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6 HYDRODYNAMICS AND GEOMORPHOLOGY

6.1 Introduction

This section describes the existing hydrodynamics and geomorphology conditions in the vicinity of the Thanet Offshore Wind Farm (Thanet) site and export cable route. The effects of the construction, operation and decommissioning of the Thanet project are discussed as a description of further work to be undertaken as part of the detailed engineering design.

6.2 Assessment Methodology

The hydrodynamic and geomorphological study has been undertaken by HR Wallingford (HR Wallingford, 2005) and utilises data and information collected as part of a detailed project specific bathymetric and geophysical survey undertaken by EGS International (EGS, 2005). The objectives of the HR Wallingford study were to:

- Based on existing information, determine the existing wave, tidal and sedimentary processes within the wind farm site and surrounding sea area, along the export cable routes and at the adjacent coastline;
- Assess the magnitude and significance of impacts resulting from the construction, operation and decommissioning of the Thanet project, giving consideration to the likely periods of 'recovery' following disturbance during construction; and
- Address the items listed in Section 3.3 of the Offshore Wind Farms: Guidance Note for Environmental Impact Assessment in Respect of FEPA and CPA Requirements, published by the Marine Consents and Environment Unit (MCEU) in June 2004 (Version 2, CEFAS, 2004), which include:
    - Scour around turbine structures and cables;
    - Effect of cable laying on suspended sediment concentrations;
    - Effect of the wind farm on wave and tidal patterns, seabed forms and sediment pathways;
    - Effect of the wind farm on the coastline;
    - Cumulative effects with other wind farms and in-combination effects with other activities; and
    - Influence of climate change.

Following agreement with the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), no new modelling was required to support this work.

A desktop study was undertaken of existing reports, data, charts, bathymetric surveys, geophysical and geotechnical surveys, model output and published papers to provide hydraulic and sedimentary information, in accordance with the requirements of the CEFAS Guidance Notes (CEFAS, 2004). HR Wallingford holds much of this information, following their work for other coastal projects in the area and for the Southern North Sea Sediment Transport Study (HR Wallingford *et al*, 2002). Other information has been collated from sources, such as the Future Coast study, the North

Kent Shoreline Management Plan (SMP), British Geological Survey (BGS) and Admiralty publications, and other coastal studies. New geophysical and bathymetric survey information has also been considered (EGS International, 2005). **Table 6.1** summarises the available key data utilised for this study.

Table 6.1 Summary of key data

Item	Source	Reference
Geophysical surveys: wind farm site and export cable route	EGS International Limited	EGS International (2005)
Environmental Scoping Report	Posford Haskoning	Posford Haskoning (2004)
Foundation Options Review	Bomel Consultants	Bomel Consultants (2005)
Proposed layout and cable routes	Thanet Offshore Wind Limited (TOW)	
Drill Stone wave buoy data, February 2004 to December 2004	London Array Limited	

The assessment includes the wind farm area, giving consideration to the wind turbine foundations, the interturbine cables and the export cable routes up to the landfall. The assessment also considers potential cumulative impacts resulting from the consented and proposed offshore wind farm sites and other seabed infrastructure and activities in the vicinity.

The impacts of the development are assessed in relation to the waves, currents, sediment distribution, sediment transport regime i.e. bedload and suspended load, and bedforms. The assessment considers impacts at each offshore structure and along the cables, within the boundaries of the wind farm and further afield, specifically including the Thanet coastline. Consideration is given to the natural variability of the coastal and nearshore system, inherent uncertainty within a dynamic environment, potential sea level rise and increased storminess.

Impacts have been assigned a level of likely significance from major to negligible or non-measurable. The impacts are described quantitatively where possible, and potential mitigation measures are noted.

Gaps in existing knowledge are highlighted, with further work recommended only where it would provide a significant improvement in the understanding of the potential impacts or mitigation measures. Consideration is given to recently completed work for the Department of Trade and Industry (DTI) and Department for Environment, Food and Rural Affairs (Defra) relating to generic impacts of wind turbines on waves, currents and sediment transport (ABPMer, 2005), seabed/foundation interactions (unpublished DTI research on suction caissons) and site specific measurements at the Scroby Sands offshore wind farm by CEFAS (in preparation).

6.3 Existing Environment

6.3.1 Seabed bathymetry

The Thanet site and export cable route have been surveyed for this project by (EGS International (2005) and by the Admiralty on a number of occasions. Visual comparison of charts and the recent site survey indicate that there are minor changes to depths throughout the area, indicative of varying survey accuracy and mobile bedforms in some areas, however the general impression is of dynamic stability at decadal timescales. The exceptions are an area of large sand waves within the main site and two areas along the export cable routes at the north end of the Goodwin Knoll sandbank and the intertidal area of Pegwell Bay that are noticeably unstable. These areas are discussed further in **Section 6.3.7**.

Water depths within the main site range from -15m CD (Chart Datum) to -27m CD. The western part is characterised by a generally smooth seabed with some megaripples, at an average depth of about -20m CD. The eastern part is more complex, with several sand wave fields and depths generally ranging from -20m CD to -25m CD. The Drill Stone Reef lies to the east of the site, rising sharply from -24m CD to only -13m CD. Further east, the seabed drops to nearly -50m CD, before again rising sharply to the very elongated South Falls Bank, which peaks at less than -10m CD.

Inshore of the Thanet site, the seabed rises gently to the broad, shallow wave-cut chalk platform that extends from North Foreland south to Ramsgate. Further north and west are the complex banks of the outer Thames Estuary, while to the south are the drying banks of the Goodwin Sands.

Both export cable routes considered run south or southwest across the gently rising slope, then intersect the dredged navigation approach channel into the Port of Ramsgate, which is maintained to -7.5m CD, continuing inshore on a westerly track along the south side of the channel, passing south of the Port of Ramsgate and into the shallows of Pegwell Bay (see **Figure 2.1**).

The northern route crosses the navigation approach channel in an area where the general seabed level is around -5m CD. Despite the difference in depths, there is apparently no requirement for maintenance dredging, as mobile sediment does not settle within the channel due to natural processes and disturbance by deep draught vessels (pers. comm., Ramsgate Harbour Master).

