surveys by RSK Environment over the exposure period that were made during the autumns and winters of 2008/09 and 2009/10 show that curlew numbers in the Mersey SPA and in the estuary as a whole only exceeded national thresholds in September in both years, during the autumn passage. Numbers were well below even the national threshold throughout the winter. Even though some birds were regularly seen at Frodsham, outside the Mersey SPA, a high proportion of curlew were found within the SPA.

As the graphic and Figure 0.8 show, the curlew recorded by RSK were distributed widely on the intertidal flats with significant numbers being recorded at five and eight sites respectively over the winters of 2008/09 and 2009/10. The birds were similarly widely distributed in the autumn. More than 75% of the foraging curlews were recorded within the SPA during the autumns and winters of both 2008/09 and 2009/10.

On the intertidal flats of estuaries, curlew mainly eat the large-sized macro-invertebrates, particularly polychaete worms, such as the ragworm *Hediste diversicolor* and lugworm *Arenicola marina* (>50mm), bivalve molluscs, particularly *Macoma balthica* and *Scrobiculari plana* (5.5-19.5mm) and crustaceans, particularly the crab *Carcinus maenas* (10-35mm). Especially in winter, curlew often supplement their intertidal diet by feeding in fields on earthworms at both high tide and low tide.

As the graphic shows, curlews were recorded by RSK on mud, muddy-sand and sandy-mud and sand. Of their low tide feeding areas on Spring tides, scheme IBv2 would leave 69.3% remaining whereas VLHBv2 and v3 would leave remaining 91.9 and 94% respectively. But as so much feeding by curlew is likely to be done at the higher shore levels throughout Neap tides and on all tides as the tide first recedes and advances, a rather larger percentage of the flats they use throughout the exposure period as a whole on all tides would remain than these figures indicate.

Wigeon (*Anas Penelope*)

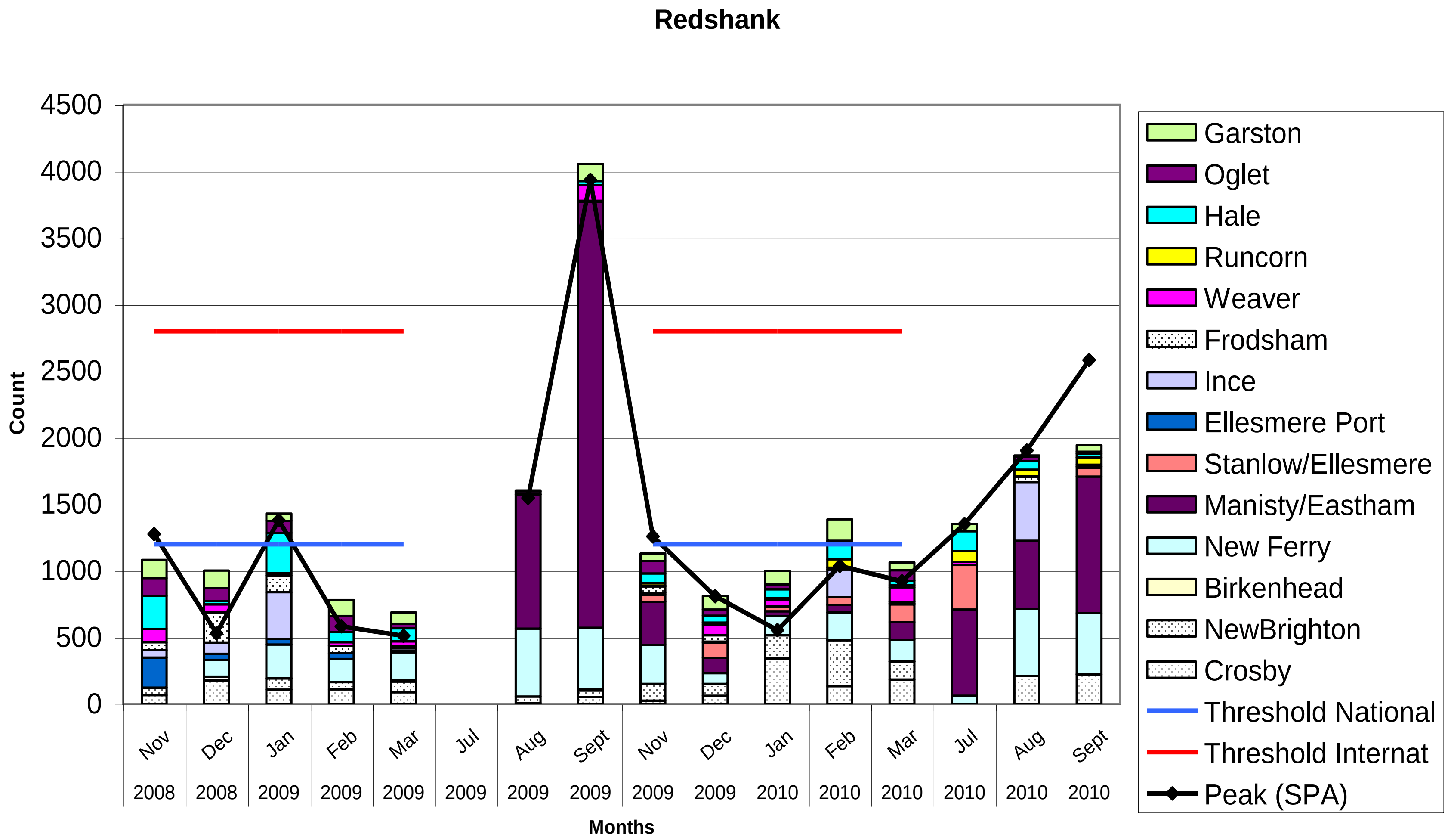
International threshold:	15,000
National threshold:	4,060
Mean peaks: (WeBS)	
1993/94-1997/98	NA
2004/05-2008/09	1,384
2008/09	800

By 2006/07, wintering numbers of wigeon had declined by approximately 95% since the Mersey SPA was first established in December 1995, despite there being no such decline in numbers in England as a whole; indeed, numbers steadily increased over much of the period.

The surveys by RSK Environment over the exposure period that were made during the winters 2008/09 and 2009/10 found so few wigeon that the analysis carried out on the other designating species could not be meaningfully carried out.

Wigeon are almost entirely vegetarian and, on estuaries, graze on saltmarsh plants on plants and algae in the intertidal zone, such as *Zostera* and *Enteromorpha*. However, nothing seems to be known of their diet on the Mersey.

