DECC

# SEVERN TIDAL POWER - SEA TOPIC PAPER

## Flood Risk and Land Drainage

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# ABBREVIATIONS

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The following abbreviations are used in this Topic Report:

| | |
|---|---|
| AAD | Average Annual Damages |
| AEP | Annual exceedance probability |
| AOD | Above Ordnance Datum Newlyn – see ODN |
| AONB | Areas of Outstanding Natural Beauty |
| ASMITA | Aggregated Scale Morphological Interaction between a Tidal inlet and the Adjacent coast (geomorphological model for estuaries) |
| BAP | Biodiversity Action Plan |
| BERR | Department for Business, Enterprise and Regulatory Reform |
| ca. | Circa, approximately |
| CCW | Countryside Council for Wales |
| CFMP | Catchment Flood Management Plan |
| CHaMP | Coastal Habitat Management Plan |
| cSAC | Candidate Special Area of Conservation |
| DECC | Department of Energy and Climate Change |
| Defra | Department for Environment, Food and Rural Affairs |
| EIA | Environmental Impact Assessment |
| EC | European Commission |
| EU | European Union |
| GHG | Greenhouse Gases |
| GIS | Geographical Information System |
| GW | Gigawatts |
| H & G | Hydraulics and Geomorphology (Topic) |
| ha | Hectare (1 ha being equivalent to approximately 2.4 acres) |
| HAT | High astronomical tide |
| Hmax | Maximum wave height in a recorded burst of raw data |
| Hmean | Mean wave height |
| HRA | Habitats Regulations Assessment |
| Hs | Significant wave height = average height of the waves which comprise the highest 33% of waves in a given sample period (typically 20 to 30 minutes) |
| HW | High water |
| LAT | Llowest astronomical tide |
| LiDAR | Light Detection and Ranging (Aerial laser scanning to give digital elevation model) |
| LNR | Local Nature Reserve |
| m | Metre |
| $m^3$ | Cubic metres |
| MHW | Mean high water |
| MHWN | Mean high water neaps |
| MHWS | Mean high water springs |
| MLW | Mean low water |
| MLWN | Mean low water neaps |
| MLWS | Mean low water springs |

| | |
|---|---|
| Mm | Millimetres (1,000 mm = 1 m) |
| MW | Megawatt |
| NERC | Natural Environment and Rural Communities Act |
| NFCDD | National Flood and Coastal Defence Database (Environment Agency) |
| NNR | National Nature Reserve |
| ODN | Ordnance Datum Newlyn |
| PPG | Planning Policy Guidance |
| PPS | Planning Policy Statements |
| PPS25 | Planning Policy Statement 25: Development and Flood Risk |
| PSA | Public Service Agreement |
| SAC | Special Area of Conservation |
| SDC | Sustainable Development Commission |
| SEA | Strategic Environmental Assessment |
| SEFRMS | Severn Estuary Flood Risk Management Strategy |
| SLR | Sea Level Rise |
| SMP | Shoreline Management Plan |
| SMP2 | Update to Shoreline Management Plan (current process) |
| SNCI | Sites of Nature Conservation Importance |
| SPA | Special Protection Area |
| SSSI | Site of Special Scientific Interest |
| STP | Severn Tidal Power |
| SWL | Still-water level |
| TAN | Technical Advice Note |
| TAN15 | Technical Advice Note 15: Development and Flood Risk |
| TWh/year | 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. |
| UKCIP | United Kingdom Climate Impacts Programme |
| UKCP09 | United Kingdom Climate Projections 2009 |
| WAG | Welsh Assembly Government |
| WeBS | Wetland Bird Survey |
| WFD | Water Framework Directive |
| WLMP | Water Level Management Plan |

# NON TECHNICAL SUMMARY

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### Introduction

A strategic environmental assessment (SEA) is being conducted as part of the Severn Tidal Power (STP) feasibility study, in accordance with the requirements of the EU SEA Directive and UK Regulations. The SEA comprises two phases: Phase 1, the scoping stage, has already been undertaken. This Flood Risk and Land Drainage topic paper forms part of the reporting arising from Phase 2, the main assessment of short-listed options.

*Consultation*

The following consultation activities have been undertaken:

- Scoping consultation in January 2009. The scoping stage included a number of workshops and meetings with key stakeholders.
- Technical Workshops held in June 2009 to confirm the scope of SEA work planned in phase 2 and review key aspects of the assessment methodology and in November 2009 to review preliminary findings and the approaches to identifying measures to prevent, reduce and as fully as possible offset significant environmental effects.
- Meetings have been attended with Somerset, Gloucestershire and Welsh Local Authorities, the Environment Agency, Wessex Water and Dwr Cymru to describe the assessments being undertaken relating to flood risk and land drainage, to appeal for any further data which could be made available and to obtain feedback on the proposed methodology or any issues of concern.

*SEA Objectives*

SEA Objectives have been developed to enable alternative options to be compared. 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 effects of alternative options. A single SEA objective has been identified for this Flood Risk and Land Drainage Topic which is "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". In the case of the Flood Risk and Land Drainage topic, measures are required to reduce or remove effects to an acceptable level and these will need to be an integral part of any option. The final comparison of each option against the SEA objective will be made assuming these measures are in place.

