



# Chapter 8.0

## Coastal Processes, Sediment Transport and Contamination

## 8.0 Coastal Processes, Sediment Transport and Contamination

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### 8.1 Overview of existing situation

- 8.1.0.1 The Severn Estuary has many unique coastal process characteristics but it is the regular exceptionally large tidal range that makes this location of particular interest to tidal lagoons and tidal barrages. For the Project (see Figure 8.1) the tidal range is likely to be greater than 11 m on spring tides, a magnitude that is often described as a ‘hyper-tidal’ range (>6 m). The occurrence of the large tidal range is explained by a combination of resonance with the incident North Atlantic tidal wave approaching the Bristol Channel and with further amplification and convergence as the tide moves into the funnel-shaped form of the Severn Estuary.
- 8.1.0.2 The large tidal range leads to a large volume of water being exchanged between successive high and low waters. This exchange creates very strong tidal currents which are sufficient to keep large amounts of fine material in suspension and prevent major channels, such as Bristol Deep (Figure 8.1), from silting up.
- 8.1.0.3 At low water, large areas of muddy inter-tidal are exposed around the margin of the estuary as well as an expanse of well-sorted sandy inter-tidal within the middle of the estuary (e.g. Middle Grounds) (Figure 8.1).
- 8.1.0.4 There are several major rivers that discharge into the estuary, notably the Wye and Severn being the largest. Rivers are the source of freshwater input, as well as providing moderate amounts of fine sediment.
- 8.1.0.5 The expanse of sand in the estuary is mainly of marine origin and moves up the estuary under the influence of a stronger flood tide than ebb. The primary source of sand from the floor of the Bristol Channel is impoverished, resulting in large expanses of exposed bedrock to the west of Steep Holm and Flat Holm (Figure 8.1).
- 8.1.0.6 The change in orientation of the estuary from the Bristol Channel, from east to west downstream of Flat Holm and Steep Holm to north east upstream of these locations, limits the influence of large Atlantic swells from the west within the estuary. As a consequence, the wave environment within the estuary is predominantly wind-driven. Fetches are dramatically reduced within the estuary, when intertidal areas dry towards low waters. Strong flood and ebb flows also interact with waves, leading to wave blocking<sup>1</sup> in some locations and at some states of tide.
- 8.1.0.7 The combined influence of waves and tides creates a dynamic environment which continually moves sediments around the estuary and evolves the morphology

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<sup>1</sup> **Wave blocking** occurs when strong opposing currents slow down waves leading to increased wave steepness, which may eventually lead to wave breaking. Waves get blocked when the current is strong enough to prevent further propagation of wave energy.

towards equilibrium. Over the longer term, climate change is predicted to have an influence on water levels, waves and rainfall (and associated river discharges), each of which will contribute to some further changes across the estuary.

## **8.2 Scope of potential impact to be assessed**

8.2.0.1 The development of a tidal lagoon between Cardiff and the River Usk will have a direct effect on coastal processes during construction, operation and decommissioning phases. The scope for coastal processes will therefore examine potential changes to water levels, flows and waves for each of these phases as well as how the combination of these processes influence sediment transport and long-term estuary morphology.

8.2.0.2 In the context of this chapter, contamination refers to the potential for disturbance of sediments which have a level of contamination that may be above a given action level, such as those defined in CEFAS (2003). Such sediments may occur around the estuary at specific locations where industrial inputs have or still exist or where dredging and sea disposal activities take place and, as such, they reflect on the industrial history of the estuary.