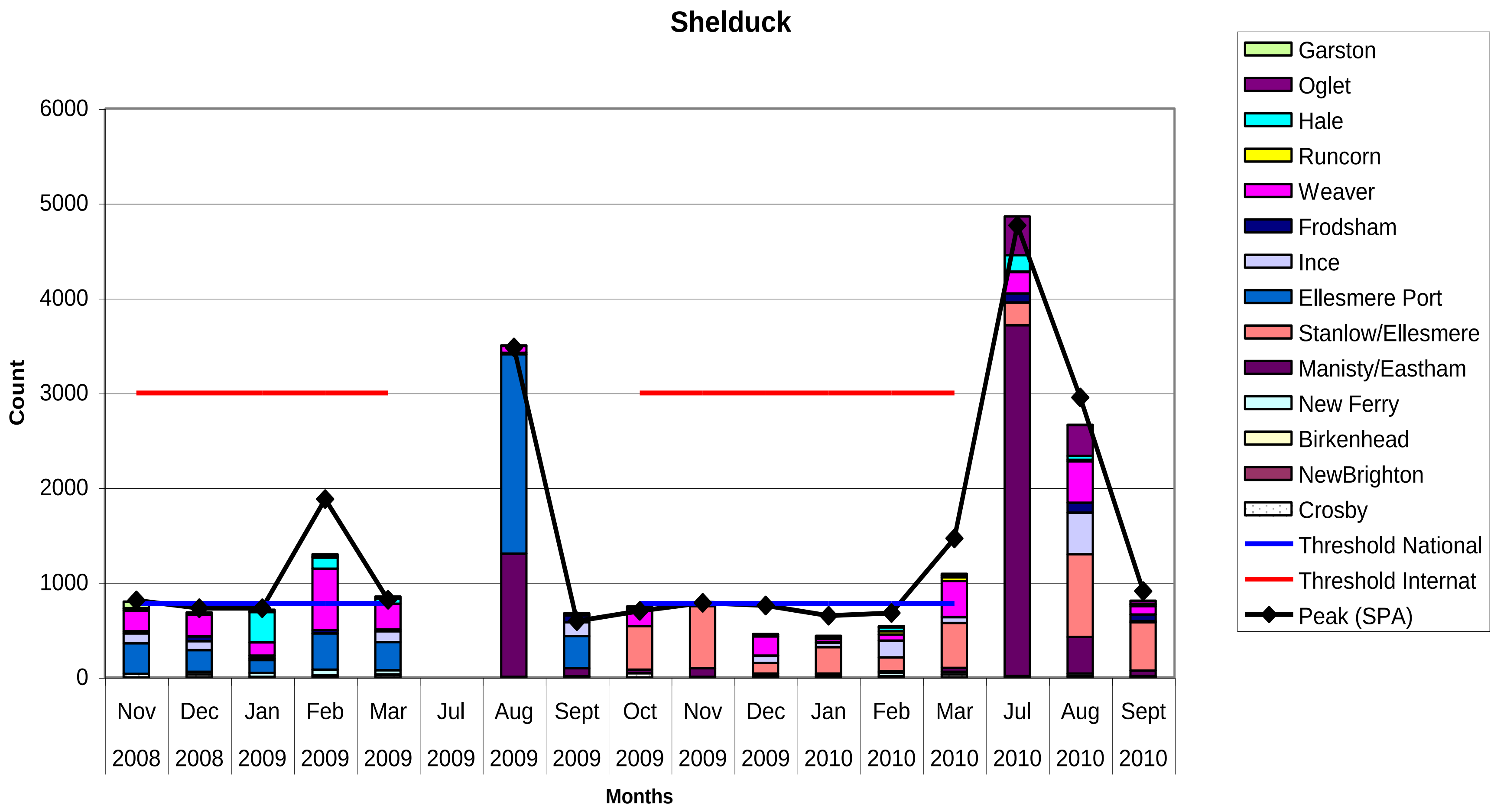
Figure 0.1: Average and peak Redshank counts from passage and wintering bird surveys carried out at various locations in the Mersey Estuary from Nov 08 to Sept 2010



NB. Stacked bars are average counts from two surveys within each month.

Peak counts are peak counts from only sites within the Mersey Estuary SPA on either the first or second survey of the month.

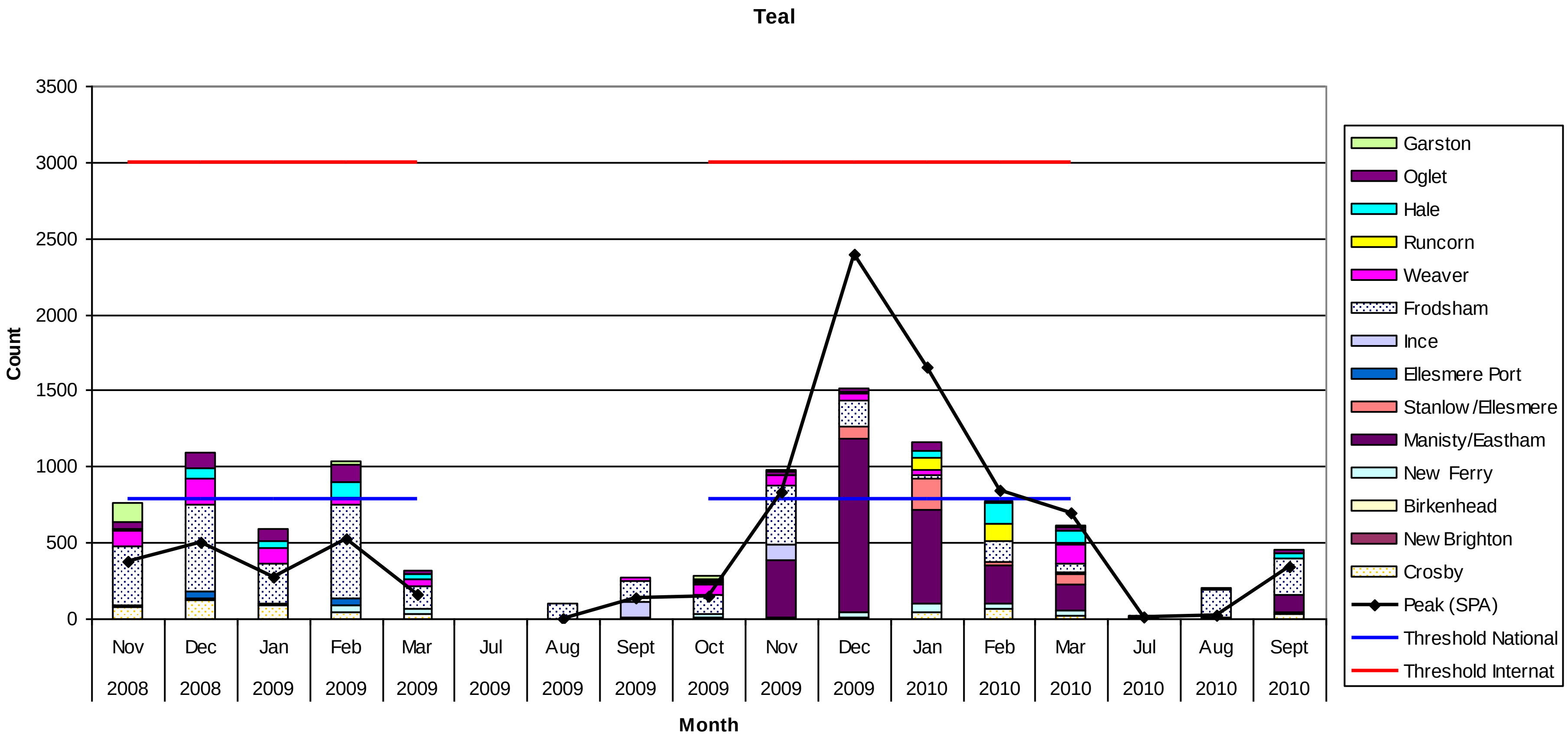
Figure 0.2: Average and peak Shelduck counts from passage and wintering bird surveys carried out at various locations in the Mersey Estuary from Nov 08 to Sept 2010



NB. Stacked bars are average counts from two surveys within each month.

Peak counts are peak counts from only sites within the Mersey Estuary SPA on either the first or second survey of the month.

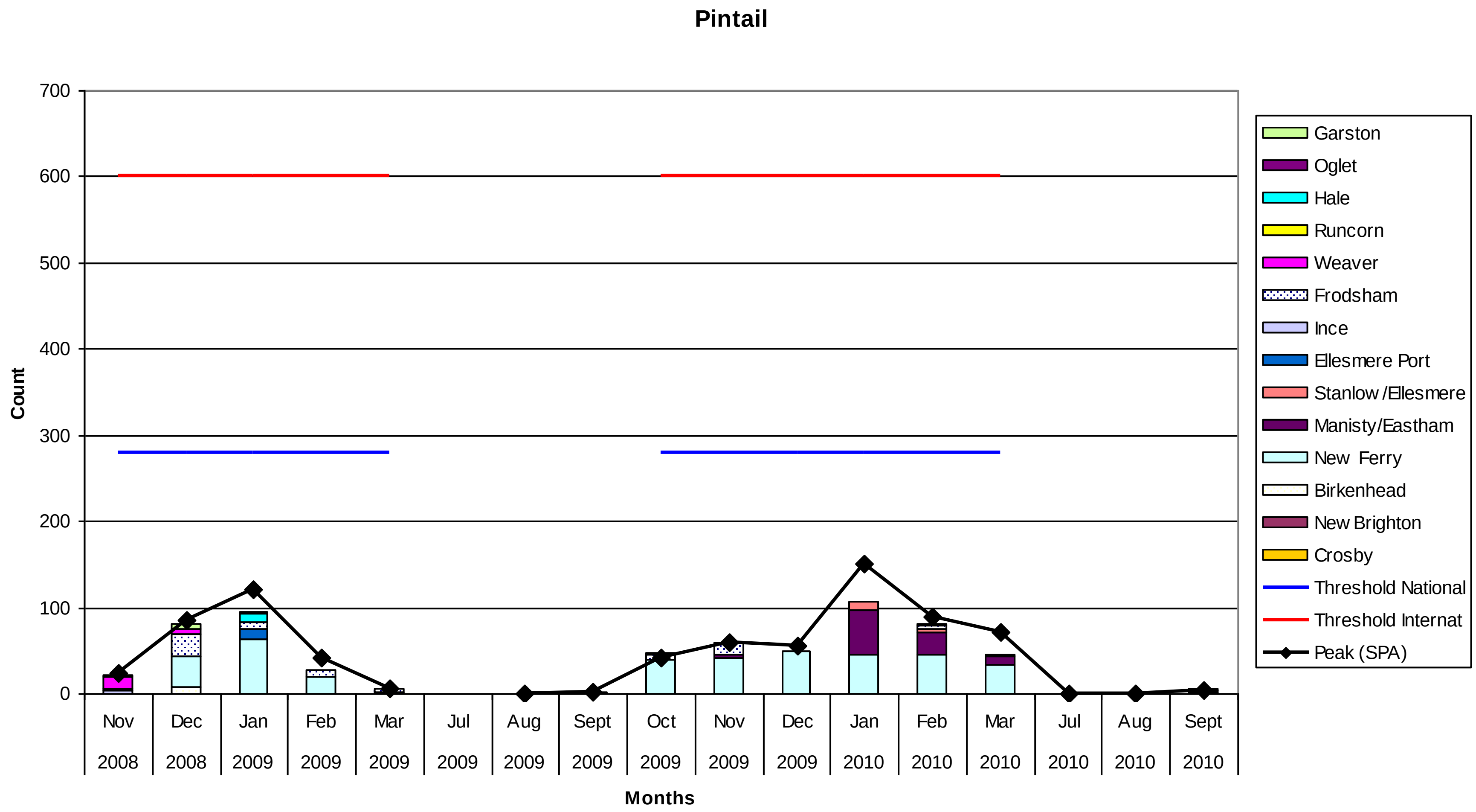
Figure 0.3: Average and peak Teal counts from passage and wintering bird surveys carried out at various locations in the Mersey Estuary from Nov 08 to Sept 2010