### Baseline Environment

Baseline information provides the basis for predicting and monitoring environmental effects, by describing the area that may be affected. Due to the long timescales associated with the construction and operation of alternative options, baseline information is considered over three time periods, to reflect the predicted changes in the area when considered without the development of a Severn Tidal Power project. The baseline therefore also describes the estuary in a 'do-nothing' scenario.

There is an expectation that flood risks will increase in the future as parameters change in response to climate change. This particularly applies to sea levels and fluvial flows. The UK Climate Impacts Programme (UKCIP) published its latest projections for sea level rise and other parameters in June 2009 (UKCP09, 2009). These were based on confidence ranges for a number of emission scenarios for greenhouse gases. These outputs were considered, together with the latest advice specifically relating to flood risk, published by Defra in October 2006 (Defra, 2006c), but these have not yet been updated following the UKCP09 release. The proposed allowances for use in STP topics were presented in a paper to DECC (Severn Tidal Power, 2009c). It was agreed that the Defra allowances, which are more precautionary than the UKCP09 central estimate, would be used within the Flood Risk and Land Drainage topic to ensure consistency with the Environment Agency's emerging Severn

Estuary Flood Risk Management Strategy (SEFRMS) and the Coastal Goups' Shoreline Management Plans (SMPs) which are now being reviewed and updated (SMP2s)

The Defra 2006 allowances are incorporated into Planning Policy Statement 25 (PPS25). Similar guidance is provided in TAN15, the equivalent guidance in Wales, although the parameters are not defined.

The table below shows the allowances for sea level rise.

| Region | Assumed Vertical Land Movement (mm/yr) | Net Sea Level Rise (mm/yr) | | | |
|---|---|---|---|---|---|
| | | 1990 to 2025 | 2025 to 2055 | 2055 to 2085 | 2085 to 2115 |
| South West and Wales | -0.5 | 3.5 | 8.0 | 11.5 | 14.5 |

The table below shows the allowances for rainfall and fluvial flows, which will also increase flood risks in the baseline.

| Time band | 1990 to 2025 | 2025 to 2055 | 2055 to 2085 | 2085 to 2140 |
|---|---|---|---|---|
| Peak rainfall intensity | +5% | +10% | +20% | +30% |
| Peak river flow | +10% | +20% | | |

*Baseline environment up to 2009*
The tidal floodplain of the Severn Estuary is protected from inundation by extensive tidal defences on both banks. The existing standard of protection varies, but generally property and infrastructure assets are protected to a standard of at least 2% (1 in 50) annual exceedance probability (AEP).[1] In some rural areas the standard is as low as 20% (1 in 5) AEP. The Severn Estuary has one of the highest tidal ranges in the world of some 14m and in many locations tidal and sea defences prevent major inundation from surge tides which can exceed ground levels by in excess of 2m. The Environment Agency's tidal flood zone includes some 80,000 residential and 10,000 non residential properties in over 550 $km^2$ of tidal floodplain within the study area, using the National Property Database as a source . Many of these are concentrated in major urban areas such as Newport and Weston super Mare. The existing flood risk management policies for the Estuary in the absence of an approved Strategy, are consistent with those adopted in the current SMPs, which generally involved a 'hold the line' approach improving defences where required, usually with an allowance for sea level rise.

Many of the drainage outfalls, both from land drainage and piped drainage systems, experience some restriction of free flow during high spring tides, otherwise known as 'tide-locking'. Roads and buildings are generally located on ground which is above spring high tide level, so are unaffected by this tide-locking. The majority of rural areas are also above spring high tide level. However, some rural areas are below spring high tide level and in these areas the land drainage systems are actively managed by Internal Drainage Boards or the Environment Agency to offset the impacts of restricted drainage due to tidal influence.. There are no complete records of assets which are significantly at risk of flooding from tide-locking of outfalls to the estuary. Commercial and industrial areas to the south of Newport for example were developed on land at risk of tide-locking and in that particular case flood storage areas were created to store surface water runoff when the drainage outfalls are tide-locked. The level for new development in Cardiff Bay was set by consideration of the discharge of the Taff/Ely flood flows through the barrage, which is itself influenced by the tide levels in the estuary. However, for this strategic assessment considering the effect of alternative options it is the change in

[1] The annual exceedance probability refers to the chance of a particular flood magnitude being equalled or exceeded in any year

flood risk which is more important than a full record of the extent to which assets are currently at risk in the baseline.

*Future baseline during construction: 2014-2020 Future*
The Environment Agency's emerging SEFRMS analyses have found that during the period to 2020 only isolated lengths of the tidal defences are at any significant risk of failure and it can be assumed that the existing standard of protection will be maintained. The sea level rise expected during this period is 3.5mm per year.

A number of lengths of the defences are currently being considered as sites for managed realignment further inland. These would serve a dual purpose of overcoming deficiencies in the defences and also to create intertidal habitat to comply with national policy targets. The Coastal Group's emerging SMP2s for most of the area under consideration are currently at public consultation stage and a number of further lengths of defences have been identified for managed realignment, although generally these would be considered for implementation during the later STP operation stage.