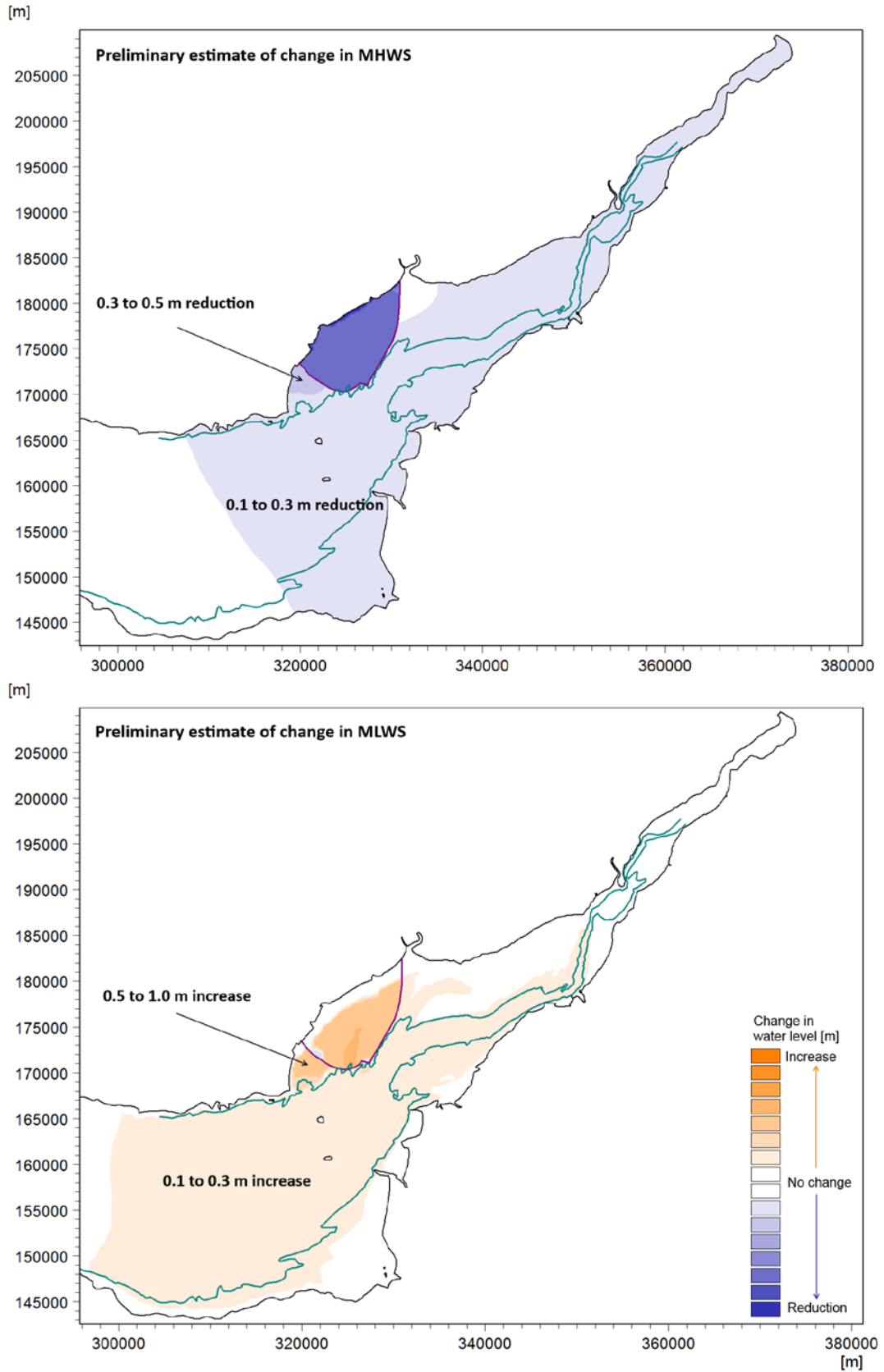
8.2.0.3 Changes to coastal processes are recognised as a primary consideration for a range of other EIA topics, notably; flood risk, water quality, navigation and marine ecology, etc. Each of these topics will require an understanding of specific issues and for specific topic related receptor features which will be facilitated by close liaison between specialists throughout the assessment process. The detailed requirements for each of these topics will be confirmed as part of the overall scope for coastal processes. Notwithstanding this confirmation process, the main issues for consideration will include, amongst others:

- i. Changes in water levels across the estuary, and within the lagoon, and how this may concern navigation, lead to a change in inter-tidal habitats, alter flood risk and modify the propagation of the tide upriver (including saline intrusion);
- ii. Modified flows changing the dispersion characteristics from wastewater outfalls, potentially affecting water quality within and external to the lagoon;
- iii. Modified flows changing the movement of sands and muds within the estuary and the potential for large scale morphological change which may affect associated ecology;
- iv. Creation of localised enhancement in flows through turbines and sluices and the extent and degree of seabed scouring. Risk of releasing contaminated sediments from seabed sediments;
- v. Changes in flows across the estuary and the implications to changes in siltation, with consequence to dredging activities for ports as well as commercial aggregate extraction operations;

