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SEVERN TIDAL POWER - SEA ENVIRONMENTAL REPORT

May 2010

Prepared by
Parsons Brinckerhoff Ltd
Queen Victoria House
Redland Hill
Bristol
BS6 6US

In association with
Black & Veatch Ltd

Prepared for
DECC
3 Whitehall Place
London
SW1A 2HD

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Prepared by	**:**	**Lara Ball (BV) and Ed Ferguson (BV)**
Checked by	**:**	**David Keiller (BV), Delyth Toghill (PB), Ursula Bycroft (BV), Paul Tarrant (BV).**
Approved by	**:**	**Tom Matthewson (BV)**

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5	DECC and Environmental and Regional Workstreams review	19 Mar 2010
6	DECC review	23 Apr 2010
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CONTENTS

ABBREVIATIONS

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The following abbreviations are used in this Environmental Report:

ABP	Associated British Ports
AONB	Area of Outstanding Natural Beauty
ASMITA	Aggregated Scale Morphological Interaction between a Tidal inlet system and the Adjacent coast (see also Glossary)
BV	Black & Veatch Ltd.
BAP	Biodiversity Action Plan
BoCC	Birds of Conservation Concern
BTO	British Trust for Ornithology
CHaMP	Coastal Habitat Management Plan
CCW	Countryside Council for Wales
CO_2	Carbon Dioxide
CSO	Combined Sewer Overflow
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
DoE	Department of Energy
DTI	Department of Trade and Industry
EC	European Commission
EEC	European Economic Community
EIA	Environmental Impact Assessment
ELC	European Landscape Convention
ETSU	Energy Technology Support Unit
EU	European Union
FTE	Full Time Equivalent
GCR	Geological Conservation Review
GHG	Greenhouse Gasses
GIS	Geographical Information System
ha	Hectare
HAM	Habitat Association Model
HABMAP	Habitat Mapping (see also Glossary)
HAT	Highest Astronomical Tide
HRA	Habitats Regulations Assessment
HRW	HR Wallingford
IBM	Individual Based Model
ICES	International Council for the Exploration of the Sea
IMADP	Interim Marine Aggregate Dredging Policy
IOS	Institute of Oceanographic Sciences
JNCC	Joint Nature Conservation Committee
LAT	Lowest Astronomical Tide
LiDAR	Light Detection And Ranging
LNR	Local Nature Reserve
LOHIW	Landscape of Outstanding Historic Interest in Wales
MAGIC	Multi-Agency Geographic Information for the Countryside
Mm^3	Million Metres Cubed
MW	Megawatt
MSOA	Middle Layer Super Output Area (see also Glossary)
NAEI	National Atmospheric Emissions Inventory
NBN	National Biodiversity Network
NNR	National Nature Reserve
NO_2	Nitrogen Dioxide
NSR	Noise Sensitive Receptor
ODPM	Office of the Deputy Prime Minister

ODR	Options Definition Report
PB	Parsons Brinckerhoff Ltd
PM_{10}	Particulate matter of 10 micrometers diameter or less
PPG	Planning Policy Guidance
PPS	Planning Policy Statement
PWS	Public Water Supply
REIS	Regional Economic Impact Study
RQO	River Quality Objectives
SAC	Special Area of Conservation
SEA	Strategic Environmental Assessment
SEFRMS	Severn Estuary Flood Risk Management Strategy
SETS	Severn Embryonic Technologies Scheme
SI	Statutory Instrument
SMP	Shoreline Management Plan
SNCI	Site of Nature Conservation Interest
SO_2	Sulphur Dioxide
SPA	Special Protection Area
SPZ	Source Protection Zone
SSSI	Site of Special Scientific Interest
STP	Severn Tidal Power
STPG	Severn Tidal Power Group
SWRDA	South West Regional Development Agency
TWh	Terrawatt hours
UK	United Kingdom
UKBAP	UK Biodiversity Action Plan
UKCP09	United Kingdom Climate Projections 2009
WAG	Welsh Assembly Government
WeBS	Wetland Bird Survey
WFD	Water Framework Directive
WwTW	Wastewater Treatment Works
ZTV	Zone of Theoretical Visibility

NON TECHNICAL SUMMARY

SEVERN TIDAL POWER – SEA ENVIRONMENTAL REPORT

NON TECHNICAL SUMMARY

N.1 Introduction

N.1.1 The Government published the terms of reference for a two-year feasibility study on harnessing the renewable energy from the tidal range of the Severn Estuary in January 2008. This work has been carried out by a cross-Government team led from the Department of Energy and Climate Change (DECC), including representatives of the Department for the Environment, Food and Rural Affairs (Defra), the Welsh Assembly Government (WAG) and the South West Regional Development Agency (SWRDA), taking external advice as necessary and engaging stakeholders and the wider public.

N.1.2 The aim of the Severn Tidal Power (STP) Feasibility Study was to investigate whether the Government could support a tidal power scheme in the Severn and, if so, on what terms.

> This is the Non Technical Summary of the Strategic Environmental Assessment (SEA) for the Severn Tidal Power Feasibility Study. It informs Government decision-making. *Key messages within the non technical summary are provided in boxes such as this.*

N.2 Contents of Environment Report

N.2.1 Strategic Environmental Assessment (SEA) is the term used to describe environmental assessment as applied to plans and programmes, under the European Union (EU) 'SEA' Directive. This SEA has been carried out in support of the STP Feasibility Study, and its purpose is to identify, describe and evaluate the likely significant effects on the environment of a tidal power project within the Severn Estuary. The preparation of this Environmental Report has included consultation with the public, key stakeholders and statutory authorities.

N.2.2 The contents of this Environmental Report are set out in Table N.1, and were the subject of a scoping consultation exercise conducted in 2009. This report, alongside others being prepared within the Feasibility Study, will inform the Government's decision on whether or not it could support a tidal power project within the Severn Estuary.

Table N.1 Report structure

Section	Description
1. Background	• An overview of the STP Feasibility Study and the objectives of the plan. • Purpose of the SEA. • An outline of the contents of the Environmental Report.
2. Approach adopted	• Scope and structure of the SEA. • Approach adopted in the SEA. • Overview of the consultation undertaken throughout the SEA process. • The difficulties encountered in compiling information or carrying out the assessment.
3. Baseline environment and SEA objectives	• Other international, national, regional and local plans and programmes, and relevant environmental protection objectives and how these have been taken into account.

Section	Description
	• Baseline characteristics of the study area and the predicted evolution of this baseline. • The existing environmental issues and problems which are relevant to this SEA. • Limitations of the data and key assumptions made. • SEA objectives used to test the Feasibility Study proposals and compare alternative options.
4. Plan alternatives	• STP alternative options and how they were identified.
5. Likely significant effects on the environment and measures to prevent, reduce and as fully as possible offset any significant adverse effects	• The likely significant effects on the environment of each alternative option and how they were identified, including cumulative effects and effects of consequential development (this does not include measures to prevent or reduce significant effects except those already included in the definition of alternative options). • Limitations of the assessment and key assumptions made. • Potential measures to prevent, reduce and as fully as possible offset any significant adverse effects on the environment. • Potential need for compensation under the European Commission (EC) Habitats Directive.
6. SEA objectives comparison of alternative options	• Comparison of each alternative option against the SEA objectives.
7. Implementation	• Monitoring measures that may be required, for the significant environmental effects arising from the implementation of each alternative option. • Suggestions for further research.

N.2.3 A series of SEA Theme and Topic Papers provide evidence to support the findings of the Environmental Report. The Topic and Theme Papers are listed in Appendix 1. This work was defined during Phase One (Scoping) of the Feasibility Study, conducted in 2008 and consulted on in 2009. Table N.2 lists the themes and the topics that were developed to assist with the undertaking of the SEA.

Table N.2 SEA themes and topics

Severn Tidal Power SEA Theme	Severn Tidal Power SEA Topic
Physicochemical	Hydraulics & Geomorphology
	Marine Water Quality
	Flood Risk & Land Drainage
	Freshwater Environment & Associated Interfaces
Biodiversity	Marine Ecology
	Migratory & Estuarine Fish
	Waterbirds
	Terrestrial & Freshwater Ecology
Historic Environment and Landscape & Seascape	Historic Environment
	Landscape & Seascape
Air & Climatic Factors and Resources & Waste	Air & Climatic Factors
	Resources & Waste
Society & Economy	Communities
	Noise & Vibration
	Navigation
	Other Sea Uses

The SEA has been undertaken in accordance with the EU SEA Directive. Its purpose is to describe the likely significant effects on the environment of tidal power projects within the Severn Estuary. The outcome is reported here. A hierarchy of technical reports provides more evidence.

N.3 Main objectives of plan and relationship with other plans and programmes

N.3.1 In 2007, the UK agreed with its European Union (EU) partners to a binding target that 20% of the EU's energy consumption must come from renewable sources by 2020. The EU Renewables Directive states that the UK's contribution to this should be to increase the share of renewables in the UK's energy mix from around 1.3% in 2005 to 15% by 2020. The Climate Change Act (2008) has set legally binding targets to reduce carbon dioxide (CO_2) emissions by at least 26% by 2020 and 80% by 2050. In the UK 2009 budget, the 2020 target was revised and therefore the currently legally binding target is to achieve a carbon emissions reduction of 34% by 2020. The Government published its Renewable Energy Strategy in July 2009 which sets out how these targets will be met. The Marine Energy Action Plan, which was launched in March 2010, details the Government's vision for the marine energy sector in the UK to 2030 and sets out the actions needed to drive this forward.

N.3.2 Any project to generate power from the tidal range of the Severn Estuary will need to meet the following objectives:

- To generate electricity from the renewable tidal range resource of the Severn Estuary in ways that will have an acceptable overall impact on our environment and economy both locally and nationally, will meet our statutory obligations and provide benefit to the UK; and
- To deliver a strategically significant supply of renewable electricity, which is affordable and represents value for money compared to other sources of supply in the context of the UK's commitments under the EU Renewable Energy Directive and Climate Change Act and our goal to deliver a secure supply of low-carbon electricity.

N.3.3 A review of other international, national, regional and local level plans and policies has also been undertaken to identify their relevant environmental protection objectives. This review is provided as an annex to this Environmental Report.

The Feasibility Study sits in the context of UK renewable energy policy. The SEA has been informed by this, and the relevant environmental objectives of other relevant policies and programmes.

N.4 Current state of the environment and likely evolution thereof

N.4.1 The Severn Estuary forms the border between South Wales and South West England, in the UK, as far upstream as Beachley. On the northern side of the estuary is the city of Newport; and, to the west, Cardiff. On the southern, English, side, are Avonmouth, just to the west of the City of Bristol, and Weston-super-Mare (see Figure N.1).

N.4.2 The Estuary is characterised by its large tidal range, and the movement of very large quantities of mud and sand between the seabed and in suspension in the water column. The Severn Estuary and Bristol Channel provide one of the highest UK nutrient inputs to the marine environment, reflecting the estuary's size, the location of human settlements and the intensity of agricultural land use. The Estuary's high tidal range means it has periodically been the subject of serious investigation as a source of renewable energy since the early 1980's.

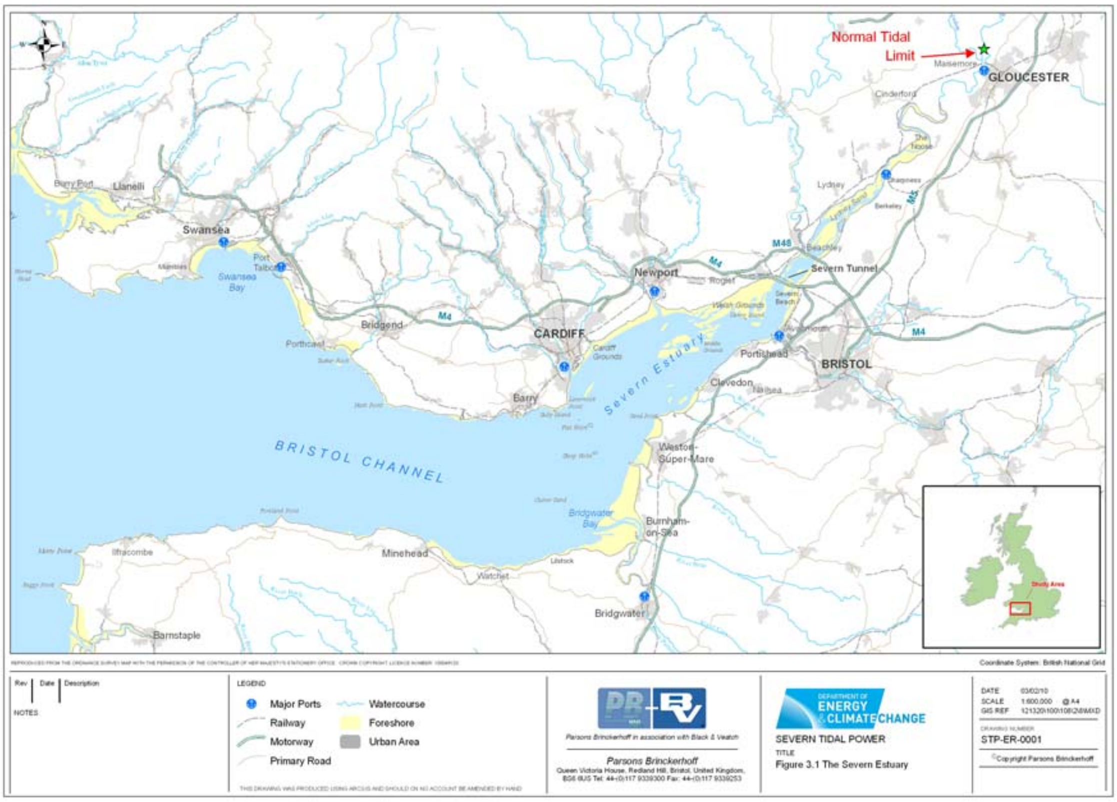

Figure N.1 The Severn Estuary

N.4.3 The high tidal range of the Severn Estuary creates unusual physical conditions which influence the composition, distribution and quantity of its plants and animals. The consequent biodiversity importance of the estuary is recognised through international, national and local nature conservation designations. Paramount is the Severn Estuary/Môr Hafren Special Area of Conservation (SAC) designated under the EC Habitats Directive[1] which supports mudflats and sandflats not covered by seawater at low tide, Atlantic salt meadows, sandbanks which are slightly covered by seawater all the time and subtidal Sabellaria alveolata reefs (reefs built by a worm).

N.4.4 The Severn Estuary is also designated as a Special Protection Area (SPA) under the EC Birds Directive[2] for supporting qualifying populations of species of waterbird. At least six waterbird species occur in internationally important numbers (ringed plover, curlew, dunlin, pintail, redshank and shelduck), and are protected under the SPA designation. The overall waterbird assemblage using the Severn Estuary during winter has been calculated to be nearly 73,000 individual birds.

N.4.5 The Severn Estuary, and the Rivers Tywi, Usk and Wye (all SACs) support seven migratory fish species, including five species protected under the EC Habitats Directive, notably allis and twaite shad, sea and river lamprey and Atlantic salmon (the last of these not applying to the River Tywi) in addition to many other diverse

[1] Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora.
[2] Council Directive 09/147/EC on the conservation of wild birds.

species. The Severn Estuary is also designated as a Ramsar site for its bird interest and all seven of the migratory fish species that pass through or use the Severn Estuary are also part of the qualifying criteria for the Ramsar designation. Together, the Severn Estuary/Môr Hafren SAC, Severn Estuary SPA and Severn Estuary Ramsar site are known as the Severn Estuary/Môr Hafren European Marine Site.

N.4.6 Some of the protected species and habitats in the study area currently have unfavourable conservation status, or their populations have declined, as a result of existing man-made pressures on the environment. Changing climatic and physical conditions may affect the marine ecology of the Severn Estuary. For example, increased sea level rise is expected to result in the loss of intertidal mudflats and sandflats and saltmarsh habitats. The Severn Estuary Flood Risk Management Strategy and the Shoreline Management Plan policies include plans for the planning and creation of replacement habitats. Changes in the extent and distribution of habitat types within the estuary may affect the species supported by the estuary system. The Estuary's bird and fish populations may alter in response to climate-driven changes to temperature, as well as to habitats. Such ecosystem adaptation to changing climatic and physical conditions should ensure the future importance of the protected species and habitats.

N.4.7 In addition to the estuary based designated sites and species, the surrounds of the Severn Estuary and Bristol Channel host a broad mix of terrestrial and freshwater ecology conservation features. The Severn Estuary also contains many sites of geological and geomorphological interest, several of which are nationally designated. The Lower and Middle Severn Estuary, Wye Estuary, Bristol Channel Inner South and Bristol Channel Outer North and Bridgwater Bay coastal waters have all been assessed as having 'moderate' status under the Water Framework Directive (WFD) in respect of their nitrogen content. Bridgwater Bay was also assessed as being at moderate status in respect of macroalgae and phytoplankton.

The Severn Estuary is located at the border of South Wales and South West England. The Estuary's size and large tidal range mean it is important for the conservation of estuarine habitats, fish, birds and physical features. These are protected under international, European and national law; and are responding to changing climatic and physical conditions.

N.4.8 The main tributaries of the Severn Estuary are the Ely, Taff, Rhymney, Ebbw, Usk, Wye, influent River Severn, Avon and Parrett. Surface water processes dominate the regional hydrology with a large number of surface water abstractions. Predicted reductions in summer low flow suggest that licensed abstractions will become increasingly constrained.

N.4.9 Some 90,000 properties and commercial assets are at risk of flooding in over 500 km2 of low lying tidal floodplains of the Severn Estuary, concentrated in the urban centres of Cardiff, Newport, Burnham-on-Sea and Weston-super-Mare. The Severn Estuary Flood Risk Management Strategy and the Shoreline Management Plan are underway to ensure that flood risk continues to be managed.

N.4.10 The Severn Estuary is a busy commercial estuary. The catchment supports coarse, salmonid and eel freshwater fisheries as well as being a fish nursery for commercially important species elsewhere and these contribute to the regional economy. The main ports within the Severn Estuary are Cardiff, Newport, Bristol and Sharpness. The ports and the services they support are also an important part of the local and regional economy and are responsible for handling a substantial proportion of UK trade. UK shipping is likely to grow as an economic, low carbon method of national and international trade.

N.4.11 The Severn Estuary and Bristol Channel are also important for marine aggregate extraction and waste disposal. A large number of sewage and industrial discharges are made to the Severn Estuary, using the dilution and dispersion driven by its high tidal range. In addition, a number of power stations abstract and discharge large volumes of cooling water to the Severn Estuary and Bristol Channel. Other sea uses include recreation and tourism, military activity, energy (including oil and gas, renewable energy resources and power stations) and cables and pipelines. Four new non-nuclear power stations are scheduled to be operational in Wales and England in the next four years and both Hinkley and Oldbury have been identified as possible sites for new-build nuclear power stations.

> The tributaries of the Severn Estuary are important for water supply and also support recreational fisheries. A large number of properties are protected by flood defences around the estuary. These are also affected by sea level rise and climate change. The estuary supports important commercial activity, such as shipping, aggregate extraction and waste disposal; and diverse tourism and recreation.

N.4.12 The UK is generally self-sufficient in its demand for aggregate and embankment materials (sand bed and sand core, gravel, crushed rock and armour rock) although it is reliant on imports for steel. In terms of waste, there are 137 landfills within the vicinity of the Severn Estuary, including hazardous (England only); non-hazardous and inert waste landfills. Policy drivers are acting to increase the usage of secondary and recycled aggregates and ensure a long-term reduction in construction and demolition waste to landfill.

N.4.13 The historic environment of the Severn Estuary and its surrounds comprises (but is not limited to) internationally, nationally, regionally and locally important sites, and is a finite resource. The low-lying wetland landscapes and the intertidal areas have protected prehistoric land surfaces and evidence relating to historic estuarine specific activities such as fish weirs and fish traps. Within the subtidal environment, the areas of deep mud and sand offer high potential for the preservation of wrecks and other maritime archaeological materials. The resource within the subtidal and intertidal areas is particularly vulnerable to loss and damage resulting from sea level rise, coastal erosion and consequential flood management responses.

N.4.14 Seascape character ranges from the appearance of a wide river in the upper estuary, to the open sea bounded by cliffs, sandy beaches and muddy bays. The landscape looking down onto the Severn Estuary is also varied. It includes high ground which affords expansive views out over the estuary such as the Quantocks Hills Area of Outstanding Natural Beauty (AONB), Brean Down and the South Wales Valleys ridges above Cardiff. In contrast, there are considerable stretches of flat low lying ground butting up to the Severn Estuary such as the Gwent Levels Landscape of Outstanding Historic Interest in Wales.

> The Severn Estuary supports important and varied landscapes, and contains diverse and protected archaeology that is finite. These will respond to changes in the climate.

N.5 Existing environmental problems

N.5.1 Climate change is a key environmental problem which is likely to have subsequent effects on many aspects of the natural and built environment, including the heritage resource and seascape character. Climate change and the response of the natural environment are expected to be slower than the more immediate changes that may occur in response to the implementation of alternative options.

N.5.2 Climate change effects are also compounded by the influences of population growth and the built environment that increasing populations generate. Pressures for undeveloped land are likely to be greater than ever before, mainly to non-designated areas.

N.5.3 Demand for water is expected to increase due to population growth, while at the same time there is the potential for a reduced supply or greater seasonal variations due to climate change.

N.5.4 With regards to marine, terrestrial and freshwater ecology, the features supported are in varying levels of condition. These pose challenges for conservation agencies to meet targets set by the Government to address biodiversity decline.

Climate change and development pressures are seen as the main existing problems in the estuary and its hinterland. Policies are in place to address the poor condition of some natural features of the estuary.

N.6 Environmental protection objectives

N.6.1 SEA objectives are a recognised tool for comparing alternative options. These objectives may not necessarily be met in full by a given alternative option, but the degree to which they do will provide a way of identifying preferences when comparing alternative options. SEA objectives were drafted using the review of other environmental plans, programmes and their environmental protection objectives, the baseline data collection and the identification of environmental issues. SEA objectives were confirmed following the Government response to the 2009 scoping consultation. Using the STP SEA objectives as a tool for comparing the alternative options thus takes into account the environmental protection objectives identified in the review of other environmental plans and programmes.

Environmental objectives have been developed as a tool to test the tidal power alternative options. Indicating the desired direction of change, they reflect the environmental objectives of existing plans and programmes.

N.7 Alternative options (and reasons for selection)

N.7.1 Following the review of responses to the public consultation in 2009 on Phase One (Scoping) of the Feasibility Study, the Government confirmed that five alternative options would be studied further within the Feasibility Study and its SEA. This followed an initial assessment of a wider range of options and variants, including different modes of operation. These alternative options comprise three tidal barrages and two tidal lagoons all of which would be operational for a period of at least 120 years. These are shown in Table N.3 and Figure N.2.

N.7.2 Alternative options B3 Cardiff to Weston Barrage, B4 Shoots Barrage, B5 Beachley Barrage and L2 Welsh Grounds Lagoon are all designed with an ebb-only mode of operation - high water levels are held behind the structure to create a sufficient difference in water level to permit energy generation on the ebb (outgoing) tide. L3d Bridgwater Bay Lagoon is designed with an ebb-flood mode of operation – there is a sustained duration of high and low water and electricity is generated when the tide is coming in (flood) and going out.

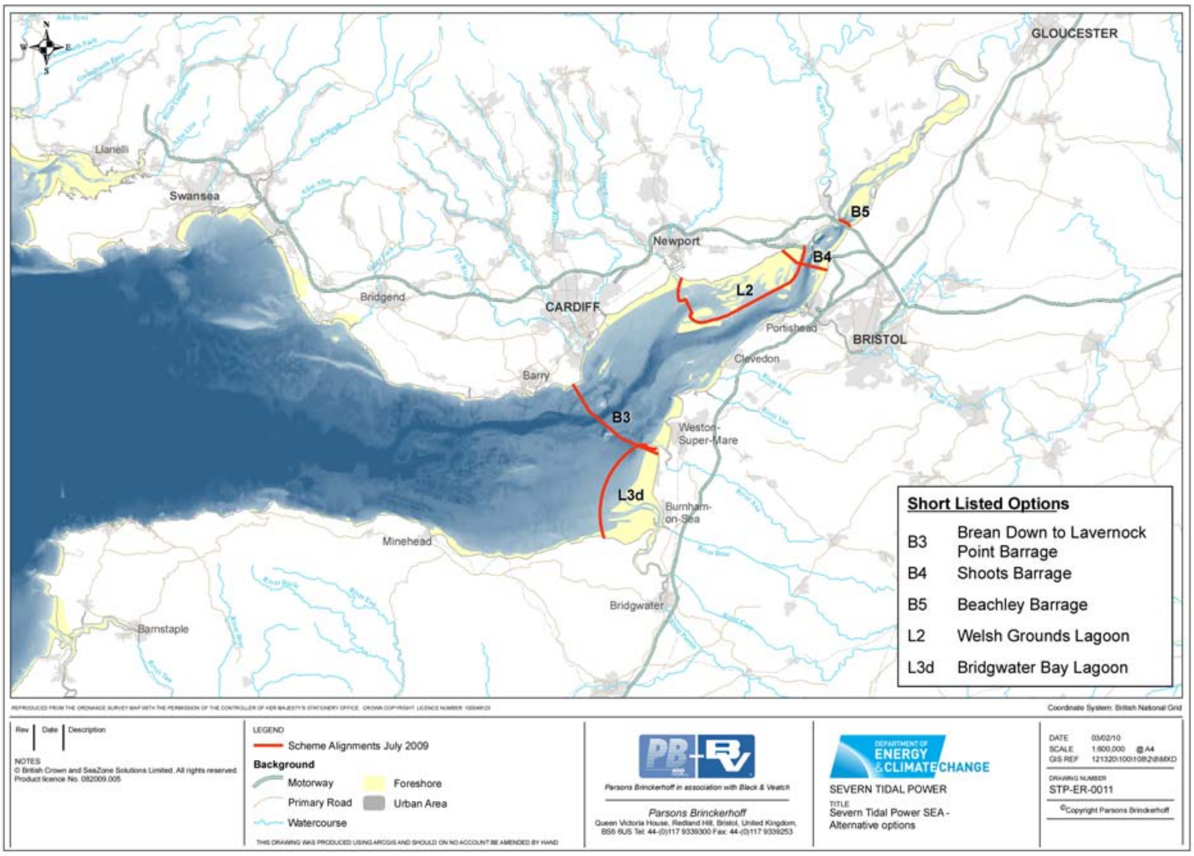

Figure N.2 Severn Tidal Power Alternative Options

Table N.3 Alternative options

Alternative	Location	Length (approx)	Operating mode	No. turbines	Annual energy output	Commercial Vessel Locks
B3: Cardiff to Weston Barrage	Brean Down to Lavernock Point	16km	Ebb only	216 (40MW)	15.1 to 17.0 TWh/year	2
B4: Shoots Barrage	West Pill to Severn Beach	7km	Ebb only	30 (35MW)	2.7 to 2.9 TWh/year	1
B5: Beachley Barrage	Beachley to land directly to the east on the English side	2km	Ebb only	50 (12.5MW)	1.4 to 1.6 TWh/year	1
L2: Welsh Grounds Lagoon	River Usk to Second Severn Crossing	28km	Ebb only	40 (25MW)	2.6 to 2.8 TWh/year	1
L3d: Bridgwater Bay Lagoon	Brean Down to Hinckley Point	16km	Ebb & Flood	144 (25MW)	5.6 to 6.6 TWh/year	1

N.7.3 Following an evaluation process, one multiple basin and two combinations of options were identified for further high-level review. This does not constitute the same level of detail as assessment of the short listed alternatives and no additional modelling was undertaken. The multiple basin variant comprises two basins within the L3d Bridgwater Bay Lagoon alternative option. These basins are configured to provide a more flexible energy yield profile. The first combination variant comprises the L3d

Bridgwater Bay Lagoon with the B3 Cardiff to Weston Barrage and the second combination variant comprises the L3d Bridgwater Bay Lagoon with the B4 Shoots Barrage.

Five tidal power alternative options are considered within the SEA. These were the product of an initial assessment of a wider range of options and variants, including different modes of operation. Combinations of these, and the inclusion of multiple basin variants, have also been considered but outside the SEA.

N.8 How the assessment was undertaken

N.8.1 The purpose of the Environmental Report is to describe the likely significant effects on the environment during construction, operation and decommissioning. Significant effects (positive or negative) were determined using professional judgement taking into account the probability, duration, frequency and reversibility of the effects; the magnitude and spatial extent of the effects and the value and vulnerability of the area likely to be affected. As such, significant effects may, for example, include the negative effect of the permanent loss of a migratory fish species from the Severn Estuary, and / or the positive effect of the temporary creation of construction related jobs. Non-significant effects may, for example, include the negative effect of a temporary increase in construction noise and / or the permanent positive effect of the reduction in turbidity and current velocity providing more favourable conditions for scuba diving. See section N.11 for a summary of the significant effects. These effects include:

- Direct effects;
- Indirect effects (those which occur away from the original effect or as a result of a complex pathway);
- Far-field effects (those which occur large distances from the Severn Estuary);
- Cumulative effects (where, for instance, several developments each have insignificant effects but together have a significant effect); and
- Effects of Consequential Development (other developments attracted by a major tidal power scheme).

N.8.2 The significant effects identified do not take into account measures to prevent or reduce significant effects, except those already included as ancillary works in the definition of alternative options (i.e. works that are necessary as a consequence of the construction of a tidal power facility to prevent or reduce the effect on day to day operation of existing assets – such as the modification of port facilities, pumping systems from tidal outfalls and additional flood defence protection). Specialist studies were undertaken in order to assess the effects. These studies included desk based reviews of existing literature, consideration of analogous sites and the development of numerical models to represent baseline conditions and then the application of these models to each of the alternative options. In addition, qualitative assessments were undertaken using expert judgement utilising outputs from within the full range of SEA studies.

N.9 The study area

N.9.1 This Phase Two (SEA) study area was determined by the footprint of the alternative options which could extract tidal range power from the Severn Estuary, and any areas which may be affected by doing so.

The SEA considers potential effects using desk-based studies, supplemented in some cases by modelling and other more sophisticated analysis. Significant effects are identified, prior to the application of measures that have been identified to prevent and reduce effects.

N.10 <u>Difficulties encountered in compiling the required information</u>

N.10.1 Difficulties were encountered in compiling information for the SEA and carrying out the assessment. These lead to uncertainties that cascade through the assessment, which are identified in the reporting. Whilst these do not undermine the findings of the SEA, they would need to be considered further if an alternative option is taken forward. These are summarised below.

- The methods used to predict the effects are consistent with the strategic nature of the Feasibility Study. Some uncertainty is therefore carried through the assessment, from the project assumptions made, to the specific modelling parameters used. Where there are uncertainties, there are acknowledged alongside the assessments.
- The models used in the physicochemical theme assessments are subject to different levels of uncertainties. The integrated and complex nature of estuarine environments means that any difficulties (such as technical deficiencies or lack of knowledge) that arise in the hydraulics and geomorphology assessment are carried through to other topics. These uncertainties are identified in both the physicochemical theme assessments and the assessment of other topics that use this data.
- There is limited information on some species and habitats and a lack of knowledge and understanding about the functional requirements and linkages for some receptors and how human pressures, such as from tidal power development, might affect them.
- The biodiversity work is the subject of uncertainty in relation to effects, especially ecological effects and consequences for migratory and estuarine fish. These uncertainties are acknowledged alongside the assessments.
- When predicting the future evolution of the environment, the nearer term predictions are more certain than estimations into the future.
- There are often inconsistencies between data sets and their coverage, level of research and terminology at the local and national (Wales and England) level. Future work would reduce this inconsistency.

The SEA is a high-level assessment, and parts have been undertaken using incomplete data. The assessment is also the product of diverse integrated studies, undertaken in a dynamic and complex estuarine system. There are some weaknesses in our understanding of the physical and biological processes within the estuary. These lead to uncertainties that cascade through the assessment, which are identified in the reporting, and would need to be considered further if an alternative option is taken forward.

N.11 <u>Likely significant effects on the environment</u>

N.11.1 This section describes the likely significant effects on the environment resulting from each alternative option. In some instances, including the assessment of cumulative and consequential development effects, the effects identified are not significant and thus they are not described below. The description below does not account for measures to prevent or reduce significant effects except those already included as ancillary in the definition of alternative options (i.e. works that are necessary as a consequence of the construction of a tidal power facility to prevent or reduce the effect on day to day operation of existing assets). For each theme the key effects are explained. See Appendix 9 for a summary of all the identified likely significant effects of the alternative options.

Key significant physicochemical effects

N.11.2 All the alternative options are shown to reduce the tidal range within the impounded part of the Severn Estuary. Under an ebb-only mode of operation (B3 Cardiff to Weston Barrage, B4 Shoots Barrage, B5 Beachley Barrage and L2 Welsh Grounds Lagoon), a high water stand and extended ebb period is created, which distorts the tidal regime within the impounded estuary. Under an ebb-flood mode of operation (L3d Bridgwater Bay Lagoon), a sustained duration of high and low water and distorted tidal regime is predicted within the impounded area. All impoundments would modify flow speeds and the existing wave climate. There is also the likelihood of a long-term trend (over the 120 year operation period of the alternative options) of intertidal erosion in response to enclosure of part of the estuary.

N.11.3 For all alternative options, these effects are likely to result in a change to ‘characteristic physical form and flow’ of the Severn Estuary (i.e. changing the existing hydraulics and geomorphology). This is feature of the Severn Estuary/Môr Hafren European Marine Site and thus the changes would result in a significant negative effect on the designated sites.

N.11.4 For all alternative options, changes to peak tide and wave action would influence the level of flood risk. There would be lengths of flood defence that benefit from lower water levels and there would also be lengths outside the impoundments that would experience higher water levels than previously; and would need to be raised as a result. Flood risk within rivers would also be adversely affected by restrictions to the normal operation of drains and outfalls, owing to the changed tidal regime (tide-locking). Unless managed, this would increase the flood risk to properties and assets within the floodplain.

N.11.5 For the B3 Cardiff to Weston Barrage only, far-field increases in high water levels are predicted on the West Wales coast and, to a lesser degree, along parts of the Irish coast. Increases in water levels on the peak of the spring tides would result in a significant negative effect in terms of a potential increase in flood risk to properties in Cardigan Bay and the Llŷn Peninsula in Wales. Smaller increases in high water levels around the coasts of the Irish Sea are also possible resulting in significant negative transboundary effects, though the extent and magnitude is uncertain. Limitations of the modelling have prevented consideration of potential increases in high water levels beyond the Llŷn Peninsula on to the North Wales and North West England coast. No significant far-field effects on water levels are identified for any of the other alternative options.

N.11.6 For all alternative options, decreased flows and flow speeds would reduce the suspended sediment concentration within the impounded areas and downstream. This would result in the deposition in the short-term (a spring neap tidal cycle) of very large quantities of sediment, mainly within the deeper, less active parts of the impoundment (see Table N.4). This would result in an increase in light penetration and subsequent increase in plant growth and decay, which has the potential to result in a lack of oxygen and reductions in water quality, fish and other animal populations. The presence of an impoundment may also cause long-term changes (over the operational period of 120 years) in the form (morphology) of the estuary as a result of erosion and deposition at different locations. For the barrages in particular, this may result in large quantities of sediment being deposited inside their impoundment throughout their operational life.

Table N.4 Total mass deposited as short term deposition

Alternative Option	Total mass of previously mobile sediment deposited inside the impoundment in the short-term (M tonnes)
B3: Cardiff to Weston Barrage	6.9
B4: Shoots Barrage	1.3
B5: Beachley Barrage	1.3
L2: Welsh Grounds Lagoon	0.8
L3d: Bridgwater Bay Lagoon	0.7

N.11.7 For all alternative options, the reduction in tidal currents may change the form of some of the linear sandbank features of the Bristol Channel such as Culver Sands, Nash Bank and Helwick Bank. This may affect the English and Welsh Grounds as well as some of the other sandbank features.

N.11.8 L3d Bridgwater Bay Lagoon would affect the release of warm water from the Hinkley Power Station and alter the dispersion of treated waste water from Weston wastewater treatment works; which has the potential to significantly negatively affect bathing beaches. None of the other alternative options would be expected to affect discharges from Hinkley Power Station.

N.11.9 With regards to the Water Framework Directive, all of the alternative options are predicted to give rise to effects that could change the chemical status of one or more water bodies in the Severn Estuary, its tributaries or the wider Bristol Channel as a consequence of potential changes in the physical characteristics of water bodies. The Water Framework Directive does, subject to specific tests, allow for new sustainable human development activities to proceed notwithstanding negative effects on status.

Prior to the application of measures to prevent and reduce effects, all alternative options would change the tidal regime within the enclosed part of the estuary, leading to the permanent submergence of large areas of previously intertidal mud and sandflat. The effects are broadly proportional to the size of each alternative option. Long-term responses over 120-years to the enclosure of the estuary may lead to erosion and additional loss of intertidal area. Large quantities of sediment would be deposited within the enclosure, which for the B4 Shoots Barrage and B5 Beachley Barrage may prove an ongoing issue for the maintenance of navigation. The B3 Cardiff to Weston Barrage may cause small but potentially significant elevated spring tide water levels remote from the Severn Estuary. All alternative options would negatively affect land drainage and flood risk that would need to be managed. In the case of B3 Cardiff to Weston Barrage this may extend to works needed on the West Wales coast. B3 Cardiff to Weston Barrage and L3d Bridgwater Bay Lagoon would have beneficial effects on flood water levels. The L3d Welsh Grounds Lagoon may affect nearby waste and cooling water discharges.

Key significant biodiversity effects

N.11.10 Changes to water levels, bathymetry and sediment type and distribution are predicted to result in changes to the extent and nature of the Severn Estuary/Môr Hafren SAC European designated habitats and species. The modelled Estuary-wide (not just within the SAC) extent in habitat at the intertidal – terrestrial interface following scheme implementation is shown in Table N.5 (NB this is without the application of measures to prevent or reduce significant effects). The expected long-term trend (over the 120 year operational period of each alternative option) of intertidal erosion would result in additional loss of habitat. This effect is hard to forecast but may represent a loss of approximately an additional 7% of the current intertidal extent for the B3 Cardiff to Weston Barrage. Other alternative options would see less long-term effect on habitats through erosion.

N.11.11 Other negative effects predicted for marine ecology receptors include a significant negative effect on subtidal sandbanks for all of the alternative options, due to changes in sand transport and mud deposition. Significant negative effects on subtidal Sabellaria alveolata reefs as a result of reductions in flow speed are predicted to occur if any of the options except L3d Bridgwater Bay Lagoon were implemented.

N.11.12 For the B3 Cardiff to Weston Barrage, there is the potential for far-field significant negative effects, particularly for saltmarsh as a result of increases in the level of high water along much of the South-West and West Wales coast. For the B4 Shoots Barrage and L3d Bridgwater Bay Lagoon, there is the potential for far-field significant negative effects, particularly for saltmarsh as a result of increases in the level of high water in the vicinity of the Kenfig/Cynffig SAC. No significant far-field effects from raised water levels are identified for any of the other alternative options.

N.11.13 With regards to water quality, it is unlikely that there would be any deterioration in the ecological status of water bodies for the B4 Shoots Barrage, B5 Beachley Barrage and the L2 Welsh Grounds Lagoon, although there may be deteriorations of some components of the relevant WFD water bodies. It is uncertain whether there would be any deterioration in the ecological status of water bodies for B3 Cardiff to Weston Barrage and L3d Bridgwater Bay Lagoon.

Table N.5 Areas of intertidal-terrestrial interface following short-term changes to Severn Estuary

Alternative Option	Area of habitat remaining at the terrestrial – intertidal interface (ha) following scheme implementation						
	Grass-land (ha)	Mud-flat (ha)	Sand-flat (ha)	Salt-marsh (ha)	Intertidal Rock (ha)	Intertidal Shingle (ha)	Total Intertidal (ha)
Baseline	60	12520	13860	990	2240	1310	30980
B3: Cardiff to Weston Barrage	590	8360	3850	780	1130	360	15070
B4: Shoots Barrage	110	12150	11890	1130	1430	1010	27720
B5: Beachley Barrage	120	12170	11620	1070	1950	1290	28210
L2: Welsh Grounds Lagoon	110	11580	7730	1070	2210	1080	23780
L3: Bridgwater Bay Lagoon	140	10810	13080	1240	2120	1140	28530

*to nearest 10 hectares (ha)
NB: Total intertidal represents area between the Highest Astronomical Tide (HAT) and the Lowest Astronomical Tide (LAT) and includes saltmarsh, intertidal mudflat and sandflat, intertidal rock and intertidal shingle. Estimates do not include changes arising from long term morphological processes or the intertidal areas of sub-estuaries.
The predictions of initial habitat extent take account of short-term changes in water levels, bathymetry (water depth), sediment type, tidal curve and fetch. In this context the initial changes are in relation to the outputs of a spring neap cycle immediately post scheme implementation.
This assessment does not include measures to prevent or reduce significant effects except those already included in the definition of alternative options.

N.11.14 The effect of changes or loss of access to the intertidal mud or saltmarsh habitat is likely to have a negative effect on the waterbird populations supported by the Severn Estuary. This includes the waterbird species of the Severn Estuary SPA and Ramsar designations. In addition, waterbirds are also likely to be negatively affected during construction and decommissioning phases by disturbance effects. Effects on each bird species vary for each alternative option, but all options would have a significant negative effect on waterbirds. A total of 50 waterbird receptors (species and the overall assemblage of species on the estuary) were considered as part of the SEA. Changes to intertidal habitat are predicted to have significant negative effects on 30 of these receptors including ringed plover, curlew, dunlin, redshank and shelduck as a result of the B3 Cardiff to Weston Barrage, 17 as a result of the B4 Shoots Barrage, 15 as a result of the B5 Beachley Barrage, 13 as a result of the L2 Welsh Grounds Lagoon and 9 as a result of the L3d Bridgwater Bay Lagoon. In addition, loss of saltmarsh (in both the short- and long-term) is predicted to cause significant negative effects to 4 waterbird receptors for B3 Cardiff to Weston Barrage.

N.11.15 Displacement to far-field sites is predicted to have significant effects on waterbirds for 15 waterbird receptors on three sites as a result of the B3 Cardiff to Weston Barrage, and 1 receptor (Pintail) on two sites as a result of the B4 Shoots Barrage. Far-field effects of changes in water levels are predicted to cause significant negative effects to two waterbird receptors on the Dyfi Estuary/Aber Dyfi SPA and Cors Fochno & Dyfi Ramsar Site as a result of the B3 Cardiif to Weston Barrage only. Other significant effects to waterbirds include disturbance (largely during construction and decommissioning), for all alternative options except B4 Shoots Barrage. This effect is predicted to be largest for the L2 Welsh Grounds Lagoon, having a significant negative effect on 11 waterbird receptors, because the lagoon structure crosses extensive areas of intertidal habitat used by waterbirds.

N.11.16 In summary, and bearing in mind that species can be affected in more than one way, the B3 Cardiff to Weston Barrage would significantly negatively affect a total of 33 waterbird species and the waterbird assemblage, the B4 Shoots Barrage would affect 16 species and the waterbird assemblage negatively, and 2 species positively. The B5 Beachley Barrage and L2 Welsh Grounds Lagoon would both negatively affect 14 species and the waterbird assemblage, and the L3d Bridgwater Bay Lagoon would negatively affect 13 waterbird species but not the assemblage.

N.11.17 Fish species designated under the Severn Estuary/Môr Hafren SAC, River Usk/Afon Wysg SAC and River Wye/Afon Gwy SAC would be affected by alterations to migratory cues (sensory stimulants that trigger and/or direct fish migratory activity; e.g. freshwater discharge, light intensity and water temperature) and disruption to route of passage. Fish may also be affected by habitat change and/or loss, changes to water quality and anthropogenic noise disruption. Fish passage through tidal power schemes, in particular turbines, is likely to be the primary source of fish injury and mortality. If injuries are not immediately lethal, fish could suffer delayed and indirect mortality. Not all fish species and life stages would suffer injuries and the extent of injury sustained would differ.

N.11.18 A summary of the predicted effects of each alternative option on selected migratory and estuarine fish is shown in Table N.6. In addition, all alternative options would result in the potential risk of:

- reductions in population size of sea trout and river specific stock collapse for the Rivers Wye, Severn and Usk; and

- reductions in population size of Allis shad and river specific stock extinction for the Rivers Wye, Severn and Usk and to a lesser extent the Tywi which could put the UK stock at risk of extinction.

N.11.19 The sea lamprey populations of the Rivers Usk and Wye are not genetically distinct, and instead form part of a wider European stock. Extinctions in these rivers therefore risk a reduction in the European stock of this species. Similarly, the river lamprey forms part of a wider UK stock and therefore extinctions in these rivers risk a reduction in the UK stock.

Table N.6 Summary of predictions of effects on migratory and estuarine fish

Alternative Option	Fish Species (E = population collapse / extinction and R = reductions in population size)				
	Atlantic salmon	Twaite shad	Sea lamprey	River lamprey	Eel
B3: Cardiff to Weston Barrage	E: Rivers Wye, Severn, less certainty for the Usk	E: Rivers Wye, Severn and Usk R: River Tywi	R: Rivers Usk, Wye	R: Rivers Usk, Wye	R: Rivers, Usk, Wye and Severn
B4: Shoots Barrage	E: Rivers Wye, Severn, less certainty for the Usk	E: Rivers Wye, and Severn R: River Usk and Tywi	E: River Wye R: River Usk	E: Rivers Usk and Wye	R: Rivers Wye and Severn
B5: Beachley Barrage	E: Rivers Wye, Severn and Usk	E: Rivers Wye, Severn and Usk R: River Tywi	E: Rivers Usk and Wye	E: Rivers Usk and Wye	R: Rivers Wye and Severn
L2: Welsh Grounds Lagoon	E: Rivers Wye, Severn and Usk	E: Rivers Wye, Severn and Usk R: River Tywi	E: River Usk R: River Wye	R: Rivers Usk, Wye	R: Rivers, Severn, Wye and Usk
L3d: Bridgwater Bay Lagoon	E: Rivers Wye, Severn and Usk	E: Rivers Wye, Severn and Usk R: River Tywi	R: Rivers Usk, Wye	R: Rivers Usk, Wye	R: Rivers, Usk, Wye and Severn

N.11.20 With regard to terrestrial and freshwater ecology, for all alternative options, the construction activities at each landfall point would result in temporary and permanent disturbance and habitat loss. This includes sites designated for nature conservation. Increased water levels within the impoundment would result in increased levels in watercourses and above the ground surface. In extreme events this could result in partial or complete flooding of designated sites (including the Gwent Levels for the B3 Cardiff to Weston Barrage and L2 Welsh Grounds Lagoon, and the Somerset Levels for the L3d Bridgwater Bay Lagoon) which may lead to degradation and / or permanent habitat loss, fragmentation at a landscape corridor level and mortality of species.

Under all alternative options, water level changes and sedimentation would lead to the loss of large areas of protected habitat, including intertidal sand and mud. As well as being of conservation importance in their own right, the submergence of these habitats threatens internationally designated sites and important bird populations. Sedimentation within subtidal areas would also affect the conservation interest of the estuary and lead to the loss of designated species. All alternative options risk the loss from the estuary and its tributaries of most migratory fish species, that are internationally protected and some represent the only UK populations. Effects on land drainage pose negative effects for terrestrial ecology.

Key significant historic environment and landscape & seascape effects

N.11.21 Changes to the sedimentation and erosion patterns caused by all alternative options could lead to the covering of areas of historic interest which were previously exposed, thus increasing their protection. Conversely in other areas there could be the exposure of sites on the seabed which were previously buried thus increasing their vulnerability. Changes to the tides and wave climate caused by all alternative options could add to existing coastal erosion of soft coastline which is a major threat to part of this irreplaceable historic environment resource. For the L2 Welsh Grounds Lagoon this includes some of the most important components of the archaeological resource along the Welsh coast. For the B3 Cardiff to Weston Barrage this may include parts of the Irish and West Wales coastlines.

N.11.22 The historic environment may also be directly affected by the footprint of each alternative option. For B3 Cardiff to Weston Barrage, this would include effects upon the setting and context of three irreplaceable Scheduled Monuments (Brean Down, Sully Island Fort and St Mary's Well), for L3d Bridgwater Bay Lagoon, Brean Down; and for B4 Shoots Barrage, the Gwent Levels Landscape of Outstanding Historic Interest in Wales. Enabling and construction for permanent, temporary and ancillary works could result in loss or damage to a broad spectrum of the irreplaceable historic environment resource.

N.11.23 For all alternative options, construction (and decommissioning) disturbance could have significant negative effects on the landscape and seascape character and there would also be an altering of the views in and around the landfall points. The change in landscape character and visual effects from the presence of a structure would remain during the operational phase but at a reduced level. The physicochemical and biodiversity changes to the estuary would lead to significant negative effects in both the landscape and seascape character of the estuary and its tributaries.

N.11.24 With regard to significant negative effects on existing landscape character, both the B4 Shoots Barrage and L2 Welsh Grounds Lagoon could affect the Gwent Levels and the B3 Cardiff to Weston Barrage and the L3d Bridgwater Bay Lagoon would affect the character of Brean Down. With regards to visual effects, for B3 Cardiff to Weston Barrage, there would be effects at Lavernock Point, Flat Holm, Steep Holm, Brean Down and Brean Beach. For B4 Shoots Barrage, this would include the Gwent Levels and Severn Beach, especially the users of both Severn Way coastal paths and for B5 Beachley Barrage the Beachley Peninsula. For the L2 Welsh Grounds Lagoon this would include the Gwent Levels and the users of the Welsh Severn Way coastal path, and for the L3d Bridgwater Bay Lagoon the shore around Bridgwater Bay and especially at the Stolford landfall point.

All alternative options pose risks to the historic environment, visual amenity and landscape and seascape character, some of which is already designated. The nature of the risk depends on the location of the alternative option, rather than solely a function of its size. Far-field water level effects for the B3 Cardiff to Weston Barrage may pose risks of effects on the West Wales and Irish coasts.

Key significant air & climatic factors and resources & waste effects

N.11.25 For each alternative option, Table N.7 records the significant resources and waste requirements and the emissions which would occur during construction, operation and decommissioning.

N.11.26 The major resources required to construct the alternative options would include aggregates and embankment materials (sand bed and sand core, gravel, crushed rock and armour rock) from within Great Britain and from Europe, albeit in varying amounts for each alternative. Substantial quantities of other resources, including steel, would be entailed but none have been judged to be significant for any alternative option.

N.11.27 Table N.7 also includes the carbon payback period (the number of years that it takes for the emissions displaced from the production of renewable electricity to offset the carbon emissions released during construction, operation and decommissioning). All alternative options demonstrate a significant positive effect on global and UK greenhouse gas emissions.

Table N.7 Air & Climatic Factors, Resources & Waste: Selected Statistics

Factor	B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
Construction					
Net annual demand for virgin aggregates and embankment materials (m tonnes)[1] (average over total construction period)	3.6 (61%)	3.1 (28%)	0.4 (50%)	13.9 (6%)	17.9 (0%)
Operation					
Base net emissions displaced (Mt CO_2) (low-high estimates)	-114 (-147, -78)	-22 (-34, -16)	-13 (-20, -9)	-17 (-30, -9)	-47 (-54, -29)
Base carbon payback (yrs) (low-high estimates)	2.6 (-0.8, 7)	3.5 (-6.3, 7.8)	2.8 (-5.7, 7.7)	6.1 (-4.2, 13.3)	3.2 (2.6, 8.5)

[1]Proportion assumed to be from reused project dredging materials and not included in total.

All alternative options would use large resource quantities in their construction and, making assumptions about the UK energy mix over a 120-year timeframe, relatively rapidly pay back the carbon used in their construction, operation and decommissioning. Alternative options would displace fossil fuel-derived emissions of carbon, in proportion to their size.

Key significant society & economy effects

N.11.28 Construction activities are likely to have significant negative temporary effects on health and quality of life of the local population adjacent to the landfall points for some of the alternative options. The reasons for this include changes to the existing flood risk, landscape and air quality. For B3 Cardiff to Weston Barrage there would be a significant effect on the local population within areas of Vale of Glamorgan and Sedgemoor, for L2 Welsh Grounds Lagoon, Monmouthshire and Newport and for L3d Bridgwater Bay Lagoon, West Somerset and Sedgemoor. Whilst it is anticipated that there would also be effects on the health and quality of life of local populations in the vicinity of B4 Shoots Barrage and B5 Beachley Barrage, these are not considered to be significant effects in terms of this SEA.

N.11.29 During the operational period, all alternative options would result in the loss of salmon and sea trout fisheries employment as a result of the identified closure of salmon and sea trout fisheries within the Rivers Wye, Severn and Usk. All alternative options would also result in the loss of heritage (elver) fisheries supported employment as a result of the partial or complete closure of heritage (elver) fisheries within the Severn Estuary and tributary rivers (see Table N.8).

N.11.30 Only the B3 Cardiff to Weston Barrage is expected to reduce ports' trade, which may have a negative effect on employment (see Table N.8). Based upon the conclusions of the DTZ Regional Economic Impact Study (REIS) (DTZ, 2009) and subsequent REIS update (STP Regional Workstream, 2010), a 'medium impact scenario' has been applied as an indicator for the potential effect of the alternative options on the ports sector. For the B3 Cardiff to Weston Barrage, this scenario represents loss of 30% trade from all ports affected during the construction phase, increasing to 60% by the end of the operational phase. For the purposes of this SEA, it is assumed that port-related employment corresponds directly with port trade, resulting in a significant negative effect of a loss of 1,850 full-time equivalent (FTE) employees by the end of the construction phase, increasing to 4,200 FTE lost by 2140[3]. Smaller decreases are set out under the REIS medium impact scenario for the other alternative options (2.5% by the end of construction, increasing to 5% by the end of operation) which are not considered significant in terms of the SEA.

N.11.31 For all alternative options, the construction period is likely to lead to a temporary increase in local employment and there would also be a permanent increase in employment during the operational period (see Table N.8). This ranges from 7,500 – 8,500 FTE/year during 4 peak years of construction, and 750 – 1,000 FTE permanent operational employment for B3 Cardiff to Weston Barrage to 1,500 – 3,000 FTE/year during 3 peak years of construction plus 80 – 100 FTE permanent operational employment for B5 Beachley Barrage. These are considered to be positive, although non-significant effects (based on the SEA methodology described above).

Table N.8 Summary of Significant Employment Effects for each Alternative Option

Effect	Alternative Option				
	B3 Cardiff to Weston Barrage	**B4 Shoots Barrage**	**B5 Beachley Barrage**	**L2 Welsh Grounds Lagoon**	**L3d Bridgwater Bay Lagoon**
Construction Employment[1]	7,500 – 8,500 FTE/year during 4 peak years of construction	2,000 – 3,000 FTE/year during 3 peak years of construction	1,500 – 3,000 FTE/year during 3 peak years of construction	3,000 – 4,000 FTE/year during 4 peak years of construction	4,000 – 6,000 FTE/year during 5 peak years of construction
Operational Employment	750 – 1,000 FTE permanent operational employment.	100 – 200 FTE permanent operational employment.	80 – 100 FTE permanent operational employment.	120 – 180 FTE permanent operational employment.	200 – 300 FTE permanent operational employment.
Effects on Ports During Construction[2]	1,850 FTE lost	Not significant			
Effects on Ports During Operation[2]	4,200 FTE lost	Not significant			
Effect on recreational / tourism fisheries employment.	Loss of salmon and sea trout fisheries employment and heritage (elver) fisheries	Loss of salmon and sea trout fisheries employment and heritage (elver) fisheries	Loss of salmon and sea trout fisheries employment and heritage (elver) fisheries	Loss of salmon and sea trout fisheries employment and heritage (elver) fisheries	Loss of salmon and sea trout fisheries employment and heritage (elver) fisheries

[3] NB: Results are derived from a regional level analysis (DTZ Regional Economic Impact Study (DTZ, 2009)) and subsequent update (STP Regional Workstream, 2010).

Effect	Alternative Option				
	B3 Cardiff to Weston Barrage	**B4 Shoots Barrage**	**B5 Beachley Barrage**	**L2 Welsh Grounds Lagoon**	**L3d Bridgwater Bay Lagoon**
	supported employment 58 FTE lost	supported employment 58 FTE lost	supported employment 58 FTE lost	supported employment 58 FTE lost	supported employment 58 FTE lost

[1] These are considered to be positive, although non-significant effects (based on the SEA methodology described above).
[2] Based upon the conclusions of the DTZ Regional Economic Impact Study (REIS) (DTZ, 2009) and subsequent REIS update (STP Regional Workstream, 2010), a 'medium impact scenario' has been applied as an indicator for the potential effect of the alternative options on the ports sector. It is assumed that port-related employment corresponds directly with port trade.

N.11.32 Physicochemical changes have the potential to result in significant effects for navigation. Changes in tide levels would affect the access window that vessels have to access the ports. Deposition of sediment has the potential to negatively affect navigation. Changes to tidal currents could aid or hinder navigation depending on velocity, location and direction as well as affect the time it takes to navigate locks. In addition, potential negative effects during the construction phase may arise as a result of construction activities and additional ship movements. The ports of Bristol (including the Deep Sea Container Terminal), Cardiff, Newport and Sharpness Dock would all be affected by all alternative options, either during construction, operation or both. The Port of Bridgwater would be affected by B3 Cardiff to Weston Barrage and L3d Bridgwater Bay Lagoon.

N.11.33 Other sea uses may also be significantly affected by physicochemical changes, effects on biodiversity and effects on the historic environment and landscape and seascape. All alternative options are likely to affect the aggregate extraction industry as a result of the diminished resupply of aggregate resource sites in the study area and for the B3 Cardiff to Weston Barrage, as a result of increases in transit time, there would be reduced access of aggregate extraction dredgers to ports upstream of the barrage. The L2 Welsh Grounds Lagoon is likely to further affect the aggregate extraction industry as the structure itself is located on several reserve sites – this may also affect employment within this industry. The waste disposal industry is also likely to be affected as the L2 Welsh Grounds Lagoon also occupies the same location as two dredged material disposal sites. The L3d Bridgwater Bay Lagoon alternative option traverses a number of telecommunication cable routes and these cables are thus at risk. The presence of the lagoon also has the potential to reduce bathing water quality at Weston-super-Mare and has the potential to increase incident response times for rescue organisations operating in the vicinity of the structure.

N.11.34 Within the L3d Bridgwater Bay Lagoon, peak flow speeds within Bridgwater Bay may increase and this may be undesirable for small craft users and bathers. By contrast, all other alternative options are likely to create calmer conditions within the impoundment and this would generally favour recreational users of the estuary. All barrage alternative options are likely to prevent the formation of a surfable Severn Bore, but the lagoon alternative options would not have this significant effect.

Alternative options would generate employment and some also pose health and quality of life effects to the nearby population during their construction. All alternative options but notably the B3 Cardiff to Weston Barrage, would have negative effects on navigation and port related employment. All alternative options, and the L2 Welsh Grounds Lagoon especially, risk negative effects on marine aggregate extraction. There would be positive and negative effects for recreation and tourism for all alternative options. The B3 Cardiff to Weston Barrage, B4 Shoots Barrage and B5 Beachley Barrage would result in the loss of a bore that can be surfed.

N.12 Multiple Basins and Combinations Variants

N.12.1 Variants of the alternative options have also been considered in the SEA at a high level. These variants have not been subject to modelling or detailed assessment at this stage and were therefore not considered to the same level of detail as the alternative options. If selected to form part of a preferred approach, these would need to be considered within an updated SEA. An initial assessment of multiple basin or combination variants has not identified any new issues that were not already evident from considering the main options.

N.12.2 This SEA has undertaken a high-level assessment of a double basin L3d Bridgwater Bay Lagoon. During construction and decommissioning, a double basin L3d Bridgwater Bay Lagoon would result in additional temporary land-take and slightly greater construction employment opportunities, compared to the single basin L3d Bridgwater Bay Lagoon. There is also likely to be increased disturbance to communities and biodiversity due to a longer construction period. Other construction and decommissioning effects are likely to be largely the same as for a single basin L3d Bridgwater Bay Lagoon. During operation, there are likely to be differences in the effects on the hydraulics and geomorphology of the estuary, most notably, a greater loss in intertidal area which would have further negative effects on waterbirds and marine ecology.

N.12.3 A high-level assessment has also been undertaken of the combination of the L3d Bridgwater Bay Lagoon with the B3 Cardiff to Weston Barrage, and a combination of L3d Bridgwater Bay Lagoon with the B4 Shoots Barrage.

N.12.4 During construction and decommissioning, a combination of L3d Bridgwater Bay Lagoon and B3 Cardiff to Weston Barrage is likely to largely have the same effects upon the environment as the sum of the individual effects of the construction of both alternative options in isolation. There are however additional risks of effects to migratory and estuarine fish associated with construction, which could result in longer disturbance effects on fish populations. During operation, there is likely to be a reduction in high-water levels throughout the Severn Estuary and a greater far-field effect when compared to B3 Cardiff to Weston Barrage alone. There are also likely to be greater effects on the local landscape and seascape and communities, due to the presence of both alternative options in close proximity. There are likely to be greater effects upon waterbird and fish populations than the sum of the effects from operating the individual alternative options in isolation.

N.12.5 The combination of the L3d Bridgwater Bay Lagoon with the B4 Shoots Barrage could be built either concurrently or sequentially (with either the barrage or the lagoon built first).

N.12.6 During construction and decommissioning, a combination of L3d Bridgwater Bay Lagoon and B4 Shoots Barrage is likely to generally have the same significant effects upon the environment as the sum of the individual effects. Concurrent construction is likely to have a greater negative effect on fish and emissions to air than if construction were sequential. Concurrent decommissioning is likely to have a reduced positive effect on local employment and greater pressure upon sites and facilities for re-use of treatment of waste materials.

N.12.7 The combined operation of L3d Bridgwater Bay Lagoon and B4 Shoots Barrage is likely to result in a small reduction in high-water levels and a small raising of low water levels throughout the Severn Estuary. This would result in greater effects upon navigation and a greater loss of intertidal area throughout the estuary. The relative reduction in intertidal area is also likely to result in greater effects on marine ecology and waterbirds.

An initial assessment of multiple basin and combination variants has not identified any new issues that were not already evident from considering the five alternative options.

N.13 Measures to prevent, reduce and as fully as possible offset significant adverse effects

N.13.1 During earlier stages of the feasibility study, the alternative options were refined and measures to prevent or reduce significant adverse effects on the environment were considered. The modifications included changes in operating mode (ebb-only generation compared with ebb-flood generation), changes in turbine numbers and sizes, changes in sluice capacity, and changes in alignment.

N.13.2 Further measures to prevent or reduce likely adverse effects on the environment have been suggested and refined, during later stages of development of the SEA. Key recommended measures are listed below. The scale and nature of many of these potential measures are unprecedented and their implementation would present significant challenges (further information is provided in Section 5.4 and Appendix 10). Several of the measures are of uncertain effectiveness and, in particular, would not prevent negative effects on habitats, birds and migratory fish.

- Flood Risk & Land Drainage: Pumping stations at tidal outfalls (which would otherwise become tide-locked), to lift water to discharge at similar stages of the tide as would occur in the future baseline case. Other measures include improvements and monitoring of tidal or sea defences; erosion protection through large-scale revetment systems in front of tidal defences; and the provision of a flood relief channel for the River Axe. There is reasonable certainty of the effectiveness of these measures. The costing of these measures has been assessed and is provided within the Severn Tidal Power Options Definition Report (Parsons Brinckerhoff, 2010).
- Marine Ecology and Waterbirds: Seawater level management through pumping at high water (alternative options B3 Cardiff to Weston Barrage, B4 Shoots Barrage, L2 Welsh Grounds Lagoon & L3d Bridgwater Bay Lagoon) and sluicing after the generation period, combined with early commencement of turbine generation, in ebb-only mode (alternative options B3 Cardiff to Weston Barrage, B4 Shoots Barrage, B5 Beachley Barrage and L2 Welsh Grounds Lagoon only). For B3 Cardiff to Weston Barrage, such a change in mode of operation could potentially lead to low water levels being lowered by up to 0.5m, thereby potentially reducing intertidal habitat loss by up to 500ha. Other measures include use of construction materials that would enhance colonisation of new structures (although there may be an increase in the settlement potential of non-native species); topographic modification (the creation of intertidal area); and the introduction of new refuges and/or bird roosts (B3 Cardiff to Weston Barrage only). With regards topographic modification, this is of uncertain efficacy and further study would be required prior to implementation. All other measures can be reasonably expected to be effective. No measures have been identified that could effectively prevent or reduce the adverse effects predicted to *Sabellaria alveolata* reef.
- Migratory & Estuarine Fish: Altering the current proposed type, size, number and / or position of sluices during detailed design; increasing permeability by diverting a proportion of the available volume of water through safer passage routes - whether they are sluices, free-wheeling turbines or free gaps - also ensuring that

all operating turbines are at optimum efficiency during periods of generation (thereby resulting in less (damaging) changes in pressure forces on fish). These measures are all of very uncertain effectiveness. Freewheeling turbines would still result in fish mortality and the scale of benefit of increasing permeability would depend on the volume of water that could be made available to pass through the safer passage routes. Other measures include and intertidal habitat creation (topographic modification) and enhancement (of uncertain efficacy and further modelling is required prior to implementation); and controls over predatory piscivorous birds; and using measures to minimise underwater noise disturbance and sediment release during construction and decommissioning (all predicted to be partially effective).

- Navigation: Various measures including: co-ordination of construction activities and traffic; improving logistics to manage the arrival and transit of vessels through locks during operation (all alternative options). For alternative options B3 Cardiff to Weston Barrage, B4 Shoots Barrage and L3d Bridgwater Bay Lagoon, dredging of approach channels to affected ports; and for B3 Cardiff to Weston Barrage, B5 Beachley Barrage and L3d Bridgwater Bay Lagoon, altering port infrastructure (such as lowering of sill levels). For all alternative options, annual dredging to maintain navigation channels to ensure continued navigability. These measures can be reasonably expected to be effective for navigation.
- Communities: Various measures including those to reduce effects on the quality of life of the local population for B3 Cardiff to Weston Barrage and L3d Bridgwater Bay Lagoon. Measures include improving air quality by reducing the number of construction vehicles on local roads through rationalising deliveries; use of larger vehicles and delivery of construction materials by alternative routes (e.g. rail or sea) and maximising the use of existing temporary/permanent works arrangements. These measures would be effective but further consideration of logistical arrangements would be required.

N.13.3 An assessment has been made of the estimated residual loss of intertidal area of the Severn Estuary/Môr Hafren SAC, following the application of these measures to prevent or reduce likely adverse effects on the environment. This is provided in Table N.9. These estimates do not include uncertain estimates of long term morphological change.

Table N.9 Summary of estimated area losses of designated intertidal habitat within the Severn Estuary/Môr Hafren SAC, after adoption of potential measures to prevent or reduce significant adverse effects

Alternative Option	Estimated area loss of designated intertidal habitat *before* application of potential measures to prevent or reduce significant adverse effects		Estimated area loss of designated intertidal habitat *after* application of potential measures to prevent or reduce significant adverse effects	
	Potential Lower-bound Loss (ha)	Potential Upper-bound Loss (ha)	Potential Lower-bound Loss (ha)	Potential Upper-bound Loss (ha)
B3	14,800	18,000	11,800	16,300
B4	3,300	4,000	2,700	3,700
B5	2,700	3,300	2,100	3,000
L2	7,300	8,700	6,100	8,200
L3d	2,500	3,000	1,600	2,600
Table should be read along with notes in Section 5.4. NB: Does not include intertidal areas of sub-estuaries, habitat area losses are uncertain and small by comparison.				

A wide range of measures have been considered to prevent and reduce likely significant adverse effects on the environment. These include measures for flood risk, navigation, marine habitats, fish and waterbirds. However, the measures are of uncertain effectiveness and would not prevent negative effects on key features of the Severn Estuary such as intertidal habitats, birds and migratory fish.

N.13.4 Offsetting measures within this SEA are measures which make good for loss or damage to an environmental receptor, without directly reducing that loss / damage. These need more development to be confident of their effectiveness. The key offsetting measures which have been recommended for adoption at this stage include:

- Measures to offset effects to non-statutorily protected migratory and estuarine fish; such as habitat creation, modification and ecological enhancement, or monetary compensation in return for surrender of fishing licenses.
- Measures to offset effects of submergence of the lowest exposures of some coastal geological and geomorphological SSSI sites; the Geological Conservation Review (GCR) may include other sites that have similar examples of the particular features that may be permanently submerged. In such cases there is a possibility that the geological information lost to research by submergence could be offset by designation of a similar outcrop elsewhere. Conversely, it is also possible that the particular geological and geomorphological features being submerged are unique. In this situation, no offsetting would be possible.
- Measures to offset likely effects to aggregate and dredge disposal sites; by issuing of new aggregate licenses or altering existing licenses and/ or by creating new dredged material disposal procedures or new sites.
- The need has also been identified for a further associated measure to offset the effects on users of existing dredging disposal and aggregate extraction sites of the increased transit distance and time for access to alternative sites.
- Measures to offset likely effects to recreational/tourism salmon and sea-trout and heritage (elver) fisheries communities; by providing monetary compensation in return for surrender of recreational fishing licences. This measure is also likely to have positive effects for fish receptors.

N.13.5 In this SEA, ‘compensation’ (a type of offsetting), is used in relation to those offsetting measures that could help meet the specific compensation requirements under the EC Habitats Directive in relation to effects on Natura 2000 sites. Any compensation measure would have to be fully considered under the Habitats Regulations Assessment (HRA) framework in the event of an STP alternative option, or combination of options, being adopted. Those measures currently considered as potential compensation measures include;

- Managed realignment to create saltmarsh adjoining and at a distance from the Severn Estuary; and creation of freshwater wetland close to the Severn Estuary;
- New notification of Sabellaria alveolata reef; and
- Translocation/introduction of shad species to new locations, estuarine habitat enhancement and creation schemes for shad, stocking of salmon and shad in rivers outside the Severn Estuary and its tributaries, freshwater habitat creation/enhancement schemes for multiple species of migratory fish; and new notification of existing non-SAC populations for multiple species of migratory fish.

N.13.6 The scale and nature of many of these potential measures have never been attempted and their implementation would present significant challenges. As the level of compensation likely to be required would be unprecedented, there is a significant risk that it may not be possible to offset or compensate for all of the adverse effects on a 'like-for-like' basis.

Possible offsetting and compensation measures have been identified for the residual negative effects. These need more development to be confident of their effectiveness.

N.14 SEA Objectives comparison of alternative options

N.14.1 The SEA objectives are used to compare the effects of alternative options by examining how each alternative option performs in relation to them. A summary table for the alternative options is provided in Appendix 11. This comparison does take into consideration the above measures to prevent or reduce significant effects which if applied would avoid or lessen the significant effects identified in section N.11 above. It does not however, take into account offsetting measures as these are not detailed enough to form a reasonable basis for assessment.

N.15 Monitoring measures

N.15.1 Monitoring allows the actual significant environmental effects of implementing a Severn Tidal Power scheme to be identified. Monitoring does not negate the need for measures to prevent or reduce significant negative effects, and there are likely to be significant challenges associated with implementing effective monitoring regimes on the scale required for a Severn Tidal Power scheme. A summary of the monitoring measures proposed are set out in Table N.10.

Table N.10 Summary of envisaged monitoring measures for significant environmental effects for all alternative options

Theme	Description of monitoring
Physicochemical	LiDAR surveys combined with bathymetry and modelling. Surveys approximately every 5 years.
	Sediment sampling.
	One-off survey to confirm discharge consent compliance
	Use of existing continuous recorders at ports to measure increases in water levels. If necessary add a gauge in expected zone of far-field influence (B3 Cardiff to Weston Barrage only).
	Current flood risks due to tide-locking.
	Erosion monitoring of toe of flood defences by LiDAR (every 5 years) and physical inspection every year to determine when and where erosion protection works are required.
	Water table elevation and its variation in vicinity of buildings and services and in soils deemed potentially 'at risk'.
Biodiversity	Changes in habitat extent and quality in response to physicochemical changes
	Changes in species populations and distributions in response to construction disturbance and physicochemical changes
	WeBS Counts of the Severn Estuary and evaluation of WeBS data from other key sites. Breeding season surveys of seabirds on Flat Holm and Steep Holm
	Fish losses, population sustainability, delay to passage, effects upon reproductive success etc.
Historic Environment and	Archaeological monitoring, where appropriate, during construction phase. Planned programme of foreshore and subtidal surveys including walkovers,

Theme	Description of monitoring
Landscape & Seascape	prospection, sampling, excavation etc to reduce the long-term loss through the recording of the resource.
	Changes in landscape character and visual effects.
Air & Climatic Factors and Resources & Waste	Estuarine changes as part of the Water Quality and Marine Ecology to consider the effects on emissions cycles (carbon, methane and nitrogen).
	All materials entering and leaving site, including use of secondary and recycled aggregates. Transportation and fuel consumption.
	Air quality monitoring.
Society & Economy	Port employment and mean rod catches as indicator of employment
	Monitoring from other themes would assist with monitoring of effects on this theme.

N.16 Further Research

N.16.1 Suggestions for further research are not a requirement of the SEA Directive. However, there is a need for better understanding of some of the issues, to both inform future decision making if an alternative option is taken forward, but also to ensure a meaningful monitoring programme is investigated.

N.16.2 With regards to hydraulics and geomorphology, suggestions are made for further data collection focussing on in a number of areas, including waves, bathymetry and sediment loads. Further modelling is also recommended including the extent of far-field effects and consideration of 3D sediment modelling. A series of water quality studies are suggested to improve confidence in the predictions of water quality effects and to refine the requirements for measures to prevent or reduce effects, if an alternative option is taken forward. These include, amongst others, a detailed salinity model, estuary-wide models of suspended sediment concentrations, nutrients and oxygen and a detailed scenario modelling of bathing water compliance risks at relevant bathing waters. Regarding flood risk and land drainage, further modelling is also suggested on tributaries for surge tides and fluvial floods, including detailed modelling of far-field effects.

N.16.3 Suggestions are made for further research on the distribution and abundance of some marine ecology receptors; and for a further five years of birds data to inform the waterbirds topic, along with further development of modelling techniques for waterbirds. Further research into the behaviour of fish within the estuary and the life stages of many species within the Severn Estuary would improve levels of certainty. Further research into measures to prevent or reduce significant effects on fish is also suggested.

N.16.4 There is currently a shortage of information on the economic contribution and direct and indirect employment generation of salmon and sea-trout fishing on the rivers Usk, Wye and Severn, and it is suggested that further study is undertaken in this area. It is also suggested that further study be undertaken into current transit times associated with navigation to enable future modelling of transit times through any alternative option to be supported.

Monitoring measures have been identified for the appraisal of alternative options, if taken forward. Suggestions are also made for research and development that would be needed to reduce uncertainties of the effects of alternative options, and how they can be managed, prior to taking any alternative option forward.

SECTION 1

BACKGROUND

1 BACKGROUND

1.1 Severn Tidal Power Feasibility Study

1.1.1 The Government published the terms of reference for a two-year feasibility study on harnessing the renewable energy from the tidal range of the Severn Estuary in January 2008. This work has been carried out by a cross-Government team led from the Department of Energy and Climate Change (DECC), including representatives of the Department for the Environment, Food and Rural Affairs (Defra), the Welsh Assembly Government (WAG) and the South West Regional Development Agency (SWRDA), taking external advice as necessary and engaging stakeholders and the wider public. The aim of the Severn Tidal Power (STP) Feasibility Study was to investigate whether the Government could support a tidal power scheme in the Severn and, if so, on what terms.

1.1.2 Any project to generate power from the tidal range of the Severn Estuary will need to meet the following objectives:

- To generate electricity from the renewable tidal range resource of the Severn Estuary in ways that will have an acceptable overall impact on our environment and economy both locally and nationally, will meet our statutory obligations and provide benefit to the United Kingdom (UK); and

- To deliver a strategically significant supply of renewable electricity, which is affordable and represents value for money compared to other sources of supply in the context of the UK's commitments under the European Union (EU) Renewable Energy Directive and Climate Change Act and our goal to deliver a secure supply of low-carbon electricity.

1.1.3 The Feasibility Study was split into two phases:

- Phase One: Examined the scope of work and analysis required to make an evidence-based decision on whether to support a tidal power project in the Severn and what potentially feasible schemes exist for converting this energy. A public consultation document was published in January 2009. Phase One ended on the 15th July 2009, with the publication of the Government's response to the Phase One consultation and confirmation of the five shortlisted alternative options.

- Phase Two: Work on environmental, economic, commercial, technical and regulatory issues to inform the study conclusions including whether any of the potential schemes are feasible.

1.2 Strategic Environmental Assessment

1.2.1 Strategic Environmental Assessment (SEA) is the term used to describe environmental assessment as applied to plans and programmes in accordance with Council Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment. Council Directive 2001/42/EC (known as the SEA Directive) is enacted in Wales and England through the Environmental Assessment of Plans and Programmes Regulations (Welsh SI 2004/1656 and SI 2004/1633).

1.2.2 This STP SEA has been carried out in support of the Feasibility Study, and its purpose is to identify, describe and evaluate the likely significant effects on the environment of a tidal power project within the Severn Estuary. This report, alongside others being prepared within the Feasibility Study[4], will inform the Government's decision on whether or not it could support a tidal power project within the Severn Estuary. The alternatives it considers are a 'do-nothing' alternative (as baseline) and the five shortlisted alternative options based around the estuary.

1.2.3 In parallel to the Feasibility Study, the Severn Embryonic Technologies Scheme (SETS) is helping proposers of emerging technologies address key risk areas and map their development path. These embryonic technologies have not been assessed as part of this SEA, as they lack the definition necessary to be considered as reasonable alternatives.

1.3 Purpose and structure of this Environmental Report

The SEA Directive requires the preparation of *'an environmental report…in which the likely significant effects on the environment of implementing the plan or programme, and reasonable alternatives taking into account the objectives and the geographical scope of the plan or programme, are identified, described and evaluated'* (Article 5 (1)).

1.3.1 In the terms of the SEA Directive, the 'plan' is the Government's proposal to generate tidal power from the tidal range of the Severn Estuary.

1.3.2 The 'reasonable alternatives' for the STP Feasibility Study are the five shortlisted alternative options, together with their associated measures to prevent, reduce and as fully as possible offset any significant adverse effects on the environment of implementing an STP scheme. A 'do-nothing' alternative has also been considered in the form of the baseline environment.

1.3.3 This Environmental Report meets the requirements of the SEA Directive Article 5 (1): to identify, describe and evaluate the likely significant effects on the environment of implementing the five STP alternative options over their lifetime. The preparation of this Environmental Report has included consultation with statutory authorities, key stakeholders and the public.

1.3.4 The structure of this Environmental Report adheres to the requirements of the SEA Directive and follows the guidance set out in 'A Practical Guide to the Strategic Environmental Assessment Directive' (The Practical Guide) (Office of the Deputy Prime Minister (ODPM) *et al*., 2005). Table 1.1 sets out the structure of this Environmental Report. Where relevant, at the start of each subsequent section of this Environmental Report, the requirements of the SEA Directive are summarised.

[4] Other reports which are being prepared within the Feasibility Study include Options Definition Report (Parsons Brinckerhoff, 2010); Report to inform a Stage 2 (Appropriate Assessment) Habitats Regulations Assessment (Severn Tidal Power, 2010); Supply Chain Report (DECC, 2010) and Severn Tidal Grid Impact Report (National Grid, 2010).

Table 1.1: Report structure

Section	Description
1. Background	• An overview of the STP Feasibility Study and the objectives of the plan. • Purpose of the SEA. • An outline of the contents of the Environmental Report.
2. Approach adopted	• Scope and structure of the SEA. • Approach adopted in the SEA. • Overview of the consultation undertaken throughout the SEA process. • The difficulties encountered in compiling information or carrying out the assessment.
3. Baseline environment and SEA objectives	• Other international, national, regional and local plans and programmes, and relevant environmental protection objectives and how these have been taken into account. • Baseline characteristics of the study area and the predicted evolution of this baseline. • The existing environmental issues and problems which are relevant to this SEA. • Limitations of the data and key assumptions made. • SEA objectives used to test the Feasibility Study proposals and compare alternative options.
4. Plan alternatives and potentially significant issues	• STP alternative options and how they were identified.
5. Likely significant effects on the environment and measures to prevent, reduce and as fully as possible offset any significant adverse effects	• The likely significant effects on the environment of each alternative option and how they were identified, including cumulative effects and effects of consequential development (NB; this does not include measures to prevent or reduce significant effects except those already included in the definition of alternative options). • Limitations and uncertainties of the assessment and key assumptions made. • Potential measures to prevent, reduce and as fully as possible offset any significant adverse effects on the environment. • Potential need for compensation under the Habitats Directive[5].
6. SEA objectives comparison of alternative options	• Comparison of each alternative option against the SEA objectives.
7. Implementation	• Monitoring measures that may be required, for the significant environmental effects arising from the implementation of each alternative option. • Suggestions for further research.

1.3.5 This Environmental Report contains the relevant information to meet the requirements of the SEA Directive. A series of SEA Theme and Topic Papers provide evidence to support the findings of the Environmental Report. The Topic and Theme Papers are listed in Appendix 1 to this Report.

[5] Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora.

1.3.6 This Environmental Report has been developed separately but in parallel with a Report to inform a Stage 2 (Appropriate Assessment) Habitats Regulations Assessment (Severn Tidal Power, 2010) in accordance with the European Commission (EC) Habitats Directive in relation to effects on Natura 2000 sites (the European Union-wide network of protected areas, including two types of designated areas: Special Areas of Conservation (SAC) and Special Protection Areas (SPA)).

1.4 Authors of this report

The SEA was conducted on behalf of the cross-government group, by a consortium of environmental consultants. This consortium was led by Parsons Brinckerhoff and Black & Veatch, and also included ABPmer, APEM, the BTO, HR Wallingford, Ryder Landscape Consultants and Wessex Archaeology. The report was authored by Black & Veatch Ltd.

This is the Strategic Environmental Assessment (SEA) for the Severn Tidal Power Feasibility Study. It informs Government decision-making. *Key messages within the summary are provided in boxes such as this.*

SECTION 2

APPROACH ADOPTED

2 APPROACH ADOPTED

2.1 Scope and structure of the SEA

2.1.1 In January 2009, the Government launched a public consultation on the conclusions of the first phase of the STP Feasibility Study (DECC, 2009a). This consultation included the proposed scope of the SEA. The Government's response to the consultation published in July 2009 confirmed the scope of the SEA (DECC, 2009b).

2.1.2 This Environmental Report is the key output of the STP SEA and meets the requirements of the SEA Directive Article 5 (1). This Environmental Report presents the current state of the environment and its likely evolution, information on the likely significant effects on the environment of the alternative options and the measures to prevent, reduce and as fully as possible offset any significant adverse effects on the environment.

2.1.3 The Environmental Report is informed by a series of SEA Theme and Topic Papers (see Appendix 1), that provide evidence on the likely significant environmental effects. These SEA Theme and Topic Papers were defined by the scoping stage to ensure that they provide the necessary evidence. Table 2.1 below lists the STP SEA topics (referred to as 'topics' hereafter) and shows how they relate to the indicative range of issues in the SEA Directive.

Table 2.1 Severn Tidal Power SEA topics

Severn Tidal Power SEA Topic	SEA Directive Topic (Annex 1(f))
Hydraulics & Geomorphology	Water
Marine Water Quality	Water
Flood Risk & Land Drainage	Water, Material Assets
Freshwater Environment & Associated Interfaces	Water, Soil
Marine Ecology	Biodiversity, Fauna, Flora
Migratory & Estuarine Fish	Biodiversity, Fauna
Waterbirds	Biodiversity, Fauna
Terrestrial & Freshwater Ecology	Biodiversity, Fauna, Flora
Historic Environment	Cultural Heritage
Landscape & Seascape	Landscape
Air & Climatic Factors	Climatic Factors, Air
Resources & Waste	Material Assets
Communities	Population, Human Health, Cultural Heritage, Material Assets
Noise & Vibration	Population
Navigation	Material Assets, Population
Other Sea Uses	Material Assets, Population

2.1.4 Theme Papers were produced to summarise the interrelationships between related topics and thereby ensure that the many complex relationships between topics are recognised and their implications understood (see Appendix 1). This approach emerged from the SEA scoping stage to allow related topics to interact and interface more effectively. The SEA themes are set out in Table 2.2.

2.1.5 Each Theme Paper also examines the interrelationships between each theme and other themes within the SEA. The SEA theme papers provide evidence to support the findings of the Environmental Report by identifying the difficulties (such as technical deficiencies or lack of know-how) encountered in compiling the required information (SEA Directive Annex 1(h)).

Table 2.2 Severn Tidal Power SEA themes and topics

Severn Tidal Power SEA Theme	Severn Tidal Power SEA Topic
Physicochemical	Hydraulics & Geomorphology Marine Water Quality Flood Risk & Land Drainage Freshwater Environment & Associated Interfaces
Biodiversity	Marine Ecology Migratory & Estuarine Fish Waterbirds Terrestrial & Freshwater Ecology
Historic Environment and Landscape & Seascape	Historic Environment Landscape & Seascape
Air & Climatic Factors and Resources & Waste	Air & Climatic Factors (including Carbon Footprint) Resources & Waste
Society & Economy	Communities Noise & Vibration Navigation Other Sea Uses

2.2 Approach adopted in the SEA

2.2.1 The approach taken in the SEA is adapted from The Practical Guide (ODPM *et al.,* 2005). A summary of this is provided in Table 2.3. For a more detailed description of each SEA task in the STP SEA, see Appendix 2.