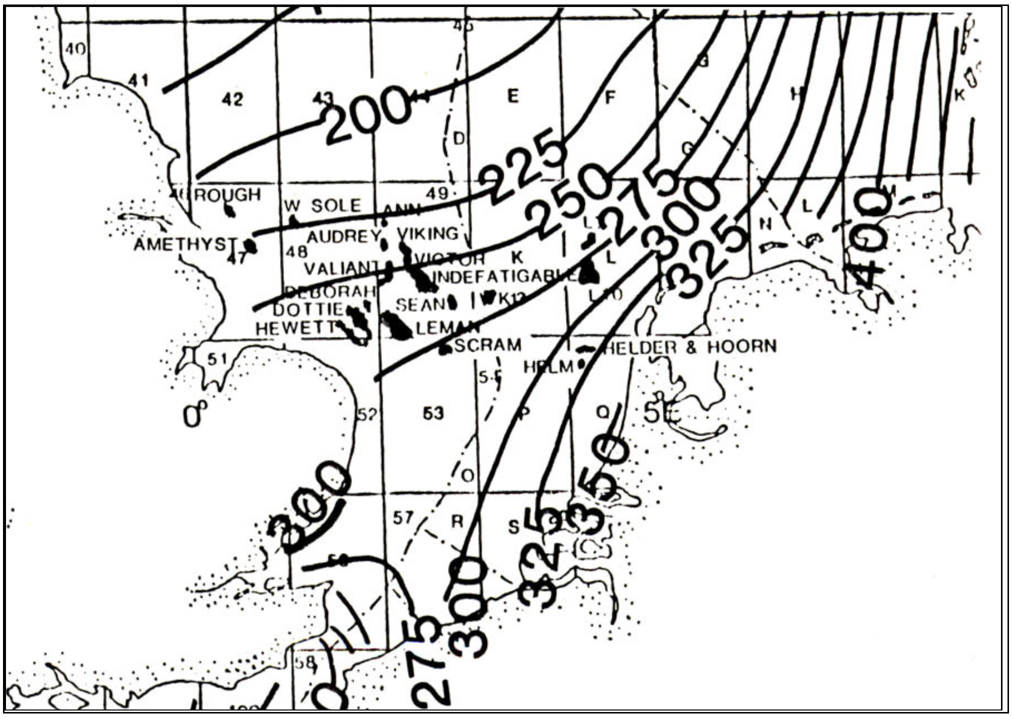
The alternative southern route crosses the line of the navigation approach channel near the north end of the Goodwin Knoll. At this point, the Goodwin Knoll comprises up to 8m depth of sand, rising from the chalk bed to a depth of around -6m CD at its shallowest point.

6.3.2 Water level

The tidal level at any instant in time will be the summation of an ‘astronomical’ tidal level and a ‘residual’ level caused by meteorological effects. Astronomical tidal levels can be accurately forecast, but the residual components due to atmospheric pressure, winds, and temperature are not easily predicted. Deep atmospheric depressions and strong winds can form storm surges, radically altering the predicted tides. If a large storm surge coincides with a high astronomical tidal level, then the resulting 'total' water level can cause great problems to coastal defences, occasionally leading to disastrous flooding of low lying areas, as seen in 1953 and 1978.

North Sea surges tend to originate off the northwest coast of Scotland, and propagate into the North Sea in the form of a progressive long wave. Coriolis forces guide the surges southwards down the eastern coast of the UK and around the North Sea in an anticlockwise direction. The speed of propagation of the surge is similar to that of the astronomical tidal wave and the potential amplitude tends to increase to the southeast. The predicted 50 year return period surge level is between 2.5m and 2.25m for the Thanet site and the landfall (Lee and Ramster, 1981 and **Figure 6.1**).

Figure 6.1 Southern North Sea 1:50 year surge elevations (cm)



(source: HR Wallingford, 2005)

Table 6.2 sets out the tidal ranges for adjacent coastal sites based on Admiralty Tide Table information, with conversions to Ordnance Datum for convenience. It has been assumed that Chart Datum (CD) is 2.5m below Ordnance Datum (OD) for Margate, 2.4m for Broadstairs and 2.6m for Ramsgate. It is assumed that the levels for Margate are approximately correct for the Thanet site based on offshore tidal range contours (Admiralty Co-tidal Chart 5057) and that the Ramsgate levels are appropriate for the landfall in Pegwell Bay.

Table 6.2 Tidal ranges for adjacent coastal sites from Admiralty Tide Tables

	Margate		Broadstairs		Ramsgate	
	m CD	m OD	m CD	m OD	m CD	m OD
HAT	5.1	2.6	-	-	-	-
MHWS	4.8	2.3	4.6	2.2	5.2	2.6
MHWN	3.9	1.4	3.7	1.3	4.0	1.4
MSL	2.6	0.1	2.5	0.2	2.7	0.1
MLWN	1.4	-1.1	1.3	-1.1	1.4	-1.2
MLWS	0.5	-2.0	0.6	-1.8	0.6	-2.0
LAT	0.1	-2.4	-	-	-	-

Extreme water levels i.e. tide plus surge, around the UK have been studied by a variety of authors over a number of years (Graff, 1981; Flather, 1987; Dixon and Tawn, 1997). Dixon and Tawn (1997) use the most advanced methods and their work is generally regarded as containing the most reliable information. The results have been adopted for use in this study, in combination with the long term tidal record from the A-Class tide gauge at Margate.

Extreme water levels for Margate and Ramsgate are set out in **Figures 6.2** and **6.3** and **Table 6.3**.