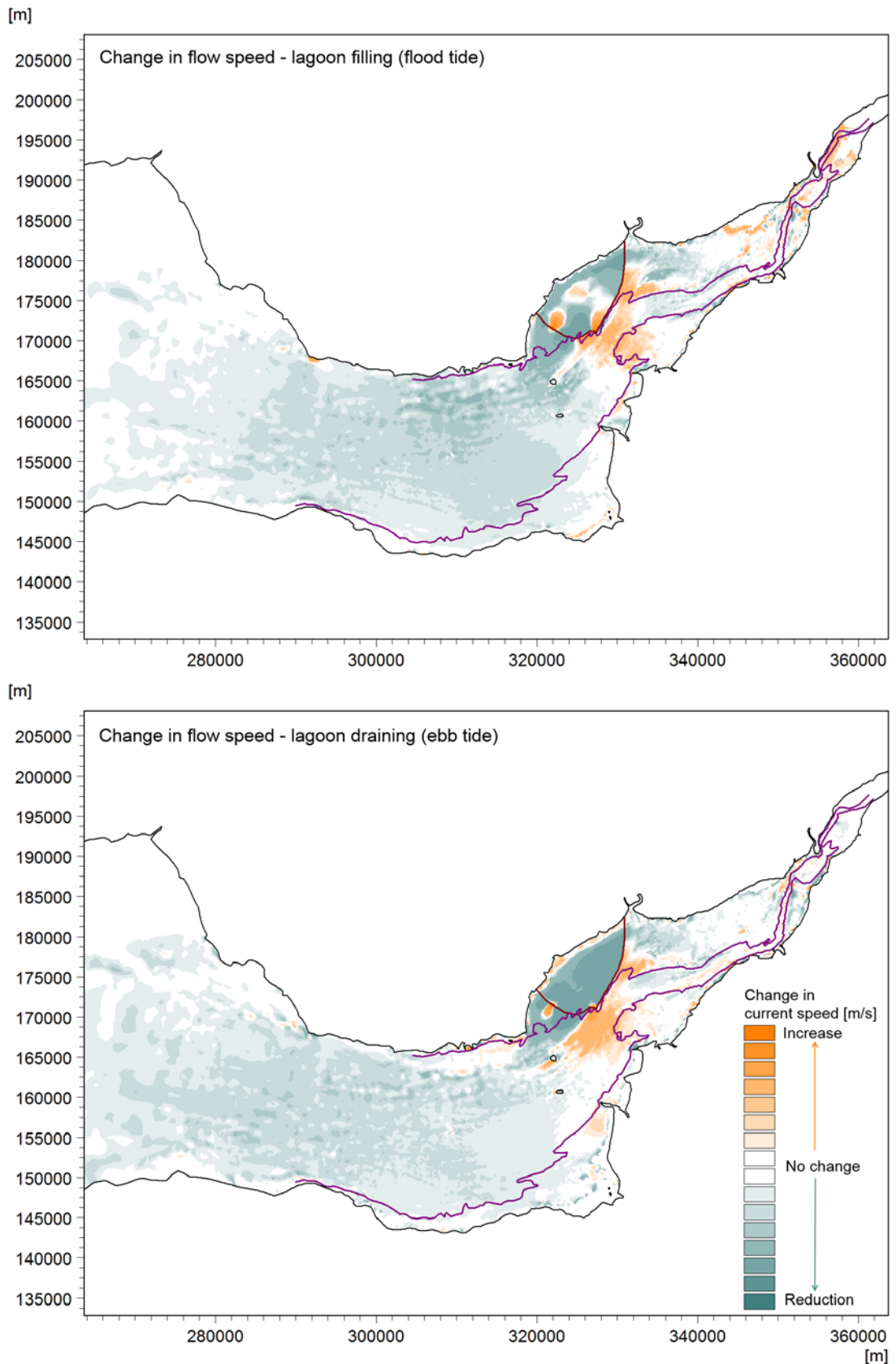
- vi. Level of siltation within the lagoon and the potential requirement of maintenance dredging and sea disposal; and
- vii. Changing the fetch characteristics in localised areas of the estuary, reducing the capacity for wind-generated waves, creation of local sheltering, changing patterns of wave energy dissipation on foreshore, altering flood risk, coastal erosion, etc.