Table 2.3 Stages in the SEA process (adapted from the Practical Guide, Figure 5)

SEA Stages	Tasks
Stage A: Setting the context and objectives, establishing the baseline and deciding the scope	A1. Identifying other relevant plans, programmes and environmental protection objectives
	A2. Collecting baseline information
	A3. Identifying environmental problems
	A4. Developing SEA objectives
	A5. Consulting on the scope of the SEA
Stage B: Developing and refining alternatives and assessing effects	B1. Testing the plan or programme objectives against the SEA objectives
	B2. Developing strategic alternatives
	B3. Predicting the effects of the plan or programme, including alternatives
	B4. Evaluating the effects of the plan or programme, including alternatives
	B5. Considering ways of preventing, reducing or as fully as possible offsetting adverse environmental effects
	B6. Proposing measures to monitor the environmental effects of plan or programme implementation

SEA Stages	Tasks
Stage C: Preparing the Environmental Report	C1. Preparing the Environmental Report
Stage D: Consulting on the draft plan or programme and the Environmental Report	D1. Consulting the public and Consultation Bodies on the draft plan or programme and the Environmental Report
	D2. Assessing significant changes
	D3. Making decisions and providing information
Stage E: Monitoring the significant effects of implementing the plan or programme on the environment	E1. Developing aims and methods for monitoring
	E2: Responding to adverse effects

2.2.2 The tasks listed under Stage A of Table 2.3 were undertaken during Phase One (Scoping) of the Feasibility Study. Through the review of other relevant plans, programmes and environmental protection objectives (see Section 3.1) and the gathering of baseline data (see Section 3.2) it was possible during scoping stage to identify potential environmental issues that the SEA has since taken into account (see Appendix 3). The identification process retained a strategic perspective and was focussed upon those issues that are particularly relevant in view of the nature and scale of development of tidal power in the Severn Estuary.

2.2.3 SEA objectives (see Section 3.5) were developed to compare the effects of the alternative options. The SEA objectives were developed through review of baseline data and the review of other relevant plans, programmes and their environmental protection objectives. The Scoping Report presented these tasks and was issued to accompany the STP Feasibility Study consultation document as the first step in the SEA process and invited views on the scope of the SEA.

2.2.4 The Government's response to the consultation (DECC, 2009b) confirmed the scope of Phase Two of the SEA and refined the SEA objectives. The Government's consultation response also confirmed the shortlist of five alternative options.

2.2.5 The five alternative options were then refined via an optimisation process which used the SEA objectives to undertake a high-level environmental assessment (see Section 4.1). This optimisation process tested the original options and variants of these in order to evaluate their environmental effects, scheme costs, energy output and energy cost. With regards to the environmental effects, the optimisation process was linked to the SEA objectives and a high-level assessment was undertaken using a selection of the SEA objectives assessment criteria.

2.2.6 Optimisation of the schemes initially focussed only on individual schemes. However, variants of the alternative options have also been considered in this SEA at lesser detail as the alternative options. These variants include a multiple basin alternative which comprises two basins within a lagoon alternative option. These basins are configured to provide a more flexible energy yield profile. Variants also include alternatives which are a combination of some of the five alternative options.

2.2.7 The tasks listed under Stage B of Table 2.3 have been undertaken and are reported within this Environmental Report. Further baseline data was collected and the review of other relevant plans, programmes and environmental protection objectives was updated. The likely significant effects on the environment of the five alternative options were identified. Following this, measures to prevent, reduce and as fully as possible offset significant adverse effects on the environment were developed. Measures to monitor the significant environmental effects were also proposed.

2.2.8 Specialist studies were undertaken as part of the SEA to supplement the evidence base for the assessment and thereby ensure that the SEA findings are robust. A summary of the specialist studies undertaken are listed in Table 3.2 (studies to inform the description of the environment and area likely to be affected) and Table 5.2 (studies to inform the assessment of likely significant environmental effects). The SEA topic papers provide further information (see Appendix 1).

2.2.9 The tasks listed under Stages D and E of Table 2.3 are outside the scope of this Environmental Report.

The SEA has been undertaken in accordance with the EU SEA Directive. Its purpose is to describe the likely significant effects on the environment of tidal power projects within the Severn Estuary. The outcome is reported here. A hierarchy of technical reports provides more evidence.

2.3 Consultation

The SEA Directive requires that consultation is undertaken with authorities designated by Member States *'which, by reason of their specific environmental responsibilities, are likely to be concerned by the environmental effects of implementing plans and programmes'* (Article 6 (2)).

Consultation should be undertaken with these authorities *'when deciding on the scope and level of detail of the information to be included in the environmental report'* (Article 5 (4)).

Furthermore, authorities with environmental responsibility and the public *'…shall be given an early and effective opportunity within appropriate time frames to express their opinion on the draft plan or programme and the accompanying environmental report before the adoption of the plan or programme'* (Article 6(2)).

2.3.1 Consultation has been undertaken and opportunities for informal input have occurred with the Consultation Bodies[6] of Wales and England (known hereafter as statutory advisors) as well as wide range of other bodies and the public (including relevant non-governmental organisations) in accordance with the SEA Directive.

2.3.2 The membership of an SEA Steering Group was established in May 2008. The full membership is listed in Appendix 4. The Steering Group provided valuable guidance on the process of conducting an SEA and in turn a level of assurance for the Project Board in their decision making. In addition, groups of representatives of Government bodies and statutory advisors also provided informal advice throughout the study. Figure 2.1 below summarises the consultation activities undertaken and opportunities for input provided to date.

Input during Phase One (Scoping)

2.3.3 Informal input from statutory advisers, non-governmental organisations, industry, trade associations, academics and individuals was also received during Phase One (Scoping). In some cases this included technical workshops. Seven technical

[6] The SEA Regulations designate particular organisations as 'Consultation Bodies'. In Wales, the Consultation Bodies are: Cadw, the Countryside Council for Wales, and the Environment Agency Wales. In England, the Consultation Bodies are: English Heritage, the Environment Agency, and Natural England.

workshops were held and typically each workshop was attended by approximately 15 technical specialists. These meetings concentrated on establishing the evidence base for each technical area and identifying the key issues that would apply to the assessment of alternative options.

Consultation during Phase One (Scoping)

2.3.4 In January 2009, the Government launched the public consultation on Phase One of the Feasibility Study (including a recommended short-list of schemes and the SEA Scoping Report). The Scoping Report identified the issues that needed to be considered, the tools that should be adopted, and the overall approach to the main assessment phase. In total, 734 formal responses were received to the consultation. A full list of respondents can be found in Annex C of the Government's response to the consultation (DECC, 2009b). They included statutory advisers, non-governmental organisations, industry, trade associations, academics and individuals. The Government's response to the consultation summarised the views received and where appropriate how they have influenced the study.

Input during Phase Two (SEA)

2.3.5 A series of technical workshops was also convened during Phase Two (the main SEA assessment phase) of the Feasibility Study, principally to provide the opportunity for technical specialists across many organisations to input to the developing SEA. At least two technical workshops were held for each topic (with the exception of the Noise & Vibration topic[7]); the first addressing the overall approach to the SEA and the process for identifying likely significant effects, baseline and future baseline data including any uncertainties and SEA objectives; and the second presenting the baseline and future baseline, the emerging results and predicted effects of alternative options and seeking views on interpretation of the results. Attendees at each workshop included representatives of Government bodies and statutory advisors, non-governmental organisations, industry and academia.

2.3.6 In addition, throughout Phase Two (SEA), at least two teleconference update meetings were held with representatives of Government bodies and statutory advisors to provide progress reports and in the case of the latter calls, technical input for each topic area.

2.3.7 Representatives of Government bodies and statutory advisors were provided with an opportunity to comment on the draft Environmental Report and its appendices prior to it being published for public consultation alongside the wider Feasibility Study.

2.3.8 It should be noted that attendees at the workshops may not necessarily agree or endorse the conclusions of this report. No agreement as to a preferred option(s) has been given and the formal consultation process is still to occur (see below).

Consultation during Phase Two (SEA)

2.3.9 This Environmental Report forms part of the formal consultation on the Severn Tidal Power Feasibility Study (Phase Two (SEA)).

[7] No invitations to the planned Noise & Vibration topic workshops were accepted and thus the workshops were cancelled.

Transboundary Consultation

2.3.10 Where a plan or programme is likely to have significant effects on the environment in another Member State of the European Union, the SEA Directive provides for consultation with that Member State on the draft plan and the environmental report. The findings of the SEA indicate that there is the potential for significant effects on Republic of Ireland and therefore that transboundary consultation will be required.

Terms of Reference published.
Call for Evidence published (call for proposals & call for information).

↓

SEA Steering Group established with membership from selected organisations.

↓

Phase One: Technical workshops and individual conversations with representatives of Government bodies, statutory advisors and key stakeholders.

↓

Severn Tidal Power Phase One Consultation including scope of the SEA.

↓

Consultation response published confirming the shortlist of five alternative options, and the scope of Phase Two of the SEA.

↓

Agreement of topic workplans, methodologies and discussion of emerging results with representatives of Government bodies and statutory advisors via meetings, teleconferences and individual conversations.

↓

Discussion of baseline data and agreement of methodologies at Technical Workshops with representatives of Government bodies, statutory advisors and key stakeholders.

↓

Testing of applied methods and emerging results at Technical Workshops with representatives of Government bodies, statutory advisors and key stakeholders.

↓

Publication of SEA Environmental Report for
Public Consultation.

Figure 2.1 Consultation and input undertaken during preparation of the SEA

2.4 Difficulties encountered in compiling information or carrying out the assessment

2.4.1 Difficulties were encountered in compiling information for the SEA and carrying out the assessment. These are described below, with further explanation provided in the SEA Theme and Topic Papers (see Appendix 1). Assumptions, limitations and uncertainty associated with determining the baseline environment are set out in Section 3.4 and the assumptions, limitations and uncertainty associated with determining the significant environment effects are set out in Section 5.3. Section 7.2 sets out suggestions for future work which would assist in reducing the uncertainty described in these sections, if an alternative option is taken forward.

2.4.2 When predicting the future evolution of the environment, the nearer term predictions are more accurate than estimations into the future. Therefore the future evolution of the environment during the construction phase has more certainty than that during the operational life of a scheme.

2.4.3 The methods used to predict the effects are consistent with the strategic nature of the Feasibility Study. Some uncertainty is therefore carried through the assessment, from the project assumptions made, to the specific modelling parameters used. Where there are uncertainties, there are acknowledged alongside the assessments.

2.4.4 The models used in the physicochemical theme assessments are subject to different levels of uncertainties. There are some data gaps and limitations which affect the reliability of predictions, though these are not considered critical for this strategic assessment. Changes in water levels, currents and waves can be modelled with reasonably high levels of certainty although these predictions are associated with a specific set of barrage operating rules. Uncertainty in these rules or how the barrage might be operated in the future would affect predictions. The prediction of changes in the sediment regime and the evolution of the estuary morphology are subject to much greater uncertainties as the controlling processes are very complex and the models are only able to include simplified representation of the key processes. These uncertainties are identified in both the physicochemical theme assessments and the assessment of other topics that use this data.

2.4.5 There is limited information on some species and habitats and similarly, there is a generally ill-defined understanding of some key ecological variables, particularly in relation to the functional requirements and linkages within marine ecosystems and how human pressures, for example a tidal power scheme, might affect them. Future work would reduce this uncertainty.

2.4.6 The integrated and complex nature of estuarine environments means that any difficulties (such as technical deficiencies or lack of knowledge) that arise in the hydraulics and geomorphology assessment are carried through to other topics within the physicochemical theme and also on to subsequent themes such as biodiversity and also to topics such as historic environment and navigation. These uncertainties are identified in both the physicochemical theme assessments and the assessment of other topics that use this data.

2.4.7 Representation of the baseline environment, as a coherent entity at the large scale required for SEA is particularly difficult. There are often inconsistencies between data sets, level of research and terminology at the local and national (Wales and England) level. Future work would reduce this inconsistency.

2.4.8 The assessment of effects upon migratory estuarine fish has used a weak evidence-base for the ecology of several designated fish species, how tidal power structures would affect these species, and how such effects could be prevented or reduced. The assessment is therefore made using judgements in this context, and is therefore inherently uncertain. A substantial programme of research could address this difficulty if an alternative option is taken forward.

The SEA is a high-level assessment, and parts have been undertaken using incomplete data. The assessment is also the product of diverse integrated studies, undertaken in a dynamic and complex estuarine system. There are some weaknesses in our understanding of the physical and biological processes within the estuary. These lead to uncertainties that cascade through the assessment, which are identified in the reporting, and would need to be considered further if an alternative option is taken forward.

SECTION 3

BASELINE ENVIRONMENT AND SEA OBJECTIVES

3 BASELINE ENVIRONMENT AND SEA OBJECTIVES

3.1 Other plans and programmes

The SEA Directive requires that the Environmental Report describes '*the relationship [of the plan or programme] with other relevant plans and programmes'* (Annex I(a)).

The Environmental Report should also include *'the environmental protection objectives, established at international, Community or Member State level, which are relevant to the plan or programme and the way those objectives and any environmental considerations have been taken into account during its preparation'* (Annex I(e)).

3.1.1 In accordance with Annex I(a), a review of other relevant plans and programmes was undertaken to identify the environmental protection objectives of relevant international, national, regional and local level plans and policies (Severn Tidal Power, 2010a). Each SEA Topic Paper provides a summary of the existing legislation and policy of particular relevance to its topic assessment (see Appendix 1). Key overarching energy policy is summarised below.

3.1.2 In 2007, the UK agreed with its EU partners to a binding target that 20% of the EU's energy consumption must come from renewable sources by 2020. The EC Renewables Directive (Council Directive 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC) states that the UK's contribution to this should be to increase the share of renewables in the UK's energy mix from around 1.3% in 2005 to 15% by 2020.

3.1.3 The Climate Change Act (2008) has set targets to reduce CO_2 emissions by at least 26% by 2020 and 80% by 2050. In the UK 2009 budget, the 2020 target was revised and therefore the currently legally binding target is to achieve a carbon emissions reduction of 34% by 2020.

3.1.4 The Government published its Renewable Energy Strategy in July 2009 (HM Government, 2009a). The Strategy sets out the path for the UK to meet the target of ensuring 15% of our energy comes from renewable sources by 2020 and the strategic role the Government will adopt and the specific actions it will take to lead delivery. The Renewable Energy Strategy states that achieving the UK's share of the EU target could require a third or more of electricity to be generated from renewable sources by 2020. Tidal range technologies (potentially including a major tidal range project in the Severn Estuary) have the potential to provide low carbon energy and thereby contribute to the delivery of the Renewable Energy Strategy.

3.1.5 The UK Low Carbon Transition Plan (HM Government, 2009b) plots how the UK will meet a 34% cut in emissions on 1990 levels by 2020, as set out in the April 2009 Budget. The Plan anticipates that by 2020, around 40% of electricity will be from low-carbon sources, from renewables, nuclear and clean coal. The Plan set out that a Severn Tidal Power project could make an important contribution to delivering our renewable energy and climate change targets but that there are drawbacks including the potential impact on the natural environment. This STP Feasibility Study is investigating these issues to inform the decision on whether the Government could support a project in the Severn Estuary.

3.1.6 The Marine Energy Action Plan (HM Government, 2010) outlines the actions required by both private and pubic sectors to facilitate the development and deployment of marine energy technology and intends to fulfil the vision set out in the UK Renewable Energy Strategy and Low Carbon Industrial Strategy. The Action Plan, which has a UK-wide focus and covers wave, tidal range and tidal stream energy (without prejudice to the STP Feasibility Study's conclusion), states that the Government envisages that marine renewable energy could play an important role in the period to 2020 as the sector begins to roll out larger arrays of devices. This is expected to be followed by large scale deployment in the period beyond 2020 that the Government envisages will help to meet their policy for an 80% cut in carbon emissions by 2050.

3.1.7 In accordance with Annex I(e), the review of other relevant plans, programmes and environmental protection objectives (Severn Tidal Power, 2010a) has informed the following:

- Baseline data collection (see Section 3.2) by identifying key indicators and baseline trends; and
- Development of the STP SEA framework which comprises objectives, indicators and targets (see Section 3.5).

The Feasibility Study sits in the context of UK renewable energy policy. The SEA has been informed by this, and the objectives of other relevant policies and programmes.

3.2 Current state of the environment and likely evolution thereof

The SEA Directive requires that the Environmental Report includes '*relevant aspects of the current state of the environment and the likely evolution thereof without implementation of the plan or programme*' and '*the environmental characteristics of area likely to be significantly affected*' (Annex I(b),(c)).

Identification of baseline and likely evolution

3.2.2 The current state and characteristics of the environment have been identified and described to provide the basis for predicting and monitoring environmental effects. This has been referred to as the 'baseline' and both qualitative and quantitative information has been used for this purpose.

3.2.3 The evolution of the state of the environment without the implementation of an STP alternative option has been referred to as the 'future baseline'. Alternative options considered within this Feasibility Study would only be developed several years into the future and would have a long life. It was therefore necessary to project a 'future baseline' against which to compare effects, rather than using the present day baseline. This is an especially important concept when considering dynamic systems such as estuaries that are subject to climate change effects such as sea level rise.

3.2.4 The approach taken was therefore to describe the baseline in the following stages:

- Baseline environment and receptors up to 2009, including environmental problems and opportunities;

- Future baseline during construction: 2014-2020, including anticipated problems and opportunities;
- Future baseline during operation 2020-2140, decommissioning and longer term trends, including anticipated problems and opportunities.

Study area

3.2.5 The study area used for describing the baseline environment during Phase One (Scoping) of the SEA broadly extended from the River Severn upstream tidal limit at Maisemore to downstream on the Severn Estuary as far as a line drawn between Worm's Head and Morte Point (Figure 3.1). It included the landward fringe and tributaries such as the River Wye and the River Usk up to the tidal limit and where necessary further inland.

3.2.6 This Phase Two (SEA) study area was determined by the footprint of the alternative options which could extract tidal range power from the Severn Estuary, and any areas which may be affected by doing so.

Insert Fig 3.1

Insert Figure 3.2

3.2.7 Phase One (Scoping) identified the need to extend the study area beyond this general definition. The topic specific study areas are summarised in Table 3.1. Further information is provided in the SEA Topic Papers (see Appendix 1).

Table 3.1 Topic specific study areas

SEA Topic	Topic Specific Study Areas
Hydraulics & Geomorphology	• Primary divisions were located across the estuary to create the following zones (see Figure 3.2): Zone 1 – Outer Bristol Channel Zone 2 – Inner Bristol Channel Zone 3 – Severn Estuary Zone 4 – The Shoots Zone 5 – Upper Severn Estuary • The study area was also extended west and north including the coastline of St. George's Channel to account for any water level effects outside of the Severn Estuary and Bristol Channel.
Marine Water Quality	• From the River Severn upstream tidal limit at Maisemore to downstream on the Severn Estuary as far as a line drawn between Worm's Head and Morte Point.
Flood Risk & Land Drainage	• Lateral extent included the coastline and foreshore of the Severn Estuary and Bristol Channel enclosed by the alternative options. • The inland extent included at least the 1:200 year floodplain, in the absence of flood defences, extended to consider the upland catchments of watercourses draining into the tidal floodplain. • The study area was also extended west and north including the coastline of St. George's Channel to account for any water level effects outside of the Severn Estuary and Bristol Channel.
Freshwater Environment & Associated Interfaces	• As the Flood Risk & Land Drainage topic with a particular focus on a buffer 2km inland from the coast and 2km upstream of the tidal limit on the main tributaries and the 1:200 year floodplain.
Marine Ecology	• From the River Severn upstream tidal limit at Maisemore to downstream on the Severn Estuary as far as a line drawn between Worm's Head and Morte Point, extended to cover the spatial extent of all effects identified.
Migratory & Estuarine Fish	• To include all sites designated for their protection for fish both within and to some extent outside of the immediate area potentially affected. • To also include Natura 2000 network sites within the UK and sites further afield.
Waterbirds	• The five zones of the Severn Estuary and Bristol Channel (see Figure 3.2). • To include the 1:200 year floodplain. • Also to include other sites outside of the Severn Estuary, including the Natura 2000 network.
Terrestrial & Freshwater Ecology	• To cover the spatial extent of all effects identified.
Historic Environment	• The terrestrial estuary environment including the intertidal zone, a 1km wide strip of adjacent coastal land and the extent

SEA Topic	Topic Specific Study Areas
	of the drift geology defined by the alluvium of the coastal floodplain. • Included targeted study areas of 1km around the locations of the landfalls of the alternative options. • The marine estuary environment up to Mean High Water.
Landscape & Seascape	• The Severn Estuary and Bristol channel and surrounds with an inshore limit of 10km and any high ground that affords views out over the Severn Estuary and an offshore extent of 35km.
Air & Climatic Factors	• Severn Estuary, Bristol Channel and surrounds, national study area and global study area (for greenhouse gases).
Resources & Waste	• The study area for resources varied depending on current source of resource (steel resources - International; aggregates and energy resources - UK wide; and water resources - local study area). • The study area for waste was a 75 mile radius of the Severn Estuary and Bristol Channel, incorporating southern Wales, southwest England and the West Midlands.
Communities	• 12 estuarine Local Authority districts bordering the Severn Estuary and River Severn and subsequently refined.
Noise & Vibration	• 2km radius from the alternative options.
Navigation	• From the River Severn upstream tidal limit at Maisemore to downstream on the Severn Estuary as far as a line drawn between Worm's Head and Morte Point, with a particular focus on the key commercial ports (Bristol, Cardiff, Newport, Sharpness and Bridgwater) and existing and proposed navigation channels utilised by these ports.
Other Sea Uses	• From the River Severn upstream tidal limit at Maisemore to downstream on the Severn Estuary as far as a line drawn between Worm's Head and Morte Point.

Sources of Data

3.2.8 At the scoping stage, the proposed sources of data to inform the baseline environment were identified and this was consulted upon to ensure that the most relevant and appropriate sources were used. This varied between topics and data has included primary sources (for example surveys) and secondary sources, including both qualitative and quantitative data. Where appropriate, the Department of Energy (DoE) Energy Technology Support Unit (ETSU) from the early 1980s and the Severn Tidal Power Group (STPG) reports from the late 1980s were used. Section 5 provides further information on the studies that informed the assessment stage.

3.2.9 A summary of the sources of data used by each topic to identify and describe the baseline and future baseline is shown in Table 3.2. Further information is provided in the SEA Topic Papers (see Appendix 1).

Table 3.2 STP Sources of data to identify and describe baseline and future baseline

SEA Topic	Specialist Studies to Identify and Describe Baseline and Future Baseline
Hydraulics & Geomorphology	• Desk-based research as primary data source (including previous STPG study reports) • Creation of new bathymetric dataset (combining existing Light Detection and Ranging (LiDAR) mapping and Hydrographic surveys) • Consideration of analogous sites (La Rance, Annapolis Royal, Eastern Scheldt and three sites in the Severn Estuary) • Numerical models: o Hydraulics (flows & water levels) o Hydraulics (waves) o Sand transport o Mud transport o Intertidal profile form o Aggregated scale morphological change
Marine Water Quality	• Desk-based research as primary data source • Numerical modelling o Salinity o Flushing o Stratification o Thermal plumes o Dispersion/dilution of treated sewage effluent • Data analysis (Environment Agency review of consents) • Desk based assessments o Dissolved oxygen o Contaminants o Temperature o Nutrients and eutrophication • Outputs from other topics: Hydraulics & Geomorphology
Flood Risk & Land Drainage	• Desk-based research as primary data source o Environment Agency data on flood risk management assets (including 3rd party assets) and flood maps o Water company records of outfalls o Previous STP documents (STPG reports) o Draft Shoreline Management Plan 2 o Early draft (Jan 2009) of baseline flood consequence assessment for the Severn Estuary Flood Risk Management Strategy o Public consultation documents on draft policies for the Severn Estuary and North Devon and Somerset Shoreline Management Plans o Hydraulic models of some rivers o LiDAR data o National Property database • Simplified 1D models • Outputs from other topics: Hydraulics & Geomorphology
Freshwater Environment & Associated Interfaces	• Desk-based research as primary data source • Collection, collation and assessment of readily accessible info in public domain: o Published maps o Direct information requests to Statutory Consultees and

SEA Topic	Specialist Studies to Identify and Describe Baseline and Future Baseline
	Local Authorities o Environment Agency website o British Geological Survey o Local record offices & interest groups • Outputs from other topics: Hydraulics & Geomorphology; Flood Risk & Land Drainage; and Marine Water Quality
Marine Ecology	o Desk-based research as primary data source, including: Previous STP documents (STPG reports) o Data and information collected as part of the recent Severn Coastal Habitat Management Plan (CHaMP); o Information on the distribution of habitats and species within the Severn Estuary and Bristol Channel from a wide range of sources; o Wider scientific literature on the physical and chemical tolerances of marine ecological receptors. • Outputs from other topics: Hydraulics & Geomorphology; Marine Water Quality; Waterbirds; and Migratory & Estuarine Fish
Migratory & Estuarine Fish	• Desk-based research as primary data source • Key migratory fish species life-cycle modelling including age/stage structured matrix populations • 140 year baseline population simulations • Assessment of population status including review of conservation listings and site designations (condition assessment monitoring, Salmon Action Plans, Biodiversity Action Plan status, etc) • Analysis of existing data-sets including long-term power station entrainment data and fisheries catch statistics • Economic valuation of recreational, heritage and commercial fisheries • Specialist advice (International Council for the Exploration of the Sea (ICES) / Environment Agency) • Outputs from other topics: Hydraulics & Geomorphology; and Marine Water Quality
Waterbirds	• Desk-based research as primary data source • Interrogation of existing Wetland Bird Survey (WeBS) • New survey work (2008-2009) o WeBS Core High Tide Counts o WeBS Low Tide Counts • Outputs from other topics: Hydraulics and Geomorphology; Marine Water Quality; and Marine Ecology
Terrestrial & Freshwater Ecology	• Desk-based research as primary data source • Data collection (Multi-Agency Geographic Information for the Countryside (MAGIC), National Biodiversity Network (NBN), and data held by Countryside Council for Wales (CCW), Joint Nature Conservation Committee (JNCC) & Natural England) • Modelling outputs from Flood Risk & Land Drainage topic outputs o Environment Agency data on flood risk o Water company records of outfalls o Hydraulic river models o LiDAR data

SEA Topic	Specialist Studies to Identify and Describe Baseline and Future Baseline
	• Outputs from other topics: Hydraulics & Geomorphology; Marine Ecology; Flood Risk & Land Drainage; and Waterbirds
Historic Environment	• Desk-based research as primary data source • Outputs from other topics: Hydraulics & Geomorphology; Landscape & Seascape; Resources & Waste; Flood Risk & Land Drainage; Navigation; and Communities
Landscape & Seascape	• Desk-based research as primary data source • Existing Guidelines • New field surveys (day & night) • GIS analysis – Zone of Theoretical Visibility (ZTV) • Outputs from other topics: Hydraulics & Geomorphology; Flood Risk & Land Drainage; Historic Environment; Communities; Marine Ecology; Waterbirds; Terrestrial & Freshwater Ecology; Freshwater Environment & Associated Interfaces; Resources & Waste; Navigation; and Other Sea Uses
Air & Climatic Factors	• Desk-based research as primary data source o Human data from National Accredited Air Quality Sources (e.g. National Air Quality Strategy). o Habitat data from JNCC, CCW • Existing and future predictions of emissions from DECC, IPCC and ENSEMBLES data. • Outputs from other topics: Communities; Navigation; Resources & Waste; and Marine Ecology
Resources & Waste	• Desk-based research as primary data source. • Outputs from other topics: Hydraulics & Geomorphology; Other Sea Uses; Communities; Marine Water Quality; Navigation; Flood Risk & Land Drainage; Marine Ecology; and Historic Environment
Communities	• Desk-based research as primary data source (DTZ Regional Economic Impact Study (REIS) (DTZ, 2009) and subsequent REIS update (STP Regional Workstream, 2010). • Review of available existing data (census, air quality, noise, National Statistics population projections) • Outputs from other topics: Flood Risk & Land Drainage; Other Sea Uses; Navigation; Noise & Vibration; Marine Water Quality; Resources & Waste; and Migratory & Estuarine Fish; Waterbirds; and Landscape & Seascape
Noise & Vibration	• Desk-based research as primary data source (including maps and guidance documents) • Qualitative assessment • Outputs from other topics: Communities; Resources & Waste; Marine Ecology; Waterbirds; and Migratory & Estuarine Fish
Navigation	• Desk-based research as primary data source • Ship movements data and other existing data from ports and Harbour Trustees • Modelling results from other topics • Navigation & admiralty tide tables • Outputs from other topics: Hydraulics & Geomorphology; Communities; Other Sea Uses; and Resources & Waste
Other Sea Uses	• Desk-based research as primary data source

SEA Topic	Specialist Studies to Identify and Describe Baseline and Future Baseline
	• Consultation with stakeholders • Outputs from other topics: Hydraulics & Geomorphology; Communities; Marine Water Quality; Noise & Vibration; Navigation; and Resources & Waste

Description of baseline environment and predicted future baseline

3.2.10 The Severn Estuary forms the border between South Wales and South West England, in the UK, as far upstream as Beachley. On the northern side of the estuary is the city of Newport; and, to the west, Cardiff. On the southern, English, side, are Avonmouth, just to the west of the City of Bristol, and Weston-super-Mare (see Figure 3.1).

Physicochemical

3.2.11 This section describes the relevant aspects and characteristics of the current state and the likely evolution of the physicochemical environment of the Severn Estuary including issues such as soil and water (SEA Directive, Annex 1(f)). The baseline environment described below has been informed by the following Topic Papers and their annexes; Hydraulics & Geomorphology, Marine Water Quality, Flood Risk & Land Drainage and Freshwater Environment & Associated Interfaces as well as the Physicochemical Theme Paper (see Appendix 1).

Plate 3.1 Intertidal aerial over Severn

Plate 3.2 Mouth of River Wye

Plate 3.3 Dinosaur Footprints at Hayes Point to Bendrick Rock SSSI (near Barry)

3.2.12 The Severn Estuary has one of the highest tidal ranges of the world (12m mean spring tidal range at Avonmouth). This is a reflection of its funnel shape, and positioning towards the direct approach of ocean tides across the European continental shelf. Figure 3.3 shows the bathymetry of the Severn Estuary.

3.2.13 The high tidal range leads to an estuary environment typified by the cyclical movement of very large quantities of mud between the seabed, and in suspension in the water column. On spring tides around 12.5 million tonnes of sediment are in suspension, leading to areas of high concentrations of suspended sediment. Conversely, sediment in suspension reduces to around 4.3 million tonnes on smaller neap tides. The remainder is temporarily deposited on the estuary bed, especially in deeper areas such as the Bristol and Newport Deeps and in Bridgwater Bay. The concentration of suspended sediments varies vertically, with much higher concentrations near the sea bed than the water surface, and horizontally, with higher concentrations on the English shore than the Welsh shore. Figure 3.4 shows the seabed sediment of the Severn Estuary.

3.2.14 Within the Severn Estuary and Bristol Channel are a number of subtidal linear sandbank features, such as Culver Sands, Nash Bank and Helwick Bank. These are held in place by the balance of the tidal currents of the estuary and the wave climate.

3.2.15 The Severn Estuary's tidal range ensures that in general the estuary is well-mixed for other parameters such as contaminated sediments, salinity, dissolved oxygen, temperature, and pH. Nonetheless, the estuary has a north-south salinity gradient in addition to the normal increases in salinity downstream. Dissolved oxygen levels in the estuary are generally high; however, intermittent oxygen sags do occur especially around the Severn Road Crossings when high levels of fine sediment are entrained. Oxygen sags have also been observed in the Usk, Wye and Parrett tributary estuaries. There are elevated water temperatures in the vicinity of large thermal discharges, such as at Hinkley B power station and localised greater acidity in the vicinity of Aberthaw Power Station.

3.2.16 The Severn Estuary and Bristol Channel provide one of the highest UK inputs of nitrogen and phosphorus to the marine environment, reflecting the estuary's size, the location of human settlements and the intensity of agricultural land use. The Lower, Middle and Upper Severn Estuary, Usk Estuary, Wye Estuary and Parrett Estuary as well as Bristol Channel Inner South and Bristol Channel Outer North and Bridgwater Bay coastal waters have all been assessed as having 'moderate' status under the Water Framework Directive (WFD) in respect of their nitrogen content (see Figure 3.5). Bridgwater Bay was also assessed as being at moderate status in respect of macroalgae and phytoplankton (see Figure 3.5).

3.2.17 Most bathing waters within the Severn Estuary and Bristol Channel have been regularly complying with the more stringent guideline standards of the EU Bathing Waters Directive. The Food Standards Agency has classified Swansea Bay South as suitable for the harvesting of shellfish (see Figure 3.5).

3.2.18 The main tributaries of the Severn Estuary are the Ely and Taff (which are impounded by the Cardiff Bay Barrage), the Rhymney, Ebbw, Usk, Wye, the influent River Severn, the Avon and Parrett. There are a large number of surface water abstractions within the 1:200 year floodplain (i.e. a flood predicted to occur on average every 200 years) and 2km upstream of the tidal limit on the main tributaries which are used for the Public Water Supply (PWS) and other uses (Figure 3.6).

3.2.19 The geology bordering the estuary comprises low permeability bedrock overlain by low permeability soils, principally related to estuarine alluvium. Thus the surface water processes dominate the regional hydrology and hence there is limited groundwater resource potential. The key exceptions to this are the presence of a Carboniferous Limestone aquifer which is harnessed for the PWS, the fluvio-glacial deposits in Cardiff and to a lesser extent, isolated deposits of River Terrace gravels and dune sands. Groundwater quality is generally good.

3.2.20 The variation in soil type within the 1:200 year floodplain is vast and complex. A simplified representation is that soils occurring above the estuarine alluvium and glacial till are generally heavy, clay-rich and poorly drained, whereas those overlying sand and gravel deposits are lighter, more sandy and better drained. The Severn Estuary contains many sites of geological and geomorphological interest, several of which are designated as Sites of Special Scientific Interest (SSSIs) (see Figure 3.7).

3.2.21 Nationally important subterranean assets include the Severn Railway Tunnel which runs through the bedrock deposits. Locally important subterranean infrastructure within urban centres includes sewers and other services as well as building foundations and basements which are located within the more geologically recent deposits.

3.2.22 Some 90,000 properties and commercial assets are at risk of flooding in over 550 km^2 of low lying tidal floodplains of the Severn Estuary (approximately 35,000 properties in Wales and 54,000 properties in England) with concentrated in the urban centres of Cardiff, Newport, Burnham-on-Sea and Weston-super-Mare. The standard of flood protection provided by existing defences varies throughout the Severn Estuary, but generally property and infrastructure assets are protected to a standard of at least a 1 in 50 year level (i.e. a flood predicted to occur on average every 50 years). In some rural areas, the flood defence standard is as low as 1 in 5 years.

3.2.23 Many of the drainage outfalls, both from land drainage and piped drainage systems, experience some restriction of free flow during high spring tides, known as ‘tide-locking’. Roads and buildings are generally located on ground which is above spring tide level, so are unaffected by this. However, some rural areas are below this level. In these areas the land drainage systems are actively managed by Internal Drainage Boards or the Environment Agency to offset the impacts of tide-locking. Figure 3.8 shows the tidal floodplain and land drainage of the Severn Estuary.

Plate 3.4 Land drainage outfalls around the Severn Estuary

3.2.24 Climate change projections (UKCP09) show increases in mean sea level and storminess (winds and waves), drier summers and wetter winters which will alter patterns of river flows. The median prediction for the medium emissions scenario is that by 2100 sea levels will have risen about 0.5m, which has been extrapolated to an estimated rise of about 0.6m in around 2140. When considering flood risk and land drainage, the more precautionary guidance of Planning Policy Statement (PPS) 25 and Technical Advice Note (TAN) 15 has been adopted to provide compatibility with the assumptions underpinning the Severn Estuary Flood Risk Management Strategy (SEFRMS) and the Shoreline Management Plan (SMP) review. This guidance anticipates around 0.9m increase in sea level in 2100.

3.2.25 Study indicated that, climate change notwithstanding, the historic need to protect sections of defence against foreshore erosion is likely to continue. Coastal policy, which is likely to lead to maintaining the standards of defence in areas where there are assets or communities at risk, will result in a reduced intertidal area through coastal squeeze. The predicted rise in sea level will also increase the risks of tide-locking of fluvial flow through outfalls into the estuary. There may also be an increasing risk of flooding as a result of an increase in fluvial peak flows.

3.2.26 Ambient water temperatures in the estuary are also predicted to rise and the past trend of ocean acidification as a result of CO_2 absorption by the sea is predicted by climate scientists to continue. The UKCP09 median prediction for the medium emissions scenario is that by 2100 seasonal sea surface temperatures will have risen by 2.5 to 2.8°C in winter, spring and summer and by around 3.5°C in autumn compared with conditions in the period 1961-1990. The effects of climate change are also expected to vary salinity, particularly in the upper parts of the estuary as freshwater flows are affected by increased winter precipitation, less snow melting and more frequent droughts. Predicted sea level rise, combined with lower summer river flows will also result in increased saline intrusion to tributaries open to the Severn Estuary. The upstream movement of the saline interface has the potential to adversely affect existing freshwater abstractions close to the tidal limits of rivers discharging to the Severn Estuary.

3.2.27 Predicted reductions in summer low flows and groundwater resources are likely to lead to increased competition for the available water resources. The soil resource will also come under increasing stress as a result of increased temperatures and lower summer soil moisture. The effects of sea level rise and other changes on geological and geomorphological SSSIs will have an effect on exposure and access in the period up to 2140. Regulation to align with the requirements of River Basin Management Plans under the WFD will lead to tighter controls on contaminants and pathogens and thus it is expected that the water quality of the Severn Estuary and its tributaries will improve.

Insert Figure 3.3

Insert Figure 3.4

Insert Figure 3.5

Insert Figure 3.6

Insert Figure 3.7

Insert Figure 3.8

Biodiversity

3.2.28 This section describes the relevant aspects and characteristics of the current state and the likely evolution of the natural environment of the Severn Estuary focusing on issues such as biodiversity, fauna and flora (SEA Directive, Annex 1(f)). The baseline environment described below has been informed by the following Topic Papers and their annexes; Marine Ecology, Migratory & Estuarine Fish, Waterbirds and Terrestrial & Freshwater Ecology as well as the Biodiversity Theme Paper (see Appendix 1).

3.2.29 The high tidal range and the high turbidity of the Severn Estuary creates unusual physical conditions which influence the composition, distribution and abundance of its flora and fauna. The consequent biodiversity importance of the estuary is recognised through international, national and local nature conservation designations. Figure 3.7 shows the international and national nature conservation designations of the Severn Estuary and surrounds.

3.2.30 Paramount is the Severn Estuary/Môr Hafren Special Area of Conservation (SAC, designated under the EC Habitats Directive) which is part of the Severn Estuary/Môr Hafren European Marine Site, protected under European legislation. Figure 3.9 shows the marine habitats of the Severn Estuary. The extensive intertidal mudflats and sandflats, Atlantic salt meadows, sandbanks which are slightly covered by seawater all the time, and *Sabellaria alveolata* reefs (both intertidal and subtidal) form the SAC designation, and are also important in their own right (subtidal *Sabellaria alveolata* reefs are extremely rare). The Severn Estuary is also designated under national legislation as a Ramsar site, for; *inter alia*, its immense tidal range and unusual estuarine communities with reduced diversity and high productivity. It is also designated a Ramsar site for its bird interest, discussed below.

Plate 3.5 Edges of the Severn Estuary at Beachley

3.2.31 Generally, the range and number of seabed animals and plants in the Severn Estuary is relatively low compared to other estuarine systems in the UK and this is one of the important reasons the Severn Estuary is designated for its nature conservation interest. This relatively low biodiversity is attributed to the Severn Estuary's high suspended sediment loads, mobility of sediment and tidal currents.

3.2.32 The marine ecology provides an important food source in the Severn Estuary for fish and waterbirds. Plant life in the water column is also limited by the high turbidity and small animals in the water are dominated by detrital grazers. Animals living on the estuary bed include seasonally large populations of the brown and other shrimps.

Harbour porpoise are seasonally present, but overall there are few records for marine mammals in the estuary.

3.2.33 Lundy Island, England's first Marine Conservation Zone, is designated under the UK Marine and Coastal Access Act 2009 to protect its nationally important and representative habitats and species.

3.2.34 Under the Water Framework Directive, the Bristol Channel Inner North and Bristol Channel Outer South Coastal waters have all been designated as having good ecological status and the Tawe, Afan and Bristol Avon estuaries have been designated as having good ecological potential. The Lower, Middle and Upper Severn, Usk and Parrett Estuaries and the Inner Bristol Channel Outer North, Carmarthen Bay and Bridgwater Bay Coastal waters are also designated as having moderate ecological potential (as they are modified water bodies, generally on account of the flood or coastal protection works that they have undergone) (see Figure 3.5).

3.2.35 Changing climatic and hydrodynamic conditions may have effects on the marine ecology. Increased sea level rise is expected to result in the loss of intertidal mudflats and sandflats and saltmarsh habitats. There is an obligation through the EC Habitats Directive to compensate for coastal squeeze by creation of new intertidal habitats, and the Severn Estuary Flood Risk Management Strategy (SEFRMS) and the Shoreline Management Plan (SMP) policies will include plans for the planning and creation of replacement habitats. The Steart Coastal Management Project has the potential to create between 200 and 800 ha of additional intertidal habitat and saltmarsh through managed realignment in the area of Bridgwater Bay. One of the aims of this project is to offset losses of intertidal habitat resulting from coastal squeeze. Changes in the extent and distribution of habitat types within the estuary may affect the species supported by the estuary system. Species composition and abundance will also be determined by physiological tolerances to the changing environmental conditions and the corresponding changes in species interactions.

3.2.36 The Severn Estuary/Môr Hafren, and the Afon Tywi/River Tywi SAC, River Usk/Afon Wysg SAC and River Wye/Afon Gwy SAC support seven migratory fish species, including five Annex II species protected under the EC Habitats Directive, notably allis and twaite shad, sea and river lamprey and Atlantic salmon (the last of these not applying to the Afon Tywi/River Tywi SAC). Salmon stocks are believed to be 50% down on the ten-year average. Spawning populations of allis shad and twaite shad are restricted in the UK with spawning populations of twaite shad now limited to only four rivers, all of which could potentially be affected by an STP alternative option. During recent condition assessments of the UK populations, river lamprey were classed as in favourable condition only in the River Usk while sea lamprey were in favourable condition only in the River Wye. European eel is believed to be beyond safe biological limits throughout Europe, and the upper reaches of the Severn and Avon catchments are believed to be below carrying capacity. Sea trout is less abundant than salmon in the Severn Estuary tributaries and since 1965 catches of the species have been low. While there are no formal UK records of sturgeon breeding in UK waters, there are historical records of individuals in the Severn Estuary and tributaries. With regard to the fish guilds (broad categories) of marine migrants, marine stragglers, estuarine species and freshwater stragglers, current baseline conditions are largely unknown.

3.2.37 All seven of the migratory fish species that pass through or use the Severn Estuary (sea trout and eel in addition to those listed above) are part of the qualifying criteria for the Severn Estuary's Ramsar designation. The Severn represents a major component of the UK eel stock and is provided international protection through the EU Eel Recovery Plan.

Plate 3.6 Allis Shad

Plate 3.7 Atlantic Salmon and Putcher Nets

Plate 3.8 Twaite Shad

3.2.38 Other rivers of note for their fisheries include the Ely, Taff, Rhymney, Ebbw, Avon, Yeo, Parrett, Axe and Severn. In the Inner Bristol Channel, marine fish are dominant and the majority of individuals within the estuary are juveniles. The River Severn catchment supports coarse, salmonid and eel freshwater fisheries and these contribute to the regional economy. The Severn Estuary and other tributaries of the Severn Estuary and Bristol Channel, particularly the River Usk and Wye and coalfield rivers are important for recreational fisheries. Some fisheries have heritage as well as economic value, especially fishing for elvers.

3.2.39 Future climate change and stock management issues may have effects on the distribution and survival of migratory fish species and other fish. Climate change is likely to result in a decrease in the river carrying capacity and smolt production of Atlantic salmon and poor growth rates for sea trout populations. Increasing temperatures may increase shad recruitment and eel growth rates (to an optima and then subsequently decline). Some marine migrants and marine stragglers may be adversely affected by increases in water temperature. Conversely bass and sole could benefit and conger eel and red mullet would extend their range. Increased winter rainfall leading to decreased salinity could affect the distribution of estuarine fish species and freshwater stragglers.

3.2.40 The large tidal range acts over a wide shallow basin to expose large areas of intertidal habitat at times of low water, which provides an important feeding ground for birds. The overall waterbird assemblage using the Severn Estuary during winter has been calculated to be nearly 73,000 individual birds. The Severn Estuary is designated as a Special Protection Area (SPA) under the EC Birds Directive[8] for supporting qualifying populations of species of waterbird. The Severn Estuary is also designated as a Ramsar site – a wetland of international importance. At least six waterbird species occur in internationally important numbers (ringed plover, curlew, dunlin, pintail, redshank and shelduck), and are protected under the SPA and Ramsar site. Other waterbirds or seabirds are features of further SSSIs within the Severn Estuary and Bristol Channel and surrounds. A waterbird assemblage is also a feature of the Somerset Levels and Moors SPA and Ramsar site, where a five-year average maximum of 99,000 individual waterbirds has been recorded.

[8] Council Directive 2009/147/EC on the conservation of wild birds.

  

Plate 3.9 Knot | Plate 3.10 Dunlin | Plate 3.11 Mute Swan

3.2.41 Decreasing trends in the proportions of waders that winter in south-west Britain have been correlated to increasing temperature and hence to climate change. This trend has been predicted to continue, however, populations that currently winter further south could move north to winter in the Severn Estuary. Species that currently use intertidal habitat are likely to be adversely affected by predicted rises in sea level, although it cannot be assumed that population trends of recent decades would continue. In some circumstances sea level rise and extreme weather events could reduce the attractiveness of east coast estuaries and increase the importance of the Severn Estuary as an area for wild birds. The Severn Estuary's importance as a cold weather refuge for waterbirds is thus unlikely to change. Further to this, the status of the Severn Estuary as an SPA means that action to halt and reverse any declining waterbird interest is expected. Thus it is unlikely that the net interest of the site will decline over time.

3.2.42 In addition to the estuary based designated sites and species, the surrounds of the Severn Estuary and Bristol Channel host a broad mix of terrestrial and freshwater ecology conservation features. These include SACs and Annex I habitats, Ramsar sites, SSSIs and National Nature Reserves (NNRs) (see Figure 3.7), Local Nature Reserves (LNRs), habitats and landscape corridors, lichens and fungi, plants, crustaceans and molluscs, invertebrates, herpetiles, birds and mammals.

  

Plate 3.12 Bracket Fungus | Plate 3.13 Somerset Levels | Plate 3.14 Winter Starlings

3.2.43 In the short term, an improvement to the designated features is likely through conservation actions that have already been undertaken or planned. In the longer term, continued maintenance and enhancement of the designated site network will continue to be of high priority for the Government and statutory agencies.

Insert Figure 3.9

Historic Environment and Landscape & Seascape

3.2.44 This section describes the relevant aspects and characteristics of the current state and the likely evolution of the historic environment (including cultural, architectural and archaeological heritage) and the landscape and seascape (SEA Directive, Annex 1(f)). The baseline environment described below has been informed by the following Topic Papers and their annexes; Historic Environment and Landscape & Seascape as well as the Historic Environment and Landscape & Seascape Theme Paper (see Appendix 1).

3.2.45 The historic environment encompasses archaeological sites and monuments, evidence for past environments, historic buildings and structures, historic landscapes and artefacts and structures related to seafaring. In the Severn Estuary and Bristol Channel and surrounds, it consists of both natural and built components and comprises (but is not limited to) internationally, nationally, regionally and locally important sites. Figure 3.10 shows the historic environment designations and locations of wrecks and obstructions of the Severn Estuary and Bristol Channel and its surrounds. However, it should be noted that this represents only part of the potential historic environment resource, as many existing sites and features are undiscovered.

3.2.46 The low-lying wetland landscapes along the fringes of the Severn Estuary and the intertidal areas have preserved prehistoric land surfaces and evidence relating to historic estuarine specific activities such as fish weirs and fish traps. The intertidal area also preserves the remains of sunken vessels, harbour installations and aircraft. Within the subtidal environment, the areas of deep mud and sand offer areas of high potential for the preservation of ship wrecks, aircraft wrecks and other maritime archaeological materials.

3.2.47 The expected trend is for piecemeal development within the surrounds of the Severn Estuary and Bristol Channel to continue. The associated loss of the terrestrial historic environment resource as a result of this development would continue to be managed through the land-use planning system, (both terrestrial and maritime) in the form of preservation and conservation or preservation by record. The historic environment resource within the subtidal and intertidal areas is particularly vulnerable to loss and damage resulting from sea level rise, coastal erosion and consequential flood risk management responses.

Plate 3.15 Quantock Hills AONB Panorama

Plate 3.16 Twmbarlwm panorama looking towards Newport

3.2.48 Seascape character ranges from the appearance of a wide river in the upper estuary, to the open sea bounded by cliffs, sandy beaches and muddy bays. The landscape looking down onto the Severn Estuary is also varied. It includes high ground which affords expansive views out over the estuary such as the Quantocks Hills Area of Outstanding Natural Beauty (AONB), Brean Down and the South Wales Valleys ridges above Cardiff. In contrast, there are considerable stretches of flat low lying ground butting up to the Severn Estuary such as the Gwent Levels Landscape of Outstanding Historic Interest in Wales. The estuary itself is framed by a number of substantial man-made landmarks, including the two road crossings, wind turbines at Bristol Port and the nuclear power station at Oldbury. Figure 3.11 shows the landscape features of the Severn Estuary and its surrounds.

Plate 3.17 Gwent Levels

Plate 3.18 M48 Crossing

Plate 3.19 Brean Down

3.2.49 It is considered that in the short term, there will be little noticeable change to the landscape, seascape and visual characteristics of the Severn Estuary with current land uses continuing and major landmarks such as the bridges and power stations remaining unchanged. In the longer term, the effects of sea level rise on the seascape may become more visible. Landscape change is likely to remain heavily related to development around the estuary.

Insert Figure 3.10

Insert Figure 3.11

Air & Climatic Factors and Resources & Waste

3.2.50 This section describes the relevant aspects and characteristics of the current state and the likely evolution of the environment with regards to air and climatic factors and resources and waste (SEA Directive, Annex 1(f)). The baseline environment described below has been informed by the following Topic Papers and their annexes; Air & Climatic Factors and Resources & Waste as well as the Air & Climatic Factors and Resources & Waste Theme Paper (see Appendix 1).

3.2.51 The Severn Estuary supports a range of habitats, including large intertidal areas which both store carbon and nitrogen and interact with atmospheric levels of greenhouse gasses (GHG) (principally CO_2) through the capture of carbon from the atmosphere. Decomposition of organic matter in these habitats may also act as a source of methane, another GHG.

3.2.52 Within the surrounds of the Severn Estuary and Bristol Channel, air quality is generally good, although areas with air quality problems have been associated with concentrations of industrial activity or traffic emissions associated with highways congestion within urban areas, notably Cardiff and Bristol.

3.2.53 With regards to carbon emissions, planned policies for carbon reduction indicate that beyond 2022 there will be a gradual decrease in UK emissions towards the 2050 target of 80% reduction. Decreases in emissions to air and ambient pollutant concentrations due to improvements in technology and a move to a low carbon economy are anticipated to result in gradual decreases in the level of pollutant deposition over time.

3.2.54 In terms of resources, the UK is generally self-sufficient in its demand for aggregate and embankment materials (sand bed and sand core, gravel, crushed rock and armour rock) although it is reliant on imports for steel. With regards to energy resources, the UK's energy consumption in 2008 was 165 million tonnes of oil equivalent, 3% of which was used by the construction sector. In the vicinity of the Severn Estuary, Welsh Water manages water resources across Wales, with South West Water, Severn Trent and Bristol Water being responsible on the English side of the estuary. Together, the water companies supply over 3 million m^3 per day, half of which is consumed by households.

3.2.55 In terms of waste, construction and demolition companies in Wales produced 12.2 million tonnes of construction and demolition waste in 2005/6 and a further 90 million tonnes per year in England. Within the Environment Agency's reporting areas of Wales, the South West of England and the West Midlands, there are 137 landfills, which include hazardous (England only), non-hazardous and inert waste landfills. Figure 3.12 shows aggregate extraction and waste discharge sites within the Severn Estuary, Bristol Channel and its surrounds.

3.2.56 Policy drivers are acting to increase the usage of secondary and recycled aggregates, rather than virgin aggregates. With regards to energy resources, national energy policy will affect the energy supply mix, rather than its availability. Population pressures and climate change will seasonally affect the availability of water supply. With regards to waste, the Welsh Assembly Government policy and the Strategy for Sustainable Construction will drive a long-term reduction in construction and demolition waste to landfill. It is likely that sustainability and climate change will continue to be key policy drivers and increasing preference for secondary and recycled aggregates, recycled steel and low carbon energy is expected.

Insert Figure 3.12

Society & Economy

3.2.57 This section describes the relevant aspects and characteristics of the current state and the likely evolution of the society and economy of the Severn Estuary and its surrounds focusing on issues such as population, human health and material assets (SEA Directive, Annex 1(f)). The baseline environment described below has been informed by the following Topic Papers and their annexes; Communities, Noise & Vibration, Navigation and Other Sea Uses as well as the Society & Economy Theme Paper (see Appendix 1).

3.2.58 The Wales and South West regions are generally characterised by low density rural areas with small settlements and a few major towns and cities. In 2008, the total population of the 12 estuarine Local Authority districts bordering the Severn Estuary and River Severn was estimated to be 2.02 million, with Bristol, Cardiff, South Gloucestershire and North Somerset being the largest local populations. Within the Local Authority districts, the local areas suffering relatively high deprivation are concentrated in Cardiff and Bristol, with pockets of deprivation in Newport, Gloucester, North Somerset and Sedgemoor.

3.2.59 Historically, Wales was considered a country of mining and heavy industry, but the economy is now diversified with growth in sectors including manufacture, electricity, gas and water supply, wholesale and retail trade, hotels and restaurants and real estate, renting and business activities. The key business sectors in the South West of England are primarily service-based industries, with the fastest growing being business, education and hotels and catering.

3.2.60 Findings of the Welsh Health Survey 2005/6, released in 2007, show that 79% of adults reported that their health in general was ‘good or better’, with 95% reporting their health as ‘fair or better’. Some of the quality of life indicators for Wales show that the proportions of population affected by poverty and social exclusion have been reduced. In south west England, the quality of life is considered to be generally high, with 91.5% of people reporting their health as ‘good’ or ‘fairly good’. Noise climates in the study area vary considerably from quiet rural areas to noisy urban areas with sources of noise including transportation, commercial and industrial activities. Health and quality of life is also considered to include air quality, landscape and flood risk which have been addressed above.

Plate 3.20 Commercial shipping and recreational boating around the Severn

3.2.61 The existing planning framework will continue to govern land use within the 12 estuarine Local Authority districts bordering the Severn Estuary and River Severn and in the short term a number of known proposed developments are likely to be completed. Four new non-nuclear power stations are scheduled to be operational in England and Wales in the next four years. In addition, both Hinkley and Oldbury have been identified as possible sites for new-build nuclear power stations, although neither site has been consented. The Outer Bristol Channel has also been identified as a suitable area for wind farm development.

Plate 3.21 Hinkley Point Nuclear Power Station

3.2.62 The 2017 population in the study area is projected to be 2.2 million. Between 2017 and 2031, population growth is projected to continue at an average of 0.9% per year for the study area as a whole until a 2031 projected total of 2.5 million. After falling substantially, economic output in the UK stabilised in the second half of 2009 and a period of gradual expansion is in prospect (Bank of England, 2010). Productivity growth in the UK is therefore expected to resume, but will be subject to future social and economic commitments. Tourism, construction and marine aggregate employment in the study area is expected to grow around 9% up to 2017 and a further 60% to 2140 (in proportion with population growth).

3.2.63 Inequalities in health correlated with socio-economic deprivation are widening, however, life expectancy for males and females is increasing. Furthermore, population and industrial and commercial growth are likely to result in a gradual increase in terrestrial noise levels. By contrast, the underwater noise levels are not anticipated to alter greatly.

3.2.64 The main ports within the Severn Estuary (Cardiff, Newport, Bristol – at Portbury and Avonmouth, Sharpness and Bridgwater) (Figure 3.12) receive approximately 4,200 commercial vessels each year, with daily averages ranging between 7 and 15 vessels for Cardiff, Newport and Bristol. The ports and the services they support are an important part of the local and regional economy and are responsible for handling a substantial proportion of UK trade.

Plate 3.22 Sharpness Port

Plate 3.23 Bristol Port

Plate 3.24 Cardiff Bay

3.2.65 Access to the ports is tidally restricted, with water levels within the ports (apart from Bridgwater) being contained by lock gates and controlled by impounding pumps. Navigation to the ports is often reliant on the incoming high tides and the lock gates to the ports are usually only operated for a few hours on either side of the high tide. Pilotage to the main commercial ports within the estuary is compulsory for the majority of large vessels. The pilot station for the ports is located at Barry and the transit time from the pilot station to the impounded docks ranges between 1 and 3.5 hours.

3.2.66 The operation of the ports also requires regular survey and dredging of navigation channels. The immediate approaches to the entrances to Portbury and Avonmouth

Docks (Bristol Port) are subject to major sediment deposition and require maintenance dredging in order to maintain safe navigable depths. The total wet volume of dredged material is in the region of 1.5 to 2 Mm^3/y. Cardiff and Newport Ports and approaches also require maintenance dredging, the total wet volume of dredged material is up to 600,000 and 100,000 m^3/y respectively. The entrance to Sharpness Dock is also dredged, the total wet volume of dredged material is in the region of 8,000 m^3/y. No maintenance dredging is undertaken for the Port of Bridgwater.

3.2.67 Marine aggregate extraction is currently licensed at ten sites within the Severn Estuary (including upstream of Cardiff – Weston-super-Mare) and the Bristol Channel and there are a number of additional sites for which licence applications are in progress (Figure 3.12). Approximately two-thirds of production is landed at Cardiff, Newport and Avonmouth and the industry supports around 1700 jobs. The Severn Estuary and Bristol Channel are also important for marine waste disposal (Figure 3.12). A large number of sewage and industrial discharges are made to the Severn Estuary using the dilution and dispersion driven by the high tidal range. In addition, a number of power stations (Hinkley, Oldbury, Uskmouth and Aberthaw) abstract and discharge large volumes of cooling water to the Severn Estuary and Bristol Channel.

3.2.68 With regards to noise, the Severn Estuary is a busy commercial estuary which also supports recreational uses such as motor boats, sailing boats and fishing vessels. This results in a noisy estuarine environment, although the relatively shallow water means that long distance sub-surface noise propagation is not supported.

3.2.69 Tourism is also an economic activity in the 12 estuarine Local Authority districts bordering the Severn Estuary and River Severn with 7.5m tourist visits generating around £1.7bn per annum. A wide range of recreational activities occur including sailing, boating, windsurfing, canoeing, surfing, bore surfing, sand surfing, bathing, diving, wildfowling and bird watching. Figure 3.13 shows the tourism of the Severn Estuary and its surrounds.

3.2.70 Other sea uses that occur in the Severn Estuary and Inner Bristol Channel include commercial fisheries, military activity, energy (including oil and gas, renewable energy resources and power stations) and cables and pipelines. Figure 3.12 shows other uses of the Severn Estuary.

Plate 3.25 Surfing the Bore

Plate 3.26 Brean Beach

Plate 3.27 Foreshore fishing

3.2.71 UK shipping is likely to grow as an economic, low carbon method of national and international trade and there is capacity for growth within the ports within the vessel size limits which can currently be received. There is therefore likely to be an increase in the percentage of larger vessels entering the ports. In particular, as of March 2010, the Bristol Port Company has been granted a Harbour Revision Order to allow the construction of a new Deep Sea Container Terminal (DSCT) near Avonmouth which would increase the size and number of vessels received by Bristol Port.

3.2.72 As shipping needs alter to meet demand and port approaches and channels need to be maintained for safety grounds, the requirement for dredge disposal grounds may change. Capital dredge programmes associated with large-scale coastal developments may also generate large volumes of dredge material which will need to be disposed of.

3.2.73 In the longer term, it is likely that forecasted population growth in South Wales and South West England as well as projected climate change will have effects on other sea uses. Population increases will necessitate further housing development and this will place additional demands on marine aggregate extraction. A change in regional population may also result in increased waste water entering the estuary. Warmer temperatures in the South West region are potentially beneficial to the tourism industry as well as marine recreational users.

Insert Figure 3.13

3.3 Existing environmental problems

The SEA Directive requires that the Environmental Report describes '*any existing environmental problems which are relevant to the plan or programme including, in particular, those relating to any areas of a particular environmental importance, such as areas designated pursuant to Directives 79/409/EEC* [the Birds Directive, now 09/147/EC] *and 92/43/EEC* [the Habitats Directive]*'* (Annex I(d)).

Physicochemical

3.3.1 Climate change (projections which include sea level rise and increased storminess) is an environmental problem affecting the hydraulics and geomorphology of the Severn Estuary and Bristol Channel with subsequent effects on many aspects of the natural and built environment.

3.3.2 There is likely to be ongoing deterioration of tidal defences, owing to both natural aging processes and sea level rise. Flood risk management responses are likely to include raising the level of tidal defences, providing protection against sea level rise (causing coastal squeeze) or set back new defences. Further to this, development control for Planning Authorities will be an increasing issue as pressure will grow to develop on a tidal floodplain which is increasingly at risk of inundation. Under the WFD, a large number of transitional and coastal water bodies in the estuary and inner Bristol Channel are identified as being heavily modified for reasons of flood and coast protection (Figure 3.5). Catchment nutrient sources have led to water bodies having 'moderate' potential under the WFD.

3.3.3 Climate change will also affect the availability and quality of water resources and the soil resource although this may be managed through regulatory mechanisms initiated by the Government.

Biodiversity

3.3.4 There is an obligation through the EC Habitats Directive to compensate for coastal squeeze by creation of new intertidal habitats, and the Severn Estuary Flood Risk Management Strategy and the Shoreline Management Plan policies will include plans for the planning and creation of replacement habitats. While management policies in relation to biodiversity will support the long-term maintenance of intertidal habitats, such actions will not be effective in addressing rising sea temperatures or ocean acidification and the effect that these may have on the distribution of marine species. In addition, inputs of nutrients, particularly nitrogen, to coastal waters have long been recognised as contributing to the risk of eutrophication effects. Under the WFD, a large number of coastal waters have been assessed as having 'moderate' status in respect of their nitrogen content.

3.3.5 Bird species whose populations have declined since the designation of the SPA and Ramsar site include European white-fronted goose, pochard, tufted duck, grey plover and dunlin. Some of these declines can be explained by birds "short-stopping" on their migration (they do not migrate as far as the UK because the winter temperatures at sites closer to their breeding grounds are warmer than in the past) or birds shifting from the west to the east because warmer winter temperatures mean that food-rich sites in the east are now more climatically suitable for winter species.

3.3.6 With regards to migratory and estuarine fish, shad and salmon are currently classified as having unfavourable conservation status in both the River Usk/Afon Wysg SAC and River Wye/Afon Gwy SACs. River lamprey has unfavourable conservation status in all sites except the River Usk while all sites but the River Wye has unfavourable conservation status for sea lamprey. A number of issues have been identified as contributing towards the unfavourable conservation status of the River Usk/Afon Wysg SAC and River Wye/Afon Gwy SAC and it is assumed that management actions will return these SACs to favourable conservation status in the future baseline. Eel recruitment has also declined since the 1970s, which is believed to be due to a loss of habitat. Catches of sea trout have declined since 2000, although this species only occurs in small numbers.

3.3.7 The EU Marine Strategy Framework Directive is due to be transposed into UK law by the end of 2010. Once enacted, the new powers will enable additional measures to be taken to protect marine habitats and species where required. The Marine and Coastal Access Act 2009 also provides for nationally important habitats and species to be protected through 'Marine Conservation Zones'. Implementation of the provisions of this Act provides an opportunity to afford additional protection to seabed features where necessary. The marine planning provisions of the Act will also provide a management framework of objectives and targets, including ecosystem-based objectives to address damaging activities where necessary.

3.3.8 Overall, the range of measures currently being implemented or which will be implemented in the future will lead to improvements in the biological quality of the marine environment. However, it is likely to continue to be difficult to tackle effects arising from temperature increases or ocean acidification.

3.3.9 With regards to terrestrial and freshwater ecology, the features supported within the baseline study areas are in varying levels of condition. These pose challenges for conservation agencies to meet targets set by Government to halt biodiversity decline. This is further compounded by the predicted influences of climate change. A number of strategic documents have been produced that set out the approaches to help combat climate influence, though they acknowledge that it is unlikely that it will be feasible to retain biodiversity features as we know them today.

3.3.10 Climate change effects are compounded by the influences of population growth and the built environment that increasing populations generate. Pressures for undeveloped land are likely to be greater than ever before and this poses a threat to those areas of non-designated land that fulfil so many valuable functions to ecosystems. Increasingly water resources will need to be safe-guarded and managed to maximum efficiency, and such measures are likely to offer potential benefits to freshwater ecology receptors.

Historic Environment and Landscape & Seascape

3.3.11 The heritage resource is inherently sensitive to change as it is a finite resource and once lost can not be reinstated or replaced. Whilst the estuary environment provides excellent conditions for preservation, it is also the source of a number of natural and anthropogenic factors contributing to the ongoing loss of the resource such as coastal erosion, strong tidal currents, marine aggregates extraction, managed coastal defence and retreat, and major industry and infrastructure which combine to threaten the survival of the heritage resource.

3.3.12 The landscape and seascape of the Severn Estuary, Bristol Channel and surrounds are also sensitive to natural and anthropogenic changes. Sea level rise is likely to alter the seascape character of the intertidal zones within the estuary. Sea level rise may lead to the construction of new hard, sea defences around the estuary which will also alter the seascape. Demand for onshore and offshore wind power development and development pressure within and around existing settlements for commercial and leisure projects will contribute to changes in the landscape and seascape. In addition, change in agricultural character around the estuary as a result in changing food demands or drive to plant woodlands will also contribute to changes in the landscape.

Air & Climatic Factors and Resources & Waste

3.3.13 With regards to waste, there is a shortage of waste sites, and developing new facilities can be a slow process. There are increasingly stringent waste management requirements, particularly to divert waste from landfill. In terms of resources, whilst aggregates are plentiful in the UK, there is an environmental cost associated with their extraction, and increased demand could lead to the development of new quarries or dredging areas. Government policy, which aims to reduce demand for virgin aggregates, is to encourage the production of secondary and recycled aggregates. Demand for water is expected to increase due to population growth, while at the same time there is the potential for a reduced supply or greater seasonal fluctuations due to climate change.

Society & Economy

3.3.14 The South West Regional Development Agency's (SWRDA) Regional Economic Strategy envisages continuing strong growth in the North East Triangle (the sub-region which broadly includes the North Somerset, Bristol, Sedgemoor and South Gloucestershire Local Development Authorities) suggesting that a continuing high level of population increase is provided for in current economic and spatial development plans.

3.3.15 Restoring the River Wye to its former status as a major salmon and salmon trout river over the period to 2017 is the aim of the Wye and Usk Foundation. Increased fish stocks will support an expanded tourism angling business and increase employment in this and related local activities.

3.3.16 Bristol Port accounts for the majority of port employment in the region. The port's attraction to users depends in part on vessel accessibility and tidal and other restrictions. Maintaining vessel accessibility, including accessibility for vessels that will use the consented Deep Sea Container Terminal in the future, is a key issue for Bristol Port and the employment generated. The ability to navigate safely to and from all commercial ports is significantly dependant on the environmental conditions experienced within the estuary.

3.3.17 Within the Severn Estuary and Bristol Channel, dredging for marine aggregates follows a common cycle which is controlled by tidal movements. Disruptions to this cycle (e.g. through inclement weather) are known to result in adverse economic effects to the industry.

The Severn Estuary is located at the border of South Wales and South West England. The Estuary's size and large tidal range mean it is important for the conservation of estuarine habitats, fish, birds and physical features. These are protected under international, European and national law; and are responding to changing climatic and physical conditions.

The tributaries of the Severn Estuary are important for water supply and also support recreational fisheries. A large number of properties are protected by flood defences around the estuary. These are also affected by sea level rise and climate change. The estuary supports important commercial activity, such as shipping, aggregate extraction and waste disposal; and diverse tourism and recreation.

The Severn Estuary supports important and varied landscapes, and contains diverse and protected archaeology that is finite. These will respond to changes in the climate.

Climate change and development pressures are seen as the main existing problems in the estuary and its hinterland. Some natural features of the estuary are not in good condition.

3.4 Assumptions, limitations and uncertainty

3.4.1 The assumptions, limitations and uncertainties associated with defining the baseline and future baseline environment that are common to all topics within the STP SEA are described here. Theme-specific assumptions, limitations and uncertainties are set out subsequently. These lead to uncertainties that cascade through the assessment, and would need to be considered further if an alternative option is taken forward.

3.4.2 In order to provide as representative a picture as possible of the future baseline environment, it was necessary to make assumptions regarding the effects of climate change. It was assumed that UKCP09 (UKCP09, 2009) central estimate projections for the medium emissions scenario applied for most topics (except for Flood Risk and Land Drainage, which used the Department for Environment, Food and Rural Affairs (Defra) 2006 Guidance for Sea Level Rise and storminess scenarios in order to be consistent with other flood risk management plans and strategies in the estuary.

3.4.3 In developing the future baseline projections, assumptions were made about environmental trends, and policy responses to these trends. It was therefore assumed that, in general, existing Government policies relating, for example, to climate change response and biodiversity, would continue to apply into the future.

3.4.4 A review was conducted of other projects in and around the Severn Estuary that may have an influence on the future baseline (STP, 2009b). Projects that were due to be implemented by 2014 were considered part of the future baseline environment.

Physicochemical

3.4.5 The models used in the physicochemical theme assessments are subject to varying degrees of uncertainty. There is high uncertainty about predictions of future morphology as the methods available can only account for some of the processes involved and will be influenced by future storm events. There are some data gaps and limitations which affect the reliability of predictions, though these are not considered critical for this strategic assessment.

3.4.6 Further, the majority of scientific measurements tend to have been focussed in the main body of the estuary, whereas above The Shoots and in tributary estuaries the amount of available data is markedly reduced. Uncertainties in understanding the baseline and future baseline of the hydraulics and geomorphology of the Severn Estuary and Bristol Channel inevitably affect the level of certainty in the data used for the other themes such as biodiversity and also for topics such as historic environment and navigation.

3.4.7 With regards to water quality, there are variations in the spatial coverage and the range of substances for which information is available. For example, limited information is available on contaminant distributions for the tributary estuaries.

3.4.8 In terms of flood risk and land drainage, there are some data gaps regarding the outfall locations, size and level. Some assumptions have been made, resulting in the absence of a completely reliable record. A simplified approach has been used to assess tide-locking issues for all outfalls using a digital elevation model.

3.4.9 With regards to freshwater environment and associated interfaces, in the absence of ground investigations it has not been possible to ascertain the exact number and details of properties with basements nor the extent and condition of important underground services, such as sewers and communication infrastructure.

Biodiversity

3.4.10 There is limited information on some species and habitats, particularly cuttlefish and the precise distribution of receptors such as *Sabellaria alveolata* reefs. There is also a lack of knowledge and understanding about the functional requirements and linkages for some receptors and how human pressures, such as from tidal power development, might affect them. Many studies that have been used to define the baseline and hence future predictions are site specific. Extrapolation of these data to other locations within the study area has therefore introduced a degree of uncertainty. Very few studies provide a synoptic view of the bio-physical relationships that occur within the Severn Estuary, but they do provide sufficient detail to develop a conceptual understanding of the system and the likely physical drivers that may affect change in ecology.

3.4.11 The data used to represent the baseline for the non-breeding numbers of the waterbirds using the Severn Estuary in this assessment incorporates counts from 2004/05 - 2008/09. As coverage in years prior to 2008/09 was less complete, the five-year mean peak values for some species may provide underestimates of the overall numbers using the estuary. It is also assumed that the WeBS (Wetland Bird Survey) Low Tide Counts are representative of the average distribution of waterbirds across the estuary and, notably, the numbers in the areas of the alternative options. Some species are difficult to detect during surveys, e.g. Bittern, Water Rail, Snipe, and thus counts of these species are always likely to be underestimates of the true population.

3.4.12 With regards migratory and estuarine fish, key assumptions, limitations and uncertainty in the development of baseline scenarios for migratory and estuarine fish include uncertainties surrounding the life history parameters for the models used to predict future baseline values for salmon, shad, lamprey and eel. It was considered that data was so scarce, and life histories so poorly understood, or that there were too many species within each of the ecological guilds, that modelling was not an appropriate or feasible approach for sea trout or marine and estuarine species. Limited understanding of climate change upon species populations prevents confidence in the assessment of long-term baseline scenarios. There is also a lack of knowledge of fish behaviour within the Severn Estuary.

3.4.13 With regards to terrestrial and freshwater ecology, the value of local sites and undesignated habitat features are acknowledged. However data for individual local sites has not been analysed in this strategic study.

Historic Environment and Landscape & Seascape

3.4.14 None of the data sources record all of the surviving elements of the historic environment resource but instead contain information about the known and recorded historic environment resource. The information from these sources is not complete and does not preclude the subsequent discovery of further elements of the historic environment that are, at present, unknown.

3.4.15 With regards to landscape and seascape, the issue of uncertainty relates to the future built development around the estuary and what resulting effects it has on the future landscape and seascape baseline.

Air & Climatic Factors and Resources & Waste

3.4.16 The air quality baseline was limited to the key pollutants associated with activities typical of a large scale construction project as well as those associated with power production. Emissions for air pollutants were derived from the National Atmospheric Emissions Inventory (NAEI) and estimates were restricted to either the emissions available within the inventory or available emissions factors. It has been assumed that improvements to air quality and emissions are made through existing and emerging legislation and policy and there is some uncertainty as to whether these targets can be met.

Society & Economy

3.4.17 Where possible, communities data was collected at local or sub-regional local level (known as Middle Layer Super Output Areas (MSOAs)), allowing an understanding of society and economy issues. However, due to the large scale of the study area, it was necessary also to collect data at wider level (Wales and South West England). With regards to other sea uses, some of the data available on recreational (tourist) usage of the study area is only applicable to the region as a whole and does not focus on the Severn Estuary and Bristol Channel coast. Quantitative data were not always readily available and the method of reporting data differs between Wales and England, making direct comparisons difficult. In addition, the dynamic nature of communities means that changes often occur rapidly, affecting the accuracy of any trend predictions made.

3.4.18 Due to the relatively remote location of the land surrounding the Severn Estuary, much of the area does not have any associated noise mapping. Where noise maps do exist, they offer predicted average noise levels. Future trends in noise levels are not expressly defined or documented; however, it is clear that environmental noise is on the increase.

3.4.19 With regards to navigation, only those commercial ports which are likely to be most affected by the alternative options (Bristol, Cardiff, Newport, Sharpness and Bridgwater) have been included within the assessment. The arrival draught has been considered and internal vessel movements within each of the ports have not been taken into consideration. It is assumed that current limitations to the maximum size of vessel which can navigate through The Shoots and enter the impounded docks of each port will remain unchanged.

3.5 SEA objectives

The Practical Guide states that *'whilst not specifically required by the Directive, SEA objectives are a recognised way of considering the environmental effects of a plan or programme and comparing the effects of alternatives'* (5.A.12).

3.5.1 SEA objectives are a recognised tool for comparing alternative options. This technique is proposed in The Practical Guide (ODPM *et al*., 2005). SEA objectives usually reflect the desired direction of change. It therefore follows that these objectives may not necessarily be met in full by a given alternative option, but the degree to which they do will provide a way of identifying preferences when comparing alternative options.

3.5.2 This approach requires judgments to be made on the performance of alternative options against each SEA objective. During the SEA scoping stage, 'assessment criteria' and 'indicators' were also developed to aid these judgements. The assessment criteria are a series of questions developed to guide the judgement of objective compliance. An indicator is measure of a variable over time, often used to measure achievement of objectives.

3.5.3 The SEA objectives, assessment criteria and indicators were drafted using the review of other environmental plans and programmes which identifies environmental protection objectives (Severn Tidal Power, 2010a) (see also Section 3.1), the baseline data collection and the identification of environmental issues. The SEA objectives were consulted upon as part of the SEA scoping stage. The Government response to the consultation confirmed the SEA objectives and in some cases made some minor modifications (DECC, 2009b).

3.5.4 Due to the way that the SEA objectives have been developed, the STP SEA objectives are generally consistent with the environmental protection objectives set out in other plans and programmes (Severn Tidal Power, 2010a). Using the STP SEA objectives as a tool for comparing the alternative options thus takes into account the environmental protection objectives identified in the review of other environmental plans and programmes (Severn Tidal Power, 2010a).

3.5.5 The SEA objectives focus on avoiding adverse effects on the environment. However, the environmental objectives of other plans and programmes make reference to environmental enhancement in addition to seeking to avoid adverse effects.

3.5.6 The review of other plans and programmes has also identified that the SEA objectives do not deal specifically with transport issues (Severn Tidal Power, 2010a). Network Rail and the Highways Agency have reported that the existing road and rail links across the Severn Estuary are sound and have the capacity to meet the forecast increase in demand over the next two decades. The Phase One (Scoping) consultation has not produced any evidence to invalidate these conclusions and so transport links remain outside the scope of the alternative options (DECC, 2009b). The SEA will consider the onshore infrastructure required to construct a STP alternative option and such transport issues are considered within other topics.

3.5.7 Appendix 5 presents the SEA objectives, as confirmed following the Government response to the consultation in addition to the corresponding assessment criteria and indicators for each objective.

Environmental objectives have been developed as a tool to test the tidal power alternative options. Indicating the desired direction of change, they reflect the environmental objectives of existing plans and programmes.

SECTION 4

PLAN ALTERNATIVE OPTIONS

4 PLAN ALTERNATIVE OPTIONS

4.1 Identifying the alternative options

The SEA Directive requires that the Environmental Report provides '*an outline of the reasons for selecting the alternatives dealt with…*' (Annex I(h)).

4.1.1 The plan objectives are to use the renewable tidal range resource of the Severn Estuary, and as such the identification of reasonable alternatives focused on proposals based in the study area.

4.1.2 The identification of potential alternative options was undertaken using:

- Call for Proposals, issued as part of the Call for Evidence issued on 12 May 2008.
- The options studied by the Sustainable Development Commission in 'Turning the Tide' (Sustainable Development Commission, 2007).
- Other strategic options which were not covered by proposals in the items listed above.

4.1.3 This led to a long-list of ten potential options being identified. These are set out in Table 4.1 below. An assessment was undertaken of each of the options to identify the proposals that have the technical capability to meet the quantitative elements of the plan objectives. This included a technical consideration of both quantitative (energy yield, carbon reduction, cost etc.) and qualitative factors (environmental effects etc.) along with sensitivity testing. This is reported within the Interim Options Analysis Report (Parsons Brinckerhoff, 2008) and summarised in Appendix 6.

Table 4.1 Long-listed options

Option Number	Option Name
B1	Outer Barrage from Minehead to Aberthaw (and R1 Tidal Reef)
B2	Middle Barrage from Hinkley to Lavernock Point
B3	Middle Barrage from Cardiff to Weston (commonly known as the Cardiff to Weston Barrage)
B4	Inner Barrage (Shoots Barrage)
B5	Beachley Barrage
F1	Tidal Fence Proposal
L2	Lagoon Enclosure on the Welsh Grounds (Fleming Lagoon)
L3	Tidal Lagoon Concept
R1	Tidal Reef
U1	Severn Lake Scheme

4.1.4 This information, alongside that gathered in other reports, helped the Government identify on a fair basis which of the long-listed options were not potentially feasible and eliminate them from further investigation – leaving a short-list of options to study in the STP SEA. This process used several short-listing criteria:

- technical risk (risk that the technology may not work as planned, confidence levels around costs and yields, likely operation dates and the risks/impact of sedimentation);

- construction cost and the cost of energy produced;

- how this cost compared to other ways of meeting our energy and climate change goals;

- affordability – i.e. the burden on taxpayers and energy consumers and the role that Government would have to play in delivering the project.

The following were used to judge whether more costly options presented benefits that justified further study:

- environmental effects – high-level view on options' environmental effects using predicted habitat loss as an indicator of severity and a high-level view on effects on ports, fishing and employment in the Severn Estuary area.

4.1.5 The process used to short-list the options, and the short-list, was consulted on at the same time as the scoping report (DECC 2009a). Following the review of responses to the public consultation, the Government confirmed that five alternative options would be studied further within the SEA (see Section 4.2 and Figure 4.1). In addition, as the principal question the Feasibility Study is addressing is whether the Government can support a tidal power project in the Severn Estuary; a 'do-nothing' alternative is provided by the SEA's future baseline.

4.1.6 The short-listed options were defined sufficiently to permit their selection during Phase One (Scoping) but were not necessarily in the most favourable form having regard to energy and economic issues, and their environmental effects. In order to define the alternative options, the initial configuration of each short-listed option was tested to determine whether it represented the optimal or whether it required modification to achieve optimal (Parsons Brinckerhoff, 2010). The process was described as 'optimisation'.

4.1.7 This optimisation process tested the original options and several variants of these in order to evaluate their environmental effects, scheme costs, energy output and energy cost. With regards to the environmental effects, the optimisation process was linked to the SEA objectives and a high-level assessment was undertaken using a selection of the SEA objectives assessment criteria.

4.1.8 The modifications included, where appropriate, changes in operating mode (ebb-only generation compared with ebb-flood generation), changes in turbine numbers and sizes, changes in sluice capacity, and changes in alignment. The output from this optimisation process was not intended to provide a final definition of the options. Instead, it provided a preliminary definition of each option which was considered to be potentially preferable having regard to energy, cost, economic and environmental effects. This is reported within the Options Definition Report (Parsons Brinckerhoff, 2010).

4.1.9 During the environmental assessment of the options, the options' definitions were further refined and measures to prevent or reduce anticipated significant adverse effects on the environment (see Section 5.4) were incorporated where appropriate. The resultant options have been developed to represent the forms which are potentially preferable taking account of the additional evidence obtained during the assessment (Parsons Brinckerhoff 2010).

4.1.10 Optimisation initially focussed only on individual options. However, variants of the alternative options have also been considered in the SEA at a high level, but they are not confirmed as 'alternative options'. These variants have therefore not been subject to modelling or detailed assessment at this stage and were therefore not considered to the same level of detail as the alternative options. If selected to form part of a preferred approach, these would need to be considered within an updated SEA. The variants include a multiple basin alternative which comprises two basins within a lagoon alternative option. These basins are configured to provide a more flexible energy yield profile. Variants also include alternatives which are a combination of some of the five alternative options.

4.2 Alternative options

4.2.1 The five alternative options comprise three tidal barrages and two tidal lagoons. Each of these would be operational for a period of at least 120 years. The details of the variants developed for assessment through optimisation are described below. Further information on each alternative option can be found in the Option Definition Report (Parsons Brinckerhoff, 2010). Figure 4.1 shows the locations of the alternative options and Figures 4.2 – 4.6 show the outline design for each alternative option.

Alternative Option B3: Cardiff to Weston Barrage

4.2.2 B3 'Cardiff to Weston' Barrage (also known as the *Brean Down to Lavernock Point Barrage*) is the largest of the barrages short-listed, being an approximately 16km long structure impounding the Severn Estuary between Lavernock Point, near Cardiff, and Brean Down, adjacent to Weston-super-Mare. The deepest point of this barrage location is at its centre, reaching between 30 to 40m deep. The chosen variant (original) functions in ebb only mode. In total there are 216 Bulb-Kapeller type turbines with a rated output of 40 megawatts (MW). The estimated annual energy output for the variant (including 5% outages) is 15.1 to 17.0 terrawatt hours per year (TWh/year).

4.2.3 Key features include a total of 129 caissons of which 29 are plain caissons, 46 are sluice caissons and 54 are turbine caissons, spread across the length of the barrage. The central point includes a 778m long embankment flanked by two sets of the turbine caissons. The barrage also includes two shipping locks and two small craft locks. The option definition also includes onshore infrastructure such as access roads.

Alternative Option B4: Shoots Barrage

4.2.4 The B4 Shoots Barrage is an approximately 7km long structure impounding the Severn Estuary between land adjacent to West Pill on the Welsh side and Severn Beach on the English side. The structure comprises a combination of embankments within the shallow water and caissons within the deeper channel. Variant 3 was chosen as the alternative option. It operates in ebb only mode with 30 Bulb-Kaplan type turbines, with a rated output of 35MW. The estimated annual energy output for the variant (including 5% outages) is 2.7 to 2.9 TWh/year.

4.2.5 The barrage consists of a total of 46 caissons (6 plain, 25 sluice and 15 turbine/sluice caissons), enclosed on both sides by 2 embankments totalling approximately 5km

(3km approximate length of embankment to the Welsh Side and 2.2km approximate length to the English side). A 40m wide shipping lock has been placed at the deepest section of the channel. The option definition also includes onshore infrastructure such as access roads.

Alternative Option B5: Beachley Barrage

4.2.6 The B5 Beachley Barrage is the smallest of the barrages short-listed. It is a 2km long structure running from Beachley on the Welsh side of the River Severn to land directly to the east on the English side. The original variant was chosen as the alternative option, operating in ebb only mode with 50 Straflo type turbines with a rated output of 12.5 MW. The estimated annual energy output for the variant (including 5% outages) is 1.4 to 1.6 TWh/year.

4.2.7 Its key features include a total of 31 caissons (9 plain, 9 sluice and 13 turbine/sluice) spread across approximately 1.5km of the length of the barrage and flanked by two embankments. A 40m wide shipping lock is located on the English side of the barrage. The option definition also includes onshore infrastructure such as access roads.

Alternative Option L2: Welsh Grounds Lagoon

4.2.8 L2 Welsh Grounds Lagoon is the largest of the lagoon alternative options with an approximate length of 28km starting from land adjacent to the mouth of the River Usk, running in a general easterly direction across an area referred to as Welsh Grounds, continuing to the south of Denny Island and reaching land fall adjacent to the Second Severn Crossing. L2 Welsh Grounds Lagoon variant 8 was based on a turbine selection proposed by the Fleming group. It was unique in this respect compared to other variants whose turbine selections have all been made by Parsons Brinkerhoff. Variant 8 operates in ebb only mode with 40 Bulb Turbines with a rated output of 25MW. The estimated annual energy output for the variant (including 5% outages) is 2.6 to 2.8TWh/year.

