16 HYDRODYNAMICS AND COASTAL GEOMORPHOLOGY

16.1 Introduction

a) Scope of Assessment

16.1.1 The location of the site for the proposed Hinkley Point C power station (HPC) on the southern shore of the Severn Estuary and the need to site and build components of the nuclear power station across both the adjacent intertidal area and offshore means that there will be some degree of interaction between the development and estuarine hydrodynamic and sedimentary processes.

16.1.2 This chapter of this Environmental Appraisal describes the existing hydrodynamic regime and sediment transport processes operating in the Severn Estuary with an emphasis on the Hinkley Point area – i.e. the area in which these processes could potentially interact with the proposed development. The effects during the construction and operational phases of the proposed development are described. Where appropriate, measures that have been incorporated within the design in order to minimise potentially adverse change are identified and discussed.

16.1.3 The following development components have been identified as having the potential, either during construction or operation, to have an influence upon these processes:

- During construction:
    - o the emplacement of the new sea wall fronting the proposed nuclear power station;
    - o the construction, operation and subsequent dismantling of the temporary jetty;
    - o the drilling of horizontal tunnels for the intake / outfall structures;
    - o the drilling of vertical shafts for the intake / outfall structures; and
    - o the capital and any subsequent maintenance dredging of the berthing basin for the temporary jetty.
- During operation:
    - o the presence of the new sea wall;
    - o the abstraction and discharge of cooling water; and
    - o the presence of cooling water intake and outfall structures on the seabed.

16.1.4 The assessment presented in the following sections addresses the potential effects of the activities described above on processes operating within the littoral and offshore zones bordering Hinkley Point. For the purposes of these particular sections the littoral zone is regarded as the area between the seaward limit of terrestrial plants (i.e. the splash-zone, above High Water Mark) and the subtidal location where seabed sediment is not disturbed by waves. In this area, both tidally-driven and wave-driven sediment transport processes are active although the relative significance of these will vary both through the tidal cycle and according to wave conditions at any specific location. In the offshore zone of the Severn Estuary, tidal currents are dominant. The effects of the proposed development on both bedload processes (sediment particles transported in contact with the bed) and suspended sediment processes (sediment particles transported in suspension) are considered where these are relevant to overall sediment transport processes. The effects of the proposed development with regard to suspended sediment concentrations as an attribute of water quality are covered in **Chapter 17** (Marine Water and Sediment Quality) of this Appraisal.

16.2 Methodology

a) Summary of Approach

16.2.1 The methods adopted to understand and assess changes to coastal processes inevitably differ from those adopted for other chapters of this Appraisal.

16.2.2 While the development of HPC may alter hydrodynamic and sedimentary processes (both locally and potentially more widely), the significance of such a change cannot readily be measured as the processes themselves have no intrinsic value (i.e. they are not considered as a resource sensitive to change). A change to a process can only be predicted and described with respect to the known baseline. Thus, a local change in current speed that may result from the construction of a solid structure in the path of a current can be described with reference to known current speed in the affected area and the nature of this change determined in relation to natural variability. The consequences and significance of this change can be assessed with respect to those environmental resources that are influenced by current speed (or any other physical process), such as marine ecological interests.

16.2.3 The commentary in this chapter therefore focuses on describing potential change in process variables rather than defining impact. Potential impacts on marine resources caused by changes in geomorphology and sedimentary processes are described in **Chapter 19** (Marine Ecology) of this Appraisal.

b) Limitations and Assumptions

16.2.4 Due to the extremely large tidal range and tidal currents, marine surface sediments are kept in a state of almost constant flux within the Estuary. As a result the subtidal and intertidal sedimentary environment is highly dynamic. The Bristol Channel is an inherently difficult environment in which to survey sediment movements and deposits due to the high current velocities, the elevated suspended sediments load and the constant movement of bottom deposits. As a result, any detailed understanding of the distribution and movement of marine sediments, for example, quickly becomes dated. Both for this reason and due to the level of academic interest in an environment subject to one of the most extreme tidal ranges in the world, such matters have, at times, been the subject of much debate in the literature.

16.2.5 That same level of interest in the estuarine and marine environments in the vicinity of Hinkley Point has permitted the development of a high level of consensus on its key features. A reflection of this understanding, directly pertinent to the topics covered within this section as well as those on marine ecology and marine water quality and the design and operation of the engineering plant itself, is provided below.

c) Key Features

16.2.6 A consideration of the key features of the physical environment is directly relevant to both the design of engineering plant and its management within a dynamic environment.

16.2.7 The current understanding of key physical features is illustrated by **Table 16.1**.

16.2.8 In sum, the bathymetry and dynamics of the Severn Estuary make it unique in the UK. This is a highly turbid system although the seabed itself is starved of sediment. What sediment there is on the seabed is strongly affected by the Spring/Neap cycle and it is highly mobile. Where subtidal sediment is found, its depth and composition will change significantly with time.

16.2.9 The vast majority of the seabed in the Bristol Channel and Severn Estuary system is rock or coarse gravel; there is relatively little sand, and most (though not all) of the mud is in suspension or is intermittently mobilised. The sediments are not related to the hypertidal (i.e. ›

8 m tidal range) nature of the system, but rather to the geological and indeed comparatively recent industrial history (the suspended material off Hinkley Point contains a very high proportion of coal and slag-derived particulates).

Table 16.1: Key Physical Features

Key Features: Physical	Comment
Large funnel shaped Estuary facing the Atlantic	Influences fish species (particularly migratory) and other physical features, particularly tidal regime.
Large branching Estuary	Sub-estuaries absorb energy at tidal frequencies, but input energy at longer frequencies because of river flow variation. The Parrett, Usk and others are not insignificant regarding freshwater influx into the system.
High salinity variation	Seasonal and tidal variation – The Parrett significantly adds to this in the Hinkley Point area.
Estuary controlled by geological constriction	The geological constriction in the area of the Holm Islands (constraining the Estuary width and depth) is the key large scale physical feature.
Hypertidal	Rare at global scale – includes Bay of Fundy (Canada), Seine and Somme (France).
Periodic energy inputs	Spring to Neap changes are major in magnitude, resulting in a system with a major component of fortnightly change (as well as other tidal periods). Long periods of low winds reduce the suspended solids concentrations, at least in surface waters. The sedimentary system is therefore periodic, which directly effects light regime (hence production), the benthic habitats and thus the benthos.
Waves dominant in shallow water	In shallow areas, waves are dominant over the effects of tidal currents. Most important in the Hinkley Point area are the intertidal and shallow 'flats' where it is waves that are mostly responsible in terms of mobilising and/or changing the physical environment and thus affecting the biota.
Surprisingly sediment starved	The vast majority of the seabed in the Bristol Channel and Severn Estuary system is rock or coarse gravel; there is relatively little sand, and most (though not all) of the mud is in suspension or is intermittently mobilised.
Not in morphological equilibrium	For the Severn, the geological constriction at the Holm Islands means that the Estuary is compartmentalised.
No new significant sources of sediment	The limited supply of 'new' sediments makes the Severn susceptible to change e.g. from developments such as the Bristol Port and the various proposed tidal power schemes. Because of the preponderance of hard surfaces on the sea bed, and the relatively thin nature of sands and muds where present, a small change in the sedimentary regime might cause major changes in the nature of the seabed habitats – i.e. significant change can happen relatively easily.

Key Features: Physical	Comment
Physics makes change in subtidal habitats the norm not the exception	Changes to the sediment transport system have the potential to induce major changes in habitat. Changes in sediment distribution (natural and man made) are likely and these will affect habitats.
Highly turbid – unique in UK	A lot of material (many g/l) is moving about in the system (in both permanent and temporary suspension and intermittently deposited) but there is relatively little coming in from the rivers or from the outer Bristol Channel.
Entrance to the Parrett – mobile banks	The mouth of the Parrett has a variety of intertidal and subtidal banks, which consist of layered sediments and are extremely mobile. They thus tend to have low density biota.
Existing Parrett plume impact on intertidal area	Freshwater runoff peaks are significant in that they affect the extent of the plume across Bridgewater Bay.
Periodic major changes in bed elevation	Erosion/deposition cycles occur naturally and periodically, especially in outer Bridgwater Bay.
Coastline and seabed near the Parrett susceptible to change	The Stert Flats peninsula is susceptible to breaching in the longer term (century scale), and breaching would significantly affect cooling water flows across the (greatly changed) intertidal habitats.
Residual circulation	Tidal averaging of flows shows strong outward residual flow from Flat Holm to the south side of the Channel off Kilve. Recirculation cells occur to north and south. This could both trap persistent contaminants or effluent, and provides routes for fish migration. Crudely summarised as: 'fish in north, out south'. This feature persists to Holm Island. Given the small magnitude of any residual circulation compared to the regular tidal flows the significance of this feature is uncertain.

16.3 Data Collection and Surveys

a) Sources of Information

16.3.1 A wide range of studies have been undertaken over the last 50 years in order to better understand the coastal processes operating in the Severn Estuary. Much of the original work was carried out in the 1970s and 1980s and, although there has been relatively little field based data collection and re-interpretation of this data undertaken since then, much of this work remains of direct relevance to the current proposed development.

16.3.2 Much of that historical effort has been summarised and reviewed for this application and is contained in the Hinkley Point Physical Science report, BEEMS, 2009a (Ref 16.1). The material presented in this chapter is based both upon that BEEMS report and other relevant sources, referenced where appropriate. There are, in the literature, inevitable differences of opinion and interpretation of data relating to some aspects of the physical processes operating in the

Severn Estuary, notably with regard to sediment transport. Expert review of this material has thus been undertaken as part of the overall assessment work. The pertinence of any such differences in view is presented in this chapter where this is of significance in relation to the potential effects of the development on hydrodynamic and sedimentary processes.

16.3.3 The published studies have been supported and supplemented by specifically commissioned marine surveys in support of this application, during which extensive measurements of bathymetry, sediment type and distribution, waves, tidal currents and suspended sediment concentrations have been taken and, where pertinent, continue. These surveys are described in more detail in the following section. In addition, a series of numerical hydrodynamic models have been developed and been validated utilising the data arising from these surveys.