### **Spatial extent**

- 8.2.0.4 For changes in water levels, the area involved is likely to extend beyond the estuary with far-field effects expected out to the Bristol Channel as well as effects upstream in the tributaries. The most prominent effects will be local to the lagoon (near-field), such as flow exchanges through turbines and sluices.
- 8.2.0.5 High-level preliminary modelling of the potential effects on hydrodynamics (water levels and flow) of the Project has been completed, in order to provide an indication of the likely extent and magnitude of such effects. As shown in Figure 8.2, the predicted change in the elevations of MHWS and MLWS, as a result of the operation of the Project (the approximate location of the 5 mCD contour is also shown to provide context to the predicted change in relation to the main channel).
- 8.2.0.6 The results show that the predicted extent of effect on the elevation of MHWS extends downstream approximately between Rhoose Point and Hinkley Point, and upstream at least as far as Frampton-on-Severn (the upper extent of the high-level modelling). When considering the predicted effect on MLWS, the downstream extent extends a little further, approximately as far as Aberthaw and Minehead, with effects extending upstream approximately to The Shoots.
- 8.2.0.7 When considering potential changes to flows, Figure 8.3 shows the predicted magnitude and extent of effect to flood and ebb flow speed, and during lagoon filling and draining. It is shown that the largest effect is seen in close proximity to the lagoon structure, particularly related to the filling and draining of the lagoon through the turbines and sluice gates. In both cases, the full extent of effect is predicted downstream approximately as far as Lynton, and upstream approximately as far as Oldbury-on-Severn.
- 8.2.0.8 The results of the preliminary, high-level modelling of hydrodynamics suggests that the far-field extent of the present modelling tools is sufficient to encompass the likely effect of the Project (with the model extending downstream through the Bristol Channel, out to the southern coast of Eire in the west, Caernarfon in the north and the northern coast of France in the south). This supports the findings of the Severn Tidal Power SEA (DECC, 2010), which also found the far-field extent of the modelling tools was sufficient for a lagoon option (discussed further in Section 8.4). As noted above, there will likely be a requirement to include a representation of the main tributaries within the detailed assessment, in order to investigate the potential magnitude and extent of upstream effects within the rivers Severn, Avon, Wye, Usk and Parrett.



**Figure 8.2 Preliminary estimate of predicted changes to MHWS and MLWS from the Project.**



**Figure 8.3 Preliminary estimate of predicted changes to flood and ebb flow speed from the Project.**

## Timescales

- 8.2.0.9 Changes to coastal processes will be immediate as well as lasting over the longer-term as the estuary morphology adjusts. Indicative timescales for construction suggest a period of 4 to 5 years followed by an operational phase of around 120 years. Any decommissioning would also lead to a further period of disturbance, depending on the nature of any works proposed, with subsequent morphological adjustment as the estuary moves towards a new equilibrium.

## Climate change

- 8.2.0.10 Whilst the lagoon may have a variety of effects on the estuary during each phase of development, the estuary will continue to respond to climate change effects, irrespective of whether the lagoon is developed or not. Consequently, the baseline for the estuary also evolves; therefore a future baseline in around 120 years is unlikely to be the same as the present day baseline.
- 8.2.0.11 Climate change is predicted to influence sea level, surge behaviour, waves, river flood flows and waves. The degree of change in these processes depends on which climate change scenario is applied. Present guidance from Welsh Government (2011) and Environment Agency (2011) draws on UKCP09 evidence to define change factors for each process and for periods as far as 2080 for most parameters and 2115 for sea level rise. The change factor is regarded as the most probable climate change projection and is generally related to the UKCP09 Medium Emission projection 95<sup>th</sup> %ile. To help manage uncertainties in the change factors and allow for alternative projections, the guidance offers upper and lower estimates to help bound the likely outcome and account for a wider range of future change. The coastal process investigations will draw on the guidance, as appropriate, to include for climate change influences on both baseline and lagoon scenarios.
- 8.2.0.12 Whilst climate change scenarios for coastal processes aim to follow this approach, there may be specific reasons for other EIA topics to require a different consideration of climate change. Any different requirements will be clearly highlighted with justification.

## 8.3 Existing baseline data, consultation and need for survey

- 8.3.0.1 To help inform project development, a high-level review of coastal processes has been completed, which includes an assessment of baseline data gap analysis and provides recommendations for additional data collection. The primary data types considered to support coastal process understanding include:
- i. Bathymetry (inter-tidal and sub-tidal morphology), present-day and past;
  - ii. Water levels, from tide gauges;
  - iii. Currents;
  - iv. River flows, from gauging stations;

- v. Waves and winds;
- vi. Seabed sediments;
- vii. Suspended sediments, including water sampling across the estuary and through the water column; and
- viii. Salinity and temperature, including CTD (conductivity-temperature-depth) vertical profiling.