NB. Stacked bars are average counts from two surveys within each month.

Peak counts are peak counts from only sites within the Mersey Estuary SPA on either the first or second survey of the month.

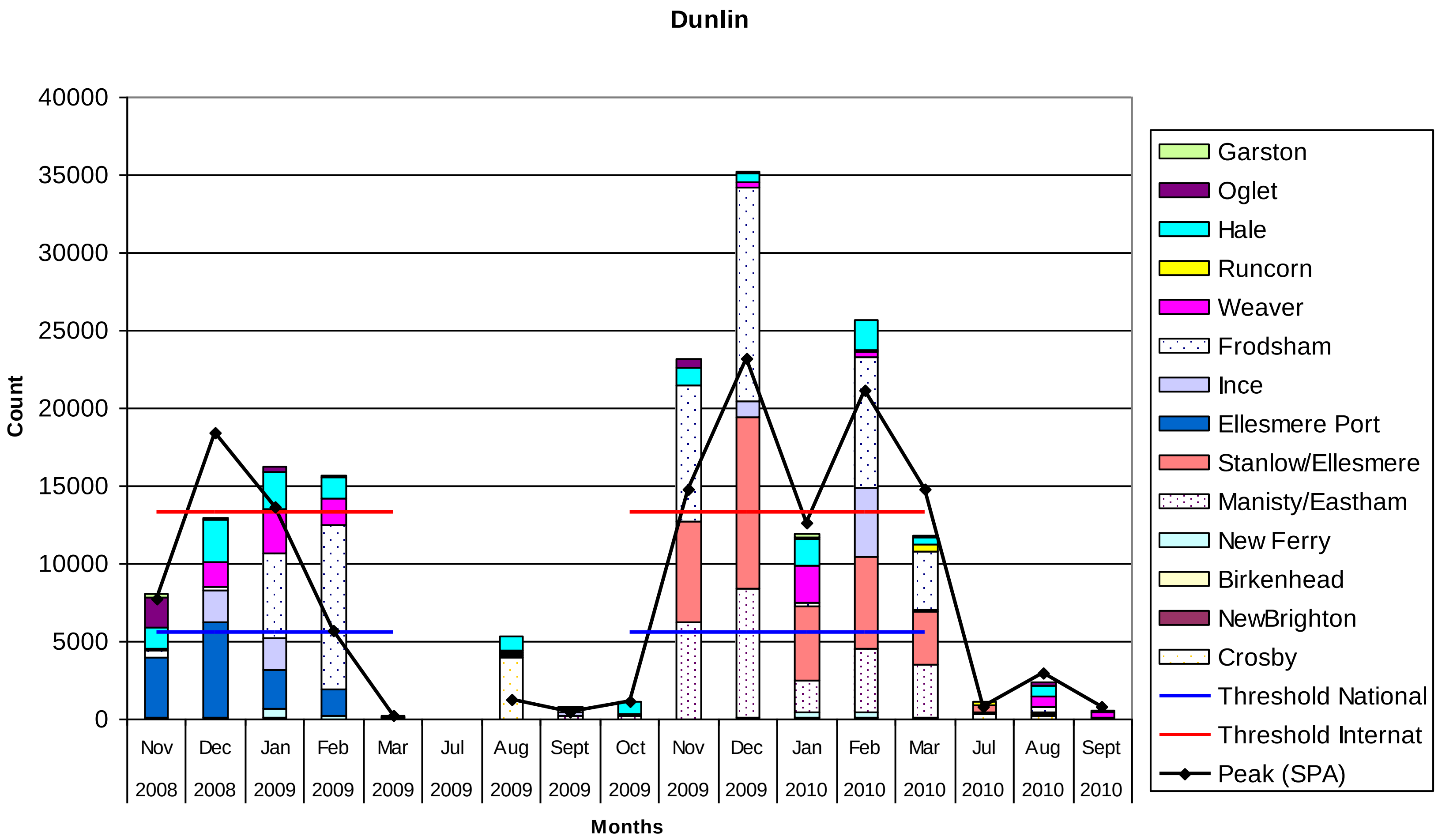
Figure 0.4: Average and peak Pintail counts from passage and wintering bird surveys carried out at various locations in the Mersey Estuary from Nov 08 to Sept 2010



NB. Stacked bars are average counts from two surveys within each month.

Peak counts are peak counts from only sites within the Mersey Estuary SPA on either the first or second survey of the month.

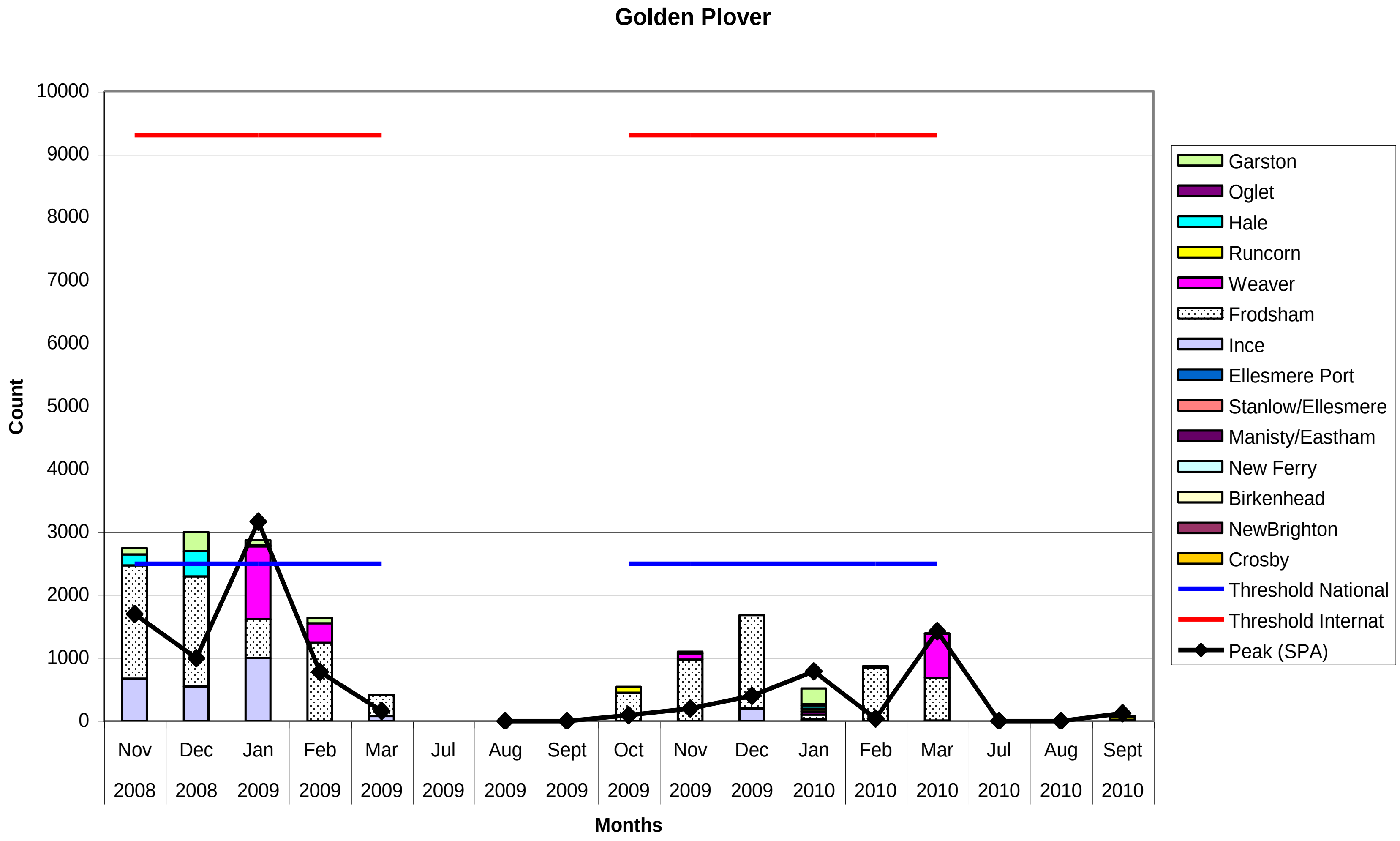
Figure 0.5: Average and peak Dunlin counts from passage and wintering bird surveys carried out at various locations in the Mersey Estuary from Nov 08 to Sept 2010