16.3.4 A desk-based expert assessment of potential scour of seabed sediments around marine infrastructure (the temporary jetty and cooling water intake and outfall structures) has been undertaken (BEEMS, 2010a (Ref. 16.2)), utilising both empirical data (such as that from the hydrographic survey (BEEMS, 2009b (Ref 16.2)), and numerical modelling outputs to determine hydrodynamic characteristics around these structures. The degree of scour is a result of a combination of prevailing hydrodynamic conditions combined with the geotechnical properties of the marine sediments.

16.3.5 Two different assessment approaches were applied to the data to predict likely scour effects: these are the SRICOS method and the Earth Materials approach (BEEMS, 2010a (Ref 16.3)). The scour assessment study only assesses the operational phase of the temporary jetty and the cooling water structures i.e. there is no assessment of the scour that may occur due to any of the temporary works associated with their construction should these extend beyond the specific operational footprint considered in each instance.

b) Dedicated Surveys

16.3.6 An intensive fieldwork campaign (BEEMS, 2009b (Ref 16.2)) to monitor oceanographic processes was undertaken in August and September 2008 covering 4 Spring-Neap cycles; see **Figure 16.1**. The work used both instrumentation deployed from dedicated survey vessels as well as fixed instrumentation. The sampling sites included three sub-tidal moorings (H1, H5, H6), three intertidal moorings (H2, H3, H4), three ADCP sections (A, B, C), a short anchor station at H1, as well as deployment of a series of drogues and a thermal-plume monitoring survey (locations are shown in **Figure 16.2**) designed to calibrate numerical modelling simulations. A summary of the measurement techniques employed is provided below.

i) Tidal Excursion

16.3.7 To obtain data on tidal excursion (flood and ebb) within the study area, standard cruciform drogues comprising a fibreglass spar buoy, suspending two 1m^2 heavy-duty polythene skirts were used during tracking surveys. The floats used were clearly numbered to aid identification, and visibility enhanced by the use of a flag. An Aquatec 510 temperature logger was attached below the float to provide temperature data on the water body surrounding the drogue.

16.3.8 Six standard drogue excursions, 4 GPS tracked drogue excursions and 1 streamline drogue study were conducted over the course of the survey with drogues deployed from 3 locations. For the standard drogue excursions, deployment commenced with the release of four drogues arranged, where possible, in a 50m box around the release point with the drogues tracked until the turn of the tide. The drogues were then followed and position fix taken on each drogue every 20 minutes by going along side each drogue to a fixed offset point on the vessel and recording its Easting and Northing. Measurements of wind speed and direction were recorded using hand held instruments at the time of each drogues fix. For the streamline studies, streamline drogues (x4) were repeatedly released from a single site to cover a complete tide (13 hours.). A location fix was taken every 15 minutes for each drogue with concurrent wind speed and direction data recorded using handheld **anemometer** and compass. At the end of 60 minutes tracking all four drogues were retrieved and re-deployed back at the release point such that a picture of the variation of tidal streams prevailing at the release site could be built up.

ii) Currents and Waves

16.3.9 Current flow measurements were undertaken using Acoustic Doppler Current Profilers (ADCP). These instruments provide a near complete profile of the flow in 3 dimensions from a single bed or surface mounted instrument. Fixed Current Profilers were deployed at the three inter-tidal sites (H2, H3 and H4) (see **Figure 16.2**) on the shore face and were equipped with a 90° head allowing their use in shallow water. They were configured to collect a profile of velocities through the water column every 600 seconds. In order to withstand the strong currents and intense wave action at these sites the instruments were deployed in specially designed stainless steel mounting brackets which were bolted to the actual shore face using special rock fastening bolts. The times during which the instrument was exposed and thus not providing valid current information was established using the instrument's onboard pressure sensor to provide information on the prevailing water depth at each measurement interval with invalid data masked out.

16.3.10 In order to provide information on the spatial variation of the currents in the vicinity of the proposed cooling water intake and outfall locations (see **Figure 19.9** in **Chapter 19** of this Appraisal) a campaign of moving vessel (MV) ADCP measurements was undertaken over a Spring tide such that data was collected over a series of three transects, with each transect line being passed along successively over a full tidal cycle. MV ADCP data was additionally collected during the two spatial extents surveys (Spring and Neap) as well as during the Spring tide anchor station. In order to acquire this dataset a 600 kHz RD Instrument Workhorse ADCP system was deployed on a sidemount pole over the starboard side of the survey vessel to record current velocities through the water column during vertical profiling of the Estuary. The instrumentation was configured to derive a velocity profile every 5 seconds which was determined to provide a good balance between the accuracy of the measurements and the spatial coverage required.

16.3.11 A Nortek AWAC ('Acoustic Wave And Current') profiler was used to obtain current profile and wave directional data. This instrument measures current speed and direction in 1-m thick layers from the bottom to the surface, detecting any type of waves created, from storm waves to boat traffic. The AWAC instrumentation was deployed at three sites (H1, H5 and H6) in specially designed low drag floatation collars (SUBS) deployed approximately 1.5m above the surrounding sea bed and configured to collect data for a period of 42 days. The mooring design provided a stable platform from which wave and current measurements could be acquired and that would be sufficiently damped such that the motion of the buoy itself would not affect the wave measurements.

iii) Turbidity

16.3.12 Turbidity was measured using an AQUAlogger 210. This was deployed at three sites (H1, H5 and H6) on top of specially designed low drag floatation collars (SUBS) which housed Nortek AWACs. The turbidity loggers were deployed approximately 1.5m above the surrounding sea bed. Wipers were added to the loggers to clean the sensors every 180 minutes, in order to prevent biofouling and improve the quality of the data collected.

iv) Water Sampling

16.3.13 Water sampling to determine suspended solids concentrations was conducted during the Spring tide anchor station. Water samples were also taken over the Spring tide period at mooring locations H1, H5 and H6 Mooring samples were collected half hourly or hourly. Onboard the survey vessel samples were collected using a Casella Water Sampler or a par pump setup with samples collected 1m above the seabed. A total of 52 water samples were collected. From the anchor station 16 samples were collected on 16-17/08/2008 from each of the three mooring locations (H1, H5 and H6) and 12 samples were collected on 17-18/09/2008. The samples were gravimetrically analysed by the Environment Agency Llanelli Laboratories using a two-paper filtration method such that salinity corrections could be applied to the data.

v) Meteorological Data Collection

16.3.14 Wind speed and direction along with sea state and weather conditions were recorded from the survey vessel on a half hourly basis during drogue survey operations. Wind speed was collected using a hand held Anemometer and wind direction via hand bearing compass. Sea conditions were assessed using standard observation techniques. A met station was erected onsite at position E 320468.6, N 146163.3 to measure atmospheric pressure, dry air temperature, wind speed and wind gust for the duration of the moored instrument deployment and survey period.

vi) Further Survey Work

16.3.15 In order to allow investigation of the relationship between winter waves, currents and suspended sediment concentrations, two Cefas 'MiniLander' deployments were undertaken at the Gore Buoy (51°13'.77N, 003°9'.66W, just north of 'Cobbler Patch') in a mean water depth of 10 m between December 2008 and April 2009 (i.e. for nearly 8 Spring-Neap cycles). As well as temperature, suspended sediment concentrations (at two elevations – 95 cm and 165 cm above the seabed), oxygen concentration, chlorophyll concentration and salinity were measured.

16.3.16 As part of a longer-term monitoring program to determine the wave climate at the Gore Buoy, a Datawell Waverider MK III buoy was deployed in mid-December 2008 and added to the national Wavenet network. The buoy is located at 51° 13.77' N and 003° 09.66' W, in approximately 10 m of water (at low tide). The buoy, which follows the wave movements, records motion using three on-board accelerometers, which are then used to construct a wave record. The buoy is held on location with a mooring consisting of an anchor weight, a rope riser and an elastic rubber bungee that allows the buoy sufficient freedom of movement to accurately follow wave motion. A wave record is generated every 30 minutes and data are transmitted from the buoy using Orbcomm satellite data telemetry. Data has been collected from this buoy since 16/12/2008; its deployment is continuing.

16.4 Baseline Environmental Characteristics

a) Hydrodynamic Regime

i) Wind and Wave Climate

16.4.1 As might be expected given the regional setting, winds at Hinkley Point are dominated by those arriving from the west-north-west. These wind directions occur around 1/3 of the time and there is an effective fetch (the extent of open water) for wave generation of 400 km. When the wind is of force 5 or above, 50% of the time it is from this sector (Rendel, Palmer & Tritton, 1986 (Ref. 16.4)). Winds from the north-west to north-east occur for around 10% of the time; with the fetch in this direction being 23 km. Winds are least frequent and are weakest from the NE-S sectors where fetch is also minimal. In combination with the regional bathymetry and coastal configuration, the result is that Hinkley Point is mostly subjected to waves from the west-north-west. The shoaling effects of the near-shore bathymetry are highly significant in determining the actual wavefield experienced on the Hinkley frontage.

16.4.2 Halcrow, 2002 (Ref. 16.5) describes a significant swell component within the wave climate of the Bristol Channel, dominated by the open fetch to the North Atlantic. Wave energy is focused at headlands, although the offshore banks do dissipate energy.

16.4.3 Waves are asserted to play a significant role in sediment transport at the coast itself (Ref. 16.5). As described, tidal circulation within the Channel is complex but is considered to be ebb-dominant with large volumes of sand and mud being transported westward in the Channel's centre. Conversely, the dominant waves from the west and southwest are held to cause littoral drift, predominantly eastward, and flood-dominant sediment transport occurs for limited periods throughout the year along the coastal fringe.