8.3.0.2 Recommendations for additional data collection are made in the high-level review and are designed to augment the existing data and monitoring, whilst reflecting on the recommendations from the Severn Tidal Power SEA (DECC, 2010). Surveys are based on an estuary wide campaign to collect suites of measurements that will help to examine the interaction between waves, tides and sediment transport at strategic locations. Four types of survey activity are recognised:

- i. Hydrographic survey – map seabed bathymetry (surveys ongoing 2014-2015);
- ii. Geophysical survey – characterise the surface and (near) sub-surface sedimentology features (surveys ongoing 2014-2015);
- iii. Oceanographic survey – measure properties of the water column (surveys to commence early 2015); and
- iv. Benthic survey – sample surface sediments to establish particle size and contaminant levels, noting the primary objective of this survey will be to address the requirements of marine ecology.

8.3.0.3 The Oceanographic Survey includes for up to eight concurrent instrument deployments placed at strategic locations to complement existing data as well as to fill key data gaps (Figure 8.1). The final nomination of deployment locations will consider likely engineering layouts for the lagoon as well as the logistical constraints of conducting the survey. The Oceanographic Survey also includes for a comprehensive suite of water sampling to characterise the vertical structure of temperature, salinity and suspended sediments for periods over a spring and neap tide. This suite of data will help characterise the water body, confirm the requirements for coastal process modelling (e.g. 2D depth-averaged versus 3D approach) and provide important information to help validate the models used for the EIA.

### **Consultation**

8.3.0.4 The full scope of issues to be investigated by coastal processes will be confirmed from the Scoping Opinion and through stakeholder consultation, recognising these issues are likely to be drawn from a variety of EIA topics. This will primarily be through the development of a modelling work plan which will set out the proposed strategy for assessment covering the three key work components of coastal



processes (ABPMer), water quality (Intertek, see Chapter 9) and flooding (Atkins, see Chapter 10). As discussed in Chapter 2 Proposed Approach, it is proposed that the modelling work plan will be progressively developed throughout the phases of assessment through a stakeholder topic group, likely to include:

- i. Severn Estuary Coastal Group (and related to Shoreline Management Planning);
- ii. Natural Resources Wales (NRW);
- iii. Environment Agency (EA);
- iv. Natural England (NE);
- v. Cefas; and
- vi. Marine Management Organisation (MMO).

8.3.0.5 Data holdings will also be confirmed with each of the consultees to ensure use of the most appropriate information for the assessment.

## **8.4 Proposed assessment methodology**

8.4.0.1 The estuary has been the subject of potential tidal power options for nearly a century, with one of the earliest comprehensive studies being commissioned in 1926 (Gibson, 1933). More recently, the Department of Energy & Climate Change (DECC) published the cross-Government Strategic Environmental Assessment (SEA) of the feasibility of Severn Tidal Power (STP) options (DECC, 2010). The SEA examined various combinations of tidal lagoons and barrage options, but this did not specifically include an option equivalent to the Project. The SEA did, however, establish a robust framework for investigating environmental issues, including a work plan to deliver the topic of 'Hydraulics and Geomorphology'. This work plan was presented to the Government's Chief Scientific Advisors and an Expert Panel and is considered to remain largely relevant as a framework for the proposed assessment methodology for the present EIA.

8.4.0.2 The proposed assessment methodology for the EIA aims to improve the evidence base and baseline understanding by drawing together existing data and survey outputs. These data will provide a means to support the development and allow validation of suitable modelling tools to assist in the evaluation of potential impacts. In line with the SEA recommendations, consideration will be given to:

- i. The use of 3D flow modelling to support requirements for more detailed sediment modelling; and
- ii. The use of 3D sediment modelling on the assumption that suitable validation data is available (N.B. improved validation data is an aim of the Oceanographic Survey).