Table 6.3 Extreme water levels at Margate and Ramsgate

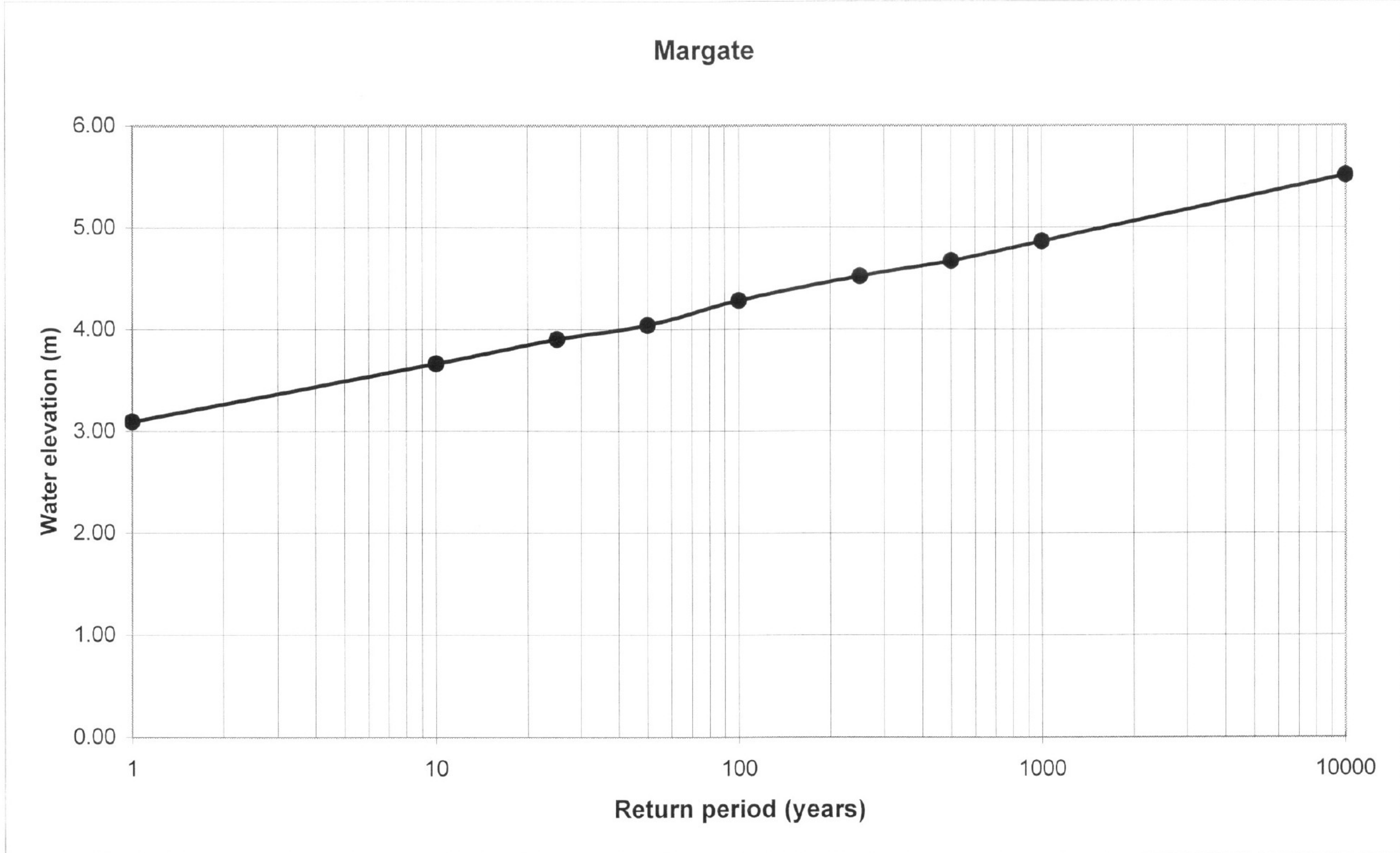
Return Period (years)	Extreme Elevations (m OD)	
	Margate	Ramsgate
1	3.1	3.3
10	3.7	3.8
100	4.3	4.4

(source: Dixon and Tawn, 1997)

Extreme Water Levels for Margate

HR Wallingford

Return Period (Years)	Water Elevation (m ODN)
1	3.09
10	3.66
25	3.90
50	4.04
100	4.28
250	4.52
500	4.67
1000	4.86
10000	5.51



Notes:

Predictions for year: 2005
Based on a trend of: 2.24 mm/yr

Grid Points Analysed
Grid point number: 33

Based on the analysis presented in: Dixon M J & Tawn J A (1997). Spatial analysis for the UK coast. Proudman Oceanographic Laboratory Internal Publication No. 112

Drawing No : 9P5164/06/901	Scale : NOT TO SCALE	Source : Dixon and Tawn, 1997, cited within HR Wallingford, 2005	Title : EXTREME WATER LEVELS, MARGATE
Date : 12/10/2005	Layout : SMG / Checked : JE		Project : THANET OFFSHORE WIND FARM
Figure : 6.2	Revision No : 001	ROYAL HASKONING	Client : THANET OFFSHORE WIND LTD

HR Wallingford

Extreme Water Levels for Ramsgate

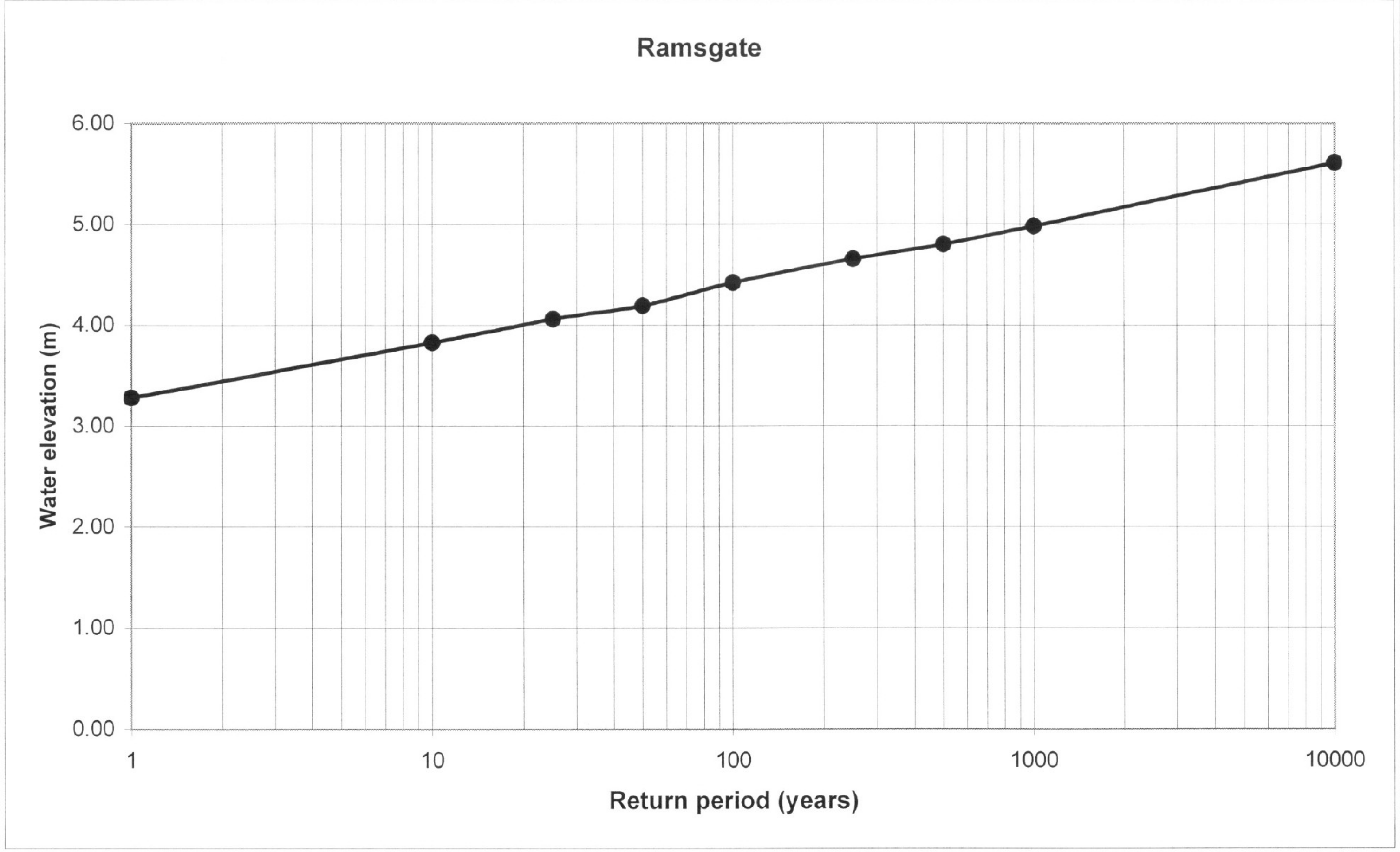
Return Period (Years)	Water Elevation (m ODN)
1	3.28
10	3.83
25	4.06
50	4.19
100	4.42
250	4.66
500	4.80
1000	4.98
10000	5.61