16.4.4 In order to provide additional information on the local wave climate, data was obtained between December 2008 and July 2009 (over a period of 225 days) using the Waverider at Gore Buoy, offshore and northwest of Hinkley Point in about 10 m of water (Ref 16.1). The data collected from the Waverider show that the dominant wave approach was from the west-northwest with less frequent waves from the west. Significant wave heights (the mean height of the highest third of waves) were mostly less than 1 m, but did reach over 2 m at times, with a peak of 2.3m recorded in early March. The highest energy waves with periods greater than 5 seconds approached from the west-northwest with less frequent shorter period waves from the west. **Figure 16.3** summarises the wind direction, strength and frequency and **Figure 16.4** the analogous wave distribution in terms of wave height, and **Figure 16.5** in terms of wave period.

ii) Tidal Elevations

16.4.5 The mean high water Spring and mean low water Spring elevations at Hinkley Point are 11.5 m CD and 0.8 m CD, respectively. The mean Spring tide range is therefore 10.7 m. The emplacement of structures for the new development within the Estuary would not have the potential to induce any change in tidal elevations, and this aspect is thus not discussed further within this section.

iii) Extreme Water Levels

16.4.6 The astronomical tidal elevations can be raised significantly by interaction with surge events influenced by global weather systems. Positive surges, causing higher tidal elevations in the Severn Estuary, are associated with low pressure systems crossing the Atlantic and approaching from the west. Small surges are frequent (Pugh, 1987 (Ref. 16.6)), with positive surges of about 1 m occurring every 1–2 years, and those of 2 m or more occurring on a decadal time scale (Lennon, 1963 (Ref. 16.37)). There is also a potential response to meteorological forcing at frequencies similar to the tide, resulting in intense surges which are generated and then decay during a single semi-diurnal tidal cycle. The estimated extreme water levels for a range of return periods at Hinkley Point are provided in **Table 16.2** (from Halcrow, 2007 (Ref. 16.7)).

Table 16.2: Estimated Extreme Water Levels for Range of Return Periods

Extreme Water Levels	
Return Period (years)	Level (m OD)
1:2	6.78
1:5	7.00
1:10	7.11

Extreme Water Levels	
1:20	7.19
1:50	7.29
1:100	7.33
1:200	7.38

iv) Observed Sea-level Rise and Climate Change

16.4.7 Hinkley Point has a tide-gauge station operated by the Proudman Oceanographic Laboratory as part of a national network, and this particular gauge has recorded local levels at high resolution for the past 15 years. The data shows a rise of 4.65 mm/yr for mean high water spring over this time period (BEEMS, 2009c (Ref. 16.8)). This rate is considered likely to increase in the future due to climate change.

16.4.8 Relevant sources of historical data on the range of marine hazards that could potentially be influenced by climate change, together with the most recent advice available (e.g. UKCIP, 2005 (Ref. 16.38), UKCIP, 2006 (Ref. 16.39), 1PCC, 2007 (Ref. 16.40) and the 2009 outputs of UKCIP, primarily Lowe *et al.*, 2009 (Ref. 16.41) and Murphy *et al.*, (Ref. 16.42)) have been taken into account in considering the engineering design requirements for HPC.

v) Tidal Currents

16.4.9 Tidal currents in the Severn Estuary flow from west to east on the flood tide and east to west on the ebb tide. Along the Estuary, maximum tidal current velocities increase upstream, from approximately 0.7 m/s at Lundy to 2.4 m/s off Avonmouth. Overall, tidal circulation in the Severn Estuary is considered to be ebb dominated. Data from two Admiralty tidal diamonds in the Severn Estuary; one 6 km north of Watchet and the other between Steep Holm and Brean Down, show peak ebb current velocities are slightly higher than flood velocities **(Table 16.3)**.

Table 16.3: Peak Ebb and Current Velocities at 2 Locations in the Severn Estuary (from current Admiralty chart)

	6 km North of Watchet		**Between Steep Holm and Brean Down**	
	Neaps (m/s)	**Springs (m/s)**	**Neaps (m/s)**	**Springs (m/s)**
Flood	0.75	1.45	0.85	1.6
Ebb	0.80	1.5	0.80	1.5

16.4.10 The marine surveys to gather site-specific tidal current data have already been described (see preceding section and Ref 16.2). These data show that tidal currents flow approximately parallel with the shoreline. In the subtidal zone adjacent to Hinkley Point (H1), the subtidal current velocities reached a maximum of 1.5 m/s on Spring tides and 1.0 m/s on Neap tides. Further offshore (H6), the maximum velocities increased to 1.7 m/s on Spring tides and 1.4 m/s on Neap tides. At Gore Buoy, peak surface velocities were approximately 2.0 m/s. At all locations the ebb currents were faster than the flood currents. Residual currents were to the west or northwest at H1 and H6, and to the southeast at H5. Typical currents at the intertidal zone moorings were approximately 1.0 m/s on Spring tides, but did reach a maximum of 1.3 m/s during a strong wind event. The ADCP data showed peak currents of approximately 1.4 m/s on the ebb tide. Overall, these data show that across the Estuary, current flows at Hinkley Point are smaller than those towards the centre of the Channel.

vi) Predicted Extreme Water Levels

16.4.11 The predicted pattern of wave modelling (seasonal mean and extreme waves etc) around the UK is one of high variability, although there is a suggestion of a slight decrease in the Bristol Channel area. Observations in the northeast Atlantic and southwest Approaches show considerable variability on a decadal timescale (BREEMS, 2010b (Ref. 16.9)).

16.4.12 BEEMS, 2010b (Ref 16.9) calculated return water levels for 2100 based on estimated joint probability of predicted astronomical tides and skew surges recorded at Hinkley Point 1990 to 2008 and waves recorded off Hinkley Point in 2008 to 2009. A number of increases are assumed in the calculations e.g. high water increase, skew surges increase, significant wave height increase. The results of this study are illustrative only, but indicate that by 2100 a 1:10,000 year event combination of high water levels, surge and waves could produce resultant water levels in excess of 12 m OD. This level may be compared to the proposed seawall height of 13 m OD.

16.4.13 Occurrences of extreme water levels associated with the coincidence of high tides, surges and even large waves are not necessarily of great importance from the viewpoint of coastal morphological change (erosion or accretion). Morphological changes such as changing patterns of coastal erosion / accretion or changes in the pattern of estuarine banks and Channels are brought about by the operation of coastal processes over periods of decades or longer.

16.4.14 The impact of storm waves at the shoreline during a single storm is dependent on duration, as well as the elevation, of high water levels. The expenditure of wave energy at various levels across the inter-tidal and supra-tidal zones is strongly dependent on the time interval over which higher water levels are maintained (Ref 16.9). In areas of very large tidal range, such as Bridgwater Bay, the wave energy is spread over a large vertical range during any single tide. An increase in average wave energy conditions, or the occurrence of several severe storm surge events within a short period of time, is likely to result in lowered foreshore levels. If sustained for a significant period of time, greater wave energy may be expected to enhance the break-up and erosion of the limestone intertidal platform which fronts the Hinkley Point power station and neighbouring cliffs, however, this is likely to be a progressive rather than catastrophic process. These potential changes are as a result of predicted future change in coastal processes, they are not changes as a result of the power station development.

16.5 Sedimentary Processes and Geomorphology

a) Introduction

16.5.1 This section describes information on the geomorphology and present distribution of sediments and nature of sedimentary processes operating in the Severn Estuary and Bristol Channel. Consideration is also given to potential future geomorphological scenarios for the area and changes that might be expected in relation to the distribution and transport of sediments. The importance of understanding and identifying potential geomorphological and sedimentary change has been highlighted by Turnpenny *et al.*, 2010 (Ref. 16.10). These authors note that given the long life-cycle of nuclear power stations, coastal processes in some dynamic locations may lead to shifts in bathymetry that could threaten cooling water supply. Some sedimentation can be dealt with by dredging, but the movement of offshore banks may cut off or limit flow around intake and outfall zones which could reduce coastal water exchange. Understanding the potential for such coastal process and geomorphological change at the planning stage for a nuclear power station is therefore of critical importance in order that the dynamics of these processes can be accommodated for in the design process.

16.5.2 Studies of sediment distribution and landforms can provide clear evidence for the nature and magnitude of some past environmental changes and trends, and thus give a robust basis for the development of clear indicators of possible future geomorphological scenarios. However, it is apparent that when dealing with a wide variety of physical oceanographic and sedimentary processes, across large and variable physical areas, significant uncertainty may exist in our knowledge and hence in the assessment process. For example, models of sediment transport simply do not exist at the levels of sophistication and reliability which would be required to sensibly predict the sedimentary future of the Bristol Channel and Severn Estuary system. In dealing with this uncertainty, the role of expert opinion, taking into account available information and evidence, is a useful approach to address areas of complexity and increase confidence in the conclusions reached. The work described in this chapter has used targeted expert meetings, assembled for the specific purpose of considering the potential future scenarios that this development might be subject to in the longer term, in order to review and assess available information and determine likely geomorphological and coastal process responses to the proposed development.

b) Geological and Geomorphological Setting of the Bristol Channel and Severn Estuary

16.5.3 Evans, 1982 (Ref. 16.11) described the geology and superficial sediments of the inner Bristol Channel and Severn Estuary. The area is floored by a gently folded and faulted succession of Carboniferous to Lower Jurassic limestones, mudstones and siltstones. Over much of the western part of the area, bedrock is exposed at the sea bed. In the inner Bristol Channel, this bedrock comprises gently folded Lower Jurassic (Lias) strata, comprising interbedded limestone and shales. Between Brean Down and Lavernock Point is a zone of complex folding which produces inliers of Carboniferous Limestone (the islands of Flat Holm and Steep Holm) surrounded by Triassic strata.

16.5.4 Overlying the bedrock are a series of superficial sediments which were divided by Evans, 1982 (Ref. 16.11) into: glacial till; post-glacial valley infill; thick recent accumulations and surface sediments. These sediments lie atop an incised valley drainage system, whose overall axial profile drops from -20 to -30 m OD in the east to ~-40 m north of Minehead, in the extreme west. This system represents the net effect of drainage and erosion during the last glacial period (at sea-level lowstand) combined with the erosive effects of postglacial marine inundation and estuarine erosion. It is possible that part or all of this system contains glacial sediments, but the few successful vibrocores show only sands and gravels. Glacial tills have been identified in cores on the North Devon coast, and seismic profiles indicate that this layer is a few metres thick and extends offshore.