There may be an increasing risk of flooding in the baseline through this period to 2020 as a result of an increase in fluvial peak flows, with or without any influence of the tide in restricting flow to the estuary.

*Future baseline during operation 2020-2140, decommissioning and longer term trends*
Sea level rise will increase the risk of failure of the defences. The emerging strategic assessments being carried out for the SEFRMS suggest that some lengths of defences would fail in 2028 and many in 2058 without management action to maintain and improve the defences, particularly to keep pace with sea level rise. This is based on a sea level rise of 1072mm by 2115, taken from the recommended allowances for flood risk given by Defra in October 2006.

In the absence of any firm policies to the contrary, for this SEA we can assume that a managed adaptive approach will emerge for any of the Policy Units with significant assets. Work undertaken by operating authorities will effectively maintain the existing standards of defence as a baseline throughout the timescales indicated above. The work required will increase as sea levels rise and the condition of the tidal defences deteriorates over time. Where the draft SMP2 shows a policy of managed realignment, it is usually for lengths of defences protecting low value assets. Where these have been identified, the assumption for the baseline is that the defences will be realigned in accordance with the draft policies.

The predicted rise in sea level will also increase the risks of tide-locking of fluvial flow through outfalls into the estuary, but this will increase the flood risk to a smaller percentage of receptors than those affected by the increased risk of failure of the defences.

*Key Environmental Issues and Problems*
The main flood risk issues in the baseline without a tidal power option are important because over the centuries the tidal floodplain of the Severn Estuary has been developed. Many thousands of properties, assets and infrastructure will experience an increasing flood risk, particularly as a result of sea level rise. The main issues and problems will be:

- There will be an increasing risk of overtopping or breaching of the tidal defences, due to general deterioration with time and the effects of sea level rise. The increasing risk of overtopping would lead to direct flooding of assets in the tidal floodplain, but more importantly defences subject to high volumes of overtopping during storm events can be at a high risk of a breach of the defence, which would increase in width as water poured through the breach. The draft Baseline Flood Consequence Assessment undertaken as part of the SEFRMS (Atkins, 2009) shows that without improvements, many defences would fail by 2028 and the majority would fail by 2058. The development of the SEFRMS and SMP2 policies will be guided by the importance of avoiding uncontrolled breaches. This will normally be achieved

by raising the level of tidal defences, providing protection against wave action, set back to a new defence alignment or to natural higher ground levels.

- The Severn Estuary Coastal Habitat Management Plan (CHaMP) (ABPmer, 2006) assessed the geomorphological development of the Estuary to 2105 taking into account sea level rise. It suggested that there would be a progressive loss of intertidal area, generally up to 10%, but up to 20% above Chepstow. This could lead to erosion of saltmarsh fronting, and providing a natural protection to, some of the tidal defences.
- 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 tidal inundation. Nationally budgetary constraints may limit the extent to which major engineering works could be implemented to deal with the higher estimates of sea level rise.
- Sea level rise will cause coastal squeeze. This will occur where man-made defences prevent a roll back of the defence alignment inland, which is the natural response to sea level rise. There is an obligation through the EC Habitats Directive transposed into English and Welsh law through the Habitats Regulations 1994 (as amended) to compensate for coastal squeeze by creation of new intertidal habitats and SEFRMS and SMP2 policies will include plans for the planning and creation of replacement habitats.
- There is no definitive overall assessment of the existing flood risks associated with tide-locking of existing outfalls and drainage systems or to future risks of this occurring as sea levels rise. However, operating authorities including the Environment Agency, Drainage Boards and Water Companies take tide-locking into account when considering the performance of individual discharges from watercourses or piped drainage systems. Impeded drainage as a result of tidal influences contributes to the flood risks in many of the low lying areas in the tidal floodplain and this is particularly important in urban areas such as Newport. Sea level rise will increase the risks in the baseline future.

Whilst the SEFRMS and SMP2 Reviews are ongoing and policies have not been adopted, there is sufficient material available to allow an assumed baseline for comparison with a future with any of the alternative options. If any of the alternative options were to be pursued, the assessment could be refined at project level, by which time the SEFRMS and SMP2 policies will have been adopted.

**Evaluation of Plan Alternatives**

*Assessment Methodology*

The SEA Directive specifies the criteria that should be taken into account when determining the likely significant effects of the plan and thus these criteria have been adopted throughout the assessment process of this SEA. This topic paper therefore considers the characteristics of the effects and of the area likely to be affected.

This topic has also used the following specific assessment methods.

- The Hydraulics and Geomorphology (H&G) topic assessments included hydraulic modelling of water levels and wave heights and predictions of the geomorphological development of the estuary for the baseline and for each of the five shortlisted alternative options. Extensive use has been made of the outputs from these analyses.
- 2-D model outputs from the H&G topic were used to determine baseline surge tide and wave action for representative points in the estuary and also the changes to these as a result of the alternative options. This paper does not consider the possibility of changes in the operation of any option to reduce flood risks.
- Sea level rise allowances were based on the STP Climate Change note (STP, 2009c) using the Defra allowances values for flood risk purposes. (1260mm rise between 2010 and 2140).
- All future costs and benefits were discounted to give present values.