- 8.4.0.3 Modelling will be based on the application of the same tools used for the SEA. The far-field extents of the models are already considered sufficient for lagoon options as the SEA recommendation to extend the flow model was only relevant to a large barrage option. Preliminary modelling for the Project (as described in Section 8.2) confirms the far-field extent on water level effects is sufficiently accommodated by the model.
- 8.4.0.4 Refinements to these modelling tools will be targeted to ensure they provide a suitable level of detail, draw on up-to-date survey data and are validated locally. Outline engineering descriptions for the lagoon will help ensure the highest levels of detail are used to represent flow exchanges through turbines and sluices.
- 8.4.0.5 Key stages of the construction phase are also intended to be represented as part of the scenarios to be evaluated, such as end of Year 1, 2, 3 etc., to completion. The operational phase will then be initiated as the position that the estuary has evolved to at the end of the construction period. The possible scenarios for decommissioning (see Chapter 6) will also be considered for appropriate time intervals.
- 8.4.0.6 The modelling will include a suite of complementary tools, with short-term detailed deterministic assessment based on the MIKE FM flow model, complemented by other analytical tools to examine long term morphology, such as 2D regime theory. Interaction with other EIA topics will also be recognised, specifically with regard to the water quality and flood risk assessments.
- 8.4.0.7 Models will be applied to describe a range of representative scenarios, including an agreed range of tidal and wave conditions, along with consideration of potential future climate change effects. These modelled scenarios will help develop specific understanding of effects for specific locations and specific environmental receptors. The quantification of change in the magnitude and extent of coastal process parameters for each phase of development will be achieved by comparison between lagoon scenarios and equivalent baseline scenarios (no lagoon). The proposed approach to the assessment of the significance of effects is described further in Section 8.5.
- 8.4.1.8 Scenarios will also include for potential in-combination and cumulative impact concerns with other planned developments with the study area detailed in Chapter 3 (list of developments to be agreed with stakeholders).

## **8.5 Assessment of significance**

### **Estimation of change and exposure**

- 8.5.0.1 Whether a receiving environment can be exposed to an impact or change depends on there being a route or pathway. The magnitude of the exposure and its ability to affect a receptor also depends on a range of other factors, such as its duration, frequency and spatial extent.

8.5.0.2 Many different methods may be used to determine the exposure to changes, and in some cases it is also desirable to take account of uncertainty. Table 8.1 sets out the basic criteria proposed to determine the magnitude of the impact of the Project on the coastal processes and receptors for the purposes of the impact assessment. Whilst these are basic criteria, not all changes can be neatly defined. To take account of this the assessment will likely need to be ‘moderated’ taking account the holistic understanding of the physical system to ensure consistency.

**Table 8.1 Basic criteria for defining magnitude of impact.**

Magnitude	Definition
<i>Large</i>	Far-field spatial extent with scale of change greater than the natural variability with a continuous signal extending long-term.
<i>Medium</i>	Near-field spatial extent with scale of impact with the same order as the natural variability, frequently occurring in the long-term; OR Immediate spatial extent (the Project footprint) with scale of change greater than the natural variability, occurring frequently over a short timescale.
<i>Small</i>	Near-field spatial extent with scale of impact smaller than the natural variability, frequently occurring over a short/temporary timescale.
<i>Negligible</i>	Immediate spatial extent, with scale of impact smaller than the natural variability, occurring infrequently over a short/temporary timescale

8.5.0.3 Inevitably this process is subjective and some of the impacts that are identified will not neatly fall into these criteria. On this basis, expert judgement based on the overall system understanding will be used to ‘moderate’ the assessment to ensure consistency for each issue at different locations.

8.5.0.4 The matrix in Table 8.2 is based on the Department of Environment’s (DoE) approach to risk assessment (DoE, 1995) and is used as a means of generating an estimate of exposure. This matrix is a guide and does not always represent the true complexity of the change; therefore, some further qualification may be necessary.

**Table 8.2 Exposure to change, combining magnitude and probability of change.**

Probability of Occurrence	Magnitude of Change			
	<i>Large</i>	<i>Medium</i>	<i>Small</i>	<i>Negligible</i>
<i>High</i>	High	Medium	Low	Negligible
<i>Medium</i>	Medium	Medium/ Low	Low/ Negligible	Negligible
<i>Low</i>	Low	Low/ Negligible	Negligible	Negligible
<i>Negligible</i>	Negligible	Negligible	Negligible	Negligible

### Sensitivity of receptor

8.5.0.5 An effect can only occur if a receiving environment (receptor) is exposed to a change to which it is sensitive. Hence, it is necessary to understand the sensitivity of receiving environments. Sensitivity can be described as the intolerance of a

receiving environment to readily accept the levels of predicted change to which they are exposed.