4.2.9 Key features include a total of 32 caissons (8 plain, 14 sluice & 10 turbine caissons), and one shipping lock. The option definition also includes onshore infrastructure such as access roads.

Alternative Option L3d: Bridgwater Bay Lagoon

4.2.10 L3d Bridgwater Bay Lagoon is a land connected tidal lagoon comprising approximately 16km long embankment, proposed to run from land falls at Brean Down in the north to just east of Hinkley Point in the south. The short-listed Variant 9 is the only scheme to operate in ebb-flood mode, with a total of 144 Bulb-Kaplan turbines with a rated output of 25MW. The estimated annual energy output for this variant (including 5% outages) is 5.6 to 6.6 TWh/year.

4.2.11 Key features include a total of 42 caissons (6 plain and 36 turbine caissons), a 40m wide shipping lock and approximately 12km of embankment. The option definition also includes onshore infrastructure such as access roads.

Plate 4.1 La Rance Tidal Power Barrage (750m long with 24 bulb turbines)

Plate 4.2 Small craft lock at La Rance Tidal Power Barrage

Plate 4.3 Bulb turbine at La Rance Tidal Power Barrage (10MW with 5.7m diameter)

Multiple basins

4.2.12 The multiple basin option shortlisted for further high-level consideration of environmental effects is a double basin version of the L3d Bridgwater Bay Lagoon (with pumping). The double basin concept splits the L3d Bridgwater Bay Lagoon into a high basin and a low basin using a rockfill dividing wall with its landfall at Berrow. The scheme is then configured to provide a continuous cycle of water from the sea to the high basin, from the high basin to the low basin and then from the low basin to the sea.

4.2.13 The detail currently available only permits a high-level qualitative assessment to identify key issues and no modelling was undertaken. These variants were therefore not considered to the same level of detail as the alternative options. If selected to form part of a preferred approach, these would need to be considered within an updated SEA.

4.2.14 In a double basin L3d Bridgwater Bay Lagoon scheme, the available head and flows for generation would be expected to be lower than for a single basin L3d Bridgwater Bay Lagoon and, therefore, the installed capacity would also be lower. Although it has not been modelled, each basin would experience a tidal range, but that the high basin water levels would always be kept above the low basin. Pumping is used to raise water levels in the high basin and lower them in the low basin to increase power output. The scheme would utilise single direction turbines (in contrast to the ebb-flood generation of the standard L3d Bridgwater Bay Lagoon alternative option).

Combinations

4.2.15 Both of the shortlisted combinations of options include the standard single basin L3d Bridgwater Bay Lagoon option, with the assumption that it would be generating with an ebb-flood configuration. The combinations of options have not been subject to modelling at this stage, however, following an evaluation process (considering energy yield, costs, programme and opportunities for optimisation) a combination of L3d Bridgwater Bay Lagoon (ebb-flood) with B3 Cardiff to Weston Barrage (ebb only) has been shown to be worthy of further consideration; as has a combination of L3d Bridgwater Bay Lagoon (ebb-flood) with B4 Shoots Barrage (ebb only).

4.2.16 The detail currently available only permits a high-level qualitative assessment to identify key issues and no modelling was undertaken. These variants were therefore not considered to the same level of detail as the alternative options. If selected to form part of a preferred approach, these would need to be considered within an updated SEA.

4.2.17 L3d Bridgwater Bay Lagoon and B3 Cardiff to Weston Barrage would be constructed sequentially due to the large amount of resources required to build either of these alternative options. Either alternative option could be constructed first. L3d Bridgwater Bay Lagoon and B4 Shoots Barrage could be constructed either sequentially or concurrently. The operating rules and forms of construction for the combined options are assumed at this stage of study' to be the same as those for the individual schemes.

Ancillary works

4.2.18 All alternative options require ancillary works which are works that are necessary as a consequence of the construction of a tidal power facility to prevent or reduce the effect on day to day operation of existing assets (Parsons Brinckerhoff, 2010). Ancillary works are included in the assessment of significant effects. Such works include:

- Modification of port facilities as a consequence of reduced high water levels and changes in vessel buoyancy;
- Navigational aid requirements;
- Pumping systems at tidal outfalls to allow land drainage discharges that would otherwise have been prevented from the reduced tidal range;
- Permanent works for dredging and sedimentation management;
- Additional flood defence protection from increased erosion due to changed water levels.

Grid connection works

4.2.19 Potential grid connection works comprise the transmission infrastructure from generator terminals to National Grid sub-stations, the construction of new or modified sub-stations, and the wider reinforcement of the National Grid (Parsons Brinckerhoff, 2010). Where new or reinforced lines are required as a consequence of a scheme either to connect to the grid or to deal with wider reinforcement requirements, the SEA has examined the effects at a strategic level taking into account the degree of precision available in the definition of the works. Grid connection works are included in the assessment of significant effects.

Five tidal power alternative options are considered within the SEA. These were the product of an initial assessment of a wider range of options and variants, including different modes of operation. Combinations of these, and the inclusion of multiple basin variants, have also been considered but outside the SEA.

Insert Figure 4.1

Insert Figure 4.2 – B3 from ODR

Insert Figure 4.3 – B4 from ODR

Insert Figure 4.4 – B5 from ODR

Insert Figure 4.5 – L2 from ODR

Insert Figure 4.6 – L3d from ODR

SECTION 5

LIKELY SIGNIFICANT EFFECTS ON THE ENVIRONMENT AND MEASURES TO PREVENT, REDUCE AND AS FULLY AS POSSIBLE OFFSET ANY SIGNIFICANT ADVERSE EFFECTS

5 LIKELY SIGNIFICANT EFFECTS ON THE ENVIRONMENT AND MEASURES TO PREVENT, REDUCE AND AS FULLY AS POSSIBLE OFFSET ANY SIGNIFICANT ADVERSE EFFECTS

5.1 How the assessment was undertaken

The SEA Directive requires that the Environmental Report provides '*…a description of how the assessment was undertaken…*' (Annex I(h)).

5.1.1 The purpose of the Environmental Report is to describe the likely significant effects on the environment. In doing so, methods have been applied to:

- Develop an understanding, through the STP SEA themes described in Section 2.1, of the effects on the environment; and
- Then define the basis upon which of these effects can be described as 'significant'. This *does not* include measures to prevent or reduce significant effects except those already included in the definition of alternative options. In section 6, the SEA objectives are used to compare the effects of alternative options by examining how each alternative option performs in relation to them. This comparison *does* take into consideration the above measures to prevent or reduce significant effects.

Defining significant effects

5.1.2 The SEA Directive specifies in Annex II the criteria that should be taken into account when determining the likely significant effects of the plan. The criteria for identifying these significant effects are defined in the SEA Directive in relation to determining whether an SEA is needed. The Practical Guide (ODPM *et al.,* 2005) advises the use of these criteria for assessing significant environmental effects; and thus these criteria were adopted for this assessment.

The SEA Directive sets out the criteria for determining the likely significance of effects.

Annex II requires that the environmental assessment considers the characteristics of the effects and of the area likely to be affected, having regard, in particular, to:

- **a) the probability, duration, frequency and reversibility of the effects;**
- **b) the cumulative nature of the effects;**
- **c) the transboundary nature of the effects;**
- **d) the risks to human health or the environment (for example, due to accidents);**
- **e) the magnitude and spatial extent of the effects (geographical area and size of the population likely to be affected);**
- **f) the value and vulnerability of the area likely to be affected due to;**
  - **i. special natural characteristics or cultural heritage;**
  - **ii. exceeded environmental quality standards or limit values; or**
  - **iii. intensive land-use; and**
- **g) the effects on areas or landscapes which have a recognised national, Community or international protection status.**

5.1.3 Assessment of likely significant effects on the environment has been described in terms of a range of 'receptors'. A receptor is an entity that may be affected by direct or indirect changes to an environmental variable. Relevant receptors were identified and consulted upon during the SEA scoping stage (DECC, 2009a). These receptors were refined during Phase Two (SEA) and a full list is set out in Appendix 7.

5.1.4 In forming a judgement on effect significance, each receptor was assigned a value and vulnerability (see also Appendix 8). For the purposes of this STP SEA, the following definitions were used:

- Value: the value of a receptor is based on the scale of geographic reference, rarity, importance for biodiversity, social or economic reasons, and level of legal protection;

- Vulnerability: the potential for a pathway for exposure of a receptor to a given environmental effect, brought about by a Severn Tidal Power alternative option, together with the sensitivity of the receptor to that effect (the sensitivity is the tolerance of a receptor to a given environmental effect and its ability to recover from that effect).

5.1.5 Framework guidelines and judgements on receptor value and vulnerability were developed into bespoke criteria for each topic assessment. These criteria were discussed during Phase Two (SEA) Technical Workshops for each topic and subsequently agreed. Topic-specific definitions for value and vulnerability are provided in the topic papers (Appendix 1).

5.1.6 Classification thresholds for the magnitude of an effect (high, medium, low, very low or no change) were developed for each topic receptor and refined through discussions held at the technical workshops and subsequent correspondence. Thresholds were defined by each topic and were both qualitative and quantitative, as appropriate (see also Appendix 8). The topic-specific definitions for thresholds of magnitude of effect are provided in the topic papers (Appendix 1).

5.1.7 As such, significant effects may, for example, include the negative effect of the permanent loss of a migratory fish species from the Severn Estuary, and / or the positive effect of the temporary creation of construction related jobs. Non-significant effects may, for example, include the negative effect of a temporary increase in construction noise and / or the permanent positive effect of the reduction in turbidity and current velocity providing more favourable conditions for scuba diving. See section 5.2 for a description of the significant effects and Appendix 9 for a summary of all the identified likely significant effects of the alternative options.

5.1.8 The SEA Directive (Annex I) also states that these significant effects should include secondary, cumulative, synergistic, short, medium and long-term permanent and temporary, positive and negative effects. The Practical Guide recognises that some of these terms are not always mutually exclusive and for the avoidance of doubt, within this SEA the following assessment approaches were undertaken (see also Appendix 8).

- Direct effects are those which are a direct result of a Severn Tidal Power alternative option.

- Indirect effects are those which are not a direct result of a Severn Tidal Power alternative option, but occur away from the original effect or as a result of a complex pathway. There are many such interactions within estuarine systems that are taken into account in this assessment and these were considered within each topic and theme. The SEA does not use the term 'secondary effects' as this is covered by indirect effects.

- There is the potential for effects to extend large distances from the Severn Estuary. The assessments of these 'far-field' effects generally have greater uncertainty attached.

- Cumulative effects arise, for instance, where several developments each have insignificant effects but together have a significant effect. The plans and projects taken into account in the cumulative effects assessment were identified and agreed (STP, 2009b). These were discrete projects or programmes which were expected to be implemented during the planned Severn Tidal Power project construction period (2014-2020) or during the operation period (2020-2140). The time-scales considered are those that are appropriate should the Government conclude to support a tidal power project in the Severn Estuary and the project consequently moves directly into the delivery phase. The plans and projects taken into account in the assessment of cumulative effects are shown on Figure 5.1[9].

- This SEA has not used the term 'combined' effects, as these are considered to be included within cumulative effects, nor has it used the term 'synergistic' effects, as these are contained within direct, indirect and cumulative effects.

- A major tidal power scheme may facilitate or attract other developments, which may themselves pose significant environmental effects. These developments are described in this SEA as 'consequential developments'. The types of

[9] On March 25 2010, the Department for Transport granted the Harbour Revision Order submitted by the Bristol Port Company to allow construction of a new Deep Sea Container Terminal (DSCT) near Avonmouth. At the time of writing the SEA Topic and Theme Papers, the DSCT was identified, with other schemes, as a known project that had not yet been consented and the effects in relation to the DSCT are therefore considered in the consideration of 'cumulative effects'. The timescale for the implementation of the DSCT is uncertain. This was the assumption at the time of the consideration of cumulative effects, and the assessment findings are therefore unaffected. If an STP alternative option is developed further, the status of the DSCT will need to be reviewed.

consequential development considered throughout the assessment were identified (STP, 2009b). It is not appropriate at this stage of environmental assessment to define these consequential developments in detail, however, a high-level qualitative assessment of the likely effects has been undertaken.

5.1.9 The assessment of likely significant effects does not include measures to prevent or reduce significant effects, except those already included in the definition of alternative options (i.e. the ancillary works which are works that are necessary as a consequence of the construction of a tidal power facility to prevent or reduce the effect on day to day operation of existing assets (see Section 4.2)).

5.1.10 For a full explanation of the methodology that was used to identify and assess significance of effects, see Appendix 8.

Insert Figure 5.1

Methods used to assess environmental effects

5.1.11 This Environmental Report describes the significant environmental effects of the alternative options. The options have associated aspects that are also considered to the extent possible on the available information (Parsons Brinckerhoff, 2010). Table 5.1 describes the treatment of each aspect in the SEA.

Table 5.1 Treatment in assessment

Aspect of SEA	Treatment in assessment
Alternative Options	**Strategic environmental assessment in line with SEA Directive requirements**
Grid connections (part of the definition of each alternative option)	The detail currently available only permits a high-level assessment to identify key issues. If selected to form part of a preferred approach, these would need to be considered further,
Ancillary Development (part of the definition of each alternative option) and Cumulative effects	Considered within the SEA on the basis of generic information. If an alternative option were proposed then during the project–level Environmental Impact Assessment (EIA) of that alternative option, a more detailed assessment of the effects of ancillary development and cumulative effects will be required.
Consequential development	High-level assessment of effects undertaken on generic types of development. If an alternative option were proposed then during the project–level EIA of that alternative option, the effects of some forms of consequential development may be required.
Far-field effects	The detail currently available only permits a high-level assessment to identify key issues. Issues will need to be revisited in more detail if a preferred option is to be developed, as part of project-level EIA.
Combination Options and Multiple Basin Options	The detail currently available only permits a high-level qualitative assessment to identify key issues and no modelling has been undertaken (see also Section 4)

5.1.12 Topic-based studies have been undertaken to inform the assessment of the effects upon each receptor. These studies are described below (Table 5.2) with further information provided in the Topic Papers listed in Appendix 1.

Table 5.2 Topic based studies undertaken for assessment of effects

SEA Topic	Topic Based Studies for Assessment of Effects
Hydraulics & Geomorphology	• Desk based literature review of an extensive private archive of information held by Dr Robert Kirby which includes data originally obtained by IOS (Institute of Oceanographic Sciences). • Desk based review of the extensive surveys commissioned during the earlier studies for generation of tidal energy from the Severn Estuary.

SEA Topic	Topic Based Studies for Assessment of Effects
	• Development of numerical models to represent baseline conditions and then the application of these models to each of the alternative options. The key models employed represented: o Tidal water levels and water flow o Waves in the estuary o Suspended sediments and short term deposition of mud o Sand transport o Intertidal profile evolution o Long term geomorphological evolution of the estuary • Consideration of analogous sites (both international and in the Severn Estuary)
Marine Water Quality	• Numerical modelling of salinity, flushing, pathogens, thermal plumes and stratification/mixing. • Qualitative desk based assessment using expert judgement of temperature, dissolved oxygen, contaminants and nutrient loadings. • Outputs from other topics: Hydraulics and Geomorphology.
Flood Risk & Land Drainage	• Simplified 1D models - Modelling of increased flood risks due to restriction of land drainage • Expert assessment of erosion risk and analysis of changes in standard of flood protection. • Outputs from other topics: Hydraulics and Geomorphology
Freshwater Environment & Associated Interfaces	• Interpretation of output of predictive modelling: o Hydrodynamics (geological Sites of Nature Conservation Interest (SSSIs), water resources, assets) o Water quality (water resources) o Groundwater levels (soils and assets) • Semi-quantitative assessment • Outputs from other topics: Hydraulics and Geomorphology, Flood Risk & Land Drainage and Marine Water Quality.
Marine Ecology	• Intertidal and subtidal habitat modelling predictions (Coastal Habitat Management Plan (CHaMP) style model) • Subtidal biotope modelling (HABMAP type model) • Regression-based modelling (*Zostera* and subtidal *Sabellaria alveolata* reefs) • Long-term saltmarsh modelling – Intertidal profiles, ASMITA • Outputs from other topics: Hydraulics and Geomorphology, Marine Water Quality, Waterbirds and Migratory & Estuarine Fish
Migratory & Estuarine Fish	• Desk-based research/literature review. • Numerical models to determine potential direct effects arising from turbine passage. • HR Wallingford (HRW) fish movement model (salmon adults & smolts) and extrapolation to provide an indication of potential for multiple passes through turbine of all fish species or groupings. • Qualitative assessment of effects of changes to habitat and water quality. • Economic Valuation of potential effects to fisheries. • Outputs from other topics: Hydraulics and Geomorphology and Marine Water Quality.

SEA Topic	Topic Based Studies for Assessment of Effects
Waterbirds	• Habitat association models (HA models) and individual-based models (IBMs) to assess effects on numbers of waterbirds • IBMs were also used to evaluate the effects of further long-term changes predicted in the extent of intertidal habitats. • The principal effect for waterbird receptors was modelled numerically using these two complementary modelling approaches to provide a better understanding of the range of uncertainty in model predictions. • A qualitative approach was used in the assessment of the potential significance of other effects on waterbirds. • Outputs from other topics: Hydraulics and Geomorphology, Marine Water Quality and Marine Ecology
Terrestrial & Freshwater Ecology	• Geographical Information System (GIS) based interrogation and analysis of data. • Outputs from other topics: Hydraulics and Geomorphology, Marine Ecology, Flood Risk & Land Drainage and Waterbirds.
Historic Environment	• Qualitative assessment informed by expert judgement. • Outputs from other topics: Hydraulics and Geomorphology, Landscape & Seascape, Resources & Waste, Flood Risk & Land Drainage, Navigation and Communities.
Landscape & Seascape	• Estimation of Zone of Theoretical Visibility (ZTV) • Qualitative assessment • Outputs from other topics: Hydraulics and Geomorphology, Flood Risk & Land Drainage, Historic Environment, Communities, Marine Ecology, Freshwater Environment & Associated Interfaces, Resources & Waste, Navigation and Other Sea Uses.
Air & Climatic Factors	• Tailored emissions modelling for atmospheric pollutants (using existing data). • Tailored modelling of other transportation methods using assumed journey lengths and relevant National Atmospheric Emissions Inventory (NAEI) emissions factors • Numerical projections for each alternative option (using assumptions from Hydraulics & Geomorphology, engineering team & supply chain study where available) • Outputs from other topics: Communities, Navigation, Resources & Waste and Marine Ecology.
Resources & Waste	• Desk based research • DECC Supply Chain study and Options Definition Report • Qualitative assessment • Outputs from other topics: Hydraulics & Geomorphology, Other Sea Uses, Communities, Marine Water Quality, Navigation, Flood Risk & Land Drainage, Marine Ecology and Historic Environment.
Communities	• Informal discussions with key stakeholders • Desk based investigations • Review of construction project case studies to provide evidence based assumptions • Qualitative assessment using expert judgement • Outputs from other topics: Other Sea Uses, Communities,

SEA Topic	Topic Based Studies for Assessment of Effects
	Marine Water Quality, Navigation, Flood Risk & Land Drainage, Marine Ecology, Noise & Vibration, Resources & Waste, Migratory & Estuarine Fish, Waterbirds and Landscape & Seascape.
Noise & Vibration	• Desk based research & literature review • Qualitative assessment • Outputs from other topics: Communities, Marine Ecology, Resources & Waste, Migratory & Estuarine Fish and Waterbirds.
Navigation	• Modelling results from Hydraulics & Geomorphology topic, engineering team and economics information from DTZ • Informal discussions with key stakeholders • Outputs from other topics: Communities, Other Sea Uses and Resources & Waste.
Other Sea Uses	• Modelling results from Hydraulics & Geomorphology and Marine Water Quality topics • Informal discussions with key stakeholders • Desk based review • Outputs from other topics: Communities, Resources & Waste, Navigation and Noise & Vibration.

The SEA considers potential effects using desk-based studies, supplemented in some cases by modelling and other more sophisticated analysis. Significant effects are identified, prior to the application of measures that have been identified to prevent and reduce effects.

5.2 Likely significant effects on the environment

The SEA Directive requires that the Environmental Report describes *'the likely significant effects on the environment, including on issues such as biodiversity, population, human health, fauna, flora, soil, water, air, climatic factors, material assets, cultural heritage including architectural heritage, landscape and the interrelationship between the above factors'* (Annex I(f)).

5.2.1 This section describes the likely significant effects[10] on the environment resulting from each alternative option (including ancillary works). This assessment *does not* include measures to prevent or reduce significant effects except those already included in the definition of alternative options. (In section 6, the SEA objectives are used to compare the effects of alternative options by examining how each alternative option performs in relation to them. This comparison *does* take into consideration the above measures to prevent or reduce significant effects).

5.2.2 Significant effects may arise from direct, indirect, far-field, cumulative and consequential development effects during construction, operation and decommissioning phases. The significant effects only are presented in this section and are summarised in Appendix 9. In some instances, including the assessment of cumulative and consequential development effects, the effects identified are not significant and thus they are not described below. Supporting information on the significant effects for each topic can be found within the SEA Topic Papers (Appendix 1).

5.2.3 Each alternative option alters the tidal prism – the difference between the mean high-water volume and the mean low-water volume - of at least part of the Severn Estuary. This, together with the physical presence and operation of a barrage or a lagoon; has the potential to cause an array of effects. These are a consequence of the diverse and complex interrelationships that exist between the natural and human environment in estuarine systems.

5.2.4 Figure 5.2 below illustrates the potential pathways and interrelationships that may lead to an STP alternative option having environmental effects. It is neither appropriate nor possible to capture all possible interrelationships and feedbacks within a strategic-scale study. Nonetheless it can be seen from this figure the many potential pathways that have been identified as potentially leading to a significant effect.

[10] The SEA Directive states that these effects should include secondary, cumulative, synergistic, short, medium and long-term permanent and temporary, positive and negative effects (Annex 1).

Key:

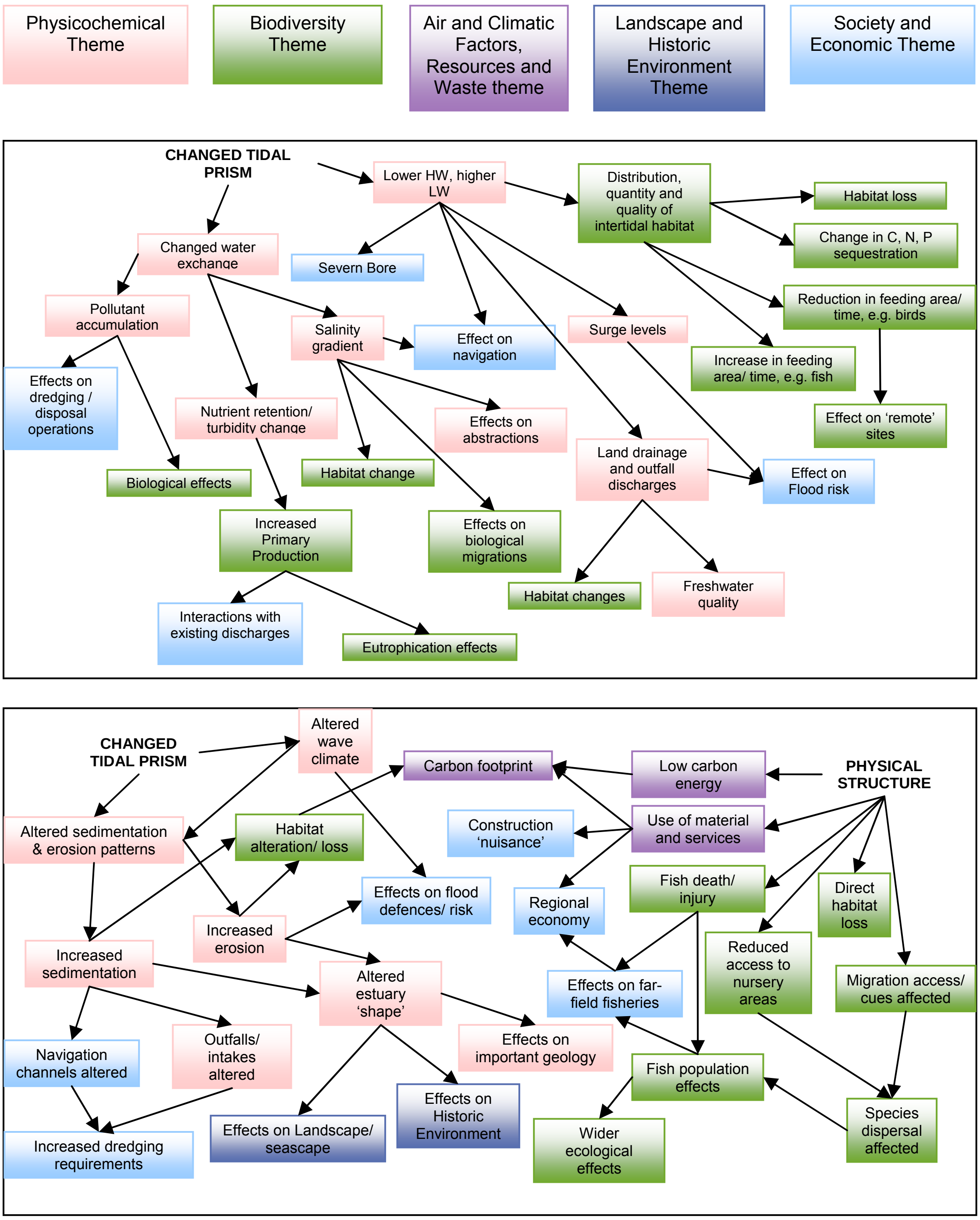

Figure 5.2 Potential pathways and interrelationships of environmental effects

5.2.5 The significant effects for each theme are described below. This does not include measures to prevent or reduce significant effects except those already included in the definition of alternative options. For each theme the generic effects are explained and then more detailed information is provided on an option by option basis.

Physicochemical effects

5.2.6 The significant effects described below have been informed by the following Topic Papers and their annexes; Hydraulics and Geomorphology, Marine Water Quality, Flood Risk & Land Drainage and Freshwater Environment & Associated Interfaces as well as the Physicochemical Theme Paper (see Appendix 1). See Appendix 9 for a summary of all the identified likely significant effects of the alternative options.

5.2.7 All the alternative options are shown to reduce the mean spring tidal range within the impounded part of the Severn Estuary (Figure 5.3a and b). Under an ebb-only mode of operation (B3 Cardiff to Weston Barrage, B4 Shoots Barrage, B5 Beachley Barrage and L2 Welsh Grounds Lagoon), high water levels are held behind the structure to create a sufficient difference in water level to permit energy generation on the ebb tide. This creates a high water stand and extended ebb period, which distorts the tidal regime within the impounded area (Figure 5.4). Under an ebb-flood mode of operation (L3d Bridgwater Bay Lagoon), a sustained duration of high and low water and distorted tidal regime is predicted within the impounded area. The lowest low water levels in the tidal basins for ebb-only generating schemes are associated with neap tides. The highest low water levels are associated with the largest spring tides. In the flood-ebb generating lagoon of L3d Bridgwater Bay Lagoon, the tides more closely resemble baseline tides, with the lowest low water levels associated with the largest spring tide.

5.2.8 Figure 5.3a shows the longitudinal profiles for water level changes compared with the baseline and Figure 5.3b shows predicted changes to spring tide levels within the semi-impounded tidal basins (for one tide). Figure 5.4 shows the time series water levels within the basins (for an entire spring neap tidal cycle) compared with the baseline.

5.2.9 All alternative options would result in a decrease in the spring tidal prism (the difference between the mean high water volume and the mean low water volume of an estuary) and all alternative options would modify flow speeds. For the ebb-generating alternative options, peak flow speeds are predicted to reduce within the impounded area and downstream and flow speeds within the vicinity of the turbines and sluices are predicted to increase. For the ebb-flood generating lagoon of L3d Bridgwater Bay Lagoon, peak flow speeds within much of the lagoon and immediately outside are predicted to increase.

5.2.10 All alternative options would also modify the existing wave climate. Figure 5.5 shows the modelled predicted changes to the mean high water springs wave heights with south-westerly winds.

5.2.11 A qualifying interest feature of the European Marine Site (Severn Estuary/Môr Hafren SAC, SPA and Ramsar site) is 'Estuaries'. The feature defines this as the 'characteristic physical form and flow, estuarine habitat communities and species assemblages'.[11] Thus any change to characteristic form and flow of the Severn Estuary as described above would result in a significant negative effect to the designated site.

[11] Criterion 1: Qualifies due to immense tidal range (second-largest in world), this affects both the physical environment and biological communities. Criterion 2b: Qualifies due to its unusual estuarine communities, reduced species diversity and high productivity. The high tidal range leads to strong tidal streams and high turbidity, producing communities characteristic of the extreme physical conditions of liquid mud and tide swept sand and rock. Criterion 3: Qualifies due to its unusual estuarine communities, reduced diversity and high productivity.

5.2.12 Changes to peak tide and wave action would also influence the level of flood risk (Table 5.3). There would be lengths of flood defence that benefit from lower water levels, and the need to intervene to raise flood defences in response to sea level rise consequently deferred. Table 5.3 shows the length of flood defence that would 'benefit' from lower water levels. The number of years by which the need to intervene to raise flood defences is deferred is also shown. Further information is provided in the Flood Risk & Land Drainage Topic Paper (see Appendix 1).

Table 5.3 Flood risk benefits of each alternative option

Alternative Option	Length of defence 'benefiting' from reduced water levels (km)	Number of years by which investment is deferred (years)
B3: Cardiff to Weston Barrage: Inside impoundment Outside impoundment to Hinkley Point - Cardiff Bristol Channel beyond Hinkley Point - Cardiff	 203 (90) 38 (10) 29	 75 to 105 55 to 75 Up to 40
B4: Shoots Barrage	0	N/A
B5: Beachley Barrage	0	N/A
L2: Welsh Grounds Lagoon	0	N/A
L3d: Bridgwater Bay Lagoon: Inside impoundment Outside impoundment to Hinkley Point - Cardiff Bristol Channel beyond Hinkley point - Cardiff	 36 (9) 96 (78) <1	 95 to 120 Up to 40 Up to 35
Note Figures in brackets exclude lengths which have a draft policy for managed realignment within 100 years No benefit claimed where reduction in level is less than 0.2m Excludes benefits to Bristol on River Avon.		

Source: Flood Risk & Land Drainage Topic Paper

5.2.13 There would also be lengths of flood defence outside the impoundments that would experience higher water levels than previously; and would need to be raised as a result. Furthermore, long-term geomorphological responses have the potential to cause erosion of the upper intertidal zone, threatening the integrity of tidal defences. Flood risk would also be adversely affected by restrictions to the normal operation of drains and outfalls, owing to the changed tidal regime (tide-locking). Figure 5.6 shows the predicted negative effect on land drainage performance (ranging from negligible to significant) following the implementation of an alternative option.

5.2.14 As a method of quantifying the flood risk, Table 5.4 shows the requirements for measures to prevent or reduce significant effects on flood risk and land drainage as a result of implementing each alternative option. The total length of flood defences and erosion protection required as a result of raised water levels increased erosion is shown along with the timeframe of intervention. Where pumping of outfalls is required as a result of tide locking, the area drained is shown along with the timeframe of intervention. Further information is provided in the Flood Risk & Land Drainage Topic Paper (see Appendix 1).

Table 5.4 Requirements for measures to prevent or reduce significant effects on flood risk and land drainage

Alternative Option	Flood defences to be improved		Erosion protection to be provided		Pumping of outfalls to be undertaken	
	Total length (km)	Time frame of intervention	Total length (km)	Time frame of intervention	Area drained (ha)	Time frame of intervention
B3: Cardiff to Weston Barrage	44-87 far-field	Construction phase	134 ±50%	Year 5-50 repeated every 50 years	372	Construction phase
B4: Shoots Barrage	45 inner estuary 17 outer estuary	Construction phase	32 ±50% 41 ±50%	Year 5-20 repeated every 50 years Year 75-100	97	Construction phase
B5: Beachley Barrage	95 inner estuary 1.5 outer estuary	Construction phase	16 ±50%	Year 5 repeated every 50 years	73	Construction phase
L2: Welsh Grounds Lagoon	0 inner estuary 25 outer estuary	Construction phase	18 ±50%	Year 5-50 repeated every 50 years	47	Construction phase
L3d: Bridgwater Bay Lagoon	0	-	37 ±50%	Year 75-100	243	Construction phase

Source: Flood Risk & Land Drainage Topic Paper

5.2.15 The raising of tidal water levels would also result in a permanently higher water table within the ground immediately behind the impoundments and higher water levels in surface watercourses and ditch systems. This would lead to increased soil wetness and a potential loss of the soil resource as well as potentially significant negative effects on subterranean infrastructure.

5.2.16 Decreased flows and flow speeds would reduce the suspended sediment concentration within the impounded areas and downstream (Figure 5.7). This would result in the deposition of large quantities of sediment, mainly within the deeper, more quiescent parts of the lagoon or impoundment (Table 5.5).

5.2.17 Figure 5.7 shows the spring tide, time averaged depth mean suspended sediment concentration for the baseline and for each of the alternative options. Table 5.5 shows the total mass of sediment which is predicted to be deposited inside each impoundment in the short term following the implementation of an alternative option Modelling indicated deposition over a spring neap tidal cycle, although in practice this would occur more gradually during the construction and commissioning of the structure.

Table 5.5 Total mass deposited as short-term deposition

Alternative Option	Total mass of previously mobile sediment deposited inside the impoundment in the short-term (M tonnes)
B3: Cardiff to Weston Barrage	6.9
B4: Shoots Barrage	1.3
B5: Beachley Barrage	1.3
L2: Welsh Grounds Lagoon	0.8
L3d: Bridgwater Bay Lagoon	0.7

Source: Hydraulics & Geomorphology Topic Paper

5.2.18 Extensive reductions in tidal velocity would also lead to a risk of change to the subtidal sandbanks.

5.2.19 The presence of an impoundment also is predicted to cause long-term changes in the morphology of the estuary (over the operational period of 120 years for each alternative option). This is as a result of erosion and deposition at different locations. Figures 5.8a-c show the predicted average change to bed level based on long-term morphological modelling and the intertidal profile modelling.

5.2.20 Increased light penetration as a result of a reduction in the suspended sediment concentration would result in increased primary productivity. This has the potential to increase the risk of eutrophication effects.

5.2.21 The changes arising from all alternative options slightly reduce the range of salinity but these changes are not considered significant effects in view of the natural variability of salinity at each point in the estuary. Figure 5.9 shows the effects of the alternative options on the maximum (i.e. low flows) salinity.

5.2.22 With regards to the Water Framework Directive, all of the alternative options are predicted to give rise to effects that could change the chemical status of one or more water bodies in the Severn Estuary, its tributaries or the wider Bristol Channel as a consequence of potential changes in the physical characteristics of water bodies (although the Water Framework Directive does, subject to specific tests, allow for new sustainable human development activities to proceed notwithstanding negative effects on status).

Insert figure 5.3a

Insert figure 5.3b

Insert Figure 5.4

Insert Figure 5.5

Insert Figure 5.6

Insert Figure 5.7

Insert Figure 5.8a

Insert Figure 5.8b

Insert Figure 5.8c

Insert Figure 5.9

Insert Figure 5.10

Insert Figure 5.11

Alternative Option B3: Cardiff to Weston Barrage – Physicochemical effects

5.2.23 A generic discussion of physicochemical effects is described in sections 5.2.6 – 5.2.22. More information for this alternative option is provided below.

5.2.24 The B3 Cardiff to Weston Barrage would reduce the tidal range within the impoundment by around 50% by raising low water levels close to the baseline mean tide level. High tide levels would be reduced by up to 1m on spring tides within the impoundment, though the effect on neap tides is less. Outside the barrage there would be reduced high water levels and raised low water levels. These effects would extend, with reducing effect, as far west as Ilfracombe and the Gower peninsular. Some increases in high tide levels are predicted, however, around the St George's Channel. The extent of the intertidal foreshore would reduce by just over 50% over the whole study area (see Figures 5.3a, 5.3b and 5.4).

5.2.25 There is a high risk of an increase in high water levels including surge levels along the coast of West Wales especially in the Pwhelli to Barmouth area where increases of 0.2-0.3m are predicted. Increases in high water level of 0.1-0.2m are also predicted for 10 to 20km of the Republic of Ireland coastline between Wicklow and Wexford. Smaller increases in high water levels around the coasts of the Irish Sea are also possible though the extent and magnitude is uncertain. Limitations of the modelling have prevented consideration of potential increases in high water levels beyond the Llŷn Peninsula on to the North Wales and North West England coast. Figure 5.10 shows the far-field effects on water levels at spring tides in comparison with the baseline.

5.2.26 B3 Cardiff to Weston Barrage would result in a decrease in the spring tidal prism and modification of the existing wave climate which includes both increases and reductions in wave height (see Figure 5.5). For south westerly waves at high water, the wave height is predicted to decrease within the impounded area by up to and above 20%. Increases in wave height are predicted on the downstream side of the barrage. The magnitude of these decreases with distance from the structure and are most likely the result of reflections.

5.2.27 B3 Cardiff to Weston Barrage would also reduce fetch lengths for westerly and south westerly waves at high water and as a result of the raised water levels increase the fetch length for locally generated waves at low water. A reduction in flow speeds throughout the whole estuary as a result of the reduction in tidal range means that peak bed shear stresses would be reduced over much of the study area.

5.2.28 Such changes to the characteristic physical form and flow of the Severn Estuary/Môr Hafren SAC would result in a significant negative effect to the designated site.

5.2.29 The B3 Cardiff to Weston Barrage would bring about both positive and negative effects on flood risk. Throughout the Severn Estuary and inner Bristol Channel, high water levels would reduce as a result of operating the B3 Cardiff to Weston Barrage so there would not be a negative effect on tidal flood risk from high water level change (see Table 5.3). The reduced high water levels would benefit around 89,000 properties in the tidal flood plain including 42 critical infrastructure assets by reducing the tidal flood risk to the whole estuary.

5.2.30 The increased far-field spring tide water levels predicted for the West Wales coast would have a negative effect on the standard of protection provided by existing sea defences to around 6,000 properties. The length of defences at risk is estimated to be in the range of 44-87km, with a best estimate of 58km at risk (see Table 5.4). As described above, small increases in high water levels around the coasts of the Irish Sea are also possible, resulting in the potential for significant negative transboundary effects on flood risk, though the extent and magnitude is uncertain.

5.2.31 The raised low water level within the B3 Cardiff to Weston Barrage is predicted to negatively affect the drainage of around 372km^2 of low lying land alongside the estuary containing around 50500 residential and commercial properties and 28 critical infrastructure assets (see Table 5.4 and Figure 5.6). Low lying parts of Bristol and Newport containing around 13100 residential and commercial properties and 4 critical infrastructure assets are within the areas affected by raised low water levels.

5.2.32 There is predicted to be erosion of intertidal foreshores fronting the existing flood defences over 67 to 201km of the estuary within 120 years (see Table 5.4). This erosion is expected to start to negatively affect adjacent flood defences within 5 to 10 years of starting operation.

5.2.33 Increased soil wetness upstream of the barrage may have a significant negative effect and result in loss of the soil resource. It also has the potential to have a significant negative effect on subterranean infrastructure of local importance, particularly in parts of Weston-super-Mare, Cardiff, Newport, Avonmouth and Clevedon. Raising of low water levels may also have a significant negative effect and result in loss of access to ten sites designated for important geological features, including direct loss of the southernmost portion of Penarth Coast SSSI during construction, loss of safe access to the Otter Hole Cave system and loss of access to eight others during operation. The B3 Cardiff to Weston Barrage would not have a significant effect on the operation of the existing Cardiff Bay Barrage.

5.2.34 Within the first month after impoundment, around 6.9 M tonnes (million tonnes) of material previously suspended would permanently settle within the impoundment (see Table 5.5). This would initially take up a volume of about 40 Mm^3 (million metres cubed), eventually reducing after consolidation to 16 Mm^3. This would result in widespread deposition of mud over areas of the estuary currently comprising rock, sand or mud both upstream and downstream of the barrage in the short term (see Figure 5.7). Over the lifetime of the barrage, a net gain of deposited sediment is predicted, much of this immediately upstream of the structure. Long term morphology modelling predicts that between 140 and 500 Mm^3 of sediment may settle within the subtidal areas of the barrage impoundment over 120 years. The predictions also suggest that around 25 - 60 Mm^3 of sediment may erode from the intertidal flats over this same period (see Figures 5.8a-c).

5.2.35 Extensive reductions in tidal velocity lead to a very high risk of change in morphology to the English and Welsh Grounds, Culver Sands and Nash Bank. The long term risk of change in morphology to Helwick Bank is also considered high because of the reductions in tidal velocities that are predicted for this area.

5.2.36 The reduced suspended sediment concentrations during neap tide periods might increase water clarity sufficiently to allow enhanced algal growth for limited periods within the impoundment near to the barrage. As there are sufficient nutrients to support primary productivity, this could increase the potential risk of eutrophication effects in the estuary.

Alternative Option B4: Shoots Barrage – Physicochemical effects

5.2.37 A generic discussion of physicochemical effects is described in sections 5.2.6 – 5.2.22. More information for this alternative option is provided below.

5.2.38 The B4 Shoots Barrage would reduce the tidal range within the impoundment by around 50% by raising low water levels above the baseline mean tide level, reducing high water levels by 0.3m. Outside the barrage there would be a 0.2m increase in high water levels from Newport, extending, with reducing effect, as far west as Swansea. Further west any effects are generally expected to be less than 0.1m. The extent of the intertidal foreshore would reduce by about 10% over the whole study area (see Figures 5.3a, 5.3b and 5.4).

5.2.39 Modelling of far field effects at high tide of the B4 Shoots Barrage indicates that changes to high water levels would be less than 0.05m west of Swansea. Around the West Wales, Irish and Cornish coasts spring high water levels are also generally changed by less than 0.05m. These far-field effects are not considered to be significant effects. There is an isolated area around the Llŷn peninsular where the model predicts a change of more than 0.1m. This change affects a short length of coastline and since the magnitude is close to the limit of measurable effects, it is not considered significant (see Figure 5.10).

5.2.40 There would be a reduced spring tidal prism within the impounded area and modification of the existing wave climate which includes both increases and reductions in wave height (see Figure 5.5). For south westerly waves at high water, the wave height is predicted to decrease by up to 20% upstream of the barrage. Downstream, the effects are much less severe with only localised changes exceeding 2%. There are also localised increases in height caused by either reflections from the structure or from changes in water levels.

5.2.41 B4 Shoots Barrage would also reduce fetch lengths for westerly and south westerly waves at high water and as a result of the raised water levels increase the fetch length for locally generated waves at low water. A reduction in flow speeds within the impounded area and downstream as far as Cardiff as a result of the reduction in tidal range means that peak bed shear stresses would be reduced in these areas.

5.2.42 Such changes to the characteristic physical form and flow of the Severn Estuary/Môr Hafren SAC would result in a significant negative effect to the designated site.

5.2.43 The rise in high tide levels outside the B4 Shoots Barrage is likely to have an adverse effect on the standard of protection provided by 62 km of flood defence (see Table 5.4). Within the impoundment of the B4 Shoots Barrage, and for a short distance outside, high water levels would reduce. The reduced high water levels are not however estimated to reduce the tidal flood risk sufficiently to allow a delay in the raising of flood defences that would otherwise be required to combat the effects of rising sea levels.

5.2.44 The raised low water levels within the B4 Shoots Barrage is predicted to adversely affect the drainage of 97km^2 of low lying land alongside the estuary containing around 2400 residential and commercial properties and three items of critical infrastructure (see Table 5.4 and Figure 5.6). There is predicted to be erosion of intertidal foreshores fronting the existing flood defences, which would affect 36 to 109km of estuary defences within 120 years (see Table 5.4). This erosion may start to negatively affect adjacent flood defences within about 5 years of starting operation.

5.2.45 Increased soil wetness upstream of the barrage may have a significant effect resulting in loss of the soil resource. Raising of low water levels may also have a significant negative effect with permanent loss of access to one site designated for important geological features (Otter Hole SSSI) and partial access to four others.

5.2.46 Within the first month after impoundment, around 1.3 M tonnes of material previously suspended would permanently settle within the impoundment (see Table 5.5). This would initially take up a volume of about 10 Mm^3, eventually reducing after consolidation to 4 Mm^3. This would lead to the permanent deposition of fine sediment in the main estuarine channels within one spring neap tidal cycle (see Figure 5.7). Over the lifetime of the barrage, a net gain of deposited sediment is predicted, much of this in the Inner Severn Channel with less deposition predicted elsewhere. Long term morphology modelling predicts that around 300 Mm^3 of sediment may settle within the subtidal areas of the barrage impoundment over 120 years. The modelling also predicts erosion of the intertidal foreshores upstream of the barrage (see Figures 5.8a-c).

5.2.47 The B4 Shoots Barrage would lead to a high risk of change in morphology to the English and Welsh Grounds, but only a medium risk of long term change in morphology to Culver Sands and Nash Bank. The risk of change to Helwick Bank is considered small.

5.2.48 While the reduced suspended sediment concentrations may allow some increased primary productivity, strong light limitation would continue to prevent full utilisation of the available nutrients. The risk that the reduced suspended sediment concentrations could increase water clarity sufficiently to cause substantial eutrophication effects such as algal growth is therefore considered to be small.

Alternative Option B5: Beachley Barrage – Physicochemical effects

5.2.49 A generic discussion of physicochemical effects is described in sections 5.2.6 – 5.2.22. More information for this alternative option is provided below.

5.2.50 The B5 Beachley Barrage would reduce the tidal range within the impoundment by almost 50% by raising low water levels above the baseline mean tide level, reducing high tide levels by 0.3-0.4m. Outside the barrage there would be an increase of up to 0.2m in high water levels near Newport, extending, with reducing effect, as far west as Minehead. Further west any effects are generally expected to be less than 0.1m. The extent of the intertidal foreshore would reduce by about 9% over the whole study area (see Figures 5.3a, 5.3b and 5.4).

5.2.51 Modelling of far-field effects at high tide of the B5 Beachley Barrage indicates that changes to high water levels would be less than 0.05m west of Swansea. Around the West Wales, Irish and Cornish coasts spring high water levels are also generally changed by less than 0.05m. These far-field effects are not considered to be significant effects. There is an isolated area around the Llŷn peninsular where the model predicts a change of more than 0.1m. This change affects a short length of coastline and since the magnitude is close to the limit of measurable effects, it is not considered significant (see Figure 5.10).

5.2.52 There would be a reduced spring tidal prism within the impounded area and modifications to the existing wave climate which includes both increases and reductions in wave height (see Figure 5.5). For south westerly waves at high water, the wave height is predicted to decrease by up to 20% upstream of the barrage. There are also localised increases in height caused by either reflections from the structure or from changes in water levels.

5.2.53 B5 Beachley Barrage would also reduce fetch lengths for westerly and south westerly waves at high water and as a result of the raised water levels increase the fetch length for locally generated waves at low water. A reduction in flow speeds within the impounded area and downstream as far as Avonmouth as a result of the reduction in tidal range means that peak bed shear stresses would be reduced in these areas.

5.2.54 Such changes to the characteristic physical form and flow of the Severn Estuary/Môr Hafren SAC would result in a significant negative effect to the designated site.

5.2.55 The rise in high tide levels outside the B5 Beachley Barrage is likely to have a negative effect on the standard of protection provided by about 97 km of flood defence (see Table 5.4). Within the impoundment of the B5 Beachley Barrage, and for a short distance outside, high water levels would reduce. The reduced high water levels are not however considered to reduce the tidal flood risk sufficiently to allow a delay in the raising of flood defences that would otherwise be required to combat the effects of rising sea levels.

5.2.56 The raised low water levels upstream of the B5 Beachley Barrage is predicted to negatively affect the drainage of 73km^2 of low lying land alongside the estuary containing around 1000 residential and commercial properties (see Table 5.4 and Figure 5.6). There is predicted to be erosion of 8 to 23 km of intertidal foreshores fronting the existing flood defences downstream of the barrage within 5 years of commissioning of the B5 Beachley Barrage. Erosion of around 41km of foreshore is also predicted upstream of the barrage, but as the rates upstream of the barrage are relatively slow, this is unlikely to become an issue until around 100 years after commissioning (see Table 5.4)

5.2.57 Increased soil wetness and potential waterlogging upstream of the barrage may have a significant effect and result in loss of the soil resource. Raising of low water levels may also have a significant negative effect with permanent loss of part of one site designated for important geological features (Aust Cliff SSSI) and reduced access to two others (Purton Passage and Lidney Cliff).

5.2.58 Within the first month after impoundment, around 1.3 M tonnes of material previously suspended would permanently settle within the impoundment (see Table 5.5). This would initially take up a volume of about 7.5 Mm^3, eventually reducing after consolidation to 3 Mm^3. This would result in the permanent deposition of fine sediment in the main estuarine channels within one spring neap tidal cycle of operation (see Figure 5.7). Over the lifetime of the barrage, a net gain of deposited sediment is predicted, much of this in the estuarine channels immediately upstream of the structure. Long term morphology modelling predicts that around 150 Mm^3 of sediment may settle within the subtidal areas of the barrage impoundment over 120 years. The subtidal deposition may be enhanced by a small volume of erosion from the intertidal areas within the impoundment (see Figures 5.8a-c)

5.2.59 The sand and gravel banks of English Grounds and Welsh Grounds are considered to have a medium risk of long term change in morphology as a result of the B5 Beachley Barrage. The risk of change in morphology to Culver Sands, Nash Bank and Helwick Bank is considered low.

5.2.60 While the reduced suspended sediment concentrations may allow some increased primary productivity, strong light limitation would continue to prevent full utilisation of the available nutrients. The risk that the reduced suspended sediment concentrations could increase water clarity sufficiently to cause substantial eutrophication effects such as algal growth is therefore considered to be small.

Alternative Option L2: Welsh Grounds Lagoon – Physicochemical effects

5.2.61 A generic discussion of physicochemical effects is described in sections 5.2.6 – 5.2.22. More information for this alternative option is provided below.

5.2.62 The L2 Welsh Grounds Lagoon would reduce the tidal range within the lagoon by 50% by raising low water levels above the baseline mean tide level, but with little change to high tide levels. In the Severn Estuary outside the lagoon there would be a small decrease in high water levels, though in the Bristol Channel between Barry and Swansea increases of around 0.1m in spring high level are predicted. Further west any effects are generally expected to be less than 0.1m. The extent of the intertidal foreshore would reduce by about 25% over the whole study area (see Figures 5.3a, 5.3b and 5.4).

5.2.63 The high water far field effects of the L2 Welsh Grounds Lagoon shown in modelling are that changes to high water levels would be less than 0.05m west of the Gower Peninsular and Ilfracombe. Around the West Wales, Irish and Cornish coasts spring high water levels are also generally predicted to change by less than 0.05m. Any isolated areas where changes of more than 0.1m are predicted by the model seem more likely to represent artefacts of the modelling process rather than real effects. These far-field effects are not considered to be significant effects (see Figure 5.10).

5.2.64 There would be a decrease in the spring tidal prism downstream of the lagoon and increases and decreases in wave height are predicted within the impounded area at low and high water respectively (see Figure 5.5). At high water, for south westerly waves, increases of up to 5% are predicted at the southern end of the structure as a result of reflections. Elsewhere outside the lagoon decreases in wave height of between 10% and 20% are predicted. Within the lagoon, wave heights are predicted to decrease by >20% due to the sheltering effect of the structure.

5.2.65 A reduction in flow speeds within the impounded area and as far downstream as Cardiff means that bed shear stresses would be marginally reduced in certain areas but the spatial extent of these changes would be local to the lagoon.

5.2.66 Such changes to the characteristic physical form and flow of the Severn Estuary/Môr Hafren SAC would nonetheless result in a significant negative effect to the designated site.

5.2.67 Within the inner Bristol Channel there is expected to be a small rise in high water levels which would have a negative effect on about 25 km of flood defence (see Table 5.4). The raised low water levels within the L2 Welsh Grounds Lagoon is predicted to negatively affect the drainage of 47km^2 of low lying land alongside the estuary containing around 275 residential and commercial properties (see Table 5.4 and Figure 5.6). There is predicted to be erosion of intertidal foreshores fronting the existing flood defences over around 9 to 28 km of the estuary outside the lagoon (see Table 5.4). Around half this length is expected to adversely affect adjacent flood defences within 5 to 10 years of starting operation. The remaining length would start to negatively affect the flood defences after about 50 years of operation.

5.2.68 Increased soil wetness alongside the lagoon may have a significant effect and may result in loss of the soil resource. It also has the potential to have a significant negative effect on subterranean infrastructure in Llanwern, eastern Caldicot and southern Newport, on the eastern side of the River Usk.

5.2.69 Within the first month after impoundment, around 0.8 M tonnes of material previously suspended would permanently settle within the impoundment (see Table 5.5 and Figure 5.7). This would initially take up a volume of about 5 Mm^3, eventually reducing after consolidation to 2 Mm^3. Over the lifetime of the lagoon, a net gain of deposited sediment is predicted. Long term morphology modelling predicts that around 300 Mm^3 of sediment may settle within the lagoon over 120 years. Outside the lagoon, the predictions anticipate accretion of around 65 Mm^3 of sediment in the channels adjacent to the lagoon and upstream as far as the River Wye confluence and also on the intertidal flats opposite the lagoon on the English shore (see Figures 5.8a-c).

5.2.70 The sand and gravel banks of English Grounds and Welsh Grounds are considered to have a high risk of long term change in morphology as a result of the L2 Welsh Grounds Lagoon. The risk of change in morphology to Culver Sands is considered medium, while the risk of change for Nash Bank and Helwick Bank is considered low.

5.2.71 The concentrations of suspended sediment within the lagoon on neap tides are expected to be sufficiently low to allow algal blooms to occur. However, any algae that grew within the lagoon would be rapidly flushed out and so prevent blooms forming within the lagoon. Outside the lagoon, the suspended sediment concentrations are predicted to remain too high to permit substantial algal growth on any tides. There is therefore not considered by a significant risk of eutrophication effects.

Alternative Option L3d: Bridgwater Bay Lagoon – Physicochemical effects

5.2.72 A generic discussion of physicochemical effects is described in sections 5.2.6 – 5.2.22. More information for this alternative option is provided below.

5.2.73 The L3 Bridgwater Bay Lagoon would reduce the tidal range within the lagoon by about 1m by raising low water levels and reducing high tide levels. In the Severn Estuary outside the lagoon there would be a small decrease in tide range lowering high tides by about 0.3m and raising low tide levels by a similar amount. These changes should reduce to less than 0.05 west of Port Talbot. Further west any effects are generally expected to be less than 0.1m. The extent of the intertidal foreshore would reduce by about 7% over the whole study area (see Figures 5.3a, 5.3b and 5.4).

5.2.74 The high water far-field effects of the L3d Bridgwater Bay Lagoon shown in modelling are that changes to high water levels would be less than 0.05m west of Port Talbot. Around the West Wales, Irish and Cornish coasts spring high water levels are predicted to generally change by less than 0.05m. Any isolated areas where changes of more than 0.1m are predicted by the model seem more likely to represent artefacts of the modelling process rather than real effects. These far-field changes are not considered to be significant effects (see Figure 5.10).

5.2.75 L3d Bridgwater Bay Lagoon would result in a decrease in the spring tidal prism inside and outside the lagoon and modifications to the existing wave climate (see Figure 5.5). For south westerly waves at high water, wave heights are predicted to increase by up to 10% in the vicinity of the structure possibly due to reflections. Wave heights inside the structure would decrease by more than 20%.

5.2.76 Within the impounded area there would be considerable increases in velocity, especially in the area adjacent to the turbines, where maximum speeds more than double (>100% increases) are expected, though over much of this area, velocities remain fairly low. In the mouth of the Parrett estuary velocities are 10-40% higher.

Maximum velocities are also more than doubled in the areas where the turbines discharge outside the lagoon. Away from the area around the lagoon, changes in peak velocity would be less than 10%.

5.2.77 Such changes to the physical characteristic form and flow of the Severn Estuary/Môr Hafren SAC would result in a significant negative effect to the designated site.

5.2.78 The L3d Bridgwater Bay Lagoon would bring about both positive and negative effects on flood risk. Throughout the Severn Estuary and inner Bristol Channel, high water levels would reduce as a result of operating the L3d Bridgwater Bay Lagoon and thus would reduce the tidal flood risk to the whole estuary. This reduction would be equivalent to around 100 years of sea level rise inside the lagoon and 40 years outside (see Table 5.3).

5.2.79 The raised low water levels within the L3d Bridgwater Bay Lagoon are predicted to negatively affect the drainage of around 243km^2 of low lying land alongside the estuary containing around 1150 residential and commercial properties and one item of critical infrastructure (see Table 5.4 and Figure 5.6). Although the area of land potentially affected by impeded drainage is large, the rise in low water levels at 0.5m is relatively small. There is predicted to be erosion of intertidal foreshores fronting the existing flood defences affecting 18 to 56km of the estuary outside the lagoon. This erosion is not expected to adversely affect adjacent flood defences until 75 to 100 years after starting operation (see Table 5.4).

5.2.80 Increased soil wetness alongside the lagoon and in the Parrett estuary may have a significant negative effect resulting in loss of the soil resource. It also has the potential to significantly negatively affect subterranean infrastructure, most likely in southern parts of Bridgwater.

5.2.81 Within the first month after impoundment, around 0.7 M tonnes of material previously suspended would permanently settle within the impoundment (see Table 5.5 and Figure 5.7). This would initially take up a volume of about 5 Mm^3, eventually reducing after consolidation to 2 Mm^3. Long term morphology modelling predicts that around 45 Mm^3 of sediment may settle within the lagoon over 120 years. Outside the lagoon, the predictions anticipate relatively small changes over the 120 year life of the lagoon (see Figures 5.8a-c).

5.2.82 The L3d Bridgwater Bay Lagoon leads to a medium risk of change in morphology to the English and Welsh Grounds, Culver Sands and Nash Bank. The risk of change in morphology to Helwick Bank is considered small.

5.2.83 The concentrations of suspended sediment within the lagoon on neap tides are expected to be sufficiently low to allow algal growth to occur. However, any algae that grew within the lagoon would be rapidly flushed out and so prevent blooms forming within the lagoon. Outside the lagoon, the suspended sediment concentrations are predicted to remain too high to permit substantial algal growth on any tides. There is therefore not considered by a significant risk of eutrophication effects.

5.2.84 L3d Bridgwater Bay Lagoon would constrain the thermal plume from the Hinkley Power Station outfall against the lagoon wall. Figure 5.11 shows the effects of the L3d Bridgwater Bay Lagoon on the thermal plume from the Hinkley Power Station in comparison with the baseline. The development of Hinkley Point C Nuclear Power Plant may also result in cumulative effects on marine water quality.

5.2.85 L3d Bridgwater Bay Lagoon would also result in the increased extent of the effluent plume from Weston Wastewater Treatment Works (WwTW) risking non-compliance under the Bathing Waters Directive. Figure 5.11 shows the effects of the L3d Bridgwater Bay Lagoon on the effluent plume from Weston WwTW, in comparison with the baseline.

Biodiversity effects

5.2.86 The significant effects described below have been informed by the following Topic Papers and their annexes; Marine Ecology, Migratory & Estuarine Fish, Waterbirds and Terrestrial & Freshwater Ecology as well as the Biodiversity Theme Paper (see Appendix 1). See Appendix 9 for a summary of all the identified likely significant effects of the alternative options. The studies undertaken within the physicochemical theme have informed the biodiversity study. Effects on fish have also been informed by the noise & vibration topic.

5.2.87 Changes to water levels, bathymetry and sediment type and distribution are predicted to result in changes in quality and extent of the Severn Estuary/Môr Hafren SAC European designated habitats and species (see Figures 5.12 and 5.13 and Tables 5.6 and 5.7 for changes in extent) as well as designated habitats such as *Sabellaria alveolata* not shown in the figures or tables.

5.2.88 Figure 5.12 shows the intertidal habitat of the Severn Estuary and Bristol Channel and the percentage predicted change from the baseline. Figure 5.13 shows the subtidal habitat of the Severn Estuary and Bristol Channel and the percentage predicted change from the baseline. Table 5.6 shows the predicted areas of estuary-wide intertidal habitat as a result of short-term (i.e. approximately within a month) changes to water levels, bathymetry and sediment type and distribution, tidal curve and fetch. In this context, the initial changes are in relation to the outputs of a spring-neap cycle immediately post scheme implementation. Table 5.7 shows equivalent information for subtidal habitat.

5.2.89 Long term (over the operational period of a barrage or lagoon) morphological changes and their effects on habitats are harder to predict but can also be expected to alter the intertidal area extent (Table 5.8) mainly through further erosion of the intertidal area. For subtidal sandbanks such as the English and Welsh Grounds, Culver Sands and Nash Banks, the long-term morphological effects may result in a flattening and widening of existing sandbanks which would have a significant negative effect on these features. These habitat changes would have consequential effects on seaweed and eelgrass species and a number of mobile epibenthic species. Table 5.8 shows the predicted long-term changes in area of intertidal habitat from the existing baseline as a result of long-term morphological change. The assessment, and hence Table 5.8 is not able to quantify any changes in location of intertidal habitat, nor changes in quality of habitat.

Table 5.6 Areas of the intertidal – terrestrial interface following short term changes to the Severn Estuary

Alternative Option	Area of remaining habitat at the terrestrial – intertidal interface (ha)[1] following scheme implementation						
	Grassland	Saltmarsh	Mudflat	Sandflat	Rock	Shingle	Total[2]
B3: Cardiff to Weston Barrage	589 (1080)	775 (78)	8357 (67)	3853 (28)	1135 (51)	363 (28)	15072 (49)
B4: Shoots Barrage	109 (201)	1132 (114)	12155 (97)	11888 (86)	1430 (64)	1009 (77)	27723 (89)
B5: Beachley Barrage	118 (216)	1070 (108)	12170 (97)	11620 (84)	1949 (87)	1287 (98)	28214 (91)
L2: Welsh Grounds Lagoon	111 (203)	1065 (107)	11560 (92)	7728 (56)	2210 (98)	1083 (83)	23780 (77)
L3d: Bridgwater Bay Lagoon	144 (264)	1235 (124)	10814 (86)	13077 (94)	2211 (95)	1140 (87)	28531 (92)

[1] Numbers in brackets represent the predicted habitat area as a percentage of modelled baseline (value of 100 is equivalent to the baseline, values less than 100 represent predicted reduction on area and values greater than 100 indicate predicted increase in area). The entire modelled estuary is included, i.e. inside and outside the Severn Estuary/Môr Hafren SAC.
[2] Total intertidal represents area between the Highest Astronomical Tide (HAT) and the Lowest Astronomical Tide (LAT) and includes saltmarsh, intertidal mudflat and sandflat, intertidal rock and intertidal shingle. Does not include intertidal areas of sub-estuaries, habitat area losses are uncertain and small by comparison. Estimates do not include changes arising from long term morphological processes.
NB: Estimates of habitat change within the Marine Ecology assessment cannot be directly compared with intertidal area calculations within the Hydraulics & Geomorphology assessment. This is because the estimates have been generated by different tools for different purposes.
This assessment does not include measures to prevent or reduce significant effects except those already included in the definition of alternative options.

Source: Marine Ecology Topic Paper

Table 5.7 Subtidal areas following short term changes to the Severn Estuary

Alternative Option	Area of remaining subtidal habitat (ha)[1]				
	Sand	Shingle	Rock	Mud	Total[2]
B3: Cardiff to Weston Barrage	32237 (143)	24560 (103)	39049 (104)	16843 (137)	112689 (117)
B4: Shoots Barrage	23732 (105)	23894 (101)	38687 (102)	13528 (110)	99841 (103)
B5: Beachley Barrage	23939 (106)	23668 (100)	38225 (100)	13460 (109)	99293 (103)
L2: Welsh Grounds Lagoon	28000 (124)	23815 (101)	38083 (100)	13903 (113)	103801 (108)
L3d: Bridgwater Bay Lagoon	23224 (103)	23819 (101)	38138 (100)	13777 (112)	98958 (103)

[1] Numbers in brackets represent percentage change from modelled baseline. The entire modelled estuary is included, i.e. inside and outside the Severn Estuary/Môr Hafren SAC.
[2] Total subtidal represents areas below the Lowest Astronomical Tide (LAT). Does not include subtidal areas of sub-estuaries, habitat area losses are uncertain and small by comparison. Estimates do not include changes arising from long term morphological processes
NB: Estimates of habitat change within the Marine Ecology assessment cannot be directly compared with intertidal area calculations within the Hydraulics & Geomorphology assessment. This is because the estimates have been generated by different tools for different purposes.

Source: Marine Ecology Topic Paper

Table 5.8 Changes in Severn Estuary intertidal habitat areas in long term

Alternative Option	Area of habitat (ha)				
	Baseline Intertidal extent[1]	Predicted short-term (post-closure) extent	Predicted long-term (120y) change	Predicted long term extent [2]	Long-term extent as % of baseline
B3: Cardiff to Weston Barrage	31,900	15,700	-2,000	13,700	43%
B4: Shoots Barrage	31,900	28,600	-500	28,200	88%
B5: Beachley Barrage	31,900	29,200	0	29,200	91%
L2: Welsh Grounds Lagoon	31,900	24,600	+200	24,800	78%
L3d: Bridgwater Bay Lagoon	31,900	29,400	-300	29,100	91%

Figures rounded to nearest 100ha.
1. Total intertidal represents area between approximately LAT and HAT and includes (saltmarsh, intertidal mudflat and sandflat, intertidal rock and intertidal shingle). Upstream of the option, the lower limit is based on MLWN (which is predicted to be lower than LAT). The entire modelled estuary is included, i.e. inside and outside the Severn Estuary/Môr Hafren SAC.
2. The intertidal areas of the sub-estuaries have been included based on the same & change as the main estuary.
NB: Estimates of habitat change within the Marine Ecology assessment cannot be directly compared with intertidal area calculations within the Hydraulics & Geomorphology assessment. This is because the estimates have been generated by different tools for different purposes.

Source: Marine Ecology Topic Paper

5.2.90 Within the limitations of the study, modelling has shown that no alternative option materially alters the intertidal habitat losses resulting from climate change related sea level rise that may occur in the absence of a barrage or a lagoon.

5.2.91 The reduction in suspended sediment concentration and increases in mud composition of the sediment would lead to overall increases in the diversity, abundance and biomass of benthic invertebrates in subtidal and intertidal areas. It would also improve conditions for seaweed and eelgrass. However, the increases in light, reductions in suspended sediment and high availability of nutrients have the potential to lead to eutrophication effects. Reductions in suspended sediment concentration together with reductions in flow speeds would lead to a reduction in sediment-induced scour. Depending on the scale of sediment deposition, this may benefit shingle and rocky shore habitats and seaweed. However, changes in sand transport and mud deposition may have negative effects on the subtidal sandbanks. The reef-building worm *Sabellaria alveolata* is reliant on the high flows as a source of sediment for reef building and reductions in current speed would therefore negatively affect this species.

5.2.92 During construction, all the alternative options would have the potential to introduce non-native species to the Severn Estuary through the use of the construction infrastructure. Further to this, should the operation of a barrage or a lagoon encourage water based recreation within the impoundment, there is also the potential for the introduction of non-native species via boat hulls.

5.2.93 Although the suitability of the remaining intertidal habitat for some species may increase, this effect is considered likely to be far outweighed by the scale of intertidal habitat loss, such that significant negative effects are still predicted for most marine ecology and waterbird receptors. These effects would also alter the unique stressed environment that is one of the characteristics for which the Severn Estuary / Môr Hafren SAC is currently protected (see also the Report to inform a Stage 2 (Appropriate Assessment) Habitats Regulations Assessment (Severn Tidal Power, 2010b)). The required annual maintenance dredging may also reduce intertidal habitat quality (by exposing mudflats to erosion and affecting the maintenance or development of invertebrate communities).

5.2.94 The effect of changes to quality or loss of access to the intertidal habitat (including duration of exposure) is likely to have a negative effect on the waterbird species of the Severn Estuary SPA and Ramsar designations which using these areas for feeding. Further to this, the immediate loss of habitat that would occur once construction is completed may displace birds and would cause them to redistribute either within the Severn Estuary or to other far-field sites. This might in turn affect the birds wintering at those sites through competition and density-dependent mortality. There is however, some evidence that the remaining intertidal would have greater productivity as a feeding ground, owing to increases in mud composition of the sediment, although an altered invertebrate assemblage may not be appropriate for the existing waterbird species.

5.2.95 The Steart Coastal Management Project has the potential to create between 200 and 800 ha of additional intertidal habitat and saltmarsh through managed realignment in the area of Bridgwater Bay. One of the aims of this project is to offset losses of intertidal habitat resulting from coastal squeeze. This project may potentially act cumulatively with the principal effect for waterbirds of changes to or loss of intertidal habitat and it is thus considered within the assessment of that effect. Aside from any permanent loss of habitat, waterbirds of the Severn Estuary SPA and Ramsar designations are also likely to be negatively affected during construction and decommissioning phases by disturbance effects.

5.2.96 Population effects on waterbirds arising from the changes in feeding opportunities within the areas of the Severn Estuary have been modelled through two approaches - a Habitat Association Model and an Individual Based Model. These models quantity the effects on waterbirds of the change in intertidal area, this being the most important way that negative effects occur. The population changes relative to baseline figures identified by both modelling approaches are shown in Table 5.9, as well as a summary of the species affected by intertidal area change that have not been modelled. The modelling approaches aim to estimate the number of birds that might be expected to be supported on the Severn Estuary as a result of the immediate changes in intertidal area following implementation of each of the alternative options. The results from the two waterbird models do not necessarily equate directly to magnitudes of effect, as there is uncertainty in the accuracy of predictions and how well they take into account the forecast geomorphological and hydrodynamic changes and consequent changes in sediments and invertebrate food supplies. These issues vary by species, as well as option and modelling approach, and the key outcome is therefore the judgement on whether there is likely to be a significant effect.

5.2.97 The purpose of using these two, complementary modelling approaches was therefore to provide a better understanding of the range of uncertainty in model predictions. Further background information on these models, and the ranges and differences in their output is provided in the Waterbird Topic Paper (see Appendix 1).

5.2.98 While it is predicted that densities of some waterbird species may increase within the study area (because the productivity of the intertidal habitat, and therefore the abundance of the invertebrates that birds feed on, may increase), the scale of habitat loss and the changes to the intertidal exposure period are assessed to have much greater negative effects than any positive changes in the productivity of intertidal habitat for most waterbird receptors.

Table 5.9 Predicted changes in waterbird numbers resulting from changes to intertidal area (using Habitat-Association and Individual-Based Models)

Receptor	B3: Cardiff to Weston Barrage (% change)			B4: Shoots Barrage (% change)			B5: Beachley Barrage (% change)			L2: Welsh Grounds Lagoon (% change)			L3d: Bridgwater Bay Lagoon (% change)		
	HAM	IBM	Sig[1]	HAM	IBM	Sig[1]	HAM	IBM	Sig[1]	HAM	IBM	Sig[1]	HAM	IBM	Sig[1]
Mute Swan	-42[2]	-		-7	-		-13	-		-26	-		-7	-	
Shelduck	-22	-	Y	-15	-	Y	-11	-	Y	-31	-	Y	-2	-	
Wigeon	-49[2]	-	Y	-20	-	Y	-20	-	Y	-35	-	Y	-3	-	
Gadwall	-20[2]	-		-2	-		-17	-		-10	-		-17	-	
Teal	-44[2]	-	Y	-23	-	Y	-24	-	Y	-31	-		-8	-	
Mallard	-41[2]	-	Y	-27	-	Y	-27	-	Y	-30	-	Y	-11	-	
Shoveler	-49[2]	-	Y	11	-	Y	6	-		-29	-		3	-	
Pochard	-25[2]	-	Y	-21	-	Y	-29	-	Y	-17	-		-18	-	
Tufted Duck	-33[2]	-	Y	-11	-	Y	-19	-	Y	-21	-		-13	-	
Cormorant	-49[2]	-		-19	-		-19	-		-34	-		-3	-	
Little Egret	-49[2]	-	Y	13	-	Y	8	-		-29	-	Y	4	-	
Ringed Plover	-49[2]	-6	Y	-21	-5	Y	-21	-4	Y	-35	-4	Y	-4	-6	
Golden Plover	-49[2]	-19	Y	-18	-15	Y	-19	-15	Y	-34	-1		-3	-16	Y
Grey Plover	-76[2]	-17	Y	-40	-12		-37	-12		-44	-1	Y	-14	-17	Y
Lapwing	-48[2]	-20	Y	-23	-14	Y	-22	-14	Y	-35	-4		-5	-18	Y
Knot	-47[2]	-30	Y	-2	-9		7	-8		-39	-8		-4	-8	
Dunlin	-45	-5	Y	-25	-3	Y	-20	-3		-34	-3	Y	-10	-5	Y
Snipe	-49[2]	-21	Y	-18	-4		-18	-3		-34	-9		-2	-14	
Black-tailed Godwit	59	-1	Y	40	-11		39	-4		-23	0	Y	37	-5	Y
Curlew	-48[2]	-	Y	-24	-	Y	-22	-	Y	-35	-	Y	-5	-	
Greenshank	-49[2]	-	Y	-22	-	Y	-21	-	Y	-35	-	Y	-4	-	
Redshank	-48[2]	-21	Y	-24	-8	Y	-23	-4		-35	-11	Y	-5	-12	Y
Turnstone	-48[2]	-21	Y	-23	-9		-22	-4		-35	-12		-5	-14	
No. of modelled species significantly affected by changes to intertidal area			20 (-)			13 (-) 2 (+)			11 (-)			11 (-)			6 (-)
No. of unmodelled receptors (individual species & waterbird assemblage) significantly affected by changes to intertidal area			10 (-)			4 (-)			4 (-)			2 (-)			3 (-)

[1] The likely significance of effects reflects receptor value and vulnerability, the probability of the effect (in this case high) and the magnitude of the effect – the latter was determined using the results of modelling, taking into account its wide uncertainty. Y = significant effect is likely. (-) = negative effect; (+) = positive effect.

[2] Predictions are thought likely to have overestimated the scale of probable declines (as, for B3 Cardiff to Weston, the change in the 'fetch' value measured for this study greatly underestimated the change in turbidity predicted by the Hydrology and Geomorphology study).

No model predictions were possible or appropriate for Berwick's Swan, European White-fronted Goose, Pintail, Water Rail, Oystercatcher, Avocet, Ruff, Bar-tailed Godwit, Whimbrel, Spotted Redshank, Black-headed Gull, Common Gull, Lesser Black-backed Gull or Herring Gull. NB: the predictions from the models are a starting point to the assessment of the effect of changes to or loss of intertidal habitat. They should not be taken as the magnitude of effect as this is tempered by further other qualification, described in the Waterbirds Topic Paper (see Appendix 1).

Source: Waterbirds Topic Paper

5.2.99 Table 5.9 identifies those species affected by changes in the intertidal area arising from each option. Other ways effects could arise include displacement of bird populations to other sites, and effects during construction and decommissioning phases. Bearing in mind that species can be affected in more than way, the B3 Cardiff to Weston Barrage would significantly negatively affect a total of 33 waterbird species and the waterbird assemblage, the B4 Shoots Barrage would affect negatively 16 species and the waterbird assemblage and 2 species positively, together with, the B5 Beachley Barrage and L2 Welsh Grounds Lagoon would both negatively affect 14 species and the waterbird assemblage, and the L3d lagoon would negatively affect 13 waterbird species but not the assemblage.

5.2.100 Fish species designated under the Severn Estuary/Môr Hafren SAC, River Usk/Afon Wysg SAC and River Wye/Afon Gwy SAC are very likely to be affected by alterations to migratory cues and disruption to route of passage. Fish may also be affected by habitat change and/or loss, changes to water quality and anthropogenic noise disruption. Fish passage through tidal power schemes, in particular turbines, is likely to be the primary source of fish injury and mortality. If injuries are not immediately lethal, fish could suffer delayed and indirect mortality. Not all fish species and life stages would suffer injuries and the extent of injury sustained would differ. During coastal movements, migratory fish may make exploratory forays into the estuaries and lower reaches of non-natal rivers and may also overshoot home rivers or, through tidally-orientated estuarine excursion, be recorded in locations some way from their natal river. This means that alternative options some distance from the target river may still have a negative effect on the populations of that river. For example, salmon believed to be homing to rivers outside of the Severn Estuary have been captured within the Rivers Severn, Wye and Usk.

5.2.101 Of all the effect pathways considered, it was only possible to quantify the effects associated with turbine passage and incorporating these into life history models was possible for Atlantic salmon, twaite shad, sea lamprey, river lamprey, and eel. A summary of the predicted effects of each alternative option on the migratory and estuarine fish that could be modelled is shown in Table 5.10. The effects on other migratory and estuarine fish species is described below.

Table 5.10 Summary of predictions of effects on migratory and estuarine fish

Alternative Option	Fish Species (E = population collapse / extinction and R = reductions in population size)				
	Atlantic salmon	Twaite shad	Sea lamprey	River lamprey	Eel
B3: Cardiff to Weston Barrage	E: Rivers Wye, Severn, less certainty for the Usk	E: Rivers Wye, Severn and Usk R: River Tywi	R: Rivers Usk, Wye	R: Rivers Usk, Wye	R: Rivers, Usk, Wye and Severn
B4: Shoots Barrage	E: Rivers Wye, Severn, less certainty for the Usk	E: Rivers Wye, and Severn R: River Usk and Tywi	E: River Wye R: River Usk	E: Rivers Usk and Wye	R: Rivers Wye and Severn
B5: Beachley Barrage	E: Rivers Wye, Severn and Usk	E: Rivers Wye, Severn and Usk R: River Tywi	E: Rivers Usk and Wye	E: Rivers Usk and Wye	R: Rivers Wye and Severn
L2: Welsh Grounds Lagoon	E: Rivers Wye, Severn and Usk	E: Rivers Wye, Severn and Usk R: River Tywi	E: River Usk R: River Wye	R: Rivers Usk, Wye	R: Rivers, Severn, Wye and Usk

Alternative Option	Fish Species (E = population collapse / extinction and R = reductions in population size)				
	Atlantic salmon	**Twaite shad**	**Sea lamprey**	**River lamprey**	**Eel**
L3d: Bridgwater Bay Lagoon	E: Rivers Wye, Severn and Usk	E: Rivers Wye, Severn and Usk R: River Tywi	R: Rivers Usk, Wye	R: Rivers Usk, Wye	R: Rivers, Usk, Wye and Severn

Source: Migratory & Estuarine Fish Topic Paper

5.2.102 The sea lamprey populations of the Rivers Usk and Wye are not genetically distinct, and instead form part of a wider European stock. Extinctions in these rivers therefore risk a reduction in the European stock of this species. Similarly, the river lamprey forms part of a wider UK stock and therefore extinctions in these rivers risk a reduction in the UK stock.

5.2.103 It has not been possible to quantify the future baseline for all fish species under assessment and compound STP effects upon migratory and estuarine fish cannot be quantifiably predicted. The qualitative assessments detailed below are therefore considered to be applicable to all STP alternative options:

- Sea trout – it is considered that there is potential risk of both reductions in population size and river specific stock collapse for the Rivers Wye, Severn and Usk;

- Allis shad - It is considered that there is potential risk of both reductions in population size and river specific stock extinction for the Rivers Wye, Severn and Usk and to a lesser extent the Tywi which could put the UK stock at risk of extinction;

- Marine migrants and stragglers, estuarine residents and freshwater stragglers - It is considered that there is potential risk of reductions in population size.

5.2.104 With regards to terrestrial and freshwater ecology, the construction activities at each landfall point would require a temporary working area and permanent land take, resulting in both temporary and permanent habitat loss. The construction activities would also generate noise and vibration, visual and lighting disturbance which would be likely to disturb or result in potential mortality of terrestrial and freshwater ecology receptors located in the surrounding areas. The use of construction materials and chemicals together with vehicular movements could result in habitat degradation through pollution by land and / or air.

5.2.105 Increased water levels in the estuary would result in increased levels in freshwater watercourses within the impoundment and above the ground surface. In extreme events this could result in partial or complete inundation of terrestrial designated sites which may lead to degradation (which may be reversed following decommissioning) and / or permanent habitat loss, fragmentation at a landscape corridor level as well as mortality of species unable to avoid the significant negative effect. An overall reduction of fish within the estuary and rivers is likely to reduce the foraging resources for otter and other species such as white-clawed crayfish and aquatic invertebrate fauna.

Insert Figure 5.12a

Insert Figure 5.12b

Insert Figure 5.13a

Insert Figure 5.13b

<u>*Alternative Option B3: Cardiff to Weston Barrage – Biodiversity effects*</u>

5.2.106 A generic discussion of biodiversity effects is described in sections 5.2.86 – 5.2.105. More information for this alternative option is provided below.

5.2.107 The physicochemical effects would result in subsequent effects on biodiversity, resulting in both positive and negative effects on biodiversity, but with overall significant negative effects on the Severn Estuary/Môr Hafren SAC, SPA and Ramsar site.

5.2.108 Changes in water levels which modify the extent of habitats would result in significant negative effects on all intertidal receptors (intertidal mudflat and sandflat, saltmarsh, intertidal shingle and rock, seaweed and eelgrass) and epibenthos (see Tables 5.6 and 5.7 and Figures 5.12 and 5.13). Further significant negative effects on intertidal mudflat and sandflats and saltmarsh are predicted as a result of long-term morphological changes (see Table 5.8). There is also the potential for far-field significant negative effects, particularly on saltmarsh as a result of increases in high water levels on the West Wales coast.

5.2.109 The predicted far-field increases in the level of high water may result in a landward displacement of saltmarsh and potential loss of saltmarsh where it is constrained by flood defences or natural features. Where saltmarsh was lost, it would be expected to be replaced by an equivalent area of intertidal mudflat and sandflat. This may affect the Carmarthen Bay and Estuaries/Bae Caerfyrddin ac Aberoedd SAC, the Pembrokeshire Marine/Sir Benfro Forol SAC, the Pen Llyn a`r Sarnau/Lleyn Peninsula and the Sarnau SAC; the Kenfig/Cynffig SAC and various estuaries that are likely to contain saltmarsh, including the Taw-Torridge Estuary, the Camel Estuary, Teifi Estuary and Neath Estuary. The reduction in saltmarsh is considered to be a significant negative effect, although there is uncertainty surrounding the magnitude of far-field water level changes.

5.2.110 Changes in habitat quality are predicted to give rise to significant effects through a number of different mechanisms. Reductions in the short-term erosion and deposition of mud are predicted to have significant positive effects on the remaining intertidal mudflats especially, although changes in sand transport and mud deposition are predicted to have significant negative effects on subtidal sandbanks in the Severn Estuary and Bristol Channel. Predicted reductions in flow speed are assessed as having significant negative effects on subtidal *Sabellaria* reef.

5.2.111 A reduction in the suspended sediment concentration, by increasing light penetration, is predicted to have significant positive effects for plankton and macroalgae and subsequent increases in the diversity and abundance of zooplankton and greater diversity of suspension feeding organisms within benthic invertebrate assemblages. These changes have been assessed as significant positive effects. The change of light climate does also however have the potential to increase the risk of eutrophication effects, with algal blooms and dieback and a feedback loop with water quality.

5.2.112 The barrage would act as an obstruction to the migration of epibenthos leading to a collision risk and reduction of larval / adult transport. The dredging associated with B3 Cardiff to Weston Barrage may also have a significant negative effect on *Sabellaria* reef. Overall, the B3 Cardiff to Weston Barrage would result in the risk of complete loss of *Sabellaria* reef and a reduction in the extent of eelgrass (area uncertain).

5.2.113 With regards to water quality, it is uncertain whether there would be any deterioration in the WFD ecological status of water bodies for B3 Cardiff to Weston Barrage.

5.2.114 Despite the positive effects on some of the marine ecology receptors, the B3 Cardiff to Weston Barrage would have a negative effect on the Severn Estuary/Môr Hafren SAC as a whole (see also the Report to inform a Stage 2 (Appropriate Assessment) Habitats Regulations Assessment (Severn Tidal Power, 2010b)). This is through the reduction in intertidal area and alterations to the nature of the intertidal and subtidal habitats that remain.

5.2.115 Disturbance during construction and decommissioning may have a significant negative effect on the Lesser Black-backed Gull and Herring Gull. The effect from the operation phase of changes to or loss of intertidal habitat is likely to have an overall significant negative effect for 30 waterbird species (including Ringed Plover, Curlew, Dunlin, Redshank and Shelduck) (see Table 5.9). The effect of changes to saltmarsh was identified as a likely significant negative effect for four waterbird species (Bewick's Swan, European White-fronted Goose, Shelduck and Redshank). Effects on breeding seabirds were also identified as a likely significant negative effect for three waterbird species (Cormorant, Lesser Black-backed Gull and Herring Gull). The effect of changes to water-levels at far-field sites are identified as having significant negative effects on two waterbird species (Greenland White-fronted Goose and Greenshank) which are features of the Dyfi Estuary/Aber Dyfi SPA and Cors Fochno & Dyfi Ramsar Site. Effects of displacement to far-field sites (the Somerset Levels & Moors, Chew Valley Lake and Burry Inlet) were identified as a likely significant negative effect for 15 waterbird species. This might in turn affect the birds wintering at those sites through competition and density-dependent mortality. In summary, and bearing in mind that species can be affected via more than one pathway, the B3 Cardiff to Weston Barrage will significantly negatively affect 34 waterbird receptors (including the waterbird assemblage).

5.2.116 There is the potential for population collapse and effectively extinction of genetically distinct Atlantic salmon populations in particular within the Rivers Wye and Severn and to a lesser extent the Usk. There is the potential for the extinction of the twaite shad populations within the Rivers Usk, Wye and Severn. Furthermore, although it has not been possible to quantify far-field effects there is potential for effects to be seen within the remaining UK population within the River Tywi. Were the B3 Cardiff to Weston Barrage to result in significant population reductions within the River Tywi as well as the Usk, Wye and Severn, there is potential for whole UK stock extinction. There is the potential for reductions in the population size of sea lamprey within the Rivers Usk and Wye and the European stock and for reductions in the population size of river lamprey within the Rivers Usk and Wye and the UK stock. Thus there is likely to be a significant negative effect on the River Usk/Afon Wysg SAC, River Wye/Afon Gwy SAC and Afon Tywi/River Tywi SAC. There is the potential for reductions in the outputs of silver eel from these rivers which could make compliance with the EU Eel Regulations and associated escapement targets a significant challenge (see Table 5.10).