The methodology is described below for three separate significant issues which must be considered.

Tidal defence issues

- SEFRMS emerging results and SMP2 Review consultation stage Draft Policies were used to assess a baseline with sea level rise, including proposed management interventions over 120 years. It was assumed that as a baseline the standard of tidal defence currently afforded to receptors would be reinstated by interventions required as a result of sea level rise and deterioration, unless managed realignment was identified for particular policy units in the SMP2 Reviews.
- Outside the SEFRMS area, particularly for the tributaries, use has been made of Environment Agency data on tidal defences. There are no adopted strategies in place and an assessment has been made of the interventions required.
- The extent and cost of works required to prevent any increase in flood risk as a result of raised tidal levels were calculated on the assumption that these would need to be included within an STP project.
- Benefits of reduced peak tidal levels as a consequential effect of some options were assessed. The main benefit would arise from the avoidance or delay of expenditure which would otherwise be required to deal with sea level rise. These benefits were calculated as a range. The lower figure was calculated assuming no benefit from any length of defence where managed realignment was being proposed as a draft policy in the SMP2. A higher figure was calculated on the assumption that all lengths of defence were included in the analysis.

Tide-lock issues (drainage restricted by a higher low tide and reduced time for discharge)

- Data was collected on outfalls to the tidal estuary or watercourses draining to the tidal estuary. The initial data collected was not complete but data gaps were filled based on other available information.
- Hydrodynamic 1-D models of a range of representative land drainage channels and outfalls were constructed to test the effects of the changed tidal regime for the alternative options against a baseline for a range of rainfall events.
- Some tributary models were available and these were re-run to test the effects of the changed tidal regime.
- For outfalls from piped drainage systems (e.g. public sewers and culverted watercourses), upstream ground, invert and overflow weir levels were taken into account when assessing the impact on both the drainage system and adjacent properties and roads.

Erosion and siltation issues

The H&G modelling outputs identified a risk of erosion of the intertidal areas, which could threaten the integrity of the tidal defences. Profile (STP,2010g) and ASMITA (STP,2010h) modelling outputs were used to make an assessment of the extent of the problem and timing. An assumption was made that this would need to be countered by revetment systems as a precautionary approach at this stage.

ASMITA modelling predictions of long term geomorphological changes were also used to assess the risks of estuary wide siltation affecting fluvial flood risks.

*Alternative Options*

There are five shortlisted alternative options that are being assessed within Phase 2 of the SEA for their likely significant effects. These alternative options and key parameters associated with the alternative options are:

| Alternative | Location | Length (approx) | Operating mode | Turbine type | No. turbines | Annual energy output | Caissons | Locks |
|---|---|---|---|---|---|---|---|---|
| B3: Brean Down to Lavernock Point Barrage | Lavernock Point to Brean Down | 16km | Ebb only | Bulb-Kapeller | 216 (40MW) | 15.1 to 17.0 TWh/year | 129 | 2 |
| B4: Shoots Barrage | West Pill to Severn Beach | 7km | Ebb only | Bulb-Kapeller | 30 (35MW) | 2.7 to 2.9 TWh/year | 46 | 1 |
| B5: Beachley Barrage | Beachley to land directly to the east on the English side | 2km | Ebb only | Straflo | 50 (12.5MW) | 1.4 to 1.6 TWh/year | 31 | 1 |
| L2: Welsh Grounds Lagoon | River Usk to Second Severn Crossing | 28km | Ebb only | Bulb | 40 (25MW) | 2.6 to 2.8 TWh/year | 32 | 1 |
| L3d: Bridgwater Bay Lagoon | Brean Down to Hinckley Point | 16km | Ebb & Flood | Bulb-Kaplan | 144 (25MW) | 5.6 to 6.6 TWh/year | 42 | 1 |

*Assessment of Likely Significant Effects on the Environment*

For all options, the effects are in response to the changed tidal regime which is a feature of the operational phase of an option. Effects during construction will increase as a barrage or lagoon is completed, particularly in the final year as there will be some obstruction to tidal flows. However, it is the change in tidal regime caused by the opening and closing of sluices and running turbines under load for electricity generation which has a significant effect on flood risk. This would also apply during decommissioning. For each short listed option the summary table shows the main significant effects, prior to any measures to reduce effects.