- 8.5.0.6 The assessment of sensitivity, therefore, considers the adaptability of the environment to its former state following exposure to the impact. Sensitivity is considered as the degree of perturbation a receiving environment can tolerate in response to the predicted changes to which they are exposed. It should be noted that physical processes may, in some cases, be more appropriately considered as an ‘intermediary’ rather than a receptor in their own right, and may, therefore, not have a relative sensitivity as defined above. This stage essentially provides a benchmark against which the changes and level of exposure can be compared. In some cases it may be applicable to compare the anticipated change or exposure against either baseline conditions or other relevant thresholds such as quality criteria (i.e. for water, light or noise).

### Vulnerability

- 8.5.0.7 The vulnerability of a receiving environment is essentially the comparison of the anticipated exposure with the specific sensitivity or response characteristics. Where the exposure and sensitivity characteristics overlap then vulnerability exists and an effect may occur. Where an exposure or change occurs for which the receptor is not sensitive then no effect will occur. Table 8.3 sets out how the level of vulnerability is determined.

**Table 8.3 Estimation of vulnerability based on sensitivity and exposure to change.**

Sensitivity of Receptor	Exposure to Change			
	<i>High</i>	<i>Medium</i>	<i>Low</i>	<i>Negligible</i>
<i>High</i>	High	High	Moderate	None
<i>Moderate</i>	High	Moderate	Low	None
<i>Low</i>	Moderate	Low	Low	None
<i>None</i>	None	None	None	None

- 8.5.0.8 In determining the vulnerability with respect to coastal processes, consideration will be given to the known, past behaviour of the system at the locations of change and how this is likely to have changed due to the parameter being assessed. This is a subjective assessment based on the understanding of the natural system and set criteria for determining vulnerability are not possible to establish.
- 8.5.0.9 The vulnerability is an expression of the risk associated with an impact. Whether this ‘vulnerability state’ or risk is significant or not is then considered.

### Significance criteria

- 8.5.0.10 Estimating and categorising the significance of an effect involves a degree of subjectivity. A receiving environment may have a high or low vulnerability, but whether the potential effect is ‘significant’ may depend on other factors, such as its potential recoverability (temporary or permanent impact), its relative

'importance' (either to the ecosystem or in terms of statutory designations) or the scale of habitat/ population affected and its overall tolerability, either to the receiving environment itself or its users. Table 8.4 summarises the process of estimating an overall significance of effect based on vulnerability and importance of the interest feature.

**Table 8.4 Estimation of significance based on vulnerability and importance.**

Importance of Receptor	Vulnerability of Feature to Impact			
	<i>High</i>	<i>Medium</i>	<i>Low</i>	<i>Negligible</i>
<i>High</i>	Major	Moderate	Minor	Neutral
<i>Moderate</i>	Moderate	Moderate/ Minor	Minor/ Neutral	Neutral
<i>Low</i>	Minor	Minor/ Neutral	Neutral	Neutral
<i>None</i>	Neutral	Neutral	Neutral	Neutral

8.5.0.11 The significance statement provides a summation of the evaluation process and considers both adverse and beneficial effects, which may be categorised as being neutral, minor, moderate or major.

8.5.0.12 In summary, therefore, effects can be beneficial or adverse and can be described as follows:

- i. neutral - insignificant change not having a discernible effect;
- ii. minor - effects that are discernible but tolerable;
- iii. moderate - effects that are of a local to regional nature, of medium to long-term duration and/ or where effects are anticipated to potentially be above accepted guidelines/standards. Where these changes are adverse they will usually require some impact reduction or mitigation measure where feasible; or
- iv. major - acute effect on a national or international scale, of long-term or permanent duration, and clearly above accepted guidelines or standards (or indeed against best practice policy, or even illegal in nature). Where these changes are adverse they will generally require extensive impact reduction or mitigation.

8.5.0.13 For the proposed assessment, effects will be considered significant if they are of major or moderate significance.

## 8.6 References

CEFAS, 2003. The use of Action Levels in the Assessment of Dredged Material Placement at Sea and in Estuarine Areas under FEPA (II), DEFRA. Project AE0258.

DECC, 2010. Severn Tidal Power – SEA Topic Paper: Hydraulics and Geomorphology. April 2010.