5.2.117 Construction activities at each landfall point would require a temporary working area of 10ha and a permanent land take of 2.5ha, resulting in temporary and permanent habitat loss in some areas of the Penarth Coast SSSI and the Mendip Limestone Grasslands SAC and Brean Down SSSI and some fragmentation and / or degradation of these sites is likely. This may also result in species disturbance and / or mortality. Significant cumulative negative effects may arise as a result of the proposed Steart Coastal Management Project managed realignment at Bridgwater Bay. Similar significant negative effects may also occur during decommissioning.

5.2.118 Increased water levels in watercourses within the impoundment could lead to permanent habitat loss, fragmentation and degradation affecting two SACs (River Wye/Afon Gwy SAC and River Usk/Afon Wysg SAC), three SSSIs (two of which are the SACs above) and three LNRs. Such increases in water levels may counteract the water level reduction predicted as a result of climate change. This would result in a significant positive effect (which may be reversed following decommissioning). Increases in water above the ground surface are likely to negatively affect the Mendip Limestone Grasslands SAC, the complex of SSSIs that make up the Gwent Levels, Magor Marsh SSSI, Severn Estuary SSSI and the Newport Wetlands NNR[12] through permanent habitat loss, fragmentation and degradation. There may also be significant negative effects resulting from species mortality and / or a reduction in abundance. Terrestrial and freshwater ecology may also be significantly negatively affected by far-field effects on water levels.

Alternative Option B4: Shoots Barrage – Biodiversity effects

5.2.119 A generic discussion of biodiversity effects is described in sections 5.2.86 – 5.2.105. More information for this alternative option is provided below.

5.2.120 The physicochemical effects would result in subsequent effects on biodiversity, resulting in both positive and negative effects on biodiversity, but with overall significant negative effects on the Severn Estuary/Môr Hafren SAC, SPA and Ramsar site.

5.2.121 Changes in water levels which modify the extent of habitats would result in significant negative effects on most intertidal receptors (intertidal mudflat and sandflat, intertidal shingle and rock, seaweed and eelgrass) (see Table 5.6 and Figure 5.12). Further significant negative effects on intertidal mudflat and sandflats are predicted as a result of long-term morphological changes (see Table 5.8).

5.2.122 The predicted far-field increases in the level of high water may result in a landward displacement of saltmarsh and potential loss of saltmarsh where it is constrained by flood defences or natural features. Where saltmarsh was lost, it would be expected to be replaced by an equivalent area of intertidal mudflat and sandflat. This may affect the Kenfig/Cynffig SAC. The reduction in saltmarsh is considered to be a significant negative effect, although there is a significant level of uncertainty surrounding the magnitude of far-field water level changes.

5.2.123 Changes in habitat quality are predicted to give rise to significant effects through a number of different mechanisms. Reductions in the short-term erosion and deposition of mud are predicted to have significant positive effects on the remaining intertidal mudflats especially, although changes in sand transport and mud deposition are predicted to have significant negative effects on subtidal sandbanks in the estuary and Bristol Channel. Predicted reductions in flow speed are assessed as having significant negative effects on subtidal *Sabellaria* reef. Overall, the B4 Shoots Barrage would result in a reduction in the extent of *Sabellaria* reef (area uncertain) and the potential for the substantial reduction in eelgrass (area uncertain). The barrage would act as an obstruction to the migration of epibenthos leading to a collision risk and reduction of larval / adult transport. The alignment of the B4 Shoots Barrage also overlays eelgrass habitat and thus results in a significant negative effect.

[12] As of the 26th March 2010, the Gwlyptiroedd Casnewydd/Newport Wetlands SSSI has been notified. This new SSSI, which falls entirely within the Newport Wetlands NNR boundary, will need to be taken into account in any future assessments.

5.2.124 With regards to water quality, it is unlikely that there would be any deterioration in the WFD ecological status of water bodies for the B4 Shoots Barrage although there may be deteriorations of some components of the relevant WFD water bodies.

5.2.125 Despite the positive effects on some of the marine ecology receptors, the B4 Shoots Barrage would have a negative effect on the Severn Estuary/Môr Hafren SAC as a whole (see also the Report to inform a Stage 2 (Appropriate Assessment) Habitats Regulations Assessment (Severn Tidal Power, 2010b)). This is through reduction in intertidal area and changes to the quality of inter and subtidal habitats that remain.

5.2.126 The effect from the operation phase of changes to or loss of intertidal habitat is likely to have an overall significant negative effect for 16 waterbird species including Ringed Plover, Curlew, Dunlin, Redshank and Shelduck) (see Table 5.9). Significant positive effects were predicted for two waterbird species (Shoveler and Little Egret). Displacement to adjacent sites (Burry Inlet and Somerset Levels & Moors SPA / Ramsar sites) would result in a significant negative effect for the Pintail. This might in turn affect the birds wintering at those sites through competition and density-dependent mortality. In summary, and bearing in mind that species can be affected via more than one pathway, the B4 Shoots Barrage will significantly negatively affect 17 waterbird receptors (including the waterbird assemblage) and will significantly positively affect two waterbird receptors.

5.2.127 There is the potential for population collapse and effectively extinction of genetically distinct Atlantic salmon populations in particular within the Rivers Wye and Severn and to a lesser extent the Usk. There is the potential for the extinction of the River Severn and Wye twaite shad populations. Furthermore, there is potential for reductions in the population size of the Rivers Usk and Tywi (from far-field effects) stocks. It is considered however, that on the basis of the predicted model outputs that populations although reduced in size would likely be retained within the Rivers Usk and Tywi. Predicted losses would represent a significant reduction in sea lamprey population size which with inclusion of additional effects for which it has not currently been possible to quantify could result in population collapse in particular on the River Wye and could reduce European stock size. Predicted losses of river lamprey represent a significant reduction in population size which with incorporation of all compound effects could potentially put the population at risk of collapse and reduce the UK stock size. Thus there is likely to be a significant negative effect on the River Usk/Afon Wysg SAC, River Wye/Afon Gwy SAC and Afon Tywi/River Tywi SAC. Predicted reduced outputs for the Rivers Severn and Wye could represent eel population reductions and place compliance of the EU Eel Regulations at significant risk. Effects upon the outputs of the River Usk however, are considered unlikely to result in significant reductions in population size (see Table 5.10).

5.2.128 Construction activities at each landfall point would require a temporary working area of 7.5ha and a permanent land take of 2.5ha, resulting in temporary and permanent habitat loss in some areas of the Gwent Levels SSSI series as well as undesignated habitat and some fragmentation / degradation of the SSSI site is likely. This may also result in species disturbance and / or mortality. Similar significant negative effects may also occur during decommissioning. During operation, increases in water above the ground surface are likely to negatively affect the River Wye/Afon Gwy SAC and the River Wye and Upper Severn Estuary SSSIs through permanent habitat loss, fragmentation and degradation. There may also be significant negative effects resulting from species mortality and / or a reduction in abundance.

Alternative Option B5: Beachley Barrage – Biodiversity effects

5.2.129 A generic discussion of biodiversity effects is described in sections 5.2.86 – 5.2.105. More information for this alternative option is provided below.

5.2.130 The physicochemical effects would result in subsequent effects on biodiversity, resulting in both positive and negative effects on biodiversity, but with overall significant negative effects on the Severn Estuary/Môr Hafren SAC, SPA and Ramsar site.

5.2.131 Changes in water levels which modify the extent of habitats would result in significant negative effects on intertidal mudflat and sandflat, intertidal shingle and rock (see Table 5.6 and Figure 5.12).

5.2.132 Changes in habitat quality are predicted to give rise to significant effects through a number of different mechanisms. Reductions in the short-term erosion and deposition of mud are predicted to have significant positive effects on intertidal mudflats especially, thus improving the quality of the remaining habitat, although changes in sand transport and mud deposition are predicted to have significant negative effects on subtidal sandbanks in the estuary at Welsh and English Grounds. Predicted reductions in flow speed are assessed as having significant negative effects on subtidal *Sabellaria* reef. Overall, the B5 Beachley Barrage would result in a reduction in the extent of *Sabellaria* reef (area uncertain). The barrage would act as an obstruction to the migration of epibenthos leading to a collision risk and reduction of larval / adult transport.

5.2.133 With regards to water quality, it is unlikely that there would be any deterioration in the WFD ecological status of water bodies for the B5 Beachley Barrage although there may be deteriorations of some components of the relevant WFD water bodies.

5.2.134 Despite the positive effects on some of the marine ecology receptors, the B5 Beachley Barrage would have a negative effect on the Severn Estuary/Môr Hafren SAC as a whole (see also the Report to inform a Stage 2 (Appropriate Assessment) Habitats Regulations Assessment (Severn Tidal Power, 2010b)). This is through the reduction in intertidal area and alterations to the nature of the intertidal and subtidal habitats that remain.

5.2.135 Disturbance during construction and decommissioning may have a significant negative effect on the Wigeon. The effect from the operation phase of changes to or loss of intertidal habitat is likely to have an overall significant negative effect for 15 waterbird species (including Ringed Plover, Curlew and Shelduck) (see Table 5.9). In summary, and bearing in mind that species can be affected via more than one pathway, the B5 Beachley Barrage will significantly negatively affect 15 waterbird receptors (including the waterbird assemblage).

5.2.136 There is the potential for population collapse and effectively extinction of genetically distinct Atlantic salmon populations within the Rivers Wye, Severn and Usk. There is the potential for twaite shad population collapse and extinction in the River Severn, Wye and Usk. There is also potential for reductions in population size for the River Tywi, were significant population reductions to be seen on this river as well there is potential for whole UK stock extinction. There is the potential for population collapse of the sea lamprey populations of the Rivers Wye and Usk and reductions in the European stock size. There is the potential for collapse of the river lamprey population on the Rivers Wye and Usk and reductions in the UK stock size. Thus there is likely to be a significant negative effect on the River Usk/Afon Wysg SAC, River Wye/Afon Gwy SAC and Afon Tywi/River Tywi SAC. It is considered that predicted reduced outputs for the Rivers Severn and Wye could represent eel population reductions and place compliance of the EU Eel Regulations at risk. It is not predicted that output from the River Usk would be reduced and as such there would be no non-compliance risk for this stock (see Table 5.10).

5.2.137 Construction activities at the Aust landfall point would require a permanent land take of 2.5ha, resulting in temporary and permanent loss of undesignated habitats, habitat degradation and species disturbance. Increases in levels in watercourses within the impoundment could affect the Upper Severn Estuary SSSI through permanent habitat loss, fragmentation and degradation. Such increases in water levels may counteract the water level reduction predicted as a result of climate change. This would result in a significant positive effect (which may be reversed following decommissioning). There may also be significant negative effects resulting from a reduction in species abundance.

Alternative Option L2: Welsh Grounds Lagoon – Biodiversity effects

5.2.138 A generic discussion of biodiversity effects is described in sections 5.2.86 – 5.2.105. More information for this alternative option is provided below.

5.2.139 The physicochemical effects would result in subsequent effects on biodiversity, resulting in both positive and negative effects on biodiversity, but with overall significant negative effects on the Severn Estuary/Môr Hafren SAC, SPA and Ramsar site.

5.2.140 Changes in water levels which modify the extent of habitats would result in significant negative effects on intertidal mudflat and sandflat (see Tables 5.6 and 5.7 and Figures 5.12 and 5.13), eelgrass and epibenthos. Changes in eelgrass habitat extent as a result of changes in water level would have a significant negative effect on this species. Overall, the L2 Welsh Grounds Lagoon would result in a reduction in the extent of *Sabellaria* reef (area uncertain) and the potential for the substantial reduction in eelgrass (area uncertain). Long term morphological change may result in an increase in the intertidal area (see Table 5.8), although the overall area would still be smaller than that prior to operation. Changes in habitat quality due to reductions in sand transport would result in significant negative effects on the subtidal sandbanks in the estuary at the Welsh and English Grounds.

5.2.141 With regards to water quality, it is unlikely that there would be any deterioration in the WFD ecological status of water bodies for the L2 Welsh Grounds Lagoon, although there may be deteriorations of some components of the relevant WFD water bodies.

5.2.142 Disturbance during construction and decommissioning may have a significant negative effect on 11 waterbird species as this lagoon alternative option crosses extensive areas of intertidal habitat used by waterbirds. The effect from the operation phase of changes to or loss of intertidal habitat is likely to have an overall significant negative effect for 13 waterbird species, (including Ringed Plover, Curlew, Dunlin, Redshank and Shelduck) (see Table 5.9). In summary, and bearing in mind that species can be affected via more than one pathway, the L2 Welsh Grounds Lagoon will significantly negatively affect 15 waterbird receptors (including the waterbird assemblage).

5.2.143 There is the potential for population collapse and effectively extinction of genetically distinct Atlantic salmon populations within the Rivers Wye, Severn and Usk. There is the potential for twaite shad population collapse and extinction in the River Severn, Wye and Usk. There is also potential for reductions in population size for the River Tywi, were significant population reductions to be seen on this river as well there is potential for whole UK stock extinction. There is the potential for collapse of the sea lamprey population on the River Usk, a significant reduction in population size on the Wye and reductions in European stock size. The losses predicted from the river lamprey population would represent a significant reduction in the River Usk and Wye population size and a reduction in the UK stock size. Thus there is likely to be a significant negative effect on the River Usk/Afon Wysg SAC, River Wye/Afon Gwy SAC and Afon Tywi/River Tywi SAC. Predicted reduced outputs for the Rivers Severn, Wye and Usk could represent eel population reductions and place compliance of the EU Eel Regulations at risk (see Table 5.10).

5.2.144 Construction activities at the Uskmouth landfall point would require road enhancement and a permanent land take of 5ha, resulting in temporary and permanent habitat loss / degradation of some areas of the Newport Wetlands NNR[13]. This may also result in species disturbance and / or mortality. Similar significant negative effects may also occur during decommissioning. During operation, significant negative through hydrology effects would be likely to extend into the Gwent Levels SSSI series located to the east. This would also lead to fragmentation of the NNR and SSSI. Increases in water above the ground surface are likely to negatively affect the Gwent Levels SSSI series and Newport Wetlands NNR through permanent habitat loss, fragmentation and degradation. There may also be significant negative effects resulting from a reduction in species abundance.

Alternative Option L3d: Bridgwater Bay Lagoon – Biodiversity effects

5.2.145 A generic discussion of biodiversity effects is described in sections 5.2.86 – 5.2.105. More information for this alternative option is provided below.

5.2.146 The physicochemical effects would result in subsequent effects on biodiversity, resulting in both positive and negative effects on biodiversity, but with overall significant negative effects on the Severn Estuary/Môr Hafren SAC, SPA and Ramsar site.

5.2.147 Changes in water levels which modify the extent of habitats would result in significant negative effects on intertidal mudflat and sandflat (see Table 5.6 and Figure 5.12). There would also be significant negative long term effects of morphological change on intertidal mudflats and sandflats (see Table 5.8).

5.2.148 The predicted far-field increases in the level of high water may result in a landward displacement of saltmarsh and potential loss of saltmarsh where it is constrained by flood defences or natural features. Where saltmarsh was lost, it would be expected to be replaced by an equivalent area of intertidal mudflat and sandflat. This may affect the Kenfig/Cynffig SAC. The reduction in saltmarsh is considered to be a significant negative effect, although there is a significant level of uncertainty surrounding the magnitude of far-field water level changes.

5.2.149 Changes in habitat quality are predicted to give rise to significant positive effects on intertidal mudflats especially, and significant negative effects on intertidal rock and subtidal sandbanks as a result of changes in erosion and deposition.

[13] As of the 26th March 2010, the Gwlyptiroedd Casnewydd/Newport Wetlands SSSI has been notified. This new SSSI, which falls entirely within the Newport Wetlands NNR boundary, will need to be taken into account in any future assessments.

5.2.150 With regards to water quality, it is uncertain whether there would be any deterioration in the WFD ecological status of water bodies for the L3d Bridgwater Bay Lagoon.

5.2.151 Despite the positive effects on some of the marine ecology receptors, the L3d Bridgwater Bay Lagoon would have a negative effect on the Severn Estuary/Môr Hafren SAC as a whole (see also the Report to inform a Stage 2 (Appropriate Assessment) Habitats Regulations Assessment (Severn Tidal Power, 2010b)). This is through reduction in intertidal area and changes to the quality of inter and subtidal habitats that remain.

5.2.152 Disturbance during construction and decommissioning may have a significant negative effect on three waterbird species (Wigeon, Ringed Plover and Grey Plover). The operational effect of changes to or loss of intertidal habitat is likely to have an overall significant negative effect for nine waterbird species (including Dunlin and Redshank). Effects on breeding seabirds were also identified as a likely significant negative effect for two waterbird species (Lesser Black-backed Gull and Herring Gull) (see Table 5.9). In summary, and bearing in mind that species can be affected via more than one pathway, the L3d Bridgwater Bay Lagoon will significantly negatively affect 13 waterbird receptors. It is considered that the overall waterbird assemblage will not be significantly affected by the L3d Bridgwater Bay Lagoon..

5.2.153 There is the potential for population collapse and effectively extinction of genetically distinct Atlantic salmon populations within the Rivers Wye and Severn and to a lesser extent the Usk. There is the potential for twaite shad population collapse and extinction in the River Severn, Wye and Usk. There is also potential for reductions in population size for the River Tywi, were significant population reductions to be seen on this river as well there is potential for whole UK stock extinction. With regards sea lamprey, these losses would represent reductions in population size for both the Rivers Wye and Usk and the European population. With regards river lamprey, these losses would represent reductions in population size for both the River Wye and Usk and the UK population. Thus there is likely to be a significant negative effect on the River Usk/Afon Wysg SAC, River Wye/Afon Gwy SAC and Afon Tywi/River Tywi SAC. Although representing a reduction to the population size of eel with potential implications for compliance of the EU Eel Regulations it is considered very unlikely that the effects would affect the status of the European eel stock (see Table 5.10).

5.2.154 Construction activities at the Hinkley landfall point would require a permanent land take of 2.5ha and a potential new access required from the existing road network. The construction activities at the Brean Down landfall point would require a temporary working area of 10ha and a permanent land take of 2.5ha. This would result in temporary and permanent habitat loss / degradation of some areas of the Mendip Limestone Grasslands SAC together with Brean Down SSSI. This may also result in species disturbance and / or mortality. Similar significant negative effects may also occur during decommissioning. During operation, increases in water above the ground surface are likely to negatively affect the Somerset Levels Ramsar site, 11 SSSIs and six NNRs and one LNR through permanent habitat loss, fragmentation and degradation. Such increases in water levels may counteract the water level reduction predicted as a result of climate change. This would result in a significant positive effect (which may be reversed following decommissioning). There may also be significant negative effects resulting from a reduction in species abundance.

Historic Environment and Landscape & Seascape effects

5.2.155 The significant effects described below have been informed by the following Topic Papers and their annexes; Historic Environment and Landscape & Seascape as well as the Historic Environment and Landscape & Seascape Theme Paper (see Appendix 1). See Appendix 9 for a summary of all the identified likely significant effects of the alternative options. The studies undertaken within this theme have been informed by the physicochemical and biodiversity themes.

5.2.156 The historic environment is likely to be directly affected by the footprint of the alternative option, albeit that the alignment is only indicative at this strategic stage. Enabling and construction for permanent, temporary and ancillary works could result in loss/damage to a broad spectrum of the historic environment resource, within and immediately adjacent to the final design footprints. There may also be negative cumulative effects on the historic environment resource, depending on the location and timing of other projects.

5.2.157 During operation, alterations to the tides and wave climate could change the erosion/accretion patterns of the upper intertidal area adding to existing coastal erosion of soft coastline which is an existing major threat to the survival of broad spectrum of the historic environment resource. Furthermore, changes to the sedimentation and erosion patterns within the intertidal zone could lead to the covering of sites/areas which were previously exposed thus increasing their protection from erosion and damage. Changes to the sedimentation and erosion patterns within the subtidal zone could lead to the exposure of sites on the seabed which were previously buried thus increasing their vulnerability to erosion and damage; or the covering of sites on the seabed which were previously exposed thus increasing their protection from erosion and damage.

5.2.158 With regards to landscape and seascape, construction and decommissioning disturbance from the alternative option, working areas and associated lighting would have significant negative effects on the landscape and seascape character. There would also be an altering of the views in and around the barrage landfalls and for landscape and seascape areas with inter-visibility with the construction sites. The zones of theoretical visibility are shown in Figure 5.14.

5.2.159 The significant negative effects on landscape character and visual amenity would remain during the operational phase but at a reduced level without the temporary construction areas and related disturbance. The hydraulics and geomorphology changes to the estuary, including the change in the tidal prism, may lead to significant negative effects in terms of changes to both the landscape and seascape character of the estuary and its tributaries. Where the reduced tidal range leads to permanent inundation of the estuary bed, there would be an appearance of a higher tide around the estuary. This effect would greatly reduce the daily visual variety of the estuary's seascape. Changes in habitat extent and presence of waterbirds would also have a significant negative effect on the seascape character.

Insert Figure 5.14

Alternative Option B3: Cardiff to Weston Barrage – Historic Environment and Landscape & Seascape effects

5.2.160 A generic discussion of historic environment and landscape & seascape effects is described in sections 5.2.155 – 5.2.159. More information for this alternative option is provided below.

5.2.161 Significant negative effects would result from the loss of the known and potential historic environment resource within the design footprint. The barrage corresponds with 68 recorded components of the historic environment resource and also passes through areas of medium to high archaeological potential. There would also be negative effects to the setting and context of three Scheduled Monuments (Brean Down, Sully Island Fort and St Mary's Well) which are in close vicinity to the barrage. Proposed dredging routes would affect a number of known wrecks and pass through areas of medium to high maritime archaeological potential.

5.2.162 Within the Severn Estuary and the Shoots, hydraulics and geomorphology changes may result in both positive and negative significant effects on the historic environment. Increased subtidal sedimentation may afford protection to the known and potential resource in the Inner Bristol Channel, the Severn Estuary, The Shoots and the Upper Severn Estuary although it may also restrict access and the study of the resource. There may also be permanent loss of or damage to the historic environment resource and the restriction of access to the intertidal resource. Raised water levels along parts of the Irish and West Wales coastlines may have a significant negative effect on the survival of the historic environment resource where it exists and is sensitive to this type of change.

5.2.163 With regards to landscape, there would be significant negative effects on landscape character at Lavernock Point, Brean Beach and Brean Down and on the seascape from Nash Point to Gold Cliff on the Welsh side and from Berrow/Steart to Weston on the English side of the estuary. There would also be a reduction in the extent of saltmarsh upstream of B3 Cardiff to Weston Barrage resulting in a significant negative effect on the quality and interest of the seascape character. The seascape character of the entire estuary upstream of B3 Cardiff to Weston Barrage would be negatively affected with loss of sight to the lower parts of the intertidal zone. This may be considered by some to have a significant positive effect on the river corridors that flow through settlements into the Severn Estuary upstream of B3 Cardiff to Weston Barrage, primarily the Usk and Wye. Others may consider the change to the appearance of the rivers as a loss of visual character and local distinctiveness.

5.2.164 There would also be a significant negative effect on the River Severn's character by loss of the natural Severn Bore phenomenon and on the night-time seascape character by the provision of illumination in a relatively dark area of the Severn Estuary. Power transmission lines running from the proposed Hinkley Point C Nuclear Power Station may result in a cumulative effect on the landscape character.

5.2.165 In terms of visual effects, there would be significant negative effects on land based visual receptors at Lavernock Point, Flat Holm, Steep Holm, Brean Down and Brean Beach through the blocking of views; and intrusion on the wider views experienced at these locations and on sea based visual receptors within 3km of the barrage as it blocks views up and down the estuary (see Figure 5.14). The works associated with large construction compounds and new road infrastructure would result in significant negative landscape and visual effects on both sides of the estuary. Furthermore, the B3 Cardiff to Weston Barrage would result in a significant negative effect in perception of the estuary, especially upstream of the barrage as it becomes 'tamed' by this large structure.

Alternative Option B4: Shoots Barrage – Historic Environment and Landscape & Seascape effects

5.2.166 A generic discussion of historic environment and landscape & seascape effects is described in sections 5.2.155 – 5.2.159. More information for this alternative option is provided below.

5.2.167 Significant negative effects would result from the loss of the known and potential historic environment resource within the design footprint. The barrage passes through areas of medium to high archaeological potential and corresponds with 10 recorded components of the historic environment resource including the remains of a submerged Mesolithic forest and numerous fish traps and fish weirs. The area is also identified as being of high potential for the presence and survival of additional archaeological and palaeo-environmental remains, especially buried prehistoric material. There would also be negative effects during operation on the setting and context of the Gwent Levels Landscape of Outstanding Historic Interest in Wales. Dredging is proposed within areas of medium to high maritime archaeological potential and there are a number of known wrecks on either side of the caisson tow and set down dredging area.

5.2.168 Within the Upper Severn Estuary and the Shoots, hydraulics and geomorphology changes may result in both positive and negative significant effects on the historic environment. Increased subtidal sedimentation may afford protection to the known and potential resource in The Shoots and the Upper Severn Estuary although it may also restrict access and the study of the resource. There may be permanent loss of or damage to the historic environment resource and the restriction of access to the intertidal resource.

5.2.169 With regards to landscape, there would be significant negative effects on landscape character at Caldicot Moor in the Gwent Levels and within the settlement of Severn Beach and on the seascape from Gold Cliff to Chepstow. There would be a significant negative effect on the seascape character of the entire estuary upstream of B4 Shoots Barrage with loss of sight to the lower parts of the intertidal zone. The extent of saltmarsh in the estuary upstream of B4 Shoots Barrage would reduce the quality and interest in the seascape character of the estuary. In addition, the loss of estuarine pattern of sand, mud and rock under the footprint of the barrage through The Shoots would result in a significant negative seascape effect.

5.2.170 The altering of the tidal prism would lead to higher water in the River Wye which may be considered by some to be a significant positive effect to the landscape character of the River Wye corridor through Chepstow, although others may consider the change to the appearance of the rivers as a loss of visual character and local distinctiveness. The altering of the tidal prism would also be a significant negative effect on the lower sections of the Wye Valley AONB upstream of Chepstow.

5.2.171 There would also be a significant negative effect on the River Severn's character by loss of the natural Severn Bore phenomenon, and on the night-time seascape character by the provision of illumination on and offshore of the Gwent Levels, as both are relatively dark area of the Severn Estuary.

5.2.172 In terms of visual effects, there would be significant negative effects on land based visual receptors on the Gwent Levels and at Severn Beach with foreshortening of views and potential reduction in the quality of the wider views experienced at these locations (see Figure 5.14).. This would especially be the case for the users of both Severn Way coastal paths. There is also the potential for consequential significant negative effect should a major power dependent industry site itself on the Gwent Levels and on the relative tranquillity of the landscape of the Gwent Levels from the siting of either the B4 Shoots Barrage alone, or the B4 Shoots Barrage and associated industry. There would also be significant negative effects on sea based visual receptors within 3km of the barrage as it blocks views up and down the estuary.

5.2.173 The works associated with large construction compounds and new road infrastructure would result in significant negative landscape and visual effects on both sides of the estuary and be particularly noticeable in the Gwent Levels. Furthermore, the B4 Shoots Barrage would result in a significant negative effect in perception of the estuary, especially upstream of the barrage as it becomes 'tamed' by this large structure.

Alternative Option B5: Beachley Barrage – Historic Environment and Landscape & Seascape effects

5.2.174 A generic discussion of historic environment and landscape & seascape effects is described in sections 5.2.155 – 5.2.159. More information for this alternative option is provided below.

5.2.175 Significant negative effects would result from the loss of the known and potential historic environment resource within the design footprint. The barrage corresponds with 13 recorded components of the historic environment resource and the area is considered to be of medium potential for the presence and survival of as yet unrecorded remains. Within the terrestrial zone, remains of prehistoric and Romano-British date are recorded in the vicinity of Beachley, with the earthwork remains of Offa's Dyke Scheduled Monument just to the north of the proposed landfall.

5.2.176 Within the Upper Severn Estuary and the Shoots, hydraulics and geomorphology changes may result in both positive and negative significant effects on the historic environment. Increased subtidal sedimentation may afford protection to the known and potential resource in the Upper Severn Estuary although it may also restrict access and the study of the resource. There may be permanent loss of or damage to the historic environment resource and the restriction of access to the intertidal resource.

5.2.177 With regards to landscape, there would be significant negative effects on landscape character at Beachley Peninsula and on the opposite shore at Severn View and on the character of the Upper Severn Estuary. This arises from the physical presence of the Barrage and loss of sight to the lower parts of the intertidal zone. In addition, the loss of the estuarine pattern of sand, mud and rock under the footprint of the barrage would result in a significant negative effect. There would be a significant negative effect on the extent of saltmarsh in the estuary upstream of B5 Beachley Barrage reducing the quality and interest in the seascape character of the upper estuary and on the River Severn's character by loss of the natural Severn Bore phenomenon.

5.2.178 In terms of visual effects, there would be significant negative effects on land based receptors on the Beachley peninsula with foreshortening of views and a potential reduction in the quality of the wider views experienced from this location (see Figure 5.14). There is also the potential for a consequential significant negative effect should a major power dependent industry site itself on the Beachley Peninsula. There would also be significant negative effects on sea based visual receptors within 3km of the barrage as it blocks views between the Upper Severn Estuary and The Shoots. The works associated with large construction compounds and new road infrastructure would result in significant negative landscape and visual effects on the Beachley peninsula side of the barrage.

Alternative Option L2: Welsh Grounds Lagoon – Historic Environment and Landscape & Seascape effects

5.2.179 A generic discussion of historic environment and landscape & seascape effects is described in sections 5.2.155 – 5.2.159. More information for this alternative option is provided below.

5.2.180 Significant negative effects would result from the loss of the known and potential historic environment resource within the design footprint as the lagoon corresponds with 13 recorded components of the historic environment resource. The impounded area of the lagoon contains some of the most important components of the archaeological resource along the Welsh coast including the prehistoric activity and settlement site of Goldcliff, prehistoric peat exposures in the intertidal zone containing prehistoric artefacts and the Gwent Levels Landscape of Outstanding Historic Interest in Wales. There is one known wreck within the lagoon impoundment.

5.2.181 Within the northern part of the Severn Estuary, hydraulics and geomorphology changes may result in both positive and negative significant effects on the historic environment. Increased subtidal sedimentation may afford protection to the known and potential resource within the lagoon although it may also restrict access and the study of the resource. There may also be permanent loss of or damage to the historic environment resource and the restriction of access to the intertidal resource.

5.2.182 With regards to landscape, there would be significant negative effects on the landscape character of the northern part of Gwent Levels running from Portskewett to Uskmouth and the character of the seascape between Gold Cliff and Chepstow and of Avonmouth and Portishead looking out onto the lagoon wall. The loss of the estuarine pattern of sand, mud and rock under the footprint of the lagoon would result in significant negative effects on the seascape. There would be a significant negative effect on the extent of saltmarsh in the lagoon area and the loss of the lower parts of the intertidal zone reducing the quality and interest in the seascape character of the estuary. There would also be a significant negative effect on the night-time seascape character by the provision of illumination on and offshore of the Gwent Levels as it is a relatively dark area of the Severn Estuary.

5.2.183 In terms of visual effects, there would be significant negative effects on land based receptors on the Gwent Levels and especially the users of the Welsh Severn Way coastal path, with foreshortening of views and potential reduction in the quality of the wider views experienced within the Gwent Levels (see Figure 5.14). There is also the potential for a consequential significant negative effect should a major power dependent industry site itself on the Gwent Levels and on the relative tranquillity of the landscape of the Gwent Levels from the siting of either the L2 Welsh Grounds Lagoon alone, or the L2 Welsh Grounds Lagoon and associated industry. There would also be significant negative effects on sea based visual receptors within 3km of the lagoon wall as it blocks views onto the shore of the Gwent Levels and across to the English shore.

Alternative Option L3d: Bridgwater Bay Lagoon – Historic Environment and Landscape & Seascape effects

5.2.184 A generic discussion of historic environment and landscape & seascape effects is described in sections 5.2.155 – 5.2.159. More information for this alternative option is provided below.

5.2.185 Significant negative effects would result from the loss of the known and potential historic environment resource within the design footprint. The barrage corresponds with 59 recorded components of the historic environment resource and also passes through areas of high archaeological potential. Significant negative effects during operation would occur to the setting and context of the Scheduled Monument of Brean Down.

5.2.186 Hydraulic and geomorphology changes may result in both positive and negative significant effects on the historic environment. During operation, increased subtidal sedimentation may afford protection to the known and potential resource in the Inner Bristol Channel, particularly within the impoundment although it may also restrict access and the study of the resource.

5.2.187 With regards to landscape, there would be significant negative effects on the landscape character of Brean Down Scheduled Monument, Stolford and the wider Somerset Levels and Moors regional landscape character area and on the seascape character at Berrow/Steart. There would be a significant negative effect on the extent of saltmarsh in the lagoon area reducing the quality and interest in the seascape character of the estuary. There would also be a significant negative effect on the night-time seascape character by the provision of illumination offshore of Bridgwater Bay as it is a relatively dark area of the Severn Estuary.

5.2.188 In terms of visual effects, there would be significant negative effects on land based receptors on the shore around Bridgwater Bay and especially at the Stolford landfall point where viewers would have views foreshortened and enclosed by the lagoon wall (see Figure 5.14). There is the potential for a consequential significant negative effect should a major power dependent industry site itself on the Somerset Levels and on the relative tranquillity of the landscape of parts of the Somerset Levels from the siting of either the L3d Bridgwater Bay Lagoon alone, or the L3d Bridgwater Bay Lagoon and associated industry. There would also be significant negative effects on sea based visual receptors within 3km of the lagoon wall as it blocks views onto the shore of Bridgwater Bay, across to the Welsh shore and down the Bristol Channel out to open sea. The works associated with large construction compounds and new road infrastructure would result in significant negative landscape and visual effects around the Brean Beach area.

Air & Climatic Factors and Resources & Waste effects

5.2.189 The significant effects described below have been informed by the following Topic Papers and their annexes; Air & Climatic Factors and Resources & Waste as well as the Air & Climatic Factors and Resources & Waste Theme Paper (see Appendix 1). See Appendix 9 for a summary of all the identified likely significant effects of the alternative options. The studies undertaken within this theme have been informed by the physicochemical and biodiversity themes. Most notably, the carbon footprinting assessment has been informed by estuarine changes, particularly changes in the intertidal areas.

5.2.190 There would be no significant negative effects on air quality as a result of any of the alternative options. All alternative options would result in a significant positive effect on global and UK greenhouse gas emissions due to the generation of electricity from a renewable source. The construction and operational greenhouse gas emissions are most profound for the physically larger schemes due to embodied emissions and transport of materials. During operation the main source of emissions are from maintenance dredging and therefore greatest for the barrage structures.

5.2.191 Operational effects also include estuarine changes; i.e. sequestration, siltation, methanogenesis and nitrogen flux. A gain in areas of saltmarsh above the new high tide levels would mean increased carbon sequestration. Areas of mudflat would be lost due to raised water levels under a new tidal regime although it is thought that there would be no change to this carbon store. However, there would be an increase in methanogenesis due to anaerobic conditions generated by raised water levels. Development of other electricity generation projects in the area could add to the greenhouse gas global effect on a positive or a negative way depending on the sustainability of these projects.

5.2.192 The carbon payback period – the number of years that it takes for the emissions displaced from the production of renewable electricity to offset the carbon emissions released during construction, operation and decommissioning is shown for each alternative option in Table 5.11.

5.2.193 The major resources required to construct the alternative options would include aggregates and embankment materials (sand bed and sand core, gravel, crushed rock and armour rock) from within Great Britain and from Europe, albeit in varying amounts for each alternative (Table 5.11). During operation there would be a demand for sites for the reuse of dredged materials and during decommissioning, there would also be a demand for sites for the reuse of recycled aggregates (Table 5.11). During decommissioning, the quantity of recycled aggregates for which reuse opportunities need to be found would be comparable to the quantity of aggregates and embankment materials used during construction. Substantial quantities of other resources and waste generated would be entailed but none have been judged to be significant for any alternative option.

5.2.194 For all alternative options, there is likely to be a significant negative effect on aggregates and embankment materials from additional quarrying and dredging requirements to meet demand, as well as transport. There is also likely to be a significant negative far-field effect on aggregates and embankment materials for all alternative options (except B5 Beachley Barrage) as construction would require armour stone imported from Europe. For all alternative options, a significant negative cumulative effect on aggregates and embankment materials is also likely, should any of the proposed projects in the vicinity of the Severn Estuary be undertaken at the same time as any of the alternative options.

5.2.195 For each alternative option, Table 5.11 records the significant resources and waste requirements and the emissions which would occur during construction, operation and decommissioning. It also includes the carbon payback period and emissions displaced which for all alternative options demonstrates a significant positive effect on global and UK greenhouse gas emissions.

Table 5.11 Air & Climatic Factors, Resources & Waste: Selected Statistics

Factor	B3 Cardiff to Weston Barrage	B4 Shoots Barrage	B5 Beachley Barrage	L2 Welsh Grounds Lagoon	L3d Bridgwater Bay Lagoon
Construction					
Net annual demand for virgin aggregates and embankment materials (m tonnes) (average based on the total demand divided by number of years construction) (Proportion assumed to be from reused project dredging materials and not included in total)	3.6 (61%)	3.1 (28%)	0.4 (50%)	13.9 (6%)	17.9 (0%)
NOx emissions (Tonnes)	110443	25172	7247	84523	84651
PM_{10} emissions (Tonnes)	2345	515	152	1089	1672
SO_2 emissions (Tonnes)	27615	5582	1949	16708	16708
GHG emissions (Mt CO_2)	14 - 28	2.3 - 4.5	0.8 - 1.6	7 -14	8 - 15
Operation					
Dredging for navigation (Mm3/yr)	2	1.75	1	0	0.06
NO_2 Offsetting (kT) over lifespan of option[1]	1.8	-3.5	-1.1	2.9	1.7
PM_{10} Offsetting (kT) over lifespan of option[1]	-0.1	-0.2	-0.1	0.1	0.00
SO_2 Offsetting (kT) over lifespan of option[1]	3.5	-0.7	-0.6	2.1	1.3
Base net emissions displaced (Mt CO_2) (low-high estimates) (range accounts for uncertainty)	-114 (-147, -78)	-22 (-34, -16)	-13 (-20, -9)	-17 (-30, -9)	-47 (-54, -29)
Base carbon payback (yrs) (low-high estimates)	2.6 (-0.8, 7)	3.5 (-6.3, 7.8)	2.8 (-5.7, 7.7)	6.1 (-4.2, 13.3)	3.2 (2.6, 8.5)
Decommissioning					
GHG emissions (Mt CO_2)	0.7- 3	0.1- 0.4	0.03- 0.07	0.4- 0.75	0.3- 0.7

[1] Offsetting was calculated using Options Definitions Report (Parsons Brinckerhoff, 2010), emissions factors for fossil fuel derived electrical power were used from the NAEI database, taking into account the gradual reduction of the fossil fuel mix of electrical power generation by ensuring that fossil fuel air pollution emissions remained proportionate to the CO_2 emissions from overall power generation.

Source: Air & Climatic Factors and Resources & Waste Theme Paper

Society & Economy effects

5.2.196 The significant effects described below have been informed by the following Topic Papers and their annexes; Communities, Noise & Vibration, Navigation and Other Sea Uses as well as the Society & Economy Theme Paper (see Appendix 1). See Appendix 9 for a summary of all the identified likely significant effects of the alternative options. The studies undertaken within this theme have been informed by all the preceding themes.

5.2.197 Each alternative option is likely to have significant negative temporary effects on health and quality of life of the local population adjacent to the landfall points resulting from the concentration of construction activities in these areas and temporary disruption from construction traffic, air quality and landscape issues during the construction period. Figure 5.15 shows the middle layer super output areas (MSOAs) affected by each alternative option.

5.2.198 The construction period is likely to lead to a temporary increase in employment and the operational period would lead to a permanent increase in local employment[14]. These are considered to be positive, although non-significant effects (see Table 5.12).

5.2.199 In addition, during the operation stage of all the alternative options, there would be significant negative effects on salmon fishing supported employment as a result of the identified closure of salmon and sea trout fisheries within the Rivers Wye, Severn and Usk. There are also predicted to be negative effects on eel populations within the Rivers Severn and Wye, potentially leading to the partial or complete closure of heritage (elver) fisheries (also sometimes referred to as migratory commercial fisheries) within the Severn Estuary and tributary rivers (see Table 5.12).

5.2.200 The B3 Cardiff to Weston Barrage is expected to reduce ports' trade, which may have a negative effect on employment. Based upon the conclusions of the DTZ Regional Economic Impact Study (REIS) (DTZ, 2009) and subsequent REIS update (STP Regional Workstream, 2010), a 'medium impact scenario' has been applied as an indicator for the potential effect of the alternative options on the ports sector. For the purposes of this SEA, it is assumed that port-related employment corresponds directly with port trade. Smaller decreases are set out under the REIS medium impact scenario for the other alternative options which are not considered significant in terms of the SEA (see Table 5.12).

[14] The expectation is that up to 20% of construction labour will be recruited locally provided this does not exceed 10% of the local area's supplier of construction sector employment. The balance of construction labour (80%+) will be incomers combining a mix of daily commuting construction workers from the wider sub-region and more distant incomers requiring local accommodation. In the absence of information on the skills mix required for operations and maintenance it is assumed that 50% of staff can be recruited locally and 50% will be from outside the local area.

Table 5.12 Summary of Significant Employment Effects for each Alternative Option

Effect	Alternative Option				
	B3 Cardiff to Weston Barrage	**B4 Shoots Barrage**	**B5 Beachley Barrage**	**L2 Welsh Grounds Lagoon**	**L3d Bridgwater Bay Lagoon**
Operational Employment	750 – 1,000 FTE permanent operational employment.	100 – 200 FTE permanent operational employment.	80 – 100 FTE permanent operational employment.	120 – 180 FTE permanent operational employment.	200 – 300 FTE permanent operational employment.
Effects on Ports During Construction[1]	1,850 FTE lost	No significant effects			
Effects on Ports During Operation[1]	4,200 FTE lost	No significant effects			
Effect on recreational / tourism fisheries employment	Loss of salmon and sea trout fisheries employment and heritage (elver) fisheries supported employment 58 FTE lost	Loss of salmon and sea trout fisheries employment and heritage (elver) fisheries supported employment 58 FTE lost	Loss of salmon and sea trout fisheries employment and heritage (elver) fisheries supported employment 58 FTE lost	Loss of salmon and sea trout fisheries employment and heritage (elver) fisheries supported employment 58 FTE lost	Loss of salmon and sea trout fisheries employment and heritage (elver) fisheries supported employment 58 FTE lost

[1] Based upon the conclusions of the DTZ Regional Economic Impact Study (REIS) (DTZ, 2009) and subsequent REIS update (STP Regional Workstream, 2010), a 'medium impact scenario' has been applied as an indicator for the potential effect of the alternative options on the ports sector. It is assumed that port-related employment corresponds directly with port trade.

5.2.201 Construction phase activities that would generate noise disturbance include rock breaking through the use of explosives and rock fill, dredging and trenching activities and movement of vessels. Decommissioning activities would also generate similar noise disturbance. During operation, the turbines, movement of other mechanical components and movements of vessels required for maintenance would also create noise. However, none of these result in significant shore-based noise effects associated with any of the alternative options.

5.2.202 With regards to navigation, the primary significant negative effect is to provide a direct barrier to navigation, requiring the addition of locks to allow vessels to traverse the two different water levels. It is assumed that locks in the structures, port modifications and dredging of navigational channels would be undertaken as part of each alternative option. Potential significant negative effects to navigation during the construction phase may also arise as a result of construction activities and additional ship movements related to the construction of the barrage or lagoon.

5.2.203 The physicochemical changes which have the potential to result in significant effects for navigation comprise alteration to tide water levels, water velocity, mud and sand transport, morphological evolution and water density. Reduction of spring tide levels would affect the access window that vessels with large draughts would have to access the ports. Conversely, an increase in low water level for both spring and neap tides would increase the access windows for vessels with smaller draughts to ports. Deposition of sediment and long term effects on seabed morphology have the potential to significantly negatively affect navigation. Changes to tidal currents within the Severn Estuary could aid or hinder navigation depending on velocity, location and direction as well as affect transit time to navigate locks.

5.2.204 Other sea uses may also be significantly affected by physicochemical changes, effects on biodiversity and effects on the historic environment and landscape and seascape. Further details are provided for each alternative option below.

Insert Figure 5.15

<u>*Alternative Option B3: Cardiff to Weston Barrage – Society & Economy effects*</u>

5.2.205 A generic discussion of society & economy effects is described in sections 5.2.196 – 5.2.204. More information for this alternative option is provided below.

5.2.206 Construction of B3 Cardiff to Weston Barrage is likely to have significant negative effects on health and quality of life of the local population within areas of Vale of Glamorgan and Sedgemoor (see Figure 5.15), resulting from the concentration of construction activities in these areas and the resultant disruptions from construction traffic, air quality and landscape issues during the construction period. The effects are likely to include increased traffic movements along the local road network and associated with this it is anticipated that there would be localised increases in noise effects and a reduction in air quality, which could be compounded through congestion at pinch points in the local road network. Overall this could have a detrimental effect upon the quality of life for those affected. Cumulative effects may also occur should the construction period coincide with the construction period of other projects.

5.2.207 The B3 Cardiff to Weston Barrage would result in both positive and negative effects on employment. The construction period is likely to lead to a temporary increase in employment (7,500 – 8,500 FTE/year during 4 peak years of construction) and the operational period would lead to a permanent increase in local employment (750 – 1,000 FTE). These are considered to be positive, although non-significant effects.

5.2.208 The B3 Cardiff to Weston Barrage is expected to reduce ports' trade, which may have a negative effect on employment (see table 5.12). Based upon the conclusions of the DTZ Regional Economic Impact Study (REIS) (DTZ, 2009) and subsequent REIS update (STP Regional Workstream, 2010), a 'medium impact scenario' has been applied as an indicator for the potential effect of the alternative options on the ports sector. For the B3 Cardiff to Weston Barrage, this scenario represents loss of 30% trade from all ports affected during the construction phase, increasing to 60% by the end of the operational phase. For the purposes of this SEA, it is assumed that port-related employment corresponds directly with port trade, resulting in a significant negative effect of a loss of 1,850 full-time equivalent (FTE) employees by the end of the construction phase, increasing to 4,200 FTE lost by 2140[15]. Smaller decreases are set out under the REIS medium impact scenario for the other alternative options (2.5% by the end of construction, increasing to 5% by the end of operation) which are not considered significant in terms of the SEA.

5.2.209 The potential for the collapse of salmon and sea trout populations within the Rivers Wye and Severn and with less certainty the Usk would lead to the cessation in salmon and sea trout fishing and would also result in a significant negative effect on salmonid fishing supported employment.

5.2.210 Bristol Port (including the recently consented Deep Sea Container Terminal) and the Port of Newport would be significantly negatively affected during construction by risks to navigational safety and insufficient depth in the new deep water navigation channel from Lavernock Point. It would also be negatively affected during operation by increased transit time, reduced high tide levels, an increase in peak water velocity at the barrage and a reduction in navigable depth in the port approach channel.

5.2.211 The Port of Cardiff would be significantly negatively affected during construction by risks to navigational safety and insufficient depth in the new deep water navigation

[15] NB: Results are derived from a regional level analysis (DTZ Regional Economic Impact Study (DTZ, 2009)) and subsequent update (STP Regional Workstream, 2010).

channel from Lavernock Point. It would also be negatively affected during operation by increased transit time, an increase in peak water velocity at the barrage and a reduction in navigable depth in the port approach channel.

5.2.212 Sharpness Dock would be significantly negatively affected during construction by risks to navigational safety. It would also be negatively affected during operation by increased transit time, reduced high tide levels, an increase in peak water velocity at the barrage and a reduction in navigable depth in the port approach channel. The Port of Bridgwater would be negatively affected during operation by reduced high tide levels.

5.2.213 In addition, increased traffic associated with operation of the consented Deep Sea Container Terminal at Bristol Port may result in a cumulative effect on the Port of Cardiff and the Port of Bridgwater in terms of increased transit times through barrage locks.

5.2.214 The B3 Cardiff to Weston Barrage would also result in a number of negative significant effects to other sea uses. These include a loss of marine aggregate resource area at Holm sands and a diminished resupply of aggregate resource sites. Construction plant, barges and caissons would disrupt aggregate dredging operations and, as a result of increases in transit time, there would also be a reduced access of aggregate extraction dredgers to ports upstream of the barrage. The waste disposal industry is likely to be affected by undermining or smothering of waste outfalls and tide locking of outfalls (as identified in the physicochemical theme). Immediately following the initial operation of the B3 Cardiff to Weston Barrage, there would be an increase in volume of dredge material requiring disposal. Furthermore, there would be reduced current speeds resulting in existing dredge waste disposal sites becoming unsuitable. In addition, there would be significant negative effects on the energy industry through morphological changes affecting the integrity of power station intake and outfall structures and possible oversupply of power to the national grid in combination with the construction of Oldbury and Hinkley C nuclear power stations.

5.2.215 With regards tourism and recreation, the B3 Cardiff to Weston Barrage would result in both positive and negative significant effects. The barrage is likely to create far calmer hydrodynamic conditions upstream and this would generally favour recreational users of the estuary, resulting in a significant positive effect. Furthermore, there may be positive effects if the barrage becomes a visitor attraction.

5.2.216 However, the barrage is likely to prevent the formation of the Severn Bore, resulting in significant negative effects. Furthermore, increases in coastal erosion upstream of the barrage may affect the integrity of structures used for marine recreation and siltation may affect the viability of marinas and mooring sites. The presence of the barrage also has the potential to increase incident response times for rescue organisations operating in the vicinity of the structure.

5.2.217 Coastal tourism may be negatively affected if the construction phase of the barrage coincides with other large-scale projects. Coastal tourism may also be negatively affected during the operational phase through a reduced aesthetic appeal of the estuary. Changing patterns of sediment transport and deposition on the coastline may affect tourism associated with pleasure beaches and nature-based tourism may be reduced through the reductions in the population of estuary waterbirds.

Alternative Option B4: Shoots Barrage – Society & Economy effects

5.2.218 A generic discussion of society & economy effects is described in sections 5.2.196 – 5.2.204. More information for this alternative option is provided below.

5.2.219 The B4 Shoots Barrage would result in both positive and negative effects on employment. The construction period is likely to lead to a temporary increase in employment (2,000 – 3,000 FTE/year during 3 peak years of construction) and the operational period would lead to a permanent increase in local employment (100 – 200 FTE). These are considered to be positive, although non-significant effects.

5.2.220 The potential for the collapse of salmon and sea trout populations within the Rivers Wye and Severn and with less certainty the Usk would lead to the cessation in salmon and sea trout fishing and would result in a significant negative effect on salmonid fishing supported employment.

5.2.221 Sharpness Dock would be significantly negatively affected during construction by risks to navigational safety. It would also be negatively affected during operation by increased transit time, an increase in peak water velocity at the barrage and a reduction in navigable depth in the port approach channel. Bristol Port (including the consented Deep Sea Container Terminal) would be significantly negatively affected during construction by risks to navigational safety. It would also be negatively affected during operation by a reduction in navigable depth in the port approach channel. The Ports of Cardiff and Newport would be significantly negatively affected during construction by risks to navigational safety.

5.2.222 The B4 Shoots Barrage would also result in a number of significant effects to other sea uses. The marine aggregate extraction industry is likely to be affected by the diminished resupply of aggregate resource sites in the study area. The waste disposal industry is likely to be affected by smothering or undermining waste outfalls and tide locking of outfalls (as identified in the physicochemical theme). The B4 Shoots Barrage is in very close proximity to the military practice areas near Redwick and plant is likely to require access to this area during the construction period which has the potential to disrupt military practice activity.

5.2.223 With regards tourism and recreation, the B4 Shoots Barrage would result in both positive and negative significant effects. There may be positive effects if the barrage becomes a visitor attraction.

5.2.224 With regards to marine recreational users, the barrage is likely to prevent the formation of the Severn Bore. The presence of the barrage also has the potential to increase incident response times for rescue organisations operating in the vicinity of the structure.

5.2.225 Coastal tourism may be negatively affected if the construction phase of the barrage coincides with other large-scale projects. Coastal tourism may also be negatively affected during the operational phase through a reduced aesthetic appeal of the estuary. Changing patterns of sediment transport and deposition on the coastline may affect tourism associated with pleasure beaches and nature-based tourism may be reduced through the reductions in the population of estuary waterbirds.

Alternative Option B5: Beachley Barrage – Society & Economy effects

5.2.226 A generic discussion of society & economy effects is described in sections 5.2.196 – 5.2.204. More information for this alternative option is provided below.

5.2.227 The B5 Beachley Barrage would result in both positive and negative effects on employment. The construction period is likely to lead to a temporary increase in employment (1,500 – 3,000 FTE/year during 3 peak years of construction) and the operational period would lead to a permanent increase in local employment (80 – 100 FTE). These are considered to be positive, although non-significant effects.

5.2.228 The potential for the collapse of salmon and sea trout populations within the Rivers Wye, Severn and Usk would lead to the cessation in salmon and sea trout fishing and would result in a significant negative effect on salmonid fishing supported employment.

5.2.229 The Port of Newport would be significantly negatively affected during construction by risks to navigational safety. It would also be negatively affected during operation by increased transit time, changes to the tidal regime, an increase in peak water velocity at the barrage and a reduction in navigable depth in the port approach channel. Bristol Port (including the consented Deep Sea Container Terminal), the Port of Cardiff, the Port of Newport and Sharpness Dock would be significantly negatively affected during construction by risks to navigational safety..

5.2.230 The B5 Beachley Barrage would also result in a number of significant effects to other sea uses. The aggregate extraction industry would be affected by a diminished resupply of aggregate resource sites in the study area. There would also be a significant negative effect on the waste disposal industry through the tide locking of outfalls (as identified in the physicochemical theme).

5.2.231 With regards tourism and recreation, the B5 Beachley Barrage would result in both positive and negative significant effects. There may be positive effects if the barrage becomes a visitor attraction.

5.2.232 With regards to marine recreational users, the barrage is likely to prevent the formation of the Severn Bore and siltation may affect the viability of marinas and mooring sites. The presence of the barrage also has the potential to increase incident response times for rescue organisations operating in the vicinity of the structure.

5.2.233 Coastal tourism may be negatively affected if the construction phase of the barrage coincides with other large-scale projects. Coastal tourism may also be negatively affected during the operational phase through a reduced aesthetic appeal of the estuary. Changing patterns of sediment transport and deposition on the coastline may affect tourism associated with pleasure beaches and nature-based tourism may be reduced through the reductions in the population of estuary waterbirds.

Alternative Option L2: Welsh Grounds Lagoon – Society & Economy effects

5.2.234 A generic discussion of society & economy effects is described in sections 5.2.196 – 5.2.204. More information for this alternative option is provided below.

5.2.235 Construction of L2 Welsh Grounds Lagoon is likely to have significant negative temporary effects on health and quality of life of the local population within areas of Monmouthshire and Newport (see Figure 5.15) as a result of the cumulative disturbance from increased traffic and associated air quality and landscape issues during construction. The effects are likely to include increased traffic movements along the local road network and associated with this it is anticipated that there would be localised increases in noise effects and a reduction in air quality, which could be compounded through congestion at pinch points in the local road network. Overall this could have a detrimental effect upon the quality of life for those affected.

5.2.236 The L2 Welsh Grounds Lagoon would result in both positive and negative effects on employment. The construction period is likely to lead to a temporary increase in employment (3,000 – 4,000 FTE/year during 4 peak years of construction) and the operational period would lead to a permanent increase in local employment (120 – 180 FTE). These are considered to be positive, although non-significant effects.

5.2.237 During operation, there may also be possible effects on the marine aggregates dredging cycle for Bedwyn Sands and North Middle Ground extraction which would have a negative effect on employment within this industry.

5.2.238 The potential for the collapse of salmon and sea trout populations within the Rivers Wye, Severn and Usk would lead to the cessation in salmon and sea trout fishing and would result in a significant negative effect on salmonid fishing supported employment.

5.2.239 Bristol Port (including the consented Deep Sea Container Terminal) would be significantly negatively affected during construction by risks to navigational safety. It would also be negatively affected during operation by a reduction in navigable depth in the port approach channel. The Port of Cardiff, Newport and Sharpness Dock would be significantly negatively affected during construction by risks to navigational safety.

5.2.240 The L2 Welsh Grounds Lagoon would also result in a number of significant effects to other sea uses. The marine aggregate extraction industry is likely to be affected during the construction phase as plant would be present at a number of aggregate reserve sites within the estuary, potentially disrupting industry operations. The structure itself is located on several reserve sites, causing a reduction in the area available for aggregate operations. There would also be a diminished resupply of aggregate resource sites in the study area. The waste disposal industry is likely to be affected as the lagoon also occupies the same location as two dredged material disposal sites and is located within 500m of another site, thus reducing the area available for dredged material disposal waste.

5.2.241 With regards tourism and recreation, the L2 Welsh Grounds Lagoon would result in both positive and negative significant effects. The lagoon is likely to create far calmer hydrodynamic conditions within the impoundment and this would generally favour recreational users of the estuary.

5.2.242 The presence of the lagoon also has the potential to increase incident response times for rescue organisations operating in the vicinity of the structure, resulting in a significant negative effect. Coastal tourism may be negatively affected if the construction phase of the lagoon coincides with other large-scale projects. Coastal tourism may also be negatively affected during the operational phase through a reduced aesthetic appeal of the estuary. Changing patterns of sediment transport and deposition on the coastline may affect tourism associated with pleasure beaches. Nature based tourism may be reduced through the reduction in the population of estuary waterbirds and disruption to the Gwent Levels bird population during construction.

Alternative Option L3d: Bridgwater Bay Lagoon – Society & Economy effects

5.2.243 A generic discussion of society & economy effects is described in sections 5.2.196 – 5.2.204. More information for this alternative option is provided below.

5.2.244 Construction of L3d Bridgwater Bay Lagoon is likely to have significant negative temporary effects on health and quality of life of the local population within areas of West Somerset and Sedgemoor (see Figure 5.15) due to traffic and air quality and landscape issues during construction. The effects are likely to include increased traffic movements along the local road network and associated with this it is anticipated that there would be localised increases in noise effects and a reduction in air quality, which could be compounded through congestion at pinch points in the local road network. Overall this could have a detrimental effect upon the quality of life for those affected. It is thought that these effects could be further compounded should the development of L3d Bridgwater Bay Lagoon take place concurrently with the development of a new nuclear facility at the proposed Hinkley Point C site. Cumulative effects may also occur should the construction period coincide with the construction period of other projects.

5.2.245 The L3d Bridgwater Bay Lagoon would result in both positive and negative effects on employment. The construction period is likely to lead to a temporary increase in employment (4,000 – 6,000 FTE/year during 5 peak years of construction) and the operational period would lead to a permanent increase in local employment (200 – 300 FTE). These are considered to be positive, although non-significant effects.

5.2.246 The potential for the collapse of salmon and sea trout populations within the Rivers Wye, Severn and to a lesser extent Usk would lead to the cessation in salmon and sea trout fishing and would result in a significant negative effect on salmonid fishing supported employment.

5.2.247 The Port of Bridgwater would be significantly negatively affected during construction by risks to navigational safety (there would also be a significant negative cumulative effect on navigational safety during the construction of Hinkley Point C Nuclear Power Plant), changes to the tidal regime and a reduction in navigable depth in the port approach channel. Bristol Port (and the consented Deep Sea Container Terminal), the Port of Cardiff, the Port of Newport and Sharpness Dock would also be affected during operation of changes to the tidal regime.

5.2.248 The L3d Bridgwater Bay Lagoon would also result in a number of significant effects to other sea uses. The marine aggregate extraction industry would be significantly negatively affected as a result of the diminished resupply of aggregate resource sites in the study area. The energy industry is likely to be significantly negatively affected as the lagoon inhibits the dispersion of the thermal plume from Hinkley nuclear power station, resulting in changes to plume characteristics. There is also the risk of a possible oversupply of power to the national grid in combination with construction of Oldbury and Hinkley C nuclear power stations. The L3d Bridgwater Bay Lagoon alternative option also traverses a number of telecommunication cable routes and these cables are likely to be at risk from enhanced basal scour.

5.2.249 With regards tourism and recreation, peak flow speeds within Bridgwater Bay may increase with the presence of the lagoon and this may be undesirable for small craft users and bathers. The presence of the lagoon also has the potential to reduce bathing water quality at Weston-super-Mare and has the potential to increase incident response times for the Burnham-on-Sea lifeboat operating in the vicinity of the structure.

5.2.250 Coastal tourism may be negatively affected if the construction phase of the lagoon coincides with other large-scale projects. Coastal tourism may also be negatively affected during the operational phase through a reduced aesthetic appeal of Bridgwater Bay. Changing patterns of sediment transport and deposition on the coastline may affect tourism associated with pleasure beaches. Nature-based tourism may be reduced through the reductions in the population of estuary waterbirds.

Summary of significant environmental effects

Prior to the application of measures to prevent and reduce effects, all alternative options would change the tidal regime within the enclosed part of the estuary, leading to the permanent submergence of large areas of previously intertidal mud and sandflat. The effects are broadly proportional to the size of each alternative option. Long-term responses over 120-years to the enclosure of the estuary may lead to erosion and additional loss of intertidal area. Large quantities of sediment would be deposited within the enclosure, which for the B4 Shoots Barrage and B5 Beachley Barrage may prove an ongoing issue for the maintenance of navigation. The B3 Cardiff to Weston Barrage may cause small but potentially significant elevated spring tide water levels remote from the Severn Estuary., All options would negatively affect land drainage and flood risk that would need to be managed. In the case of B3 Cardiff to Weston Barrage this may extend to works needed on the West Wales coast. B3 Cardiff to Weston Barrage and L3d Bridgwater Bay Lagoon would have beneficial effects on flood water levels. The L3d Bridgwater Bay Lagoon may affect nearby waste and cooling water discharges.

Under all alternative options, water level changes and sedimentation would lead to the loss of large areas of protected habitat, including intertidal sand and mud. As well as being of conservation importance in their own right, the submergence of these habitats threatens internationally designated sites and important bird populations. Sedimentation within subtidal areas would also affect the conservation interest of the estuary and lead to the loss of designated species. All alternative options risk the loss from the estuary and its tributaries of most migratory fish species, that are internationally protected and some represent the only UK populations. Effects on land drainage pose negative effects for terrestrial ecology.

All alternative options pose risks to the historic environment, visual amenity and landscape and seascape character, some of which is already designated. The nature of the risk depends on the location of the alternative option, rather than solely a function of its size. Far-field water level effects for the B3 Cardiff to Weston Barrage may pose risks of effects on the West Wales and Irish coasts.

All alternative options would use large resource quantities in their construction and, making assumptions about the UK energy mix over a 120-year timeframe, relatively rapidly pay back the carbon used in their construction, operation and decommissioning. Alternative options would displace fossil fuel-derived emissions of carbon, in proportion to their size.

Alternative options would generate employment and some also pose health and quality of life effects to the nearby population during their construction. All alternative options but notably the B3 Cardiff to Weston Barrage, would have negative effects on navigation and port related employment. All alternative options, and the L2 Welsh Grounds Lagoon especially, risk negative effects on marine aggregate extraction. There would be positive and negative effects for recreation and tourism for all options. The B3 Cardiff to Weston Barrage, B4 Shoots Barrage and B5 Beachley Barrage would result in the loss of a bore that can be surfed.

See also Appendix 9 for a summary of all the identified likely significant effects of the alternative options.

Multiple Basin Alternatives

5.2.251 The detail currently available only permits a high-level qualitative assessment to identify key issues and no modelling was undertaken. These variants were therefore not considered to the same level of detail as the alternative options (see also section 4.2).

5.2.252 The following high-level assessment is based on a double basin L3d Bridgwater Bay Lagoon with single directional turbines and pumping (as detailed in section 4.2 and within the Options Definition Report (ODR) (Parsons Brinkerhoff, 2010).

5.2.253 During construction, a double basin L3d Bridgwater Bay Lagoon is likely to have largely the same significant effects as a single basin L3d Bridgwater Bay Lagoon. However, the construction period would be longer and there would be greater civil engineering requirements. It is assumed that this would result in greater noise and vibration levels; greater disturbance to biodiversity and communities, recreation and tourism; and greater disruption to navigation within the vicinity of Bridgwater Bay. There are also likely to be slightly greater construction employment opportunities as a result of the longer construction period. The additional civil engineering would also result in greater demands on resources and there would be greater emissions to air in the extraction and transportation of these resources and in the powering of the additional construction activities required.

5.2.254 Construction of the double basin lagoon would require additional land-take, compared to the single basin lagoon. This is due to the additional dividing wall with the landfall point at Berrow. This is likely to have an increased negative effect for marine ecology; which in turn is likely to have increased significant effects on waterbirds compared with a single basin L3d Bridgwater Bay Lagoon. Construction of the additional embankment structure and landfall point would likely result in greater negative effects on recreation and tourism; landscape and seascape; and potentially the historic environment.

5.2.255 The hydraulics and geomorphology effects are likely to differ between a single basin L3d Bridgwater Bay Lagoon and a double basin L3d Bridgwater Bay Lagoon. When compared with the single basin L3d Bridgwater Bay Lagoon, a double basin L3d Bridgwater Bay Lagoon would result in a greater reduction in intertidal area within the impoundment; the complete loss of the lowest intertidal and an increase in intertidal exposure time (albeit it on the reduced area). There would also be the elimination of stand times and the constant presence of exposed intertidal area (due to the tidal curves being necessarily out of phase between the two basins).

5.2.256 With a double basin L3d Bridgwater Bay Lagoon, there would be major internal differences between the high basin and low basin, with water levels kept constantly lower in the low basin to facilitate constant flow of water through the turbines. In the upper basin, high tide levels may exceed those occurring in the baseline. This may have effects on flood risk. In the lower basin, flood risk would not be a major issue. Depending on which basin the Parrett Estuary drains into, this may have effects on the standard of flood protection provided to the Somerset Levels. Similarly, behind the high basin, groundwater levels would rise with the risk of waterlogging and flooding of basements and subsurface infrastructure. Behind the lower basin, there would be a fall in the groundwater levels with the risk of drying out wetlands. The high level basin which receives inflows from the estuary would be the area where sediment drawn in from the estuary is likely to settle leading to long term accretion.

5.2.257 The loss of intertidal area is likely to result in greater effects than the single basin L3d Bridgwater Bay Lagoon for waterbirds (although within the overall impoundment there would be potential feeding ground at all stages of the tide), as well as marine ecology and landscape and seascape. There are also likely to be greater levels of noise and vibration arising as a result of the extra powerhouse and pumping equipment when compared with the single basin L3d Bridgwater Bay Lagoon. The use of pumping equipment would also increase the carbon emissions of the double basin L3d Bridgwater Bay Lagoon. Furthermore, the installed capacity is likely to be lower than the single basin L3d Bridgwater Bay Lagoon, resulting in a reduction in renewable energy generated and therefore less opportunity for the offsetting of carbon emissions compared to a single basin L3d Bridgwater Bay Lagoon. Whilst access to recreation would still be facilitated within the double basin lagoon, the presence of the dividing rock-filled embankment between the high and low basins would result in greater disruption to other sea users than the single basin L3d Bridgwater Bay Lagoon. It has been assumed for this assessment that there would only be two single directional turbines incorporated in the double basin lagoon. However, were additional turbines to be incorporated, then there would be additional negative effects on migratory and estuarine fish in comparison with the single basin lagoon.

5.2.258 During decommissioning, a double basin L3d Bridgwater Bay Lagoon is unlikely to differ greatly in its significant effects upon the environment, compared with a single basin L3d Bridgwater Bay Lagoon. However due to the greater civil engineering components of the double basin lagoon and the increased resources utilised during construction, it is likely that there would be greater noise and vibration levels and emissions to air generated during decommissioning, greater effects upon the landscape and seascape and greater disruption to navigation. There are also likely to be greater negative effects on the local community due to disruption caused by increased labour force requirements for decommissioning when compared with the single basin lagoon. The increased volume of aggregate and embankment material utilised during construction of the double basin lagoon would result in a greater demand for sites within which to re-use the waste materials arising.

<u>Combinations of alternatives</u>

5.2.259 There are two combinations of alternative options that have been shown to be worthy of further consideration (as detailed in section 4.2 and within the ODR (Parsons Brinckerhoff, 2010)). The first is a combination of L3d Bridgwater Bay Lagoon with the B3 Cardiff to Weston Barrage. The second is a combination of L3d Bridgwater Bay Lagoon with the B4 Shoots Barrage.

5.2.260 The detail currently available only permits a high-level qualitative assessment to identify key issues and no modelling was undertaken. These variants were therefore not considered to the same level of detail as the alternative options (see also section 4.2)

Combination of L3d Bridgwater Bay Lagoon with B3 Cardiff to Weston Barrage

5.2.261 This combination of L3d Bridgwater Bay Lagoon and B3 Cardiff to Weston Barrage could only be built sequentially (with either the barrage or the lagoon being built first). During construction, this combination is likely to have approximately the same significant effects upon the environment as the sum of the individual effects of the construction of each alternative option. However, there are likely to be greater effects upon the local community and landscape and seascape than the sum of the individual effects due to the sequential construction of the two alternative options, which are in close proximity to each other. It is likely that there would be opportunities to utilise the same caisson construction yards for both alternative options, reducing both the need for yard construction and shipping of the caissons. There are also likely to be opportunities to reuse the site compounds for the sequential construction of both alternative options – resulting in reduced land take compared to the sum of the land take needed for the compounds of both alternative options in isolation. There may also be the opportunity for only a single grid connection as both L3d Bridgwater Bay Lagoon and B3 Cardiff to Weston Barrage could be grounded at Brean Down (depending on the capacity of the network). As there would be only one connection, this would result in reduced effects on landscape, terrestrial ecology and the historic environment than the sum of the effects of the construction of both alternative options in isolation.

5.2.262 The effects of the combination on water levels are likely to be larger than with either alternative option on its own. The presence and operation of B3 Cardiff to Weston Barrage and L3d Bridgwater Bay Lagoon is likely to result in a reduction in high-water levels throughout the Severn Estuary and further afield when compared with B3 Cardiff to Weston Barrage alone. It is also possible (subject to further detailed modelling) that they could result in lower high-water levels than the sum of the individual effects of B3 Cardiff to Weston Barrage and L3d Bridgwater Bay Lagoon built in isolation. However, for the purposes of this high-level assessment it is considered likely that the hydraulics and geomorphology effects of this combination would be predominantly equal to those of the sum of the individual effects of the two alternative options operating in isolation.

5.2.263 During operation, there are likely to be greater negative effects on the local landscape and seascape and communities, due to the presence of both alternative options in close proximity. There are likely to be greater negative effects upon waterbird and fish populations than the sum of the effects from operating the individual alternative options in isolation. By operating the two alternative options together, a 15% loss of energy yield is predicted. This means that there would be less renewable energy generated and therefore less opportunity for offsetting of carbon emissions; when compared with the sum of the individual alternative options operating in isolation. However, in relation to noise, the effect experienced is likely to be less than the sum of the individual effects.

5.2.264 During decommissioning, a combination of B3 Cardiff to Weston Barrage and L3d Bridgwater Bay Lagoon is unlikely to differ greatly in its significant effects upon the environment, compared with the sum of the individual effects of the alternative options decommissioned in isolation. However, there are likely to be greater effects upon hydraulics and geomorphology – resulting from more rapid increases in high water levels, decreases in low water levels and redistribution of sediments that would be retained behind the structures. Simultaneous decommissioning would result in greater effects on the local landscape and seascape and fewer effects on air quality, carbon emissions and local communities than the sum of the individual effects.

Combination of L3d Bridgwater Bay Lagoon with B4 Shoots Barrage

5.2.265 This combination could be built either concurrently or sequentially (with either the barrage or the lagoon built first).

5.2.266 During construction, a combination of L3d Bridgwater Bay Lagoon and B4 Shoots Barrage is likely to generally have the same net effects as the sum of the individual effects of the construction of each alternative option. However, there are some differences in the likelihood of effects arising depending on whether construction is carried out concurrently or sequentially.

5.2.267 In order to facilitate concurrent construction, caissons would need to be built outside of the estuary and shipped in. There are likely to be greater emissions to air as a result, compared to the sum of the individual effects of constructing the two alternative options in isolation, where caissons could be constructed on site. Conversely, the sequential construction of the combination would be likely to result in reduced emissions as a result of opportunities to utilise the same caisson construction yards within the estuary. If construction was carried out concurrently, there may be opportunities for reuse of excess materials arising from construction at one site within the other. This is likely to result in reduced demands upon resources for concurrent construction than the sum of the individual demands of constructing the two alternative options in isolation. Sequential construction is likely to result in roughly equal demands, although there may be some minor opportunities for reduction.

5.2.268 There are likely to be opportunities for savings in flood risk costs with sequential construction if L3d Bridgwater Bay Lagoon was constructed before B4 Shoots Barrage, compared to the sum of the individual costs of managing flood risk if the two alternative options were built in isolation. This is because, if built first, L3d Bridgwater Bay Lagoon would be likely to reduce the water levels within the estuary to the degree that the flood risk works associated with B4 Shoots Barrage would no longer be needed. However, if B4 Shoots Barrage was built first then the works would still be needed and there would be no relative savings. There are likely to be greater effects upon fish populations as a result of concurrent construction compared to with sum of the effects of constructing the two alternative options in isolation (effects are expected to be equal with sequential construction). This is due to an increased length of time working in the marine environment.

5.2.269 The effects of the combination on water levels are likely to be larger than with either alternative option on its own. The simultaneous presence and operation of L3d Bridgwater Bay Lagoon and B4 Shoots Barrage is likely to result in a small reduction in high-water levels and a small raising of low water levels throughout the Severn Estuary. This would result in greater effects upon navigation and a marginally greater loss of intertidal area throughout the estuary, than would be expected as a sum of the individual effects of the two alternative options operating in isolation.

5.2.270 The relative reduction in intertidal area is also likely to result in greater effects on marine ecology, waterbirds, and landscape and seascape. The operation of L3d Bridgwater Bay Lagoon and B4 Shoots Barrage would result in greater risks of extinction to fish species that utilise the whole of the estuary, compared to the sum of the individual effects on fish of operating both alternative options in isolation. This is due to the presence of two barriers to route of passage. A 5% loss of energy yield is predicted as a result of the combination of L3d Bridgwater Bay Lagoon and B4 Shoots Barrage. This means that there is likely to be relatively less renewable energy generated and therefore there would be less opportunity for the offsetting of carbon emissions.

5.2.271 During decommissioning, a combination of L3d Bridgwater Bay Lagoon and B4 Shoots Barrage is unlikely to differ greatly in its significant effects upon the environment, compared with the sum of the individual effects of the alternative options decommissioned in isolation. However, there are likely to be fewer effects on local communities, as it is likely that there would be a reduced labour-force requirement during decommissioning. There are also likely to be relative reductions in disturbance and health and quality of life effects upon communities. However, there would also be a reduced positive effect of local employment opportunities compared to the sum of the opportunities that would be expected if both alternative options were decommissioned in isolation. The decommissioning of L3d Bridgwater Bay Lagoon and B4 Shoots Barrage together would result in greater pressure upon sites and facilities for re-use of treatment of waste materials, than the sum of the pressures expected as a result of decommissioning the two alternative options in isolation.

An initial assessment of combination schemes and multiple basin variants has not identified any new issues that were not already evident from considering the five alternative options.

5.3 Assumptions, limitations and uncertainty

The following uncertainties would need to be considered further if an alternative option is taken forward.

Physicochemical

5.3.2 Uncertainties within the hydraulics and geomorphology assessment inevitably lead to uncertainties in the input information used for the other topics. In many cases, for example water level or wave information, the uncertainty surrounding this information is relatively small and does not degrade the assessments that are made using this information. With regards to water levels and associated flood risk far-field effects, limitations of the modelling have prevented consideration of potential increases in high water levels beyond the Llŷn Peninsula on to the North Wales and North West England coast.

5.3.3 The prediction of future suspended solids concentrations and long term morphology evolution is subject to considerable uncertainty. The salinity model provides a reasonable level of agreement with observed salinities that are suitable for a strategic study, but would require a more refined calibration in a more detailed study of an individual option.

5.3.4 For work in the Flood Risk & Land Drainage topic, predictions were taken directly from the Hydraulics & Geomorphology topic. Although high uncertainty surrounds some predictions, the type of change that is expected is more certain than the likely magnitude of change and the rate of change. This has allowed this topic to express the effects of uncertain morphology predictions by uncertain timing of interventions.

5.3.5 The uncertainty in future morphology predictions is also an important contributor to uncertainty in the Biodiversity theme and the scale of long term changes that are likely to affect the navigation and other sea uses topics within the Society and Economy theme.

Biodiversity

5.3.6 There is uncertainty surrounding the predicted changes to marine ecology because the assessment has made a number of simplifying assumptions. There is also a lack of knowledge of the present distribution of some habitats and species in the estuary and limited understanding of the functioning of marine ecosystems resulting in uncertainty regarding the implications of some predicted changes. The assessment also relies on predicted changes to water quality from the physicochemical theme, which have a degree of uncertainty, primarily with regards to eutrophication risk. Uncertainty in the suspended sediment concentrations and the long-term morphology changes also have implications for the assessment of effects on the marine ecology.

5.3.7 There is uncertainty surrounding the predicted changes to waterbirds. The relationships between bird numbers and habitat are well understood, but there are uncertainties surrounding predicted changes in the quality of the remaining intertidal habitat, on which the waterbird modelling is based. The main uncertainties are the extent to which the remaining intertidal habitat would become mud (rather than sand), and thus support increased densities of invertebrates and birds, and the extent to which productivity would increase. Data on intertidal invertebrates within the Severn Estuary and other south-west English estuaries used within the individual-based models is over 20 years old and, though this was the best dataset available, invertebrate communities may have changed since then. Because of these uncertainties the different modelling approaches give quite different predictions for some waterbirds. Nevertheless, subject to qualification, the predictions provided by the IBM default scenario and the HA models do indicate the most likely outcome and so together provide a reasonable basis for assessing the likely significance of effects at this strategic stage.

5.3.8 There is substantial uncertainty surrounding the magnitude of effects on migratory and estuarine fish. This is because there is little information available regarding the behaviour of fish within the estuary, habitat utilisation by fish species and their prey, the effects of water quality on fish populations, the cumulative and synergistic effects of contaminants, or the hearing frequencies and range of many species. In addition, there is little information on the effect of turbine passage on fish populations and the effects of a barrage or lagoon barrier on navigation, orientation and homing behaviour of fish.

Historic Environment and Landscape & Seascape

5.3.9 There is an inherent uncertainty in the predictions of how the intertidal and subtidal profiles would respond to changes to the existing tidal regime and associated patterns of erosion and sediment deposition. This has resultant uncertainty in the assessment of the effects on the historic environment.

5.3.10 With regards to landscape and seascape, there is also uncertainty as to what the reformed tidal areas would look like as sedimentation is likely to have altered considerably the current seascape character of the intertidal areas. Another area of uncertainty is how long it would take the Severn's estuarine system to return to a point of balance where intertidal areas can be readily defined and ascribed a recognisable character e.g. mudflat or sand bank.

Air & Climatic Factors and Resources & Waste

5.3.11 Although the results obtained are as realistic as possible, they do have a substantial range attached to them. Examples of assumptions include source of construction materials; transport means and distances; workers accommodation; dredging material re-use; maintenance requirements; dredging requirements during operation; estuarine changes (sequestration, methanogenesis, siltation and changes to the nitrogen cycle) and emissions factors.

Society & Economy

5.3.12 With regards to the effects on society and economy, there are a number of uncertainties in addition to the physicochemical uncertainties. There is likely to be an increase in ship movements related to the construction of an alternative option. At this stage it is not possible to quantify this potential increase as the number of ship movements would be highly dependent on the detailed design of the selected option and the chosen construction methodology. Furthermore, during operation, there is likely to be an increase in the proportion of larger vessels entering the ports. At this stage only current ship movement data has informed the assessment of potential effects to navigation as it is not possible to accurately quantify the nature of any potential increase.

5.3.13 In considering the noise effects of the construction phase, a suggested list of construction equipment has been assumed. There are no available studies to establish any comparable underwater acoustic issues. Thus the prediction of the long-term effects on the underwater ecosystems of the Severn cannot be assessed with accuracy.

5.4 Measures to prevent, reduce and as fully as possible offset any significant adverse effects on the environment

The SEA Directive requires that the Environmental Report details '*the measures envisaged to prevent, reduce and as fully as possible offset any significant adverse effects on the environment of implementing the plan or programme'* (Annex I(g))

5.4.1 In this SEA, and in line with UK practice, these measures were split into those measures to prevent or reduce effects, and measures to as fully as possible offset any significant adverse effects on the environment.

Measures to prevent or reduce likely significant adverse environmental effects

5.4.2 The process of option refinement during the feasibility study, or optimisation (see Section 4.1), tested the original options and several variants of these in order to evaluate their environmental effects, scheme costs, energy output and energy cost. This identified modifications to options to prevent or reduce their effects. The modifications included, where appropriate, changes in operating mode (ebb-only generation compared with ebb-flood generation), changes in turbine numbers and sizes, changes in sluice capacity, and changes in alignment.

5.4.3 The modifications to the original (Phase One (Scoping)) designs which were fully or partly driven by environmental concerns are described in the Options Definition Report (Parsons Brinckerhoff, 2010). The options considered in the SEA were the outcome of this process.

5.4.4 Since the optimisation process, a wide range of further measures to prevent or reduce likely adverse effects on the environment have been considered. Following consideration of the likely significant effects arising, a range of effect prevention and/or reduction measures were identified. These potential measures were then further refined through research and discussion with statutory advisors and their likely efficacy was assessed, feeding into a criteria-based comparative analysis. A recommendation was then made on which measures should be taken forward. Where a measure has been suggested to prevent or reduce the likely adverse effects arising for a particular topic, the potential effects of that measure have also been considered by all other relevant topics. For example, many of the flood defence measures have the potential to affect the receptors discussed within the marine ecology and landscape & seascape topics (see Appendix 10 for further details).

5.4.5 Table 5.13 shows those measures to prevent and reduce effects which have been identified at this stage and would be feasible for adoption by 2020. The scale and nature of many of these potential measures are unprecedented and their implementation would present significant challenges. For a full description of all of the measures that have been considered throughout the SEA process, and an explanation of how the decision on which measures to adopt was made, see Appendix 10. Further information is provided in the SEA Topic Papers (see Appendix 1). These anticipated measures to prevent and reduce effects are taken into account in the alternative option appraisal against SEA objectives (Section 6).