Alternative Option B3: Brean Down to Lavernock Point Barrage

| Effect | Extent |
|---|---|
| <u>Tidal Flood Risk</u><br>Flood risk affected by changes to peak tide and wave action | • General reduction of up to 1.5m in flood peak throughout the impounded section, but reductions extending to a line from Ilfracombe to Swansea. There would be a reduction in flood risk from tidal inundation for all assets in the study area. In the impounded section the reduction in flood risk would be immediate and over the life of the option would negate the majority of the effects of sea level rise over 100 years. Outside of the impoundment in Bridgwater Bay, the reduction in peak level is equivalent to between 55 and 75 years of sea level rise. Benefits have a present value of £129m which would increase to £219m if lengths of defences which may be realigned are included. The benefits would apply to approximately 79,000 residential and 10,000 non residential properties and 42 essential infrastructure assets.<br>• Increases of up to 0.25m on the peak of spring tides as a far field effect, which is also assumed for peak surge tides. Potential |

| Effect | Extent |
|---|---|
| | increase in flood risk to in the region of 6,000 properties in Wales, most significant in Cardigan Bay. The increased flood risk for far field receptors is of a lower extent and magnitude than the reductions within the estuary. |
| Fluvial Flood Risk<br>Flood risk affected by ability to discharge against a changed tidal regime | • Increased flood risk during fluvial flood events combining with tide-lock conditions. Reduced drainage performance could affect 372 $km^2$ of land containing 45,436 residential properties, 5,037 non residential properties and 28 critical infrastructure assets. There would be no increase in the water levels in Cardiff Bay in peak flood events on the Rivers Taff and Ely. Flood flows from the River Axe would be impeded. For other tributaries and the main River Severn, fluvial flood levels would be reduced when discharging against normal spring tides. |
| Erosion or siltation<br>Erosion threatening the integrity of tidal defences<br><br>Siltation within the impoundment | • Geomorphological modelling has shown the potential for erosion which could threaten the integrity of tidal defences. Particular issues identified around Welsh Grounds, (1m in 10-20 years, up to 3m in 120 years) Woodhill Bay near Clevedon, (1m in 10 years, 2m over 120 years)and outside the impoundment over Stert Flats (1.5m over 50 years).<br>• Modelling has not identified that long term siltation will affect flood risks. |

Alternative Option B4: Shoots Barrage

| Effect | Extent |
|---|---|
| Tidal Flood Risk<br>Flood risk affected by changes to peak tide and wave action | • Little change in peak tide levels in the impounded section.<br>• Peak tide levels would be raised in the Bristol Channel to a line between Minehead and Swansea. This rise is up to 0.3m.<br>• Some far-field effects in Cardigan Bay and the Irish Sea have been identified by the modelling. Some are positive, some negative. These are within model tolerances and none of the locations indicated have tidal floodplains. It has been assumed there are no effects on flood risk receptors. |
| Fluvial Flood Risk<br>Flood risk affected by drainage restricted by changed tidal regime | • Increased flood risk during fluvial flood events combining with tide-lock conditions. Reduced drainage performance could affect 97 $km^2$ of land containing 2,300 residential properties, 92 non residential properties and 3 critical infrastructure assets.<br>• No significant difference in peak water levels in the River Severn when compared with the baseline for spring and neap tides. |
| Erosion or siltation<br>Erosion threatening the integrity of tidal defences<br><br>Siltation upstream of a barrage | • Geomorphological modelling has shown the potential for erosion which could threaten the integrity of tidal defences. Particular issues identified around Woodhill Bay where 2m of erosion is predicted within the first 5 to 10 years (3m after 100 years) and Severn Beach, of 1m within 20 years (3m after 50 years). Also within The Shoots area where over 3m is predicted in 120 years.<br>• ASMITA modelling suggest up to 7m of subtidal accretion upstream of the barrage in 120 years, although there is some uncertainty associated with this prediction. If this does happen, it could restrict the ability to evacuate flood flows and increase fluvial flood risks. |

Alternative Option B5: Beachley Barrage

| Effect | Extent |
|---|---|
| Tidal Flood Risk<br>Flood risk affected by changes to peak tide and wave action | • Little change in peak tide levels in the impounded section.<br>• Peak tide levels would be raised in the lower estuary to Hinkley/Barry. This rise is up to 0.3m.<br>• Some far-field effects in Cardigan Bay and the Irish Sea have been identified by the modelling. These are within model tolerances and none of the locations indicated have tidal floodplains. It has been assumed there are no effects on flood risk receptors. |
| Fluvial Flood Risk<br>Flood risk affected by drainage restricted by changed tidal regime | • Increased flood risk during fluvial flood events combining with tide-lock conditions. Reduced drainage performance could affect 73 $km^2$ of land containing 961 residential properties, 43 non residential properties and no critical infrastructure assets.<br>• No significant difference in peak water levels in the River Severn when compared with the baseline for spring and neap tides. |
| Erosion or siltation<br>Erosion threatening the integrity of tidal defences | • Geomorphological modelling has shown the potential for erosion which could threaten the integrity of tidal defences. Particular issues are identified around Severn Beach, where up to 5m of erosion is predicted within the first 10 years, reaching a maximum of 6m within 20 years and at Welsh Grounds where 1m is predicted within the first 5 to 10 years (to 1.5m after 20 years). There is also potential for erosion in the long term (over 100 years) upstream of the structure.<br>• ASMITA modelling suggests up to 3m of subtidal accretion upstream of the barrage over 120 years, although there is some uncertainty associated with this prediction. If this does happen, it could restrict the ability to evacuate flood flows and increase fluvial flood risks upstream. |