NB. Stacked bars are average counts from two surveys within each month.

Peak counts are peak counts from only sites within the Mersey Estuary SPA on either the first or second survey of the month.

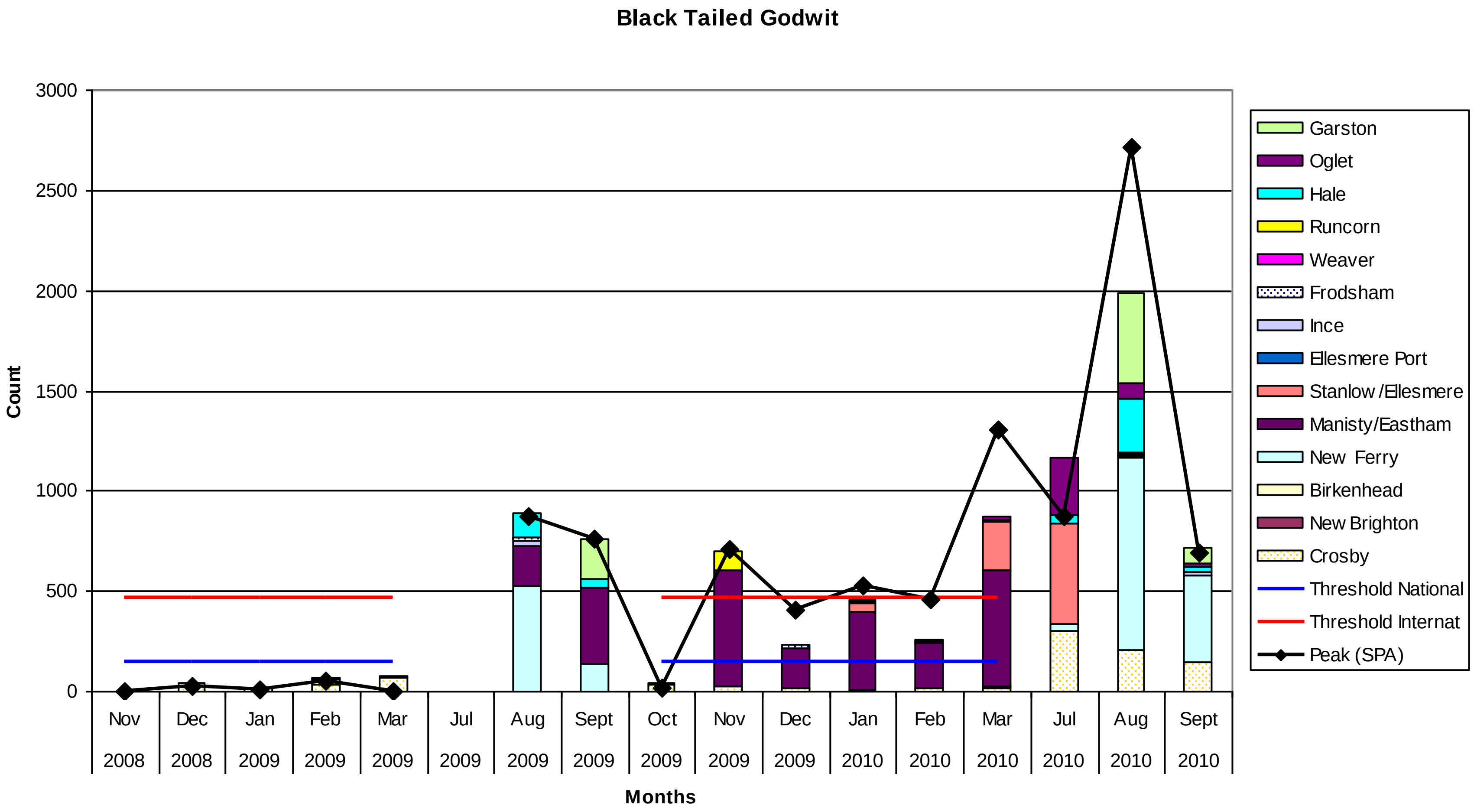
Figure 0.6: Average and peak Golden Plover counts from passage and wintering bird surveys carried out at various locations in the Mersey Estuary from Nov 08 to Sept 2010



NB. Stacked bars are average counts from two surveys within each month.

Peak counts are peak counts from only sites within the Mersey Estuary SPA on either the first or second survey of the month.

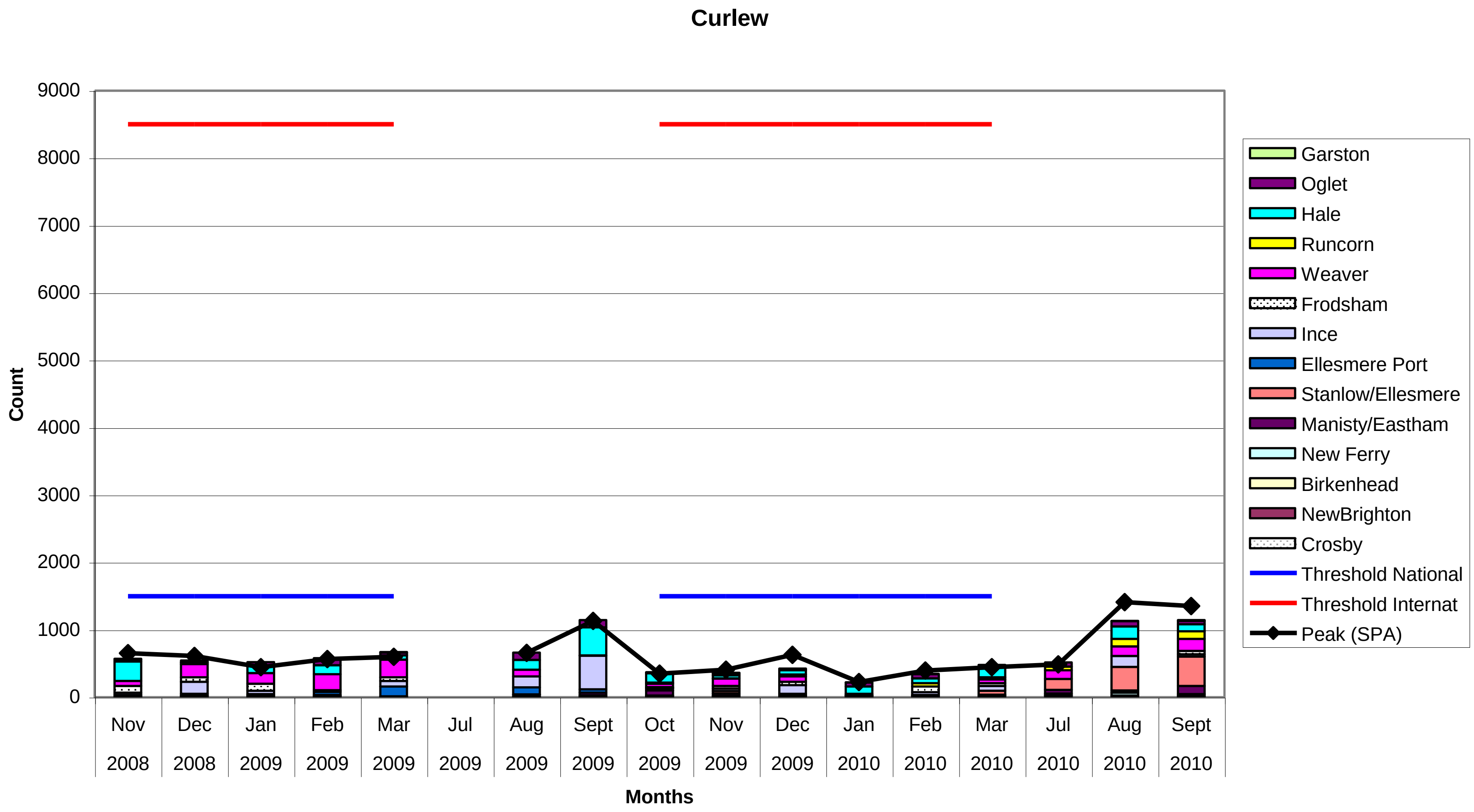
Figure 0.7: Average and peak Black-Tailed Godwit counts from passage and wintering bird surveys carried out at various locations in the Mersey Estuary from Nov 08 to Sept 2010