Table 5.13 Measures identified to prevent or reduce significant adverse effects on the environment

Topic	Measures recommended to prevent or reduce significant adverse effects on the environment	Alternative options that the measure is applicable to
Marine Water Quality	Reconfiguration of intake at Hinkley Point B nuclear power station	L3d Bridgwater Bay Lagoon only
	Improved treatment at Weston Wastewater Treatment Works (WwTW)	L3d Bridgwater Bay Lagoon only
Flood Risk & Land Drainage	Provision of a flood relief channel for the River Axe to allow flood drainage to the south, instead of to the north, of Brean Down	B3 Cardiff to Weston Barrage
	Improvements to tidal or sea defences	B3 Cardiff to Weston Barrage, B4 Shoots Barrage, B5 Beachley Barrage & L2 Welsh Grounds Lagoon
	Erosion protection through large-scale revetment systems in front of tidal defences	All
	Monitoring of flood defences	All
	Pumping stations at tidal outfalls (which would otherwise become tide-locked), to lift water to discharge at similar stages of the tide as would occur in the future baseline case	All
Freshwater Environment & Associated Interfaces	Alternative access points to the Otter Hole geological SSSI site	B3 Cardiff to Weston Barrage & B4 Shoots Barrage
	Targeted pumping to manage groundwater levels	B3 Cardiff to Weston Barrage, B4 Shoots Barrage, L2 Welsh Grounds Lagoon & L3d Bridgwater Bay Lagoon
Marine Ecology; Waterbirds	Sluicing after the generation period, combined with early commencement of turbine generation, in ebb only mode	B3 Cardiff to Weston Barrage, B4 Shoots Barrage, B5 Beachley Barrage & L2 Welsh Grounds Lagoon
	Topographic modification[1] (the creation of intertidal area).	All
	Seawater level management -	B3 Cardiff to Weston

Topic	Measures recommended to prevent or reduce significant adverse effects on the environment	Alternative options that the measure is applicable to
	pumping at high water[2]	Barrage, B4 Shoots Barrage, L2 Welsh Grounds Lagoon & L3d Bridgwater Bay Lagoon
	Use of construction materials that would enhance colonisation of new structures.	All
Marine Ecology[3]; Waterbirds; Terrestrial & Freshwater Ecology; Historic Environment	Minor alignment adjustments during detailed design, where practical, to avoid specific features within the footprint	All
Noise & Vibration; Migratory & Estuarine Fish	Measures to minimise noise & vibration levels during all stages of construction, operation and decommissioning	All
Migratory & Estuarine Fish	Increased permeability by diverting a proportion of the available volume of water through safer passage routes; whether they are sluices, free-wheeling turbines or free gaps. Also ensuring that all operating turbines are at optimum efficiency during periods of generation.	All
	Altering the current proposed type, size, number and/or position of sluices during detailed design	All
	Intertidal habitat creation and enhancement within the Severn Estuary catchment (including topographic modification[1]).	All
	Controls over predatory piscivorous birds (e.g. wires/netting of structure and/or the use of deterrent and exclusion systems)	All
	Measures to minimise and control sediment disruption/displacement during construction and decommissioning	All
	Measures to minimise underwater noise levels during construction and decommissioning	All
Waterbirds	Adjustment of Cardiff to Weston Barrage alignment to reduce disturbance to breeding birds and prevent sediment connecting the two islands of Flat Holm and Steep Holm	B3 Cardiff to Weston Barrage only
	Introduction of new refuges and/or bird roosts within the estuary area	B3 Cardiff to Weston Barrage only
Waterbirds;	Alterations to construction timings	All

Topic	Measures recommended to prevent or reduce significant adverse effects on the environment	Alternative options that the measure is applicable to
Terrestrial and Freshwater Ecology	during detailed design (if necessary)	
Terrestrial & Freshwater Ecology	Adjustments to locations of onshore works (depots, site compounds, etc)	All
	Targeted pumping to manage waterlevels	B3 Cardiff to Weston Barrage, B4 Shoots Barrage, L2 Welsh Grounds Lagoon & L3d Bridgwater Bay Lagoon
Historic Environment	Preservation of historic environment resources *in situ*	All
	Preservation of the historic environment resource by record	All
Landscape & Seascape	Detailed design of structures to integrate into the surrounding landscape and seascape	All
Air & Climatic Factors	Efficient usage of shipping vessels – use of larger and/or more efficient shipping vessels during construction	All
	Use of low emission construction plant and delivery vehicles	All
	Use of on-site renewable energy generation for heat and electricity during construction	All
Resources & Waste	Inclusion of re-used/recycled primary and secondary construction materials within the detailed design of the final selected option, or combination of options	All
	Detailed design to utilise construction techniques which minimise the amount of waste spoil arising	All
	Liaison with suppliers such as water companies, steel suppliers and aggregates bodies to secure supply.	All
Communities	Measures to encourage maximum recruitment of local labour	All
Communities; Air & Climatic Factors	Reducing the number of vehicles on local roads through rationalising deliveries and use of larger vehicles	All
	Delivery of construction materials by alternative routes (e.g. rail or sea) and maximising the use of existing temporary/permanent works arrangements	B3 Cardiff to Weston Barrage and L3d Bridgwater Bay Lagoon
Communities	Measures (to be defined) targeted at altering the perception that the construction phase would restrict navigation to the estuary's ports	All
Navigation	Coordination and phasing of	All

Topic	Measures recommended to prevent or reduce significant adverse effects on the environment	Alternative options that the measure is applicable to
	construction and decommissioning activities and traffic	
	Improved logistics to manage the arrival and transit of vessels through locks	B3 Cardiff to Weston Barrage, B4 Shoots Barrage, B5 Beachley Barrage & L3d Bridgwater Bay Lagoon
	Use of demarcation within navigation channels to raise awareness of high-risk areas	All
	Relocation of locks for B4 Shoots Barrage & B5 Beachley Barrage; to align with the proposed temporary navigation channels to the west of the barrages	B4 Shoots Barrage & B5 Beachley Barrage
	Dredging of approach channels to affected ports	B3 Cardiff to Weston Barrage, B4 Shoots Barrage & L3d Bridgwater Bay Lagoon
	Dredging to maintain navigation and approach channels to ensure continued navigability	All
	Dredging of proposed new deep water navigation channel from Lavernock Point	B3 Cardiff to Weston Barrage only
	Alterations of port infrastructure (such as lowering of sill levels)	B3 Cardiff to Weston Barrage, B5 Beachley Barrage & L3d Bridgwater Bay Lagoon
Other Sea Uses	Modifying alignment of the L3d Bridgwater Bay Lagoon to avoid existing seabed telecommunications cables	L3d Bridgwater Bay Lagoon only
	Use of specialist extraction/ aggregate cleaning equipment to reduce the effect of increased sediment within aggregate extraction sites	B3 Cardiff to Weston Barrage
	Structural modifications to marine recreation infrastructure (such as slipways)	All
	Beach recharge (where residual effects require it)	All
	The relocation of existing rescue stations to new sites or the construction of new stations would address this problem	All
[1]The unprecedented scale and nature of topographic modification that would be required to offset the likely effects of a Severn Tidal Power scheme would present significant challenges to implementation (see Appendix 10). It is assumed that it would be necessary to create a larger area of intertidal area than that lost through the implementation of an alternative option. This reflects the uncertainty regarding the quality of habitat that would be created. [2]Note that additional mechanisms would also need to be put in place to ensure that the sediment requirements of saltmarsh could also be sustained.		

Topic	Measures recommended to prevent or reduce significant adverse effects on the environment	Alternative options that the measure is applicable to
[3]Note that no measures have been identified that could effectively prevent or reduce the adverse effects predicted to *Sabellaria alveolata* reef.		

5.4.6 An assessment has been made of the estimated residual loss of intertidal area of the Severn Estuary/Môr Hafren SAC, following the application of these measures to prevent or reduce significant adverse effects. This is provided in Table 5.14 below.

Table 5.14 Summary of estimated area losses of designated intertidal habitat within the Severn Estuary/Môr Hafren SAC, after adoption of potential measures to prevent or reduce significant adverse effects

Alternative Option	Estimated area loss of designated intertidal habitat *before* application of potential measures to prevent or reduce significant adverse effects		Estimated area loss of designated intertidal habitat *after* application of potential measures to prevent or reduce significant adverse effects	
	Potential Lower-bound Loss (ha)	Potential Upper-bound Loss (ha)	Potential Lower-bound Loss (ha)	Potential Upper-bound Loss (ha)
B3	14,800	18,000	11,800	16,300
B4	3,300	4,000	2,700	3,700
B5	2,700	3,300	2,100	3,000
L2	7,300	8,700	6,100	8,200
L3d	2,500	3,000	1,600	2,600

Table notes:

a) Estimates rounded to nearest 100ha.
b) Intertidal area is defined as HAT-LAT.
c) Calculations are for the area within the Severn Estuary/Môr Hafren SAC only, i.e. excluding SEA Hydraulics and Geomorphology model units 2a, 2b and 2c. These habitat area losses are small by comparison.
d) Calculations do not include sub-estuaries; habitat area losses are uncertain and small by comparison.
e) Estimates are for intertidal habitats that are a qualifying feature or sub-feature of the SAC only. These are: intertidal hard substrate communities; mudflats and sandflats not covered by seawater at low tide; Atlantic saltmeadow. The calculations for Atlantic salt meadow do not include the modelled intertidal grassland: this transitional habitat is not considered to be part of the SAC habitat.
f) Estimates include habitat losses from barrage footprints and from changes in tidal regime.
g) Calculations are based on model outputs of intertidal habitat extents at closure, provided by the Marine Ecology Topic Paper, Annex 3, (see Appendix 1).
h) Calculations for Atlantic saltmeadow are based on the predicted short-term losses at commencement of operations due to changes in water levels. Potential longer-term term colonisation of new areas of suitable habitat by saltmarsh communities is excluded.
i) Calculations do not include uncertain estimates of long term morphological change.
j) The range of values is calculated by applying the following to the central output provided by SEA Marine Ecology Topic Paper (see Appendix 1):
   - Uncertainty around model output: +/-10% predicted area change.
   - Measures to prevent or reduce significant adverse effects where quantifiable: pumping at high water (only quantified for B3); additional sluicing on ebb tide (only quantified for B3); topographic modification (quantified for all options with a predicted range of effectiveness).
k) The 'Minimum Loss' value = minimum loss (model output -10%) – maximum prevention or reduction of significant adverse effects (greatest value for effectiveness of measures to prevent or reduce significant adverse effects).
l) The 'Maximum Loss' value = maximum loss (model output +10%) – minimum prevention or

	reduction of significant adverse effects (lowest value for effectiveness of measures to prevent or reduce significant adverse effects).
m)	This approach is consistent with that applied to individual habitat types to generate the residual effects quoted in the Habitats Regulations Assessment reporting.

A wide range of measures have been considered to prevent and reduce likely significant adverse effects on the environment. These include measures for flood risk, navigation, marine habitats, fish and waterbirds. However, the measures are of uncertain effectiveness and would not prevent negative effects on key features of the Severn Estuary such as intertidal habitats, birds and migratory fish.

Offsetting measures

5.4.7 Offsetting measures within this SEA are measures to as fully as possible offset any significant adverse effects on the environment. In this SEA, 'compensation' (a sub-set of offsetting), is used in relation to those offsetting measures considered as part of the SEA that could be used to help meet the specific compensation requirements under the EC Habitats Directive in relation to effects on Natura 2000 sites. These measures therefore make good for loss or damage to an environmental receptor, without directly reducing that loss/damage.

5.4.8 Outside of compensation requirements (under the EC Habitats Directive), few additional offsetting measures are recommended at this stage. This is because the level of offsetting required would not become evident until there is better understanding of the residual effects following the implementation of the measures to prevent and reduce effects on the environment. The scale and nature of many of these potential measures are unprecedented and their implementation would present significant challenges. See Appendix 10 for full details of those offsetting measures which have been considered to date. The offsetting measures which have been identified for adoption (in addition to compensation measures) at this stage are:

- Monetary compensation in return for surrender of marine commercial fishing licences (to offset for the likely loss of non-statutorily protected fish populations). This measure may also have an adverse effect on fishing communities.

- Habitat creation, modification and ecological enhancement in other areas, targeted to be of benefit to non-statutorily protected marine estuarine species. This measure may also have a positive effect on other biodiversity and society and economy receptors.

- Offsetting the submergence of specific geological SSSI sites - the Geological Conservation Review (GCR) may include other sites that have similar examples of the particular features that may be permanently submerged. In such cases there is a possibility that the geological information lost to research by submergence could be offset by designation of a similar outcrop elsewhere. Conversely, it is also possible that the particular geological and geomorphological features being submerged are unique. In this situation, no offsetting would be possible.

- Issuing of new aggregate licences or alterations to existing licences, to offset the likely reduction in area available for aggregate extraction. This measure may also have adverse implications for marine ecology and has the potential to adversely affect commercial marine fishing activities.

- New dredged material disposal procedures or sites, to offset the effect of lost functionality of existing sites (B3 Cardiff to Weston Barrage and L2 Welsh Grounds Lagoon only). This measure may also have adverse implications for marine ecology and has the potential to adversely affect commercial marine fishing activities.

- The need has also been identified for a further associated measure to offset the effects on users of existing dredging disposal and aggregate extraction sites of the increased transit distance and time for access to alternative sites.

- Monetary compensation in return for surrender of salmon and sea-trout and heritage (elver) fishing licences (to offset for the likely loss of the salmon and sea-trout and heritage (elver) recreational/tourism fisheries). This measure is likely to have positive effects for fish receptors but may also have adverse effects on the wider fishing community.

5.4.9 As part of the STP Feasibility Study, an investigation has examined landward managed realignment on the Severn Estuary and whether this would be plausible as an offsetting measure for intertidal habitat loss (Severn Tidal Power, 2009b). The review concluded that opportunities for mudflat creation under the baseline situation are very limited, although 5,500ha of saltmarsh and coastal grassland can be created. After option implementation, the potential for compensatory habitat through managed realignment within the Severn Estuary varies. Excluding SSSIs that support other habitats, there remains the opportunity to create between 300ha (B3 alternative option) and nearly 5,000ha (L2 alternative option) of intertidal habitat within the Severn Estuary. If SSSI habitat was considered suitable for inclusion the opportunity for intertidal habitat creation landward of existing sea walls would increase to between 700ha (for B3 alternative option) and 7,000ha for the L2 alternative option. This may have implications for separate existing programmes for compensation for coastal squeeze through sea level rise, under Severn Estuary Flood Risk Management planning.

5.4.10 Where there is an adverse assessment of the implications for a Natura 2000 site and in the absence of alternative solutions a plan or project must be carried out for imperative reasons of overriding public interest, the Secretary of State must secure any necessary compensatory measures to ensure the overall coherence of Natura 2000 is protected. The adverse implications for a Natura 2000 site are determined by the competent authority through an Appropriate Assessment under the Habitats Regulations. Draft assessments of STP alternative options have been prepared to inform the STP Feasibility Study which include consideration of in-combination effects. The STP Feasibility Study has also considered possible compensatory measures that might be adopted in the eventuality that there was a strategic case to progress with a scheme and that the other requirements within Article 6(4) of the Habitats Directive (no alternatives and Imperative Reasons of Overriding Public Interest) could be met for that alternative option.

5.4.11 The requirement for compensation and potential compensation measures (a specific form of offsetting) are set out in Table 5.15. The scale and nature of many of these potential measures are unprecedented and their implementation would present significant challenges. The measures listed include those which have been included within the overall compensation framework as well as those that have only been conditionally included. The latter are indicated with a (C) and are dependant upon further study. Any compensation measure would have to be fully considered under the Habitats Regulations Assessment (HRA) framework in the event of an STP alternative option, or combination of options, being adopted in order to further consider is applicability. Further information on compensation is contained within the HRA (Severn Tidal Power, 2010).

Table 5.15 Compensation need identified and potential compensation measures (under the EC Habitats Directive)

Receptor	Compensation needs identified (under the Habitats Directive)	Potential compensation measure (C= conditional)
Migratory birds	Compensate for the effects of loss of habitat within Severn Estuary on SPA bird populations	Managed re-alignment to create saltmarsh adjoining the Severn Estuary (C)
	Compensate for the effects of loss of habitat within Severn Estuary on SPA bird populations	Managed re-alignment to create saltmarsh and mudflat at a distance from the Severn Estuary (C)
	Compensate for the effects of loss of habitat within Severn Estuary on SPA bird populations	Creation of freshwater wetland habitat close to Severn Estuary
Atlantic saltmeadow	Compensating for loss of extent of SAC habitat	Managed re-alignment adjoining the Severn Estuary
	Compensating for loss of extent of SAC habitat	Managed re-alignment at a distance the Severn Estuary (C)
Intertidal mudflat and sandflat	Compensate for loss of extent of SAC habitat	Managed realignment at distance from the Severn Estuary (C)
Sabellaria reef	Compensation for loss or decline of reef	New notification (C)
Allis & Twaite shad	Compensating for population declines in the Severn Estuary and its rivers by increasing populations elsewhere	Translocation/introduction of species to new location (C).
Allis & Twaite shad	Offsetting population declines in Severn Estuary and its rivers by increasing populations elsewhere	Stocking in rivers outside the Severn Estuary and its tributaries. (C)
Atlantic Salmon	Offsetting population declines in Severn Estuary and its rivers by increasing populations elsewhere	Stocking in rivers outside the Severn Estuary and its tributaries. (C)
Migratory fish (multiple species)	Offsetting population declines in Severn Estuary and its rivers by increasing populations elsewhere	Freshwater habitat enhancement/creation schemes and improvements to other population limiting factors. (C)
Migratory fish (Allis & Twaite shad species).	Offsetting population declines in Severn Estuary and its rivers by increasing populations elsewhere	Estuarine habitat enhancement and creation schemes (C)
Migratory fish (multiple species)	Compensating for losses to the network of designated sites by notifying new areas	New notification of existing non-SAC populations. (C)

Possible offsetting and compensation measures have been identified for the residual negative effects. These need more development to be confident of their effectiveness.

SECTION 6

SEA OBJECTIVES COMPARISON OF ALTERNATIVE OPTIONS

6 SEA OBJECTIVES COMPARISON OF ALTERNATIVE OPTIONS

6.1 Performance of alternative options in relation to SEA objectives

6.1.1 Whilst not specifically required by the SEA Directive, the Practical Guide (ODPM *et al*, 2005) recommends that SEA objectives are used to compare the effects of alternative options. In this respect, the STP SEA objectives assessment differs from the rest of the Environmental Report. This section summarises on a theme by theme basis, how each alternative option performs in relation to the SEA objectives. This appraisal *does* include measures to prevent or reduce significant effects (as set out in section 5.4). Further information is provided in the SEA Topic Papers (see Appendix 1) and a summary table for the alternative options is provided in Appendix 11. See Appendix 5 for the list of SEA objectives.

Physicochemical

6.1.2 There are no specific SEA objectives for hydraulics and geomorphology however there are distinct differences between the relative performances of each alternative option. The B3 Cardiff to Weston Barrage results in the most widespread effects on hydraulics and geomorphology and in general, the magnitude of change is also greatest for this alternative option. However, the smaller barrages, B4 Shoots Barrage and B5 Beachley Barrage, and the L2 Welsh Grounds Lagoon are shown to produce larger changes to the sedimentary and morphological regime, albeit over much smaller areas. The L3d Bridgwater Bay Lagoon generally causes the fewest changes to hydraulics and geomorphology.

6.1.3 With regards to water quality objectives, alternative options L2 Welsh Grounds Lagoon and L3d Bridgwater Bay Lagoon are anticipated to have no negative effects on any of the Marine Water Quality SEA Objectives. Alternative options B4 Shoots Barrage and B5 Beachley Barrage are also anticipated to have no negative effects on any of these objectives. There is however an acknowledged level of uncertainty about the concern of localised sediment concentrations of contaminants in the future for both these alternative options; leading to a 'no effects' / 'uncertain' performance against the objective to avoid adverse effects on designated marine wildlife sites of international and national importance due to changes in water quality (MWQ.2). The B3 Cardiff to Weston Barrage is anticipated to result in a 'minor negative' / 'uncertain' performance against MWQ.1 and MWQ.2. The 'minor negative' performance against both these objectives is due to the enhanced risk of eutrophication effects with this alternative option, as a result of increases in light penetration in response to the reduction in suspended sediment concentrations. It is uncertain whether these possible effects can be prevented or reduced.

6.1.4 With regards to flood risk and land drainage, alternative options B4 Shoots Barrage, B5 Beachley Barrage and L2 Welsh Grounds Lagoon have no effect on the objective to avoid an increase in flood risk to property, land and infrastructure (FR.1). Both the B3 Cardiff to Weston Barrage and the L3d Bridgwater Bay Lagoon meet this objective, with the B3 Cardiff to Weston Barrage having a major positive performance against this objective due to the delay in the need to invest in measures to raise flood defences to counter rising sea levels that would occur if this alternative option is implemented. The negative effects of this alternative option can be managed through the identified measures to prevent or reduce significant effects.

6.1.5 Alternative option L2 Welsh Grounds Lagoon has no negative effects on the freshwater environment and associated interfaces objectives. The B3 Cardiff to Weston Barrage does not meet the objective to avoid adverse effects on water quality (FE.1) due to a minor negative performance on groundwater quality in relation to water quality standards. This is a consequence of increased saline intrusion into gravels and beach sand deposits around Cardiff and Weston-super-Mare. L3d Bridgwater Bay Lagoon is also anticipated to have a minor negative performance against FE.1 in relation to groundwater. This negative effect is a consequence of the predicted saline intrusion into higher permeability deposits near the Bridgwater Bay coastline. B5 Beachley Barrage may have a minor positive performance against the objective to avoid adverse effects on water abstractions, particularly those utilised for the public water supply (FE.3). This is due to the reduction in potential for saline intrusion affecting the Purton off-take on the Sharpness Canal, although the benefits may reduce with time. It is uncertain whether B3 Cardiff to Weston Barrage would meet the objective to avoid adverse effects on water abstractions (FE.3). This is because there is increased potential for saline intrusion at Clevedon Pumping Station. The likelihood of this source experiencing increased salinity is, however, uncertain as little is known about the source mechanisms.

6.1.6 B3 Cardiff to Weston Barrage is anticipated to have a major negative performance against the objective to avoid adverse effects to buildings and infrastructure (FE.5). This is due to the effects of the rise in groundwater level on infrastructure in urban areas alongside the estuary, particularly in Weston-super-Mare. B3 Cardiff to Weston Barrage is anticipated to have a major negative performance against the objectives to avoid adverse effects on geological and geomorphological sites of international and national importance (FE.8) and conserve and enhance geological and geomorphological features (FE.9). This is due to the permanent loss of access to the lowermost exposures at nine sites. B4 Shoots Barrage and B5 Beachley Barrage both have a minor negative performance against these two objectives (FE.8 and FE.9). This is due to the permanent loss of access to the lowermost exposures at four sites for B4 Shoots Barrage and two sites for B5 Beachley Barrage.

Biodiversity

6.1.7 The majority of objectives for the avoidance of negative effects on marine ecology were not considered likely to be met for any of the alternative options. However, all of the alternative options are predicted to avoid adverse effects on other protected marine species and their habitats (marine mammals and turtles) (ME.3).

6.1.8 B4 Shoots Barrage, B5 Beachley Barrage and L2 Welsh Grounds Lagoon are all anticipated to avoid deterioration in status class of Water Framework Directive (WFD) waterbodies (ME.5). Although there may be some minor reductions in high water level and reduced current speeds under the B3 Cardiff to Weston Barrage, it is considered unlikely to change the status of WFD water bodies. However there is a risk of eutrophication effect which could potentially cause deterioration in the six water bodies upstream of the barrage, but it is uncertain whether this would occur. Changes to physical processes and intertidal habitat extent may cause a deterioration in status of hydromorphological quality or biological quality elements in the Bridgwater Bay water body, leading to an uncertain effect for objective ME.5 for L3d Bridgwater Bay Lagoon.

6.1.9 All alternative options are anticipated to have a major negative performance against the objectives to avoid adverse effects on designated marine wildlife sites and protected habitats of international importance (ME.1); to avoid adverse effects on valuable marine ecosystems (ME.2); and to avoid adverse effects on national and local biodiversity target features that include marine habitats and species (ME.4). This is largely due to the predicted changes in quality and extent of the features within the study area and the fact that, while it may be possible to minimise or even avoid adverse effects for some features, this is not likely to be possible for all features affected by the alternative options. The objective to minimise the risk of introduction of non-native invasive marine species (ME.6) was considered to be met by alternative options B4 Shoots Barrage and B5 Beachley Barrage. B3 Cardiff to Weston Barrage, L2 Welsh Grounds Lagoon and L3d Bridgwater Bay Lagoon are all anticipated to have a minor negative performance against this objective, primarily due to the size of the potential new colonising surface provided by these options. B3 Cardiff to Weston Barrage, B4 Shoots Barrage and L2 Welsh Grounds Lagoon are all predicted to have a major negative performance against the objective to conserve and enhance designated marine site features (ME.7) and to restore and enhance marine Biodiversity Action Plan (BAP) species populations and/or BAP habitat (ME.8), whist B5 Beachley Barrage and L3d Bridgwater Bay Lagoon are anticipated to have a minor negative performance against both these objectives. It is considered unlikely to be able to prevent or reduce effects on subtidal *Sabellaria alveolata* reefs.

6.1.10 None of the alternative options are considered to meet the objectives for waterbirds of avoiding adverse effects on designated wildlife sites for birds and protected habitats of international and national importance (O.1); avoiding adverse effects on other protected bird habitats and species (O.2); and avoiding adverse effects on national and local biodiversity target features that include bird habitats and species (O3). However, the number of waterbirds affected for each option varied considerably, with B3 Cardiff to Weston Barrage failing to meet objectives for the largest number of waterbirds. Changes to or loss of intertidal habitat within the Severn Estuary represents the principal effect on waterbirds for all alternative options. Disturbance (mainly) during construction and decommissioning is predicted to be of particular significance for L2 Welsh Grounds Lagoon as this alternative option crosses a considerable length of existing intertidal areas. Negative effects of changes to saltmarsh are largely restricted to the B3 Cardiff to Weston Barrage option and negative effects on breeding seabirds to the B3 Cardiff to Weston Barrage and L3d Bridgwater Bay Lagoon alternative options.

6.1.11 None of the alternative options are considered to meet the first five of the migratory and estuarine fish SEA objectives; (to avoid adverse effects on designated wildlife sites for fish of international and national importance (F.1); to avoid adverse effects on the populations of other protected fish species and habitats (F.2); to avoid adverse effects on national and local biodiversity target features that include fish habitats and species (F.3); to avoid adverse effects on recreational and heritage fishing (F.4); and to avoid adverse effects on commercial fish resources (F.5)). This is because the assessment predicts major negative effects on fish populations (although there is considerable uncertainty surrounding these predictions) for all options and for all of these objectives, with the exception of objective F.5 for L3d Bridgwater Bay Lagoon which is considered to have only a minor negative performance. These effects are predominantly associated with alterations to migratory cues, disruption to route of passage, habitat change and/or loss, change to water quality (salmon, sea-trout and shad only) and anthropogenic noise disturbance (salmon, sea-trout and shad only). The objective to minimise the risk of introduction of non-native invasive fish species (F.6) is not considered to be a significant issue for any of the alternative options, as the risk of introduction of non-native fish species is considered to be low.

6.1.12 With regard to terrestrial and freshwater ecology, following application of measures considered feasible to prevent and reduce effects, all of the alternative options are considered to have a minor positive performance against the following specific objectives: to avoid adverse effects on designated terrestrial and freshwater wildlife sites of international and national importance (TFE.1); to avoid adverse effects on valuable terrestrial and freshwater ecological networks (TFE.2); to avoid adverse effects on other protected terrestrial and freshwater habitats and species (TFE.3); and to avoid adverse effects to national and local biodiversity target features including terrestrial and freshwater habitats and species (TFE.4). None of the alternative options are considered to have any apparent effects upon the objective to minimise the risk of introduction of non-native invasive terrestrial and freshwater species (TFE.5).

6.1.13 B3 Cardiff to Weston Barrage, B5 Beachley Barrage and L3d Bridgwater Bay Lagoon are considered to have a minor positive performance against the objective to conserve and enhance designated freshwater and terrestrial site features (TFE.6), principally through the opportunities that increased availability of water provides to a number of internationally and nationally important wildlife sites and their associated features. No opportunities to enhance designated features have been identified for B4 Shoots Barrage or L2 Welsh Grounds Lagoon, both of which are considered to have a minor negative performance against this objective. B3 Cardiff to Weston Barrage, B5 Beachley Barrage and L3d Bridgwater Bay Lagoon are considered to have a major positive performance, and B4 Shoots Barrage and L2 Welsh Grounds Lagoon are considered to have a minor positive performance, against the objective to restore and enhance freshwater and terrestrial BAP species populations and/or BAP habitat, principally through the opportunities that increased water provides.

Historic Environment and Landscape & Seascape

6.1.14 With regard to the historic environment, B3 Cardiff to Weston Barrage, B4 Shoots Barrage, L2 Welsh Grounds Lagoon and L3d Bridgwater Bay Lagoon all fail to meet any of the objectives relating to the historic environment. B3 Cardiff to Weston Barrage, L2 Welsh Grounds Lagoon and L3d Bridgwater Bay Lagoon are all considered to have a major negative performance against the objective to avoid adverse effects on designated sites in the historic environment (HE.1). The reasons for this are that B3 Cardiff to Weston Barrage and L3d Bridgwater Bay Lagoon would affect the limestone headland of Brean Down which is an important multi-period archaeological site and a Scheduled Monument, whilst L2 Welsh Grounds Lagoon would have an physical effect on the form and the setting of the Gwent Levels, an Historic Landscape of Outstanding Historic Interest. B4 Shoots Barrage is considered to have minor negative performance against this objective, as construction and operation would have an adverse effect on the fabric and setting of the Gwent Levels, Landscape of Outstanding Historic Interest in Wales. However, the spatial extent of the direct effect and the effects on the setting would be confined to the eastern end of the registered area. B5 Beachley Barrage is considered to have no effect against this objective.

6.1.15 All alternative options are considered to have a major negative performance against the objective to avoid adverse effects on the non-registered internationally, nationally, regionally and locally important sites within the historic environment (HE.2). B3 Cardiff to Weston Barrage, B4 Shoots Barrage, L2 Welsh Grounds Lagoon and L3d Bridgwater Bay Lagoon are all considered to have a major negative performance against the objective to avoid adverse effects on the potential historic environment, the as yet unidentified sites and finds, within the Severn Estuary (HE.3) as they all directly and indirectly effect identified areas of medium and high potential within the intertidal and subtidal zones. B5 Beachley Barrage is considered to have a minor negative performance against this objective as the footprint would have a direct effect on an area of medium potential.

6.1.16 L2 Welsh Grounds Lagoon is considered to have a major negative performance against the objective to avoid adverse effects on the character and quality of the historic landscape (HE.4) as the physical structure located along a substantial section of the foreshore of the Gwent Levels Historic Landscape of Outstanding Historic Interest and would consequently have an adverse effect on the setting of the registered landscape. B3 Cardiff to Weston Barrage, B4 Shoots Barrage, and L3d Bridgwater Bay Lagoon would are all considered to have a minor negative performance against this objective as the physical structures would have an adverse effect on a limited physical area of landscape. B5 Beachley Barrage is considered to have no effect against this objective as the physical structure situated next to the existing Severn Road Bridge is unlikely to have a significant effect on the setting of the historic landscape.

6.1.17 The three objectives for landscape and seascape (to conserve the character and qualities of the landscape/seascape, recognising its diverse features and distinctiveness at different scales – including designated and non-designated areas (LS.1); to conserve the character and qualities of the physical and visual resource associated with land and sea (LS.2); and to accord with the Aims and Articles of the European Landscape Convention (LS.3)) are not considered to be met by any of the alternative options with the exception of L3d Bridgwater Bay Lagoon, which would have a minor positive effect on the objective to accord with the Aims and Articles of the European Landscape Convention (LS.3). This is due to the design of L3d Bridgwater Bay Lagoon as it is able to retain the greater part of the tidal range and intertidal visual characteristics as well as not affecting seascape characteristics upstream of its position. Furthermore, B4 Shoots Barrage and B5 Beachley Barrage are both considered to have no effect on the 'landscapes with inter-visibility to the option' component of objective LS.1, although they do both perform negatively for the other three components of this objective.

<u>Air & Climatic Factors and Resources & Waste</u>

6.1.18 The performance of air quality has been assessed using objectives developed for other topics during Phase One (Scoping) (including communities, carbon footprinting and terrestrial and freshwater ecology). Therefore the same objectives may perform differently under air quality compared to their original topic.

6.1.19 Considering air quality, all alternative options are considered to have a minor negative performance against the objective to avoid adverse effects on physical and mental health (SE.1) during the construction phase for both the local and the UK population. There are not predicted to be any effects against this objective for the local population during operation, and a minor positive performance is considered for the UK population during operation. All alternative options are considered to have a minor negative performance against the objectives to avoid adverse effects on designated terrestrial and freshwater wildlife sites of international and national importance (TFE.1) and to avoid adverse effects on valuable terrestrial and freshwater ecological networks (TFE.2) during construction. There are not predicted to be any effects against objective TFE.1 during operation, and a minor positive performance is considered against objective TFE.2 during the operational phase.

6.1.20 With regards to carbon footprint, B3 Cardiff to Weston is considered to have a major positive performance, and all other alternative options a minor positive performance, against the objective to maximise the opportunities for use of sustainable sources of energy for the UK (CF.1). This is as a result of the potential renewable energy yields generated and the carbon payback periods. B3 Cardiff to Weston is considered to have a major positive performance, and all other alternative options a minor positive performance, against the first component of the objective to avoid adverse effects from greenhouse gas (GHG) emissions over the lifecycle of the project (CF.2), which is related to UK Net GHG emissions displaced against the baseline. Against the second component of objective CF.2, total emissions per phase, B3 Cardiff to Weston is considered to have a major negative performance, and all other alternative options a minor negative performance.

6.1.21 With regard to resources and waste, alternative options B3 Cardiff to Weston Barrage, B4 Shoots Barrage, L2 Welsh Grounds Lagoon and L3d Bridgwater Bay Lagoon are considered to have a minor negative performance against the objective to promote sustainable use of resources (RW.1) as there would be a need to source aggregate from across Great Britain and from abroad. B5 Beachley Barrage is considered to have no effect against this objective as it has the lowest demand for resources, with aggregate being supplied regionally. All alternative options have no effect on the objective to reduce waste generation and disposal, increase reuse and recycling, and achieve the sustainable management of waste (RW.2). This is because waste would be managed in accordance with the waste hierarchy and the greatest quantities of waste (dredged materials during construction and recycled aggregates from decommissioning) would be reused.

Society and Economy

6.1.22 With regard to communities, B3 Cardiff to Weston Barrage and L3d Bridgwater Bay Lagoon are both considered to have a major positive performance; and B4 Shoots Barrage, B5 Beachley Barrage and L2 Welsh Grounds Lagoon a minor positive performance, against the objective of creating local employment opportunities accessible to all (SE.1). All alternative options are considered to have a major negative performance against the objective to avoid adverse effects on the local and regional economy (SE.2) this is because of the expect effects upon ports, recreational/tourism salmon and sea-trout and heritage (elver) fisheries. B3 Cardiff to Weston Barrage is also expected to have an adverse effect on the on tourism at Brean Beach and Lavernock Point and L3d Bridgwater Bay Lagoon is expected to also have a negative effect on tourism at Brean Beach.

6.1.23 None of the alternative options are considered to have an effect on the following objectives: SE.3 - To promote the development of sustainable communities; SE.4 - To avoid adverse effects on physical and mental health; SE.5 - To avoid adverse effects on access to community services and facilities; SE.6 - To promote access to recreational facilities and open space; SE.7 - To avoid adverse effects on existing, proposed and committed land uses; and SE.9 - To avoid adverse effects on the housing market. It is not considered possible to speculate at this stage on whether the alternative options as currently described would support objective SE.8 – To seek opportunities to improve degraded environments.

6.1.24 With regards to noise and vibration, all alternative options are considered to have no effect or a minor negative effect on the objective to avoid adverse effects of negative noise and vibration on (humans) noise sensitive receptors (NV.1). It is considered uncertain how all the alternative options perform against the objective to avoid adverse effects on the acoustic quality of the marine environment (NV.2). Following consideration and implementation of measures to prevent or reduce effects, it is considered that all alternative options have a minor positive performance against the objective to avoid adverse effects on noise (vibration) sensitive receptors (NV.3). The adverse effects on the acoustic quality of the marine environment (NV.2) are also considered in more detail by the migratory and estuarine fish topic, and the adverse effects on noise (vibration) sensitive receptors (wildlife) (NV.3) are considered by the terrestrial and freshwater ecology topic. All alternative options are considered to have a minor positive performance against the objective to avoid adverse effects through vibration (NV.4), as no building structures have been identified at distances considered to expose them to significant vibration.

6.1.25 With regards to navigation, whilst potentially significant risks to navigation have been identified, it is considered that the measures suggested to prevent or reduce these risks would be successful, and it is considered that none of the alternative options would have a negative effect on Severn Estuary navigation arising from sedimentation, geomorphology, water density, and tidal water levels (objective N.1). Similarly, it is considered that following implementation of suggested measures to prevent or reduce effects, alternative options L2 Welsh Grounds Lagoon and L3 would not have an effect on the objective to avoid adverse effects on the integrity of existing and proposed port operations (N.2). However, alternative options, B3 Cardiff to Weston Barrage, B4 Shoots Barrage and B5 Beachley Barrage are still considered to have a minor negative performance against the this objective due to the residual risk of an increase in peak water velocities and increased transit times through locks.

6.1.26 With regard to other sea uses, B3 Cardiff to Weston Barrage is considered to have a major negative performance, and L2 Welsh Grounds Lagoon a minor negative performance, against the objective to avoid adverse effects on the aggregate extraction industry (SU.1). This is because even following the implementation of measures to prevent and reduce effects, both alternative options still have the potential to disrupt the estuary dredging cycle. The remaining alternative options have no effect on this objective. B3 Cardiff to Weston Barrage is considered to have a major positive performance, and B4 Shoots Barrage, B5 Beachley Barrage, and L2 Welsh Grounds Lagoon a minor positive performance, against the objective to avoid adverse effects on marine recreational users (SU.3) as implementation of these alternative options has the potential to create far calmer conditions and this is likely to greatly increase recreational user numbers of the estuary. Conversely, peak flow speeds may increase within the L3d Bridgwater Bay Lagoon, potentially making conditions less amenable for most users, and resulting in this option being considered to have a minor negative performance against this objective. It is highly probable that all three barrage alternative options would prevent the formation of a 'surfable' Severn Bore and therefore alternative options B3 Cardiff to Weston Barrage, B4 Shoots Barrage and B5 Beachley Barrage are considered to have a major negative performance against the objective to minimise adverse effects on the Severn Bore (SU.8). It is considered uncertain how L2 Welsh Grounds Lagoon and L3d Bridgwater Bay lagoon would perform in relation to this objective.

6.1.27 All of the alternative options have the potential to have both a positive and negative influence on sustainable estuary based tourism (SU.4). Whilst each alternative option may become a visitor attraction in its own right, the alternative options also have the potential to have a negative effect on the aesthetics of the estuary, both during the construction/ decommissioning phases and during operation. Providing appropriate measures to prevent or reduce effects are adopted, none of the alternative options are predicted to have any effect on the following objectives: SU.2 - to avoid adverse effects on marine waste disposal sites and infrastructure; SU.5 - to avoid adverse affects on military activity in the region; SU.6 - to avoid adverse effects on the energy industry; and SU.7 - to avoid adverse effects on seabed cables in the region.

Multiple Basin Alternatives

6.1.28 The detail currently available only permits a high-level assessment to identify key issues and no modelling was undertaken. These variants were therefore not considered to the same level of detail as the alternative options. A double basin L3d Bridgwater Bay Lagoon would be likely to perform against the SEA objectives in a similar manner as the shortlisted L3d Bridgwater Bay Lagoon alternative option (the single basin L3d Bridgwater Bay Lagoon). However, a double basin L3d Bridgwater Bay Lagoon would be likely to result in greater effects upon the hydraulics and geomorphology due to changes in the form and function of the estuary within the impounded area. Unlike the shortlisted L3d Bridgwater Bay Lagoon alternative option, a double basin L3d Bridgwater Bay Lagoon would be unlikely to meet the landscape and seascape objective (LS.3). This is because the design would not retain the greater part of the tidal range. A double basin design is likely to partially reduce the adverse effects upon marine recreational users within the estuary (SU.3) as there would be likely to be calmer conditions within the high basin. However, the division of the lagoon into two basins would restrict movement of recreational users.

Combinations of alternative options

6.1.29 The detail currently available only permits a high-level assessment to identify key issues and no modelling was undertaken. These variants were therefore not considered to the same level of detail as the alternative options. In relation to the SEA objective; the performance of the two combinations of options (L3d Bridgwater Bay Lagoon and B3 Cardiff to Weston Barrage; and L3d Bridgwater Bay Lagoon and B4 Shoots Barrage) would be likely to be largely the same as the worse performing of the individual alternative options. For either combination, it is possible that there would be greater effects on hydraulics and geomorphology due to changes in estuary water levels and morphology associated with the two alternative options operating together. The individual alternative options fail the SEA objectives for waterbirds (O.1 – O.3). However, it is likely that either combination would result in a failure to meet the objectives for a greater number of waterbird species than just those being affected by the worse performing alternative option. All alternative options are considered to meet the SEA objectives for Noise and Vibration (NV.1 - NV.4), providing that appropriate measures to prevent and reduce effects are adopted. However it is possible that the L3d Bridgwater Bay Lagoon and B3 Cardiff to Weston Barrage combination would make these objectives more difficult to meet, due to the close proximity of the two alternative options to each other – which would result in greater noise effects in these locations.

SECTION 7

IMPLEMENTATION

7 IMPLEMENTATION

7.1 Monitoring measures

> ***'Member States shall monitor the significant environment effects of the implementation of plans and programmes in order,* inter alia*, to identify at an early stage unforeseen adverse effects, and to be able to undertake appropriate remedial action'* (Article 10.1).**
>
> **The SEA Directive requires that the Environmental Report provides '*a description of the measures envisaged concerning monitoring*'…(Annex I(i))**

7.1.1 Monitoring allows the actual significant environmental effects of implementing a Severn Tidal Power scheme to be identified.

7.1.2 The STP SEA alone does not identify a preferred alternative option, but supports the wider decision making framework. Thus the monitoring is not specific to the implementation of any alternative option. Table 7.1 provides a summary of the high-level framework for envisaged monitoring measures, which can be applied to all of the Severn Tidal Power alternative options under consideration.

7.1.3 More detailed discussion of the monitoring framework identified for individual topics - including a brief description of monitoring proposed and the relationship between proposed monitoring, predicted likely significant environmental effects and receptors affected - can be found within the individual Topic Papers (see Appendix 1).

Table 7.1: Summary of envisaged monitoring measures for significant environmental effects for all alternative options

Theme	Description of monitoring
Physicochemical	LiDAR surveys combined with bathymetry and modelling. Surveys approximately every 5 years (a cost effective interval to ensure trends can be identified).
	Sediment sampling
	One-off survey to confirm discharge consent compliance
	Use of existing continuous recorders at ports to measure increases in water levels. If necessary add a gauge in expected zone of far-field influence (B3 Cardiff to Weston Barrage only).
	Current flood risks due to tide-locking.
	Erosion monitoring of toe of flood defences by LiDAR (every 5 years) and physical inspection every year to determine when and where erosion protection works are required.
	Water table elevation and its variation in vicinity of buildings and services and in soils deemed potentially 'at risk'.
Biodiversity	Changes in habitat extent and quality in response to physicochemical changes
	Changes in species populations and distributions in response to construction disturbance and physicochemical changes
	WeBS Counts of the Severn Estuary and evaluation of WeBS data from other key sites. Breeding season surveys of seabirds on Flat Holm and Steep Holm
	Fish losses, population sustainability, delay to passage,

Theme	Description of monitoring
	effects upon reproductive success etc.
Historic Environment and Landscape & Seascape	Archaeological monitoring, where appropriate, during construction phase. Planned programme of foreshore and subtidal surveys including walkovers, prospection, sampling, excavation etc to reduce the long-term loss through the recording of the resource.
	Changes in landscape character and visual effects.
Air & Climatic Factors and Resources & Waste	Estuarine changes as part of the Water Quality and Marine Ecology to consider the effects on emissions cycles (carbon, methane and nitrogen).
	All materials entering and leaving site, including use of secondary and recycled aggregates. Transportation and fuel consumption.
	Air quality monitoring.
Society & Economy	Port employment and mean rod catches as indicator of employment
	Monitoring from other themes would assist with monitoring of effects on this theme.

7.2 Suggestions for further research to inform the environmental assessment of tidal power schemes on the Severn Estuary

7.2.1 Suggestions for further research are not a requirement of the SEA Directive. However, should one of the alternative options be taken forward, the studies listed below may need to be carried out to develop an alternative option.

Physicochemical

7.2.2 With regards to hydraulics and geomorphology, data collection in a number of areas is recommended. The following specific data collection suggestions are made:

- Additional wave data;
- A single one-off bathymetric survey of the Severn Estuary and its main tributaries, particularly the River Wye;
- A survey of the Upper River Severn;
- Flow and water level and sediment load data in the upper reaches of the estuary;
- Knowledge of the proposed turbine structures should be improved and fed back into the models;
- Suspended sediment, intertidal morphology, and subsurface intertidal data should be collected over sensitive areas of intertidal habitat;
- The analysis of the long-term record of intertidal morphological change should be extended; and

- Research into the recharging of sand dune systems and beaches.

7.2.3 The following suggestions have been made for hydraulics and geomorphology modelling:

- The offshore northern boundary of the flow model should be extended to at least the Mull of Kintyre, and far-field effects should be refined;

- The effects of construction and decommissioning activities on the hydraulic, sediment and morphology regime should be quantified;

- The use of 3D flow modelling to support requirements for more detailed sediment modelling should be considered; and

- A detailed scour assessment.

7.2.4 A series of water quality studies are suggested to improve confidence in the predictions of water quality effects and to refine the requirements for measures to prevent or reduce effects. A detailed water quality survey of the estuary and tributaries would provide robust baseline data on water and sediment quality. A more detailed estuary-wide 2-D salinity model would better resolve lateral salinity gradients and the effects of changes in water circulation on those gradients. Further modelling and assessment of estuary-wide changes in suspended sediment concentrations would better quantify the spatial extent and magnitude of potential changes. It is suggested that an estuary-wide nutrient model and an estuary-wide dissolved oxygen model are developed and it is also suggested that detailed scenario modelling of bathing water compliance risks at relevant bathing waters and detailed modelling of thermal plume issues should be undertaken. Laboratory studies of potential changes in biogeochemical cycling of contaminants are suggested. Development of a temperature model to evaluate changes in temperature within lagoon options is suggested if a lagoon option were to be pursued.

7.2.5 With regards to flood risk and land drainage, before the design of any of the alternative options could be undertaken, there are a number of assessments which would benefit from refinement through further modelling or analyses to reduce and uncertainties. These include, further modelling of tributaries for surge tides and fluvial floods; detailed modelling of far field effects for surge tide conditions; modelling of individual outfalls to determine the extent of tide-lock effects and to determine the most appropriate measure to reduce the effects (whether additional storage or duplication of outfalls would be preferable to a pumping station); modelling to improve the estimated erosion risks which could affect tidal or sea defences; and modelling to confirm the accretion upstream of the smaller barrages in the long term and to determine whether there are any significant effects which would require measures to reduce these to an acceptable level.

7.2.6 With regards to freshwater environment and associated interfaces, further detail on geological / geomorphological SSSI designations would assist in reducing levels of uncertainty and that it would be beneficial to establish the feasibility and associated cost of providing an alternative access into Otter Hole; and the feasibility of off-setting significant effects to geological and geomorphological SSSIs, through other GCR sites. In addition, further baseline information would be useful regarding soil types, their current condition and quality, and vulnerability to changes in soil moisture, Quaternary and recent deposits adjacent to the Severn Estuary, the distribution and nature of made ground deposits and subterranean assets, particularly in the vicinity of

Weston-super-Mare. It is suggested that a high-level review is made of the post-closure closure monitoring information available from the Cardiff Bay scheme to identify actual versus predicted effects from the impoundment on subterranean infrastructure.

7.2.7 Additional physicochemical studies would also support the assessment of significant effects for other themes. This is discussed below.

Biodiversity

7.2.8 With regards to the biodiversity theme, further data and information on the baseline conditions for biodiversity would help better inform some of the effects. This includes further research on the distribution and abundance of some marine ecology receptors, particularly cephalopods and *Sabellaria.* It is suggested that WeBS core counts are conducted for a period of five years, in order that the five-year mean peak values used to represent the baseline are complete and accurate.

7.2.9 Further development of modelling techniques for waterbirds could reduce the levels of uncertainty surrounding predictions. Specifically, developing habitat association models to made predictions at the mudflat scale rather than the whole-estuary scale could improve certainty surrounding predictions of effects. Work to compare the habitat association and individual-based models, so that differences between their predictions can be better understood in the future, would also be of considerable benefit in reducing uncertainty surrounding predicted effects on waterbirds.

7.2.10 Further research into the behaviour of fish within the estuary, habitat utilisation by fish species and their prey, the effects of water quality on fish populations, the cumulative and synergistic effects of contaminants and research to understand the hearing frequencies and range of many species would improve levels of certainty surrounding the migratory and estuarine fish assessment. Additionally, data describing important life stages in many species' life-history within the Severn Estuary would benefit the study. In addition, our understanding of measures to prevent or reduce significant effects on fish is weak. Further research building on our understanding of marine ecology is suggested in order to develop effective measures.

7.2.11 Field research to establish an accurate, detailed baseline would improve certainty surrounding the terrestrial and freshwater ecology topic. With regards to marine ecology, additional work is recommended to determine the effectiveness of habitat creation as a compensation measure, especially in relation to the creation of intertidal habitat on a large scale.

Historic Environment and Landscape & Seascape

7.2.12 Further research at detailed design stage for the historic environment would assist in the prevention and reduction of significant environmental effects. It is suggested that the results of desk-based archaeological assessment are combined with the results of specific field surveys at a later stage of an alternative option development in order to ground-truth the known and potential resource identified by desk-based assessment. The results of these surveys would assist with identifying measures to prevent and reduce negative effects on the historic environment resource.

7.2.13 Further research at detailed design stage with regards to landscape and seascape would assist in the prevention and reduction of significant environmental effects. Local landscape and visual assessment would provide a more detailed view of the receiving environment and assist in the specification of measures to reduce the effects of an alternative option.

Air & Climatic Factors and Resources & Waste

7.2.14 For the air & climatic factors and resources and waste theme, it is suggested that detailed design and review is assessed in relation to the effect of the carbon footprint effect on construction, operation and decommissioning. During the detailed design process for any of the alternative options it is suggested that the demand for aggregates and embankment materials is kept under review to ensure an adequate supply during construction. At this stage, targets could be set for reuse of dredged materials and use of secondary and recycled aggregates.

Society & Economy

7.2.15 There are no significant environmental noise effects anticipated with any of the alternative options. However, the underwater assessment has been made without confirmed knowledge of the underwater baseline noise environment, and on limited information available for the noise levels of the tidal turbines. Therefore, it is recommended that monitoring of the baseline noise environment is undertaken in order to quantify the underwater noise environment and assist in the assessment of any potential effects that may arise as a result the implementation of this feasibility study.

7.2.16 There is currently a shortage of information on the economic contribution and direct and indirect employment generation of salmon and salmon trout fishing on the rivers Usk, Wye and Severn. It would be beneficial to have a better understanding of these issues should one of the barrage alternative options be taken forward.

7.2.17 It is suggested that further study into current transit times associated with navigation is undertaken to inform and enable future modelling of the transit time effects of any alternative option taken forward.

7.2.18 Some of the topics within the society and economy theme would benefit from further physicochemical studies. These are discussed below.

7.2.19 The resolution of the hydraulics and geomorphology modelling is not sufficient to provide accurate results at specific locations within the estuary with regards to the effects on commercial navigation, such as in proximity to turbine blocks or within immediate approach channels to the ports where the magnitude of potential effects would be most critical. Further modelling work is recommended to improve the predictions should a scheme in the Severn Estuary be taken forward.

7.2.20 A degree of uncertainty surrounds the nature of sediment supply to the sand banks found in the study area. It is probable that many of the sand reserves are essentially relict (finite) resources deposited during glacial times and which do not experience substantial re-supply. However, further research is suggested to ascertain the extent to which this holds true for all sites in the study area in order to determine the effects of an alternative option on the sandbanks.

7.2.21 The formation and propagation of tidal bores are sensitive to a number of factors including tidal range, current velocity and seabed/ estuary morphology. Whilst it is highly probable that the barrage options would all prevent the formation of the Severn Bore, more detailed modelling analyses are recommended to confidently address the effect with regards to the lagoon options.

7.2.22 More detailed (site specific) modelling is recommended to obtain a better understanding of exactly how pleasure beaches may be affected with regards to sediment transport and resupply of beaches.

Monitoring measures have been identified for the appraisal of alternative options, if taken forward. Suggestions are also made for research and development that would be needed to reduce uncertainties of the effects of alternative options, and how they can be managed, prior to taking any alternative option forward.

SECTION 8

GLOSSARY

8 GLOSSARY

Term	Definition
Alluvial	Material that is transported by rivers
Alternative options	Options screened from long-listed options, to be taken forward for analysis in the SEA following the public consultation conducted in 2009.
Anthropogenic	Processes or materials that are derived from human activities.
Appropriate Assessment	A process required by the Habitats Regulations (SI 2010/ 490) to avoid adverse effects of plans, programmes and projects on Natura 2000 sites and thereby maintain the coherence of the Natura 2000 network and its features.
Analogous	Similar or alike in some particular respects.
Ancillary development	Works that are necessary as a consequence of the construction of a tidal power facility to prevent or reduce the effect on day to day operation of existing assets.
ASMITA	A behaviour–based model that describes morphological interaction between a tidal basin and it adjacent coastal environment. ASMITA is typically used to examine the long term morphological evolution in estuaries.
Barrage	A manmade obstruction across a watercourse to retain a head of water on the rising tide, and then run the water through turbines when the tide level drops.
Bathymetry	The measurement of water depth of oceans, seas or other large bodies of water.
Bristol Channel	The area seaward of the headlands at Lavernock Point on the Welsh coast and Brean Down on the English coast (see Severn Estuary and also Inner Bristol Channel and Outer Bristol Channel)
Bulb Kapeller type turbines	The Kapeller Bulb turbine is a turbine regulated only by its adjustable runner blades (single regulation). It has fixed wicket gates. It is adaptable to pumping as well as generation but only suited to one way generation. Kapeller Bulb turbine technology has largely been superseded by Bulb Kaplan turbines.
Bulb Kaplan turbines	The Kaplan turbine is a propeller-type water turbine that has adjustable blades and adjustable wicket gates (double regulation). It is adaptable to pumping as well as generation. Kaplan turbines are now widely used throughout the world in high-flow, low-head power production. The Kaplan turbine is an inward flow reaction turbine, which means that the working fluid changes pressure as it moves through the turbine and gives up its energy. The Kaplan turbine is suited to one or two way generation.
Bulb turbines	The generator is mounted in a bulb on the main turbine axis upstream of the runner blades for one way generation. Bulb turbines can be used for one or two way generation depending on the type (see above).

Term	Definition
Caissons	Prefabricated concrete units used to construct parts of a barrage, lagoon or other offshore structures. Caissons can be used to house turbines, sluices or to construct navigation locks, or they may just be plain units used for impoundment construction.
Cephalopods	Any mollusc of the class Cephalopoda, including cuttlefish, squid and octopus.
Coalfield river	A river draining a coalfield valley
Coastal Squeeze	Process whereby the coastal margin is squeezed between a fixed landward boundary and the rising sea level
Compensation	Measure which makes good for loss or damage to an SAC or SPA feature, without directly reducing that loss/damage. Only used in relation to the Habitats Directive (see offsetting, below).
Compensation need	The need for compensation arising, following implementation of measures to prevent and reduce effects, due to residual effects on Natura 2000 sites.
Conservation status	The sum of the influences acting on the species concerned that may affect the long term distribution and abundance of its population within its territory (conservation status can be assessed as favourable or unfavourable).
Consequential development	It is conceivable that a major tidal power scheme would facilitate or attract other developments, which may themselves pose significant environmental effects. These developments are described as 'consequential developments'.
Cumulative effects	Effects arise, for instance, where several developments each have insignificant effects but together have a significant effect, or where several individual effects of the plan have a combined effect.
Decommission	To dismantle, deactivate or remove something from service.
Digital Elevation Model	A digital map of the elevation of an area of the earth. Images contain pixel values which are elevation numbers.
Direct effects	The original effect as a result of an alternative option (see indirect effects)
Ebb	When the sea or tide ebbs, it moves away from the coast and falls to a lower level
ebb mode	One way generation on ebb tides only i.e. during the period between high tide and the next low tide in which the sea is receding.
Ebb and flood mode	Two way generation during the ebb and flood tides
Effect	Used to describe changes to the environment as a result of an alternative option (see also direct effects, indirect effects, far-field effects and cumulative effects)
Eutrophication	An increase in chemical nutrients (compounds containing nitrogen or phosphorus). This in turn can lead to 'eutrophication effects' – an increase in an ecosystem's primary productivity (excessive plant growth and decay), and further effects including lack of oxygen and severe reductions in water quality,

Term	Definition
	fish, and other animal populations.
Far-field effects	Effects that are felt outside the Severn Estuary study area.
Flood	The inward flow of the tide – this is the opposite of ebb. This refers to a mode of operation for a STP alternative option
Flushing time	The time required to replace a substance, usually freshwater within estuaries accumulated by the river discharge. Generally flushing time is primarily influenced by freshwater flow from river discharge.
Freshwater stragglers	Freshwater species found in low numbers in estuaries and whose distribution is usually limited to the low salinity, upper reaches of estuaries.
Future baseline	Baseline during construction (2014-2020) and operation (2020-2140), decommissioning and longer term trends.
Geomorphology	The study of the changing form of the estuarine environment and its components in relation to physical forcing.
HABMAP	HABMAP is a three-year seabed mapping project covering the southern part of the Irish Sea. The HABMAP project has produced working habitat maps of the seabed of the southern Irish Sea using novel predictive modelling techniques.
Historic land-use assessment	The process of mapping the extent of past and present land use areas, categorised according to their form, function and period of origin
Hydrodynamics / hydraulics	The science of physical forces acting on the water.
Hypertidal	A tidal range in excess of 6m.
Impoundment	A body of water, such as a reservoir, made by impounding
Inclement weather	Stormy or severe weather.
Indicator	A measure of variables over time, often used to measure achievement of objectives.
Indirect effects	Those effects which occur away from the original effect or as a result of a complex pathway.
Inner Bristol Channel	The downstream limit extends from Nash Point in Wales to the west of Minehead along the English coast. The upper limit extends from Swanbridge on the Welsh coast to Brean Down along the English coast.
Intertidal	For the physicochemical theme this is considered as the area between mean high water springs and mean high water neaps. For the biodiversity theme, this is considered as the area between the highest astronomical tide (HAT) and the lowest astronomical tide (LAT).

Term	Definition
Irreversible	Cannot be reversed. If the timescale for a receptor's return to baseline condition is greater than 50 years then it would be considered irreversible.
Lagoon(s)/ Land-connected lagoons	A man-made enclosed body of water that retains a head of water on the rising tide and then runs the water through turbines when the tide level drops. A land connected lagoon uses the shoreline to make the enclosure.
Landscape	An area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors. (Article 1, European Landscape Convention Council of Europe, 2002). The explanatory note expands on this definition as follows: "Landscape" is defined as a zone or area as perceived by local people or visitors, whose visual features and character are the result of the action of natural and/or cultural (that is, human) factors. This definition reflects the idea that landscapes evolve through time, as a result of being acted upon by natural forces and human beings. It also underlines that a landscape forms a whole, whose natural and cultural components are taken together, not separately."
Landscape impacts	The likely effects on landscape character or components due to a development proposal or change in land management. They can therefore affect the way in which the landscape is experienced. Impacts can be positive (beneficial) or negative (detrimental); and can also be cumulative.
Long-listed options	All options identified in the SDC report, Call for Proposals and other strategically selected proposals as well as the Interim Options Analysis Report.
Marine migrants	Species that spawn at sea and often enter estuaries in large numbers and particularly as juveniles.
Marine stragglers	Species that spawn at sea and typically enter estuaries only in low numbers.
Measures to prevent or reduce effects	Measures to prevent or reduce any significant adverse effects on the environment.
Methanogenesis	The formation of methane by microbes known as methanogens.
Migratory cues	Sensory stimulants in the natural environment that trigger and/or direct fish migratory activity; e.g. freshwater discharge, light intensity and water temperatures.
'Moderate' status (under the WFD)	The values of the biological quality elements for the surface water body type deviate moderately from those normally associated with the surface water body type under undisturbed conditions. The values show moderate signs of distortion resulting from human activity and are significantly more disturbed than under conditions of good status.
Morphological	The form and structure of landforms.
Middle Layer Super Output Area (MSOA)	Geographical area designed for the collection and publication of small area statistics. Middle Layer Super Output Area has a minimum population 5000, mean population 7200.

Term	Definition
Natura 2000	Natura 2000 is the European Union-wide network of protected areas, recognised as 'sites of Community importance' under the EC Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora). The Natura 2000 network includes two types of designated areas: Special Areas of Conservation (SAC) and Special Protection Areas (SPA).
Negative effects	Changes which are unfavourable for a receptor. Can sometimes be referred to as 'adverse'.
Noise Sensitive Receptor (NSR)	Any entity that is sensitive to noise (or vibration).
Offsetting	Measures to as fully as possible offset any significant adverse effects on the environment. Such measures would aim to make good for loss or damage to an environmental receptor, without directly reducing that loss/damage. Not used in relation to the Habitats Directive (see compensation, above).
One way generation	The operating mode whereby power is generated on only one phase of the tidal cycle. For Severn tidal power, one way generation is typically ebb mode.
Original scheme	The form of the scheme when it was shortlisted at the end of Phase One (Scoping).
Outer Bristol Channel	The outer limit extends from St. Govan's Head in Pembrokeshire to Hartland Point in Devon, which traditionally defines the lower limit of the Bristol Channel. The upper limit extends from Nash Point in Wales to the west of Minehead along the English coast.
Permanent effect	An effect which would last at least for 50 years.
Permeable	Allowing liquid or gas to pass through.
Phase One	The previous stage of the STP Feasibility Study - i.e. the Decision Making Assessment Framework (developing a short-list of options) and SEA Scoping.
Phase Two	The current stage of the STP Feasibility Study - i.e. short-listed options appraisal and main assessment stage of the SEA.
Physicochemical	The combination of physical and chemical components of the environment
Positive effects	Changes which are favourable for a receptor. Can sometimes be referred to as 'beneficial'.
Pumping	Operating turbines in reverse to pump water from lower to higher levels. Pumping can be used during one way generation to raise impounded water levels so that more energy can be generated when the ebb tide is receding.
Ramsar site	Ramsar sites are designated under the International Convention on Wetlands of International Importance 1971 especially as Waterfowl Habitat (the Ramsar Convention).

Term	Definition
Receptor	An entity that may be affected by direct or indirect changes to an environmental variable.
Reversible	Can be reversed. If the timescale for a receptor's return to baseline condition is less than 50 years then it would be considered reversible.
Scoping	The process of deciding the scope and level of detail of an SEA, including the environmental effects and alternative options which need to be considered, the assessment methods to be used, and the structure and contents of the Environmental Report.
SEA objective	A statement of what is intended, specifying the desired direction of change in trends.
SEA8	Offshore Energy SEA Area 8.
Seabed	The areas permanently covered by the sea, i.e. Lowest Astronomical Tide. Sometimes referred to as subtidal.
Seascape	The definition of seascape is taken from the Welsh Seascape Assessment – CCW 2010 – 'An area of sea, coastline and land, as perceived by people, whose character results from the actions and interactions of land and sea, by natural and/or human factors.'
Sequestration	The removal and storage of carbon from the atmosphere in carbon sinks (such as in oceans, soils and plants) through physical or biological processes.
Severn Estuary	This is the physical extent of the estuary and does not reflect the Study Area (see below) or nature conservation designations. Downstream limit - headlands at Lavernock Point on the Welsh coast and Brean Down on the English coast passing through the small island features of Flat Holm and Steep Holm. Upstream limit – Haw Bridge, upstream of Gloucester on the River Severn (based on 1 in 100 year flood risk area and also used by Shoreline Management Plan (SMP) (Gifford, 1998) and Coastal Habitat Management Plan (CHaMP) (ABPmer, 2006)). N.B. The tidal limit, which for the Severn is at Maisemore (West Parting) and Llanthony (East Parting) weirs, near Gloucester.
Severn Tidal Power Study Area	The general study area used for the project broadly extended from the River Severn upstream tidal limit at Maisemore to downstream on the Severn Estuary as far as a line drawn between Worm's Head and Morte Point. It included the landward fringe and tributaries such as the River Wye and the River Usk up to the tidal limit and where necessary further inland. This study area was determined by the footprint of the alternative options which could extract tidal range power from the Severn Estuary and any areas which may be affected by doing so.
Short-listed options	Options screened from long-listed options, to be taken forward for analysis in the SEA following the public consultation conducted in 2009.

Term	Definition
Significant environmental effects	Effects on the environment which are significant in the context of a plan or programme. Criteria for assessing significance are set out in Annex II of the SEA Directive (Council Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment). (See also Appendix 8).
Site of Special Scientific Interest (SSSI)	Designated under the Wildlife and Countryside Act 1981, any land considered by Natural England to be of special interest because of any of its flora, fauna, or geological and physiographical features.
Sluice caissons	Prefabricated concrete structures placed into the water to house a sluice.
Special Area of Conservation (SAC)	Protected site designated under the EC Habitats Directive (Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora). Article 3 of the Habitats Directive requires the establishment of a European network of important high-quality conservation sites that will make a significant contribution to conserving the 189 habitat types and 788 species identified in Annexes I and II of the Directive (as amended). The listed habitat types and species are those considered to be most in need of conservation at a European level (excluding birds).
Special Protection Area (SPA)	Protected site classified in accordance with Article 4 of the EC Directive on the Conservation of Wild Birds (Council Directive 09/147/EC), also known as the Birds Directive. They are classified for rare and vulnerable birds, listed in Annex I to the Birds Directive, and for regularly occurring migratory species.
Straflo type turbines	A more compact turbine compared to Bulb turbine technology. Instead of containing the generator in a bulb, it is located and designed for ebb only operation and not suited to pumping.
Strategic Environmental Assessment (SEA)	Term used to describe environmental assessment as applied to policies, plans and programmes. 'SEA' is used to refer to the type of environmental assessment required under the SEA Directive.
Subtidal	Areas (particularly with reference to habitats) that lie below the level of the lowest astronomical tide.
Synergistic effects	Effects which interact to produce a total effect greater than the sum of the individual effects, so that the nature of the final impact is different to the nature of the individual effects. Included within cumulative effects (see above).
Temporary effects	An effects which only lasts part of the project lifetime, e.g. is confined to the construction period.
Terrestrial	Of, or pertaining to, land as distinct from water.
The Shoots	The downstream boundary extends from Undy along the Welsh coast to Severn Beach along the English coast, just to the south of the M4 motorway crossing. The upstream limit extends just to the north of the M46 motorway crossing,

Term	Definition
	between Beachley on the Welsh coast and Aust on the English coast.
Tidal bore	A tidal phenomenon in which the leading edge of the incoming tide forms a wave (or waves) of water that travel up a river or narrow bay against the direction of the current.
Tidal curve	A graphic representation of the rise and fall of the tide.
Tidal Prism	The difference between the mean high-water volume and the mean low-water volume of an estuary
Tidal range	The vertical difference in between the highest high tide and the lowest low tide
Transboundary effect	An environmental effect upon another EU Member State
Turbine caissons	Prefabricated concrete structures placed into the water to house turbines.
TWh/year	A unit used to describe how much energy generated, sold, consumed, etc. A terawatt-hour refers to generating or using power at a capacity of 1 terawatt (10^{12} watts) for one hour. A terawatt-hour per year means the equivalent amount of power sometime within the period of a year.
Two way generation	The operating mode whereby power is generated on both phases of the tidal cycle (ebb and flood)
Upper Severn Estuary	Upstream from the M46 motorway crossing, between Beachley on the Welsh coast and Aust on the English coast, to the tidal limit along the River Severn at Maisemere, Gloucestershire.
Variant	A modified version of the original shortlisted scheme.

SECTION 9

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9 REFERENCES

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Plate reference list

Plate number	Title	Credit	Year
3.1	Intertidal aerial over Severn	Chris Sattlberger	2008
3.2	Mouth of the River Wye	Ed Ferguson	2008
3.3	Dinosaur Foot-prints at Hayes Point to Bendrick Rock SSSI (near Barry)	Tom Sharpe, Department of Geology, National Museum of Wales"	Supplied 2010
3.4	Land drainage outfalls around the Severn Estuary	Environment Agency Coastal Habitat Management Plan	2006
3.5	Edges of the Severn Estuary at Beachley	Chris Sattlberger	2008
3.6	Allis shad	Keith Hiscock (MarLIN)	Accessed 2010
3.7	Atlantic Salmon and Putcher Nets	Delyth Toghill	2009
3.8	Twaite Shad	APEM	2010
3.9	Knot	Neil Calbrade / BTO	Accessed 2010
3.10	Dunlin flock in flight	Jill Packenham / BTO	Accessed 2010
3.11	Mute swan family	Jill Packenham / BTO	Accessed 2010
3.12	Bracket Fungus	Charles Morrison	2009
3.13	Somerset Levels	Charles Morrison	2009
3.14	Winter Starlings	Charles Morrison	2009
3.15	Quantocks Hills AONB panorama	Ryder Landscape Consultants	2009
3.16	Twmbarlwm panorama looking towards Newport	Ryder Landscape Consultants	2009
3.17	Gwent Levels	Defra / Environment Agency Coastal Habitat Management Plan	2006
3.18	The M38 Severn Crossing	Chris Sattlberger	2008
3.19	Brean Down scheduled monument	Defra / Environment Agency Coastal Habitat Management Plan	2006
3.20	Commercial shipping and recreational boating	Chris Sattlberger	2008
3.21	Hinkley Point	Ryder Landscape Consultants	2009
3.22	Sharpness Port	Defra / Environment Agency Coastal Habitat Management Plan	2006
3.23	Bristol Port	Defra / Environment Agency Coastal Habitat Management Plan	2006
3.24	Cardiff Bay Lagoon	Defra / Environment	2006

Plate number	Title	Credit	Year
		Agency Coastal Habitat Management Plan	
3.25	Severn bore surfing at Minsterworth	Jim Nicholls	2007
3.26	Severn beach	David Walker	2009
3.27	Foreshore fishing	Robin Drayton	2009
4.1	La Rance Tidal Power Barrage	David Keiller	2009
4.2	Lock at La Rance Tidal Power Barrage	Tom Matthewson	2009
4.3	Bulb Turbine at La Rance Tidal Power Barrage	Adrian Williams	2009

SECTION 10

APPENDICES

10 APPENDICES:

Appendix 1 - Theme Papers and Topic Papers and associated annexes

Appendix 2 – Stages in the SEA Process and how they were undertaken in the Severn Tidal Power SEA

Appendix 3 – Potentially Significant Issues Identified at Scoping

Appendix 4 – Organisations represented in the SEA Steering Group

Appendix 5 – SEA objectives, Assessment Criteria and Indicators

Appendix 6 – Executive Summary for each of the Ten Alternatives

Appendix 7 – Severn Tidal Power Environmental Receptors

Appendix 8 – Approach to Identifying the Significant Effects of the Alternative Options

Appendix 9 – Summary of Likely Significant Effects of the Alternative Options

Appendix 10 – Log of measures to prevent, reduce and as fully as possible offset any significant adverse effects on the environment of implementing the plan or programme

Appendix 11 – Summary of how each alternative option performs in relation to the SEA objectives

10.1 Appendix 1: Theme Papers and Topic Papers and associated annexes

Theme papers and topic papers and associated annexes:

Theme Paper	Topic Paper	Annex No.	Report Title (Note: Appendices are included within Topic Papers)	Version No.
Physicochemical	Hydraulics & Geomorphology		Hydraulics & Geomorphology Topic Paper Appendix A – Value, Vulnerability & Magnitude of Effect	1.5
		Annex 1	Geo 12 Summary report	4.0
		Annex 2	Geo 1 Conceptual design for short-listed options	2.0
		Annex 3	Geo 2 Analogues	4.0
		Annex 4	Geo 3 Improve baseline understanding of intertidal morphology	6.0
		Annex 5	Geo 4 Improve baseline understanding of suspended sediment regime HRW	6.0
		Annex 6	Geo 4 Improve baseline understanding of suspended regime (River inputs) ABP	4.0
		Annex 7	Geo 5 Confirm far-field extent of effects on hydraulics	4.0
		Annex 8	Geo 6 Investigate changes to hydraulics for short-listed options (water levels and flows) - Part A HRW	6.0
		Annex 9	Geo 6 Investigate changes to hydraulics for short-listed options (water levels and flows) - Part B ABPmer	4.0
		Annex 10	Geo 7 Investigate Wave Regime	4.0
		Annex 11	Geo 7 Wave conditions for sediment and morphology assessment (HRW)	4.0
		Annex 12	Geo 8 Investigate mud transport	5.0
		Annex 13	Geo 9 Sediment budget	3.0
		Annex 14	Geo 10 Investigate sand transport	4.0
		Annex 15	Geo 11 Morphological evolution of intertidal	5.0
		Annex 16	Geo 12 Morphological evolution of estuary	4.0
		Annex 17	Geo 14 Construction related issues	4.0
	Marine Water Quality		STP Marine Water Quality SEA Topic Paper	2.0

Theme Paper	Topic Paper	Annex No.	Report Title (Note: Appendices are included within Topic Papers)	Version No.
			Appendix A - Policy Review Appendix B – Value, Vulnerability & Magnitude of Effect	
		Annex 1	Flushing and pH	3.0
		Annex 2	Salinity	4.0
		Annex 3	Temperature	2.1
		Annex 4	Thermal plumes	2.0
		Annex 5	Stratification	2.0
		Annex 6	Nutrients and eutrophication	3.0
		Annex 7	Dissolved oxygen	3.0
		Annex 8	Pathogens	2.0
		Annex 9	Contaminants	3.0
	Flood Risk & Land Drainage	None	STP Flood Risk & Land Drainage SEA Topic Paper Appendix A – Value, Vulnerability & Magnitude of Effect Appendix B _ Land Drainage Cells and Characterisation Appendix C - Benefits of Reduced Tidal Levels or Wave Action - Summary of GIS Analysis Appendix D - Details of the Assessment of Increased Flood Risks due to Restrictions of Land Drainage Appendix E - Urban Drainage Outfalls Appendix F - Assessment of Erosion Risks to Defences as a Result of Geomorphological Changes Appendix G - Effect of Alternative Option B3 on Cardiff Bay Flood Levels STP Flood Risk & Land Drainage SEA Topic Paper Figures	2.0
	Freshwater Environment & Associated Interfaces	None	STP Freshwater Environment & Associated Interfaces SEA Topic Paper STP Freshwater Environment & Associated Interfaces SEA Topic Paper Figures Appendix A – Value, Vulnerability & Magnitude of Effect Note Appendix B – Contaminated Land Appendix C – Surface Water Abstractions	2.0

Theme Paper	Topic Paper	Annex No.	Report Title (Note: Appendices are included within Topic Papers)	Version No.
			Appendix D – Groundwater Abstractions Appendix E – Geological SSSIs	
Biodiversity	Marine Ecology		STP Marine Ecology SEA Topic Paper	2.0
		Annex 1	Baseline Information	2.0
		Annex 2	Evaluation of options - supporting information	1.0
		Annex 3	Habitat Modelling	2.0
		Annex 4	Ecological (logistic regression & HABMAP) modelling based predictions	1.0
			Numerical Modelling of Saltmarsh in the Severn Estuary – EX 6180	2.0
	Migratory & Estuarine Fish		STP Migratory & Estuarine Fish SEA Topic Paper	2.0
		Annex 1	Evaluation of Plan Alternatives	1.0
		Annex 2	Measures to prevent and/or reduce STP plan alternative effects	2.0
		Annex 3	Measures to offset STP Plan Alternative Effect	2.0
		Annex 4	Migratory fish life cycle models	2.0
		Annex 5	Fish passage through tidal power schemes	2.0
		Annex 6	Assessment of the Economic Impacts to Fishing	2.0
		Annex 7	Fish Behaviour and Ecology	2.0
		Annex 8	Assessment of current telemetry technologies for the tracking of fish in the Severn Estuary	2.0
			Fish modelling to support study of effects of Severn Barrage and Lagoon proposals on fish migration through the Severn Estuary	4.0
	Waterbirds		STP Waterbirds SEA Topic Paper Appendix A - Information used to Derive the List of Receptors Appendix B - A Review of other sites within the Natura 2000 Network that could potentially be affected by the alternative options Appendix C - Summary Information used to inform the Baseline Accounts for each receptor Appendix D - Waterbirds Value, Vulnerability and Magnitude of Effect Advice Notes - June 2009 Appendix E - Summary of Potentially Significant Issues, the Approaches used to assess them and modelling results	3.0

Theme Paper	Topic Paper	Annex No.	Report Title (Note: Appendices are included within Topic Papers)	Version No.
		Annex 1	Waterbird Surveys	2.0
		Annex 2	Waterbird Habitat-Association Modelling	2.0
		Annex 3	Individual-Based Modelling	2.0
	Terrestrial & Freshwater Ecology	None	STP Terrestrial & Freshwater Ecology SEA Topic Paper Appendix A - Terrestrial and Freshwater Ecology Receptors Baseline Study Appendix B - Terrestrial and Freshwater Ecology Receptor Value and Vulnerability STP Terrestrial & Freshwater Ecology SEA Topic Paper Figures	2.0
Historic Environment, Landscape and Seascape	Historic Environment		STP Historic Environment SEA Topic Paper	2.0
		Annex 1	Technical Annex	2.0
		Annex 2	Value, Vulnerability and Magnitude of Effect	
	Landscape & Seascape	None	STP Landscape and Seascape SEA Topic Paper Appendix A - Local Landscape and Seascape Baseline at Landing Points Appendix B - Natural England's Countryside Character Area Summary Reports Appendix C - GIS Modelling Methodology for Production of Zones of Theoretical Visibility STP Landscape and Seascape SEA Topic Paper - ZTV Figures	2.0
Air & Climatic Factors and Resources & Waste	Air & Climatic Factors	None	Air & Climatic Factors - Air Quality and Carbon Footprint Topic Paper Appendix A - Air Quality Baseline Receptor: Value, Vulnerability and Thresholds for Magnitude of Effect Appendix B - Value, Vulnerability and Thresholds for Magnitude of Effect - Carbon Footprinting Appendix C - Air Quality Local Habitat Identification & Calculations Appendix D - Air Quality Emissions Assumptions Appendix E - Rail and Shipping Capacity Assumptions Appendix F - Air Quality Off-setting Appendix G - Air Quality Transport Emissions Appendix H - Air Quality Total Dredging Emissions	3.0

Theme Paper	Topic Paper	Annex No.	Report Title (Note: Appendices are included within Topic Papers)	Version No.
	Resources & Waste	None	STP Resources & Waste SEA Topic Paper Appendix A - Value, Vulnerability and Magnitude of Effect Appendix B - Methodology for Assessment of Effects	3.0
Society and Economy	Communities	None	STP Communities SEA Topic Paper Appendix 1 - Figures Appendix 2 – Discussion paper Appendix 3 – Baseline Appendix 4 – Assessment Methodology	4.0
	Navigation	None	STP Navigation SEA Topic Paper Appendix A - Location Plan Appendix B - STP Short list options Appendix C - Navigation Authority Limits Appendix D - Plan of Proposed Navigation Routes and Channel Dredging Appendix E - Value, Vulnerability and Thresholds for Magnitude of Effect Appendix F - Detailed Assessment of Likely Significant Effects on the Environment. Alternative Option – B3: Cardiff to Weston Barrage Appendix G - Detailed Assessment of Likely Significant Effects on the Environment. Alternative Option – B4: Shoots Barrage Appendix H - Detailed Assessment of Likely Significant Effects on the Environment. Alternative Option – B5: Beachley Barrage Appendix I - Detailed Assessment of Likely Significant Effects on the Environment. Alternative Option – L2: Welsh Grounds Lagoon Appendix J - Detailed Assessment of Likely Significant Effects on the Environment. Alternative Option – L3 - Bridgwater Bay Lagoon Appendix K - Tidal Modelling Results for All Schemes and Baseline Ship Movement Data	2.0
	Noise & Vibration	None	Topic Paper	

Theme Paper	Topic Paper	Annex No.	Report Title (Note: Appendices are included within Topic Papers)	Version No.
			Appendix A - Value, Vulnerability and Thresholds for Magnitude of Effect	2.0
	Other Sea Uses	None	STP Other Sea Uses SEA Topic Paper Appendix A - Recommended Bathing Beaches within the Study Area Appendix A - Beaches in Study Area used for Leisure Activities Appendix C - Canoe and Diving Clubs in the Study Area Appendix D - Baseline Receptor: Value, Vulnerability and Thresholds for Magnitude of Effect STP Other Sea Uses SEA Topic Paper Figures	2.0

10.2 Appendix 2: Stages in the SEA process and how they were undertaken in the Severn Tidal Power SEA

Stages in the SEA process (based on the Practical Guide to the SEA Directive, Figure 5) and how they were undertaken in the Severn Tidal Power SEA

SEA Stages and Tasks	Purpose	STP SEA
Stage A: Setting the context and objectives, establishing the baseline and deciding the scope		
A1. Identifying other relevant plans, programmes and environmental protection objectives.	To establish how the plan or programme is affected by outside factors, to suggest ideas for how any constraints can be addressed, and to help to identify SEA objectives.	Stage A was largely undertaken in Phase 1 (Scoping) of the STP Feasibility Study. Table 2.1 in the Scoping Report sets out how these tasks were reported within the Scoping Report. During Phase Two (SEA), feedback received during the scoping consultation process was used to refine the information gathered during stages A1-A4. Further information is provided in Section 3.1 – 3.5.
A2. Collecting baseline information	To provide an evidence base for environmental problems, prediction of effects, and monitoring; to help in the development of SEA objectives.	
A3. Identifying environmental problems.	To help focus the SEA and streamline the subsequent stages, including baseline information analysis, setting of the SEA objectives, prediction of effects and monitoring.	
A4. Developing SEA objectives	To provide a means by which the environmental performance of the plan or programme and alternatives can be assessed.	
A5. Consulting on the scope of SEA	To ensure that the SEA covers the likely significant environmental effects of the plan or programme.	
Stage B: Developing and refining alternatives and assessing effects		
B1. Testing the plan or programme objectives against the SEA objectives	To identify potential synergies or inconsistencies between the objectives of the plan or programme and the SEA objectives and help in developing alternatives.	This stage was completed as part of Phase Two (SEA) of the STP Feasibility Study. Further information is provided in section 3.5.
B2. Developing strategic alternatives	To develop and refine strategic alternatives.	This process commenced in Phase One (Scoping) of the STP Feasibility Study, with the evaluation of a long list of options, within an 'assessment framework', to produce five short-listed alternative options. The assessment framework included technical, environmental and social criteria. The five short-listed alternative options were defined and optimised at the outset of Phase Two (SEA), using a set of refined criteria that reflected the SEA objectives (see B1).
B3. Predicting the effects of the plan or	To predict the significant environmental effects of the plan or	During Phase One (Scoping), potentially significant issues

SEA Stages and Tasks	Purpose	STP SEA
programme, including alternatives	programme and alternatives.	associated with generic alternatives were identified. During Phase Two (SEA) of the STP Feasibility Study, the environmental effects of the five short-listed alternative options were identified.
B4. Evaluating the effects of the plan or programme, including alternatives	To evaluate the predicted effects of the plan or programme and its alternatives and assist in the refinement of the plan or programme.	Appendix 8 sets out the approach undertaken within the SEA topic assessments to identify the significant effects of the five alternative options. Section 6 details the evaluation of the predicted significant environmental effects on individual receptors against the SEA objectives.
B5. Considering ways of mitigating adverse effects	To ensure that adverse effects are identified and potential measures to *prevent, reduce or as fully as possible offset* those effects are considered.	This SEA considered the efficacy of potential measures to *prevent, reduce and as fully as possible offset* likely adverse effects. Each topic assessment has also considered the likely effects of such measures suggested by other topics. During the environmental assessment of the schemes, the alternative options were further refined and measures to prevent or reduce anticipated significant adverse effects on the environment were incorporated where appropriate (for further details see Section 5.4).
B6. Proposing measures to monitor the environmental effects of plan or programme implementation	To detail the means by which the environmental performance of the plan or programme can be assessed.	Section 7.1 of this environmental report provides a high-level framework for envisaged monitoring measures, which can be applied to all of the Severn Tidal Power alternative options under consideration.
Stage C: Preparing the Environmental Report		
C1. Preparing the Environmental Report	To present the predicted environmental effects of the plan or programme, including alternatives, in a form suitable for public consultation and use by decision-makers.	The structure and content of this environmental report has been agreed following extensive informal input between the project team and representatives of Government bodies and statutory advisors.
Stage D: Consulting on the draft plan or programme and the Environmental Report		
D1. Consulting the public and Consultation Bodies	To give the public and the Consultation Bodies an opportunity to express their	Extensive opportunities for informal input were provided

SEA Stages and Tasks	Purpose	STP SEA
on the draft plan or programme and the Environmental Report.	opinions on the findings of the Environmental Report and to use it as a reference point in commenting on the plan or programme. To gather more information through the opinions and concerns of the public.	throughout the SEA Feasibility Study process, including technical and stakeholder workshops. This Environmental Report has is issued for public consultation (see Section 2.3 for further details).
D2. Assessing significant changes	To ensure that the environmental implications of any significant changes to the draft plan or programme at this stage are assessed and taken into account.	Any significant changes that are made to the plan or programme arising from consultation will be taken into account within the 'SEA Statement' (see below).
D3. Making decisions and providing information	To provide information on how the Environmental Report and consultees' opinions were taken into account in deciding the final form of the plan or programme to be adopted.	Following the public consultation period, an 'SEA Statement' will be issued detailing this information.
Stage E: Monitoring the significant effects of implementing the plan or programme on the environment		
E1. Developing aims and methods for monitoring	To track the environmental effects of the plan or programme to show whether they are as predicted; to help identify adverse effects.	This stage follows the completion of Phase Two (SEA) of the STP Feasibility Study. However, following the evaluation of environmental effects and proposed measures to prevent, reduce or as fully as possible offset effects, it is envisaged that the high-level monitoring suggestions detailed in Section 7.1 of this report would be reviewed prior to implementation.
E2. Responding to adverse effects	To prepare for appropriate responses where adverse effects are identified.	