Notes:

Predictions for year: 2005
Based on a trend of: 2.25 mm/yr

Grid Points Analysed
Grid point number: 33
and grid point number: 34

The point of interest is 20 % of the distance between grid point number 33 and grid point number 34 .



Based on the analysis presented in: Dixon M J & Tawn J A (1997). Spatial analysis for the UK coast. Proudman Oceanographic Laboratory Internal Publication No. 112

Drawing No : 9P5164/06/902	Scale : NOT TO SCALE	Source : Dixon and Tawn, 1997, cited within HR Wallingford, 2005	Title : EXTREME WATER LEVELS, RAMSGATE
Date : 12/10/2005	Layout : SMG / Checked : JE		Project : THANET OFFSHORE WIND FARM
Figure : 6.3	Revision No : 001	ROYAL HASKONING	Client : THANET OFFSHORE WIND LTD

6.3.3 Tidal currents

Tidal currents in the area around North Foreland have been measured and modelled for a number of studies by HR Wallingford (HR Wallingford *et al*, 2002; HR Wallingford, 1981; HR Wallingford, 1992). Admiralty Charts 1828 and 1610 include tidal current diamonds for locations within the Thanet site and along the export cable route towards the Port of Ramsgate. The peak current velocities for mean spring and neap tides are set out in **Table 6.4**. Spring tide currents reach 1.0m/s within the wind farm site and are up to 1.6m/s along the export cable route.