Alternative Option L2: Welsh Grounds Lagoon

| Effect | Extent |
|---|---|
| Tidal Flood Risk<br>Flood risk affected by changes to peak tide and wave action | • Reduction in peak tidal level by up to 0.3m at some locations in the estuary, but raised at other locations in the lower estuary.<br>• Peak tide levels would be raised in the Bristol Channel by up to 0.3m.<br>• Some far-field effects in Cardigan Bay and the Irish Sea have been identified by the modelling. These are within model tolerances and none of the locations indicated have tidal floodplains. It has been assumed there are no effects on flood risk receptors. |
| Fluvial Flood Risk<br>Flood risk affected by drainage restricted by changed tidal regime | • Increased flood risk during fluvial flood events combining with tide-lock conditions. This would affect all outfalls discharging to the impoundment. Reduced drainage performance could affect 47 $km^2$ of land containing 254 residential properties, 19 non residential properties and no critical infrastructure assets.<br>• There is no significant effect on peak flood levels in the River Severn or other tributaries when compared with the baseline for spring and neap tides. |
| Erosion or siltation | • Geomorphological modelling has shown the potential for 2m of erosion within 10 years at Severn Beach and 1m of erosion in the |

| Effect | Extent |
|---|---|
| Erosion threatening the integrity of tidal defences | Shoots Area over 50 years.<br>• ASMITA modelling predicts that there will be long term accretion within the lagoon. This would be likely to affect outfalls into the lagoon, although measures will be required to deal with the changed tidal regime which could also overcome this as an issue. |

Alternative Option L3d: Bridgwater Bay Lagoon

| Effect | Extent |
|---|---|
| <u>Tidal Flood Risk</u><br>Flood risk affected by changes to peak tide and wave action | • Reduction in peak tidal level within the impoundment up to 1.5m. The reduction in flood risk would be immediate and over the life of the option would negate the effects of sea level rise over 100 years for the Somerset coastline within the impoundment.<br>• There is also a general reduction in peak surge tide levels of up to 0.3m over the majority of the estuary outside the impoundment, extending to a line between Porlock and Porthcawl.<br>• Benefits valued at a present value of £59m which would increase to £88m if lengths of defences which may be realigned are included.<br>• Some far-field effects on the Lleyn Peninsula and the Irish Sea have been identified by the modelling. These mainly show as reductions in peak tide levels but are within model tolerances. It has been assumed there are no effects on flood risk receptors. |
| <u>Fluvial Flood Risk</u><br>Flood risk affected by drainage restricted by changed tidal regime | • There may be a small but measurable increase in flood risk during fluvial flood events combining with tide-lock conditions. Reduced drainage performance could affect 243 $km^2$ of land containing 1054 residential properties, 91 non residential properties and 1 critical infrastructure asset.<br>• Peak fluvial flood levels in the River Parrett upstream of Bridgwater would not be significantly affected by this option and there would be no effect on other tributaries outside the impoundment. |
| <u>Erosion or siltation</u><br>Erosion threatening the integrity of tidal defences | • Geomorphological modelling has shown the potential for erosion in the long term (over 100 years) downstream of the lagoon structure in the Outer Severn area of the estuary.<br>• ASMITA modelling predicts 0.4m of accretion within the lagoon in 120 years, but this should not affect flood risk. |

*Assumptions, Limitations and Uncertainty*

Assumptions

- For the Flood Risk and Land Drainage Topic the higher sea level rise allowances published by Defra in 2006 have been used as a more precautionary approach than the middle range estimates from UKCP09. This will ensure consistency with the emerging SEFRMS and Severn Estuary SMP2, both of which are using the Defra allowances.
- There are a number of aspects of the analyses where data has not been available and generally these were anticipated during scoping. This particularly applies to outfall invert levels and diameters. Data gaps in outfall locations, size and level have been filled using information from sources including ground levels, historical records (Binnie and Partners, 1981 and Tinkler, 1989) and in the case of piped systems, pipe levels in adjacent manholes

from Water Company records. The available data and information has been sufficient for this SEA, which is not intended to be to a project level of detail.

- A simplified approach has been used to attribute catchment areas to all land drainage outfalls using the digital elevation model.
- There were a limited number of tributary river models available to use as a baseline and to test the effect of options. These have been used to assess the effects for similar tributaries.
- Far field effects have been identified as far away as Cardigan Bay (for option B3). This is based on modelling for a spring tide but no modelling has been undertaken for extreme tides involving surges, which will be more important for any effects on flood risk receptors. For this assessment it has been assumed that similar far field changes apply to surge tides.
- The SMP2 Review and the SEFRMS are both work in progress. The draft policies from the SMP2 Reviews, which have been issued for public consultation, have been used to set the baseline.
- The approach to identifying the flood risk benefits of any option were defined by the Environment Agency as the cost of providing similar protection by other means. Where tidal levels are reduced by an option, the main benefit is the cost that would be avoided or delayed to cater for climate change or deteriorating defences. For this exercise it is not essential to determine the cost of the programme of work over the lifetime of the SEFRMS, as it is not yet available. The benefits as defined can be assessed from a relative rather than an absolute value.
- The cost of measures to reduce effects and the valuation of flood risk management benefits have both been discounted to take account of future costs to arrive at 'present values'. For the measures to reduce effects, a discount factor of 8% for the first 35 years of the investment period and 3.5% thereafter has been taken in line with the private sector discount factors being used within the feasibility study. However, flood risk management benefits are to public sector investment in flood management and it is more appropriate to measure these to be consistent with flood risk management investment rules set out in the Treasury 'Green Book' used by the Environment Agency and Defra. This discount rate is variable, reducing from 3.5% to 2.5% over a 100 year period. The 2.5% rate has been extended to 2140 for this assessment.