16.5.5 The post-glacial marine transgression associated with melting of the continental ice sheets and glaciers led to the sedimentary infilling of many areas around the valley margins, such as the Somerset Levels. Elsewhere, superficial sediments form a variety of sedimentary features, including mudflats, linear sand ridges, sand banks and sandwave fields, which partly overlie older valley infill or glacial till (Ref. 16.11).

16.5.6 Close to Hinkley Point, sedimentation is strongly influenced by that of Bridgwater Bay. The bay comprises an extensive area of coastal lowland bounded in the north by Brean Down and the south by Hinkley Point. On the coast, south of Brean are a set of coastal aeolian dunes overlying post-glacial (Holocene) estuarine deposits and freshwater peats, whilst between the River Parrett and Hinkley Point, Holocene deposits are mainly overlain by storm shingle ridges which reach elevations of +6 m OD, which are in turn backed by relict aeolian sand dunes near Steart (Long *et al.*, 2002 (Ref. 16.12)).

16.5.7 Landwards of the present coastline extend the Somerset Levels, which comprise three infilled valleys – the Axe, Brue and Parrett - separated from each other by Nyland Hill, the Isle of Wedmore and the Polden Hills. Surficial deposits across the 5-10 km wide coastal plain comprise estuarine clays, landwards of which are fen peats and clays, and, in the innermost levels, raised-bog peat deposits (Kidson & Heyworth, 1976 (Ref. 16.13)).

16.5.8 Long *et al.*, 2002 (Ref. 16.12) delineated coastline changes as either small scale (over decades to centuries and one to two kilometres), or large scale (occurring over thousands of years and tens of kilometres). The large-scale changes have involved major inundations of the Somerset Levels during the early and late Holocene. The main factor to note from the studies that have been undertaken is that this is a sedimentary system which has largely adapted to the past few thousand years of coastal change. Whilst it is not liable to undergo major changes, this does mean that there is potential for change, in particular with respect to the structure of and sedimentary processes in Bridgwater Bay.

16.5.9 Hinkley Point forms a natural boundary between two lengths of shoreline along which the behaviour of physical and sedimentary processes are essentially consistent and relatively independent from the processes operating within neighbouring shoreline sections.

16.5.10 The shoreline to the west of Hinkley Point as far as Lilstock is characterised by a cliff fronted by a shore platform (**Figure 16.6**). The cliffs are approximately 3 m high in front of the existing power stations and rise up to 25 m high at Lilstock, and are composed of friable limestones and shales interbedded with mudstones of Lower Jurassic and Upper Triassic age (see **Chapter 14** of the this Appraisal for a detailed description of the geology). Fronting the cliffs is a shore platform, up to 500 m wide, composed of limestones and shales dipping to the north partially covered by a veneer of limestone and shale cobbles. A narrow storm beach is present at the junction between the platform and the cliff consisting of shingle derived from erosion of the cliffs and platform. Immediately offshore from the platform is a narrow discontinuous zone of subtidal sand and gravel, followed by large areas of mud that extend into the centre of the Estuary.

16.5.11 To the east of Hinkley Point, the shoreline forms part of the outer Parrett Estuary and is characterised by post-glacial saltmarsh and mudflat deposits. These deposits have, historically, been largely reclaimed for agricultural purposes. At Stolford, this extensive reclaimed area is interrupted by a ridge of head deposits that project into the nearshore. East of Stolford, the shoreline comprises a complex series of shingle ridges with some sand dunes fronted by a narrow strip of saltmarsh. Offshore, the sediments comprise a wide expanse of intertidal mudflat (and some sandflat) up to 3 km wide extending into Bridgwater Bay. **Figure 16.7** illustrates the distribution of intertidal sediments around Hinkley Point and **Figure 16.8** the distribution of seabed sediments.

16.5.12 Coastal erosion along the Hinkley frontage is predominantly of two types: cliff erosion and shore platform down-cutting. Cliff erosion occurs predominantly by undercutting at the cliff base (a wave-cut notch may develop particularly where shale is exposed) followed by collapse of the overlying strata. In addition to wave undercutting, it is likely that the cliffs also fail due to excess groundwater pressures just behind their face as well as weathering by rain, frost etc. Based on measurements over a period of 30 months, Rendel, Palmer and Tritton, 1986 (Ref 16.4) showed that the rate of cliff recession was approximately 0.1 to 0.5 m/yr. This rate was calculated over a relatively short period of time, and may be subject to short-term fluctuations and not representative of the long-term rate. A long-term recession rate for the cliff section along the proposed development site has been estimated as approximately 0.13 m/yr since 1888 (Halcrow, 2007 (Ref. 16.7)). The mean high water mark was estimated to have retreated 0.04 m/yr over the same time period. The rate of cliff erosion may increase in the future as a result of higher sea-levels and enhanced wave attack linked to climate change.

16.5.13 Erosion of the shore platform is caused by subaerial weathering and marine erosion processes. Weathering of the platform takes place along planes of weakness, joints and bedding planes in the limestone and bedding planes in the shales. Marine processes, particularly mechanical wave erosion leads to the detachment of cobble-sized blocks from the platform, which are then scattered across the surface. During storms, some of these detached pieces are transported by waves to form a shingle beach at the base of the cliffs. Down-cutting of the shore platform will continue into the future, regardless of the construction of any coastal defences at the cliff face, but would have no impact on the structural integrity of the sea wall. Evidence from other shore platforms around the UK with similar environmental characteristics to the Hinkley Point platform, but differing in lithology, suggests that lowering rates are likely to be less than 0.02 m.yr^{-1} Royal Haskoning, 2007 (Ref. 16.14).

c) Sediment Distribution – Bristol Channel and Hinkley

16.5.14 Due to the large tidal range and strong currents operating in the Severn Estuary the sedimentary regime is very dynamic. Deposits of fine sediments in the Bristol Channel are very mobile and a large amount of mobile fine sediment (e.g. Dyer, 1984 (Ref. 16.15); Henderson & Seaby, 1999 (Ref. 16.16)) are present in the system at any time. Suspended sediment concentrations are relatively high and bedload sediment erosion, transport and deposition is complex with many areas subject to reworking. The majority of fine sediment in the Estuary and Bristol Channel is material eroded originally from the surrounding catchments, and supplied via rivers. The hard bed rock and coastal cliffs are not a major source of fine sediment (Allen, 1991 (Ref. 16.17)).

16.5.15 There is a large variation in the type and distribution of sediment within the Bristol Channel and along the Hinkley Point frontage. The distribution and movement of different sediment sizes across the Channel is complex. Exposed bedrock covers extensive sections of the Channel bottom, particularly across the central Channel (BGS, 1986 (Ref. 16.18), Davies, 1980 (Ref. 16.19)). The tidal velocity is an important factor influencing the distribution of seabed sediment and respective grain size within the Bristol Channel and large areas of the Channel are characterised by thin veneers of sand and gravel that are mobile on the bed.

16.5.16 Regionally, the seabed is dominated by mud with significant areas of mega-rippled sand at the Parrett Estuary confluence and around Gore Sand, and coarse sediment comprising gravel and cobble substrates occur throughout the area, with the most extensive deposits to the northwest of the site, as illustrated in **Figure 16.8**. In some areas, at distance from Hinkley Point, the underlying bedrock is close to the surface beneath the mud. Locally, the intertidal and subtidal areas are dominated by the bedrock shore platform. As demonstrated by high resolution sidescan and swathe, this platform is fronted offshore by narrow strips of gravel and mega-rippled sand (Ref. 16.1), followed further seaward by mud with sand **(Figure 16.8)**.

16.5.17 Generally, sediments range from finer sediment in the east (around Bridgwater Bay) to coarser material in the west. The sea-bed sediments immediately offshore of Hinkley Point are muds (BGS, 1986 (Ref. 16.18)) and described by Wallingford, 2008 (Ref. 16.20) as a thin muddy veneer overlaying the bedrock.

16.5.18 Off Hinkley Point, the superficial sedimentary succession and spatial distribution of sediments, is well described by Mantz & Wakeling, 1981 (Ref. 16.21) whose study draws upon a total of 50 vibrocores and a variety of geophysical and oceanographic techniques. They found that most vibrocores penetrated through soft sediments to a stiff clay which lay immediately above the rockhead. In general, there was a thin topmost layer of about 10 cm thickness consisting of a brown, very soft, silty clay (representing oxidised sediments changed over the last few tides), which was underlain by dark grey, very soft, silty clay. These soft sediments were underlain in many cores by a soft, medium grey, silty clay, which in turn was underlain by a thin, firm layer or layers of peat of about 10 cm thickness at depths of 3-4 m. These organic layers finally graded into the stiff, bottom clay layer in which the vibrocores refused. Sand and gravels were also found at various levels throughout most of the cores, interpreted by Mantz & Wakeling, 1981 (Ref 16.21) as representing storm events.

16.5.19 Later work has used the presence and absence of radionuclides (e.g. ^{137}Cs) to investigate past changes in bed elevation offshore of Hinkley. At a location 1.4 km west-north-west of the existing cooling water intake, Rendel, Palmer & Tritton, 1985 (Ref 16.4) interpreted vertical changes in radionuclides and past bathymetric survey data to indicate ~2 m of sediment accumulation since the 1950s.

16.5.20 More recent analysis has been undertaken on vibrocore data from Bridgwater Bay by Long *et al.*, 2002 (Ref 16.12). Of particular relevance to HPC are the detailed results from cores taken in 2001 close to Hinkley Point (BWB11, approx 1 km NW and BWB15, 2.5 km NW of Hinkley Point respectively – see **Figure 16.9**). Based on the assumed introduction of the radionuclide ^{137}Cs into the system during atomic weapons testing in the 1950s, a maximum estimated net sediment accumulation rate of 4 $mm.yr^{-1}$ was determined for the location at BWB11 and a maximum accumulation rate at BWB15 of 18 mm/yr. For further details see BEEMS, 2009a (Ref. 16.1).