NB. Stacked bars are average counts from two surveys within each month.

Peak counts are peak counts from only sites within the Mersey Estuary SPA on either the first or second survey of the month.

Figure 0.8: Average and peak Curlew counts from passage and wintering bird surveys carried out at various locations in the Mersey Estuary from Nov 08 to Sept 2010



NB. Stacked bars are average counts from two surveys within each month.

Peak counts are peak counts from only sites within the Mersey Estuary SPA on either the first or second survey of the month.

Appendix 5: Prevent Harm, Mitigation and Compensation Table

Category of measure	Adverse impact for which measure is preventing, mitigating or compensating. Timing and duration of impact.	Measure to prevent/ mitigate/ compensate	Cost implication	Estimate of impact on energy outputs	Established practice/ method?	Requirement for further study/investigation
Prevent harm	Fish injury/mortality during passage past/through the scheme and resultant life history and population impacts. Impact during operation only. Permanent impact during life of operation of project with potential for consequences upon population to remain following decommissioning.	Use of more fish friendly turbine technologies	There may be direct increases in capex cost associated with the use of more fish friendly turbine technologies. The cost would depend upon the technology employed.	There is potential for the use of more fish friendly turbine technologies to have an adverse impact upon energy dependent upon technology type employed	The use of more fish friendly turbine types is an established practice for run of river hydropower schemes.	Fish friendly technology development specific for a tidal power scheme of this size and type would be required by manufacturers.
		Fish passage routes (assumed at this stage to be full depth sluice gate with a width suitable to divert 0.5% of the total flow per structure). To focus upon seaward migrants only under the assumption that landward migrants will be able to pass through the existing sluice structures and free-wheeling turbines. Key species to include migratory salmonid smolts, silver eel and lamprey adults. Other species include estuarine residents, marine migrants and marine stragglers navigating seaward past the scheme.	The cost of replacing a blank caisson and associated sand ballast with a sluice gate suitable for passing 0.5% of the total flow.	The operation of fish passage routes will have a direct impact upon energy outputs. It is possible that between 2 and 10% of the flow is passed through fish passage routes. It is assumed at this time that 2% of the total flow will be diverted through fish passage routes for each scheme. If water is diverted through the fish passage structures during generation only then the reduction in energy output will be roughly commensurate to the percentage of flow diverted i.e. 2%. If the fish passage routes are also operated during low and high water slack periods then there will be a further energy output penalty through loss of stored water which would be in the region of tenths of a percentage.	The provision of a safe route for fish passage at a hydropower project is standard practice and is specified under a number of legislative drivers and consent processes. Where sufficient natural route locations cannot be identified, fish passage structures are regularly specified and incorporated into scheme design. The Annapolis Royal tidal power plant is the most applicable example to a tidal power scheme in the Mersey Estuary.	The incorporation of fish passage routes within a MTP scheme would require further ecological and engineering technical development.
		Channel fixing for fish passage attraction. Measures will focus upon the creation of fixed channels away from the turbine units and the maintenance of a constant attraction flow in these channels to funnel fish away from the attraction of the flow from the turbines towards areas of safer passage.	Costs are dependent on the locations and width of channels. Material would also need to be disposed of.	There is likely to be some impact upon energy outputs due to some of the flow which could be used for powering turbines being directed through fish passage route facilities and down the fixed channels targeted for providing safe passage routes for migratory fish species. This impact is not however expected to be beyond that for the fish passage routes detailed above.	Existing methods involve the creation of bypass channels, of the use of deterrent technology and screening to increase the avoidance of turbine intakes by fish.	The practical feasibility of creating guidance channels and maintaining an adequate attraction flow within them requires further investigation.
		Fish screening – behavioural deterrents / attractants (acoustic and/or lights). Measure to focus upon seaward migrants only under the assumption that landward migrants will pass through the existing sluice structures and free-wheeling turbines. Measure to be used as an attract towards safe fish passage routes and/or a deterrent from areas of turbine passage. Key species to include migratory salmonid smolts, silver eel and lamprey transformers. Other species include estuarine residents, marine migrants and marine stragglers navigating seaward past the scheme.	An acoustic and strobe combination scheme to be placed across the whole of the turbine caisson frontage at distance from the scheme requiring self-supporting structure would have high cost implications.	No predicted impact upon energy outputs. There will be an energy requirement and associated cost for operation.	The use of behavioural fish screening technologies are an established practice for hydropower developments including the Annapolis Royal tidal power plant. They are also regularly used in estuarine environments for power station and other intakes.	Refinement of design, location placement and operation would be required for a preferred scheme. Further desk based investigation would be required on the stimuli response of the target species, their swimming ability and the likely efficacy of this measure.

	Reduction in exposed area of intertidal habitat Impact during operation Permanent impact during lifetime of project	Alterations to operation regime: Ebb vs ebb-flood generation.	Costs have been estimated by the overall project team as part of the scheme assessments.	There will be an effect on energy output which has been assessed by the wider project team as part of alternative scheme assessment.	La Rance generates on both the ebb and flood tide.	The ebb-flood generation scenario provides a tidal regime which is the least unfavourable of the options. Investigations should therefore be carried out to determine how the regime in an ebb only scenario can be manipulated to be more like that of the ebb-flood. The incorporation of more sluice gates in ebb only operation will assist lowering the low water level, thus exposing more intertidal area for birds to feed on. The numbers of sluices to be incorporated could therefore be optimised in future studies.
		Alterations to operation regime: low tide sluicing.	Costs have been estimated by the overall project team through inclusion of the measure within the Stage 3 scheme report.	Potential for effects on energy output. By allowing the low tide level to fall to an almost natural level, it is possible that the optimum level of water is not achieved in the basin during the flood tide.	Unknown at present.	Further modelling work would need to be carried out on the effects on tidal range of the incorporation of sluices. The numbers of sluices to be incorporated will need to be optimised in future studies in relation to basin recharge.
		Alterations to operation regime: high tide pumping.	Costs have been estimated by the overall project team through consideration of the measure during the Stage 3 assessment.	Would increase energy output and get closer to baseline high water levels. But would result in an energy penalty in pumping	Unknown at present.	Further modelling work would need to be carried out on the effects on tidal range and energy cost of the incorporation of high tide pumping.
		Alterations to operation regime: seasonal/tidal operation.	Costs have been estimated by the overall project team through consideration of the measure during the Stage 3 assessment.	Would probably reduce energy, but is dependent upon the actual regime imposed. Could be the case that in mild winters there is no need to change the regime.	Unknown at present.	Further work would be required to establish what level of tidal exposure faunal assemblages inhabiting the sub-littoral might survive.
		Encourage sediment deposition via caisson placement.	Neutral. No increase in blank caisson number.	Depending on the location of the structures changes in energy may be apparent but are likely to be negligible.	Sediments naturally deposit around structures with pooled back eddy waters and as such it is considered that sediments would naturally deposit around the blank caissons within the scheme designs.	Sedimentation modelling indicating the likely area of accretion would be required before the preferred location of caisson placement could be determined or the area that could be gained could be quantified.
		Accretion guide walls.	Low Depending on the length of walls and the identification of potentially suitable locations for their deployment.	Depending on the location of the structures changes in energy may be apparent but are likely to be negligible.	There are a number of case study examples from the UK whereby rock sills have been implemented e.g. South Ferriby, Goxhill and Barrow Haven, Humber Estuary. The majority of information is in the form of grey literature held by the statutory bodies.	Further investigation into whether accretion guide walls could be located within the Mersey Estuary and an assessment of their effectiveness should be undertaken. Sedimentation modelling indicating the likely area of accretion would be required before the