Limitations

- This paper does not consider the possibility of change in the operating of any option to reduce flood risk.
- The analyses set out in this Paper have been completed in sufficient detail to highlight the issues, to assess the effect of options and also to identify the range and outline cost of measures that would be required to prevent or reduce any significant adverse effects of the alternative options.
- The benefits from delaying or avoiding expenditure which would be required to improve defences to deal with the effects of sea level rise or deterioration have been calculated for those options where peak levels are reduced. These benefits cannot be directly compared with the cost of measures to reduce other effects, which will be required as part of the option. This is due to the difference in the timing of the work and the different bases for deriving present value for private and public expenditure.
- The consideration of measures to avoid or reduce the effects of erosion has been undertaken for flood risk receptors only in this topic.

Uncertainties

- An assessment of the far field effects has been carried out at a high level only, using basic information on tidal defences and floodplains from the Environment Agency's database. Further modelling and testing would be required at project level.

- The H&G modelling has given an indication of the erosion and deposition predicted for the baseline and the alternative options. Cost estimates for erosion protection Costs of erosion protection measures are precautionary. Managed realignment for example may be a more cost effective way of meeting the flood risk management obligations, but that would rely on a change of policy which cannot be assumed at this stage.

*Measures to prevent, reduce and as fully as possible offset any significant adverse effects*

The measures identified to prevent or reduce likely significant adverse effects identified within this topic are described below.

Measures to reduce the effects of raised tidal levels

- Where peak tide levels would be increased as a consequence of operation of the tidal power option, measures have been included to improve the standard of defences to remove the adverse effect by defence raising. If 0.3m rise in peak level was forecast, this is the amount allowed for in cost estimates. For costing purposes it is assumed this would take place in or before 2020. Sea level rise would result in an increase in flood risk during the operating period and this would also have applied to the baseline. The measures would not be designed to give protection against sea level rise as this would not have been an effect of any option adopted. The following measures have been assumed and can be implemented. Opportunities exist to incorporate other improvements or realignment of the defences at the same time, using other public or private finances.

| Option | Length of defence raising (km) | | | Cost of measures (£m) | | |
|---|---|---|---|---|---|---|
| | SEFRMS Area | Bristol Channel | Far field | SEFRMS Area | Bristol Channel | Far field |
| B3 | 0 | 0 | 58 [44-87] | 0 | 0 | 29 [22-43.5] |
| B4 | 45 (17) | 17 | 0 | 22.5 (8.5) | 8.5 | 0 |
| B5 | 95 (75) | 1.5 | 0 | 47.5 (37.5) | 0.75 | 0 |
| L2 | 0 | 25 | 0 | 0 | 12.5 | 0 |
| L3 | 0 | 0 | 0 | 0 | 0 | 0 |

Note: The extent of work required to cover far field effects is uncertain, both in linear extent and in cost. A range is indicated to reflect this. [ ]
Figures in brackets ( ) assumes no work will be required where managed realignment may be an option.

Measures to reduce the effects of increased tide-lock as a result of the changed tidal regime.

- The changed tidal regime increases flood risk as a result of the reduced period in which free discharge from outfalls could take place or permanent drowning out of outfalls.
- The main measure proposed to reduce this effect is the use of pumping stations to lift water to discharge at similar stages of the tide as in the existing case. Their effectiveness in performing this function has been proven in many locations, including locally in Somerset. Options to store water during tide-lock or to increase the size or duplication of outfalls may be effective at some locations, but their effectiveness cannot be assumed without more detailed studies at project level. Either of these other options would be likely to be less costly over 120 years and also would be more sustainable and therefore would be preferred wherever they can be shown to be effective. The pumping station measure as the standard is therefore precautionary.
- Some outfalls will experience a degree of tide-lock with the current tidal regime and this will increase with sea level rise. The measure is not designed to deal with either of these risks,

although the opportunity could be taken to increase the extent of works to improve flood risks using other public or private funds.

- Where pumping stations already exist to perform a land drainage function or to pump a sewage works outfall, the opportunity would be taken to increase the capacity or duration of pumping where measures are required. At this strategic level the costs are included in the general pumping measure described above.
- The River Axe would outfall into the impoundment of option B3 at a level close to 0m AOD. The raised low tide levels within the impoundment would restrict the free drainage during flood conditions and measures would be required to overcome this. The size of pumping station required is such that a river diversion is a more cost effective option. A flood relief channel to discharge south, rather than north of Brean Down inside the impoundment, is proposed at an estimated cost of £10m.
- The estimated costs of reducing tide-lock effects to an acceptable level are shown in the following table.

| Option | Land drainage outfall measures (£m) | River Axe diversion (£m) | Urban drainage outfalls (£m) | Total costs (£m) |
|---|---|---|---|---|
| B3 | 114 (76) | 10 (10) | 57 (37) | 181 (123) |
| B4 | 108 (72) | 0 | Negligible | 108 (72) |
| B5 | 51 (34) | 0 | Negligible | 51 (34) |
| L2 | 16 (11) | 0 | Negligible | 16 (11) |
| L3 | 17 (11) | 0 | Negligible | 17 (11) |

Note: All costs are present value. Construction cost only in brackets.