16.5.21 Both on the basis of these studies and the side scan sonar survey data BEEMS, 2009a (Ref 16.1) describes the area around the proposed cooling water intake and outfall locations as one of sediment accumulation.

d) Sediment Distribution - Bridgwater Bay

16.5.22 To the east of Hinkley Point, Bridgwater Bay is characterised by a large (18 km^2) subtidal and intertidal expanse of muddy silts. Langston *et al.*, 2007 (Ref. 16.22) describes the sublittoral substrate as highly mobile, nearly liquid mud with some areas of sand waves and isolated reefs of agglomerated *Sabellaria* worm tubes.

16.5.23 The sediment cover within Bridgwater Bay is dominated by the presence of inter tidal mudflats and sandflats. The sediments in Bridgwater Bay are mobile, both in terms of movements within the bay and changes to the height of these flats over short time scales (Kirby and Parker, 1983 (Ref. 16.23)).

16.5.24 Over most of the Bristol Channel and Severn Estuary superficial sediments are up to only a few metres thick, but in Bridgwater Bay, the present 'mud belt' (or patch) sediments (green area of **Figure 16.8**) are over 6 m thick in places. These sediments are dark-grey to black, soft, plastic, silty sandy muds with sand laminae (Ref 16.11). The seaward extent of the mud belt is clearly defined on side-scan sonar records (BEEMS, 2009d, Ref. 16.43)) but thin mud drapes and mud pebbles are common outside this limit.

16.5.25 Based on extensive datasets from geophysical surveys, water column samples and bed samples (Kirby & Parker, 1980 (Ref. 16.24) and Parker & Kirby, 1982 (Ref. 16.25) proposed that the mud belt comprises three distinct regions of mobile and stationary suspensions, and of settled mud (see **Figure 16.10**). Long *et al.,* 2002 (Ref 16.12) have demonstrated that there is strong evidence supporting long term sediment accumulation in the western part of the mud patch.

e) Sediment Transport

16.5.26 At a relatively simple level, it is considered that the distribution of sediment within the Bristol Channel correlates with maximum bed shear stress and that variation in this explains the existence of fine sediment around the margins of the Channel and sand, gravel and rocky areas in axial regions. However, the huge range of processes at work, themselves operating over a range of timescales and on different grades of material suggest that such a simplistic relationship does not fully explain the observed pattern of sediment distribution.

16.5.27 There is no major modern source of sand fraction sediment (0.05-2.0 mm) currently present for the upper Bristol Channel and Severn Estuary (Dyer, 1984 (Ref 16.15)). Bedrock, subtidal rock and coastal cliffs are made of material that would not principally produce sand grade materials and supply from rivers is likely to be minimal given the various weirs along their length (Ref 16.25). The most mobile sediments present are generally fine sands and muds.

16.5.28 A wide range of sandy bedforms can be found e.g. megaripples, sand waves, sand ribbons and such features have been observed and mapped as a result of habitat mapping exercises locally. The distribution of these bedforms is highly variable and studies of these features have contributed to the understanding of this complex sediment transport system.

16.5.29 Many studies have described an apparent net eastward (up-Estuary) movement of sand from an approximate line between Bridgwater Bay and Barry, and a net westward (seaward) movement to the west of this line. The presence of this 'sediment transport divide' is based upon various observations of sediment distributions, movements, bedforms and grain size studies (e.g. see Figure 16.11). The sediments that are transported eastwards are thought to accumulate within the Severn Estuary, on the Cardiff Grounds and Middle Grounds for example. Sediments that are swept westwards are transported into the outer Bristol Channel. This model of sand transport may be an oversimplification of the situation, and study of the bedforms in particular indicate local transport pathways and upstream coastal sand transport (flood dominated), contrasting with downstream mid-Channel movement (ebb dominated) (Harris & Collins, 1985 (Ref. 16.26) and Harris & Collins, 1991 (Ref. 16.27)).

16.5.30 Interpretation of the available wave data indicates that in the region offshore of Hinkley Point, waves will tend to enhance the tidally-driven transport by increasing bed shear stresses (Ref. 16.1). Waves are thus likely to enhance the magnitude of transport rather than greatly influence its direction. In contrast, at the coast, waves are likely to drive and dominate sediment transport to the east. On the intertidal platform this would enhance along-shore transport of any packets of sand arriving from the west, and also of gravel, pebbles and cobbles (which tend to be generated on the platform itself and at the cliff face) during storm events. The short period, height and occurrence of waves from the north north-east would not appear to provide a significant mechanism to move cobble and pebbles to the west along the shoreline.

16.5.31 Large sand deposits occur outside the mouth of the River Parrett and along Gore Sand (Ref. 16.1). Many small gravely-sand patches are located across the Bristol Channel, which includes the Culver Sand, a 'wake feature' created in the lee of the island of Steep Holm (Ref 16.20). Culver Sand is a mobile sandbank (overlying rocky sea bed) and is steadily moving westwards, as shown from historic charts. It is considered highly unlikely that Culver Sand will migrate inshore and pose a significant risk to the proposed intake structures as the evidence indicates that Culver Sand is migrating away from the proposed intake location, and is likely to continue to do so (Ref. 16.20).

16.5.32 The distribution of sediments within Bridgwater Bay is influenced by the presence of the River Parrett. The Channel of the River Parrett turns to an east-west orientation below the low water mark and meets the Bridgwater bar offshore of Hinkley Point. This low water Channel disrupts the pattern of muddy sediments within Bridgwater Bay and the route of the low water Channel exhibits an area of sand, which overlays the mudflats.

f) Suspended Sediments

16.5.33 The dynamic processes operating in the Severn Estuary, in particular the strong tidal currents, lead to erosion of intertidal and shallow subtidal deposits and active re-suspension of muddy seabed sediments. The suspended sediment levels in the Estuary can be exceptionally high. A field campaign, quoted in HR Wallingford, 2008 (Ref. 16.20), recorded suspended sediment concentrations in the Bristol Channel within the range of less than 100 mg/l to approaching 200,000 mg/l (fluid mud).

16.5.34 The Institute of Ocean Sciences (IOS) undertook five years of vertical sediment profiling covering an area between Watchet and The Shoots. This data was built up into representative Spring and Neap tide distributions of suspended concentration and is presented in Kirby and Parker 1981 (Ref. 16.28), Parker & Kirby, 1982 (Ref 16.25) and Kirby, 1986 (Ref 16.29). A summary plot of the survey results for observed average suspended concentrations from Kirby, 1986 (Ref. 16.29) is shown in **Figure 16.12** and illustrates the strong variation in surface to bed values for Spring and Neap tides.

16.5.35 The greatest suspended sediment concentrations found during the marine water quality sampling campaigns (see **Chapter 17** of this Appraisal) were recorded closest to the sea bed, which is consistent with data recorded from previous studies. Turbidity measurements at the three subtidal stations (H1, H5 and H6 – see **Figure 16.2**) recorded suspended sediment concentrations in excess of 1 g/l on both flood and ebb spring tides (BEEMS, 2009b (Ref. 16.2)). Suspended sediment concentrations are strongly linked to tidal current velocity (**Figure 16.13**).

16.5.36 Studies to date that have recorded a split in suspended sediment concentrations indicating the presence of a sediment front running down the centre of the Estuary, with the highest concentrations occurring on the English side and clearer water on the Welsh side of the Channel (Ref 16.22). It should be noted however, that concentrations across the Bristol Channel are highly variable and the main control on suspended sediment concentrations is undoubtedly tidal velocities. Generally, suspended sediments are greater on the flood than the ebb, greater during Spring tides when compared to Neaps and proportional to tidal range. Freshwater inputs are considered unlikely to play a significant role in the observed level of suspended sediment concentration, although the main rivers do continue to supply fine sediment into the Estuary system.

16.5.37 The bedrock and coastal cliffs are not likely to be a major source of fine sediment. Regionally, suspended sediment concentrations are highest between Avonmouth and Bridgwater Bay, including the waters fronting Hinkley Point (ABPmer, 2006) (Ref. 16.30).

16.5.38 A mineralogical analysis of suspended material collected off Hinkley Point (BEEMS, 2010c (Ref 16.31)) found that 57% of particles within the modal size of the ›63 µm fraction of 152.2 µm were composed either of coal or heavy iron-rich minerals, probably industrial slag remnants. The remainder of material was predominantly made up of quartz grains.

g) Longshore Sediment Transport

16.5.39 Halcrow, 2007 (Ref. 16.7) defined a series of coastal units around Hinkley Point, and noted historic evidence for and magnitudes of coastal change. Halcrow's 'Unit 4' covers the frontage of the proposed development site, where evidence indicated that the interbedded limestones and shales of the Blue Lias cliff top has retreated at around 0.13 m/yr since 1888, and mean high water mark by 0.04 m/yr. Material arising from this retreating frontage and from the rocky intertidal shore itself will be entrained by wind, wave and tide driven processes and as the dominant waves pattern suggests a trend of transport to the east, the geomorphological characteristics of the shoreline to the east of Hinkley Point are discussed in more detail here.

16.5.40 Kidson, 1960 (Ref. 16.32), Kidson & Carr, 1961 (Ref 16.33) and Rendel, Palmer & Tritton, 1985 (Ref. 16.4) studied the pebble ridges between Stolford and Steart, which form the primary beach defence. These are the Catsford, County Wall and Wall Common complexes comprising modern active ridges seaward of older 'fossil' ridges. The coast at Hinkley Point forms part of an intertidal pebble and cobble transport pathway to the east which supplies these features. This transport system is most active in the upper intertidal zone, around MHW and above. The pebble ridges were perhaps emplaced at the same time as the Dune belt at Brean, at around 3-4 ky BP (i.e. three to four thousand years before present day) (BEEMS 2009a (Ref. 16.1)). The planform morphology, mapped location and mineralogy of these shingle ridges indicate long-term migration to the east, possibly accompanied by a temporal change in the sediment source.