						location of accretion guide walls could be determined or the area to be gained could be quantified.
	Potential impacts on water quality from sediment movement/resuspension and accidental release of pollutants. Impacts would be during construction and decommissioning. Impacts would be temporary.	Sediment and pollution prevention/reduction measures – there are existing industry standard measures to minimise and control sediment disruption/displacement (e.g. appropriate spoil removal and disposal, deployment of silt curtains during construction).	This will depend on the precise measures to be employed which in turn depend on the exact construction and operation processes to be determined during the detailed design stage	Negligible - Any of the current industry standard methods are unlikely to have a significant impact on energy outputs and would be implemented during construction and decommissioning only, as such it would not interfere with operation.	Industry standard methods are well established and are widely deployed in the UK in both estuarine and marine environments.	Measures are largely accepted as proven and thus there is minimal requirement for further development with regard to their application to a proposed tidal power scheme.
	Impact of noise and vibration on fish, mammals and birds during construction and decommissioning of the proposed tidal power scheme. The impacts would be temporary during these periods.	Noise effect reduction measures - there are industry standard measures which would be applied to minimise noise and vibration levels during the construction and decommissioning of the proposed tidal power scheme. This could include the use of confined bubble technologies which consist of air filled fabric tubes which reduce the dispersal of sound pressure waves from activities.	Costs will depend on the precise measures to be employed which in turn depends on the exact construction and operation processes to be determined during the detailed design stage. Costs would be incorporated into the overall programme.	Measures to reduce the impact of noise are unlikely to have any impact on the energy output of the proposed scheme as they would be implemented during construction and decommissioning only, as such it would not interfere with operation.	There are established industry standard measures which have been used throughout the UK including methods employed in estuarine and marine environments.	Key migration periods for the species of most concern are relatively well understood for the Mersey Estuary. Additionally, the current methods used to reduce the effects of noise are relatively well established. The noise tolerance levels of the species present is also relatively well understood.
		Timing of works - seasonal migration timings for the various anadromous fish species using the Mersey estuary are relatively well known and construction works should be timed to avoid periods of peak migration.	Avoiding key migration periods would impact the construction timings for the development but is considered likely to have a negligible impact on costs other than potentially extending construction time.	None	This approach is often taken where there is scope for timing the works accordingly.	Given that key migration periods for anadromous fishes using the Mersey estuary are relatively well understood there is no anticipated requirement for further study. The period in which the overwintering birds are present and the location of their feeding grounds is also established.
		Predator control *Piscivorous birds* – potential control methods include the use of deterrents (e.g. visual and auditory scarers) and / or exclusion systems (e.g. netting or electrified fencing/cables along the length of the tidal power structure). *Piscivorous mammals* – acoustic deterrent technology for seals.	Cost depends on the type chosen and the operational time.	None None	Various combinations of deterrent and exclusion technologies have been used on river hydro power schemes and dams and are considered as established practice. Acoustic deterrents are widely used at salmon farms and have been used at some dams in the US. These systems are used in estuarine/marine environments but not at the scale likely to be required for this development.	Technologies are already well developed, however an assessment of the effectiveness in estuarine environments such as the Mersey would likely be required. Research needed to assess the potential impact of seal acoustic deterrents on cetaceans which may occur in the estuary and the potential effectiveness of application of this measure on this scale.
Mitigation	The impact of reducing tidal amplitude within the basin will effect a loss of bird feeding area (and potentially time available to feed) within the SPA, with	Creation of lagoons near the top of the shore, adjacent to the marsh, with porous walls (and/ or perhaps an arrangement of open and non-return flap-valve orifices at appropriate elevations) which, by holding back the incoming tide, would extend the time the birds have available for feeding on	Dependant on area required (i.e. factor of lost habitat and potential value of lagoons). A rectangular, tidal-delay lagoon adjacent to the marsh edge measuring, 1 x 2 km might require partial excavation to a depth of 2 m and loadstone sufficient to create a porous wall 2 m x 2 m in cross section– assumed to	Water retained in the lagoon will drain slowly back into the main basin, and may contribute to the volume which flows through the turbines. This is not considered to be significant in energy generation terms though. Similarly, mud accreting in the lagoons may also limit the volume of water in the basin, which will reduce the volume	Tidal delay lagoons are not known to exist in this specific context. The principle is relatively simple, and does not require innovative engineering design or techniques. Experience during reclamation on the Tees Estuary suggests that birds would use such a lagoon, and modelling suggests it could be very effective.	The incorporation of created lagoons within a MTP scheme would likely require further ecological and engineering technical development and would need to be refined for a preferred scheme.

	resulting risk of decreased bird fitness and so population size. This may affect the function of the SPA. The impact would start as soon as the tidal amplitude has been reduced by the impounding barrage and would last until decommissioning. The effect may be temporary if the function of the SPA is maintained, through replacement or re-established of mudflats of equal value.	Spring tides and increase their chances of obtaining their food requirements, whilst also maximising extent of intertidal area within lagoon.	be gabion basket creation. Operation costs: Occasional inspection and repair of structures. Potentially sequential excavation of components.	which can flow through the turbines but not to any significant extent. Depending on the degree of 'estuary' lost to them, creating lagoons is likely to result in some drop in energy output of any scheme, but further work will be required to determine the extent of such decrease.		Further investigations would likely have to be undertaken to predict the efficacy of the designed structures. Following this, the extent of their construction (in conjunction with other measures outlined) can be calculated.
	Loss of bird feeding time and area within the SPA and resulting risk of decreased bird fitness and so population size. This impact would take effect as soon as the tidal flow had been reduced by the impounding barrage and would last until decommissioning.	Excavation of new lagoons on adjacent land to estuary, and improvement of these for use by feeding birds (including by nutrient enrichment and/ or salination). Also of existing lagoons (e.g. potential for changing Frodsham lagoon from freshwater to brackish environment). This would create additional areas of feeding habitat, of extended availability, and high prey item availability.	Dependant on area required (i.e. factor of lost habitat and potential value of lagoons). Pumping costs (if lagoon above MHWS level, and to facilitate regular flushing) (Changing Frodsham lagoon from freshwater to brackish would have both capital and maintenance costs. Capital cost will be the installation of a pipe and pumping equipment that moves salt water from the Mersey to the lagoon. This would be carried out with least energy expenditure during the high water period when the head difference between the Estuary and the lagoon is lowest. Water is currently pumped out of the lagoon and into the various drains across Frodsham Marshes. To avoid Frodsham Marsh becoming too saline, there may be a requirement to pump water back into the Mersey.	No impact on energy output from this measure in itself. However, creation and use of lagoons could be a drain on energy output	Common on a global scale The first pan in a series of salt pans is recognised (around the world) as an excellent foraging site for shorebirds. If similar ecological conditions are recreated, this is likely to be a very effective measure and also provide a bird watching facility of great interest. The method of establishing such characteristics is simple and well recognised (i.e. by introducing and holding brackish water). The water would need to be exchanged on a regular basis otherwise the salinity would build up too much, and many of the invertebrate food species of shorebirds would disappear.	Further investigation is required into management of water levels in the lagoon. Discussion would also be required with the Ship Canal Company – estimates are that the existing volume within that lagoon will provide approximately 20 years worth of capacity for dredgings from the canal.
	Loss of bird feeding time and area within the SPA and resulting risk of decreased bird fitness and so population size. This impact would take effect as soon as the tidal flow had been reduced by the impounding barrage and would last until decommissioning.	Promoting recovery of areas of Mersey Estuary SPA / SSSI units which are currently unfavourable.	Costs are dependent on the areas of habitat to be improved and the measures adopted.	None	There are a number of case study examples from the UK and the US whereby a range of habitat creation and restoration techniques and methods have been implemented. The US has been implementing habitat creation and restoration methods for ~40 years. In contrast there is very little published experience in the UK peer-reviewed literature. The majority of information is in the form of grey literature held by the statutory bodies.	Further investigation into the appropriate management method for the Mersey Estuary should be undertaken. Caution must be exercised; however, when considering the US experience and its applicability in the UK. The site specific reason for habitat loss/degradation should be investigated particularly in relation to natural vs anthropogenic changes and the role of shipping in the Mersey Estuary.