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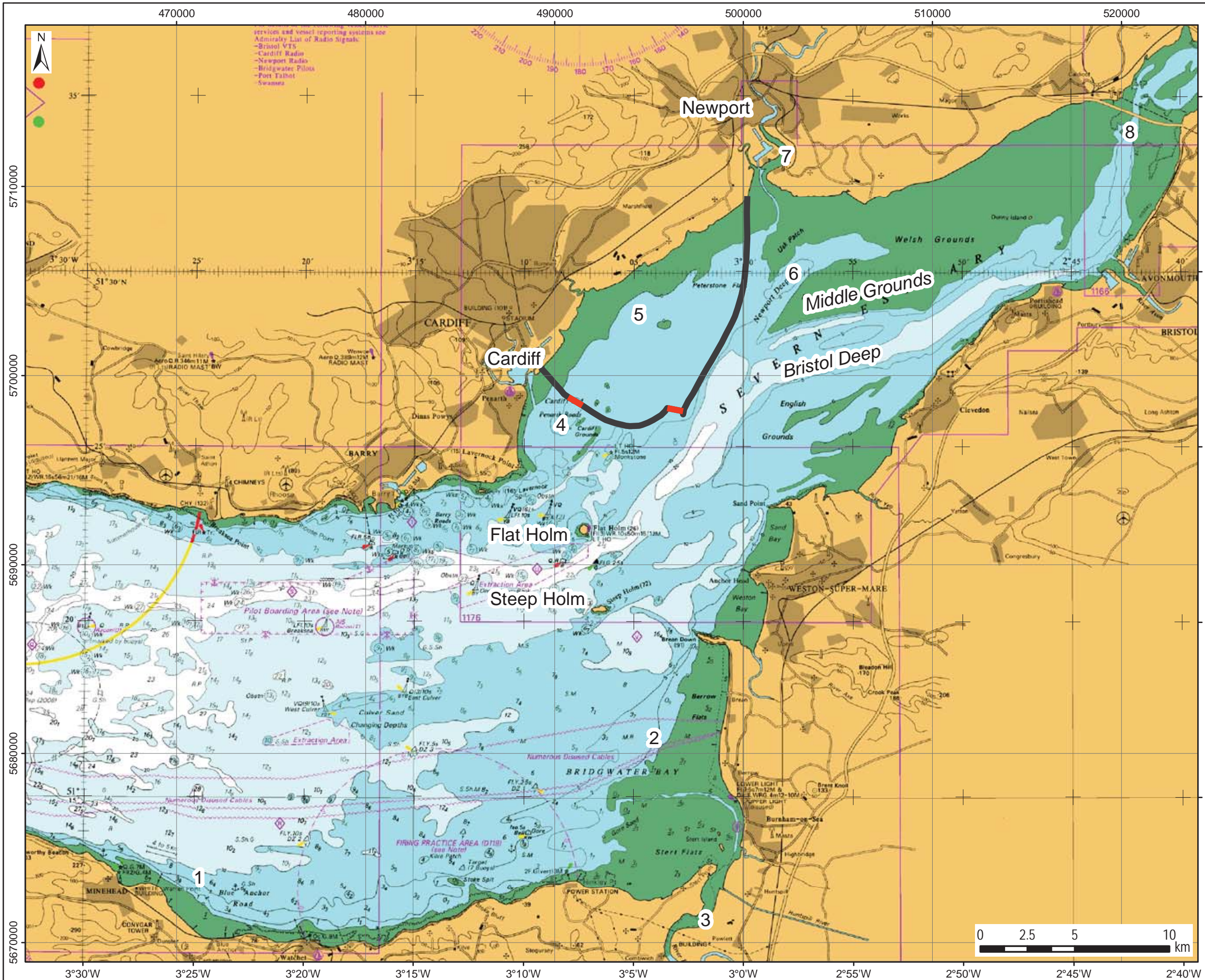
Gibson A.H., 1933. Construction and operation of a tidal model of the Severn Estuary. Severn Barrage Committee.

Welsh Government, 2011. Adapting to Climate Change: Guidance for Flood and Coastal Erosion Risk Management Authorities in Wales.



## Figures





- Proposed lagoon location
- Sluice & turbine locations
- 1-8 Planned oceanographic deployment locations

Date	By	Size	Version
Feb 15	AJB	A4	1
Coordinate System		WGS 1984 UTM Zone 30N	
Projection		Transverse Mercator	
Scale		1:275,000	
QA		DRAFT	
002_Fig_Location_Map.mxd			
Produced by ABPmer			



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Study Area



Figure 8.1