16.5.41 Ravensrodd Consulting, 1966 (Ref 16.34) note evidence for the W-E transport pathway:

> *"The overall pebble size in the complexes decreases from west to east, although all sizes are present throughout the length. In the west a half of all large material and most of the total is limestone, with other lithologies only in the smallest shingle. At the extreme eastern end only 10-20% limestone remains, the 80-90% fraction of Fenning Island gravel (near Stert Point) being ORS [Old Red Sandstone] sandstone pebbles. Kidson (1960) [Ref 16.32] attributes this longshore gradation in lithology to destruction of the limestone along the transport path. He notes that older ridges inshore have a much greater abundance of sandstone pebbles than their offshore equivalents and attributes this to source variations with time. Possibly the Lias Limestone bedrock has only recently become exposed following erosion of the intertidal sand and later underlying mud deposits?"*

16.5.42 Ravensrodd Consulting (1996) (Ref 16.34) also noted that:

> *"It is clear that little new material currently reaches the shingle complexes from the west".*

This is supported by a study involving the injection and tracking of shingle across a number of intertidal transects for 3 or 6 months over the Winter period, including one gale which included gusts of gale Force 10 (48 knots). This work, reported in Rendel, Palmer, & Tritton, 1985 (Ref 16.4) led these authors to conclude that shingle does not leave the spit in front of Catsford Common *"in significant quantities"!* They thus stated that the Wall Common Complex and areas to the east may therefore be: *"considered as isolated from any influence on littoral drift by the power station".*

They also stated that: *"The power station is not acting as a barrier to the transport of the pebbles and cobbles around the Hinkley Point itself".*

16.5.43 Erosion of these beaches has been a chronic problem for many years, so much so that the Environment Agency is actively maintaining the ridges by artificial heightening and re-profiling to prevent flooding of the low-lying land behind. This policy is potentially going to be abandoned and replaced by a managed realignment policy. The Parrett Estuary Flood Risk Management Strategy (Environment Agency, 2009 (Ref. 16.35)) described four scenarios for managed realignment of the area to the east of Hinkley Point, with a breach located through the shingle complex in all four cases.

h) Sediment Budget

16.5.44 Such is the dominance of tidally-driven sediment transport processes within the Severn Estuary and Bristol Channel, summaries of sediment budgets for the entire system (i.e. the balance of sediment volumes entering, residing in and leaving the Estuary) are generally presented in terms of suspended sediments alone. Suspended sediments include fine sediments as discussed above but also sand grade sediment fractions. **Figure 16.14** (after ABPmer, 2007 (Ref. 16.36)) summarises the sediment budget. ABPmer, 2007 (Ref 16.36) reports a long residence time for suspended solids material in the Severn Estuary and Upper Bristol Channel area, with little gain or loss from the system.

16.5.45 The intertidal zones are composed largely of relict sediments (Ref. 16.22), although short term deposits will occur during calm conditions; as such, intertidal mudflats will act as localised small capacity sinks. The sub-tidal zone is the most important sediment sink (Ref 16.22) and probably receives as much as two million tonnes annually. Conversely, erosion of tidal flats represents a major source of sediment to the Bristol Channel. To put these values in context, Langston *et al.*, 2007 (Ref 16.22) describes the combined total of fine sediment present in the subtidal mudflats, wetlands and in the water body as amounting to 1.16 x 10^{10} tonnes.

16.6 Assessment of Effects

a) Introduction

16.6.1 In this section, potential effects on hydrodynamic and sedimentary processes associated with the construction and operational phases of the proposed development are assessed. Unlike many other environmental parameters specific impact significance ratings are not provided. This is because essentially these processes have no attributable value or sensitivity and effect is limited to a potential change in a physical parameter (e.g. current velocity) that may be of a certain magnitude. For the purposes of assessment, therefore, an indication of the magnitude (or extent) of change from observed values is described. Where possible the assessment is quantified through comparison of predictions with known values. The implications of any predicted changes in hydodynamic and sedimentary processes on environmental parameters that are inherently linked to these processes (e.g. marine ecology) are presented in the relevant Chapters of the Environmental Appraisal.

16.6.2 Potential effects during construction and operational phases are considered separately and assessed in the context of the baseline description.

16.6.3 The key elements of the development during the construction phase that could affect the hydrodynamic and sedimentary regime are:

- the emplacement of the new sea wall fronting the proposed nuclear power station;
- the construction, operation and subsequent dismantling of the temporary jetty;
- the drilling of horizontal tunnels for the intake / outfall structures;
- the drilling of vertical shafts for the intake / outfall structures; and
- the capital and any subsequent maintenance dredging of the berthing basin for the temporary jetty.

16.6.4 The key elements of the development during the operational phase that could affect the hydrodynamic and sedimentary regime are:

- the presence of the new sea wall;
- the abstraction and discharge of cooling water; and
- the presence of cooling water intake and outfall structures on the seabed.

16.6.5 These structures may lead to changes in:

- bathymetry;
- current regime; and
- wave regime.

16.6.6 Any change to the local hydrodynamic regime (e.g. through the emplacement of structures in the Estuary) may also have an influence upon sedimentary processes.

16.6.7 In considering HPC, full regard has been taken of the existing hydrodynamic and coastal geomorphological processes when considering engineering design, siting and appropriate plant management issues. The aim has been to find design solutions that are both fit for purpose and fit for the environment in which they need to work. Taking this approach, the overall aim has been to, as far as practical, maintain the established dynamic equilibrium, and therefore limit alterations to existing processes, thus in turn limiting any knock-on effects for environmental parameters such as ecology. Thus the measures that have been, and will be, employed in limiting potential change are:

- appropriate engineering design;
- appropriate construction methods; and
- appropriate working practices.

16.6.8 Given the very high suspended sediment concentration of the Severn Estuary, the marine waters and the physical habitats associated with them have a particularly low sensitivity to potential releases of sediment-laden water during the construction and operation phases. Similarly, the extremely dynamic nature of the Estuary (i.e. almost exceptionally large tidal range on a global scale, combined with high current speeds), its physical scale, and the level of temporal and spatial variance that are already the norm due primarily to tidal processes strongly suggest that in order for any significant change to occur a human intervention in the system would, itself, have to be very significant indeed. Within this context, the main marine infrastructure components considered as a part of this development are, in comparison, either of a very small scale (e.g. the intake-outfall structures) or designed so as to be transparent to coastal processes (e.g. the temporary jetty). These factors are reflected in the following assessment of the likely effects of the works on estuarine processes.

b) Construction Related Effects

16.6.9 Construction by its very nature is temporary and therefore any effects that works during construction may have on hydrodynamic and sedimentary processes, even in a very much less dynamic system than the one involved here, will tend also to be of a temporary nature. Additionally, as construction is defined as the actual process of building (rather than the built structure itself), effects tend to be largely related to the disturbance to the system that construction generates. In dynamic, large-scale systems, such as the Severn Estuary, construction related disturbance events (e.g. sediment released during excavation on the foreshore) are likely to be localised and transient, and thus small scale in magnitude. Overall, it is therefore generally the case that construction causes very limited change to hydrodynamic and sedimentary properties, unless it is either prolonged or undertaken at a very significant scale (e.g. large-scale dredging). For HPC, construction for the coastal / marine located infrastructure can be generally viewed as being of relatively short duration and localised with respect to the scale of the system. The following text reflects this understanding.

16.6.10 As the temporary jetty will be constructed and operated during the construction phase, both its construction and operational effects are considered in this section.

i) Land based Drainage Works

Increase in Suspended Sediment Concentrations

16.6.11 During onshore construction activities (tunnel boring, dewatering, earthworks and site drainage), it is anticipated that existing watercourses will be removed and two main drains will be put in place. These drains will take most of the surface water run-off from the construction site via a dedicated drainage system, incorporating means of treatment as appropriate, and then discharge water to the foreshore (see **Chapter 15** of this Appraisal for details).

16.6.12 Discharges of suspended sediment of less than 50 mg/l are anticipated. As described above, background suspended sediment concentrations within the Estuary are generally extremely high, in the order of 1 g/l near bed within 5m water depth rather than this few 10s of mg/l. The impact of such a dilute suspended solids loading, would be discernible within only a few metres of the discharge itself.

ii) Influence of the Temporary Jetty

16.6.13 Information on the design and construction of the temporary jetty is provided in **Chapter 2** of this Appraisal. The key build elements of the jetty are summarised below:

- It is a temporary structure with an expected operational lifespan of 7 years, after which it will be dismantled and removed;
- It will be located on the western side of the Built Development Area West;
- It will comprise a piled bridge structure of 500 m in length that terminates in a jetty head in order to accommodate berthed vessels and off loading plant;
- Construction would be undertaken from both land and sea (e.g. using a jack-up barge or platform);
- Steel tubular piles of the order of 914 mm diameter will be installed into the bedrock layer at intervals across the intertidal shore and near sublittoral, in order to support the bridge structure; the jetty head and associated dolphins would also be supported upon piles likewise installed to bedrock;
- The operating face of the jetty head would be aligned with the direction of ebb/flood tidal currents in the vicinity. A berthing pocket immediately associated with that operational area would be dredged in order to allow safe delivery of materials across a range of tidal conditions. This dredged area is estimated to be 220 m in length and 40 m in width with sediments removed to a uniform depth of around 2 m below the existing seabed (4.5 m BCD); and
- Delivery of materials from the Jetty head to the shore will be by covered conveyor for aggregates and a closed pipe delivery system for cement.

16.6.14 The route chosen for the jetty, following a consideration of engineering practicability, navigational safety, and environmental sensitivities, crosses a gently sloping section of the shore dominated by an exposed rock platform before extending into the near sublittoral, where it first crosses a relatively steep exposed rock slope and then extends on to the edge of the extensive muddy plain habitat that dominates the local seabed (BEEMS, 2009d (Ref 16.43)).

The Jetty Structure

16.6.15 The location of the Jetty both on the foreshore and within the shallow sublittoral means that it has the potential to have a localised influence on the hydrodynamic regime and, in turn, on sediment transport.