	Loss of exposed intertidal sediment at low tide due to changes to the tidal regime. Impact during operation only. Permanent impact during life of operation of project.	Elevation of existing subtidal habitat to create new intertidal habitat.	Cost is based on the length of bund required as indicated by the figures for perimeter given in the ‘predicted effectiveness’ column. It is estimated at this stage that a 2 m high bund will be required, however, further investigation would be required following sediment transport modelling which could have implications on cost. The volume of dredged material required has been calculated. Approximately 1.5 million m^3 of sediment is currently dredged per year from existing navigation channels. Whilst the areas of dredging may not be the same post scheme there is the possibility that some of this material could be used to infill the bunds, thereby reducing the costs. This assessment is based on considerations of distribution of sediment on day one of the scheme and there may be subsequent changes in sediment transport and hydrodynamics with the scheme in place which may affect the application of this measure.	The proposed changes to intertidal would cause a change in the volume of water that could be held within the basin. Changes in potential for energy generation would be dependent on the location and volume of sediment placed within the bunds.	There are a number of examples of the successful use of this measure in the UK e.g. Horsey Island Intertidal Recharge Scheme, Hamford Water and Parkstone, Poole Harbour. All of these examples are on a relatively small scale. This measure would usually be conducted adjacent to shore rather than in the middle of an estuary channel.	Specific areas identified with the potential for the application of this measure would require more in depth individual studies to specify exact requirements. Consideration of the results of sediment transport modelling and prediction of areas of accretion/erosion in relation to areas identified for this measure would also be required as well as further clarification on the costs of application.
	Loss of exposed intertidal sediment at low tide due to changes to the tidal regime. Impact during operation only. Permanent impact during life of operation of project	Promotion of intertidal habitat creation through enhanced sedimentation by placing man-made structures such as groynes and breakwaters within the estuary.	The main material utilised for this measure is likely to be brushwood and wooden stakes secure by coated wire. Groynes would be used to enclose areas in which sedimentation would be promoted. Costs would increase depending on the system of groynes and breakwaters deployed.	Depending on the location of the structures changes in energy may be apparent but are likely to be negligible.	The ‘Schleswig-Holstein’ method of sedimentation field construction has been applied at two locations (Deal Hall and Marsh House) on the Dengie Peninsula in Essex. Each of the initial plots at each site was approximately 400m² in area and enclosed by groynes made up from double-rows of wooden stakes infilled with brushwood and secured by coated wire. They have proven to be effective at promoting accretion. Application of this measure for an MTP would likely require a larger area.	Further modelling of likely areas of accretion within the Mersey Estuary with a scheme in place is required to assess the likely effectiveness and decide on best locations for deployment.
	Loss of exposed intertidal habitat at low tide due to changes to the tidal regime. Impact during operation only. Permanent impact during life of operation of project.	Creation of new intertidal habitat through managed realignment.	Estimated costs of managed realignment have been calculated based on a figure of £65k/ha (figure provided by DECC and value used as part of the Severn Estuary Tidal Scheme Project).	Due to the relatively small scale nature of the managed realignment proposed in relation to the hydrodynamic changes in the estuary following implementation of the scheme it is considered that potential effects on energy outputs would be negligible.	Managed realignment has been applied successfully to a number of coastal locations throughout the UK including Abbotts Hall Farm, Salcott Estuary; Orplands, Blackwater Estuary, Essex; Tollesbury; North Trimley Marsh, Orwell Estuary; Northey Island, Essex; and Frieston, Lincolnshire (DEFRA 2011). The size of managed realignment schemes range from 4 to greater than 400 ha. Managed realignment can therefore be considered an established mitigation measure in the UK.	A number of site specific investigations are required to fully evaluate the potential of a particular area for managed realignment via breach of coastal defences. When a target site has been identified detailed hydrodynamic modelling is required to assess inundation scenarios of land behind the defences based on different number of breaches and the creation of creek systems within the new intertidal areas. Consideration needs to be given to slope and area and the specific type of habitat that is likely to be created from the managed realignment scheme in relation to the habitat lost.

		Creation of new areas of rocky habitat by introducing artificial rock structures in the intertidal zone.	Costs would be associated with materials, plant and personnel required for construction of the structures.	None	Rocky structures are regularly created within intertidal areas as part of coastal developments and in most cases are suitable for colonisation by intertidal organisms.	Investigations would be required to identify what structures would be most appropriate to provide potential alternative intertidal habitat for the species currently found on rocky shores in the Estuary, and where they could be constructed.
		Habitat enhancement outside the SPA boundary but for an area functionally linked with the SPA.	Activities involved could include active management of particular sites to improve their contribution to the structure and function of the SPA.	None	There are a number of case study examples from the UK and the US whereby a range of habitat creation and restoration techniques and methods have been implemented. The US has been implementing habitat creation and restoration methods for ~40 years. In contrast there is very little published experience in the UK peer-reviewed literature. The majority of information is in the form of grey literature held by the statutory bodies.	Further investigation into the appropriate enhancement method for candidate areas should be undertaken. Caution must be exercised; however, when considering the US experience and its applicability in the UK. The suitability for enhancement of candidate areas should be carefully investigated to increase the chances that selected areas will function as required and predicted. The functionality of the candidate areas should be investigated.
		Provision of alternative type of functionally linked habitat of comparable value to that lost	As well as saline lagoons, shorebirds use other wetlands, such as mature and wet meadows with high concentrations of earthworms. This relates to habitat which is functionally linked to that lost.	None	Shorebirds use many meadows but there are no known examples of where they have been managed specifically for this purpose. But the many coastal meadows used by waders makes this measure almost an established practice.	Location of a suitable site and selection of any management practice required to enhance its value to shorebirds.
	Loss of bird feeding time and area within the SPA and resulting risk of decreased bird fitness and so population size. This impact would take effect as soon as the tidal flow had been reduced by the impounding barrage and would last until decommissioning**.**	Active feeding of birds, creation of a reserve	It could be possible to create a Nature Reserve which would be managed and maintained subsequently by a voluntary body, such as a Wildlife Trust or the RSPB. If shellfish became established in the impounded basin, and shellfishing were to occur, leaving discarded shellfish along the tide line could benefit some shorebirds species.	None	There are many successful Reserves around the country which could act as models: one along the south Wales coastline that was established to compensate for the loss of Cardiff Bay may provide an appropriate precedent.	Potential locations will be investigated if appropriate sites are located, a site and a co-operating voluntary body would need to be found, as close as possible to the Mersey but not necessarily in its immediate vicinity.
	Fish injury/mortality during passage past/through the scheme and resultant life history and population impacts. Impact during operation only. Permanent impact during life of operation of project with potential for consequences upon population to remain	Fish trapping and transporting - Fish would be captured/trapped and physically relocated above or below the tidal power scheme. Fish herding **–** fish will be guided towards passage routes/facilities or away from risk areas (e.g. turbine intakes)	Highly dependent upon the anticipated scale of the operation. Medium-High	None None	Not for estuarine systems or on the scale likely to be required Not for estuarine systems	Further research would be required to establish the effectiveness of this method for an estuarine system and to clarify the cost of the method Further research would be required to establish the effectiveness of this method for an estuarine system.