10.3 Appendix 3: Potentially significant issues identified during Phase One (Scoping) and where these have been addressed during Phase Two

Potentially significant issues identified during Phase One (Scoping) and where these have been addressed during Phase Two

Phase One Topic	Potentially significant issues identified in Phase One (Scoping)	Section of Phase Two (SEA) Environmental Report and supporting documentation
Hydraulics & Geomorphology	Changing tidal conditions upstream and downstream of options	Hydraulics & Geomorphology
	Consequent effects on the baseline environment, e.g. water levels, flows (including the Severn tidal bore), waves, estuary sediment regime and morphology, water quality, existing defences	Hydraulics & Geomorphology
Marine Water Quality	Change in concentrations of contaminants in estuary water / sediments	Marine Water Quality
	Changes to estuary salinity regime and stratification	Marine Water Quality
	Changes to estuary water flushing characteristics and light attenuation	Marine Water Quality
	Changes to sediment concentrations, transport and processes	Marine Water Quality
	Changes in suspended sediments leading to changes in primary productivity and potential for eutrophication effects	Marine Water Quality
Flood Risk & Land Drainage	Attenuation of surge tides reducing flood risk	Flood Risk & Land Drainage
	Changes to propagation of wave action into the upper estuary	Flood Risk & Land Drainage
	Changes to tidal regime restricting fluvial discharge through some low outfalls in the upper estuary	Flood Risk & Land Drainage
	Morphological changes affecting defence structures	Flood Risk & Land Drainage
	Potential for enhanced water level management for nature conservation	Flood Risk & Land Drainage
Freshwater Environment & Associated Interfaces	Altered freshwater water quality	Freshwater Environment & Associated Interfaces
	Altered freshwater groundwater regimes	Freshwater Environment & Associated Interfaces
	Altered water quality affecting the Public Water Supply (PWS)	Freshwater Environment & Associated Interfaces
	Changes to Geological and Geomorphological SSSIs	Freshwater Environment & Associated Interfaces
Marine Ecology	Reduced intertidal areas and reduced inundation and extent of saltmarsh resulting in loss of functionality	Marine Ecology
	Reduction in extent of *Sabellaria alveolata* reef	Marine Ecology
	Implications for distribution and extent of	Marine Ecology

Phase One Topic	Potentially significant issues identified in Phase One (Scoping)	Section of Phase Two (SEA) Environmental Report and supporting documentation
	fauna and flora as a result of changes in sediment erosion and deposition patterns, salinity, turbidity and water exchange (flushing)	
	Changes in the primary productivity (planktonic and epibenthic) due to changes in the light climate, water depth and bed shear stresses	Marine Ecology
	Effects on spread of non-native marine species	Marine Ecology
Migratory & Estuarine Fish	Alterations to migratory cues	Migratory & Estuarine Fish
	Disruption to route of passage including turbine passage	Migratory & Estuarine Fish
	Habitat change and/or loss	Migratory & Estuarine Fish
	Changes to water quality	Migratory & Estuarine Fish
	Anthropogenic noise disruption	Migratory & Estuarine Fish
	[Ecological] effects on freshwater, marine and estuarine fish species	Migratory & Estuarine Fish
	Effects upon recreational, heritage and commercial fisheries owners [resulting from fish losses]	Migratory & Estuarine Fish
	[Economic] Effects upon recreational, heritage and commercial fisheries	Communities
Ornithology	Disturbance to waterbirds during construction and decommissioning	Waterbirds
	Changes to or loss of intertidal habitat	Waterbirds
	Changes to saltmarsh affecting breeding waders and wintering waterbirds	Waterbirds
	Effects on breeding seabirds within the area of the Severn Estuary	Waterbirds
	Changes to freshwater wetlands, due to changes to the water table and direct losses of habitat at landfalls and any associated consequential development	Waterbirds
	Displacement effects	Waterbirds
	Far-field changes in water levels.	Waterbirds
Terrestrial & Freshwater Ecology	During construction; permanent and temporary habitat loss, habitat fragmentation, habitat degradation, species mortality, disturbance (including noise and vibration, visual) and pollution (air, ground and water)	Terrestrial & Freshwater Ecology
	During operation, changes to the natural fluctuations of water levels, changes to water quality and changes to all habitats, flora and fauna associated with such sites. Habitat loss and degradation, associated with the hydrodynamic changes caused by an alternative option and the directly	Terrestrial & Freshwater Ecology

Phase One Topic	Potentially significant issues identified in Phase One (Scoping)	Section of Phase Two (SEA) Environmental Report and supporting documentation
	associated new infrastructure and associated development around the basin.	
Historic Environment	Direct damage to features and disturbance of wider surroundings	Historic Environment
	Indirect damage or exposure of features due to physical changes to the estuarine environment	Historic Environment
	Visual impact on the historic environment	Historic Environment
	Changes to access to the historic environment	Historic Environment
	Effects on heritage fishing and other cultural issues such as name places with cultural associations or traditional skills dependent on the estuary	Migratory & Estuarine Fish; and Communities
Landscape & Seascape	Changes to land use / infrastructure affecting character of the shoreline and further afield	Landscape & Seascape
	Effect on views of the estuary in its setting due to structures, change in tidal range, intertidal and salt marshes and water clarity as well as new land use / (ancillary) development	Landscape & Seascape
	Reduction in the dynamic character of the estuary through altered tidal conditions with consequent effects on the Severn tidal bore	Landscape & Seascape
	Loss of tranquillity during the construction and operational phase	Landscape & Seascape
	Effect of views from important viewpoints and designated sites	Landscape & Seascape
Carbon Footprinting	Changes to GHG emissions arising from:	Air & Climatic Factors
	Raw material supply and component manufacture	Air & Climatic Factors
	Energy generation from renewable sources	Air & Climatic Factors
	Transportation during construction and installation	Air & Climatic Factors
	Operational dredging, and pumping	Air & Climatic Factors
	Changes to the estuarine ecosystem, including habitat loss/ creation leading to changes in methanogenesis and sequestration	Air & Climatic Factors
	Decommissioning	Air & Climatic Factors
Resources & Waste	Waste management during construction including consideration of options for recycling / other treatment	Resources & Waste
	Types, quantities and sources of resources required during construction	Resources & Waste
	Energy production relative to natural resources consumption	Resources & Waste
Society & Economy	Effects of direct and indirect employment opportunities/ constraints on employment	Communities

Phase One Topic	Potentially significant issues identified in Phase One (Scoping)	Section of Phase Two (SEA) Environmental Report and supporting documentation
	and the economy	
	Effects of in-migration and economic changes on population characteristics, distribution and trends within the study area	Communities
	Effects of direct and indirect employment opportunities/constraints on the distribution of areas of social deprivation, low earnings, and high dependence on benefits	Communities
	Effects such as noise and air quality, flooding, in-migration and other indirect effects on health and quality of life	Communities
	Changes to access to community services and facilities	Communities
	Changes to access to recreational facilities and open space	Communities
	Effects on land use, quality and regeneration	Communities
	Effects of in-migration on the quality, value and availability of housing stock	Communities
Noise & Vibration	Construction phase noise affecting human health and disturbing wildlife	Noise & Vibration
	Operation phase noise affecting wildlife	Noise & Vibration
Navigation	Changes in tide levels and salinity affecting port access	Navigation
	Options acting as physical barriers to navigation	Navigation
	Changes to currents presenting a potential navigation hazard	Navigation
	Changes in immersion regime affecting marine structure maintenance	Navigation
Other Sea Uses	Changes to sediment characteristics in aggregate dredging areas	Other Sea Uses
	Change to dilution and dispersion of water discharges and disposals	Other Sea Uses; and Marine Water Quality
	Change to the hydraulic function of marine outfalls	Other Sea Uses
	Changes to the integrity of marine infrastructure in the estuary	Other Sea Uses
	Changes to navigation affecting other sea uses	Other Sea Uses
	Changes to marine fish and thus marine commercial fishing activities	Migratory & Estuarine Fish; and Communities

10.4 Appendix 4: Organisations represented in the SEA Steering Group

Organisations represented in the SEA Steering Group (as at January 2010)

- ABPmer
- Associated British Ports
- Association of Drainage Authorities
- Black & Veatch
- British Hydropower Association
- British Wind Energy Association
- Cadw
- Centre for Environment, Fisheries and Aquaculture Science
- Chamber of Commerce
- Civil Engineering Contractors Association
- Confederation of British Industry
- Countryside Council for Wales
- Crown Estate
- Department for Environment, Food and Rural Affairs
- Department for Transport
- Department of Communities and Local Government
- Department of Energy and Climate Change
- English Heritage
- Environment Agency
- Federation of Small Businesses
- Friends of the Earth
- Gloucester Harbour Trustees
- Government Office South West
- Hartley Anderson
- Institute of Directors
- Joint Nature Conservation Council
- Marine Fisheries Agency
- Natural England
- Parsons Brinckerhoff
- Bristol Port
- Renewable Energy Association
- Royal Academy of Engineering, Institute of Chartered Engineers, Institute of Mechanical Engineers, Institute of Engineering and Technology, Chartered Institution of Water and Environment Management
- Royal Society for the Protection of Birds
- Severn Estuary Partnership
- South West Regional Assembly
- South West Regional Development Agency
- Strategic Economic Partnerships/Tourism
- Swangrove Estate
- The Wales Office
- Universities of Cardiff, Bristol, University of West England and Swansea
- Welsh Assembly Government
- Wildfowl and Wetlands Trust
- Wildlife Trusts Partnership
- World Wildlife Fund – Cymru
- Wye and Usk Foundation

10.5 Appendix 5: SEA objectives, assessment criteria and indicators

SEA objectives, assessment criteria and indicators

SEA Objective	SEA Assessment Criteria	SEA Indicators
Topic: Hydraulics and Geomorphology		
Hydraulics and Geomorphology is not an SEA Directive topic in its own right, nor does it have an explicit policy framework. Objectives were therefore not assigned to this topic. However, in this SEA, an understanding of effects on hydraulics and geomorphology is fundamental to the assessment of many other topics, e.g. marine ecology, water quality and flood risk. Thus the assessment of alternative options in relation to hydraulics and geomorphology will focus on defining the physical changes that would arise and thereby informing the appraisal of alternative options in relation to other topics SEA objectives.		
Topic: Communities (known as Society and Economy during Phase One (Scoping))		
To create employment opportunities accessible to all To avoid adverse effects on the local and regional economy To promote the development of sustainable communities To avoid adverse effects on physical and mental health To avoid adverse effects on access to community services and facilities To promote access to recreational facilities and open space To avoid adverse effects on existing, proposed and committed land uses	Will the option positively affect existing local employment opportunities? Will the option create temporary &/or permanent employment in areas of deprivation? Will the key economic activities around the estuary be affected negatively by the option? Will the option have a beneficial effect on local and regional businesses? Will the option result in in-migration of population or otherwise affect existing population dynamics within the rural and urban areas of South Wales and South West England? Will the option result in an increase in crime and integration problems in a community?	Performance in the following industries: Construction and engineering Transport and logistics Fishing Tourism Accommodation Ports Aggregates Number of employment opportunities created in deprived areas Estimated number of recruited local workers. Estimated number of additional/indirect business and jobs as a result of the development. Number and type on in-migrants in relation to existing population characteristics in the study

SEA Objective	SEA Assessment Criteria	SEA Indicators
To seek opportunities to improve degraded environments To avoid adverse effects on the housing market	Will the option result in deterioration in the quality of life (health and well-being) as measured by increase in noise, air emissions, construction traffic and adverse effects on landscape and visual amenity? Will the construction of the option result in a temporary severance of access to community services and facilities? Will operation of the option result in a permanent severance of access to community services and facilities? Will the reduced access disproportionately affect different receptors? Will the construction of the option result in a temporary severance of access to recreational facilities and open space? Will operation of the option result in a permanent severance of access to recreational facilities and open space? Will the option result in the loss of existing, proposed or committed developments? Will the option result in the loss of agricultural land? Will the option result in the regeneration of brownfield land?	area Percentage of existing crime rate in the area. Percentage of population in 'good health'. Satisfaction with the local area as a place to live. Relative increases in air emissions anticipated from traffic, construction equipment, etc Number of major community services and facilities with access decreased or increased as a result of the option Number of deprived communities with a decrease in access Number of recreational facilities and / or open space with access changed as a result of the option. Area of landtake and land use of the land take. Committed and proposed developments in the area that will be directly affected by the option. Area of brownfield land directly affected by the option. Regeneration potential. Housing stock and deficit in housing provision.

SEA Objective	SEA Assessment Criteria	SEA Indicators
	Will the option provide opportunity for regeneration? Will the influx of migrants result in an increased demand for housing? Can the housing demand be met locally?	
Topic: Marine Ecology		
To avoid adverse effects on designated marine wildlife sites and protected habitats of international and national importance. To avoid adverse effects on valuable marine ecosystems. To avoid adverse effects on other protected marine species and their habitats. To avoid adverse effects on national and local biodiversity target features that include marine habitats and species. To avoid deterioration in status class of WFD water bodies. To minimise the risk of introduction of non-native invasive marine species. To conserve and enhance designated marine site features. To restore and enhance marine BAP species	Will the option result in the loss of marine habitats of international importance? Will the option result in the loss of marine habitats of national importance? Will the option adversely affect the achievement of favourable conservation status and hence integrity of internationally important marine wildlife sites (as defined for the potentially affected designated marine sites by the relevant Conservation Objectives developed under Regulation 33 of the Habitats Regulations)? Will the option adversely affect the favourable condition of nationally important marine wildlife sites? Will the option affect other statutory or non-statutory marine wildlife sites? Will the option affect populations of internationally or nationally protected marine	Changes in quality/extent of internationally important site features, e.g. within SPAs SACs Ramsar Sites. Changes in quality/extent of nationally important site features, e.g. within SSSIs. Changes in quality/extent of regionally important site features, e.g. within Local Wildlife Sites etc. Changes in abundance and range of SAC designated species. Changes to ecosystem function by reference to broad-scale physical changes. Changes in quality/ extent of BAP habitats. Changes in abundance and range of BAP species. Changes in WFD ecological elements.

SEA Objective	SEA Assessment Criteria	SEA Indicators
populations and/ or BAP habitat.	species? Will the option restore and enhance marine BAP habitats and species in line with UKBAP targets? Will the option adversely affect achievement of WFD ecological objectives?	
Topic: Waterbirds (known as Ornithology during Phase One (Scoping))		
To avoid adverse effects on designated wildlife sites for birds and protected habitats of international and national importance. To avoid adverse effects on other bird habitats and species. To avoid adverse effects on national and local biodiversity target features that include bird habitats and species.	Will the option result in changes in the populations of bird species of international importance, i.e. SPA and Ramsar features, and so affect their favourable conservation status and hence the conservation objectives and integrity of these sites (as defined for the potentially affected designated sites by the relevant Conservation Objectives developed under Regulation 33(2) of the Conservation (Natural Habitats &c.) Regulations)? Will the option affect other sites within the Natura 2000 network? Will the option result in changes in the populations of bird species of national importance, i.e. SSSI features, and so affect their favourable conservation status and hence the conservation objectives and integrity of these sites? Will the option affect other statutory or non-statutory wildlife sites important for birds?	Changes in bird abundance on the Severn Estuary SPA and Ramsar Site. Changes in bird abundance on other identified SPAs. Changes in bird abundance on the six relevant SSSIs with a bird interest. Changes in bird abundance on National Nature Reserves and other Local Nature Reserves. Changes in abundance and range of BAP and BoCC listed species.

SEA Objective	SEA Assessment Criteria	SEA Indicators
	Will the option maintain BAP habitats and bird species in line with UKBAP targets or affect the status of Section 41 / 42 listed BAP species in England and Wales or Birds of Conservation Concern (BoCC) listed species?	
Topic: Migratory & Estuarine Fish		
To avoid adverse effects on designated wildlife sites for fish of international and national importance. To avoid adverse effects on the populations of other protected fish species and habitats. To avoid adverse effects on national and local biodiversity target features that include fish habitats and species. To avoid adverse effects on recreational and heritage fishing. To avoid adverse effects on commercial fish resources. To minimise the risk of introduction of non-native invasive fish species.	Will the option result in adverse impacts upon the favourable conservation status and hence integrity of status of internationally designated sites supporting fish? Will the option adversely affect the achievement of favourable conservation status for internationally and nationally important fish species or their capacity to recover if currently designated as in unfavourable condition? Will the option result in changes in the populations of designated fish species of national importance, i.e. SSSI features? Will the option maintain BAP fish species in line with UKBAP targets? Will the option affect other statutory or non-statutory wildlife sites important for fish?	Changes in designated features and designation status for fish. Abundance of populations of internationally and nationally important fish species. Changes in the range of internationally and nationally designated fish species. Changes in the physical (biological and chemical) parameters upon which the fish species rely. Abundance of populations of fish species caught by recreational anglers. Abundance of populations of fish species caught in commercial fisheries.
Topic: Terrestrial and Freshwater Ecology		
To avoid adverse effects on designated terrestrial and freshwater wildlife sites of international and national importance.	Will the option result in the loss of terrestrial and freshwater habitats of international or national importance?	Changes in quality/extent of internationally important site features, e.g. within SPAs, SACs Ramsar Sites.

SEA Objective	SEA Assessment Criteria	SEA Indicators
To avoid adverse effects on valuable terrestrial and freshwater ecological networks. To avoid adverse effects on other protected terrestrial and freshwater habitats and species. To avoid adverse effects to national and local biodiversity target features including terrestrial and freshwater habitats and species. To minimise the risk of introduction of non-native invasive terrestrial and freshwater species To conserve and enhance designated freshwater and terrestrial site features. To restore and enhance freshwater and terrestrial BAP species populations and/ or BAP habitat.	Will the option adversely affect ecological networks for terrestrial and freshwater habitats and species? Will the option affect other statutory or non-statutory terrestrial and freshwater wildlife sites? Will the option adversely affect the achievement of favourable conservation status and hence integrity of internationally important wildlife sites (as defined by relevant Conservation Objectives)? Will the option adversely affect the achievement of favourable conservation status for nationally important terrestrial and freshwater wildlife sites? Will the option restore and enhance terrestrial and freshwater BAP habitats and species in line with UKBAP targets?	Changes in quality/extent of nationally important site features, e.g. within SSSIs. Changes in quality/extent of regionally important site features, e.g. within Local Wildlife Sites etc. Changes in abundance and range of SAC designated species. Changes to ecological networks by reference to broad-scale physical effect. Changes in quality/ extent of BAP habitats. Changes in abundance and range of BAP species.
Topic: Marine Water Quality		
To avoid adverse effects on water quality in relation to water quality standards and targets To avoid adverse effects on designated marine wildlife sites of international and national importance due to changes in water quality To avoid adverse effects on water quality which would affect human health, flora and fauna,	Will existing water quality standards (as defined in the WFD, revised Bathing Waters Directive, Shellfish Waters Directive etc) be compromised as a result of the development? Will development give rise to water quality changes which may lead to detrimental effects on internationally or nationally designated marine sites, fauna and flora or human health,	Changes to water quality parameters, including WFD priority substances. Changes to water, sediment and biota samples from key sites. Water quality standards. Dissolved oxygen, nutrients and suspended solids.

SEA Objective	SEA Assessment Criteria	SEA Indicators
recreation and other users To avoid adverse effects on inherent water characteristics (temperature, salinity, pH) that could lead to adverse changes in water quality To minimise risks of pollution incidents	water supply and other uses or lead to a deterioration in water status? Will the development result in changes to salinity, temperature or pH and if so, what are the potential consequences for dissolved oxygen, nutrients or contaminants? Will the option lead to pollution risks during the construction, operation and decommissioning of the development.	Changes to physical parameters - salinity, temperature or pH. Construction and operational discharges.
Topic: Freshwater Environment and Associated Interfaces		
To avoid adverse effects on water quality (whether surface water, groundwater or coastal waters) in relation to water quality standards. To avoid adverse effects on water quality which would affect human health, flora and fauna, recreation and other users. To avoid adverse effects on water abstractions (whether surface water or groundwater), particularly those utilised for the PWS. To avoid adverse effects to the water regime of designated water dependent sites of nature conservation interest. To avoid adverse effects to buildings and infrastructure. To avoid adverse effects on the soil resource.	Will option cause deterioration in water quality such that River Quality Objectives (RQO) or requirements of WFD are not attained / maintained? Will option allow improvements in water quality to be maintained? Will option cause potential negative effects to human health? Will option reduce available surface water resources in terms if quantity or quality? Will option reduce available fresh water resources in terms of quantity or quality? Will option negatively affect PWS or other licensed or unlicensed sources in terms of quantity of quality?	Estimate changes in physical, chemical and biological water quality (further details to be collated at nominated site stage where applicable) (Changes to water, sediment and biota samples at key sites. Water quality standards, plus WFD priority substances, where applicable) Estimate potential changes in availability and water quality at surface and groundwater abstractions. Indicators as above Plus Source Protection Zone (SPZ) configurations in the case of groundwater abstractions Estimate changes in stress on land drainage and associated infrastructure

SEA Objective	SEA Assessment Criteria	SEA Indicators
To avoid adverse effects on agricultural land currently in use. To avoid adverse effects on designated geological and geomorphological sites of international and national importance. To conserve and enhance designated geological and geomorphological site features.	Will option affect sites of nature conservation importance or protected areas, including freshwater fisheries, by changes in water levels, flows or quality? Will option negatively affect the Severn railway tunnel or other important transportation infrastructure? Will option negatively affect buildings? Will option affect land drainage, including pipes, sewers, culverts? Will option lead to loss of terrestrial soil resource or cause increased coastal erosion? Will changes to groundwater elevations so impair land drainage so as to reduce the fertility and/or usefulness of agricultural land? Will the option lead to reduced accessibility to designated geological / or geomorphological sites? Will the option lead to an increased rate of deterioration?	Assess changes in integrity of nature conservation sites due to changes in groundwater levels, and/or surface water flows and/or quality Assess changes in hydrology of Severn Estuary on Severn Tunnel and implications for tunnel integrity Assess changes in groundwater elevations and chemistry caused by impoundment schemes on buildings, sewers, Combined Sewer Overflow (CSOs) etc. Diversity, quality and coverage of soil resource Agricultural land quality, accessibility to machinery Estimate altered accessibility to geological and geomorphological SSSIs Estimate rate of increased deterioration by physical or chemical processes
Topic: Flood Risk and Land Drainage		
To avoid an increase in flood risk to property, land and infrastructure where this might otherwise occur as a consequence of the construction and operation of any tidal power	Will the option result in a reduction in flood risk to property, land and infrastructure assets? Will the option allow existing flood risk levels to	Changes to water levels at key locations. Risk of flooding of assets (land, property and infrastructure).

SEA Objective	SEA Assessment Criteria	SEA Indicators
structure.	be maintained whilst deferring improvements to flood defences? If the option results in an unacceptable increase in flood risk by the restriction of fluvial discharge to the estuary as a result of changes to the tidal regime, are adequate measures to prevent and reduce effects available? Will the option result in a potential change to flood risk as a result of any change to wave climate, and are adequate measures available to mitigate any adverse changes?	Costs to manage water levels at baseline (or alternative desired) level
Topic: Noise and Vibration		
To avoid adverse effects of negative noise and vibration on (humans) noise sensitive receptors. To avoid adverse effects on the acoustic quality of the marine environment. To avoid adverse effects on noise (vibration) sensitive receptors. To avoid adverse effects through vibration	Will noise & vibration exceed levels given in Planning Policy Guidance (PPG)24: Planning and Noise; BS4142 Rating Industrial noise affecting mixed residential and industrial areas; BS5228 Noise and vibration control on construction and open sites? Will option give rise to excessive environmental noise & vibration levels? Will vibration exceed levels given in BS5228 Noise and vibration control on construction and open sites. BS6472 Evaluation of human exposure to vibration in buildings?	Level of specific noise levels in relation to background noise levels. Distance from noise sensitive receptors. Predictions of changes of specific noise levels in relation to background noise levels. Sensitivity of receptors to changes (short and long term) – if information available/may be qualitative. Level of vibration
Topic: Air & Climatic Factors (known as Carbon Footprint during Phase One (Scoping))		
To maximise the opportunities for use of	What is the carbon footprint of each option (life	The carbon (equivalent) emissions payback

SEA Objective	SEA Assessment Criteria	SEA Indicators
sustainable sources of energy for the UK. To avoid adverse effects from GHG emissions over the lifecycle of the project.	cycle emissions in relation to other options)? What is the carbon payback period?	period will indicate which option is most carbon efficient.
Topic: Other Sea Uses		
To avoid adverse effects on the aggregate extraction industry. To avoid adverse effects on marine waste disposal sites and infrastructure. To avoid adverse effects on the commercial fishing industry. To avoid adverse effects on marine recreational users. To avoid adverse effects on sustainable estuary-based tourism in both the South Wales and South West England regions. To avoid adverse effects on military activity in the region. To avoid adverse effects on the energy industry. To avoid adverse effects on seabed cables in the region. To minimise adverse effects on the Severn Bore	Will the option result in the loss of revenue for the aggregate extraction industry? Will the option affect integrity or hydraulic functioning of marine assets? Will the option result in the loss of revenue for the commercial fishing industry? Will the option alter the recreational usability of the Inner Bristol Channel and Severn Estuary? Will the option result in the loss/increase of revenue for the tourism industry? Will option result in the reduction/increase of military activity in the Inner Bristol Channel and Severn Estuary? Will the option affect the functionality of power station water extraction facilities and dispersal of cooling waters? Will the option affect the potential future viability of oil and gas blocks in the Inner Bristol Channel and Severn Estuary? Will the option affect existing cable routes?	Number of aggregate extraction sites affected Measures to prevent or reduce effects/Compensation costs for marine infrastructure Number of outfall structures affected Number of outfall consents requiring revision Number of dredge material disposal sites affected Fisheries revenue affected Recreational usage numbers affected and economic value Visitor numbers affected Tourism income affected Military usage numbers Number of power generation sites affected Number of oil and gas blocks affected

SEA Objective	SEA Assessment Criteria	SEA Indicators
		Number of cables affected
Topic: Navigation		
To avoid adverse effects on Severn Estuary Navigation arising from sedimentation, geomorphology, water density, and water levels. To avoid adverse effects on the integrity of existing and proposed port operations.	Will the option result in significant changes to navigation within the Severn Estuary for which measures to prevent or reduce the effect are not possible? Will the option result in a reduction of feasible vessel movements to the ports within the Severn Estuary?	Reduction in the amount of dwt using the ports. Increased level of low water level. Reduced level of spring tide. Increase in delay and costs to vessels within the Severn Estuary
Topic: Historic Environment		
To avoid adverse effects on designated sites in the historic environment. To avoid adverse effects on the non-registered internationally, nationally, regionally and locally important sites within the historic environment. To avoid adverse effects on the potential historic environment, the as yet unidentified sites and finds, within the Severn Estuary. To avoid adverse effects on the character, quality and integrity of the historic and/or cultural landscape.	Will the option negatively affect the designated historic environment? Will the option negatively affect the non-registered and non-designated historic environment in the Severn Estuary Will the historic environment receive sufficient research in order to avoid negative effects on the potential and unknown historic archaeological resource? Will the option negatively affect the character and quality of the historic landscape?	Loss / damage to designated and scheduled sites, features and landscapes. Loss / damage to undesignated sites, features and landscapes. . Location of scheduled ancient monuments. Proximity of option to designated area, design and scale of option (including associated infrastructure works and habitat mitigation areas) Potential for loss / damage to unknown sites. Changes to erosion, sedimentation, water levels and water quality. Changes to the historic environment in the intertidal zone.

SEA Objective	SEA Assessment Criteria	SEA Indicators
		Changes to the submerged historic environment.
Topic: Landscape and Seascape		
To conserve the character and qualities of the landscape/seascape, recognising its diverse features and distinctiveness at different scales – including designated and non-designated areas. To conserve the character and qualities of the physical and visual resource associated with land and sea. To accord with the Aims and Articles of the European Landscape Convention	Will the option adversely affect landscapes within or immediately adjacent to a National Park, Area of Outstanding Natural Beauty, Heritage Coast or the Gwent Levels historic landscape? Will the option adversely affect the landscape character of Heritage Coast or the Gwent Levels historic landscape? Will the option adversely affect local landscape/seascape character? Will the option adversely affect visual amenity?	Changes in quality of nationally valued landscapes - number of designations and area of land affected where quantifiable. Changes in quality of landscape character, tranquillity, diversity and distinctiveness - area of land affected where quantifiable. Changes in quality of views and area of visual resource affected Architectural awards for visual merit of built structures. Adverse effects on landscape/seascape character, quality and tranquillity and areas affected
Topic: Resources and Waste		
To promote sustainable use of resources particularly with respect to aggregate. To reduce waste generation and disposal, increase re-use and recycling and achieve the sustainable management of waste.	Will the option result in reduced resource requirements compared to other options? Will the option result in sustainable use of resources that are required compared to other options? Will the option result in reduced waste arisings compared to other options?	Relative quantity and type (estimate) of waste arising from each option. Relative quantity and type (estimate) of waste requiring landfill disposal for each option. Relative resource requirements for each option. Potential source of resources.

SEA Objective	SEA Assessment Criteria	SEA Indicators
	Will the option result in reduced waste for final disposal compared to other options?	Carbon impacts of options.

10.6 Appendix 6: Executive summary for each of the ten alternative options identified during Phase One

Executive summary for each of the ten alternative options (taken from DECC: *Interim Options Analysis Report* (Vol 1), December 2008)

Option	Option Name	Key Phase One Conclusions
B1	Outer Barrage from Minehead to Aberthaw	• Largest producer of energy (25TWh/a) but with highest capital cost (£29bn); • Cost of energy is 13.94p/kWh excluding compensatory habitat costs ; • Largest environmental impact footprint, and will result in reduction of water levels and tidal range, loss of intertidal habitats and impacts on bird and fish populations in the Severn; Benefits include protection from effects of storm surges, sea level rise and reduced turbidity; • Severn Ports upstream will be affected, primarily Barry, Bristol, Cardiff, Newport and Sharpness.
B2	Middle Barrage from Hinkley to Lavernock Point (Shawater concept)	• Longest barrage option - based on the B3 option but with additional embankment extending the barrage to Hinkley Point - Energy output of 19TWh/a; • Although the capital cost is less (£22bn), the cost of energy is similar to Option B1 at 13.96p/kWh; • Environmental effects are similar to those for B1 as this option seeks to provide similar flood defence benefits by crossing Bridgwater Bay; • Severn Ports upstream will be affected, primarily Bristol, Cardiff, Newport and Sharpness.
B3	Middle Barrage from Cardiff to Weston (commonly known as the Cardiff to Weston Barrage)	• Most studied of any of the options and reported on in Energy Paper 57; • Annual energy output of 17TWh and a capital cost of £18bn; • The cost of energy is the best of all the "large" options at 12.94p/kWh excluding compensatory habitat costs ; • Environmental impacts are potentially significant, as with other large barrage options, and will result in reduction of water levels and tidal range, loss of intertidal habitats and impacts on bird and fish populations in the Severn; Benefits include protection from effects of storm surges, sea level rise and reduced turbidity. • Severn Ports upstream will be affected, primarily Bristol, Cardiff, Newport and Sharpness.
B4	Inner Barrage (Shoots Barrage)	• Significantly smaller than the large barrage options, this option is located just downstream of the Second Severn Crossing co-incident with the highest tidal range in the Severn; • Generates 2.77TWh per year at a capital cost of £2.6bn and achieves the lowest cost per unit energy at 10.4p/kWh; • Environmental impacts are similar in type (although not necessarily scale) to other barrage options although there is an increased risk of sedimentation; • This option does not impact the Ports of Bristol or the Associated British Ports (ABP) Ports on the

Option	Option Name	Key Phase One Conclusions
		Welsh coast.
B5	Beachley Barrage	• Located upstream of the Wye, smallest barrage option studied (£1.8bn) and has similar characteristics to Option B4; • Annual energy output is 1.59TWh/a, 57% of Option B4 whilst the cost per energy is 12.58p/kWh; • Similar environmental effects as Option B4 except that the Wye is not impounded and sedimentation risk is higher; • This option affects ports in the Gloucester Harbour Trustees administered waters.
F1	Tidal Fence Proposals submitted by Severn Tidal Fence Group	• Initially, proposed between Cardiff and Weston but a more feasible alignment was subsequently considered between Minehead and Aberthaw; • Annual energy output of 3.3TWh is achievable at a cost of £6.3bn. Cost of energy is more than double the lowest cost option at 22.72p/kWh; • Assumes future development costs will reduce significantly from the current demonstration project costs for tidal stream technology. This implies a significant period of further development and experience before large scale implementation could be achieved. Unlikely that a decision to proceed with a tidal fence could be made in the short-term; • It does offer the possibility of less significant environmental effects than barrage options although the area affected is as large as the biggest barrage option.
L2	Tidal Enclosure on the Welsh Grounds proposed by Fleming Energy	• Land connected lagoon located on the relatively high Welsh Grounds just downstream of the Shoots Barrage (B4); • It has an annual energy output (2.3TWh/a) achieved at a cost of £3.1bn. Cost per unit energy is 15.46p/kWh and is thus more expensive than the larger barrage options, although development alongside B4 would reduce energy cost. Additional energy output could be achieved from the Welsh Grounds if the materials used in construction were excavated from within the basin to achieve greater live storage. This would marginally increase energy yield and thus reduce the cost of energy; • Land connected lagoons, like barrages, result in loss of intertidal habitats because of the significant reduction in tidal range within the impounded area. Other environmental effects are similar to smaller barrages except that impacts on fish and navigation are expected to be less because they do not form a barrier across the estuary.
L3	Tidal Lagoon Concept (which has been subsequently modelled as four land-connected lagoons and three	• Various land connected and offshore lagoon configurations have been studied using different forms of lagoon wall construction; • As lagoon costs are influenced by the length and depth of wall forming the impounded basin, innovative methods of wall construction are required and the lowest cost option, (apart from the wall design proposed by Fleming Group for Option L2) comprises a geotextile solution using material dredged from

Option	Option Name	Key Phase One Conclusions
	offshore lagoons based on various general submissions received from the Call for Evidence)	the estuary and protected by rock armour (externally) and revetment (internally); • Aside from the L2 Welsh Grounds proposal, Bridgwater Bay offers the most cost effective lagoon option with a higher energy yield (2.64TWh/a) and slightly reduced capital costs than L2 giving a cost per kWh of 13.02p/kWh. • An offshore lagoon, located below the low water contour (and reduced impact on habitats), has been modelled to produce a similar energy output using the same forms of construction. Because of the much deeper wall construction required, it is more expensive with a capital cost of £5.8bn for almost the same energy output of 2.6TWh/a as the £3bn Bridgwater Bay land connected option. This is also reflected in the cost of energy which is more than double the land connected lagoon alternative.
R1	Tidal Reef proposed by Evans Engineering.	• Entirely new concept that has continued to evolve during the study period. • Studied and reported on to a level commensurate with the information available but the assessment has not been able to provide as definitive estimates as other options on which to develop reliable cost base and energy yields. Outline estimates provide a capital cost of £18.1bn with an energy yield of 13TWh/a with a preliminary estimated cost of energy of 20.30p/kWh. • Development period would be greater than other options and require demonstration projects to test the concept – this would take between 10 and 15 years if tidal stream technology is taken as a benchmark.
U1	Severn Lakes (promoted by Gareth Woodham)	• Originally included because one of its objectives is to produce power using the tidal range of the Severn. • The cost of constructing a 1km wide causeway 16km in length would be significantly more than a conventional tidal barrage and clearly requires additional investment streams to justify its cost. On the basis of the information within the public domain, this is also recognised by the proposer who envisages other revenue streams from land, recreational and other energy developments as part of this scheme. • This study is only examining potential options from an energy perspective. For this reason this option is not considered specifically by the Study. • Should tidal power development from the Severn form part of Government's future energy policy, a privately proposed option such as Severn Lakes could be considered in the future.

10.7 Appendix 7: Severn Tidal Power SEA environmental receptors

STP SEA Theme	STP SEA Topic	Receptors
Physicochemical	Hydraulics & Geomorphology	Nature Conservation Features
		Subtidal sandbanks
		Intertidal mudflats and sandflats
		Hard substrate habitats (Rocky shores)
		Water Levels
		Flows
		Waves
		Sediment Regime
		Morphology
		Water quality
	Marine Water Quality	Temperature
		pH
		Salinity
		Suspended sediment
		Organic matter
		Nutrients
		Dissolved oxygen
		Trace metals
		Trace organics
		Radiological contaminants
		Pathogens
	Freshwater Environment & Associated Interfaces	Surface waters
		Groundwater
		Purton (surface abstraction from Sharpness Canal – BWW 1)
		Other surface abstractions e.g. on the Wye and Usk – DC 2
		Clevedon public supply (groundwater – BWW) & Great Spring – DC
		Other groundwater abstractions e.g. WW 3 sources
		Water abstractions for PWS
		All other abstractions
		Geological Sites of Special Scientific Interest
		Other designated sites of geological and geomorphological interest
		Soils
		Infrastructure of national importance e.g. Severn Railway Tunnel
		Other Infrastructure i.e. or regional or local importance
	Flood Risk & Land Drainage	Planning Policy Statement (PPS) 25 Essential infrastructure, highly vulnerable and more vulnerable – transport, health, groups of more than 50 dwellings, education etc (also includes water and sewage treatment works
		PPS25 Less vulnerable – shops, commercial, leisure, groups of less then 50 dwellings, but excluding land for agriculture and forestry
		Land for agriculture and forestry
Biodiversity	Marine Ecology	Plankton
		Marine macroalgae

STP SEA Theme	STP SEA Topic	Receptors
		Intertidal mudflats and sandflats
		Saltmarsh
		Shingle and rocky shore
		Subtidal sandbanks
		Other subtidal habitats
		Zostera
		Sabellaria
		Epibenthos
		Cephalopods
		Marine mammals and turtles
	Waterbirds	Mute Swan
		Shelduck
		Wigeon
		Gadwall
		Teal
		Mallard
		Pintail
		Shoveler
		Pochard
		Tufted Duck
		Cormorant
		Little Egret
		Oystercatcher
		Avocet
		Ringed Plover
		Golden Plover
		Grey Plover
		Lapwing
		Knot
		Dunlin
		Ruff
		Snipe
		Black-tailed Godwit
		Bar-tailed Godwit
		Curlew
		Spotted Redshank
		Redshank
		Greenshank
		Turnstone
		Common Gull
		Less Black-backed Gull
		Waterbird assemblage
	Migratory & Estuarine Fish	Atlantic salmon
		Sea trout
		Shad (allis and twaite)
		Lamprey
		Eel
		Sturgeon
		Marine migrants (value based on UK BAP species: cod, herring, plaice, sole and whiting)
		Marine stragglers (value based on UK BAP species: blue

STP SEA Theme	STP SEA Topic	Receptors
		whiting, hake, horse mackerel, ling and saithe)
		Freshwater stragglers
		Estuarine species
	Terrestrial & Freshwater Ecology	European Protected Sites
		European Protected Species
		Nationally Protected Sites
		Nationally Protected Species
		UK and Local BAP Habitats and Species
		Local Sites
		Landscape Ecology Features (e.g. Natural Character Areas Regional Strategy Corridors)
		Discrete habitat features (e.g. woodland, hedgerows)
		Reedbed
		Ancient broadleaved woodland
		Grazing Marsh
		Otter
		Badger
		Great crested newt
		Petalwort
		White-clawed crayfish
Historic Environment and Landscape & Seascape	Historic Environment	Archaeology - Underwater
		Archaeology – Intertidal
		Archaeology – Coastal (hard geology)
		Archaeology – Coastal (soft geology)
		Archaeology – Terrestrial (hard geology)
		Archaeology – Terrestrial (soft geology)
		Palaeo-environmental deposits - Underwater
		Palaeo-environmental deposits – Intertidal
		Palaeo-environmental deposits – Coastal (hard geology)
		Palaeo-environmental deposits – Coastal (soft geology)
		Palaeo-environmental deposits – Terrestrial (hard geology)
		Palaeo-environmental deposits – Terrestrial (soft geology)
		Shipwrecks - Underwater
		Shipwrecks – Coastal (hard geology)
		Shipwrecks – Coastal (soft geology)
		Shipwrecks – Terrestrial (hard geology)
		Shipwrecks – Terrestrial (soft geology)
		Historic Landscape - Underwater
		Historic Landscape – Intertidal
		Historic Landscape – Coastal (hard geology)
		Historic Landscape – Coastal (soft geology)
		Historic Landscape – Terrestrial (hard geology)
		Historic Landscape – Terrestrial (soft geology)
		Built Heritage - Underwater
		Built Heritage – Intertidal
		Built Heritage – Coastal (hard geology)
		Built Heritage – Coastal (soft geology)
		Built Heritage – Terrestrial (hard geology)
		Built Heritage – Terrestrial (soft geology)
	Landscape & Seascape	A typical receiving landscape or seascape
		A typical surrounding landscape or seascape
		Visual receptor in a national, European or international

STP SEA Theme	STP SEA Topic	Receptors
		designated landscape
		Visual receptor near one of the landing points
		Visual receptor out on the Severn Estuary
Air & Climatic Factors and Resources & Waste	Air & Climatic Factors	Human Health Receptor – UK Population
		Human Health Receptor – Local Population
		Habitats Receptor – International feature, e.g. SPA, SAC, Ramsar Site
		Habitats Receptor – National feature, e.g. SSSI
		Habitats Receptor – Local feature, e.g. Environmentally Sensitive Area
	Resources & Waste	(Resources) Steel
		(Resources) Energy
		(Resources) Water
		(Waste) Sites for reuse opportunities
		(Waste) Treatment and recycling facilities
		(Waste) Energy recovery
		(Waste) Landfill
Society & Economy	Communities	Spatial receptors - Population
		Spatial receptors – Employment and other consequential socio-economic issues
		Spatial receptors – Land Use
		Sectoral receptors
		Sectoral receptors – ABP (Port of Cardiff)
		Sectoral receptors – ABP (Port of Newport)
		Sectoral receptors – Bristol Port Company
		Sectoral receptors – Sharpness Dock
		Sectoral receptors – Gloucester Harbour Trustees
		Sectoral receptors – Ferry Operators
		Sectoral receptors – Berth operators
		Sectoral receptors – Fisheries:
		Sectoral receptors – Wye Fishery
		Sectoral receptors – Usk Fishery
		Sectoral receptors – River Severn Fishery
		Sectoral receptors – Others:
		Sectoral receptors – Marine Aggregates
		Sectoral receptors – Marine Waste Disposal
		Sectoral receptors – Ministry of Defence
		Sectoral receptors – Energy Operators
		Sectoral receptors – Cable and pipeline owners / operators
	Noise & Vibration	Residences
		Schools & Colleges
		Hospitals
		Places of Worship
		Commercial
		Industrial
		Farms, kennels and wildlife sites
		Open Air Amenities
	Navigation	Bristol Port
		Cardiff Port
		Newport Port
		Sharpness / Gloucester Port

STP SEA Theme	STP SEA Topic	Receptors
	Other Sea Uses	Marine Aggregates
		Marine Waste Disposal
		Recreation and Tourism
		Military Activity
		Energy
		Cables and Pipelines

10.8 Appendix 8: Approach to identifying the significant effects of the alternative options

INTRODUCTION

The purpose of this appendix is to explain the methodology that was undertaken to identify the likely significant environmental effects of the STP Feasibility Study.

The assessment of likely significant effects was informed by an iterative process of collecting information, defining alternatives, identifying environmental effects and developing measures to prevent, reduce or as fully as possible offset adverse environmental effects.

The approach described below was derived to satisfy the requirements of the SEA Directive, as informed by the SEA Practical Guide. The proposed approach was the subject of consultation, alongside the outline of the scope, as part of the Phase One (Scoping) Pubic Consultation. The approach was finalised following consultation with the DECC STP team and representatives of Government bodies and statutory advisors.

IDENTIFYING SIGNIFICANT EFFECTS

The SEA Directive (Annex I(f)) requires that the Environmental Report sets out the likely significant effects on the environment (see Box 1).

Box 1: Criteria listed in Annex I(f) of the SEA Directive

In relation to significant effects, Annex I(f) of Council Directive 2001/42/EC states the following information is required:

(f) the likely significant effects on the environment, including on issues such as biodiversity, population, human health, fauna, flora, soil, water, air, climatic factors, material assets, cultural heritage including architectural and archaeological heritage, landscape and the interrelationship between the above factors;*

**these effects should include secondary, cumulative, synergistic, short, medium and long-term, permanent and temporary, positive and negative effects.*

In order to ensure that all potentially significant effects on the environment were considered within the SEA, separate topics were developed at the beginning of the scoping stage. Table 1 lists these 16 topics and shows how they relate to the requirements of the SEA Directive.

Table 1: Severn Tidal Power SEA topics

Severn Tidal Power SEA Topic	SEA Directive Topic (Annex 1(f))
Hydraulics & Geomorphology	Water
Marine Water Quality	Water
Flood Risk & Land Drainage	Water, Material Assets
Freshwater Environment & Associated Interfaces	Water, Soil
Marine Ecology	Biodiversity, Fauna, Flora
Migratory & Estuarine Fish	Biodiversity, Fauna

Severn Tidal Power SEA Topic	SEA Directive Topic (Annex 1(f))
Waterbirds	Biodiversity, Fauna
Terrestrial & Freshwater Ecology	Biodiversity, Fauna, Flora
Historic Environment	Cultural Heritage
Landscape & Seascape	Landscape
Air & Climatic Factors	Climatic Factors, Air
Resources & Waste	Material Assets
Communities	Population, Human Health, Cultural Heritage, Material Assets
Noise & Vibration	Population
Navigation	Material Assets, Population
Other Sea Uses	Material Assets, Population

The Directive lists the criteria that should be taken into account when determining likely significant effects to the environment (see Box 2). These criteria are only explicitly defined for the purpose of determining whether or not an SEA is needed. However, as they principally relate to the nature of the effects arising from the plan, and the value and vulnerability of the receptors affected, they are also applicable to the assessment of significant environmental effects and have thus been used for this purpose during the SEA. This is recognised in the SEA Practical Guide.

Box 2: Criteria listed in Annex II of the SEA Directive

When determining the likely significance of effects on the environment, the Annex II of the SEA Directive includes the following criteria:

2. Characteristics of the effects and of the area likely to be affected, having regard, in particular, to

(a) the probability, duration, frequency and reversibility of the effects;
(b) the cumulative nature of the effects;
(c) the transboundary nature of the effects;
(d) the risks to human health or the environment (for example, due to accidents);
(e) the magnitude and spatial extent of the effects (geographical area and size of the population likely to be affected);
(f) the value and vulnerability of the area likely to be affected due to -
(i) special natural characteristics or cultural heritage;
(ii) exceeded environmental quality standards or limit values; or
(iii) intensive land-use; and
(g) the effects on areas or landscapes which have a recognised national, Community or international protection status.

An assessment of significance was made by reviewing the potential effects on each receptor against the above criteria. These assessments were based upon both quantitative and qualitative information, as well as expert judgement and are fully reported within the 16 topic papers.

The flow chart below summarises the steps that were undertaken to complete the significance assessment within topic papers:

1. Identification of **baseline** and **future baseline**

↓

2. Identification of receptor **value and vulnerability**

↓

3. Identification of effects upon receptors for each alternative option

↓

4. Identification of whether if an effect is **direct or indirect, far-field, cumulative** or a result of **consequential development**.

↓

5. Identification of **probability** of effect occurring (H/M/L/VL)

↓

6. Identification of **when** the effect occurs (*construction*, *operation* or *decommissioning* phase) Identification of **how long** the effect will last for (L/M/S/VS term) and the **frequency** of the effect

↓

7. Identification of whether an effect is **irreversible/reversible** and/or **temporary/permanent**

↓

8. Identification of **magnitude** of effect (H/M/L)

↓

9. Identification of the **spatial extent** of the effect and whether the effect is **trans-boundary**

↓

10. Identification of whether the effect is **positive or negative**

↓

11. Statement of **assumptions, limitations and uncertainties** associated with assessment

↓

12. Use of all the information listed above to determine whether the effect is **significant.**

The following paragraphs explain in more detail how the steps set out in the flow chart above were undertaken during topic assessments. The paragraphs below have been numbered to correspond with the numbers within the flow chart.

1. Identification of the baseline and future baseline

The approach taken to establishing the characteristics of the area likely to be affected, or 'baseline', and its likely evolution is explained in Section 3 of the Environmental Report and is not repeated here. Key to the approach was the development of an understanding of the baseline, as defined by a series of '*receptors*'. A '*receptor*' is an entity that may be affected by direct or indirect changes to an environmental variable. Relevant receptors were identified and consulted upon during the SEA scoping stage.

2. Identification of receptor value and vulnerability

In forming a judgement on effect significance, it is necessary to assign attributes to each receptor, some of the most important of these being their '*value*' and '*vulnerability*'. For the purposes of this SEA, the following definitions were used:

- *Value*: the value of a receptor is based on the scale of geographic reference, rarity, importance for biodiversity, social or economic reasons, and level of legal protection;
- *Vulnerability*: the potential for a pathway for exposure of a receptor to a given environmental effect, brought about by a Severn Tidal Power alternative option, together with the sensitivity of the receptor to that effect (the sensitivity is the tolerance of a receptor to a given environmental effect and its ability to recover from that effect).

Framework guidelines and judgements on receptor value and vulnerability were developed into bespoke criteria for each topic assessment. These criteria were discussed at the Phase Two (SEA) Technical Workshop 1 for each topic and subsequently confirmed. Topic-specific definitions for value and vulnerability are provided in the topic papers.

3. Identification of effects upon receptors for each alternative option

During Phase One (Scoping), potentially significant issues were identified for each topic. These were used as the starting point for the assessment of significant effects in Phase Two (SEA). As topic assessments progressed through Phase Two (SEA), further significant issues were identified by topic specialists through research and consultation.

4. Identification of whether effect is direct or indirect, far-field, cumulative or a result of consequential development.

The SEA Directive specifies that the assessment of effects should include '*secondary, cumulative, synergistic... effects*' (Annex I (f)). The Practical Guide recognises that some of these terms are not always mutually exclusive and for the avoidance of doubt, within this SEA the following assessment approaches were undertaken.

- Indirect effects are those which are not a direct result of a Severn Tidal Power alternative option, but occur away from the original effect or as a result of a complex pathway. There are many such interactions within estuarine systems that taken into account in this assessment and these were considered within each topic and theme. The SEA does not use the term 'secondary effects' as this is covered by indirect effects.
- There is the potential for effects to extend large distances from the Severn Estuary. The assessments of these 'far-field' effects have greater uncertainty attached and are described separately within each topic and theme.
- Cumulative effects arise, for instance, where several developments each have insignificant effects but together have a significant effect. The plans and projects taken into account in the cumulative effects assessment were identified and confirmed (STP, 2009b). These were discrete projects or programmes which were expected to be implemented during the planned Severn Tidal Power project construction period (2014-2020) or during the operation period (2020-2140). The time-scales considered are those that are appropriate should the Government conclude to support a tidal power project in the Severn Estuary and the project consequently moves directly into the delivery phase.
- This SEA has not used the term 'combined' effects, as these are considered to be included within cumulative effects, nor has it used the term 'synergistic' effects, as these are contained within direct, indirect and cumulative effects.

- A major tidal power scheme may facilitate or attract other developments, which may themselves pose significant environmental effects. These developments are described as 'consequential developments'. The types of consequential development considered throughout the assessment were identified (Severn Tidal Power, 2009a). These consequential developments were not well-defined and only a high-level qualitative assessment of the likely effects was possible.

5. Identification of probability of effect occurring (H/M/L/VL)

The probability of whether an effect will happen has been recorded as high, medium, low or very low. Table 2 sets out the guideline framework which was used for these classifications.

Table 2: Guidelines for determining probability of effect

	Probability of effect			
Classification	**High**	**Medium**	**Low**	**Very Low**
Guideline	>90%	50-90%	10-50%	<10%

6. Identification of <u>when</u> the effect occurs (construction, operation or decommissioning phase); <u>how long</u> the effect will last for (L/M/S/VS term); and <u>frequency</u> of effect.

The SEA Directive specifies that the assessment of effects should include '*…short, medium and long-term…effects*' (Annex **I** (f)).

The timing of effects relates to the period of the project lifecycle during which time an effect will happen. This is described as either the construction, operation or decommissioning stage. The duration is the length of time that effect would last. Tables 3 and 4 set out the guidelines for describing the timing and duration of effects.

Table 3: Guidelines for determining the period of the project lifecycle

Timeline	**Phases**			
Period of project lifecycle (assumed year)	Pre-construction (2009)	Construction (2014 - 2020)	Operation (2020)	Decommissioning (2140)
Baseline	Existing baseline (2009)		Future baseline (2020 - 2140)	
Effect	None	Construction effects	Response ⇨Equilibrium*	Decommissioning effects
			Closure of structure	

** it is possible that the period for an effect to reach equilibrium may be longer than the operational phase. This has been identified where applicable.*

Table 4: Guidelines for determining duration of effect

	Duration of effect			
Classification	Long Term	Medium Term	Short Term	Very Short Term
Guideline	10+ years	5-10 years	2-5 years	<2 years

An indication of the **frequency** of predicted effects was undertaken, through consideration of whether the effect will be continual or intermittent over the period of time identified.

7. Identification of whether the effect is irreversible / reversible and temporary / permanent

The SEA Directive specifies that the assessment of effects should include '…permanent and temporary…effects' (Annex I (f)).

Effects have been described as **reversible or irreversible** referring to whether the effect could be removed if deliberate action were taken to do so. This judgement was based on the timescale for a receptor's return to baseline condition without intervention, in relation to a human lifetime. If the timescale for a receptor's return to baseline condition is greater than 50 years then it was considered irreversible and if it is less then it was considered reversible.

Effects have also been described as **temporary or permanent**, according to whether or not the effect is expected to last for an indefinite period of time. Note that it is possible for an effect to be reversible-permanent.

8. Identification of magnitude of effect

Magnitude of effect considers the percentage of the receptor affected and is categorised as high, medium, low or very low. Where no effect was predicted for an alternative option, this was recorded as 'no change'. The classification thresholds were refined for each topic receptor through discussions held at the technical workshops and subsequent correspondence. Thresholds were defined by each topic and can be both qualitative and quantitative, as appropriate. The topic-specific definitions for thresholds of magnitude of effect are provided in the topic papers.

9. Identification of the spatial extent of the effect and whether the effect is trans-boundary

The spatial scale of the effect has been defined as whether the effect is local, Unitary Authority. County, regional, national or international. Definitions of the spatial scales used within the SEA are provided in Table 5. The area or location of the effect has been identified where relevant. Where there is a transboundary effect on another EU member state, this has also been identified.

Table 5: Definitions of spatial scale

Spatial extent of effects	Definitions
International	Effects extending beyond the UK
National (UK)	Effects within the UK but extending beyond region
Regional	Effects within South Wales and South West England
Unitary Authority	Effects within an identified County / Unitary Authority
Local	Effects confined to a local area, typically <1km from source

10. Identification of whether the effect is positive or negative

The SEA Directive specifies that the assessment of effects should include '…positive and negative effects' (Annex I(f)).

Throughout the SEA reporting, a positive effect has been defined as one that is favourable or otherwise beneficial to the condition of a receptor. A negative effect is one that is unfavourable or otherwise adverse to the condition of a receptor.

11. Statement of assumptions, limitations and uncertainties associated with assessment

The SEA Directive also specifies that '*…a description of how the assessment was undertaken including any difficulties (such as technical deficiencies or lack of know-how) encountered in compiling the information*' is provided in the Environmental Report.

Where assumptions had to be made, limitations observed, and/or uncertainty remained, this was recorded. Recognition of the importance of these factors was fully understood at all stages of the

SEA reporting, including topic assessments. Confidence limits, or other suitable approaches, were applied during topic assessments to ensure that relevant uncertainties were acknowledged.

The 'precautionary principle' was not directly applied at the 'assessment of significance stage' as it is not applicable to apply such a principle prior to the decision-making stage. Rather, topic specialists have used all of the resources available to them to make the most accurate assessments possible of the potential significant effects arising as a result of implementing an STP alternative option, or combination of alternative options.

12. Use all the information to determine whether the effect is significant (Y/N)

This was the final stage of the assessment process. Topics determined whether or not an effect was significant based on all the preceding criteria, and expert judgement. This in turn was informed by inputs from the Technical Workshops and representatives of Government bodies and statutory advisors.

A conclusion was made as to whether a significant effect was likely, or not. Gradations of significance are not provided for within the SEA Directive. It should also be noted that the determination of significance of each alternative option is absolute and not comparative or relative to another Severn Tidal Power alternative option. Gradations of significance and comparison between alternative options are provided by the SEA objectives performance assessment (see Section 6.1 of the Environmental Report).

10.9 Appendix 9: Summary of Likely Significant Effects of the Alternative Options

<table>
<tr><th>Theme / Topic</th><th colspan="5">Summary Description of Likely Significant Effect[16]</th></tr>
<tr><th>Receptor</th><th>B3: Cardiff to Weston Barrage</th><th>B4: Shoots Barrage</th><th>B5: Beachley Barrage</th><th>L2: Welsh Grounds Lagoon</th><th>L3d: Bridgwater Bay Lagoon</th></tr>
<tr><td colspan="6">Theme: Physicochemical - Topic: Hydraulics & Geomorphology</td></tr>
<tr><td rowspan="3">Water levels</td><td colspan="3">Reduction in tidal range; Change in tidal shape.</td><td>No significant effect</td><td>Reduction in tidal range; Change in tidal shape.</td></tr>
<tr><td>Increase in water levels (far-field)</td><td colspan="2">Change in water levels (far field). Probably not significant.</td><td>No significant effect</td><td>Change in water levels (far field). Probably not significant.</td></tr>
<tr><td colspan="3">Change in area covered by water at HAT.</td><td>No significant effect</td><td>Change in area covered by water at HAT.</td></tr>
<tr><td>Flows</td><td colspan="3">Changes to tidal prism both upstream and downstream of barrage.</td><td>Changes to tidal prism.</td><td>No significant effect</td></tr>
<tr><td>Waves</td><td>Change in wave climate.</td><td colspan="4">No significant effect</td></tr>
<tr><td>Sediment Regime</td><td colspan="3">Reduction in spring tide suspended sediment concentrations.</td><td colspan="2">No significant effect</td></tr>
<tr><td>Morphology</td><td colspan="5">Short-term change in bed level; Long-term change in bed level; Change in shear stress around key sedimentary features; Change in extent of subtidal sandy sediments; Change in extent of intertidal area between HAT and LAT.</td></tr>
<tr><td colspan="6">Theme: Physicochemical - Topic: Marine Water Quality</td></tr>
<tr><td>Temperature</td><td colspan="4">No significant effect</td><td><u>Negative effect:</u> Change in extent of Hinkley thermal plume.</td></tr>
<tr><td>Suspended sediment</td><td><u>Negative effect:</u> Reduced suspended sediment concentrations during neap tide periods might increase water clarity sufficiently to allow enhanced algal growth for limited periods within the impoundment near to the barrage. As there are sufficient nutrients to support primary productivity this could increase the potential risk of eutrophication effects in the estuary.</td><td colspan="2"><u>Negative effect:</u> Reduced suspended sediment concentrations may allow some increased primary productivity, however strong light limitation will continue to prevent full utilisation of the available nutrients. The risk that the reduced suspended sediment concentrations could increase water clarity sufficiently to cause substantial eutrophication effects such as algal growth is considered to be small.</td><td colspan="2">No significant effect</td></tr>
<tr><td>Nutrients</td><td>Reduction in nutrient concentrations.</td><td colspan="4">No significant effect</td></tr>
<tr><td>Pathogens</td><td colspan="4">No significant effect</td><td><u>Negative effect:</u> Increase in pathogen concentration and extent in the vicinity of bathing beaches and shellfish waters at the Weston WwTW, adjacent to bathing beaches.</td></tr>
<tr><td colspan="6">Theme: Physicochemical - Topic: Flood Risk & Land Drainage</td></tr>
<tr><td>PPS25 Essential infrastructure, highly vulnerable and more</td><td><u>Positive Effect:</u> Changes in flood risk due to changes in peak tide levels.</td><td colspan="3">No significant positive effects</td><td><u>Positive Effect:</u> Changes in flood risk due to changes in peak tide levels.</td></tr>
</table>

[16] Effects that are not significant for any options are not identified here.

Theme / Topic Receptor	Summary Description of Likely Significant Effect[16] B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
vulnerable – transport, health, groups of more than 50 dwellings, education etc. (also include water and sewage treatment works)	Negative Effects: Erosion of tidal defences; Impeded land drainage.				
PPS25 Less vulnerable – shops, leisure, commercial, groups of less than 50 dwellings, but excluding land for agriculture and forestry	Positive Effect: Changes in flood risk due to changes in peak tide levels.	*No significant positive effects*			Positive Effect: Changes in flood risk due to changes in peak tide levels.
	Negative Effects: Erosion of tidal defences; Impeded land drainage.				
Land for agriculture and forestry	*No significant positive effects*				Positive Effect: Changes in flood risk due to changes in peak tide levels.
	Negative Effects: Erosion of tidal defences; Impeded land drainage.				
Theme: Physicochemical - Topic: Freshwater Environment & Associated Interfaces					
Geological and Geomorphological SSSIs:	Negative Effects: Tidal River Severn (Purton Passage, Lydney Cliff, Aust Cliff, River Wye at Lancaut (Lower Wye), Otter Hole) will prevent safe access to and egress from Otter Hole cave system. Mid Severn - Avon Gorge, Portishead Pier to Black Nore): Reduced accessibility to exposures on Portishead coast. Avon Gorge outcrop unaffected. Geological and Geomorphological SSSIs: Outer Severn (Welsh) Penarth Coast, Flat Holm, Rhymney River Section: Reduced accessibility. Effect on Flat Holm. Southern portion of Penarth Coast SSSI covered by construction.	Negative Effect: Tidal River Severn (Purton Passage, Lydney Cliff, Aust Cliff, River Wye at Lancaut (Lower Wye), Otter Hole): Reduced accessibility to lowermost exposures. Submergence of access to Otter Hole.	Negative Effect: Tidal River Severn (Purton Passage, Lydney Cliff, Aust Cliff): Direct loss of part of Aust Cliff as a result of construction.	*No significant effect*	
Soils	Negative Effect: Welsh Side downstream of original road crossing: Degradation of soil quality as a result of waterlogging. *Probable* Negative Effect: English Side downstream of original road	Negative Effects: Tidal River Severn and Inner Severn upstream of original road crossing. (English and Welsh sides) Degradation of soil quality as	Negative Effects: Tidal River Severn upstream of original road crossing. (English and Welsh sides) Degradation of soil quality as a result of waterlogging.	Negative Effect: Mid Severn (Welsh Side): Degradation through waterlogging.	*Probable* Negative Effect: English Side downstream of original road crossing: Degradation of soil quality as a result of waterlogging.

Theme/Topic	Summary Description of Likely Significant Effect[16]				
Receptor	**B3: Cardiff to Weston Barrage**	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**L3d: Bridgwater Bay Lagoon**
	crossing: Degradation of soil quality as a result of waterlogging.	a result of flooding and waterlogging.			
Other Infrastructure:	Negative Effect: Outer Severn (English side): Increased dampness in basements and flows in sewers in low – lying parts of Weston- Super-Mare and Clevedon.	*No significant effect*		Negative Effect: Mid Severn (Welsh side) Llanwern, low-lying parts of Caldicot and S. Newport, east of R. Usk: Increased dampness in basements and flows in sewers.	Unknown – but likely to be *No significant effect*
Theme: Biodiversity - Topic: Marine Ecology					
Plankton	Positive Effect – in relation to primary production. *No significant effect* for algal blooms: Changes in water quality- Decreased suspended sediment concentrations leading to increased light penetration and increased abundance and hence primary production, this may result in algal blooms.	*No significant effect*		Negative Effect: Changes to Habitat Extent and quality/stability - Changes in intertidal/subtidal extents.	*No significant effect*
Marine Macroalgae	Positive Effect in relation to increased subtidal and decreased sediment deposition; Negative effect in relation to decreased intertidal: Changes to Habitat Extent- option footprint / new hard surfaces / changed water levels/ sediment deposition. Positive Effects: Changes in water/habitat quality- reduced current speeds result in decreased suspended sediments, reduced scour, increased bed stability and increased light penetration; Changes in biological interactions - Distribution and diversity	Positive Effect in relation to increased subtidal and decreased sediment deposition; Negative effect in relation to decreased intertidal: Changes to Habitat Extent- option footprint / new hard surfaces / changed water levels/ sediment deposition.	*No significant effect*		
Intertidal mudflats and sandflats	Negative Effect: Changes in Habitat Extent due to changed water levels, bathymetry and deposition and long-term erosion leading to reduced intertidal extent. Positive Effects: Changes to Habitat Quality; Changes to biological interactions resulting from decreased disturbance and increased primary	Negative Effect: Changes in Habitat Extent due to changed water levels, bathymetry and deposition and long-term erosion leading to reduced intertidal extent. Positive Effects: Changes to Habitat Quality; Changes to biological interactions resulting	Negative Effect – in relation to water level changes, *No further significant effect* in relation to long-term changes: Changes in Habitat Extent due to changed water levels, bathymetry and deposition and long-term erosion	Negative Effect – in relation to initial changes in intertidal extent and long-term changes: Changes to habitat extent-loss of habitat to option footprint. Negative Effect – in relation to initial changes in intertidal extent and long-term changes:	Negative Effect – in relation to initial changes in intertidal extent and long-term changes: Changes in Habitat Extent due to changed water levels, bathymetry and deposition and long-term erosion leading to reduced intertidal extent. Positive Effect – in relation to

Theme/Topic	Summary Description of Likely Significant Effect[16]				
Receptor	**B3: Cardiff to Weston Barrage**	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**L3d: Bridgwater Bay Lagoon**
	production (through enhanced secondary production).	from decreased disturbance and increased primary production (positive effect in relation to decreased disturbance, *No significant effect* on primary productivity).	leading to reduced intertidal extent. Positive Effect – in relation to decreased disturbance and increased biological productivity: Changes to biological interactions resulting from decreased disturbance and increased primary production	Changes in Habitat Extent due to changed water levels, bathymetry and deposition and long-term erosion leading to reduced intertidal extent.	decreased disturbance and increased biological productivity: Changes to biological interactions resulting from decreased disturbance and increased primary production.
Saltmarsh	Negative Effect – in relation to water levels and long-term erosion and deposition: Changes to Habitat Extent-loss of saltmarsh to option footprint; reduction in extent due to water levels, tidal curve and long term morphological changes (erosion and deposition). Negative Effect: Changes in Biological interactions – species distribution and diversity.	*No significant effect*			
Shingle and Rocky Shore	Negative Effect, although positive where sediment deposition and erosion stops: Changes in Habitat Extent-changed water levels and sediment deposition will reduce the extent of this receptor.	Negative Effect: Changes in Habitat Extent-changed water levels and sediment deposition will reduce the extent of this receptor.	Negative Effect in relation to water level changes, *No significant effect* of sediment deposition: Changes in Habitat Extent-changed water levels and sediment deposition will reduce the extent of this receptor.	*No significant effect*	
Subtidal Sandbanks	Negative Effect: Changes Water/Habitat Quality- changes in current speeds resulting in changes to sediment availability and transport.				Negative Effect: Changes Water/Habitat Quality- changes in current speeds resulting in changes to sediment availability and transport. Negative Effect – in relation to current receptor, positive effect – based on effects on biological assemblage and secondary production: Changes in Habitat Quality; Deposition of finer sediments.

Theme/Topic	Summary Description of Likely Significant Effect[16]				
Receptor	**B3: Cardiff to Weston Barrage**	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**L3d: Bridgwater Bay Lagoon**
Other subtidal habitats	Positive Effect: Changes in Biological Interactions Sediment deposition, reducing short-term erosion and deposition.	*No significant effect*			
Eelgrass	Negative Effect: Changes in Habitat Extent-Changes in water levels. Positive Effect: Changes in Habitat Quality, Changes in sediment deposition.	Negative Effects: Changes in Habitat Extent-Option footprint; Changes in Habitat Extent - Changes in water levels.	*No significant effect*	Negative Effect (based on modelling outputs): Changes in Habitat Extent – changes in water level	*No significant effect*
Sabellaria	Negative Effects: Habitat extent – changes in water levels; Changes in Habitat Quality: suspended sediment concentrations and sediment transport; Changes in Habitat Extent-dredge footprint.	Negative Effects: Changes in Habitat Quality, suspended sediment concentrations and sediment transport.			*No significant effect*
Epibenthos	Negative Effects: Changes in Habitat Extent; Changes in water levels resulting in reduction in intertidal/subtidal extent and changes in flows leading to sediment deposition; Changes in Habitat Quality – leading to changes in the biological interactions. Negative Effect – in relation to collision, not larval transport: Obstruction - barrier to migration routes leading to collision risk and reduction of larval/adult transport.	Negative Effect – in relation to collision, not larval transport: Obstruction - barrier to migration routes leading to collision risk and reduction of larval/adult transport.		Negative Effect: Changes in Habitat extent; Changes in water levels resulting in reduction in intertidal.	*No significant effect*
Theme: Biodiversity - Topic: Migratory & Estuarine Fish					
Atlantic Salmon	Negative Effects: Alterations to migratory cues; Disruptions to route of passage; Habitat change/loss; Changes to water quality; Anthropogenic noise disturbance.				Negative Effects: Disruptions to route of passage; Anthropogenic noise disturbance.
Sea Trout	Negative Effects: Alterations to migratory cues; Disruptions to route of passage; Habitat change/loss; Changes to water quality; Anthropogenic noise disturbance.				Negative Effects: Disruptions to route of passage; Anthropogenic noise disturbance.
Shad	Negative Effects: Alterations to migratory cues; Disruptions to route of passage; Habitat change/loss; Changes to water quality; Anthropogenic noise disturbance.				Negative Effects: Disruptions to route of passage; Anthropogenic noise disturbance.
Sea lamprey	Negative Effects: Alterations to migratory cues; Disruptions to route of passage; Habitat change/loss; Changes to water quality; Anthropogenic noise disturbance.				Negative Effects: Disruptions to route of passage;

Theme/Topic	Summary Description of Likely Significant Effect[16]				
Receptor	B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
					Anthropogenic noise disturbance.
River lamprey	Negative Effects: Alterations to migratory cues; Disruptions to route of passage; Habitat change/loss; Changes to water quality; Anthropogenic noise disturbance.				Negative Effects: Disruptions to route of passage; Anthropogenic noise disturbance.
Eel	(Negative Effects: Alterations to migratory cues; Disruptions to route of passage; Habitat change/loss; Changes to water quality; Anthropogenic noise disturbance.			Negative Effects: Disruptions to route of passage; Habitat change/loss; Changes to water quality; Anthropogenic noise disturbance.	Negative Effects: Disruptions to route of passage; Anthropogenic noise disturbance.
Marine Migrants	(Negative Effects: Alterations to migratory cues; Disruptions to route of passage; Habitat change/loss; Changes to water quality; Anthropogenic noise disturbance. Negative/Positive Effects: Effects to freshwater marine and estuarine fish species.				Negative Effects: Disruptions to route of passage; Anthropogenic noise disturbance. Negative/Positive Effects: Effects to freshwater marine and estuarine fish species.
Marine Stragglers	Negative Effects: Disruptions to route of passage; Changes to water quality; Anthropogenic noise disturbance. Negative/Positive Effects: Effects to freshwater marine and estuarine fish species.				Negative Effects: Disruptions to route of passage; Anthropogenic noise disturbance. Negative/Positive Effects: Effects to freshwater marine and estuarine fish species.
Estuarine Residents	Negative Effects: Disruptions to route of passage; Habitat change/loss; Changes to water quality; Anthropogenic noise disturbance. Negative/Positive Effects: Effects to freshwater marine and estuarine fish species.				Negative Effects: Disruptions to route of passage; Anthropogenic noise disturbance. Negative/Positive Effects: Effects to freshwater marine and estuarine fish species.
Freshwater Stragglers	Negative Effects: Changes to water quality; Anthropogenic noise disturbance. Negative/Positive Effects: Effects to freshwater marine and estuarine fish species.				Negative Effects: Disruptions to route of passage; Anthropogenic noise disturbance. Negative/Positive Effects: Effects to freshwater marine and estuarine fish species.
Theme: Biodiversity - Topic: Waterbirds					

Theme / Topic	Summary Description of Likely Significant Effect[16]				
Receptor	**B3: Cardiff to Weston Barrage**	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**L3d: Bridgwater Bay Lagoon**
Bewick's Swan	Negative Effect: Changes to saltmarsh.	*No significant effect*			
European White-fronted Goose	Negative Effect: Changes to saltmarsh.	*No significant effect*			
Greenland White-fronted Goose	Negative Effect: Changes in water levels.	*No significant effect*			
Shelduck	Negative Effects: Changes to or loss of intertidal habitat; Changes to saltmarsh; Displacement (far-field).	Negative Effect: Changes to or loss of intertidal habitat.			*No significant effect*
Wigeon	Negative Effects: Changes to or loss of intertidal habitat; Displacement (far-field).	Negative Effect: Changes to or loss of intertidal habitat.	Negative Effects: Disturbance during construction and decommissioning; Changes to or loss of intertidal habitat.		Negative Effect: Disturbance during construction and decommissioning.
Teal	Negative Effects: Changes to or loss of intertidal habitat; Displacement (far-field).	Negative Effect: Changes to or loss of intertidal habitat.		*No significant effect*	
Mallard	Negative Effect: Changes to or loss of intertidal habitat.			Negative Effects: Disturbance during construction and decommissioning; Changes to or loss of intertidal habitat.	*No significant effect*
Pintail	Negative Effect: Changes to or loss of intertidal habitat; Displacement (far-field).		Negative Effect: Changes to or loss of intertidal habitat.	*No significant effect*	Negative Effect: Changes to or loss of intertidal habitat.
Shoveler	Negative Effects: Changes to or loss of intertidal habitat; Displacement (far-field).	Negative Effect: Changes to or loss of intertidal habitat.	*No significant effect*	Negative Effect: Disturbance during construction and decommissioning.	*No significant effect*
Pochard	Negative Effect: Changes to or loss of intertidal habitat.			*No significant effect*	
Tufted Duck	Negative Effect: Changes to or loss of intertidal habitat.			*No significant effect*	
Cormorant	Negative Effect: Effects on breeding seabirds - probability of colonisation of breeding island by rats (uncertain).	*No significant effect*			Negative Effect: Effects on breeding seabirds - probability of colonisation of breeding island by rats (uncertain).
Little Egret	Negative Effects: Changes to or loss of intertidal habitat; Displacement (far-field sites).	Negative Effect: Changes to or loss of intertidal habitat.	*No significant effect*	Negative Effects: Disturbance during construction and decommissioning; Changes to or loss of intertidal habitat.	*No significant effect*
Oystercatcher	Negative Effect: Changes to or loss of intertidal habitat.	*No significant effect*			
Ringed Plover	Negative Effect: Changes to or loss of intertidal habitat.			Negative Effects: Disturbance during construction and decommissioning; Changes to or loss of intertidal habitat.	Negative Effect: Disturbance during construction and decommissioning.

Theme / Topic	Summary Description of Likely Significant Effect[16]				
Receptor	B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
Golden Plover	Negative Effect: Changes to or loss of intertidal habitat.			*No significant effect*	Negative Effect: Changes to or loss of intertidal habitat.
Grey Plover	Negative Effects: Changes to or loss of intertidal habitat; Displacement (far-field sites).	*No significant effect*		Negative Effects: Disturbance during construction and decommissioning; Changes to or loss of intertidal habitat.	
Lapwing	Negative Effects: Changes to or loss of intertidal habitat; Displacement (far-field sites).	Negative Effect: Changes to or loss of intertidal habitat.		*No significant effect*	Negative Effect: Changes to or loss of intertidal habitat.
Knot	Negative Effects: Changes to or loss of intertidal habitat; Displacement (far-field sites).	*No significant effect*			
Dunlin	Negative Effects: Changes to or loss of intertidal habitat; Displacement (far-field sites).	Negative Effect: Changes to or loss of intertidal habitat.	*No significant effect*	Negative Effects: Disturbance during construction and decommissioning; Changes to or loss of intertidal habitat.	Negative Effect: Changes to or loss of intertidal habitat.
Snipe	Negative Effect: Changes to or loss of intertidal habitat.	*No significant effect*			
Black-tailed Godwit	Negative Effect: Changes to or loss of intertidal habitat.	*No significant effect*		Negative Effects: Disturbance during construction and decommissioning; Changes to or loss of intertidal habitat.	Negative Effect: Changes to or loss of intertidal habitat.
Bar-tailed Godwit	Negative Effect: Changes to or loss of intertidal habitat.				
Whimbrel	Negative Effect: Changes to or loss of intertidal habitat.	*No significant effect*		Negative Effect: Disturbance during construction and decommissioning.	*No significant effect*
Curlew	Negative Effects: Changes to or loss of intertidal habitat; Displacement (far-field sites).	Negative Effect: Changes to or loss of intertidal habitat.		Negative Effects: Disturbance during construction and decommissioning; Changes to or loss of intertidal habitat.	*No significant effect*
Spotted Redshank	Negative Effects: Changes to or loss of intertidal habitat; Displacement (far-field sites).	Negative Effect: Changes to or loss of intertidal habitat.		*No significant effect*	Negative Effect: Changes to or loss of intertidal habitat.
Greenshank	Negative Effects: Changes to or loss of intertidal habitat; Displacement (far-field sites); Changes in water levels (far-field sites).	Negative Effect: Changes to or loss of intertidal habitat.			*No significant effect*
Redshank	Negative Effects: Changes to or loss of intertidal habitat; Changes to saltmarsh; Displacement (far-field).	Negative Effect: Changes to or loss of intertidal habitat.	*No significant effect*	Negative Effect: Changes to or loss of intertidal habitat.	
Turnstone	Negative Effect: Changes to or loss of intertidal habitat.	*No significant effect*			
Black-headed Gull	Negative Effect: Changes to or loss of intertidal habitat.	*No significant effect*			
Common Gull	Negative Effect: Changes to or loss of	*No significant effect*			

Theme / Topic	Summary Description of Likely Significant Effect[16]				
Receptor	**B3: Cardiff to Weston Barrage**	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**L3d: Bridgwater Bay Lagoon**
	intertidal habitat.				
Lesser Black-backed Gull	Negative Effects: Disturbance during construction and decommissioning; Changes to or loss of intertidal habitat; Effects on breeding seabirds - probability of colonisation of breeding island by rats (uncertain).	*No significant effect*			Negative Effect: Effects on breeding seabirds - probability of colonisation of breeding island by rats (uncertain).
Herring Gull	Negative Effects: Disturbance during construction and decommissioning; Changes to or loss of intertidal habitat; Effects on breeding seabirds - probability of colonisation of breeding island by rats (uncertain).	*No significant effect*			Negative Effect: Effects on breeding seabirds - probability of colonisation of breeding island by rats (uncertain).
Waterbird Assemblage	Negative Effect: Changes to or loss of intertidal habitat; Displacement (far-field).	Negative Effect: Changes to or loss of intertidal habitat.		Negative Effects: Disturbance during construction and decommissioning; Changes to or loss of intertidal habitat.	*No significant effect*
Theme: Biodiversity - Topic: Terrestrial & Freshwater Ecology					
SACs and Annex I Habitats	Negative Effects: Habitat loss through construction footprint Mendip and Limestone Grasslands; Fragmentation of Mendip and Limestone Grasslands; Habitat degradation of Mendip and Limestone Grasslands; Species Mortality at Mendip and Limestone Grasslands; Habitat loss through increased water levels Mendip and Limestone Grasslands; Fragmentation of SACs through increased water levels Mendip and Limestone Grasslands; Habitat degradation of sites through increased water levels Mendip and Limestone Grasslands; Species Mortality through increased water levels Mendip and Limestone Grasslands; Habitat Loss through decreased water levels River Wye, River Usk; Reduction in species abundance, otter, through loss of fish prey River Wye, River Usk. Positive Effect: Habitat Enhancement through increased water levels River Wye, River Usk.	Negative Effects: Habitat Loss through increased water levels; Fragmentation of SACs through increased water levels; Habitat degradation of sites through increased water levels; Species Mortality through increased water levels Mendip and Limestone Grasslands; Habitat Loss through decreased water levels River Wye, River Usk.	Negative Effects: Disturbance; Reduction in species abundance, otter, through loss of fish prey River Wye.	Negative Effect: Habitat degradation; Disturbance; Reduction in species abundance, otter, through loss of fish prey River Wye.	Negative Effects: Habitat loss through construction footprint Mendip and Limestone Grasslands; Fragmentation of Mendip and Limestone Grasslands; Habitat degradation of Mendip and Limestone Grasslands; Species Mortality at Mendip and Limestone Grasslands; Habitat Loss through decreased water levels; Reduction in species abundance, otter, through loss of fish prey. Positive Effect: Habitat Enhancement through increased water levels.
Ramsar Sites	Negative Effect: Habitat Loss through	*No significant effect*			Negative Effect: Habitat Loss

Theme/Topic	Summary Description of Likely Significant Effect[16]				
Receptor	B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
	decreased water levels. Positive Effects: Habitat Enhancement through increased water levels.				through decreased water levels. Positive Effect: Habitat Enhancement through increased water levels.
SSSIs and NNR	Negative Effects: Habitat loss through construction footprint; Fragmentation; Habitat degradation; Species Mortality; Habitat loss through increased water levels; Fragmentation through increased water; Habitat degradation through increased water levels; Species Mortality through increased water levels; Habitat Loss through decreased water levels. Positive Effect: Habitat Enhancement through increased water levels.	Negative Effects: Habitat loss through construction footprint; Fragmentation; Habitat degradation; Species Mortality; Habitat loss through increased water levels; Fragmentation through increased water; Habitat degradation through increased water levels; Species Mortality through increased water levels.	Negative Effects: Disturbance; Habitat degradation; Habitat Loss through decreased water levels. Positive Effect: Habitat Enhancement through increased water levels.	Negative Effects: Habitat loss through construction footprint; Fragmentation; Habitat degradation; Species Mortality; Disturbance; Habitat Loss through decreased water levels.	Negative Effects: Habitat loss through construction; Fragmentation; Habitat degradation; Species Mortality; Habitat Loss through decreased water levels. Positive Effect: Habitat Enhancement through increased water levels.
Local Nature Reserves	Negative Effects: Habitat loss through construction footprint; Fragmentation; Habitat degradation; Species Mortality; Habitat loss through increased water levels; Fragmentation through increased water; Habitat degradation through increased water levels; Species Mortality through increased water levels; Habitat Loss through decreased water levels. Positive Effect: Habitat Enhancement through increased water levels.	*No significant effect*			Negative Effects: Habitat loss through construction footprint; Fragmentation; Habitat degradation; Species Mortality; Habitat Loss through decreased water levels. Positive Effect: Habitat Enhancement through increased water levels.
Habitats and Corridors	Negative Effects: Habitat loss through construction footprint; Fragmentation; Habitat degradation; Habitat loss through increased water levels; Fragmentation through increased water; Habitat degradation through increased water levels; Habitat Loss through decreased water levels; Habitat Enhancement through	Negative Effects: Habitat loss through construction footprint; Fragmentation; Habitat degradation; Habitat loss through increased water levels; Fragmentation through increased water; Habitat degradation through increased water levels; Habitat Loss	Negative Effects: Habitat loss through construction footprint; Habitat degradation; Habitat Loss through decreased water levels.	Negative Effects: Habitat loss through construction footprint; Fragmentation; Habitat degradation; Habitat loss through increased water levels; Fragmentation through increased water; Habitat degradation through increased water levels.	Negative Effects: Habitat loss through construction footprint; Fragmentation; Habitat degradation; Habitat Loss through decreased water levels. Positive Effect: Habitat Enhancement through

Theme/Topic Receptor	Summary Description of Likely Significant Effect[16]				
Receptor	B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
	increased water levels. Positive Effect: Habitat gain through decreased water levels.	through decreased water levels. Positive Effect: Habitat gain through decreased water levels.	Positive Effect: Habitat enhancement through increased water levels.	Positive Effect: Habitat gain through decreased water levels.	increased water levels
Lichens and Funghi	Negative Effects: Habitat Loss and species mortality; Habitat Loss and mortality through increased water levels; Habitat Loss and mortality through decreased water levels. Positive Effect: Habitat enhancement and species increase through increased water levels.	Negative Effects: Habitat Loss and species mortality; Habitat Loss and mortality through increased water levels.	Negative Effects: Habitat Loss and species mortality; Habitat Loss and mortality through increased water levels; Habitat Loss and mortality through decreased water levels. Positive Effect: Habitat enhancement and species increase through increased water levels.	Negative Effects: Habitat Loss and species mortality; Habitat Loss and mortality through increased water levels.	Negative Effects: Habitat Loss and species mortality; Habitat Loss and mortality through increased water levels; Habitat Loss and mortality through decreased water levels. Positive Effect: Habitat enhancement and species increase through increased water levels.
Plants	Negative Effects: Habitat Loss and species mortality; Habitat Loss and mortality through increased water levels; Habitat Loss and mortality through decreased water levels Positive Effects: Habitat enhancement and species increase through increased water levels.	Negative Effects: Habitat Loss and species mortality; Habitat Loss and mortality through increased water levels.	Negative Effects: Habitat Loss and species mortality; Habitat Loss and mortality through increased water levels; Habitat Loss and mortality through decreased water levels. Positive Effect: Habitat enhancement and species increase through increased water levels.	Negative Effects: Habitat Loss and species mortality; Habitat Loss and mortality through increased water levels.	Negative Effects: Habitat Loss and species mortality; Habitat Loss and mortality through increased water levels; Habitat Loss and mortality through decreased water levels. Positive Effect: Habitat enhancement and species increase through increased water levels.
Crustaceans and Molluscs	Negative Effects: Habitat Loss and species mortality; Disturbance; Habitat Loss and mortality through increased water levels; Habitat Loss and mortality through decreased water levels; Reduction in species abundance through loss of fish prey. Positive Effect: Habitat enhancement and species increase through increased water levels.	Negative Effects: Habitat Loss and species mortality; Disturbance; Habitat Loss and mortality through increased water levels; Reduction in species abundance through loss of fish prey.	Negative Effects: Habitat Loss and species mortality; Disturbance; Habitat Loss and mortality through increased water levels; Habitat Loss and mortality through decreased water levels; Reduction in species abundance through loss of fish prey. Positive Effect: Habitat enhancement and	Negative Effects: Habitat Loss and species mortality; Disturbance; Habitat Loss and mortality through increased water levels; Reduction in species abundance through loss of fish prey.	Negative Effects: Habitat Loss and species mortality; Disturbance; Habitat Loss and mortality through increased water levels; Habitat Loss and mortality through decreased water levels; Reduction in species abundance through loss of fish prey. Positive Effect: Habitat enhancement and species

Theme/Topic	Summary Description of Likely Significant Effect[16]				
Receptor	B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
			species increase through increased water levels.		increase through increased water levels.
Invertebrates	Negative Effects: Habitat Loss and species mortality; Disturbance; Habitat Loss and mortality through increased water levels; Habitat Loss and mortality through decreased water levels; Reduction in species abundance through loss of fish prey. Positive Effect: Habitat enhancement and species increase through increased water levels	Negative Effects: Habitat Loss and species mortality; Disturbance; Habitat Loss and mortality through increased water levels; Reduction in species abundance through loss of fish prey.	Negative Effects: Habitat Loss and species mortality; Disturbance; Habitat Loss and mortality through increased water levels; Habitat Loss and mortality through decreased water levels; Reduction in species abundance through loss of fish prey. Positive Effect: Habitat enhancement and species increase through increased water levels	Negative Effects: Habitat Loss and species mortality; Disturbance; Habitat Loss and mortality through increased water levels; Reduction in species abundance through loss of fish prey.	Negative Effects: Habitat Loss and species mortality; Disturbance; Habitat Loss and mortality through increased water levels; Habitat Loss and mortality through decreased water levels; Reduction in species abundance through loss of fish prey. Positive Effect: Habitat enhancement and species increase through increased water levels
Herpetiles	Negative Effects: Habitat Loss and species mortality; Disturbance; Habitat Loss and mortality through increased water levels; Habitat Loss and mortality through decreased water levels. Positive Effect: Habitat enhancement and species increase through increased water levels.	Negative Effects: Habitat Loss and species mortality; Disturbance; Habitat Loss and mortality through increased water levels.	Negative Effects: Habitat Loss and species mortality; Disturbance; Habitat Loss and mortality through increased water levels; Habitat Loss and mortality through decreased water levels. Positive Effect: Habitat enhancement and species increase through increased water levels.	Negative Effects: Habitat Loss and species mortality; Disturbance; Habitat Loss and mortality through increased water levels.	Negative Effects: Habitat Loss and species mortality; Disturbance; Habitat Loss and mortality through increased water levels; Habitat Loss and mortality through decreased water levels. Positive Effect: Habitat enhancement and species increase through increased water levels.
Birds (Terrestrial)	Negative Effects: Habitat Loss and species mortality; Disturbance; Habitat Loss and mortality through increased water levels; Habitat Loss and mortality through decreased water levels. Positive Effects: Habitat enhancement and species increase through increased water levels	Negative Effects: Habitat Loss and species mortality; Disturbance; Habitat Loss and mortality through increased water levels.	Negative Effects: Habitat Loss and species mortality; Disturbance; Habitat Loss and mortality through increased water levels; Habitat Loss and mortality through decreased water levels. Positive Effect: Habitat enhancement and species increase through increased water levels	Negative Effects: Habitat Loss and species mortality; Disturbance; Habitat Loss and mortality through increased water levels.	Negative Effects: Habitat Loss and species mortality; Disturbance; Habitat Loss and mortality through increased water levels; Habitat Loss and mortality through decreased water levels. Positive Effect: Habitat enhancement and species increase through increased water levels.
Mammals	Negative Effects: Habitat Loss and species mortality; Disturbance;	Negative Effects: Habitat Loss and species mortality;	Negative Effects: Habitat Loss and species mortality;	Negative Effects: Habitat Loss and species mortality;	Negative Effects: Habitat Loss and species mortality;

Theme/Topic	Summary Description of Likely Significant Effect[16]				
Receptor	B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
	Habitat Loss and mortality through increased water levels; Habitat Loss and mortality through decreased water levels; Reduction in species abundance, otter, through loss of fish prey. Positive Effect: Habitat enhancement and species increase through increased water levels	Disturbance; Habitat Loss and mortality through increased water levels; Reduction in species abundance, otter, through loss of fish prey.	Disturbance; Habitat Loss and mortality through increased water levels; Habitat Loss and mortality through decreased water levels. Positive Effect: Habitat enhancement and species increase through increased water levels	Disturbance; Habitat Loss and mortality through increased water levels; Reduction in species abundance, otter, through loss of fish prey.	Disturbance; Habitat Loss and mortality through increased water levels; Habitat Loss and mortality through decreased water levels. Positive Effect: Habitat enhancement and species increase through increased water levels
Theme: Historic Environment and Landscape & Seascape - Topic: Historic Environment					
Terrestrial Receptor Area Historic Environment Resource	(Zones 2 & 3) Negative Effects: *Damage to and/or loss of historic environment resource:* within and around design footprint of physical structure; resulting from increased coastal erosion (cliffs) along sections of solid geology coastline associated with change to tidal regime and hydrodynamic conditions; within and around design footprint of physical structures associated with grid reinforcement; Change to the visual setting/context of the historic environment resource including the historic landscape within immediate vicinity of physical structure.	(Zones 3 & 4) Negative Effects: *Damage to and/or loss of historic environment resource:* within and around design footprint of physical structure; resulting from increased coastal erosion (cliffs) along sections of solid geology coastline associated with change to tidal regime and hydrodynamic conditions; within and around design footprint of physical structures associated with grid reinforcement; Change to the visual setting/context of the historic environment resource including the historic landscape within immediate vicinity of physical structure.	(Zones 4 & 5) Negative Effects: *Damage to and/or loss of historic environment resource:* within and around design footprint of physical structure; resulting from increased coastal erosion (cliffs) along sections of solid geology coastline associated with change to tidal regime and hydrodynamic conditions; within and around design footprint of physical structures associated with grid reinforcement; Change to the visual setting/context of the historic environment resource including the historic landscape within immediate vicinity of physical structure.	(Zone 3) Negative Effects: *Damage to and/or loss of historic environment resource:* within and around design footprint of physical structure; within and around design footprint of physical structures associated with grid reinforcement; Change to the visual setting/context of the historic environment resource including the historic landscape within immediate vicinity of physical structure.	(Zone 2) Negative Effects: *Damage to and/or loss of historic environment resource*: within and around design footprint of physical structure; within and around design footprint of physical structures associated with grid reinforcement; Change to the visual setting/context of the historic environment resource including the historic landscape within immediate vicinity of physical structure.
Intertidal Receptor Area Historic Environment Resource	(Zones 3 to 5) Negative Effects: *Damage to and/or loss of historic environment resource:* within and around design footprint of physical structure; within intertidal peat shelves resulting from changes to existing pattern of erosion and deposition associated with changes to	(Zone 3 (close to barrage), 4 & 5) Negative Effects: *Damage to and/or loss of historic environment resource:* within and around design footprint of physical structure; within intertidal peat shelves	(Zone 5) Negative Effects: *Damage to and/or loss of historic environment resource:* within and around design footprint of physical structure; within intertidal peat shelves resulting from	(Zone 3) Negative Effects: *Damage to and/or loss of historic environment resource:* within and around design footprint of physical structure; within intertidal peat shelves resulting from changes to	(Zone 2) Negative Effects: *Damage to and/or loss of historic environment resource:* within and around design footprint of physical structure; within intertidal peat shelves resulting from changes to

Theme/Topic	Summary Description of Likely Significant Effect[16]				
Receptor	**B3: Cardiff to Weston Barrage**	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**L3d: Bridgwater Bay Lagoon**
	tidal regime and Hydrodynamic conditions; within intertidal area resulting from changes to existing pattern of erosion and deposition associated with predicted increase to spring neap tides; Loss of access to resource resulting from reduction width of intertidal profile due to alterations to tidal regime.	resulting from changes to existing pattern of erosion and deposition associated with changes to tidal regime and Hydrodynamic conditions; within intertidal area resulting from changes to existing pattern of erosion and deposition associated with predicted increase to spring neap tides; Loss of access to resource resulting from reduction width of intertidal profile due to alterations to tidal regime.	changes to existing pattern of erosion and deposition associated with changes to tidal regime and Hydrodynamic conditions; within intertidal area resulting from changes to existing pattern of erosion and deposition associated with predicted increase to spring neap tides; Loss of access to resource resulting from reduction width of intertidal profile due to alterations to tidal regime.	existing pattern of erosion and deposition associated with changes to tidal regime and Hydrodynamic conditions; within intertidal area resulting from changes to existing pattern of erosion and deposition associated with predicted increase to spring neap tides; Loss of access to resource resulting from reduction width of intertidal profile due to alterations to tidal regime.	existing pattern of erosion and deposition associated with changes to tidal regime and Hydrodynamic conditions; within intertidal area resulting from changes to existing pattern of erosion and deposition associated with predicted increase to spring neap tides.
Subtidal Receptor Area Historic Environment Resource	(Zones 2 to 5) Negative Effects: *Damage to and/or loss of historic environment resource:* within and around design footprint of physical structure; within and around areas of proposed dredging; Damage to and/or loss of heritage resource due to movements in sediment and changes in erosion patterns associated with changes to tidal regime and hydrodynamic conditions; Loss of access to resource resulting from sedimentation.	(Zones 3, close to barrage), 4 & 5) Negative Effects: *Damage to and/or loss of historic environment resource:* within and around design footprint of physical structure; within and around areas of proposed dredging; Damage to and/or loss of heritage resource due to movements in sediment and changes in erosion patterns associated with changes to tidal regime and hydrodynamic conditions; Loss of access to resource resulting from sedimentation.	(Zone 5) Negative Effects: Damage to and/or loss of historic environment resource within and around design footprint of physical structure; *Damage to and/or loss of heritage resource:* within and around areas of proposed dredging; due to movements in sediment and changes in erosion patterns associated with changes to tidal regime and hydrodynamic conditions; Loss of access to resource resulting from sedimentation.	(Zone 3) Negative Effects: Damage to and/or loss of historic environment resource within and around design footprint of physical structure; *Damage to and/or loss of heritage resource:* within and around areas of proposed dredging; due to movements in sediment and changes in erosion patterns associated with changes to tidal regime and hydrodynamic conditions; Loss of access to resource resulting from sedimentation.	(Zone 2) Negative Effects: Damage to and/or loss of historic environment resource within and around design footprint of physical structure; *Damage to and/or loss of heritage resource:* within and around areas of proposed dredging; due to movements in sediment and changes in erosion patterns associated with changes to tidal regime and hydrodynamic conditions; Loss of access to resource resulting from sedimentation.
	Positive Effect: Protection of resource where sites where resource becomes covered/protected due to movements in sediment associated with changes to tidal regime and hydrodynamic conditions.	Positive Effect: Protection of resource where sites where resource becomes covered/protected due to movements in sediment associated with changes to tidal regime and hydrodynamic conditions.	Positive Effect: Protection of resource where sites where resource becomes covered/protected due to movements in sediment associated with changes to tidal regime and hydrodynamic conditions.	Positive Effect: Protection of resource where sites where resource becomes covered/protected due to movements in sediment associated with changes to tidal regime and hydrodynamic conditions.	Positive Effect: Protection of resource where sites where resource becomes covered/protected due to movements in sediment associated with changes to tidal regime and hydrodynamic conditions.
Theme: Historic Environment and Landscape & Seascape - Topic: Landscape & Seascape					
Receiving Landscape	Negative Effects: *Changes in*	Negative Effects: *Change in*	Negative Effects: *Change in*	Significant Negative Effects:	Significant Negative Effects:

Theme / Topic	Summary Description of Likely Significant Effect[16]				
Receptor	**B3: Cardiff to Weston Barrage**	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**L3d: Bridgwater Bay Lagoon**
	landscape characteristics: at Lavernock Point caused by the actual barrage and the construction infrastructure required to build and de-commission the barrage; at Brean Down SM and Brean Beach caused by the actual barrage; in the hinterland behind Brean Beach caused by the construction infrastructure required to build and de-commission the barrage; power transmission lines running from the Lavernock Point landfall to connect to the national grid; Power transmission lines running from the proposed Brean Beach landfall to connect to the national grid; energy intensive industry siting themselves in close proximity to their major power source and a resulting alteration of the area's local landscape quality and possible change to landscape quality of the wider Somerset Levels or Glamorgan coast around Lavernock Point. <u>Positive/Negative Effect</u> Change in landscape characteristics in the hinterland approaching the barrage and at both landfall points caused by new road infrastructure, control buildings and any visitor facilities.	*landscape characteristics:* in the Gwent Levels Historic Landscape near Caldicot Moor caused by the actual barrage; around Caldicot Moor caused by the construction infrastructure required to build and de-commission the barrage; at Severn Beach from the barrage itself; in the hinterland behind between Severn Beach and Avonmouth caused by the construction infrastructure required to build and de-commission the barrage; power transmission lines running from the Severn Beach landfall to connect to the national grid leading to altered local landscape characteristics; energy intensive industry siting themselves in close proximity to their major power source and a resulting alteration of the landscape characteristics in the Gwent Levels Historic Landscape or in the vicinity of Severn Beach. <u>Positive/Negative Effect</u> Change in landscape characteristics of the hinterland approaching the barrage at the Gwent Levels Historic Landscape landfall points caused by new road infrastructure, control buildings and any visitor facilities; Altered tidal prism keeping water in the lower river system of the River Wye at Chepstow leading to a change in the	*landscape characteristics:* on the Beachley peninsula caused by the actual barrage; around Beachley caused by the construction infrastructure required to build and de-commission the barrage; at Severn View from the barrage itself; in the hinterland behind Severn View in the vicinity of the existing services and office block; power transmission lines running from the Beachley landfall to connect to the national grid; power transmission lines running from the Severn View landfall to connect to the national grid leading to altered landscape characteristics; energy intensive industry siting themselves in close proximity to their major power source and a resulting alteration of the landscape characteristics in the receiving landscape whether it be Beachley, Caldicot or around the Severn View area; Altered tidal prism in front of the barrage keeping higher water in the lower system of the River Wye at Chepstow for longer periods of time leading to a change in the landscape characteristics of the river and potential new consequential development along its corridors (potentially significant for River Wye and Chepstow).	*Change in landscape characteristics*; on the Gwent Levels Historic Landscape most notably along its shore caused by the presence of the lagoon wall and the landfall points of the wall; on the Gwent Levels Historic Landscape caused by the construction infrastructure required to build and de-commission the lagoon; in the hinterland approaching the lagoon construction and operation areas at Uskmouth and Portskewett caused by new road infrastructure, control buildings and any visitor facilities; Power transmission lines running from either landfall of the lagoon wall to connect to the existing substation at Aust and onto the national grid.	*Change in landscape characteristics:* of the Somerset Levels most notably caused by the lagoon wall's landfall points at Brean Down SM and Stolford; in the hinterland in the vicinity of the lagoon caused by the construction infrastructure required to build and de-commission this option; in the hinterland approaching the lagoon construction and operation areas at Brean caused by new road infrastructure, control buildings and any visitor facilities; Power transmission lines running from either landfall of the lagoon wall to connect to the national grid. Wider power reinforcements may be required.