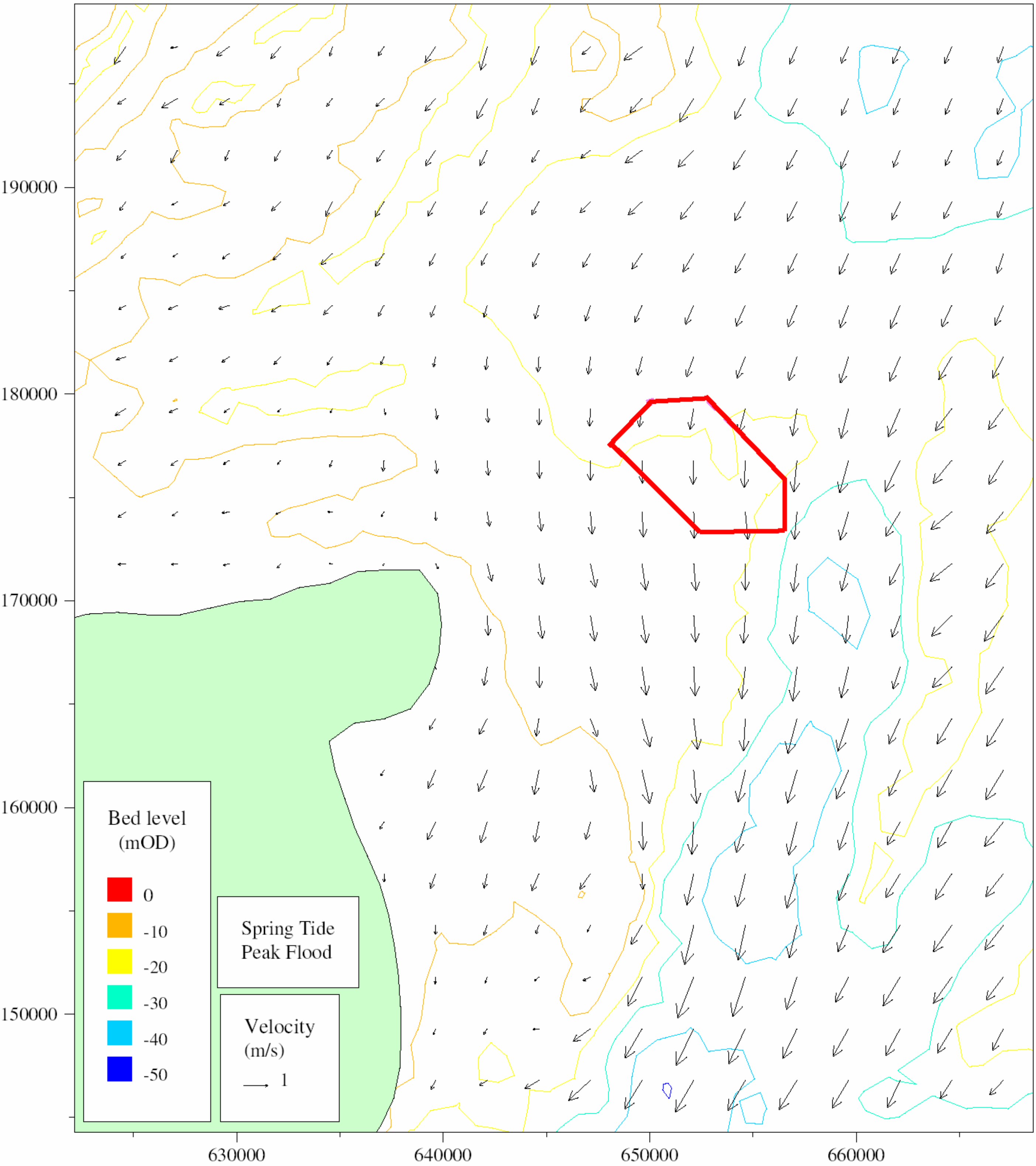
Table 6.4 Peak tidal velocities

Location		Current Direction		Velocity (m/s)	
		State	N°	Spring	Neap
51°26.0'N	Thanet site	Flood	189	1.0	0.6
1°39.0'E		Ebb	004	0.8	0.5
51°20.3'N	NE Goodwin buoy	Flood	208	1.6	0.9
1°34.3'E		Ebb	023	1.6	0.9
51°26.0'N	NE of East Brake buoy	Flood	199	1.1	0.7
1°39.0'E		Ebb	007	1.2	0.7
51°19.7'N	N of Ramsgate channel	Flood	208	1.0	0.6
1°27.7'E	buoys	Ebb	030	1.2	0.7

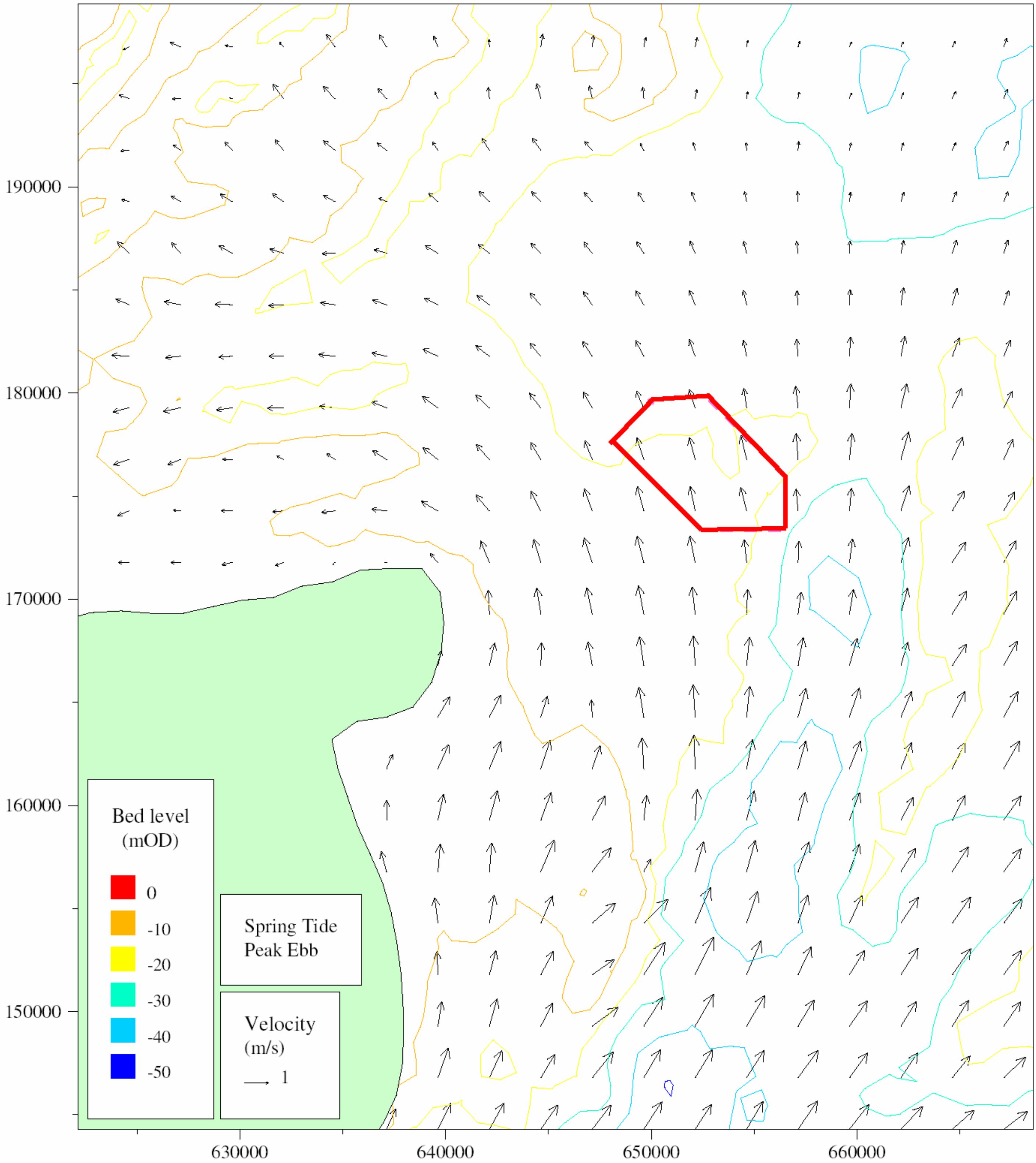
(source: Admiralty Chart diamonds)

These Admiralty data points are useful, but more detailed and extensive appraisals of tidal currents can be derived from numerical models developed for several studies. HR Wallingford has developed a regional tidal flow model of the southern North Sea using the finite element based model TELEMAC (HR Wallingford *et al*, 2002) and an earlier TIDEWAY model for the area around Ramsgate and Pegwell Bay (HR Wallingford, 1992). Storm surge conditions can increase depth averaged currents by up to 0.6m/s in the area of the Thanet site under 50 year return period conditions.