16.6.16 The existing hydrodynamic regime as described in **Section 4** is characterised by an extremely high tidal range (classified as 'hypertidal' – having a mean spring tidal range in excess of 8 m, in this instance of 10.7 m) and very strong tidal currents. Local hydrodynamic conditions are thus highly energetic. The dominant influence of tidal regime will decline in shallower water and as one moves up the shore, and the length of this jetty, wave driven processes will tend to dominate instead. This high energy system, is responsible for the scouring of the rock platform across which this jetty would run. It is solely the presence of the piles supporting the proposed jetty that would have the potential to influence the currents and waves that cross its path.

16.6.17 As the Jetty has been designed as an open structure potential effects on hydrodynamic processes, notably tidal current flow, are very much more limited in comparison to a solid structure. The main effect on hydrodynamics therefore relates to any resistance that the piles will have on tidal flow together with any consequential scour of sediments due to turbulent flows at their base (see BEEMS 2010a (Ref. 16.3)). The pile diameters and spacings represent less than a 4% obstruction of the cross section, across the tide. While there will be small-scale local eddies shed off these piles, these will tend to extend for only a few radii (3-4 m) downstream and would mean that changes to the flow regime would only be localised and not extend more than 50 m from side of the structure.

16.6.18 Given the proposed position and length of the jetty, the majority of the supports will be founded in the limestone/shale bedrock foreshore platform. Due to the relatively hard nature of the rock forming the platform, any scour that might occur would be negligible. At the seaward end of the jetty the bridge supports would be driven through several metres of unconsolidated sediment which is more likely to erode.

16.6.19 An expert assessment utilising both existing information on tidal bed shear forces, sediment characteristics and a knowledge of the proposed engineering design has been completed (Ref. 16.3). The scour depth predicted to occur in these relatively soft sediments is 1.3 m – this depth presumes a side to side placement of piles but for a single pile this reduces to 1.1 m where there are no group effects. The lateral extent of scour may be calculated from the angle of repose for different sediment types, and assuming the worst-case repose angle of 26 degrees for loose non-cohesive fine sand this equates to radial scour extent of 2.7 m for a paired jetty pile.

16.6.20 Any eroded material would be quickly transported and incorporated into either the overall suspended sediment load or bed load. The total volume of sediment that could be eroded and transported in this manner would be extremely small and would form a negligible addition to the large volume of transported bed load and suspended sediment.

16.6.21 There is a potential for the jetty supports located in the upper part of the foreshore to partially impede any longshore wave driven sediment transport to the east. The height at which predominantly cobble and shingle deposits are found on this length of shore strongly suggests that they are mobilised only during episodes of severe weather and heavy seas. The jetty structure is intentionally designed to be as transparent as possible to such wave trains not least as attempting resistance instead would require a very much more substantial structure. In addition, the historical data reviewed above indicates that very little shingle from the western side of Hinkley Point is transported eastwards. Hence, the presence of the jetty supports on the upper shore platform would not lead to any significant reduction in the volume of sediment supply to the east of Hinkley Point.

16.6.22 During construction of the temporary jetty, plant and operating platforms may be required. For example piling works may be conducted from a jack-up barge. The presence of these structures / vessels in the water column may cause a localized and temporary disturbance to current flow, much in the same way as the piled legs of the jetty. Given the extremely small spatial scale of the footprint of any plant in relation to the total foreshore platform and subtidal area, and the existing dynamic and energetic conditions, any change in flow conditions would be extremely localised and probably not discernible. Given this negligible influence on hydrodynamic conditions it follows that there would be a negligible effect on sediment transport processes. Any effect, however localised, would only persist for the duration of the construction period itself (approximately 12-18 months).

16.6.23 Installation of the piles for the jetty, through either a 'drill and drive' or a 'pre-drilled and socket' technique, will cause some release of sediment and disturbance of seabed sediments at and around each pile location. This disturbance would be very localised in extent and sediment redistribution by tidal processes, both during the construction period and following the cessation of construction, would be rapid.

Dredging of the Berthing Basin for the Jetty

16.6.24 Capital dredging of a seabed area approximately 220 m by 40 m, to a depth of approximately 2 m below the current sediment surface, yielding approximately 17,600 m^3 of sediment, will be required to establish the berthing pocket. Subsequent maintenance dredging may be required to keep this pocket operational but the degree to which this will actually be required, given the high bed shear forces associated with existing tidal regime, is unknown. The dredging will potentially have two main effects: release of suspended sediment during the dredging operation itself, and changes to hydrodynamics caused by a localised increase in water depth.

16.6.25 The local change in bathymetry associated with the removal of sediment has the potential to affect hydrodynamics (local tidal current velocities and wave climate) and in turn sediment transport. Although the increase in water depth generated by the berth would represent a significant change locally, within the scale of the wider dynamic processes operating in the Estuary, such a small scale change would be expected to have a negligible effect on processes outside of the immediate vicinity of the dredged berth. A small-scale decrease in current velocities over the depth of the water column facing the berth might be expected and this will tend to be greater in the lower half of the tidal cycle than the upper. This influence would be limited, very largely, to the lateral and longitudinal extent of the berthing pocket itself. There would be no consequence for the tidal regime at a wider scale and the only uncertainty is at what rate the berthing pocket itself will infill with fresh sediments.

16.6.26 It is assumed that the bulk of the sediments that would be removed from the dredge berth represent deposits of relatively recent geological age, which do not currently form part of the overall sediment budget of the system. As such, the potential loss from the system is not considered of significance. Depending on the dredging method used, it is possible that a proportion of the sediment could be maintained within the system and entrained into the local and potentially wider sediment transport system. Given that the volume of sediment to be dredged is very small within the context of the Estuary sediment budget it is unlikely that, whether or not the material were to be kept within the system, its effects would be discernible.

16.6.27 During dredging, suspended sediment released into the water column would generate a sediment plume that would extend out from the dredge area. The extent of the plume would vary according to a number of factors, chief amongst which would be: the composition of the sediment being dredged (e.g. fine or coarse grained), the dredging technique employed and the tidal / wave conditions at the time of dredging. It would be expected, given the relatively strong tidal currents that material within the plume would be relatively quickly dispersed and either form part of the fine sediment suspension load or be transported as bed load and deposited in appropriate locations. Again, given the volumes involved it is not considered likely that the local or wider deposition of sediment from the plume would have any effect on existing bathymetry, transport processes or depositional bedforms. The potential water quality implications of the suspended sediment generated during the dredging are considered in **Chapter 17** of this Appraisal, on marine water quality.

iii) Seawall Construction

16.6.28 The alignment of the of the 13 m high, 760 m long seawall fronting the cliffs along the western half of Hinkley Point will approximately follow the line of the existing cliff face. The wall toe will be provided with scour protection in the form of large rock pieces. Some minor reprofiling of the upper shore cobble and shingle deposits will then be undertaken to cover the scour protection rocks. The wall will be aligned with the existing sea wall across the frontage of the Hinkley Point A and B stations and in common with that engineered frontage will present a series of smooth curves in plan view. A vehicular access ramp to the foreshore will be included at the extreme western end of the sea defence wall. Additional scour protection is needed around the base of the access ramp area.

16.6.29 The construction of the sea wall would typically involve the following sequence of events:

- Excavation of the cliff face material for sea wall alignment;
- Construction of a temporary haul road and foreshore access;
- Construction of a sea wall footing and base;
- Excavation of material for the toe;
- Rock importation by barge to the foreshore and subsequent rock placement;
- Installation of a drainage system behind Sea Wall;
- Construction of Sea Wall sections in turn;
- The placement of backfill behind each new concrete Sea Wall section in turn;
- The construction of access steps and ramps; and
- The reinstatement of footpaths and fencing.

Littoral Sediment Regime

16.6.30 The construction and installation of the sea wall has the potential to release sediment into near-shore waters due to runoff from the works, excavation of the cliff face and other allied activities.

16.6.31 The discharge of sediment loads from onshore to the adjacent littoral area will depend on site activities and will be variable throughout the construction period. The volumes involved are not expected to be significant within the context of existing sediment loads present across that littoral area. The works could result in additional volumes of sediment being introduced to the upper shore, thus available for wave-driven transport. Fine grained sediment would be expected to be rapidly lost due to tidal action, while blocks of limestone and shale (unless removed from the site) would be expected to remain in situ or potentially be entrained and gradually transported locally (eastwards and down shore) by storm events over time.

iv) Drilling of Horizontal Intake/Discharge Tunnels

16.6.32 Horizontal tunnels associated with the proposed power station cooling water system will be excavated from onshore. The construction process for the drilling of these tunnels is described in Chapter 2 of this Appraisal. There is the potential for the water from this process to be discharged across the foreshore. This discharge would contain suspended solid concentrations of approximately 1 g/l (including 5% bentonite) and be discharged at a rate of about 60 m^3 per hour. It is notable that this level of turbidity is within the existing range in estuarine waters local to the site itself.

16.6.33 Given that the concentrations estimated to be discharged through the mud-assisted drilling process are similar to the background suspended sediment concentrations recorded in the Estuary, and that the volume and rate of discharge would be very small compared to the volume and suspended sediment load already present in the receiving water body, the effect on sedimentary processes is considered to be very small. The additional loading to the Estuary sediment budget locally would simply contribute to existing trends in deposition, adding to these to very minor degree, across a very wide area (Ref.16.1).

v) Changes Caused by Drilling of Vertical Wells

16.6.34 A number of vertical wells are planned to be drilled using a wet drill technique in the offshore zone. The majority of these will be excavated with an aperture diameter of 5m to a depth of 30 m below seabed, approximately 3.3 km offshore, and will be associated with the two horizontal intake tunnels. A further vertical well, associated with the outfall tunnel, will be excavated to 20 m below seabed, with an aperture diameter of 8.3 m.

16.6.35 Wet drilling would be undertaken from a rig platform fixed to the seabed with piles and anchors. Waste materials from the operation would be contained and transported from the working face below to the platform itself where solids and water would be separated. The processed water would be discharged back into the Estuary, and solids would be transported away for disposal by barge. At the water discharge point, some suspended sediment would be released into the water column. The concentration of sediment in the discharge water will be extremely low compared to the background Estuary levels and the effect is considered to be negligible.