	following decommissioning					
		Fish stocking – the introduction of fish or fish eggs into the Mersey catchment to prevent or reduce the effects of the proposed scheme on stocks of migratory fish species. The introduction of elvers to the Mersey basin is planned as part of the NW basin district eel management plan.	For the Mersey the main species of concern would be salmon and eel. Costs associated with collecting and transferring glass eel for rearing within the Mersey catchment are unknown at this time due to a paucity of information regarding population size and resultant stock levels.	None	Restocking is used frequently for a number of reasons including enhancement of existing stocks to promote the rapid recovery of natural populations. However, the cause of any decline should always be addressed first with appropriate mitigation undertaken prior to the initiation of any stocking programme. There is also an example of stocking related to the presence of a tidal barrage in Cardiff Bay where salmon are stocked into the rivers impounded by the barrage to offset the loss of any fish which cannot traverse the fish pass.	Stocking should not be undertaken without first considering other, potentially more sustainable options for enhancing fish stocks. Where stocking is deemed to be necessary in order to help improve natural stocks or to enhance fisheries it is important that the carrying capacity of the recipient waters is fully evaluated along with the potential risks to native fish associated with introducing hatchery reared fish.
		Fisheries buyout	Fisheries buyout – this would involve the purchase of any existing commercial fishing licences for the Mersey estuary and associated watercourses however there are known to be very few.	None	Where economic viability of a commercial fishery is likely to be reduced as a result of a scheme then offering an appropriate level of compensation to the commercial fishermen is likely to prove effective. The key aspect of this option will be evaluating the current and future potential value of the existing commercial fisheries.	An examination of fisheries potentially affected by the scheme and opportunities for buyout would be required. A study into the economic value of all commercial fishing operations associated with the Mersey estuary is required.
Compensation	Loss of bird feeding time and area within the SPA and resulting risk of decreased bird fitness and so population size. This impact would take effect as soon as the tidal flow had been reduced by the impounding barrage and would last until decommissioning.	Habitat enhancement outside the SPA boundary	In the absence of a specific proposal, no estimate is possible. However activities involved could include active management of particular sites to improve their contribution to the Natura 2000 network.	Negligible	There are a number of case study examples from the UK and the US whereby a range of habitat creation and restoration techniques and methods have been implemented. The US has been implementing habitat creation and restoration methods for ~40 years. In contrast there is very little published experience in the UK peer-reviewed literature. The majority of information is in the form of grey literature held by the statutory bodies.	Further investigation into the appropriate enhancement method for candidate areas should be undertaken. Caution must be exercised; however, when considering the US experience and its applicability in the UK. The suitability for enhancement of candidate areas should be investigated to increase the chances that selected areas will function as required and predicted. The functionality of the candidate areas should be investigated.
	Loss of bird feeding time and area within the SPA and resulting	Extension of SPA area	One possibility might be to designate the upper reaches of the Mersey, upstream of Runcorn bridge. The cost to the development	None	No intertidal flats have been constructed specifically for this purpose but areas of deposition following the construction of training walls (on the Wash, for example, where dredged material was also added in some	A site needs to be found and investigations made on how its value to shorebirds

	risk of decreased bird fitness and so population size. This impact would take effect as soon as the tidal flow had been reduced by the impounding barrage and would last until decommissioning**.**		would likely be minimal. However, for this to provide replacement intertidal flats for birds displaced from the present SPA, sediment management would be required to increase the area's carrying capacity.		areas) are certainly used by feeding shorebirds once the sediments have consolidated sufficiently to allow invertebrates to establish themselves. Habitat enhancement has been conducted widely in the US and more recently in the UK (see row above).	could be enhanced.
	Loss of exposed intertidal habitat at low tide due to changes to the tidal regime. Impact during operation only. Permanent impact during life of operation of project.	Managed realignment outside of the estuary	Estimated costs of this compensation habitat have been calculated based on a figure of £65k/ha (figure provided by DECC and value used as part of the Severn Estuary Tidal Scheme Project).	Managed realignment outside the estuary would have no impact on energy outputs from the scheme.	Managed realignment has been applied successfully to a number of coastal locations throughout the UK including Abbotts Hall Farm, Salcott Estuary; Orplands, Blackwater Estuary, Essex; Tollesbury; North Trimley Marsh, Orwell Estuary; Northey Island, Essex; and Frieston, Lincolnshire (DEFRA 2011). The size of these managed realignment schemes range from 16.5 to 80 ha. Managed realigned can therefore be considered an established mitigation measure in the UK.	A number of site specific investigations are required to fully evaluate the potential of a particular area for managed realignment via breach of coastal defences. When a target site has been identified detailed hydrodynamic modelling is required to assess inundation scenarios of land behind the defences based on different number of breaches and the creation of creek systems within the new intertidal areas. Consideration needs to be given to slope and area and the specific type of habitat that is likely to be created from the managed realignment scheme in relation to the habitat lost.
	Loss of bird feeding time and area within the SPA and resulting risk of decreased bird fitness and so population size. This impact would take effect as soon as the tidal flow had been reduced by the impounding barrage and would last until decommissioning.	New Natura 2000 site designation	In the absence of a specific proposal, estimation is difficult, however costs could include financial assistance to NE/JNCC to designate, manage, monitor the site.	None	The legalities under the Directive were explained as part of the Severn Tidal Power Study. Intertidal flats have not been constructed specifically for this purpose but areas of deposition following the construction of training walls (on the Wash, for example, where dredged material was also added in some areas) are certainly used by feeding shorebirds once the sediments have consolidated sufficiently to allow invertebrates to establish themselves.	A site needs to be found and investigations made on how its value to shorebirds could be enhanced. In addition the legality/acceptability of using such a compensatory measure under the Habitats Directive would need to be investigated.
	Loss of bird feeding time and area within the SPA and resulting risk of decreased bird fitness and so population size. This impact would take effect as soon as the tidal flow had been reduced by the impounding barrage and would last until decommissioning.	Measures to prevent further erosion of the coherence of the Natura 2000 network. This will take into consideration the current view of the network, how effectively it is operating and its resilience to stress.	In the absence of a specific proposal, estimation of costs is difficult. However activities involved could include active management of particular sites to improve their contribution to the Natura 2000 network – possibly re-instating or protecting features within sites to ensure conservation objectives are met.	None	There is no precedent for this.	A site or sites of value to shorebirds that are under threat need to found and then designated. Such a study could involve a review of the regional SPA condition assessment monitoring information and through discussions with NE.

	Loss of bird feeding time and area within the SPA and resulting risk of decreased bird fitness and so population size. This impact would take effect as soon as the tidal flow had been reduced by the impounding barrage and would last until decommissioning	Creation of alternative habitat types of comparable value to that lost	As well as saline lagoons, shorebirds use other wetlands, such as mature and wet meadows with high concentrations of earthworms. In the absence of a specific proposal, no estimate is possible.	None No impact	Shorebirds use many meadows but no known examples of where they have been managed specifically for this purpose. But the many coastal meadows used by waders makes this measure almost an established practice.	Location of a suitable site and selection of any management practice required to enhance its value to shorebirds.
	Potential loss of diadromous fish species during construction, operation and decommissioning of a tidal power scheme. This impact would be permanent during the life of operation of the project with potential for consequences upon populations to remain following decommissioning.	Address limiting factors upon aquatic ecology in the freshwater environment – habitat creation / enhancement could be used as compensation for the loss of individuals in the Estuary by boosting populations of diadromous species in the freshwater environment.	The costs are highly dependent upon the scale of any improvements ultimately proposed. However, costs for similar proposals for the Rivers Usk, Wye and Severn were estimated at approximately £5m (Severn Estuary Tidal Power Report). For a less pristine river such as the Mersey and its catchment however, this could be higher	None	Habitat enhancement and creation is an established measure for improving the status of fish populations within freshwater environments.	There will be a requirement for further study. This should involve an assessment of the current status of freshwater habitats utilised by diadromous fish species which also pass through the estuary and a subsequent feasibility and effectiveness assessment for a range of possible options for habitat enhancement and / or creation. It may also be possible to use EA management plans as a basis for this assessment.
	Loss of bird feeding time and area within the SPA and resulting risk of decreased bird fitness and so population size. This impact would take effect as soon as the tidal flow had been reduced by the impounding barrage and would last until decommissioning.	Address limiting factors upon bird populations in dependent habitats outside of the Mersey Estuary. This could be done in two ways. (1) Reduce mortality rate in the non-breeding season by, for example, reducing hunting (ducks) in another wintering area, or by improving the feeding conditions, as already detailed above. (2) Increase reproductive output in UK breeding species by, for example, suitably managing or extending saltmarshes or uplands and introducing predator control programmes.	In the absence of specific proposals, no estimate is possible.	None	These are standard conservation management procedures and should be effective if appropriate sites can be found.	Finding suitable sites and arranging by whom and in what way they could be managed to either decrease shorebird mortality rate or increase the reproductive rate.