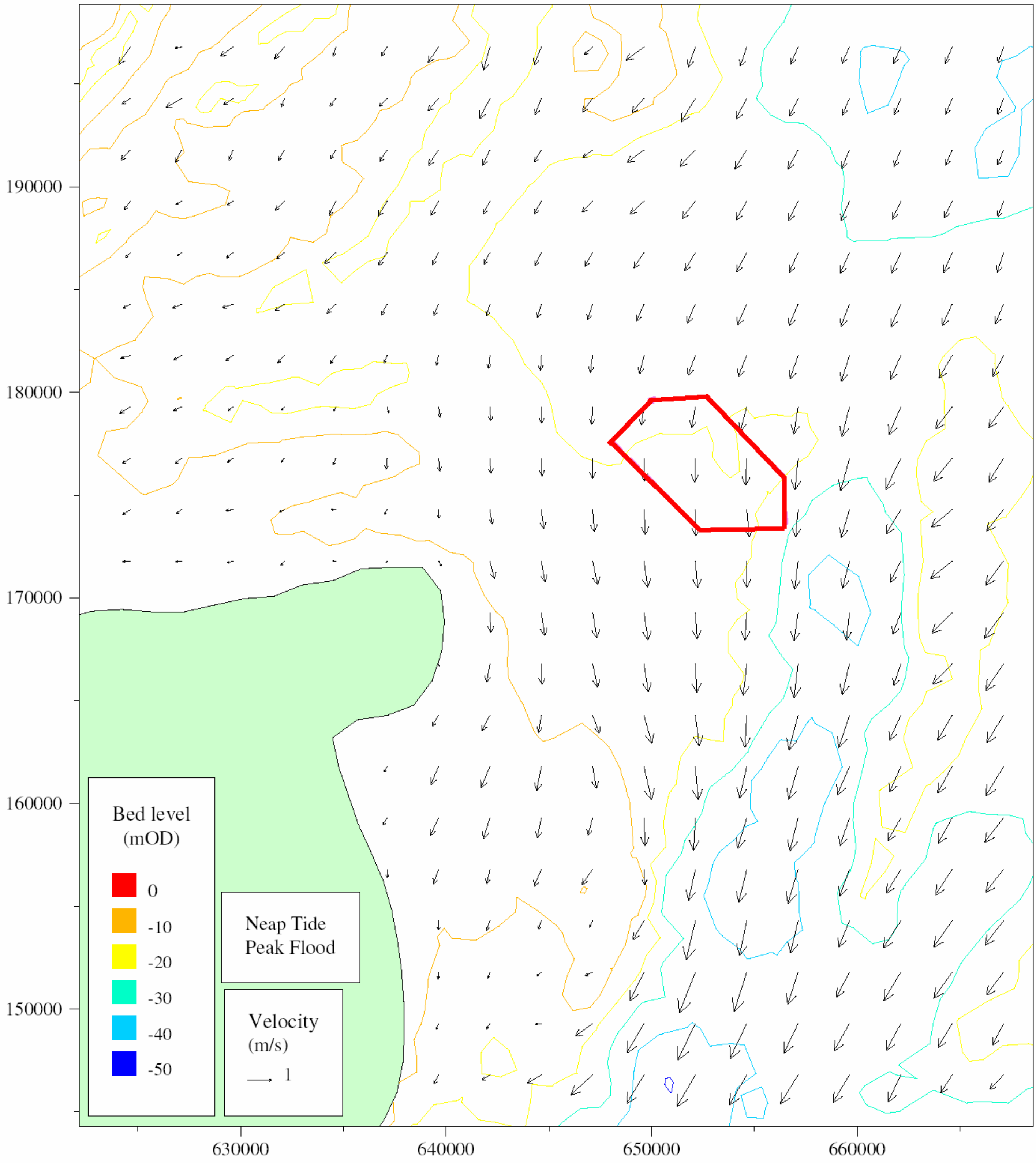
Admiralty information and the numerical model results indicate that currents across the area set in a generally southerly direction on the flood and northerly on the ebb, as shown in **Figures 6.4** to **6.7**. Residual currents, as shown in **Figures 6.8** and **6.9** are more complex. They set to the south and southeast through the Thanet site and outer cable route at up to 0.2m/s on spring tides, but set to the north along the coast including the landward end of the export cable route. The residuals are weaker on neaps, and set more generally to the north, with currents in the Thanet site being about 0.5m/s.



Drawing No : 9P5164/06/903	Scale : NOT TO SCALE	Source : HR Wallingford, CEFAS/UEA, Posford Duvivier, Dr B D'Olier, 2002	ROYAL HASKONING	Title : FLOOD CURRENT VELOCITY VECTORS, SPRING TIDE
Date : 12/10/2005	Layout : SMG / Checked : JE			Project : THANET OFFSHORE WIND FARM
Figure : 6.4	Revision No : 001			Client : THANET OFFSHORE WIND LTD



Drawing No : 9P5164/06/904	Scale : NOT TO SCALE	Source : HR Wallingford, CEFAS/UEA, Posford Duvivier, Dr B D'Olier, 2002	ROYAL HASKONING	Title : EBB CURRENT VELOCITY VECTORS, SPRING TIDE
Date : 12/10/2005	Layout : SMG / Checked : JE			Project : THANET OFFSHORE WIND FARM
Figure : 6.5	Revision No : 001			Client : THANET OFFSHORE WIND LTD