16.6.36 The presence of the rig platform would locally alter the hydrodynamics due to change in flows around the piles and anchors. Given the negligible size of the structures relative to the extent of the surrounding seabed and Estuary, the changes to the hydrodynamic processes and hence changes in sediment distribution (erosion and accretion patterns) would be very small and local, and within the range of natural variability. In addition, the works would be of a temporary nature and after the removal of the rig the seabed would be expected to revert to its pre-construction condition.

16.7 Effects Likely to Occur During Operation

16.7.1 This section focuses upon those elements of the operation of the power station that would have the greatest potential to affect hydrodynamics and sedimentary processes. These are completed and permanent infrastructure in the intertidal and subtidal zones including the seawall, and intake and outfall structures, and the discharge of cooling water into the Estuary.

a) The Presence of the Seawall

i) Hydrodynamic Processes

16.7.2 While the seawall will be constructed largely along the line of the existing cliff there will be some small scale deviation from the current cliff line. At a small-scale, a change to the existing form of the cliff line might result in localised change in hydrodynamic conditions (e.g. alteration to current velocities), but in practice this will only occur under conditions of extreme high tide as the vast majority of the intertidal shore will remain unaffected. Any impact on the tidal regime would thus be negligible.

16.7.3 The vertical, concrete face to the seawall would present a slightly different profile to that of the existing cliff section. Although the vertical profile of the existing cliff is similar to the seawall, the small-scale variations in slope along its length and in profile, give the natural cliff a more energy absorbing surface than the solid concrete face of the seawall would provide. As such, the potential for an increase in wave reflection exists. The outcome of this change is difficult to predict but is likely to impact upon the rate of transport of any available cobble/shingle material at its foot. Potentially the increase in wave reflection would increase the rate of sediment transport to the east, but as the location of the seawall at the upper margin of the littoral area effectively limits its interaction with tidal processes to all but the highest tides this slight alteration in properties would be unlikely to affect current sedimentary processes to any great degree.

ii) Sediment Release from the Cliff section

16.7.4 The seawall would eliminate any further contribution of sediment (via erosion and weathering) from the cliff section that it would replace. Estimating the volume of material that the cliff presently provides to the sediment budget is difficult. However, at 760 m in length and approximately 7-8 m in height, the cliff section represents a relatively small proportion of the existing cliff exposure between Minehead and Hinkley Point. Cliff exposures of potential coarse sediment sources (largely shales and limestones) extend for approximately 20 km to the west, with cliff heights reaching 30 m. On the basis of section length alone, the 760 m cliff section that would be lost represents about 4% of the total cliff length within this coastal area. When taking into account the greater height of much of the cliff section to the west and the extensive rocky foreshore platform, it is apparent that the potential loss of sediment that would result from construction of the seawall would be substantially less than the 4% represented by loss of the cliff section alone. Hence, it is unlikely that the potential sediment supply to the nearshore system would be reduced to a degree that would be likely to have an impact upon the existing budget and, through transport, coastal landforms to the east. In addition, as discussed previously and in Ref. 16.1, studies suggest that although Hinkley Point is not acting as a barrier to alongshore shingle transport, very little new sediment reaches the shingle complexes from the west. This suggests that even if a small reduction in available coarse sediment were to occur, this would be highly unlikely to have any implications for the integrity of the coastal landforms to the east.

16.7.5 The seawall itself is considered unlikely to interrupt the long-shore connectivity of shingle and cobble transport from west to east. This is largely because of its position on the uppermost part of the shore (i.e. in a location where sediment transport except under storm conditions is very limited) and the fact that there are no cross-shore structures associated with the wall that could interfere with transport processes. The hydrodynamic influence of the seawall, as briefly discussed above, indicates that while there may be some small scale change in properties (e.g. wave reflection) these would be highly unlikely to be significant enough to affect overall sediment transport dynamics.

b) Changes Caused by the Presence of Intake and Discharge Structures

16.7.6 Due to their location on the seabed, the intake and discharge structures that will be established atop the vertical shafts described above, may have the potential to affect hydrodynamic and sediment transport properties, albeit at a very localised scale.

16.7.7 The proposed intake structures would cover an approximate area of 1200-1800 m^2 of the seabed and the outfalls approximately 200 m^2. Considering that in cross section, the Bristol Channel in the vicinity of the structures is approximately 20 km wide, the area taken up by the structures is negligible. Similarly, in the main direction of tidal current flow and sediment transport, the area of disturbance to flow that would be caused by the structures is significantly less than in cross-section. While the structures would, in their vicinity, lead to alterations in flow (the effect will vary depending on the tidal state), any change would not be discernible beyond a few tens of metres of the structures themselves.

16.7.8 As with the temporary jetty, an expert assessment of the level of scour that will be associated with these structures has been completed (BEEMS, 2010a (Ref 16.3)). This assessment assumed a worst-case approach, where the structure occupies the full depth of the water column, which would be the case for the two outfall structures alone but only during extreme low tidal periods. This assessment did not account for the discharge of cooling water flows and was based simply on the obstruction presented to tidal flows by the headworks themselves.

16.7.9 For the outfall the total scour depth is predicted to be 2.2 m and predictions of deeper scour may be curtailed by underlying rock formations. Assuming the worst-case repose angle of 26 degrees for a loose non-cohesive fine sand this equates to radial scour of 4.3 m, again assuming curtailment by underlying bedrock.

16.7.10 The flow of water around the proposed intake heads is expected to be complex and some local field measurements of water velocity have been higher than the locally averaged values predicted from modelling studies. It is these higher field values of 1.89 m/s that have been adopted for the scour assessment. The predicted total scour depth around the intake head is 0.6 m due to curtailment by underlying rock, although it may be appropriate to assume that up to 2 m of silt overlying the bedrock may be scoured locally to the intake structures. This translates into an area of radial scour of 1.2 m – 4.1 m, with the higher figure assuming 2 m of overlying silt.

16.7.11 Given that the propagation of these slight alterations in hydrodynamic and sediment transport conditions would be highly localised, the overall effect of these structures on physical processes is considered to be negligible.

c) Intake and Discharge of Cooling Water

16.7.12 The power station's cooling water supply will be abstracted from the Estuary via the intake headworks that will be placed atop the vertical shafts described above, approximately 3.3 km offshore, in approximately 9 m water depth. The intakes headworks are expected to be about 3 m high and the intake ports themselves raised off the seabed by at least 1 m.

16.7.13 The intakes at Hinkley Point are being designed to have a low intake port velocity across all tidal conditions for fish protection purposes. In order to accomplish this aim (the target velocity across the full range of tidal conditions is 0.3 $m.sec^{-1}$) each intake structure will be approximately 10 m x 30 m in plan view, with the long axis lying in parallel to the direction of both ebb and flood tidal streams (there is an approximately 10^o asymmetry between these tidal streams and this understanding is being incorporated within current engineering design evaluations). Seawater would be abstracted through long slits, one on each of the longer sides of these structures, and a system of louvres employed to maintain even flows across their width. Water would be abstracted via the lateral flanks of these structures at mid to lower depth in the water column, dependent upon tidal condition. With the intake ports raised off the seabed by at least 1 m and the intake head itself supported on a narrower plinth, there will be a degree of isolation between bed processes and associated potential turbulence and scour and the cooling water intake area itself.

16.7.14 The cooling water would be discharged at a proposed rate of approximately 120 m^3sec^{-1} with this flow being split between two outfall headworks. Each would discharge the cooling water horizontally in an offshore (cross-tidal) direction at mid depth, or in the lower part of the water column, dependent upon tidal state. These volumes would then disperse into the Estuary with the tidal currents flowing past the outfall. The proposed outfalls would be located at -9.2 ODN. It is likely that at low water, the large volume discharge would cause scour of any soft sediments that might have deposited temporarily due to tidal state, but this impact is likely to be confined to the immediate vicinity of the outfall itself. As described earlier, the nature of the Severn Estuary is that soft sediments are subject to continuous processes of resuspension. Erosion to the bedrock is common during spring tides. The element of scour caused by the outfall plume is likely therefore to simulate the natural process of removing sediment to that bedrock surface, which locally is at shallow depth. Modelling results of the thermal plume (see Chapter 17 on Marine Sediment and Water Quality) with and without a lateral discharge momentum applied offshore indicates no difference beyond 2 grid cells (50 m resolution).

16.7.15 Due to its reduced density relative to the cooler receiving water, the tidally oscillating thermal plume would potentially impose a degree thermal stratification within its midfield area, potentially extending several km downstream on the tide. Salinity stratification does occur locally after heavy rain, but is limited to Bridgwater Bay and the plume of the Parrett Estuary itself, although at times this itself can be an extensive feature extending out towards the Hinkley Point C site following periods of high river flow. In the context of this section of this Appraisal the effect of stratification on the suspended solids regime would be to reduce vertical mixing to some degree and thus reduce the likely vertical exchange of these materials through the water column. As no suspended material is removed from the water taken into the cooling water system and what is then discharged will be virtually identical to the surrounding water in all but its temperature, the impact would be negligible. Similarly, the light climate, which is governed by turbidity and suspended matter, would not be altered significantly.

16.7.16 The wave climate over the warmed area of the thermal plume will be altered by the increased temperature, which increases seawater viscosity, but only marginally so and not to the extent that this will alter the sediment transport regime in an environment that is almost wholly dominated by tidal forcing.

16.8 Conclusions

16.8.1 The estuarine and marine environment local to Hinkley Point is dominated by an extreme, hypertidal, regime resulting in continuous processes of suspension/deposition/resuspension of available fine sediments and thus an equally extreme turbidity regime. The primary sediment transport regime within this estuarine system is thus tidally driven although wave driven processes become proportionately more significant in shoaling and intertidal areas.

16.8.2 The intertidal area fronting the development site is dominated by a wide rock platform. Sediment supply from the cliff margin at the head of this and other local shores is very limited and long-shore transport of sediments to adjacent shores equally so.

16.8.3 In this context, and with the application of appropriate engineering design, the development proposals described here will have a negligible impact on existing coastal, estuarine and marine hydrodynamic and geomorphological processes within the area concerned.

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