Measures to reduce the effects of erosion (and siltation)

- Where erosion is predicted as a consequence of the change in tidal levels and flows with options, revetment is proposed as a protection measure where flood risk management assets, including defences, could be threatened. 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. There is some uncertainty associated with the predictions of long term geomorphological change and timing and at this stage a conservative approach has been taken and a range included in the summary table below to reflect the uncertainty. The cost estimates assume that the revetment will need to be repeated at 50 years intervals.
- Subtidal accretion is predicted upstream of the smaller barrages in the long term. There may be some risks associated with a reduced capability to pass fluvial flood flows, but no allowances have been made at this SEA stage.

| Option | Total length of revetment (km) | Maximum erosion depth(m) | Cash cost (£m) | Present value cost (£m) |
|---|---|---|---|---|
| B3 | 67 to 201 | 3.1 | 672 to 2,015 | 37 to 234 |
| B4 | 36 to 109 | 3 | 216 to 648 | 17 to 99 |
| B5 | 8 to 23 | 6 | 123 to 370 | 33 to 143 |
| L2 | 9 to 28 | 2 | 87 to 260 | 14 to 66 |
| L3 | 18 to 56 | 0.5 | 33 to 98 | 0.25 to 1.8 |

*Offsetting measures*

Offsetting measures within this SEA are measures to as fully as possible offset any significant adverse effects on the environment. These measures therefore make good for loss or damage to an environmental receptor, without directly reducing that loss/damage. In this SEA 'compensation', a subset of offsetting, is only used in relation to those measures needed under the Habitats Directive.

There are no offsetting measures applicable to the flood risk and land drainage topic.

**Assessment against SEA Objectives**

This topic paper includes a full assessment of how each alternative option performs against each SEA Objective over the course of its entire life-cycle.

In summary:

For this topic paper it has been assumed that measures will be required to reduce or remove all significant adverse effects and these will be included within the option, with associated cost. The result of this is that any residual significant effects will be positive. All options therefore satisfy the agreed SEA objective "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."

**Plan Implementation**

*Legislation and policy compliance*

This paper contains a review of legislation and policy that is specifically relevant to this topic. An assessment has been made as to whether each alternative option would be compliant with existing relevant legislation and policy.

The assumption made in this topic paper is that any adverse effects of options in increasing flood risk to receptors will need to be reduced to an acceptable level. The cost of measures would need to be allowed for within the scheme costs. The term 'acceptability' would be judged by the high standards required of any new development to comply with TAN15 or PPS25 which set out safeguards to avoid any increase in flood risk to third parties. Therefore any of the options would comply with legislation and policy.

*Monitoring of significant environmental effects*

The SEA Directive requires that monitoring measures are described within the environmental reporting. The monitoring proposals contained within this paper are applicable to all of the alternative options under consideration. The proposals are set out in the table below.

| Significant Effect | Relevant receptor | Description of monitoring |
|---|---|---|
| Increase in peak tide levels | All | Monitor tide levels prior to construction, including locations to capture far field effects. Results should be compared over a full range of tide cycles to determine the accuracy of the modelling and to allow any refinement of measures should they be required. This should include monitoring of tidal levels in Cardigan Bay to determine whether they are influenced directly by tidal surges in the Severn Estuary. If a decision is made to take any of these options further, this work should be put in place at an early stage to allow sufficient time to inform further modelling. |

| Significant Effect | Relevant receptor | Description of monitoring |
|---|---|---|
| Sea level rise | All | Monitor UKCP programme outputs for actual and projected sea level rise to compare with assumptions made in the SEA. |
| Tide-lock | All | Programme of studies prior to construction to determine the current flood risks due to tide-locking. Monitor over a full range of tidal cycles and fluvial events to confirm the risks. Repeat following construction to determine the effects of operation. |

*Further modelling and analysis*

Before the design of any of the alternative options could be undertaken, there are a number of assessments described in this paper which should be refined with further modelling or analyses to reduce any uncertainties. These should be put in place at an early stage if there is a decision to pursue any of the options. These include:

- Further modelling of tributaries.
- 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.
- 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.

*Work in advance of commissioning*

For many of the options the H&G modelling identified that erosion would commence within the first 5 years of operation of the structure. This potentially would require many kilometres of major revetment systems and the necessary analyses, design and construction work would need to be commenced at a very early stage to ensure that systems were in place to safeguard vulnerable flood defences.

Measures identified to reduce any increases in flood risk as a consequence of the operation of the scheme would also need to be in place in advance of the completion of any structure. This would also be a critical element of any programme for development of an option.