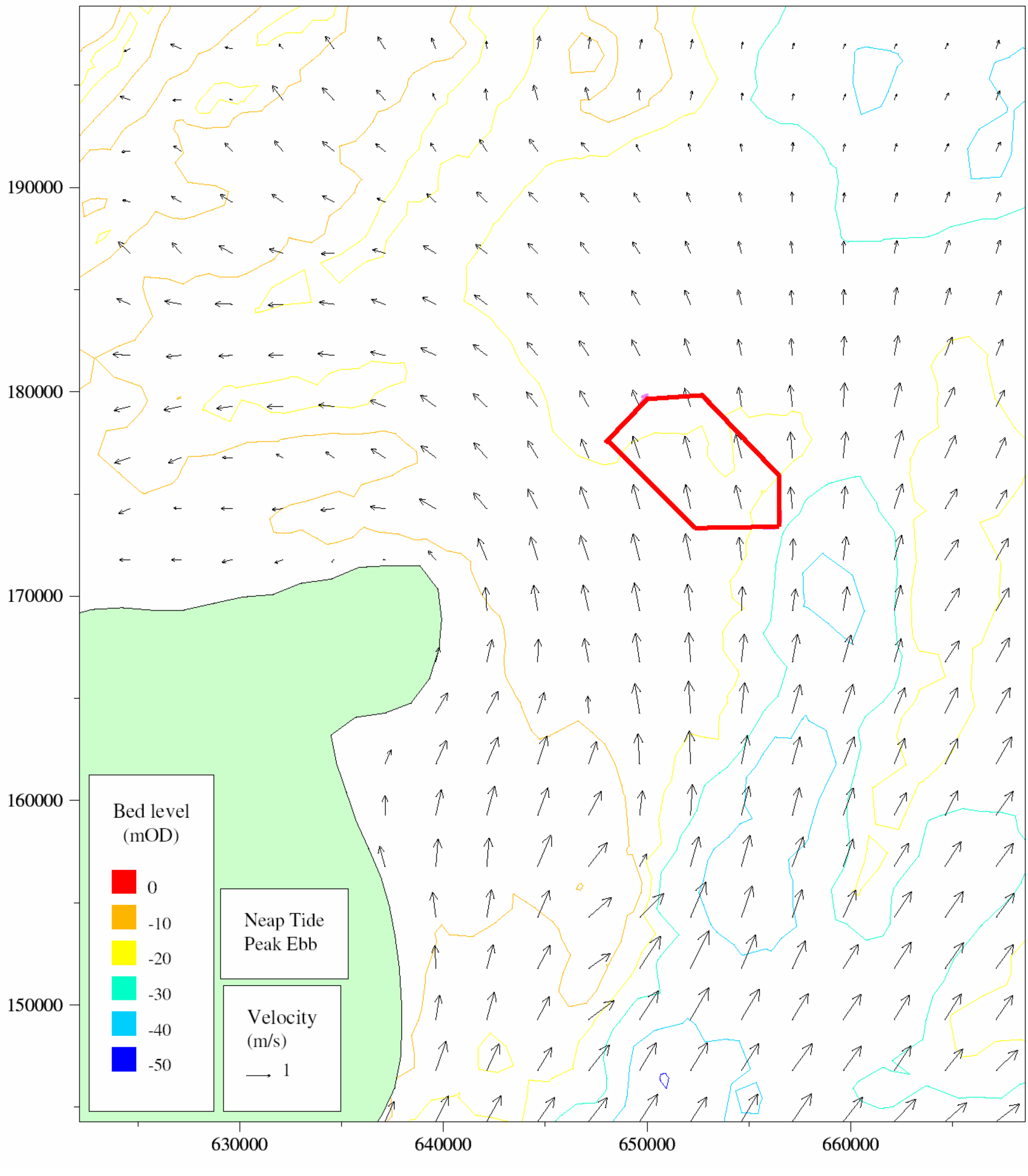
Drawing No : 9P5164/06/905	Scale : NOT TO SCALE		Source : HR Wallingford, CEFAS/UEA, Posford Duvivier, Dr B D'Olier, 2002
Date : 12/10/2005	Layout : SMG	Checked : JE	
Figure : 6.6	Revision No : 001		

ROYAL HASKONING

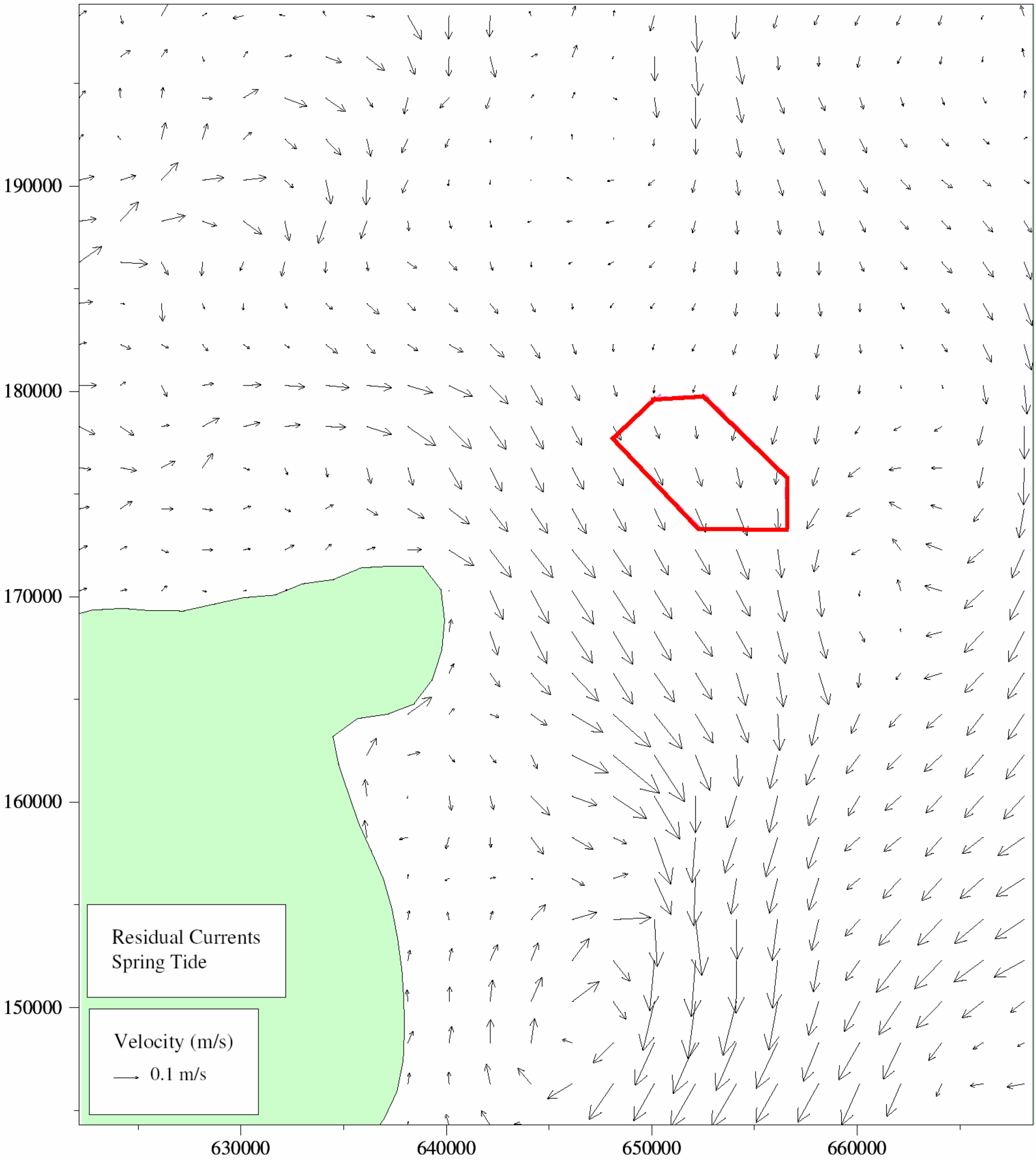
Title : FLOOD CURRENT VELOCITY VECTORS, NEAP TIDE