Theme/Topic	Summary Description of Likely Significant Effect[16]				
Receptor	B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
		landscape characteristics of the river and potential new development along its corridors.	Positive/Negative Effect Change in landscape characteristics in the hinterland approaching the barrage along the Beachley Peninsula caused by new road infrastructure, control buildings and any visitor facilities.		
Receiving Seascape	Negative Effects: Alteration of the regional seascape character units 48 Nash Point to Lavernock Point and Unit 49 Lavernock Point to Gold Cliff; Alteration of the tidal prism primarily upstream of the barrage and to a lesser extent downstream of the barrage. Effect is the removal of the lower parts of the tidal range from view; Erosion of salt marsh through the longer duration of high water stand in the estuary altering this seascape characteristic where it currently occurs; The night-time scene would be altered with the presence of safety and navigation lighting along the barrage adding illumination to a currently dark area with relatively few light sources. Positive/Negative Effect: Marina development to capitalise on the longer duration of high water upstream of the barrage altering the seascape characteristics of parts or all of the upstream area.	Negative Effects: Alteration of the Welsh regional seascape character unit 50 Gold Cliff to Chepstow; Alteration of the tidal prism primarily upstream of the barrage and to a lesser extent downstream of the barrage. Effect is the removal of the lower parts of the tidal range from view; Erosion of salt marsh through the longer duration of higher water in the estuary altering the seascape characteristics of the area; The night-time scene would be altered with the presence of safety and navigation lighting along the barrage adding illumination to a currently dark area in front of the Gwent Levels Historic Landscape; The night-time scene would be altered with the presence of safety and navigation lighting along the barrage adding further illumination to a relatively bright area with numerous light sources around Severn Beach and in the Avonmouth seascape unit. Positive/Negative Effect: Marina development and increased leisure craft activity to capitalise on the longer	Negative Effects: Alteration of the Upper Severn Estuary seascape unit's character; Alteration of the tidal prism primarily upstream of the barrage and to a lesser extent downstream of the barrage and along the River Wye. Effect is the removal of the lower parts of the tidal range from view; Loss of rock outcrops and mix of sand and mud inter-tidal areas altering the seascape character of the area; Marina development and increased leisure craft activity to capitalise on the longer duration of high water upstream of the barrage altering the seascape characteristics of parts or all of the upstream area.	Negative Effects: Alteration of the seascape characteristics of the CCW regional seascape unit's 50 from Gold Cliff to Chepstow through the physical presence of the lagoon wall and operation areas; Loss of rock outcrops and mix of sand and mud inter-tidal areas altering the seascape characteristics of the area; Alteration of the water level within the lagoon impounding water to a higher level for a longer period of time obscuring view to inter-tidal areas; Alteration of existing saltmarsh areas on the Welsh Grounds including erosion and possible development of new areas higher up the shore changing the seascape characteristics. Positive/Negative Effect: Marina development and increased leisure craft activity to capitalise on the longer duration of high water in the lagoon basin altering the seascape characteristics of the Welsh Grounds	Significant Negative Effects: Alteration of the characteristics of the regional seascape unit of Bridgwater Bay by the physical presence of the lagoon wall; Loss of rock outcrops and mix of sand and mud inter-tidal areas altering the seascape characteristics of the area; Alteration of the water level within the lagoon impounding water to a higher level at low tide obscuring view to lower parts of the inter-tidal areas; Alteration of existing saltmarsh areas around Bridgwater Bay including erosion of saltmarsh and possible development of new marsh areas higher up the shore changing the seascape characteristics.

Theme/Topic	Summary Description of Likely Significant Effect[16]				
Receptor	B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
		duration of high water upstream of the barrage forming new seascape features in parts of the upstream of the barrage.			
Landscapes with Indivisibility	Significant Negative Effects: Alteration to landscape characteristics in nationally designated landscapes in either Wales or England from the alteration o f the tidal prism upstream; Change of landscape characteristics in none nationally designated landscapes in either Wales or England from the alteration of the tidal prism upstream; Construction of overhead power transmission lines in nationally designated landscapes causing change in their landscape characteristics; Construction of overhead power transmission lines in none nationally designated landscapes causing change to their landscape characteristics; Consequential development of industry in nationally designated landscape areas; Consequential development of industry in none nationally designated landscape areas.	Significant Negative Effects: Alteration of landscape characteristics in nationally designated landscapes in either Wales or England from the alteration of the tidal prism upstream; Construction of overhead power transmission lines in none nationally designated landscapes causing change in landscape characteristics; Consequential development of industry in nationally designated landscape areas of the Wye Valley AONB; Consequential development of industry in none nationally designated landscape areas.	Significant Negative Effects: Alteration of landscape characteristics in the nationally designated landscapes primarily the Wye Valley AONB and the nationally important Gwent Levels Historic Landscape; Alteration of landscape characteristics in none nationally designated landscapes in Wales or England from the presence of the barrage and onshore facilities; Alteration of landscape characteristics in nationally designated landscapes in either Wales or England from the alteration of the tidal prism upstream; Consequential development of industry in nationally designated landscape areas of the Wye Valley AONB or the nationally important historic landscape of the Gwent Levels Historic Landscape.	*No significant effect*	
Seascape with intervisibility or interconnectivity	Significant Negative effects: Physical presence of the barrage would be perceived as dividing the estuary into two separate parts and reducing the linear seascape characteristic of the overall estuary; Change of seascape characteristics in none nationally designated seascapes in either Wales or England from the alteration of the tidal prism upstream of the B3 Barrage; Loss of the Severn Bore phenomenon.	Significant negative effects arising from alteration to tidal prism: Alteration of seascape characteristics in none nationally designated landscapes in either Wales or England from the presence of the barrage and onshore facilities. Physical presence of the barrage would be perceived as dividing the	Significant negative effects arising from alteration to tidal prism: Alteration of seascape characteristics in none nationally designated seascapes in either Wales or England from the presence of the barrage and onshore facilities. Physical presence of the barrage would be perceived as	Significant Negative Effects: Alteration of seascape characteristics in none nationally designated seascapes in either Wales or England from the presence of the lagoon and onshore facilities. Most notable in CCW Regional Seascape Unit No 49 Lavernock Point to Gold Cliff and in the English	*No significant effect*

Theme/Topic	Summary Description of Likely Significant Effect[16]				
Receptor	B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
		estuary into two separate parts and reducing the linear seascape characteristic of the overall estuary; Physical presence of the barrage would be perceived as dividing the estuary into two separate parts and reducing the linear seascape characteristic of the overall estuary; Change of seascape characteristics in none nationally designated seascapes in either Wales or England from the from the alteration o f the tidal prism upstream of the B4 Barrage; Loss of the Severn bore phenomenon.	dividing the estuary into two separate parts and reducing the linear seascape characteristic of the overall estuary; Change of seascape characteristics in none nationally designated seascapes in either Wales or England from the alteration of the tidal prism upstream of the B4 Barrage; Loss of the Severn Bore phenomenon.	seascape units from the Upper Severn Estuary down to Clevedon-Portishead; Alteration of the overall seascape character by physically narrowing the estuary.	
Viewers from Land	<u>Significant Negative effects:</u> Clear sight to the landfall of the barrage at Lavernock Point altering the appearance of the existing view across the estuary; Clear sight to the landfall of the barrage at Brean Beach altering the appearance of the existing view across the estuary and the landmark of Brean Down SM; Clear sight of the length of the barrage from the elevated viewpoint of Brean Down SM; Foreshortening or cutting long views up and down the estuary for viewers; Clear sight of the onshore construction areas behind Brean Beach; Change in the visual variety associated with the reduction in inter-tidal areas; Increased illumination of the landfall points and lights stretching out across the relatively dark estuary. <u>Significant Negative effects (within Nationally Designated Landscapes):</u> Views to consequential industrial development in the vicinity of the barrage (effect resulting from cumulative developments); Sense of	<u>Significant Negative effects:</u> Clear sight to the Gwent Levels Historic Landscape landfall of the barrage altering the appearance of the existing view up, down and across the estuary from the coastal path the estuary; Clear sight to the landfall of the barrage at Severn Beach altering the appearance of the existing view up, down and across the estuary; Inclusion in the view to the Second Severn Crossing altering the appreciation of the bridge's visual appearance; Clear sight of the onshore construction areas within the Caldicot Moor part of the Gwent Levels Historic Landscape; Change in the visual variety associated with the reduction in inter-tidal areas; Views to consequential industrial development in the vicinity of the barrage on the	<u>Negative Effects:</u> Clear sight to the Beachley landfall of the barrage altering the appearance of the existing view up, down and across the estuary from Beachley Peninsula; Clear sight to the landfall and along the length of the barrage at Severn View altering the appearance of the existing scene from Severn View to the original Severn Crossing; Inclusion in the view to the original Severn Crossing altering the appreciation of the bridge; Clear sight of the onshore construction areas on Beachley from that side of the estuary and from the elevated views offered by the Severn View look-out position. <u>Significant Negative Effects:</u> Clear sight of the onshore	<u>Significant Negative Effects:</u> Clear sight to the lagoon wall from the English Shore and any high ground behind it with an aspect that allows views out to the Welsh shore of the Severn Estuary; Inclusion in the view to the Second Severn Crossing altering the visual appreciation of the bridge; Clear sight of the onshore construction areas within the Gwent Levels Historic Landscape; Change in the inter-tidal areas visual variety associated with the impounding of water levels within the lagoon basin; Views to consequential industrial development in the vicinity of the lagoon on the Gwent Levels Historic Landscape; Sense of loss of tranquillity when the lagoon is viewed from existing areas of relative tranquillity in along the shore of the Gwent Levels	<u>Significant Negative Effects:</u> Clear sight to the lagoon wall from the English high ground behind within the hinterland behind the English shore such as the Quantocks and the Mendip Hills; Visual enclosure of Bridgwater Bay for viewers on both land and sea with the sense of the whole bay area has been separated from the wider Bristol Channel; Clear sight of the onshore construction areas within the hinterland of the Somerset Levels; Views to any consequential industrial development in the vicinity of the lagoon; Sense of loss of tranquillity when the lagoon is viewed from existing areas of relative tranquillity along the shore to the west of the River Parrett; Increased illumination of the landfall points and lagoon wall in this relatively dark part of the estuary.

Theme/Topic	Summary Description of Likely Significant Effect[16]				
Receptor	**B3: Cardiff to Weston Barrage**	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**L3d: Bridgwater Bay Lagoon**
	loss of tranquillity when the barrage is viewed from existing areas of relative tranquillity.	Gwent Levels Historic Landscape; Sense of loss of tranquillity when the barrage is viewed from existing areas of relative tranquillity in the Gwent Levels Historic Landscape; Increased illumination of the landfall points and lights stretching out across the relatively dark estuary.	construction areas on Beachley from that side of the estuary and from the elevated views offered by the Severn View look-out position; Clear sight of the onshore construction areas behind Severn View service area; Change in the inter-tidal areas visual variety associated with the raising of water levels upstream of the barrage; Views to consequential industrial development in the vicinity of the barrage on Beachley Peninsula.	Historic Landscape; Increased illumination of the landfall points and lagoon wall in this relatively dark part of the estuary; Clear sight to the L2 Lagoon wall and operational areas altering the appearance of the existing view up, down and across the estuary when viewed from the Severn Way path on the Welsh Shore.	Significant Positive/Negative Effects: Clear sight to the L3d Lagoon wall altering the appearance of existing views up, down and across the estuary when viewed from the Bridgwater Bay shore.
Viewers from the sea	Significant Negative effects: Loss of saltmarsh making a more distinct boundary between open water and land areas around the estuary; Clear sight to increased marina development and activity on the water (effect resulting from cumulative developments). Significant Negative effects (significance varies according to range): Clear sight to the barrage route across open water; Foreshortening or cutting long views up and down the estuary for viewers; Increased illumination out on the water from safety and navigation lights; Clear sight to potential consequential industrial development in proximity of barrage (effect resulting from cumulative developments).	Significant Negative effects: Clear sight to the barrage route across open water; Foreshortening or cutting of long views up and down the estuary for viewers; Increased illumination out on the water from safety and navigation lights; Clear sight to potential consequential industrial development in proximity of barrage; Loss of saltmarsh making a more distinct boundary between open water and land areas around the estuary.	Significant Negative effects: Clear sight to the barrage route across open water; Foreshortening or cutting of long views up and down the estuary for viewers; Loss of saltmarsh making a more distinct boundary between open water and land areas around the estuary.	Significant Negative effects: Clear sight to the lagoon wall running parallel to the Welsh shore; Foreshortening or cutting of long views up, down and across the estuary for viewers out on the water in the lagoon basin; Increased illumination out on the water from safety and navigation lights; Loss of saltmarsh making a more distinct boundary between the open water and shore areas around the lagoon.	Significant Negative effects: Clear sight to the lagoon wall running around Bridgwater Bay from within the Bay and from out on the Inner Bristol Channel; Foreshortening or cutting of long views up, down and across the estuary for viewers out on the water in the lagoon basin; Increased illumination out on the water from safety and navigation lights in the water and along the lagoon wall; Clear sight to potential consequential industrial development in proximity of lagoon; Loss of saltmarsh making a more distinct boundary between the open water and shore areas around the lagoon.
Theme: Air & Climatic Factors and Resources & Waste - Topic: Air & Climatic Factors					
***No significant effects* for Air Quality**					
Carbon Footprinting					
Global level of Greenhouse Gas emissions and local	Positive Effects: (Overall) Change in the overall GHG emissions; (Operation) Predicted decrease in	Positive Effects: (Overall) Change in the overall GHG emissions; (Operation) Predicted decrease in emissions due to generation of electricity from a renewable source; (Operation) Development of other electricity generation projects in the area, could add to the GHG global effect in a positive or negative way depending on the sustainability of these projects.			

Theme / Topic	Summary Description of Likely Significant Effect[16]				
Receptor	**B3: Cardiff to Weston Barrage**	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**L3d: Bridgwater Bay Lagoon**
Greenhouse Gas emissions.	emissions due to generation of electricity from a renewable source; (Operation) Development of other electricity generation projects in the area, could add to the GHG global effect in a positive or negative way depending on the sustainability of these projects.				
	Negative Effect: (Construction). Increase of GHG emissions due to production and supply of raw materials, installation, dredging. Including impacts of transportation.				
Theme: Air & Climatic Factors and Resources & Waste - Topic: Resources & Waste					
Resources:					
Aggregates and embankment materials	Negative Effects (During Construction): Demand for aggregates and embankment materials for construction from UK sources; Development of new quarries or marine dredging areas; Demand for aggregates and embankment materials for construction, especially armour stone, from abroad (far-field effect); Demand for aggregates and embankment materials, in conjunction with other proposed civil engineering projects (cumulative effect).		Negative Effects (During Construction): Demand for aggregates and embankment materials for construction from UK sources; Demand for aggregates and embankment materials, in conjunction with other proposed civil engineering projects (cumulative effect).	Negative Effects (During Construction): Demand for aggregates and embankment materials for construction from UK sources; Development of new quarries or marine dredging areas; Demand for aggregates and embankment materials for construction, especially armour stone, from abroad (far-field effect); Demand for aggregates and embankment materials, in conjunction with other proposed civil engineering projects (cumulative effect).	
Waste					
Sites for reuse	Negative Effects: Demand for sites for reuse for dredged materials (during operation); Demand for sites for reuse of recycled aggregates from removal of the structures (during decommissioning).				
Theme: Society & Economy - Topic: Communities					
Ports of Bristol, Cardiff, Newport, and Sharpness	Negative effect: Use of additional shipping lock reducing port activity and port direct and indirect employment.	*No significant effect*			
Usk, Wye and Severn river fishing	Negative effect: Disrupted salmon, sea trout and eel migration; reducing fly fishing tourism and heritage (elver) fishery direct and indirect employment.				
Populations with Middle Layer Super Output Areas (MSOA)	Negative effects on population within Vale of Glamorgan 008 and Sedgemoor 002; Effects from noise and air quality, flood risk, landscape and traffic resulting in a cumulative effect health and quality of life during construction.	*No significant effect*		Negative effects on population within Monmouthshire 009 and Newport 015; Effects from noise and air quality, flood risk, landscape and traffic resulting in a cumulative effect health and quality of life during construction.	Negative effects on population within West Somerset 004 and Sedgemoor 002; Effects from noise and air quality, flood risk, landscape and traffic resulting in a cumulative effect health and quality of life during construction.
Land Use: Effects on	*No significant effect*				Negative Effect: There is

Theme/Topic	Summary Description of Likely Significant Effect[16]				
Receptor	B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
areas proposed or committed for development					potential that the proximity of L3d to the Hinkley C site may affect the construction of one or both projects if they coincide. Assumes that there may be common access/material/land use requirements.
Theme: Society & Economy - Topic: Noise & Vibration					
***No significant effects* for Noise & Vibration Topic**					
Theme: Society & Economy - Topic: Navigation					
Port of Bridgwater	*No significant effect*				Negative Effects: Risks to the ability of vessels to navigate safely through the estuary; Increased transit time through lock structures; Reduced high water levels; Increased peak water velocities at sluice gates and turbine blocks; Short term sediment deposition within the lagoon; Long term morphological change.
Port of Bristol	Negative Effects: Risks to the ability of vessels to navigate safely through the estuary; Ability of vessels to navigate through the new navigation channel at low and mid tides; Increased transit time through lock structures; Reduced high water levels; Increased peak water velocities at sluice gates and turbine blocks; Short term sediment deposition in navigation channels and immediate approach channels following completion of the Barrage; Long term morphological change in navigation channels and immediate approach channels; Increased transit time through remaining lock structures following decommissioning. Positive Effect: Reduced peak water velocity throughout the estuary and Bristol Channel; Increased low water levels upstream of Barrage.	Negative Effects: Risks to the ability of vessels to navigate safely through the estuary; Increased low water levels upstream of Barrage; Short term sediment deposition in navigation channels and immediate approach channels following completion of the Barrage.		Negative Effects: Risks to the ability of vessels to navigate safely through the estuary; Long term morphological change in the mid-Severn.	Negative Effects: Risks to the ability of vessels to navigate safely through the estuary; Reduced high water levels.
Port of Cardiff	Negative Effects: Risks to the ability of	Negative Effects: Risks to the ability of vessels to navigate safely through the estuary.			Negative Effects: Risks to the

Theme / Topic	Summary Description of Likely Significant Effect[16]				
Receptor	B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
	vessels to navigate safely through the estuary; Ability of vessels to navigate through the new navigation channel at low and mid tides; Increased transit time through lock structures; Reduced high water levels; Increased peak water velocities at sluice gates and turbine blocks; Short term sediment deposition in navigation channels and immediate approach channels following completion of the Barrage; Long term morphological change in navigation channels and immediate approach channels; Increased transit time through remaining lock structures following decommissioning. Positive Effects: Reduced peak water velocity throughout the estuary and Bristol Channel; Increased low water levels upstream of Barrage.				ability of vessels to navigate safely through the estuary; Reduced high water levels.
Port of Newport	Negative Effects: Risks to the ability of vessels to navigate safely through the estuary; Ability of vessels to navigate through the new navigation channel at low and mid tides; Increased transit time through lock structures; Reduced high water levels; Increased peak water velocities at sluice gates and turbine blocks; Short term sediment deposition in navigation channels and immediate approach channels following completion of the Barrage; Long term morphological change in navigation channels and immediate approach channels; Increased transit time through remaining lock structures following decommissioning. Positive Effects: Reduced peak water velocity throughout the estuary and Bristol Channel; Increased low water levels upstream of Barrage.	Negative Effects: Risks to the ability of vessels to navigate safely through the estuary.			Negative Effects: Risks to the ability of vessels to navigate safely through the estuary; Reduced high water levels.
Port of Sharpness	Negative Effects: Risks to the ability of vessels to navigate safely through the estuary; Increased transit time through	Negative Effects: Risks to the ability of vessels to navigate safely through the estuary;	Negative Effects: Risks to the ability of vessels to navigate safely through the	Negative Effects: Risks to the ability of vessels to navigate safely through the estuary;	Negative Effects: Risks to the ability of vessels to navigate safely through the estuary;

Theme/Topic	Summary Description of Likely Significant Effect[16]				
Receptor	**B3: Cardiff to Weston Barrage**	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**L3d: Bridgwater Bay Lagoon**
	lock structures; Reduced high water levels; Increased peak water velocities at sluice gates and turbine blocks; Short term sediment deposition in navigation channels and immediate approach channels following completion of the Barrage; Long term morphological change in navigation channels and immediate approach channels; Increased transit time through remaining lock structures following decommissioning. Positive Effects: Reduced peak water velocity throughout the estuary and Bristol Channel; Increased low water levels upstream of Barrage.	Increased transit time through lock structures; Increased peak water velocities at sluice gates and turbine blocks; Short term sediment deposition in navigation channels and immediate approach channels following completion of the Barrage; Long term morphological change in navigation channels and immediate approach channels.	estuary; Increased transit time through lock structures; Reduced high water levels; Increased peak water velocities at sluice gates and turbine blocks; Short term sediment deposition in navigation channels and immediate approach channels following completion of the Barrage; Long term morphological change in navigation channels and immediate approach channels.	Long term morphological change in the mid-Severn.	Reduced high water levels.
Theme: Society & Economy - Topic: Other Sea Uses					
Marine Aggregates	Negative Effects: Disruption to 12 hour extraction cycle; Disruption of access to licensed extraction grounds; Reduced sand supply to aggregate reserve sites.	Negative Effect: Reduced sand supply to aggregate reserve sites.		Negative Effects: Disruption of access to licensed extraction grounds; Reduced sand supply to aggregate reserve sites.	Negative Effect: Reduced sand supply to aggregate reserve sites.
Marine Waste Disposal	Negative Effects: Reduced performance of gravity driven outfalls; Reduction upstream current speeds making disposal sites for dredged material unsuitable; Erosion of intertidal areas upstream of structure, causing outfall undermining.	Negative Effects: Reduced performance of gravity driven outfalls; Erosion of intertidal areas upstream of structure, causing outfall undermining.	Negative Effect: Reduced performance of gravity driven outfalls.	Negative Effect: Reduction upstream current speeds making disposal sites for dredged material unsuitable.	*No significant effect*
Recreation	Negative Effects: Loss of the Severn Bore; Increased siltation affecting viability of marinas/ moorings Undermining of coastal structures used for marine recreation (e.g. slipways). Positive Effect: Creation of a more benign hydrodynamic environment.	Negative Effects: Loss of the Severn Bore; Increased siltation affecting viability of marinas/ moorings.		Positive Effect: Creation of a more benign hydrodynamic environment.	Negative Effects: Increased peak flow velocities within Bridgwater Bay.
Rescue Organisations	Negative Effects: Increased incident response times.				
Tourism	Negative Effects: Reduced aesthetic appeal of the Estuary, impacting tourism; Disruption to bird population, impacting ornithological tourism; Detrimental impact to sandy pleasure beaches, impacting tourism; Construction phase coinciding with other large projects causing strain on infrastructure, impacting coastal tourism.		Negative Effects: Detrimental impact to sandy pleasure beaches, impacting tourism; Construction phase coinciding with other large	Negative Effects: Reduced aesthetic appeal of the Estuary, impacting tourism; Disruption to bird population, impacting ornithological	Negative Effects: Reduced aesthetic appeal of the Estuary, impacting tourism; Disruption to bird population, impacting ornithological

Theme / Topic	Summary Description of Likely Significant Effect[16]				
Receptor	**B3: Cardiff to Weston Barrage**	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**L3d: Bridgwater Bay Lagoon**
	Positive Effects: Tidal Power Option becoming a visitor attraction.		projects causing strain on infrastructure, impacting coastal tourism. Positive Effects: Tidal Power Option becoming a visitor attraction.	tourism; Detrimental impact to sandy pleasure beaches, impacting tourism; Construction phase coinciding with other large projects causing strain on infrastructure, impacting coastal tourism.	tourism; Detrimental impact to sandy pleasure beaches, impacting tourism; Construction phase coinciding with other large projects causing strain on infrastructure, impacting coastal tourism; Change to spatial extent of contaminant plume from Weston Super Mare waste water treatment works, affecting bathing water quality at Weston.
Cables & Pipelines	*No significant effect*				Negative Effect: Erosion of sub tidal environment causing cable scour.
Energy	Negative Effect: Local morphological changes up estuary of the barrage affecting the integrity of power station intake and to outfall structures.	*No significant effect*			Negative Effect: Changes to power station thermal plume characteristics.
Military	*No significant effect*	Negative Effect: Disruption to military practice areas.	*No significant effect*		

10.10 Appendix 10: Log of measures to prevent, reduce and as fully as possible offset any significant adverse effects on the environment of implementing the plan or programme

This appendix is intended to provide an overview of all the measures considered to prevent, reduce and as fully as possible offset the significant adverse effects to the environment that are suggested prior to, during or following the implementation of a Severn Tidal Power (STP) alternative option, or combination of options.

Information is provided on prevent, reduce and offset measures which have been suggested for adoption. The log also shows those measures which have ultimately not been suggested for adoption, following review and consultation with stakeholders, and the reason for this decision. Where a potential measure has been removed from the list, the reason for this decision is also provided and the removed measure is shown in italics without an STP measure number.

Those measures which are highlighted green in the final column have been suggested for adoption and hence have been assumed implemented in project costings and by topics in their assessment of residual effects and performance against the SEA objectives.

In the STP SEA reporting, and in line with UK practice, measures are described separately as '*measures to prevent or reduce effects*' and '*measures to as fully as possible offset any significant adverse effects*'. To aid with reporting, this document has also split these measures.

Contents

- Table 1 (Measures to prevent or reduce effects) presents measures (by topic) that have been suggested during the project development to-date to prevent or reduce any significant adverse effects on the environment.
- Table 2 (Measures to as fully as possible offset effects) then presents key measures that have been suggested to as fully as possible offset any significant adverse effects on the environment, again by topic. Where applicable, this table also indicates whether the measure is a potential compensation measure under the Habitats Directive.

Within each table; for each measure, the significant effect being discussed has been linked to specific receptors (column 2). This approach aligns with the approach taken within SEA topic paper assessments.

The nature and scale of alternative options being considered within this SEA are unprecedented, and so are the measures to prevent and reduce their effects. In some cases, suggestions on the scope and nature of measures are made in the absence of complete information.

It is therefore assumed that the measures will be the subject of further development as part of subsequent project implementation stages. Any assumptions made on the effect and applicability of these measures will need to be verified as part of project level planning and design.

It is recommended that, where applicable, consideration also is given to an offset/ compensation approach for those prevent/ reduce measures which are identified as having risks to their successful implementation.

Criteria used to identify measures to be included

A series of criteria have been applied to aid the selection of those measures to be included within each option. These are intended to reflect the risks associated with the measures in terms of their effectiveness, policy and legal compliance, time needed for development and effects on other aspects of the environment. By showing how these factors have been taken into account, it is intended to demonstrate that reasonable measures have been selected.

The criteria and their definitions used within columns 7 to 12 are as follows:

Column	Criterion	Definition
7	Effectiveness of measure	Assessment of how effective the measure is in addressing the effect. This is not a judgement on the ability of a measure to prevent the effects of an STP.
8	Established practice	Extent to which measure has precedent and is accepted as a prevention or reduction measure. Measures with an established precedent are more likely to be meet legal, policy and consenting requirements.
9	Established method	Extent to which a measure relies on established technologies or techniques or requires innovation.
10	Development timeframe	Timescale that would be required to fully implement the measure. Measures must be achievable by 2020.
11	Significant adverse effect on biodiversity	Extent to which a measure has adverse environmental consequences. Judgement is in strategic context of major national project.
12	Significant adverse effect on society and economy	Extent to which a measure has significant adverse effect on society or economy.

The text within columns 7 to 12 has been colour coded to help aid clarity on the ultimate decision within column 13 on whether or not it is suggested to adopt the measure within assessments and options costing.

Colour coding for columns 7 to 12 is according to the categorisations below:

(GREEN)	Measure clearly meets criterion
(AMBER)	Measure partially meets criterion or is capable of failing or meeting criterion depending on specific situation applied. Risk to successful implementation.
(RED)	Measure clearly fails to meet criterion. Risk to successful implementation.

The final column (13) states whether the measure has been suggested for inclusion and is therefore to be considered within the SEA assessment of residual effects, SEA Objective compliance and within the option costs.

Column 13 is therefore shaded green or red depending on whether the measure is suggested for inclusion or not, an explanation on the deciding factors for this decision is also provided within this final column.

Table 1: Key measures to PREVENT OR REDUCE any significant adverse effects on the environment

1. Topic	2. Likely significant adverse effect on environment*	3. Measure envisaged to prevent or reduce effect (followed by a cross-reference to the measure number used within earlier iterations of the ODR prevent/reduce costings table, where applicable)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Averse biodiversity effect	12. Adverse effect on society & economy.	13. Included in assessments of residual effects, SEA Objective compliance and option costs?
Marine Ecology	Reduction in area of intertidal habitat (including: mudflat, sandflat, saltmarsh, intertidal rock and shingle areas)	**M1. Operational management of barrage/lagoon regime** adoption of *ebb & flood generation as primary mode* (1) Change water levels to prevent or reduce effect of tidal range reduction with the potential for 50% less reduction in intertidal area See Marine Ecology topic paper.	Applies to **B3** and **L2** Note that L3d is already assumed to be Ebb & Flood**.**	*Note: Costings are not provided anywhere in this document. For project costings see the Options Definition Report (PB 2010)*	B3 – 5% decrease L2 – 15% increase	(GREEN) Would substantially reduce effects on tidal range; thereby reducing adverse effects on intertidal mudflats and sandflats by: B3 – 40% less L2 – 70% less Also reduces adverse effects upon birds.	(RED) No precedent	(AMBER) Modelling has shown measure to be effective	(GREEN) Would be implemented as integral part of main scheme B3 would take an additional 18 months to full generation under Ebb & Flood compared to Ebb only.	(RED) Adverse implications for fish passage	(RED) Averse implications for navigation.	**NO** Adverse implications to biodiversity and society& economy
		M2. Operational management of barrage/lagoon regime: *sluice management, - sluicing after the generation period, combined with early commencement of turbine generation, in ebb only mode.* (2) Change water levels to prevent or reduce effect of tidal range reduction. See Marine Ecology topic paper.	Applies to **B3, B4, B5 & L2** (L3d is ebb/flood)		Up to 5% reduction in energy yield for ebb generation schemes.	(GREEN) The use of sluicing after generation, combined with early start of turbine generation, has the potential to reduce intertidal habitat loss for all ebb-only alternative options (based on studies using modern turbines). For B3, this could potentially lead to low water levels being lowered by up to 0.5m for B3, thereby potentially reducing intertidal habitat loss by up to 500ha. This could also benefit feeding birds and may	(RED) No precedent	(AMBER) Modelling has shown measure to be effective	(GREEN) Would be implemented as integral part of main scheme	(AMBER) No major effects envisaged, but more detailed modelling needed on effects on fish needed to confirm this	(GREEN) No major effects envisaged	**YES – for B3, B4, B5 & L2** Effective and only minor impacts on energy cost.

1. Topic	2. Likely significant adverse effect on environment*	3. Measure envisaged to prevent or reduce effect (followed by a cross-reference to the measure number used within earlier iterations of the ODR prevent/reduce costings table, where applicable)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Averse biodiversity effect	12. Adverse effect on society & economy.	13. Included in assessments of residual effects, SEA Objective compliance and option costs?
						have additional benefit to fish.						
	Reduction in duration of intertidal mudflat and sandflat exposure times (for remaining intertidal)	***Operational management of barrage/lagoon regime** – turbine management, - commence turbine operation earlier and allow freewheeling of turbines at the end of generation (on Spring Tides only) (3)* *Changing water levels to prevent or reduce effect of tidal range reduction.*	***During optimisation, the freewheeling of turbines was shown to be beneficial to reducing the loss of intertidal and has therefore already been adopted with within the alternative option definitions.***									
	Reduction in intertidal mudflat and sandflat areas	**M3. Topographic modification** – (Intertidal creation) as a measure to prevent or reduce effects, not a compensation measure. (4) See Marine Ecology topic paper and the Topographic Modification paper.	Applies to **all** alternative options		Modifications for B3, B4, B5 and L2 would reduce live water volume but none of these schemes has a capacity which utilises the full live volume potential. Therefore it is assumed that the energy yield would not	(AMBER) Would reduce the compensation requirement for loss of intertidal habitat extent (area) by creating new intertidal habitat within the Severn Estuary. Does not address the initial loss of habitat. **It is assumed that the 2:1 ratio of replacement to loss applies to this measure** (due to its similarities with compensation measures) For details on the full amount that is shown to be potentially achievable and an explanation of the methodology used see the topographic modification paper:	(RED) Not an established measure to prevent and reduce effects and no precedent on this scale	(AMBER) Engineering methods involved are conventional although not widely applied to meet the outcomes sought here. Scale of deliverable intertidal area and its functionality is uncertain,	(GREEN) Measure considered to be technically feasible by 2020, but in need of further development before this time in order to improve confidence in efficacy and achievement of its potential.	(AMBER) Adverse effects for shallow subtidal and potential for indirect adverse effects on other habitats and fish species through H&G changes. These H&G changes would require further modelling	(GREEN) No major effects envisaged. Potential minor impacts upon carbon footprint. Also potential minor impacts upon navigation that are assumed to be preventable.	**YES - for all alternative options.** **It is assumed that the 2:1 ratio of replacement to loss applies to this measure.** **Following research and the assumptions explained here, it has been assumed that between 20% and 45% of the**

1. Topic	2. Likely significant adverse effect on environment*	3. Measure envisaged to prevent or reduce effect (followed by a cross-reference to the measure number used within earlier iterations of the ODR prevent/reduce costings table, where applicable)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Averse biodiversity effect	12. Adverse effect on society & economy.	13. Included in assessments of <u>residual effects</u>, <u>SEA Objective compliance</u> and <u>option costs</u>?
					be affected. 2D modelling of modified topography is required to improve certainty.	**It is assumed that between 20% to 45% of the potential amount of intertidal creation identified would actually be viable for implementation following more detailed feasibility work.** **<u>Assuming the 20% to 45% implementation rate and assuming that a 2:1 compensation ratio applies: the compensation requirement for intertidal habitat could be reduced by the following amounts::</u>** **B3**: 1,000ha – 2,250ha **B4**: 250ha – 562ha **B5**: 250ha –562ha **L2**: 530ha – 1,192ha **L3**: 390ha – 877ha.		but assumptions have been drawn using the knowledge currently available.		at the detailed design stage.		**total potential area would ultimately be implemented.** **Further modelling would be required at detailed design, but the measure has the potential to replace large areas of replacement habitat.**
	Change in Saltmarsh inundation regime or exposure time.	***Operational management of barrage/lagoon regime**: <u>Additional sluicing to inundate saltmarsh</u> - Saltmarsh protection through additional sluicing to reduce the lowering of upstream baseline MHWS levels and allow inundation of saltmarsh areas (5)*	***Studies have shown that the only option for which this is viable (B4) is not showing any reduction in saltmarsh. As a result this measure is not being taken forward.***									
		Operational management of barrage/lagoon regime -	***Topic assessments have shown measure not to be affective for saltmarsh***									

1. Topic	2. Likely significant adverse effect on environment*	3. Measure envisaged to prevent or reduce effect (followed by a cross-reference to the measure number used within earlier iterations of the ODR prevent/reduce costings table, where applicable)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Averse biodiversity effect	12. Adverse effect on society & economy.	13. Included in assessments of residual effects, SEA Objective compliance and option costs?
		Saltmarsh protection through topographic modification (4).										
		M4. Seawater level management: *Pumping at high water* (17) To minimise the decrease in high water levels resulting from the alternative options, thus reducing effects on intertidal habitat area (in particular, saltmarsh). See Marine Ecology topic paper.	Applies to all alternative options except B5. For B4, only applies if bulb turbines are adopted. Straflo turbines may be preferable for B4.		Pumping should increase energy output; previous studies have shown a 3% to 10% increase in energy yield for B3 with pumping	(GREEN) Would require raising upstream water levels by up to 1m on a regular basis for a defined period. If the measure was specifically targeted at preventing long-term saltmarsh losses, then it would only be relevant to B3 (as only B3 is showing predicted losses). For B3 this measure could potentially prevent the loss of up to 226ha of existing saltmarsh. This measure also has the potential to prevent or reduce the short-term effect of loss of saltmarsh immediately following commencement of operation. This short-term effect is believed to be likely for all alternative options for up to five years, after which time re-colonisation of saltmarsh is predicted to have resulted in a net-gain of saltmarsh for all options other than B3. Further detailed study would be needed to quantify the potential short-term effects of this measure.	(RED) No precedent	(AMBER) Modelling has shown measure to be effective Would likely be developed in combination with measure 5	(GREEN) Would be implemented as integral part of main scheme Requires assumptions on operations as precise regime requires detailed optimisation beyond feasibility study.	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged, although the river and tide levels would require monitoring to reduce risks of tide locking leading to flood risk.	**YES – for B3, B4, L2 & L3d (note that bulb turbines would be needed if included for B4)** **If applied for *long-term* saltmarsh effects only, then only applicable to B3.** **Potential for *short-term* saltmarsh loss reduction for all alternative options (bulb turbines would be needed if included for B4).** **Measure is effective and can also be**

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						This measure may not be fully effective without additional mechanisms to ensure that the sediment requirements of saltmarsh could also be sustained. This measure could also have beneficial effects for bird species that breed in saltmarsh.						**beneficial to energy cost.**
	Direct loss of areas of Eelgrass	**M5. Translocation of intertidal Eelgrass (49)** Techniques for establishing or restoring eelgrass beds using See Marine Ecology topic paper.	Applies to **B3**, **B4** and **L2**		Impacts unlikely assuming minor changes do not reduce installed capacity or impounded live volume	(RED) The translocation of Eelgrass has been shown to be effective in intertidal estuarine environments within a limited number of studies. However, these studies have shown only limited success of up to 15% effectiveness[1]. Whilst this fall-out rate could be taken into account when designing a translocation programme, it is recognised that there would be physical limitations on the amount of area that is suitable for translocation and it is also not currently considered that the measure is fully enough understood to be recommended as a stand-alone measure.	(AMBER) Method used elsewhere, but not established as a mainstream method. Could however be utilised along side a Topographic Modification measure with further research.	(AMBER) Method used successfully on previous projects in estuarine environments	(GREEN) Would be implemented as integral part of main scheme	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged.	**NO – Insufficient supporting study and likely effectiveness. Although could be considered in detailed design alongside Topographic Modification**
	Direct footprint losses of: key	**M6. Minor Alignment adjustments. (6)** See Marine Ecology topic	Applies to **all** alternative options.		Impacts unlikely assuming minor	(AMBER) It may be possible to avoid specific features	(GREEN) Established	(GREEN) Established	(GREEN) Would be implemented	(GREEN) No major effects	(GREEN) No major effects	**YES – for all alternative options.**

1. Topic	2. Likely significant adverse effect on environment*	3. Measure envisaged to prevent or reduce effect (followed by a cross-reference to the measure number used within earlier iterations of the ODR prevent/reduce costings table, where applicable)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Averse biodiversity effect	12. Adverse effect on society & economy.	13. Included in assessments of residual effects, SEA Objective compliance and option costs?
	Marine Ecology habitat receptors (*Intertidal mudflats and sandflats; Saltmarsh; Shingle and rocky shore; Subtidal sandbanks; Other subtidal habitats; Zostera; Sabellaria*)	paper.			changes do not reduce installed capacity or impounded live volume	within the footprint. However, physical changes would occur in the vicinity of the structures which may limit the effect of direct footprint adjustments.	practice	method widely used in large scale construction projects.	as integral part of main scheme	envisaged; although, it is unlikely to be able to avoid all designated habitats with the option footprint.	envisaged.	**Effective measure and for minimum energy cost**
		M83. Selection of construction materials that would enhance colonisation of new structures. See Marine Ecology topic paper.	Applies to **all** alternative options.		None	(AMBER) Through the use of carefully selected materials, the design would be able to enhance colonisation of native species. However, there may also be an increase in the settlement potential of non-native species.	(GREEN) Established practice and likely to be required as a permit condition.	(GREEN) Established method	(GREEN) Would be implemented as integral part of main scheme	(AMBER) Potential for increase in settlement potential of non-native species.	(GREEN) No major effects envisaged.	**YES – for all alternative options.** **Effective measure with no energy cost**
Waterbirds	Reduction in intertidal area *affecting feeding success of birds*[2]	**M7. Operational management of barrage/lagoon regime** – change water levels to prevent or reduce effect of tidal range reduction (aim to maximise the gap between LWS - HWN): *ebb & flood generation* .(1) See Waterbirds topic paper.	Applies to **B3** and **L2** (currently the only scheme that can already be assumed to be ebb/flood is L3d)		See ME above (M1)	(GREEN) Would substantially reduce effects on tidal range; thereby reducing adverse effects on intertidal mudflats and sandflats by: B3 – 40% less L2 – 70% less Would result in reduced adverse effects upon those birds affected[2].	(RED) No precedent	(AMBER) Modelling has shown measure to be effective	(GREEN) Would be implemented as integral part of main scheme B3 would take an additional 18 months to full generation under Ebb & Flood compared to Ebb only.	(RED) Adverse implications for fish passage	(RED) Averse implications for navigation.	**NO – adverse effects on biodiversity and society & economy receptors**
		M8. Operational	Applies to		See ME	(GREEN)	(RED)	(AMBER)	(GREEN)	(AMBER)	(GREEN)	**YES – for**

1. Topic	2. Likely significant adverse effect on environment*	3. Measure envisaged to **prevent or reduce** effect (followed by a cross-reference to the measure number used within earlier iterations of the ODR prevent/reduce costings table, where applicable)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Averse biodiversity effect	12. Adverse effect on society & economy.	13. Included in assessments of **residual effects**, **SEA Objective compliance** and **option costs**?
		management of barrage/lagoon regime – change water levels to prevent or reduce effect of tidal range reduction: *sluice management, e.g. sluicing after the generation period, combined with early commencement of turbine generation, in ebb only mode* (2) See Waterbirds topic paper.	**B3, B4, B5 & L2** (L3d is ebb/flood)		above (M2)	The use of sluicing after generation, combined with early start of turbine generation, has the potential to reduce intertidal habitat loss for all ebb-only alternative options (based on studies using modern turbines). For B3, this could lead to low water levels being lowered by up to 0.5m, potentially reducing intertidal habitat loss by up to 500ha. This would result in up to 5% reduction of the adverse effect upon affected bird species[2]. The additional sluicing would also be to the benefit of fish.	No precedent	Modelling has shown measure to be effective	Would be implemented as integral part of main scheme	No major effects envisaged, but more detailed modelling needed on effects on fish needed to confirm this	No major effects envisaged	**B3, B4, B5 & L2** Effective measure and only minor impacts on energy cost.
	Reduction in remaining intertidal area and exposure time, affecting bird feeding success[2]	***Increase sluice numbers*** *Potentially effective at reducing high water stand and maximising gap between LWS-HWN (5)*	***Studies have shown that the only option for which this is viable (B4) is not showing any reduction in saltmarsh. As a result this measure is not being taken forward.***									
	Reduction in extent and duration of	**M9. Topographic modification** (Intertidal creation) as a measure to prevent or reduce effects, not a compensation	Applies to **all** alternative options		See ME above (M3)	(AMBER) **Currently it is assumed that between 20% to 45% of the potential**	(RED) Not an established	(AMBER) Engineering methods	(GREEN) Measure considered to be technically	(AMBER) Adverse effects for shallow	(GREEN) No major effects envisage	**YES - for all alternative options.** **Following**

1. Topic	2. Likely significant adverse effect on environment*	3. Measure envisaged to **prevent or reduce effect** (followed by a cross-reference to the measure number used within earlier iterations of the ODR prevent/reduce costings table, where applicable)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Averse biodiversity effect	12. Adverse effect on society & economy.	13. Included in assessments of residual effects, SEA Objective compliance and option costs?
	intertidal area exposure time (for remaining intertidal) leading to loss of bird feeding ground/ time[2].	measure (4) See Waterbirds topic paper and Topographic Modification paper.				**amount of intertidal creation identified would actually be viable for implementation following more detailed feasibility work. Therefore it is currently assumed that the measure would reduce the effect upon intertidal feeding grounds by 20% to 45%** (see also Marine Ecology)	measure to prevent and reduce effects and no precedent on this scale	involved are conventional although not widely applied to meet the outcomes sought here. Scale of deliverable intertidal area and its functionality is uncertain	feasible by 2020, but in need of further development before this time in order to improve confidence in efficacy and achievement of its potential.	subtidal and potential for indirect adverse effects on other habitats through H&G changes	d. Potential minor impacts upon carbon footprint. Also potential minor impacts upon navigation that are assumed to be preventable.	**research and the assumptions explained here (and within M3). It has been assumed that between 20% and 45% of the total potential area would ultimately be implemented. Further modelling would be required at detailed design, but the measure has the potential to replace large areas of replacement habitat.**

1. Topic	2. Likely significant adverse effect on environment*	3. Measure envisaged to prevent or reduce effect (followed by a cross-reference to the measure number used within earlier iterations of the ODR prevent/reduce costings table, where applicable)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Averse biodiversity effect	12. Adverse effect on society & economy.	13. Included in assessments of **residual effects, SEA Objective compliance** and **option costs**?
	Change in Saltmarsh inundation regime or exposure time leading to reduced bird feeding area[3].	***Operational management of barrage/lagoon regime**: <u>Additional sluicing to inundate saltmarsh</u> - Saltmarsh protection through additional sluicing to allow inundation. (5)*	***Studies have shown that the only option for which this is viable (B4) is not showing any reduction in saltmarsh. As a result this measure is not being taken forward.***									
		***Operational management of barrage/lagoon regime** - Saltmarsh protection through topographic modification (4)*	***Topic assessments have shown measure not to be affective for saltmarsh***									
	Creating a physical link between Steep Holm & Flat Holm islands and the mainland. *Which would be detrimental to the breeding Lesser Black Backed Gull, Herring Gull and Cormorant colonies due to it resulting in a land link,*	**M10. Minor alignment adjustments** -*specifically, midway along B3 barrage.* (6) See Waterbirds topic paper.	Applies to **B3** only.		Impacts unlikely assuming minor changes do not reduce installed capacity or impounded live volume	(GREEN) Could limit disturbance of breeding birds on Steep Holm and Flat Holm and fully prevent sediment connecting the islands, thus eliminating the risk of colonisation by rats (which, through predation of eggs and young, can lead to large decline in numbers of breeding seabirds). A rat control programme should also be considered to negate the risk.	(GREEN) Established practice	(GREEN) Established method widely used in large scale construction projects.	(GREEN) Would be implemented as integral part of main scheme	(GREEN) No major effects envisaged; although, it is unlikely to be able to avoid all designated habitats with the option footprint.	(GREEN) No major effects envisaged.	**YES – for B3 only.** **Effective measure with limited energy cost**

1. Topic	2. Likely significant adverse effect on environment*	3. Measure envisaged to prevent or reduce effect (followed by a cross-reference to the measure number used within earlier iterations of the ODR prevent/reduce costings table, where applicable)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Averse biodiversity effect	12. Adverse effect on society & economy.	13. Included in assessments of residual effects, SEA Objective compliance and option costs?
	which would potentially allow vermin access to the colonies.											
	Direct footprint losses of key habitats affecting bird feeding (*eelgrass*)	**M11. Minor Alignment adjustments** Potentially effective for options where land-fall is to eelgrass – which is a rich waterbird feeding habitat. (6) See Waterbirds topic paper.	Applies to **B3**, **B4** & **L2.**		Impacts unlikely assuming minor changes do not reduce installed capacity or impounded live volume	(GREEN) Method would be effective at providing local relatively small-scale reductions in effects on eelgrass feeding areas.	(GREEN) Established practice	(GREEN) Established method widely used in large scale construction projects.	(GREEN) Would be implemented as integral part of main scheme	(GREEN) No major effects envisaged; although, it is unlikely to be able to avoid all designated habitats with the option footprint.	(GREEN) No major effects envisaged.	**YES – for B3, B4 & L2.** **Effective measure with limited energy cost**

1. Topic	2. Likely significant adverse effect on environment*	3. Measure envisaged to prevent or reduce effect (followed by a cross-reference to the measure number used within earlier iterations of the ODR prevent/reduce costings table, where applicable)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Averse biodiversity effect	12. Adverse effect on society & economy.	13. Included in assessments of residual effects, SEA Objective compliance and option costs?
	Disturbance to bird species during construction[4].	**M12. Alter construction timings or methods (7).** See Waterbirds topic paper.	Applies to **all** alternative options.		None	(AMBER) For those receptor species identified[4], this measure could reduce disturbance during particularly sensitive periods. However, complete avoidance of disturbance is unrealistic as SPA species sensitive to disturbance would be present throughout most parts of the year, on passage and during winter. Other protected species would be present throughout the year.	(GREEN) Established practice	(GREEN) Established method widely used in large scale construction projects.	(GREEN) Would be implemented as integral part of main scheme	(GREEN) No major effects envisaged.	(GREEN) No major effects envisaged.	**YES – for all alternative options.** **Effective measure with limited energy cost**
	Reduction in safe roosting areas resulting from saltmarsh loss [5]	**M13. Introduction of new refuges and/or bird roosts within the estuary area.** Note that this is a prevent/reduce measure, rather than a compensation measure, as it is focussed on reducing the effect <u>within</u> the estuary. See Waterbirds topic paper.	Applies to B3 only, as no other alternative options are predicting loss of saltmarsh		None	(GREEN) The scale of the effect itself is thought to be low. However the effectiveness of the measure in reducing the effect is high. Method could reduce the effect for B3 of loss of roosting areas on birds.	(GREEN) Method used elsewhere with some success. For example, roost islands have been created in Cardiff Bay and in Hartlepool.	(AMBER) Method used elsewhere with some success. The scale of the refuge creation required is likely be far larger than previously undertaken	(GREEN) Would be implemented as integral part of main scheme	(GREEN) No major effects envisaged, although consideration would be needed to avoid risking avian predator habitats.	(GREEN) No major effects envisaged.	**YES – for B3 only.** **Effective measure with marginal energy cost**
Migratory &	Fish injury/	**M14. Innovation and advancement in turbine**	Applies to **all**		Unknown	(RED)	(RED)	(RED)	(RED)	(GREEN)	(GREEN)	**NO – insufficient**

1. Topic	2. Likely significant adverse effect on environment*	3. Measure envisaged to prevent or reduce effect (followed by a cross-reference to the measure number used within earlier iterations of the ODR prevent/reduce costings table, where applicable)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Averse biodiversity effect	12. Adverse effect on society & economy.	13. Included in assessments of residual effects, SEA Objective compliance and option costs?
Estuarine Fish	mortality; due to disruption to route of passage through the structure, with consequent life history effects[6]	**design** (in particular the US based hydro-turbine designs) (9) See Migratory and Estuarine Fish Topic paper and supporting annexes.	alternative options.			In the absence of further information regarding the different technology types, discussions with the individual manufacturers and a full feasibility assessment of their application within the Severn Estuary and an STP plan alternative, it is not possible at this time to assess the potential confidence of success from implementing this reduction measure.	Not an established practice within the estuarine environment	Not an established technique within the estuarine environment	Not expected to be ready by 2020. In need of further research post-Feasibility Study (including prototype trialling) prior to the detailed design / EIA stage.	No major effects envisaged.	No major effects envisaged.	**evidence base and not considered achievable by 2020.**
		M15. Operational management of barrage/lagoon regime: *Increasing permeability of barrage/lagoon* (11) Increased permeability by diverting a proportion of the available volume of water through safer passage routes; whether they are sluices, free-wheeling turbines or free gaps. Also ensuring that all operating turbines are at optimum efficiency during periods of generation. **It has been assumed for the purpose of this assessment that the OVERALL permeability of each alternative option could be increased by between 5% and 15% of total**	Applies to **all** alternative options.		Between 5 - 15% flow volume assumed (depending on the relative amounts diverted between M15 and M17). No impact likely if regime is configured to optimise turbine efficiency	(AMBER)[7] Whilst it is clear that this measure would work to reduce effects, the scale of benefit would depend upon the volume of water that could be made available to pass through the safer passage routes, the level of any bio-fouling that may occur, the period of the generation time over which it was implemented and the behaviour of the at risk fish species. This in turn would depend upon the acceptable amount of energy generation that could be lost at the detailed design stage. On the basis of an assumed increase in permeability between 5 and 15% at varied periods	(GREEN) Operational methods to increase permeability - to assist with fish passage during key at risk periods - is considered an established practice for hydropower schemes.	(GREEN) Method can be used on hydropower schemes	(GREEN) Measure does not require further technical development. However, it would require further investigation regarding the behaviour of fish within the estuary. Implementation would be refined further during detailed design/EIA stage.	(AMBER) No major effects envisaged, although sluices, freewheeling turbines and free gaps are known to still have a risk of negative effects on fish	(GREEN) No major effects envisaged.	**YES – for all alternative options.** **Potential reduction in energy cost and reduction of effects. Achievable by 2020 and could be further refined within detailed design.**

1. Topic	2. Likely significant adverse effect on environment*	3. Measure envisaged to prevent or reduce effect (followed by a cross-reference to the measure number used within earlier iterations of the ODR prevent/reduce costings table, where applicable)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Averse biodiversity effect	12. Adverse effect on society & economy.	13. Included in assessments of residual effects, SEA Objective compliance and option costs?
		flow, to be shared between the included fish measures requiring flow diversion (M15 and M17) as required. See Migratory and Estuarine Fish Topic paper and supporting annexes.				during generation it is estimated that this measure could be between 5 and 30% effective.						
		M16. Operational management of barrage/lagoon regime: (10)*Timing of generation / cessation of generation* (seasonally and/or diurnally during peak migration periods) This measure could not be implemented for all species, it may however be possible to prioritise it for specific *at risk* species depending on their residence time within the estuary. Therefore, the measure has been discussed according to its efficacy against each species. It has been assumed for the purpose of this assessment that cessation periods over the course of the year between 5 and 15% would be acceptable. This cessation duration could be spread over the course of the year or clumped to	Applies to **all** alternative options although the efficacy would likely differ between alternatives	**Salmon smolts**	5 - 15% flow volume assumed Effect on energy uncertain but could be 5 – 15% reduction commensurate with flow diversion	(RED) On the assumption of an annual 2.6 to 7.8 week cessation period, distributed across the migration period, the efficacy is estimated to be between 15% and 75%. This measure has not been included – due to lack of confidence in its efficacy.	(GREEN) Is considered for projects for key at risk periods.	(GREEN) Method used elsewhere	(GREEN) Measure does not require further technical development however, it would require further investigation regarding the behaviour of fish within the estuary. Implementation would be refined during detailed design/EIA stage.	(GREEN) No major effects envisaged.	(GREEN) No major effects envisaged.	**NO - This measure has not been included – due to lack of confidence in its efficacy.** **It is a promising measure, but is not ready for application without substantial further investigation.**
				Adult Salmon:	5 - 15% flow volume assumed Effect on energy uncertain but could	(RED) On the assumption of a cessation programme of between a period across the year and concentration for the key migration period the efficacy is considered to	(GREEN) Is considered for projects for key at risk periods.	(GREEN) Method used elsewhere	(GREEN) Measure does not require further technical development however, it would require	(GREEN) No major effects envisaged.	(GREEN) No major effects envisaged.	**NO - This measure has not been included – due to lack of confidence in its**

1. Topic	2. Likely significant adverse effect on environment*	3. Measure envisaged to **prevent or reduce** effect (followed by a cross-reference to the measure number used within earlier iterations of the ODR prevent/reduce costings table, where applicable)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Averse biodiversity effect	12. Adverse effect on society & economy.	13. Included in assessment s of residual effects, SEA Objective compliance and option costs?
		a discrete high risk period. The scale of benefit would depend upon the extent of cessation, the period over which it was implemented and the behaviour of the at risk fish species. Efficacies are for species in isolation and cannot be considered for all species in combination. See Migratory and Estuarine Fish Topic paper and supporting annexes.			be 5 – 15% reduction commensurate with flow diversion	be between 0% and 40%. This measure has not been included – due to lack of confidence in its efficacy.			further investigation regarding the behaviour of fish within the estuary. Implementation would be refined during detailed design/EIA stage.			**efficacy.** **It is a promising measure, but is not ready for application without substantial further investigation.**
				Twaite shad (adult & juvenile)	5 - 15% flow volume assumed Effect on energy uncertain but could be 5 – 15% reduction commensurate with flow diversion	(RED) It is felt unlikely that this measure would be effective for the protection of Twaite shad due to their extended residency within the estuary. This measure has not been included – due to lack of confidence in its efficacy.	(AMBER) Not an established practice in the UK for this species, but the same principles apply as for salmon above.	(GREEN) Method used elsewhere	(GREEN) Measure does not require further technical development however, it would require further investigation regarding the behaviour of fish within the estuary. Implementation would be refined during detailed design/EIA stage.	(GREEN) No major effects envisaged.	(GREEN) No major effects envisaged.	**NO - This measure has not been included – due to lack of confidence in its efficacy.** **It is a promising measure, but is not ready for application without substantial further investigation.**
				Sea lamprey (adult and transformer)	5 - 15% flow volume assumed Effect on energy	(RED) On the assumption of an annual 2.6 to 7.8 week cessation period, distributed across the migration period, the	(AMBER) Not an established practice in the UK for this	(GREEN) Method used elsewhere	(GREEN) Measure does not require further technical development	(GREEN) No major effects envisaged.	(GREEN) No major effects envisaged.	**NO - This measure has not been included – due to lack of**

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					uncertain but could be 5 – 15% reduction commensurate with flow diversion	efficacy is estimated to be between 15% and 75%. This measure has not been included – due to lack of confidence in its efficacy.	species, but the same principles apply as for salmon above.		however, it would require further investigation regarding the behaviour of fish within the estuary. Implementation would be refined during detailed design/EIA stage.			**confidence in its efficacy. It is a promising measure, but is not ready for application without substantial further investigation.**
				River lamprey	5 - 15% flow volume assumed Effect on energy uncertain but could be 5 – 15% reduction commensurate with flow diversion	(RED) The behaviour of river lamprey within the estuarine environment is not well understood. There is suggestion that they may reside within the estuary for the entirety of their lifetime, in which case this measure to prevent and reduce effects would not be effective. However, were they to make a more active migration similar to that assumed above for sea lamprey, the efficacy would be estimated to be between 20% and 65% effective. For the purposes of this assessment a 50:50	(AMBER) Not an established practice in the UK for this species, but the same principles apply as for salmon above.	(GREEN) Method used elsewhere	(GREEN) Measure does not require further technical development however, it would require further investigation regarding the behaviour of fish within the estuary. Implementation would be refined during detailed design/EIA stage.	(GREEN) No major effects envisaged.	(GREEN) No major effects envisaged.	**NO - This measure has not been included – due to lack of confidence in its efficacy. It is a promising measure, but is not ready for application without substantial further investigation.**

1. Topic	2. Likely significant adverse effect on environment*	3. Measure envisaged to **prevent or reduce** effect (followed by a cross-reference to the measure number used within earlier iterations of the ODR prevent/reduce costings table, where applicable)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Averse biodiversity effect	12. Adverse effect on society & economy.	13. Included in assessments of residual effects, SEA Objective compliance and option costs?
						resident:transit ratio has been assumed resulting in an estimated efficacy of between 5% and 35%. This measure has not been included – due to lack of confidence in its efficacy.						
				Elver	5 - 15% flow volume assumed Effect on energy uncertain but could be 5 – 15% reduction commensurate with flow diversion	(RED) For the purposes of this assessment a 50:50 transit/resident ratio has been assumed resulting in an estimated efficacy of between 5% and 35% for yellow eel. This measure has not been included – due to lack of confidence in its efficacy.	(AMBER) Not an established practice in the UK for this life stage, but the same principles apply as for silver eel below.	(GREEN) Method used elsewhere	(GREEN) Measure does not require further technical development however, it would require further investigation regarding the behaviour of fish within the estuary. Implementation would be refined during detailed design/EIA stage.	(GREEN) No major effects envisaged.	(GREEN) No major effects envisaged.	**NO - This measure has not been included – due to lack of confidence in its efficacy.** **It is a promising measure, but is not ready for application without substantial further investigation.**
				Silver eel	5 - 15% flow volume assumed Effect on energy uncertain but could be 5 – 15%	(AMBER) Cessation over the active migration period has been assumed resulting in an estimated efficacy of between 15%and 75%. This measure has not been included – due to lack of confidence in its	(GREEN) Is used on run-of-river hydropower schemes for this species life stage.	(GREEN) Method used elsewhere	(GREEN) Measure does not require further technical development however, it would require further investigation	(GREEN) No major effects envisaged.	(GREEN) No major effects envisaged.	**NO - This measure has not been included – due to lack of confidence in its efficacy.**

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					reduction commensurate with flow diversion	efficacy.			regarding the behaviour of fish within the estuary. Implementation would be refined during detailed design/EIA stage.			**It is a promising measure, but is not ready for application without substantial further investigation.**
				Marine migrants, marine stragglers, estuarine residents and freshwater stragglers	5 - 15% flow volume assumed Effect on energy uncertain but could be 5 – 15% reduction commensurate with flow diversion	(RED) Each of these guilds contains species which reside within the estuary for protracted periods of time. It is therefore considered that this measure would not be effective for marine/estuarine guilds. This measure has not been included – due to lack of confidence in its efficacy.	(RED) No precedent for marine/estuarine fish species.	(GREEN) Method used elsewhere	(GREEN) Measure does not require further technical development. Implementation would be refined during detailed design/EIA stage.	(GREEN) No major effects envisaged.	(GREEN) No major effects envisaged.	**NO - This measure has not been included – due to lack of confidence in its efficacy. It is a promising measure, but is not ready for application without substantial further investigation.**
		M17. Type, size, number and position of sluices (12) Altering the current proposed sluice arrangements/design for alternative options.	Applies to **all** alternative options.		Between 5 - 15% flow volume assumed (depending on the relative	(AMBER) The efficacy of this measure would depend upon the exact implementation at detailed design.	(AMBER) Not regularly used in projects	(AMBER) Limited usage of measure elsewhere	(AMBER) Measure would require further technical development and further investigation	(GREEN) No major effects envisaged.	(GREEN) No major effects envisaged.	**YES – for all alternative options. Measure would be effective,**

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		It has been assumed for the purpose of this assessment that the OVERALL permeability of each alternative option could be increased by between 5% and 15% of total flow, to be shared between the two included fish measures requiring flow diversion (M15 and M17) as required. See Migratory and Estuarine Fish Topic paper and supporting annexes.			amounts diverted between M15 and M17). Effect on energy uncertain but could be 5 – 15% reduction commensurate with flow diversion	For this assessment it has been assumed that they would be implemented with between 5 and 15% of the total flow. This would, assuming designed for all species, in combination, have an estimated efficacy of between 5 and 30% per species. Were they designed for individual species or life stages however, they could afford them a higher efficacy rate. This would however, depend upon detailed design.			regarding the behaviour of fish within the estuary. Would be refined further during detailed design/EIA stage.			**but would also have an impact upon energy cost. Ultimate success of measure would depend upon the detailed design.**
		M18. Inclusion of fish passage management options within or near the barrage/lagoon: **(13a)** *Fish bypasses* (It has been assumed for the purpose of this assessment that between 5 and 15% of the total flow would be diverted to fish passage structures). The term bypass in the context of STP plan alternatives is a conduit for transporting downstream migrating fish past the dam structure. Bypasses up and down stream may be integrated into a number of the designs discussed	Applies to **all** alternative options.		5 - 15% flow volume assumed Effect on energy uncertain but could be 5 – 15% reduction commensurate with flow diversion	(RED) The efficacy of this measure would depend upon the exact implementation at detailed design. For this assessment it has been assumed that fish passageways would be implemented with between 5% and 15% of the total flow. It is estimated that on this basis an efficacy of between 5% and 30% per species could be achieved. Were they designed for individual species or life stages	(GREEN) Routinely used in projects including tidal power	(GREEN) Method used elsewhere	(AMBER) Measure would require further technical development and further investigation regarding the behaviour of fish within the estuary. Would be refined further during detailed design/EIA stage.	(GREEN) No major effects envisaged.	(GREEN) No major effects envisaged.	**NO - This measure has not been included – due to lack of confidence in its efficacy.** **It is a promising measure, but is not ready for application without substantial further investigation.**

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		above, used in isolation or combined with other additional techniques.[8] To be effective within the Severn Estuary, the entrance and exits of a fish pass would need to track the tides. See Migratory and Estuarine Fish Topic paper and supporting annexes.				however, they could afford them a higher efficacy rate. This would however, depend upon detailed design. This measure has not been included – due to lack of confidence in its efficacy.						
		M19. Inclusion of fish passage management options within or near the barrage/lagoon (13b): *inclusion of fish lifts and locks.* A lift or a series of lifts along the structure could be operated to open for fish to enter and exit at suitable water levels. An attraction flow would need to be provided into the lift to be effective. It has been assumed for the purpose of this assessment that between 5 and 15% of the total flow would be diverted to fish passage structures. A fish lock or a series of locks could also potentially be used as a passage mechanism in both landward and	Applies to **all** alternative options.		5 - 15% flow volume assumed Effect on energy uncertain but could be 5 – 15% reduction commensurate with flow diversion	(RED) The efficacy of this measure would depend upon the exact implementation at detailed design. For this assessment it has been assumed that they would be implemented with between 5 and 15% of the total flow. This could have an estimated efficacy of between 5% and 30% per species. If they were designed for individual species or life stages however, they could afford a higher efficacy rate. This would however, depend upon detailed design. This measure has not been included – due to lack of confidence in its efficacy.	(AMBER) Measure has been used in projects and is promising, but not ready for application without substantial further investigation	(AMBER) Method has been used elsewhere	(AMBER) Measure would require further technical development and further investigation regarding the behaviour of fish within the estuary. Would be refined further during detailed design/EIA stage.	(GREEN) No major effects envisaged.	(GREEN) No major effects envisaged.	**NO - This measure has not been included – due to lack of confidence in its efficacy.** **It is a promising measure, but is not ready for application without substantial further investigation.**

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		seaward directions. See Migratory and Estuarine Fish Topic paper and supporting annexes.										
		M20. Fish stock enhancement *within the Severn Estuary catchment* (50a) The placement of fish or fish eggs into a waterbody that has been affected by an STP plan alternative to prevent/reduce effects upon the population status or integrity *(note that fish stocking outside of the Severn Estuary catchment is a potential offsetting measure)* See Migratory and Estuarine Fish Topic paper and supporting annexes.	Applies to **all** alternative options.		None	(AMBER) Although effective as a prevent/reduce measure due to the unprecedented scale in this instance and its dependency on other measures as detailed elsewhere within this table and the fish topic paper to be effective, it is not considered possible at this time to quantify its potential efficacy. With further investigation however, this could be possible.	(GREEN) An established practice for barrage and hydropower schemes	(GREEN) A well established technique for some species in particular salmon	(RED) Not expected to be up and running by 2020. Would be in need of further feasibility assessment post-Feasibility Study.	(RED) Potential biodiversity effects that would need further consideration	(GREEN) No major effects envisaged	**NO – measure not included as a prevent or reduce measure as it is not likely to be achievable by 2020 and there is currently not sufficient confidence in its efficacy**
		M21. Intertidal habitat creation and enhancement to reduce the loss of individual fish and/or intertidal habitats *within the Severn Estuary catchment* (50b) It is considered feasible that habitat creation and enhancement techniques could be used as	Applies to **all** alternative options. Only for marine and estuarine fish guilds.		None	(AMBER) Although it could afford some benefits to migratory species such as shad, eel and river lamprey which are believed to spend a protracted period within the estuarine environment due to current knowledge gaps it has not been recommended as a measure specifically targeted at these species.	(AMBER) Knowledge regarding the use of intertidal habitat in particular by the migratory fish species is largely	(GREEN) A well established technique	(AMBER) This measure could be feasibly implemented within the 2020 timeframe. Is dependent upon determination of the feasibility of other	(RED) Potential biodiversity impacts that would need further consideration	(GREEN) No major effects envisaged	**Yes – for all alternative options; but for marine and estuarine fish guilds only.** **Measure not included for other species due**

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		measures to prevent/reduce the effects of an STP plan alternative by increasing overall fish populations within the key rivers. See Migratory and Estuarine Fish Topic paper and supporting annexes.				It is however recommended for inclusion within the suite of STP prevent/reduce measures for the marine and estuarine fish guilds which could if implemented also offer some benefit to the other species utilising this habitat for limited or protracted periods. It is not considered possible at this time to quantify the potential extent of intertidal habitat enhancement/creation required or indeed the resulting efficacy of the measure. Quantification is predominantly limited by knowledge gaps regarding habitat utilisation, area and density dependent functions.	unknown and requires further study. Although intertidal habitat enhancement/creation is therefore in principle an established practice and technique it does not have precedent for these species.		measures.			**to current knowledge gaps and lack of confidence in its efficacy**
		M81 Addressing factors currently limiting populations of migratory fish within freshwaters; *thereby boosting the overall populations of the fish receptors.* Potential measures include various habitat enhancements (e.g. gravel cleaning and loosening) and creation (addition of boulders/gravel)	Applies to **all** alternative options.		None	(AMBER) Although this measure shows potential for all of the migratory fish species, on the basis of predominantly the issue of potential additionality conflict, this measure has not been included within the suite of STP prevent/reduce measures. It is however, recommended that it be considered within any future STP assessments.	(GREEN) Addressing limiting factors in the freshwater environment are established practices and techniques for all of the	(AMBER) Techniques included within this measure have not previously been undertaken on the scale likely to be required for an	(AMBER) Some elements of this measure could be feasibly implemented within the 2020 timeframe.	(RED) Potentially raises an additionality conflict between current conservation management actions and those proposed for	(GREEN) No major effects envisaged.	**NO -This measure has not been included – due, predominantly, to potential conflict between current conservation management and proposals..**

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		techniques, increasing access to habitat through obstruction removal, and implementation of measures to improve water quality. See Migratory and Estuarine Fish Topic paper and supporting annexes.					migratory fish species and are regularly included within management plans for their protection.	STP plan alternative and opportunities for application may be restricted.		incorporation as SEA prevent/reduce measures.		**However, it is recommended that it be considered further within any future STP assessments.**
		M22. Predator control – *Piscivorous* birds **(51a)** e.g. Using wire or netting along the length of an STP structure and/or the use of deterrent and exclusion systems (including visual and auditory scarers) See Migratory and Estuarine Fish Topic paper and supporting annexes.	Applies to **all** alternative options.		None	(AMBER) Measure predicted to be 10% to 80% effective at reducing fish losses attributed specifically to piscivorous bird predation. Wire has been used successfully in a number of cases to reduce predation by cormorants and other piscivorous bird species; and it is considered that it would likely be most applicable at an STP plan alternative	(GREEN) Has been used on river hydro power schemes	(GREEN) Method and design have been proven successful	(GREEN) Measure does not require further technical development. Would be refined further during detailed design/EIA stage.	(RED) Potential biodiversity impacts that would need further consideration.	(GREEN) No major effects envisaged.	**YES** – for all alternative options. This measure is achievable by 2020 and would be effective. The scale of its practical implementation would be developed alongside detailed design
		M23. Predator control – *Piscivorous* fish **(51b)** See Migratory and Estuarine Fish Topic paper and supporting annexes.	Applies to **all** alternative options.		None	(RED) There are very few effective controls on predatory fish and it is considered that this measure would not be effective within the Severn Estuary	(RED) Measure has no precedent	(RED) Measure has no precedent	(RED) Not expected to be ready by 2020. Would be in need of extensive further research to prove effective.	(RED) Potential biodiversity impacts that would need further consideration.	(GREEN) No major effects envisaged.	**NO – insufficient confidence in effectiveness within the Severn Estuary and not likely to be achievable by 2020**

1. Topic	2. Likely significant adverse effect on environment*	3. Measure envisaged to prevent or reduce effect (followed by a cross-reference to the measure number used within earlier iterations of the ODR prevent/reduce costings table, where applicable)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Averse biodiversity effect	12. Adverse effect on society & economy.	13. Included in assessments of residual effects, SEA Objective compliance and option costs?
		M24. Fish exclusion and diversion: *behavioural deterrents/attractants* (Acoustic and light) **(15)** See Migratory and Estuarine Fish Topic paper and supporting annexes.	Applies to **all** alternative options.		None	(RED) Effectiveness of measures would vary depending on which species the measure was set up to attract/deter. Crucially, there is potential that some species could be attracted to measures that others would be deterred by. Therefore there is currently uncertainty regarding the efficacy of operating this measure within the Severn Estuary	(GREEN) Measure has precedent within an estuarine environment but not the Severn Estuary	(GREEN) Measure is a well recognised technique for run-of-river hydropower schemes and estuarine intakes but has no precedent within the Severn Estuary	(RED) Would be in need of extensive further research to prove effective.	(AMBER) Effects upon biodiversity possible	(GREEN) No major effects envisaged.	**NO – insufficient confidence in effectiveness within the Severn Estuary and not likely to be achievable by 2020**
		M25. Trap & transport of fish (16a) The interception of fish at a given point, transport of fish upstream or downstream from the capture site and the obstacle being circumvented, and release of fish. See Migratory and Estuarine Fish Topic paper and supporting annexes.	Applies to **all** alternative options.		None	(RED) Studies for salmon show that, theoretically possible, for anadromous fish. Confidence in success within the Severn Estuary however, is low due to complication of capture and osmoregulation. For marine fish community it should not be considered further. Therefore this measure is not considered effective in the Severn Estuary without further investigation.	(RED) Measure has no precedent	(RED) Measure has no	(RED) Would be in need of extensive further research to prove effective.	(GREEN) No major effects envisaged.	(GREEN) No major effects envisaged.	**NO – insufficient confidence in effectiveness within the Severn Estuary and not likely to be achievable by 2020**

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		M26. Herding of fish (16b) The spatial manipulation of fish within the aquatic environment by anthropogenic means such that fish are aggregated at a particular point or caused to avoid a certain area. See Migratory and Estuarine Fish Topic paper and supporting annexes.	Applies to **all** alternative options.		None	(RED) Very low confidence. Insufficient certainty to make suggestion at feasibility study stage. Therefore this measure is not considered effective in the Severn Estuary	(RED) Measure has no precedent in an estuarine environment	(RED) Measure has no precedent in an estuarine environment	(RED) Would be in need of extensive further research to prove effective.	(GREEN) No major effects envisaged.	(GREEN) No major effects envisaged.	**NO – insufficient confidence in effectiveness within the Severn Estuary and not likely to be achievable by 2020**
		M27. Pheromone release (14): *manipulation of fish communities* through use of pheromones* - for example by using eel pheromones to attract eels to a bypass structure. See Migratory and Estuarine Fish Topic paper and supporting annexes.	Applies to **all** alternative options.		None	(RED) Further study is needed. Study is underway on sea lamprey in the Great Lakes at the present time and it may be possible to determine confidence for this species soon. As knowledge with regards to the other key species is mostly lacking, the use of pheromones as a practical measure is likely many years from fruition. Therefore this measure is not considered effective in the Severn Estuary	(RED) Measure has no precedent in an estuarine environment	(RED) Measure has no precedent in an estuarine environment	(RED) Not expected to be ready by 2020. Would be in need of extensive further research to prove effective.	(AMBER) It is not thought that targeted pheromone release would impact upon other species, but further research into biodiversity impacts would be needed	(GREEN) No major effects envisaged.	**NO – insufficient confidence in effectiveness within the Severn Estuary and not likely to be achievable by 2020**
		***M80. Topographic modification** (Intertidal creation) as a measure to*	***The discussion of Topographic modification is covered by measure M21 above.***									

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		prevent or reduce effects, not a compensation measure (4)										
	Disturbance/ behavioural effects on fish species	**M28. Industry standard measures to minimise noise & vibration levels during construction and decommissioning* (37a)** ***Note, that insufficient information and an absence of existing available precedents preclude the inclusion of this concept for use during the operation phase.*** See Migratory and Estuarine Fish Topic paper and supporting annexes.	Applies to **all** alternative options.		None	(GREEN) The potential efficacy of this measure depends upon the technique that is adopted and the specific construction activities employed. This level of information would only be finalised at the detailed design/EIA stage. In the absence of this information an accurate assessment of efficacy is not possible. It is considered however that there is potential that these measures could specifically reduce construction noise and vibration effects by between 10 and 90%.	(AMBER) It is considered that there are measures to reduce the effects of noise and vibration generated during construction activities which are established practice within the UK. (for example the use of 'soft start' techniques during construction, which is recommended by Defra as best practice for piling for off-shore wind	(GREEN) Methods used successfully in estuarine and marine environments in the UK	(AMBER) Whilst further investigation would be needed into the application of such measures into the Severn environment, nevertheless it is felt that identified suitable measures could be implemented by 2020.	(GREEN) No major effects envisaged.	(GREEN) No major effects envisaged.	**YES – for all alternative options.** **Whilst it is recognised that further detailed work is required, it is still felt that there are established measures which could be developed for use in the Severn Estuary by 2020.**

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							farms). However, their application within an environment such as the Severn Estuary is largely unprecedented and further investigations are likely to be required regarding the feasibility of their application within this hostile working environment prior to implementation					
		M29. Industry standard measures to minimise and control sediment disruption/displacement and accidental release of pollutants into the aquatic environment during construction and	Applies to **all** alternative options.		None	(AMBER)[9] The efficacy of this measure depends upon the technique employed and the specific construction activity. This level of information would	(GREEN) Established practice measures	(GREEN) Methods used successfully in estuarine and	(GREEN) Measures are largely proven and would require minimal development to implement by	(GREEN) No major effects envisaged.	(GREEN) No major effects envisaged.	**YES – for all alternative options.** **Established practice that would**

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		decommissioning (37b) See Migratory and Estuarine Fish Topic paper and supporting annexes.				only be finalised at detailed design. An estimate in terms of efficacy of prevention of effects related to sediment release, smothering and resultant impacts upon the wider ecology of the estuary, a range of between 30% and 90% is predicted.		marine environments in the UK	2020.			**be achievable by 2020. Level of effectiveness would be largely determined by scale of implementation at detailed design stage.**
Terrestrial & Freshwater Ecology	Direct footprint losses of key terrestrial and freshwater habitats (including protected areas)[10].	**M30. Minor alignment adjustments** – *to landfall points.* Potentially effective for options where land-fall is to FEAI receptor. (6) See Terrestrial & Freshwater Ecology topic paper.	Applies to **all** alternative options.		See ME above (M6)	(AMBER) It may be possible to avoid specific features within the footprint; such as the dry grasslands of Mendip Limestone and Grasslands SAC. However, physical changes would occur in the vicinity of the structures which may limit the effect of direct footprint adjustments.	(GREEN) Established practice	(GREEN) Established method widely used in large scale construction projects.	(GREEN) Would be implemented as integral part of main scheme	(GREEN) No major effects envisaged; although, it is unlikely to be able to avoid all designated habitats with the option footprint.	(GREEN) No major effects envisaged.	**YES – for all alternative options.** **Measure effective and with negligible energy cost implications**
		M31. Adjustments to locations of onshore works *depots/site compounds, etc.* (18) Where feasible, adjust construction plans to locate onshore works away from protected areas.	Applies to **all** alternative options.		None	(GREEN) Measure would be effective where detailed design shows opportunities for adjustments without compromising the scheme.	(GREEN) Established practice	(GREEN) Established method widely used in large scale constructi	(GREEN) Would be implemented as integral part of main scheme	(GREEN) No major effects envisaged; although, it is unlikely to be able	(GREEN) No major effects envisaged.	**YES – for all alternative options.** **Measure effective and with negligible energy cost**

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		See Terrestrial & Freshwater Ecology topic paper.						on projects.		to avoid all designated habitats with the option footprint.		implications
	Disturbance of important terrestrial and freshwater species[11]	**M32. Timing/ methods of site clearance** Altering timing could be very effective to minimise disturbance depending on species at risk. (7) See Terrestrial & Freshwater Ecology topic paper.	Applies to **all** alternative options.		See waterbirds above (M7)	(AMBER) Would be effective at reducing effects on particular species if targeted to avoid their most sensitive periods. However, the most sensitive periods for different species would vary; therefore measure cannot be effective for all receptors (e.g. breeding birds would be most affected by habitat removal in summer, whereas herpetiles would be most affected in winter.	(GREEN) Established practice	(GREEN) Established method widely used in construction projects.	(GREEN) Would be implemented as integral part of main scheme	(GREEN) No major effects envisaged - although important to consider that different species would be affected at different times.	(GREEN) No major effects envisaged.	**YES – for all alternative options.** **Measure effective and with negligible energy cost implications**
	Detrimental effects on important habitat or species receptors due to altered freshwater and seawater levels	**M33a. Freshwater and seawater level management (55)** – *Targeted pumping to manage water levels* See Terrestrial & Freshwater Ecology topic paper and related also Freshwater Environment and Associated Interfaces topic paper and Flood Risk and Land Drainage topic paper.	Applies to B3, B4, L2 & L3d		None	(AMBER) Would need careful and localised consideration of timing and extent of the measure. Increased soil moisture would be beneficial to some species over the lifetime of the project.	(GREEN) Established practice	(GREEN) Established method and known to be effective. Currently used on areas of the Somerset levels.	(GREEN) Would be implemented as integral part of main scheme. The precise pumping regime would require further optimisation following the feasibility study.	(GREEN) No major effects envisaged - although different habitats and species would be affected in different ways by altered	(GREEN) No major effects envisaged.	**YES – for** B3, B4, L2 & L3d. **Measure effective and with negligible energy cost implications**

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										water levels (for example, there may be impacts upon fish species).		
		M33b. Freshwater and seawater level management (55) – *changing low water level through operation of sluices* See Terrestrial & Freshwater Ecology topic paper.	Applies to B3, B4, L2 & L3d		None	(RED) Changing low water level of alternative option through sluices is likely to prevent and reduce negative significant effects to the receptors however it is also likely to be less focused than a pumping regime and as a result the positive effects would be unlikely to be realised, thereby resulting in likely negligible effects for those receptors where positive effects were predicted.	(RED) No precedent	(AMBER) Modelling has shown measure to be effective.	(GREEN) Would be implemented as integral part of main scheme.	(AMBER) No major effects envisaged, but more detailed modelling needed on effects on fish needed to confirm this.	(GREEN) No major effects envisaged	**No. Although the measure has potential for further consideration, it is currently assumed that it would not be needed with measure M33a in place.**
		M33c. Freshwater and seawater level management (55) – *creation of attenuation areas to store water* See Terrestrial & Freshwater Ecology topic paper.	Applies to B3, B4, B5 & L2 (although less suitable for B3 than others)		None	(RED) Creation of attenuation areas could potentially be developed in conjunction with other measures. However such measures would not be appropriate for all alternative options due to the geographic scale of the potential effects particularly in the case of alternative option B3 where a large number of attenuation areas might	(AMBER) Methods used elsewhere	(GREEN) Established method and known to be effective.	(GREEN) Would be implemented as integral part of main scheme.	(AMBER) Attenuation would require additional land take that could have existing ecological value (or other environmental	(GREEN) No major effects envisaged	**No. Although the measure has potential for further consideration, it is currently assumed that it would not be needed with**

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						be required. Attenuation areas would also be likely to need pumping provision to manage the process effectively and would require additional land take.				interest) in its current state. However, measure also has the potential to provide valuable habitats in their own right.		**measure M33a in place.**
Navigation	Risk to navigational safety during construction and decommissioning	**M34. Coordination and phasing of construction/decommissioning activities and traffic** See Navigation topic paper.	Applies to **all** alternative options		None	(GREEN) Measure necessary to limit disruption, but unlikely to fully prevent effect	(GREEN) Established practice	(GREEN) Established method and known to be effective	(GREEN) Would be implemented as integral part of main scheme.	(GREEN) No major effects envisaged.	(GREEN) No major effects envisaged.	**YES – for all alternative options.** **Measure effective and with no energy cost implications**
	Increased transit time through lock structures	**M35. Improved logistics to manage the arrival and transit of vessels through locks** – to reduce potential queuing and to ensure that the additional time required to navigate the locks is taken into consideration when determining windows of opportunity and scheduling (23) See Navigation topic paper.	Applies to **B3, B4, B5 & L3d**		None	(GREEN) Measure necessary to limit disruption, but unlikely to fully prevent effect	(GREEN) Established practice	(GREEN) Established method and known to be effective.	(GREEN) Would be implemented as integral part of main scheme.	(GREEN) No major effects envisaged.	(GREEN) No major effects envisaged.	**YES – for B3, B4, B5 & L3d Measure effective and with negligible energy cost implications**
	Disruption to	**M36. Raise awareness through demarcation of**	Applies to **all**		None	(GREEN)	(GREEN)	(GREEN)	(GREEN)	(GREEN)	(GREEN)	**YES – for all**

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	commercial navigation due to increase in peak water velocities at structure	**high risk areas** See Navigation topic paper.	alternative options			Measure necessary to limit disruption, but unlikely to fully prevent effect	Established practice	Established method and known to be effective.	Would be implemented as integral part of main scheme.	No major effects envisaged.	No major effects envisaged.	**alternative options.** **Measure effective and with no energy cost implications**
		M37. Relocation of locks for B4 & B5 *changing lock positions to align with the proposed temporary navigation channels to the west of the B4 & B5 barrages* In order to reduce the effect on navigation transiting to and from Sharpness Dock of the potential high water velocities near to sluice and turbine blocks and lock structure. The temporary navigation channels (already proposed as part of Option Definition) would also need to be maintained throughout the operation of the barrage (19) See Navigation topic paper and ODR.	Applies to **B4 & B5** only		None	(AMBER) Measure would partially reduce the effects of increased water velocities to navigation, but would not fully prevent the effect.	(GREEN) Consideration of lock position is a conventional approach	(AMBER) Measure based on modelling study	(GREEN) Would be implemented as integral part of main scheme.	(GREEN) No major effects envisaged.	(GREEN) No major effects envisaged.	**YES – for B4 & B5.** **Measure effective and with negligible energy cost implications**
	Sediment increase leading to obstruction of	***Training walls** - Primarily to reduce effects of increases in water velocity but possibly also to keep channels clear of*	***Removed from consideration following further study, as not considered to be needed.***									

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	navigation channels	*sediment and reduce dredging (20)*										
	Obstruction to navigation due to short term sediment deposition immediately post construction in shallow navigation channels	**M38. Dredging of approach channels to affected ports for each alternative option** *(21)* Affected ports (and dredging amount): **B3**: Bristol (<0.4m); Cardiff and Newport (<0.5m) **B4**: Bristol (<0.4m) **L3d**: Bridgwater (<2m) See Navigation topic paper.	Applies to **B3, B4** and **L3d**			(GREEN) Effective at preventing obstructions to navigation	(GREEN) Established practice	(GREEN) Established method and known to be effective.	(GREEN) Would be implemented as integral part of main scheme	(AMBER) Potential adverse effects on benthic species and aquatic ecology.	(GREEN) No major effects envisaged.	**YES – for B3, B4 & L3d.** **Measure effective and would be required to retain operations at ports**
	Obstruction to navigation due to long term sediment accretion in shallow navigation channels up to 2140	**M39. Dredging to maintain navigation and approach channels affected by each alternative option to maintain navigation** *(21)* Total annual maintenance dredging requirement during operation: **B3**: 2.0 Mm3/yr **B4**: 1.75 Mm3/yr **B5**: 1.0Mm3/yr **L2**: none **L3d**: 0.06Mm3/yr See Options Definition Report[12]	Applies to **all** alternative options.		None	(GREEN) Effective at preventing obstructions to navigation	(GREEN) Established practice	(GREEN) Established method and known to be effective.	(GREEN) Would be implemented as integral part of main scheme	(AMBER) Potential adverse effects on benthic and aquatic species.	(GREEN) No major effects envisaged.	**YES – for all alternative options.** **Measure effective, but would have a negative effect on energy cost (especially for B4 & B5). Further confirmation on this would be provided within the ODR v3.**
	Obstruction /	**M40. Dredging of the new channel**	Applies to B3 only			(GREEN)	(GREEN)	(GREEN)	(GREEN)	(AMBER)	(GREEN)	**YES –forB3 only.**

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	disruption to navigation of deep draught vessels through the proposed deep water navigation channel from Lavernock Point	To a minimum depth of 16m below OD (approx 10m below CD) *(21)*				Effective at preventing obstructions to navigation	Established practice	Established method and known to be effective.	Would be implemented as integral part of main scheme	Potential adverse effects on benthic and aquatic species.	No major effects envisaged.	**Measure effective and would be required to retain operations at ports. Further confirmation on the energy cost impact would be provided within the ODR v3.**
	Reduced navigable depth to ports[13] due to reduced high tide levels	**M41. Alterations of port infrastructure** (22)**:** The following alterations would be needed: **B3:** Reduce sill levels by 0.75m at Bristol Port and Sharpness Dock and reduce sill level by 0.5m at Newport Port; Dredge sections of shallow navigation channel <0.5m to Sharpness Dock and dredge approach channel by further 0.75m to Bridgwater Port **B5**: Reduce sill level by 0.5m at Sharpness Dock and dredge sections of shallow navigation channel <0.5m to Sharpness Dock; **L3d**: Reduce sill level by 0.25 at ports of Bristol, Cardiff, Newport and	Applies to **B3, B5** and **L3d**		None	(GREEN) Effective at preventing obstructions to ports.	(GREEN) Established practice	(GREEN) Established method and known to be effective.	(GREEN) Would be implemented as integral part of main scheme	(AMBER) Potential adverse effects on benthic and aquatic species.	(GREEN) No major effects envisaged.	**Yes – for B3, B5 & L3d.** **Measure effective and would be required to retain operations at ports.**

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		Sharpness; Dredge sections of shallow navigation channel <0.5m to Sharpness Dock and dredge navigation channel by further 0.75m to Bridgwater Port. See Navigation topic paper.										
Marine Water Quality	Reduced estuary water exchange leading to adverse changes in MWQ receptors [14]	**M42. Increasing water exchange through the structure** (such as additional sluice operation). (5) See Marine Water Quality topic paper and Options Definition Report (ODR).	Applies to **all** alternative options.		See ME above (5)	(AMBER) Would provide reduction of effect on marine water quality, but given the relatively few significant MWQ effects it is not felt that such measures would justify the cost of their inclusion.	(RED) No precedent	(AMBER) Would possibly provide improvements for MWQ, but not thought to be justified given the scale of effect.	(GREEN) Could be implemented as integral part of main scheme	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**NO – measure not shown to be required.**
	Localised warming of the waters around the L3d lagoon (in an area that is currently abstracted for use as cooling water for the Hinkley Point B	**M43. Reconfiguration of intakes at Hinkley Point B (24a** To reduce the effect on abstracted cooling waters from localised warming of waters around the impoundment[15]. It may also be necessary to consider any ongoing cooling requirements for Hinkley Point A which is being decommissioned. Hinkley Point C is being considered within the	Applies to **L3d** only.		None	(GREEN) Measure would be effective	(GREEN) Established practice	(GREEN) Established method and known to be effective.	(GREEN) Could be implemented as integral part of main scheme	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**YES – for L3d only. Measure would be effective and achievable by 2020.**

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	Nuclear Reactor)	assessment of cumulative effects See Marine Water Quality topic paper.										
	Reduced dilution of discharge waters from the Hinkley Point B Nuclear Reactor[16]	**M44. Reconfiguration of outfalls at Hinkley Point B (24b)** To prevent the trapping of discharge waters within the impoundment (which would reduce the necessary dilution which currently occurs across the estuary). See Marine Water Quality topic paper.	Applies to L3d only.		None	(GREEN) Measure would be effective	(GREEN) Established practice	(GREEN) Established method and known to be effective.	(GREEN) Could be implemented as integral part of main scheme	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**YES – for L3d only.** **Measure would be effective and achievable by 2020.**
	Reduced marine water quality at Weston beach due to the effect of the L3d lagoon on pathogen plumes from Weston WwTW	**M45. Improved treatment at Weston Wastewater Treatment Works (WwTW) (48)** To prevent / reduce the effect of the potential redirection of pathogen plume towards Weston Beach. See Marine Water Quality topic paper.	Applies to L3d only.		None	(AMBER) Measure would be effective, but it is not currently possible to define the scale of the effect. Further more detailed modelling is required to define the nature of the additional treatment that would be required. However, as the results are showing that *an* effect would be felt, the measure is still recommended for adoption.	(GREEN) Established practice of wastewater treatment	(GREEN) Established method and known to be effective.	(GREEN) Could be implemented as integral part of main scheme	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**YES – for L3d only.** **Measure would be effective and achievable by 2020.**
	Risk of eutrophication within the estuary	**M46. Controls on diffuse sources of nitrogen within the Severn catchment (53)**	Applies to **all** alternative options.		None	(AMBER) Measure has the potential to be effective, but its dependence on changes	(RED) No precedent for use as	(AMBER) The component	(RED) The scale and coordination of measures	(GREEN) No major effects envisage	(GREEN) No major effects envisage	**NO – measure not achievable by 2020 and**

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	upstream of alternative option as a result of increases in light penetration in response to the reduction in suspended sediment concentrations.	For example, an additional level of treatment for municipal wastewater or extended NVZ controls. See Marine Water Quality topic paper.				to practices over which the project does not have control and the associated timescales these measures would take to implement make confidence in the implementation and effectiveness of this measure low. Likely to provide benefits to terrestrial freshwater, groundwater and soils	a measure to prevent or reduce effects of a project	principles being proposed are all established methods, but their combined use as a prevent or reduce measure is not an established approach.	required is not achievable within the 2020 timeframe.	d	d	**low confidence in effectiveness**
Resources & Waste	*Depletion of existing local aggregate extraction sites.*	***Location of material sources*** *(measures to minimise effects on local aggregate extraction sites) (25)*	***Measure not applicable, as it is not suitable to minimise effects on local sources of aggregate over other sources. Associated increase in transport costs and carbon footprint.***									
	Depletion of primary and secondary material resources.	**M47. Inclusion of re-used/recycled primary and secondary construction materials within an STP design (61)** - *including re-usable materials from STP dredging requirements* See Resources & Waste topic paper.	Applies to **all** alternative options.		None	(GREEN) Measure would be effective. The scale of opportunities for re-use/recycling would need to be development with input from the engineering team during the detailed design.	(GREEN) Established practice	(GREEN) Established method and known to be effective.	(GREEN) Could be implemented as integral part of main scheme	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**YES – for alternative options.** **Measure would be effective and would have no effect on energy cost.**
	Large volumes of spoil arisings requiring	**M48. Construction measures - *to minimise spoil generated* (26)** - *for example, by applying the waste hierarchy - of*	Applies to **all** alternative options.		None	(GREEN) Measure would be effective. The scale of opportunities for re-	(GREEN) Established practice	(GREEN) Established method	(GREEN) Could be implemented as integral part	(GREEN) No major effects envisage	(GREEN) No major effects envisage	**YES – for alternative options.** **Measure**

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	disposal.	*reduce, reuse, recycle, recovery, with landfill as the last resort – when considering the spoil arisings from the construction of an STP structure during the detailed design stage.* See Resources & Waste topic paper.				use/recycling of spoil arisings from an STP site would depend upon the opportunities available at the time (e.g. other local construction projects requiring spoil).		and known to be effective.	of main scheme	d	d	**would be effective and would have no effect on energy cost.**
	Increased peak demands on resources	**M82. Liaise with suppliers such as water companies, steel suppliers and aggregates bodies to secure supply.** See Resources & Waste topic paper.	Applies to **all** alternative options.		None	(GREEN) Measure would be effective in allowing resource planning for suppliers	(GREEN) Established practice	(GREEN) Established method and known to be effective.	(GREEN) Could be implemented as integral part of main scheme	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**YES – for alternative options.** **Measure would be effective and would have no effect on energy cost**
Flood Risk & Land Drainage	Changes to tidal regime leading to tide-lock and upstream flood risk to receptors [17]	**M49. Use of pumping stations at tidal outfalls, to lift water to discharge at similar stages of the tide as in the existing case (27)** To allow land drainage discharges that would otherwise have been prevented from the reduced tidal range See Flood Risk & Land Drainage topic paper.	Applies to **all** alternative options.		Reduction in net energy due to pumping energy requirements (to be confirmed)	(GREEN) High certainty of effectiveness. However, there would remain risks associated with failure as with all pumping systems (such as the risk of blockage, failure and overloading) which would need to be considered and mitigated.	(GREEN) Established practice	(GREEN) Established method and known to be effective.	(GREEN) Could be implemented as integral part of main scheme.	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**YES – for alternative options.** **Measure would be effective and would have no effect on energy cost.**
		M50. Outfall changes (such as enlargement or duplication). (28)	Applies to **all** alternative		None	Measure only for further consideration post feasibility study, if	(GREEN) Establish	(GREEN) Establish	(GREEN) Could be	(GREEN) No major	(GREEN) No major	**NO – measure only needs**

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		To maintain drainage capacity in a post-barrage/lagoon estuary and the associated altered water levels See Flood Risk & Land Drainage topic paper.	options.			measure M49 proves not sufficient or if it is decided at detailed design that it could substantially reduce cost	ed practice	ed method and known to be effective.	implemented as integral part of main scheme.	effects envisaged	effects envisaged	to be considered further if it is decided not to fully pursue measure M49, or pumping is shown to be insufficient on its own.
		M51. Improve fluvial flood defences (29) To prevent/reduce the effects of altered water levels See Flood Risk & Land Drainage topic paper.	Applies to **all** alternative options.		None	Measure only for further consideration post feasibility study, if measure M49 proves not sufficient or if it is decided at detailed design that it could substantially reduce cost	(GREEN) Established practice	(GREEN) Established method and known to be effective.	(GREEN) Could be implemented as integral part of main scheme.	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	NO – measure only needs to be considered further if it is decided not to fully pursue measure M49, or pumping is shown to be insufficient on its own.
		M52. Provide increased fluvial storage within flood plains (30) See Flood Risk & Land Drainage topic paper.	Applies to **all** alternative options.		None	Measure only for further consideration post feasibility study, if measure M49 proves not sufficient or if it is decided at detailed design that it could substantially reduce cost	(AMBER) Not a novel technique, but not usually applied on this scale	(GREEN) Established method and known to be effective.	(GREEN) Could be implemented as integral part of main scheme.	(AMBER) No major effects envisaged, although may have an impact upon species/habitats dependin	(GREEN) No major effects envisaged	NO – measure only needs to be considered further if it is decided not to fully pursue measure M49, or pumping is shown to

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										g on location.		be insufficient on its own.
	Obstruction of land drainage channels and/or outfalls	**M53. Provision of a flood relief channel for the River Axe (31)** (for drainage purposes) so that flood drainage discharges to the south, rather than the north (and inside the impoundment), of Brean Down. There are no other outfalls close to a structure, where fluvial flows would need to be diverted to discharge outside of an impoundment. See Flood Risk & Land Drainage topic paper.	Applies to **B3** only.		None	(GREEN) Measure would be effective.	(GREEN) Established practice	(GREEN) Established method and known to be effective.	(GREEN) Could be implemented as integral part of main scheme.	(AMBER) No major effects envisaged, but potential minor effects on terrestrial and freshwater habitats and species that would need to be considered in detailed design.	(GREEN) No major effects envisaged	**YES – for B3 only.** **Measure would be effective, but would increase the cost of energy.**
	Flooding of receptors in the tidal floodplain at locations where post-barrage peak tide levels would be raised	**M54. Improvements to tidal or sea defences (32)** To reduce effects of raised water levels on peak tides for locations in the estuary and for far field effects. See Flood Risk & Land Drainage topic paper.	Applies to **B3, B4, B5 & L2** only. .		None	(GREEN) Measures would fully prevent the effect of forecast increases in peak levels for all schemes. The length of defence raising would	(GREEN) Established practice.	(GREEN) Established method and known to be effective.	(AMBER) Could be implemented as integral part of main scheme, but would require extensive and time consuming work in its own right to implement	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**YES – for B3, B4 B5 & L2.** **Measure would be effective, but would increase the cost of energy.**

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	Flooding of receptors in the tidal floodplain at locations where post-barrage peak tide levels would be raised	**M55. Ongoing works for dredging and sedimentation management of watercourses to reduce flood risk from blocked outfalls (33).** This measure reflects the need to have an ongoing programme of dredging and sedimentation management around outfalls in order to prevent them being blocked and resulting in flooding inland. See Flood Risk & Land Drainage topic paper.	Applies to **all** alternative options.		None	Measure only for further consideration post feasibility study, if measure 49 proves not sufficient or if it is decided at detailed design that it could substantially reduce cost	(GREEN) Established practice	(GREEN) Established method and known to be effective.	(GREEN) Could be implemented as integral part of main scheme.	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**NO – measure only needs to be considered further if it is decided not to fully pursue measure M49, or pumping is shown to be insufficient on its own.**
	Increased risk of flooding arising from degradation of existing tidal flood defences through erosion resulting from changes to the tidal regime.	**M56. Erosion (and siltation) protection measures (34)** Such as large-scale revetment systems in front of tidal defences. See Flood Risk & Land Drainage topic paper.	Applies to **all** alternative options.		None	(GREEN) Whilst revetment is a proven solution and is suitable for costing purposes at this stage, more sustainable solutions could be designed and adopted at project level. It should be noted that the potential for topographic modification measures to provide erosion protection for flood defences cannot be assumed. Sites for topographic modification would be chosen with, amongst other things, tendency for accretion in mind.	(GREEN) Established practice	(GREEN) Established method and known to be effective.	(GREEN) Measure would only be implemented when required over the 140yr operational period.	(AMBER) Potential impacts upon marine ecology, waterbirds, migratory and estuarine fish	(AMBER) Potential impacts upon users of the sea-shore	**YES – for all alternative options.** **Measure would be effective, but would increase the cost of energy.**
		M57. Monitoring of flood	Applies to		Negligible	(GREEN)	(GREEN)	(GREEN)	(GREEN)	(GREEN)	(GREEN)	**YES – for**

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		defences (36) See Flood Risk & Land Drainage topic paper.	**all** alternative options.		effect on energy	Effective at monitoring and reducing indirect effects not directly preventing the flooding	Established practice	Established method and known to be effective.	Could be implemented as integral part of main scheme.	No major effects envisaged	No major effects envisaged	**B3, B4 B5 & L2.** **Measure would be effective and would have a negligible effect on the cost of energy.**
	Flooding of receptors in the tidal or fluvial floodplain	**M58. Changes to operating regime** (35) To reduce tidal or fluvial flood risks in areas where changes to the operating regime could reduce flood risk. See Flood Risk & Land Drainage topic paper.	Applies to **all** alternative options.		Loss of generation on extreme event surge tides unlikely to effect energy yield.	**(RED)** **Measure is not specifically focussed on the STP project, rather it is focussed on reducing flood risk per se. Therefore not included any further.**	(GREEN) Established practice	(GREEN) Established method and known to be effective.	(GREEN) Could be implemented as integral part of main scheme.	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**NO - Measure is not specifically focussed on the STP project, rather it is focussed on reducing flood risk per se.**
Noise & Vibration	Disturbance to people and species receptors [18]	**M59. Measures to minimise noise & vibration levels during construction, operation and decommissioning** (37a & 37b) Measures would be incorporated into a Construction Environmental Management Plan (CEMP) See Noise & Vibration topic paper.	Applies to **all** alternative options.		Negligible assumed	(AMBER) Effective at reducing construction stage noise and vibration effects. Would not prevent all effects.	(GREEN) Established practice to utilise noise minimisation measures within construction projects.	(GREEN) Includes use of established methods which are known to be effective.	(GREEN) Would be developed within CEMP and implemented as integral part of main scheme.	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**YES – for all alternative options.** **Measure would be effective and would have a negligible effect on the cost of energy.**
Commu	Adverse	**M60. Measures to**	Applies to		None	(AMBER)	(GREEN)	(GREEN)	(GREEN)	(GREEN)	(GREEN)	**YES – for**

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nities	effects on local community arising from inward migration of labour (e.g. increasing stress on local services)	**encourage maximum recruitment of local labour (38).** See Communities topic paper.	**all** alternative options.			Effective at reducing effects of incoming labour, but would not prevent need for non-local labour	Established practice within construction projects	Includes use of established methods which are known to be effective.	Would be developed and implemented as integral part of main scheme.	No major effects envisaged	No major effects envisaged	**all alternative options.** **Measure would be effective and would have a negligible effect on the cost of energy.**
	Prevent/ reduce negative socio-economic issues	***Time project construction period to avoid other large construction projects** being undertaken at the same time in the same area (to avoid drain on local resources, traffic etc) (39)*	***Measure removed following prevent/reduce workshop as expert panel considered it non-tenable***									
	Disruption to local communities due to increased traffic - due to HGV and other site traffic on local road networks.	**M61. Reducing the number of vehicles on local roads through rationalising deliveries and use of larger vehicles.** See Communities topic paper.	Applies to **all** alternative options.		Negligible assumed	(AMBER) Effective at reducing effects on local traffic, but would not prevent all effects	(GREEN) Established practice within construction projects	(GREEN) Includes use of established methods which are known to be effective.	(GREEN) Would be developed within CEMP and implemented as integral part of main scheme.	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**YES – for all alternative options.** **Measure would be effective and would have a negligible effect on the cost of energy.**
		M62. Delivery of construction materials by alternative routes (e.g. rail or sea) and maximising the use of existing	Currently assumed to apply to **B3 and L3d** only, but further		None	(AMBER) Would need further consideration of logistical arrangements. Assumed that materials	(GREEN) Established practice within	(GREEN) Includes use of established	(GREEN) Would be developed within CEMP and	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**YES –** currently assumed to apply to **B3 and L3d** only, but

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		temporary/permanent works arrangements (52) It is already planned to bring in embankment/rock fill material by rail to a railhead for transfer to ship for delivery to site. It is proposed that this approach could be extended to include other construction materials that would otherwise be brought by road. As part of this measure it is proposed that the small shipping lock for B3 and the lock in L3d are utilised as a temporary dock for offloading materials for construction. The structure itself would be used as a haul road. See Communities topic paper.	consideration should also be given to L2, B4 & B5.			can be transported to port via existing rail or road connections to hub for transporting to materials handling facility associated with the scheme.	construction projects	methods which are known to be effective.	implemented as integral part of main scheme.			further consideration should also be given to L2, B4 & B5. **Measure would be effective and would have a negligible effect on the cost of energy.**
	Employment losses within the ports sector.	**M79. Measures (to be defined) targeted at altering the perception that the construction phase would restrict navigation to the estuary's ports.** **It is likely that, as a minimum, stakeholder engagement with shipping companies and the port operators would be required.**	Applies to **all** alternative options.		None assumed	(GREEN) It is assumed that this measure would be effective	(GREEN) Established practice within construction projects	(GREEN) Includes use of established methods	(GREEN) Would be developed within the detailed design phase and implemented as integral part of main scheme.	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**Yes – included for all options as it is the perception that is the issue, not actual physical impacts.**

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Hydraulics & Geomorphology	Adverse effects arising from water flows and levels associated with wave reflection off STP structure[19].	**M63. Alteration of structure design to moderate reflective (wave) properties** (40) Potentially requires the roughening or perforation of parts of the structures. See H&G topic paper.	Applies to **all** alternative options.		None assumed	(AMBER) Measure not currently required as any increase in wave energy arising from reflective waves off an STP structure have been taken into account in modelling. The proposed measures to prevent/reduce effects of changes to flood risk have therefore already been designed to account for any reflective wave effects	(AMBER) Utilises methods that have been used within other construction projects	(GREEN) Includes use of established methods	(AMBER) It is not currently considered that this measure is required. However, if during detailed design reflective waves prove to be a more significant issue, then this measure would be revisited.	(AMBER) This measure would need further detailed design before implementation and has the potential for effecting biodiversity receptors sensitive to wave energy.	(GREEN) No major effects envisaged	**NO – measure not currently shown to be required and all reflective wave effects are accounted for in measures. However, this may need to be reviewed at the detailed design stage.**
Freshwater Environment & Associated Interfaces	*Degradation of sea defences due to altered groundwater levels - leading to saturation and reduced stability of banks.*	***Measures to preserve stability of sea defences:*** *Improving drainage on the landward side of sea-defences (41)*	**This effect is covered by the FRLD topic measures, although in detailed design it may be required to adjust measures to further take into account FEAI receptors.**									
		Measures to preserve stability of sea defences: *Relaxing slopes on the landward side of sea-defences (41)*	***This effect is covered by the FRLD topic measures, although in detailed design it may be required to adjust measures to further take into account FEAI receptors.***									
	Loss of safe access to geological and geomorph	**M64. Alternative access points to Otter Hole geological SSSI site (54)** See Freshwater Environment and	Applies to **B3** and **B4** only.		None	(AMBER) Alternative access points to existing SSSIs can only safely be provided for the Otter Hole cave system	(GREEN) Established practice	(GREEN) Includes use of established	(GREEN) Could be implemented as integral part of main	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**YES – for B3 & B4.** **Measure would be effective**

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	ological SSSI sites due to submergence	Associated Interfaces topic paper.				which would be affected by B3 & B4. Alternative access to other affected SSSIs could not be safely achieved. Possible that offsetting measures could include provision of improved access to other GCR sites not yet designated as SSSIs, however.		methods	scheme.			**and would have a negligible effect on the cost of energy.**
	Reduced quality and diversity of soil resource due to water-logging	**M65. Increased drainage through provision of measures extra to those outlined for FRLD (55)** (e.g. through additional pumping – see FRLD) and in water-dependant sites of nature conservation interest. See Freshwater Environment and Associated Interfaces topic paper.	Applies to **all** alternative options.		None	(AMBER) Would need careful consideration of timing of the measure. Overall, the greater soil moisture is likely to become increasingly advantageous throughout the operational life of an alternative option in order to compensate for the effects of climate change, so the amount of additional drainage would likely need to be adjusted over the operational phase.	(GREEN) Established practice	(GREEN) Includes use of established methods	(GREEN) Could be implemented as integral part of main scheme.	(AMBER) Potential effects on terrestrial biodiversity (could be beneficial or detrimental)	(GREEN) No major effects envisaged	**YES – for all alternative options.** **Measure would be effective and would have a negligible effect on the cost of energy.**
	Reduction in capacity of subterranean infrastructure and increased dampness in basements due to	**M66. Increased drainage through provision of measures additional to those outlined for FRLD** (see measures M49 – M58) (e.g. through additional pumping to reduce water tables in urban areas, particularly those adjacent to the coastal fringe) (55) . See Freshwater	All alternative options with possible exception of B5		None	(AMBER) Would need careful planning. May not be successful in removing all effects	(GREEN) Established practice	(GREEN) Includes use of established methods	(GREEN) Would need to be implemented as integral part of main scheme.	(GREEN) No major effects envisaged	(AMBER) Potential significant effects due to disruption in urban areas during (detrimental)	**YES – for all alternative options (although may not be applicable to B5 upon detailed design).** **Measure would be**

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	raised water tables	Environment and Associated Interfaces topic paper.										**effective and would have a negligible effect on the cost of energy.**
Historic Environment	Detrimental affects to historic environment receptors [20]	**M67. Measures to prevent effects on the historic environment resource *(in situ)* (42)** avoidance of effect through minor alignment adjustments and subsequent preservation in situ. (4) See Historic Environment topic paper.	Applies to **all** alternative options..		None	(GREEN) Established practice	(GREEN) Established practice	(GREEN) Includes use of established methods	(GREEN) Could be implemented as integral part of main scheme	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**YES – for all alternative options.** **Measure would be effective and would have a negligible effect on the cost of energy.**
		M68. Measures to reduce effects on the historic environment resource *(by record)* (43) Such as, full archaeological excavation (terrestrial and subtidal); detailed buildings recording; landscape survey; or long-term programmes of recording such as regular foreshore/intertidal monitoring programmes; monument / building condition surveys, etc. See Historic Environment topic paper	Applies to **all** alternative options.		None	(GREEN) Anticipated to be fully effective if considered justified.	(GREEN) Established practice	(GREEN) Includes use of established methods	(GREEN) Could be implemented as integral part of main scheme	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**YES – for all alternative options.** **Measure would be effective and would have a no effect on the cost of energy.**

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		HE										
	Direct footprint losses of key Historic Environment receptors 20	***Minor Alignment adjustments** – to landfall points that directly impinge upon a Historic Environment resource, e.g. Brean Down. (6)*	***Removed due to duplication with other alignment adjustment measures.***									
Landscape and Seascape	Detrimental affects on the landscape and seascape resulting from the physical presence of a barrage / lagoon[21].	***Minimising height and visual effect of proposed structures, including infrastructure and roads** (44)*	***Measure merged with measure M69 to avoid duplication.***									
		M69. Designing structures to integrate into the landscape/seascape (45) By consideration of landscape/seascape effects in detailed design where practical (e.g. careful siting, the use of locally occurring, appropriate building materials and appropriate lighting techniques) See Landscape & Seascape topic paper	Applies to **all** alternative options.		None	(AMBER) Measures would be effective at reducing effects, but would not prevent effects on landscape fully.	(GREEN) Established practice	(GREEN) Established practice	(GREEN) Includes use of established methods	(GREEN) Could be implemented as integral part of main scheme.	(GREEN) No major effects envisaged	**YES – for all alternative options.** **Measure would be effective and would have a negligible effect on the cost of energy.**
		***Minimising the extent of lighting, particularly in night-time landscape/seascape** (46)*	***Measure merged with measure M69 to avoid duplication.***									
Other Sea	Damage to existing	**M70. Modifying alignment to prevent**	Applies only to **L3d** as		None	(GREEN)	(GREEN)	(GREEN)	(GREEN)	(GREEN)	(GREEN)	**YES – for L3d only.**

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Uses	seabed (telecommunications) cables	**adverse effects on existing seabed telecommunications cables (47).** Only relevant to Bridgwater Bay Lagoon (L3d) See Other Sea Uses topic paper	no cables in region of other alternative option footprints.			Seabed (telecommunication) cables are only present near to the L3d lagoon and it is assumed that it would be possible to avoid these with detailed design	Established practice	Established practice	Includes use of established methods	Could be implemented as integral part of main scheme.	No major effects envisaged	**Measure would be effective, but would have an effect on the cost of energy.**
	Disruption / impedance of existing marine aggregate extraction sites caused by increased siltation	**M71. Use of specialist extraction / resource sorting equipment (56)** – in order to improve sorting of more mixed sand/mud resource See Other Sea Uses topic paper	Applies to **B3** option only.		None	**(GREEN)** **Detailed sedimentation studies would be required to determine the scale of effect.**	(GREEN) Established practice	(GREEN) Established practice	(GREEN) Includes use of established methods	(GREEN) Could be implemented as integral part of main scheme	(GREEN) No major effects envisaged	**YES – for B3 only.** **Measure would be effective and would have a negligible effect on the cost of energy. This would need further investigation at detailed design stage, including cost analysis.**

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	Disruption / impedance to marine waste water disposal outfalls	***Structural alterations or pumping of outfall pipes for marine waste water disposal*** *(57)*	***Waste water outfall reconfiguration is accounted for within the FRLD topic measures.***									
	Disruption / impedance to structural integrity of coastal infrastructure used for recreation and tourism (e.g. slipways)	**M72. Structural modifications to marine recreation infrastructure (58)** For example, improvements to the foundations of structures at risk from undermining (e.g. outfalls, slipways etc.). See Other Sea Uses topic paper	Applies to **all** alternative options.		None likely	(GREEN) Method expected to be effective if cost of implementation is justified.	(GREEN) Established practice	(GREEN) Established practice	(GREEN) Includes use of established methods	(GREEN) Could be implemented as integral part of main scheme.	(GREEN) No major effects envisaged	**YES – for all alternative options (if required).** **Measure would be effective and is assumed to have a negligible effect on the cost of energy. However, this cannot be quantified until detailed design stage.**
	Reduction in sediment transport resulting in diminished supply	**M73. Beach recharge (59)** See Other Sea Uses topic paper	Applies to **all** alternative options.		None assumed	(GREEN) Method expected to be effective if cost of implementation is justified.	(GREEN) Established practice	(GREEN) Established practice	(GREEN) Includes use of established methods	(AMBER) Potential implications for terrestrial biodiversity	(GREEN) No major effects envisaged	**YES – for all alternative options (if required).** **Measure would be**

1. Topic	2. Likely significant adverse effect on environment*	3. Measure envisaged to prevent or reduce effect (followed by a cross-reference to the measure number used within earlier iterations of the ODR prevent/reduce costings table, where applicable)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Averse biodiversity effect	12. Adverse effect on society & economy.	13. Included in assessments of residual effects, SEA Objective compliance and option costs?
	of sand to pleasure beaches used for recreation and tourism.											effective and it is assumed that it would not have a large effect on the cost of energy. However, this cannot be quantified until detailed design stage.
	Increased emergency response times for marine and coastal rescue craft	**M74. Relocation of existing rescue stations to new sites**	Applies to **all** alternative options.		None	Low probability of the effect arising but measure can be expected to be fully effective.	(AMBER) Engineering methods involved are conventional although not widely applied to meet the outcomes sought here	(AMBER) Engineering methods involved are conventional although not widely applied to meet the outcomes sought here	(GREEN) Measure is technically feasible to adopt now	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**YES – for all alternative options. Measure would be effective and would have a negligible effect on energy cost.**
Air & Climatic Factors	Emissions of pollutants to atmosphere from transport via shipping	**M75. Efficient usage of shipping vessels – use of larger and/or more efficient shipping vessels during construction (60);** – to optimise the emissions to atmosphere per payload.	Applies to **all** alternative options.		None	(GREEN) Method expected to be effective	(GREEN) Established practice	(GREEN) Established practice	(GREEN) Includes use of established methods	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**YES – for all alternative options. Measure would be effective and is**

1. Topic	2. Likely significant adverse effect on environment*	3. Measure envisaged to prevent or reduce effect (followed by a cross-reference to the measure number used within earlier iterations of the ODR prevent/reduce costings table, where applicable)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Averse biodiversity effect	12. Adverse effect on society & economy.	13. Included in assessments of residual effects, SEA Objective compliance and option costs?
	and road during the construction phase	See Air & Climatic Factors topic paper and the Options Definition Report										**assumed to have a negligible effect on the cost of energy. However, this cannot be quantified until detailed design stage.**
		M76. Use of Euro IV or V rated site HGVs and delivery vehicles.	Applies to **all** alternative options.		Negligible assumed	(AMBER) Effective at reducing traffic related air pollution, but would not prevent all effects	(GREEN) Established practice within construction projects	(GREEN) Includes use of established methods which are known to be effective.	(GREEN) Would be developed within CEMP and implemented as integral part of main scheme.	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**YES – for all alternative options.** **This measure would be effective and included in the detailed design.**
	Carbon emissions from generation, transportation and use of primary and secondary constructi	**M77. Re-use/recycle of materials and minimisation of resource use (61)** See Air & Climatic Factors and Resources and Waste topic papers and the Options Definition Report	Applies to **all** alternative options.		None	(GREEN) Method expected to be effective	(GREEN) Established practice	(GREEN) Established practice	(GREEN) Includes use of established methods	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**YES – for all alternative options.** **Measure would be effective and would have no effect on energy cost.**

1. Topic	2. Likely significant adverse effect on environment*	3. Measure envisaged to prevent or reduce effect (followed by a cross-reference to the measure number used within earlier iterations of the ODR prevent/reduce costings table, where applicable)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Averse biodiversity effect	12. Adverse effect on society & economy.	13. Included in assessments of residual effects, SEA Objective compliance and option costs?
	on materials											
	Carbon emissions from power consumption at on-site accommodation and offices during construction.	**M78. Use of on-site renewable energy generation for heat and electricity during construction** – for example, use of solar panels, small wind turbines, biomass wood burners and/or Combine Heat and Power (CHP)	Applies to **all** alternative options.		None assumed	(GREEN) The effectiveness of the renewable energy measures would depend upon the outcome of the recommended feasibility studies.	(AMBER) Techniques becoming established practice	(AMBER) Combination of established and fast developing practice	(GREEN) Includes use of established and rapidly developing methods	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**YES – for all alternative options. The four methods of renewable energy generation recommended for study have the potential to bring reduced carbon emissions, but do require further detailed site analysis before their impact on project costings could be provided. Recommend that detailed feasibility study should be included.**

[1] This is a precautionary estimate based upon expert judgement following a review of studies undertaken into Eelgrass translocation. A 0 -15% survival rate was established for estuarine intertidal translocation of eelgrass, but it was noted that the especially low levels were due to frost damage. Further study would be needed to ascertain the survival rate where frost damage is not expected, but it is considered that 15% survival is a conservative estimate.

[2] Specific bird receptors that would benefit from this measure: *Shelduck, Wigeon, Teal, Mallard, Pintail, Shoveler, Pochard, Tufted Duck, Little Egret, Oystercatcher, Ringed Plover, Golden Plover, Grey Plover, Lapwing, Knot, Dunlin, Snipe, Black-tailed Godwit, Bar-tailed Godwit, Whimbrel, Curlew, Spotted Redshank, Greenshank, Redshank, Turnstone, Black-headed Gull, Lesser Black-backed Gull, Herring Gull and the Waterbird assemblage*

[3] Bird species that would be affected by changes to saltmarsh are: *Bewick's Swan, European White-fronted Goose, Shelduck, & Redshank.*

[4] Bird species particularly sensitive to disturbance are:
Shelduck, Wigeon, Mallard, Shoveler, Little Egret, Ringed Plover, Golden Plover, Grey Plover, Lapwing, Knot, Dunlin, Black-tailed Godwit, Whimbrel, Curlew, Redshank, Black-tailed Godwit, Bar-tailed Godwit, Black-headed Gull, Lesser Black-backed Gull, Herring Gull, Waterbird assemblage

[5] Bird species this measure applies to are: *Oystercatcher, Ringed Plover, Golden Plover, Grey Plover, Lapwing, Knot, Dunlin, Snipe, Black-tailed Godwit, Bar-tailed Godwit, Whimbrel, Curlew, Spotted Redshank, Greenshank, Redshank, Turnstone*

[6] Fish receptors potentially effected are: Atlantic Salmon; Sea Trout; Shad (allis and Twaite); Lamprey (river and sea); Eel; Sturgeon; Marine migrants (value based on UK BAP species: Cod, herring, plaice, sole and whiting); Marine stragglers (value based on UK BAP species: blue whiting, hake, horse mackerel, ling & saithe); Freshwater stragglers; and European species.

[7] Efficacy percentages refer to turbine related effects to the populations only and not to all effects related to the fish topic.

[8] For further details see: STP Topic Paper: Migratory & Estuarine Fish, Annex 2: Measures to prevent and/or reduce STP plan alternative effects (March, 2010)

[9] The efficacies detailed relate to construction effects which may result in the release of sediment only and not all of the effects related to the fish topic.

[10] TFE habitat receptors potentially affected are: European protected sites; UK and Local BAP Habitats; Local Sites; Landscape Ecology Features (e.g. Natural Character Areas, Regional Strategy Corridors); Discrete habitat features (e.g. Woodland, Hedgerows); Reedbed; and Ancient Broadleaved Woodland.

[11] TFE receptors potentially affected include: European Protected Species; Nationally Protected Species; UK and Local BAP species; Otter; Badger; Great Crested Newt; Petalwort; White-clawed Crayfish.

[12] Parsons Brinckerhoff 2010. Strategic Environmental Assessment of Proposals for Tidal Power Development in the Severn Estuary – Options Definition Report. Version 3 – Options Definitions for Assessment. Volume 1.

[13] Specific port receptors are: Bristol Port; Cardiff Port; Newport Port; Sharpness/Gloucester Port.

[14] MWQ receptors are: Temperature; pH; Salinity; Suspended Sediment; Organic Matter; Nutrients; Dissolved Oxygen; Trace Metals; Trace Organics; Radiological Contaminants; and Pathogens.

[15] It is currently assumed that the abstraction point for Point B would fall just outside the L3d impoundment, where modelling predictions are showing that there will be localised warming of waters.

[16] It is currently assumed that the existing outfall point from Hinkley Point B will fall within the impoundment of L3d Lagoon

[17] Flood Risk & Land Drainage receptors are: PPS25 & TAN 15 Essential Infrastructure, highly vulnerable and more vulnerable – transport, health, groups of more than 50 dwellings, education etc. (also including water and sewage treatment works); PPS25 & TAN 15 Less Vulnerable – shops, commercial, leisure, groups of less than 50 dwellings, but excluding land for agriculture and forestry; and Land for Agriculture and Forestry.

[18] Noise & Vibration receptors are: Residences; Schools & Colleges; Hospitals; Places of Worship; Commercial; Industrial; Farms, kennels and wildlife sites; and Open air amenities.

[19] Adverse effects arising from H&G topic are also predicted to effect Flood Risk and Land Drainage and Other Sea Uses receptors, but could also be relevant to others.

[20] Historic Environment receptors include the underwater, intertidal, coastal (hard geology), coastal (soft geology), terrestrial (hard geology) and terrestrial (soft geology) for the following: Archaeology; Palaeo-environmental deposits; Shipwrecks; Historic Landscape; and Built Heritage.

[21] Including effects on receiving landscape and seascape; Landscape with inter-visibility; Seascape with inter-visibility or inter-relationship; viewers from the land; viewers from the sea.

Table 2: key measures to as fully as possible OFFSET any significant adverse effects on the environment

1. Topic	2. Likely significant adverse effect on environment *	3. Measure envisaged to as fully as possible offset effect… …and whether it is a potential Compensation measure, under the Habitats Directive (HD)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Significant adverse biodiversity effect	12. Adverse effect on society & economy.	13. Included in option costs?
Migratory & Estuarine Fish Migratory & Estuarine Fish	Reduction in populations of non-statutorily protected fish species (marine and estuarine fish species).	**OFF1. Commercial fisheries buy-out –** Monetary compensation in return for surrender of fishing licenses (to offset for loss of non-statutorily protected fish populations). The marine and estuarine species affected would be *Bass, Plaice, Sole, Cod, Dab, Whiting & Herring*.	All	Note: Costings are not provided anywhere in this document. For project costings see the Options Definition Report (PB 2010)	None	(GREEN) Method expected to be effective	(GREEN) Common practice	(GREEN) Measure has been used elsewhere	(GREEN) Measure is technically feasible to adopt now	(GREEN) No major effects envisaged	(AMBER) Adverse effects upon fishing communities.	**YES**
	Reduction in populations of non-statutorily protected fish species (marine and estuarine fish species)..	**OFF2.Intertidal habitat enhancement/ creation -** Topographic modification and ecological enhancement in areas outside the Severn Estuary, targeted to be of benefit to marine and estuarine species (*Bass, Plaice, Sole, Cod, Dab, Whiting & Herring*).	All		None	(GREEN) Method expected to be effective	(GREEN) Common practice.	(GREEN) Measure has been used elsewhere	(AMBER) Measure is technically feasible but would require extensive development	(GREEN) Effects can be expected, however these are likely to be positive.	(GREEN) Effects can be expected, however these are likely to be positive.	**YES**
	Reduction in populations of statutorily protected fish species.	***Other than measures OFF1 and OFF2 above, all offsetting measures identified at this strategic scale of study are also considered to be compensation measures under the Habitats Directive and are therefore identical to those identified within the Compensation Workstream. See Table 5.15 above for details of the potential compensation measures identified.***										

1. Topic	2. Likely significant adverse effect on environment *	3. Measure envisaged to as fully as possible offset effect… …and whether it is a potential Compensation measure, under the Habitats Directive (HD)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Significant adverse biodiversity effect	12. Adverse effect on society & economy.	13. Included in option costs?
Marine Ecology	*Loss of marine habitats*	***All offsetting measures identified at this strategic scale of study are also considered to also be compensation measures under the Habitats Directive and are therefore identical to those identified within the Compensation Workstream. See Table 5.15 above for details of the potential compensation measures identified.***										
Waterbirds	*Reduction in bird assemblages*	***All offsetting measures identified at this strategic scale of study are also considered to also be compensation measures under the Habitats Directive and are therefore identical to those identified within the Compensation Workstream. See Table 5.15 above for details of the potential compensation measures identified.***										
Terrestrial & Freshwater Ecology	Damage to legally protected sites and species	**OFF3. Provision of alternative habitats through either creation and /or enhancement/extension of habitats.** Also a potential HD Compensation measure	All		None	Low probability of the effect arising but measure can be expected to be fully effective.	(GREEN) Common practice.	(GREEN) Common practice.	(GREEN) Measure is technically feasible to adopt now	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**NO**
Marine Water Quality	Risk of eutrophication within the estuary upstream of alternative option as a result of increases in light penetration in response to the reduction in suspended sediment concentrations.	**OFF4. Additional controls on diffuse sources of nitrogen outside the Severn catchment,** For example, an additional level of treatment for municipal wastewater or extended NVZ controls. Not a potential HD Compensation measure	**B3** only		None	The component methods involved are conventional although not applied at the scale that may be required here. Therefore can be expected to be fully effective if necessary and applied at sufficient scale.	(RED) Unprecedented scale of measures may be required here.	(AMBER) Methods involved are conventional although not applied at the scale that may be required here.	(AMBER) Measures are technically feasible to adopt now although would require substantial planning effort.	(GREEN) No major adverse effects envisaged.	(AMBER) Implementation of such measures could affect agricultural yields and result in additional waste sludge generation from WwTW.	**NO**
Freshwater Environment and Associated Interfaces	Loss of access to discrete SSSI outcrops caused by submergence.	**OFF5. SSSI designation of existing Geological Conservation Review (GCR) sites** as a substitute for a lost geological SSSI site	All, but particularly relevant to B3		None	The Geological Conservation Review (GCR) may include other sites that have similar examples of the particular features	(RED) No precedent	(RED) No precedent	(GREEN) Measure is technically feasible to adopt now	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**YES – included on the assumption that it would be judged acceptable**

1. Topic	2. Likely significant adverse effect on environment *	3. Measure envisaged to as fully as possible offset effect… …and whether it is a potential Compensation measure, under the Habitats Directive (HD)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice ?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Significant adverse biodiversity effect	12. Adverse effect on society & economy.	13. Included in option costs?
		(where a comparable site exists). Not a potential HD Compensation measure				that may be permanently submerged. In such cases there is a possibility that the geological information lost to research by submergence could be offset by designation of a similar outcrop elsewhere. Conversely, it is also possible that the particular geological and geomorphological features being submerged are unique. In this situation, no offsetting would be possible.						**to offset effects by including additional GCR sites onto the SSSI record.**
	Loss of access/ damage to subterranean infrastructure due to increased dampness as a result of impoundment .	**OFF6. Provision of replacement services/ infrastructure.** Not a potential HD Compensation measure	All		None	This measure may not be practicable for offsetting effects to *all* receptors; for example, it would not be suitable to replace access to private basements.	(AMBER) Engineering methods involved are conventional although not widely applied to meet the	(AMBER) Engineering methods involved are conventional although not widely applied to meet the outcomes sought here	(GREEN) Measure is technically feasible to adopt now	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**NO**

1. Topic	2. Likely significant adverse effect on environment *	3. Measure envisaged to as fully as possible offset effect… …and whether it is a potential Compensation measure, under the Habitats Directive (HD)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Significant adverse biodiversity effect	12. Adverse effect on society & economy.	13. Included in option costs?
							outcomes sought here					
Other Sea Uses	Disruption to the aggregate dredging 'cycle'.	**OFF7. Construction of new wharfs or the expansion of existing facilities at sites outside of the study area.** Not a potential HD Compensation measure	All		None	There is a low probability of this effect occurring Such a move may be feasible, although if any aggregates were landed at ports outside the barrage (e.g. Briton Ferry or Barry) then material may have to be transported further.	(AMBER) Engineering methods involved are conventional although not widely applied to meet the outcomes sought here	(AMBER) Engineering methods involved are conventional although not widely applied to meet the outcomes sought here	(GREEN) Measure is technically feasible to adopt now	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**NO**
	Reduction in area available for aggregate extraction	**OFF8. New aggregate licenses, or alterations to existing licenses.** Not a potential HD Compensation measure	B3 & L2		None	Subject to the agreement of approach with affected licensees, the approaches can be fully effective.	(AMBER) If a new or varied licence is needed, this would present consenting and policy issues.	(GREEN) New or varied licences areas are a common practice.	(GREEN) Measure is technically feasible to adopt now	(RED) Adverse implications for marine ecology.	(AMBER) Not likely to adversely effect usage of existing extraction sites. Potential for adverse implications to commercial fishing. Requires further investigation.	**YES – this measure is likely to be required to enable the continued operation of essential Estuarine activities**
	Reduction in sites available for existing	**OFF9. New dredge material disposal procedures or new**	B3 & L2		None	Subject to the agreement of the consenting	(AMBER) New	(GREEN) Marine	(GREEN) Measure is	(RED) Adverse	(AMBER) Not likely to	**YES – this measure is likely to be**

1. Topic	2. Likely significant adverse effect on environment *	3. Measure envisaged to as fully as possible offset effect… …and whether it is a potential Compensation measure, under the Habitats Directive (HD)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Significant adverse biodiversity effect	12. Adverse effect on society & economy.	13. Included in option costs?
	dredge material disposal	**sites** To offset the effect of lost functionality of exiting dredging sites which are shown to be affected by B3 and L2 either new disposal practices or new sites could be utilised. Restricting waste disposal to times of peak flow (so as to ensure effective waste material dispersal) may be an effective measure for B3. For L3d, and also as an alternative for B3, new sites could be established to enable continued dredging disposal by users of this Estuary resource (such as Port of Bristol) and are also assumed to be used for the STP dredging requirements, once operational. Not a potential HD Compensation measure				authorities and with disposal licensees, the approaches can be fully effective.	dredged material disposal licence areas are rarely designated and only after substantial investigation.	disposal sites are routinely used for the disposal of dredged material.	technically feasible to adopt now	implications for marine ecology.	adversely effect usage of existing disposal sites. Potential for adverse implications to commercial fishing. Requires further investigation.	**required to enable the continued operation of essential Estuarine activities**
	Increased sailing distance for users of aggregate extraction and	**OFF10. A measure to offset the effects on users of existing dredge disposal and aggregate extraction sites - due to**	B3 & L2		None	The extent of need for this measure would need to be determined and costed at detailed design stage.	The extent of need for this measure would	The extent of need for this measure would need to be	The extent of need for this measure would need to be determined	The extent of need for this measure would need to be	The extent of need for this measure would need to be determined	**YES** – This measure is likely to be required and would be refined at

1. Topic	2. Likely significant adverse effect on environment *	3. Measure envisaged to as fully as possible offset effect… …and whether it is a potential Compensation measure, under the Habitats Directive (HD)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Significant adverse biodiversity effect	12. Adverse effect on society & economy.	13. Included in option costs?
	dredging sites.	**increased distances to travel for extraction/disposal - would be needed (see OFF08 & OFF09).**					need to be determined and costed at detailed design stage.	determined and costed at detailed design stage.	and costed at detailed design stage.	determined and costed at detailed design stage.	and costed at detailed design stage.	detailed design
Air & Climatic Factors	Carbon emissions	**OFF11. Land remediation to offset emissions resulting from an STP construction phase.**	All		None	The methods involved are emerging practice. Can be expected to be fully effective if necessary and applied at sufficient scale.	(AMBER) Carbon offset practice is an emerging practice.	(AMBER) Methods involved are emerging.	(AMBER) Measures are technically feasible to adopt now although would require substantial planning effort.	(GREEN) No major adverse effects envisaged.	(GREEN) No major adverse effects envisaged.	**NO**
Communities	Loss of amenity access	**OFF12. Financial compensation for nuisance caused and loss of amenity arising from the implementation of an alternative option.**	All		None		(GREEN) Common practice.	(GREEN) Common practice.	(GREEN) Measure is technically feasible to adopt now	(GREEN) No major effects envisaged	(GREEN) No major effects envisaged	**NO - Measure is not currently assumed, but is likely to be considered further at detailed design stage.**
	Reduction in salmonid and eel populations causes closure of salmon tourism	**OFF13.** Monetary compensation in return for surrender of fishing licenses (to offset for loss of Salmon tourism and Heritage fishing).	All		None	(GREEN) Method expected to be effective	(GREEN) Established practice	(GREEN) Measure has been used elsewhere	(GREEN) Measure is technically feasible to adopt now	(GREEN) No major effects envisaged	(AMBER) Potential adverse effects upon fishing communities resulting from	**YES**

1. Topic	2. Likely significant adverse effect on environment *	3. Measure envisaged to as fully as possible offset effect… …and whether it is a potential Compensation measure, under the Habitats Directive (HD)	4. Alternative options that this measure applies to	5. High level cost estimate (£ Value and does it take scheme above £170/MWh)	6. High level estimate of impact on energy output	7. Effectiveness of measure	8. Established practice?	9. Established method?	10. Development timeframe (measure must be ready by 2020)	11. Significant adverse biodiversity effect	12. Adverse effect on society & economy.	13. Included in option costs?
	angling and heritage (elver) fishing										loss of available fishing.	

10.11 Appendix 11: Summary of how each alternative option performs in relation to the SEA objectives

Performance is based on number or proportion of receptors linked to each SEA objective for which significant effects have been predicted, and informed by consideration of SEA Assessment Criteria. The assessment takes in to account identified measures to prevent or reduce significant effects.			
Major negative performance against SEA objective	--	Major positive performance against SEA objective	++
Minor negative performance against SEA objective	-	Minor positive performance against SEA objective	+
No Effects	0	Uncertain	?

SEA objective	**Relevant receptors**	**Alternative options performance against SEA objectives over entire life-cycle**				
		B3: Cardiff to Weston Barrage	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**L3d: Bridgwater Bay Lagoon**
Topic: Marine water quality						
MWQ.1– To avoid adverse effects on marine water quality in relation to marine water quality standards.	Temperature, pH, dissolved oxygen, nutrients, contaminants, pathogens, radiological contaminants	-/?	0	0	0	0
MWQ.2 - To avoid adverse effects on designated marine wildlife sites of international and national importance due to changes in water quality.	Suspended sediments, salinity, temperature, pH, dissolved oxygen, nutrients, contaminants, radiological contaminants	-/?	0/?	0/?	0	0
MWQ.3 – To avoid adverse effects on marine water quality which would affect	Pathogens, contaminants,	0	0	0	0	0

SEA objective	Relevant receptors	Alternative options performance against SEA objectives over entire life-cycle				
		B3: Cardiff to Weston Barrage	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**L3d: Bridgwater Bay Lagoon**
human health, flora and fauna, recreation and other users.	radiological contaminants Suspended sediments					
MWQ.4 - To avoid adverse effects on inherent water characteristics (temperature, salinity, pH) that could lead to adverse changes in marine water quality.	Salinity, temperature, pH	0	0	0	0	0
MWQ.5 – To minimise risks of pollution incidents.	Suspended sediments, contaminants, pathogens	0	0	0	0	0
Topic: Freshwater environment and other associated interfaces						
FE.1 - To avoid adverse effects on water quality (whether surface water, groundwater or coastal waters) in relation to water quality standards.	Surface waters	0	0	0	0	?
	Groundwater	-	0	0	0	-
	Coastal waters	Considered in Marine water quality topic above				
FE.2 - To avoid adverse effects on water quality which would affect human health, flora and fauna, recreation and other users.	Humans	?	0	0	0	0
	Flora & fauna	0	0	0	0	0
	Recreation & other users	0	0	0	0	0
FE.3 - To avoid adverse effects on water abstractions (whether surface water or groundwater), particularly those utilised for the PWS.	PWS sources	?	0	+	0	0
	Licensed abstraction for other users	0	0	0	0	0
FE.4 - To avoid adverse effects to the water regime of designated water dependent sites of nature conservation interest.	Designated sites of nature conservation importance	0	0	0	0	0

SEA objective	Relevant receptors	Alternative options performance against SEA objectives over entire life-cycle				
		B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
FE.5 - To avoid adverse effects to buildings and infrastructure.	Infrastructure of national importance	0	0	0	0	0
	Other infrastructure (local importance)	--	0	0	0	0
FE.6 - To avoid adverse effects to the soil resource.	Soil resource	0	0	0	0	0
FE.7 - To avoid adverse effects on agricultural land currently in use.	Agricultural land	0	0	0	0	0
FE.8 - To avoid adverse effects on designated geological and geomorphological sites of international and national importance.	Geological and geomorphological SSSIs	--	-	-	0	0
FE.9 - To conserve and enhance designated geological and geomorphological site features.	Geological and geomorphological SSSIs	--	-	-	0	0
Topic: Flood risk and land drainage						
FR.1 – To avoid an increase in flood risk to property, land and infrastructure where this might otherwise occur as a consequence of the construction and operation of any tidal power structure.	PPS25 Essential infrastructure, highly vulnerable and more vulnerable – transport, health groups of more than 50 dwellings, education etc. (also include water and sewage treatment works)	++	0	0	0	+
	PPS25 Less vulnerable – shops, leisure, commercial, groups of less than 50 dwellings,	++	0	0	0	+

SEA objective	Relevant receptors	Alternative options performance against SEA objectives over entire life-cycle				
		B3: Cardiff to Weston Barrage	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**L3d: Bridgwater Bay Lagoon**
	but excluding land for agriculture and forestry.					
	Land for agriculture and forestry	++	0	0	0	+
Topic: Marine ecology						
ME.1 **-** To avoid adverse effects on designated marine wildlife sites and protected habitats of international and national importance.	Intertidal mudflat and sandflat, shingle and rocky shore, saltmarsh, macroalage, *Zostera*, epibenthos, subtidal sandbanks and subtidal *Sabellaria alveolata*	--	--	--	--	--
ME.2 **-** To avoid adverse effects on valuable marine ecosystems.	Intertidal mudflat and sandflat, shingle and rocky shore, saltmarsh, macroalage, *Zostera*, epibenthos, subtidal sandbanks and subtidal *Sabellaria alveolata*	--	--	--	--	--
ME. 3 **-** To avoid adverse effects on other protected species and their habitats.	Marine mammals and turtles	0	0	0	0	0
ME. 4 - To avoid adverse effects on national and local biodiversity target features that include marine habitats and species.	Saltmarsh; (vegetated) shingle; rocky shore and subtidal; subtidal habitats (*Modiolus*); intertidal mudflats; *Sabellaria* reefs; seagrass beds; subtidal sands and gravels;	--	--	--	--	--
ME.5 - To avoid deterioration in status	Benthic invertebrates;	?	0	0	0	?

SEA objective	Relevant receptors	Alternative options performance against SEA objectives over entire life-cycle				
		B3: Cardiff to Weston Barrage	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**L3d: Bridgwater Bay Lagoon**
class of WFD water bodies.	Phytoplankton, macroalgae; angiosperms					
ME.6 - To minimise the risk of introduction of non-native invasive marine species.	Macroalage, saltmarsh, intertidal mudflat and sandflats, shingle and rocky shore, subtidal habitats	-	0	0	-	-
ME.7 - To conserve and enhance designated marine site features.	Intertidal mudflat and sandflat, shingle and rocky shore, saltmarsh, macroalage, *Zostera*, epibenthos, subtidal sandbanks and subtidal *Sabellaria alveolata*	--	--	-	--	-
ME.8 - To restore and enhance marine BAP species populations and/or BAP habitat.	Saltmarsh; (vegetated) shingle; rocky shore and subtidal; subtidal habitats (*Modiolus*); intertidal mudflats; *Sabellaria* reefs; seagrass beds; subtidal sands and gravels.	--	--	-	--	-
Topic: Waterbirds						
O.1 - To avoid adverse effects on designated wildlife sites for birds and protected habitats of international and national importance.	Mute Swan, Bewick's Swan, European White-fronted Goose, Greenland White-fronted Goose, Dark-bellied Brent Goose,	--	-- / +	-- / +	--	--

SEA objective	Relevant receptors	Alternative options performance against SEA objectives over entire life-cycle				
		B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
	Shelduck, Wigeon, Gadwall, Teal, Mallard, Pintail, Shoveler, Pochard, Tufted Duck, Common Scoter, Great Crested Grebe, Bittern, Little Egret, Water Rail, Oystercatcher, Avocet, Little Ringed Plover, Ringed Plover, Golden Plover, Grey Plover, Lapwing, Knot, Dunlin, Ruff, Snipe, Black-tailed Godwit, Whimbrel, Curlew, Spotted Redshank, Greenshank, Redshank, Lesser Black-backed Gull, Herring Gull, Waterbird assemblage, Lowland open waters and their (breeding) assemblage margins, Mixed (breeding) assemblage, wet grassland/moorland, Lowlands damp grassland (breeding) assemblage, Lowland fen without open water (breeding) assemblage					

SEA objective	Relevant receptors	Alternative options performance against SEA objectives over entire life-cycle				
		B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
O.2 - To avoid adverse effects on other protected bird habitats and species.	Mute Swan, Bewick's Swan, European White-fronted Goose, Greenland White-fronted Goose, Dark-bellied Brent Goose, Shelduck, Wigeon, Gadwall, Teal, Mallard, Pintail, Shoveler, Pochard, Tufted Duck, Common Scoter, Great Crested Grebe, Cormorant, Bittern, Little Egret, Water Rail, Oystercatcher, Avocet, Little Ringed Plover, Ringed Plover, Golden Plover, Grey Plover, Lapwing, Knot, Dunlin, Ruff, Snipe, Woodcock, Black-tailed Godwit, Bar-tailed Godwit, Whimbrel, Curlew, Green Sandpiper, Spotted Redshank, Greenshank, Redshank, Turnstone, Black-headed Gull, Common Gull, Lesser Black-backed Gull, Herring	-- / +	-- / +	-- / +	--	--

SEA objective	Relevant receptors	Alternative options performance against SEA objectives over entire life-cycle				
		B3: Cardiff to Weston Barrage	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**L3d: Bridgwater Bay Lagoon**
	Gull					
O.3 - To avoid adverse effects on national and local biodiversity target features that include bird habitats and species.	Mute Swan, Bewick's Swan, European White-fronted Goose, Greenland White-fronted Goose, Dark-bellied Brent Goose, Shelduck, Wigeon, Gadwall, Teal, Pintail, Shoveler, Pochard, Common Scoter, Cormorant, Bittern, Little Egret, Water Rail, Oystercatcher, Avocet, Ringed Plover, Golden Plover, Grey Plover, Lapwing, Knot, Dunlin, Ruff, Snipe, Woodcock, Black-tailed Godwit, Bar-tailed Godwit, Whimbrel, Curlew, Green Sandpiper, Spotted Redshank, Redshank, Turnstone, Black-headed Gull, Common Gull, Lesser Black-backed Gull, Herring Gull	-- / +	-- / +	-- / +	--	--
Topic: Migratory and estuarine fish						
F.1 – to avoid adverse effects on designated wildlife sites for fish of	Severn Estuary/Môr Hafren SAC	--	--	--	--	--

SEA objective	Relevant receptors	Alternative options performance against SEA objectives over entire life-cycle				
		B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
international and national importance	River Wye/Afon Gwy SAC River Usk/Afon Wysg SAC Severn Estuary Ramsar Potentially some far-field Natura 2000 sites					
F.2 – To avoid adverse effects on the populations of other protected fish species and habitats	Atlantic salmon Sea trout Allis and twaite shad River and sea lamprey Eel	--	--	--	--	--
F.3 – To avoid adverse effects on national and local biodiversity target features that include fish habitats and species	UKBAP features within the marine migrant and marine straggler ecological guilds	--	--	--	--	--
F.4 – To avoid adverse effects on recreational and heritage fishing	Recreational and heritage fishing and the species which support them in particular Atlantic salmon	--	--	--	--	--
F.5 – To avoid adverse effects on commercial fish resources	All commercially targeted marine migrant and marine straggler fish receptors	--	--	--	--	-
F.6 – To minimise the risk of introduction of non-native invasive fish species	All fish receptors	0	0	0	0	0
Topic: Terrestrial and freshwater ecology						
TFE.1 - To avoid adverse effects on	SACs and Annex 1	+	+	+	+	+

SEA objective	Relevant receptors	Alternative options performance against SEA objectives over entire life-cycle				
		B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
designated terrestrial and freshwater wildlife sites of international and national importance.	habitats Ramsar Sites (non waterbird interest) SSSIs & NNRs (non geological)					
TFE.2 - To avoid adverse effects on valuable terrestrial and freshwater ecological networks.	SACs and Annex 1 habitats Ramsar Sites (non waterbird interest) SSSIs & NNRs (non geological) LNRs Habitats and Landscape Corridors	+	+	+	+	+
TFE.3 - To avoid adverse effects on other protected terrestrial and freshwater habitats and species.	Lichens and fungi Plants Crustaceans and molluscs Invertebrates Herpetiles Birds (non waterbird species) Mammals	+	+	+	+	+
TFE.4 - To avoid adverse effects to national and local biodiversity target features including terrestrial and freshwater habitats and species.	Habitats Lichens and fungi Plants Crustaceans and molluscs Invertebrates Herpetiles Birds (non waterbird	+	+	+	+	+

SEA objective	Relevant receptors	Alternative options performance against SEA objectives over entire life-cycle				
		B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
	species) Mammals					
TFE. 5 - To minimise the risk of introduction of non-native invasive terrestrial and freshwater species.	SACs and Annex 1 habitats Ramsar Sites (non waterbird interest) SSSIs & NNRs (non geological) LNRs Habitats & Landscape Corridors Lichens and fungi Plants Crustaceans and molluscs Invertebrates Herpetiles Birds (non waterbird species) Mammals	0	0	0	0	0
TFE. 6 - To conserve and enhance designated freshwater and terrestrial site features.	SACs and Annex 1 habitats Ramsar Sites (non waterbird interest) SSSIs & NNRs (non geological) LNRs	+	-	+	-	+
TFE. 7 - To restore and enhance freshwater and terrestrial BAP species	Habitats Lichens and fungi	++	+	++	+	++

SEA objective	Relevant receptors	Alternative options performance against SEA objectives over entire life-cycle				
		B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
populations and/or BAP habitat.	Plants Crustaceans and molluscs Invertebrates Herpetiles Birds (non waterbird species) Mammals					
Topic: Landscape & Seascape						
LS.1 - To conserve the character and qualities of the landscape/seascape, recognising its diverse features and distinctiveness at different scales – including designated and non-designated areas.	Receiving landscape	--	-	-	-	--
	Receiving seascape	--	--	--	--	-
	Landscapes with inter-visibility to the option	-	0	0	-	-
	Seascapes with inter-visibility to the option	--	--	--	--	-
LS.2 - To conserve the character and qualities of the physical and visual resource associated with land and sea.	Visual receptors on land	--	-	-	-	-
	Visual receptors on the estuary	--	-	-	-	-
LS.3 - To accord with the Aims and Articles of the European Landscape Convention.	Compliance with European Landscape Convention	--	--	-	-	+
Topic: Historic Environment						
HE.1 - To avoid adverse effects on designated sites in the historic environment.	Recorded designated sites, monuments and buildings and areas within the terrestrial and intertidal receptor areas	--	-	0	--	--
HE.2 - To avoid adverse effects on the non-registered internationally, nationally, regionally and locally important sites within the historic	Recorded sites and monuments in terrestrial, intertidal and subtidal receptor areas.	--	--	--	--	--

SEA objective	Relevant receptors	Alternative options performance against SEA objectives over entire life-cycle				
		B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
environment.						
HE.3 - To avoid adverse effects on the potential historic environment, the as yet unidentified sites and finds, within the Severn Estuary.	Identified areas of potential within the intertidal and subtidal receptor areas.	--	--	-	--	--
HE.4 - To avoid adverse effects on the character and quality of the historic landscape.	Historic landscape within terrestrial receptor area.	-	-	0	--	-
Topic: Air & climatic factors						
SE.1* - To avoid adverse effects on physical and mental health.	Local population	Construction phase -	Construction phase -	Construction phase -	Construction phase -	Construction phase -
		Operational phase 0	Operational phase 0	Operational phase 0	Operational phase 0	Operational phase 0
	UK Population	Construction phase -	Construction phase -	Construction phase -	Construction phase -	Construction phase -
		Operational phase +	Operational phase +	Operational phase +	Operational phase +	Operational phase +
TFE.1* - To avoid adverse effects on designated terrestrial and freshwater wildlife sites of international and national importance.	International/ national protected habitats -local	Construction phase -	Construction phase -	Construction phase -	Construction phase -	Construction phase -
		Operational phase 0	Operational phase 0	Operational phase 0	Operational phase 0	Operational phase 0
TFE.2*- To avoid adverse effects on valuable terrestrial and freshwater ecological networks.	International/ national protected habitats – local and national	Construction phase -	Construction phase -	Construction phase -	Construction phase -	Construction phase -

SEA objective	Relevant receptors	Alternative options performance against SEA objectives over entire life-cycle				
		B3: Cardiff to Weston Barrage	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**L3d: Bridgwater Bay Lagoon**
		Operational phase +	Operational phase +	Operational phase +	Operational phase +	Operational phase +
CF.1 - To maximise the opportunities for use of sustainable sources of energy for the UK.	Renewable energy supply	++	+	+	+	+
	UK GHG emissions per unit of electricity produced (kgCO_2e/kWh)	++	+	+	+	+
	Carbon payback period (years)	++	+	+	+	+
CF.2 - To avoid adverse effects from GHG emissions over the lifecycle of the project.	UK Net GHG emissions displaced against the baseline	++	+	+	+	+
	Total emissions per phase	--	-	-	-	-
Topic: Resources & waste						
RW.1 - To promote sustainable use of resources	Aggregates and embankment materials; Steel; Energy; Water	-	-	0	-	-
RW.2 - To reduce waste generation and disposal, increase re-use and recycling and achieve the sustainable management of waste	Sites for reuse; Treatment and recycling facilities; Energy recovery; Landfill	0	0	0	0	0
Topic: Communities						
SE.1 - To create local employment opportunities accessible to all	Vale of Glamorgan, Cardiff, Newport, Monmouthshire, South Gloucestershire, Bristol, North Somerset, Sedgemoor, West	++	+	+	+	++

SEA objective	Relevant receptors	Alternative options performance against SEA objectives over entire life-cycle				
		B3: Cardiff to Weston Barrage	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**L3d: Bridgwater Bay Lagoon**
	Somerset					
SE.2 - To avoid adverse effects on the local and regional economy	Bristol Port, Brean Beach and Lavernock Point and Rivers Usk, Wye and Severn Atlantic salmon and sea trout fishing; and Rivers Severn and Wye heritage (elver) fishing	--	--	--	--	--
SE.3 - To promote the development of sustainable communities	Vale of Glamorgan, Cardiff, Newport, Monmouthshire, South Gloucestershire, Bristol, North Somerset, Sedgemoor, West Somerset	0	0	0	0	0
SE.4 - To avoid adverse effects on physical and mental health	Local population within the following MSOAs: The Vale of Glamorgan 008, The Vale of Glamorgan 006, Sedgemoor 002, North Somerset 025, North Somerset 022, North Somerset 023, Monmouthshire 010, Monmouthshire 011 South Gloucestershire 005, Monmouthshire	0	0	0	0	0

SEA objective	Relevant receptors	Alternative options performance against SEA objectives over entire life-cycle				
		B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
	009, Bristol 003 Bristol 008, Forest of Dean 010, South Gloucestershire 004, South Gloucestershire 005, Monmouthshire 008, Monmouthshire 009, Newport 015, Newport 004, Newport 018, Newport 020, West Somerset 004					
SE.5 - To avoid adverse effects on access to community services and facilities	Community and services facilities within the following MSOAs: The Vale of Glamorgan 008, Sedgemoor 002, Monmouthshire 011, Monmouthshire 010, South Gloucestershire 005, Forest of Dean 010, South Gloucestershire 004, Monmouthshire 009, Newport 015, West Somerset 004, Sedgemoor 002	0	0	0	0	0
SE.6 - To promote access to recreational facilities and open space (revised to improve coverage of non-estuary tourism related issues)	Recreational facilities and open space within the following MSOAs: The Vale of Glamorgan 008, Sedgemoor 002,	0	0	0	0	0

SEA objective	Relevant receptors	Alternative options performance against SEA objectives over entire life-cycle				
		B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
	Monmouthshire 011, Monmouthshire 010, South Gloucestershire 005, Forest of Dean 010, South Gloucestershire 004, Monmouthshire 009, Newport 015, West Somerset 004, Sedgemoor 002					
SE.7 - To avoid adverse effects on existing, proposed and committed land uses	Existing and proposed land uses within the following MSOAs: The Vale of Glamorgan 008, Sedgemoor 002, Monmouthshire 011, Monmouthshire 010, South Gloucestershire 005, Forest of Dean 010, South Gloucestershire 004, Monmouthshire 009, Newport 015, West Somerset 004, Sedgemoor 002	0	0	0	0	0
SE.8 - To seek opportunities to improve degraded environments	Cardiff, Newport, Bristol, North Somerset, Sedgemoor	?	?	?	?	?
SE.9 - To avoid adverse effects on the housing market	Vale of Glamorgan, Cardiff, Newport,	0	0	0	0	0

SEA objective	Relevant receptors	Alternative options performance against SEA objectives over entire life-cycle				
		B3: Cardiff to Weston Barrage	B4: Shoots Barrage	B5: Beachley Barrage	L2: Welsh Grounds Lagoon	L3d: Bridgwater Bay Lagoon
	Monmouthshire, South Gloucestershire, Bristol, North Somerset, Sedgemoor, West Somerset					
Topic: Navigation						
N.1 - To avoid adverse effects on Severn Estuary navigation arising from sedimentation, geomorphology, water density, and tidal water levels.		0	0	0	0	0
N.2 - To avoid adverse effects on the integrity of existing and proposed port operations.		-	-	-	0	0
Topic: Other sea uses						
SU.1 - To avoid adverse effects on the aggregate extraction industry.	Aggregate extraction	--	0	0	-	0
SU.2 - To avoid adverse effects on marine waste disposal sites and infrastructure.	Marine waste disposal sites and Infrastructure	0	0	0	0	0
SU.3 - To avoid adverse effects on marine recreational users.	Marine recreational users	++	+	+	+	-
SU.4 - To avoid adverse effects on sustainable estuary-based tourism in both the South Wales and South West England Regions.	Sustainable estuary-based tourism in both the South Wales and South West England Regions	+/-	+/-	+/-	+/-	+/-
SU.5 - To avoid adverse effects on military activity in the region.	Military activity	0	0	0	0	0
SU. 6 - To avoid adverse effects on the energy industry.	Energy Industry	0	0	0	0	0
SU.7 - To avoid adverse effects on	Seabed cables and	0	0	0	0	0

SEA objective	Relevant receptors	Alternative options performance against SEA objectives over entire life-cycle				
		B3: Cardiff to Weston Barrage	**B4: Shoots Barrage**	**B5: Beachley Barrage**	**L2: Welsh Grounds Lagoon**	**L3d: Bridgwater Bay Lagoon**
seabed cables in the region.	pipelines					
SU.8 - To minimise adverse effects on the Severn Bore.	Severn bore	--	--	--	?	?
Topic: Noise & vibration						
NV.1 - To avoid adverse effects of negative noise and vibration on (humans) noise sensitive receptors.	Noise sensitive receptors (NSR) residential And Noise sensitive receptors (NSR) non-Residential	0 to -	0 to -	0 to -	0 to -	0 to -
NV.2 - To avoid adverse effects on the acoustic quality of the marine environment.	Fish, marine mammals and the marine environment	(? Uncertain) Following consideration and implementation of measures to prevent or reduce noise effects, the effects of the alternatives should be reduced in significance. However, for further detailed assessment reference should be made to the Migratory & Estuarine Fish topic paper.				
NV.3 - To avoid adverse effects on noise (vibration) sensitive receptors.	Noise sensitive receptors (NSR) wildlife	(+) Following consideration and implementation of measures to prevent or reduce noise effects, the effects of the alternatives should be reduced in significance. However, for further detailed assessment reference should be made to the Terrestrial & Freshwater Ecology topic paper.				
NV.4 - To avoid adverse effects through vibration.	Noise sensitive receptors (NSR) residential And Noise sensitive receptors (NSR) non-Residential	+	+	+	+	+

* Note that air quality has been assessed under objectives for other topics (including communities, carbon footprinting and terrestrial and freshwater ecology) in order to assess the impacts of changes to air quality on wildlife, people and resources.

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