Project : THANET OFFSHORE WIND FARM

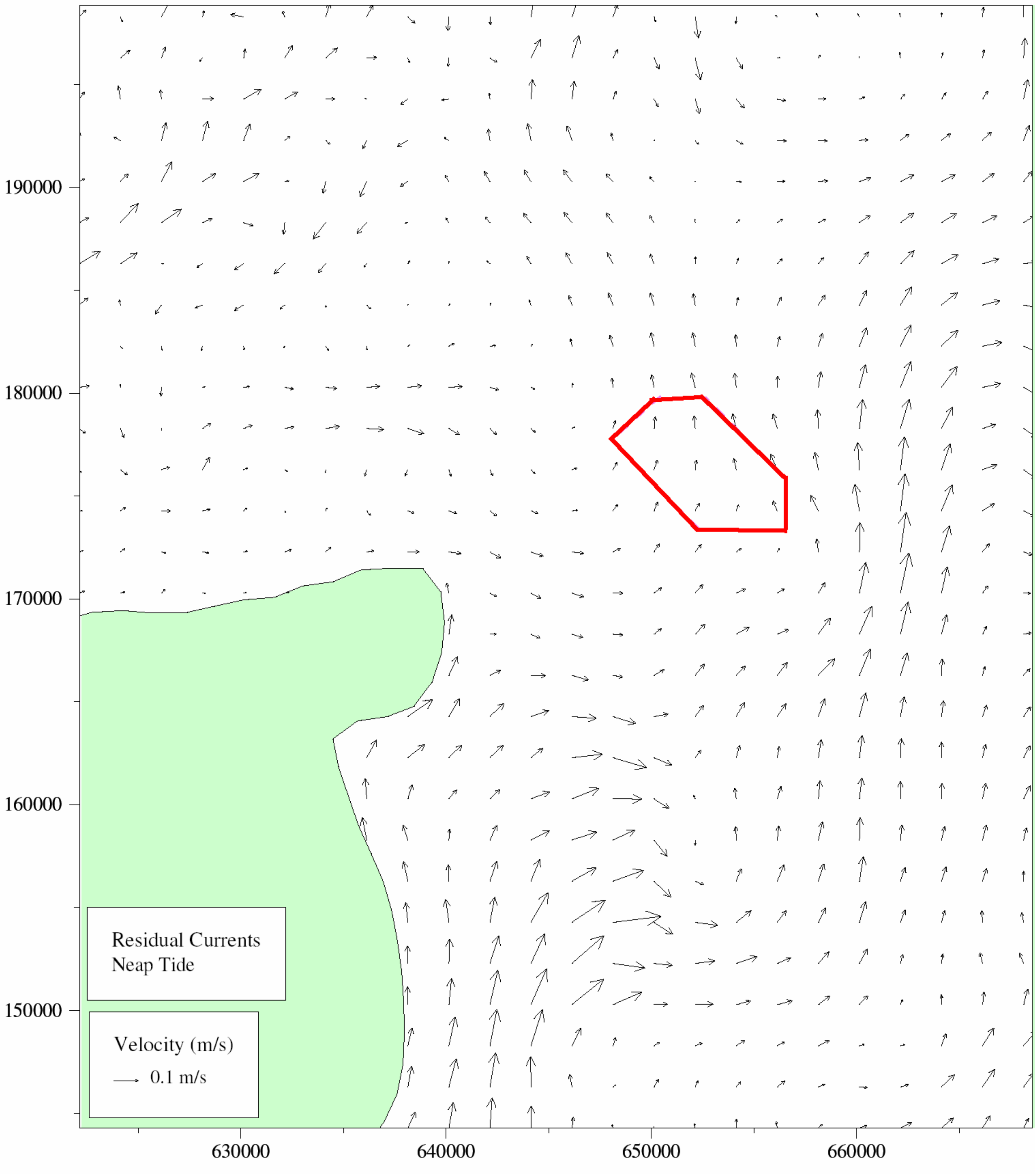
Client : THANET OFFSHORE WIND LTD



Drawing No : 9P5164/06/906	Scale : NOT TO SCALE	Source : HR Wallingford, CEFAS/UEA, Posford Duvivier, Dr B D'Olier, 2002	ROYAL HASKONING	Title : EBB CURRENT VELOCITY VECTORS, NEAP TIDE
Date : 12/10/2005	Layout : SMG / Checked : JE			Project : THANET OFFSHORE WIND FARM
Figure : 6.7	Revision No : 001			Client : THANET OFFSHORE WIND LTD



Drawing No : 9P5164/06/907	Scale : NOT TO SCALE		Source : HR Wallingford, CEFAS/UEA, Posford Duvivier, Dr B D'Olier, 2002	ROYAL HASKONING	Title : RESIDUAL CURRENT VECTORS, SPRING TIDE
Date : 12/10/2005	Layout : SMG	Checked : JE			Project : THANET OFFSHORE WIND FARM
Figure : 6.8	Revision No : 001				Client : THANET OFFSHORE WIND LTD



Drawing No : 9P5164/06/908	Scale : NOT TO SCALE		Source : HR Wallingford, CEFAS/UEA, Posford Duvivier, Dr B D'Olier, 2002	ROYAL HASKONING	Title : RESIDUAL CURRENT VECTORS, NEAP TIDE
Date : 12/10/2005	Layout : SMG	Checked : JE			Project : THANET OFFSHORE WIND FARM
Figure : 6.9	Revision No : 001				Client : THANET OFFSHORE WIND LTD

The residual currents can be set in the context of the full southern North Sea, as shown in **Figure 6.10**. It can be seen that the spring tide residuals for the outer section of export cable route are amongst the strongest in the region, and result in significant potential sediment transport towards the south.

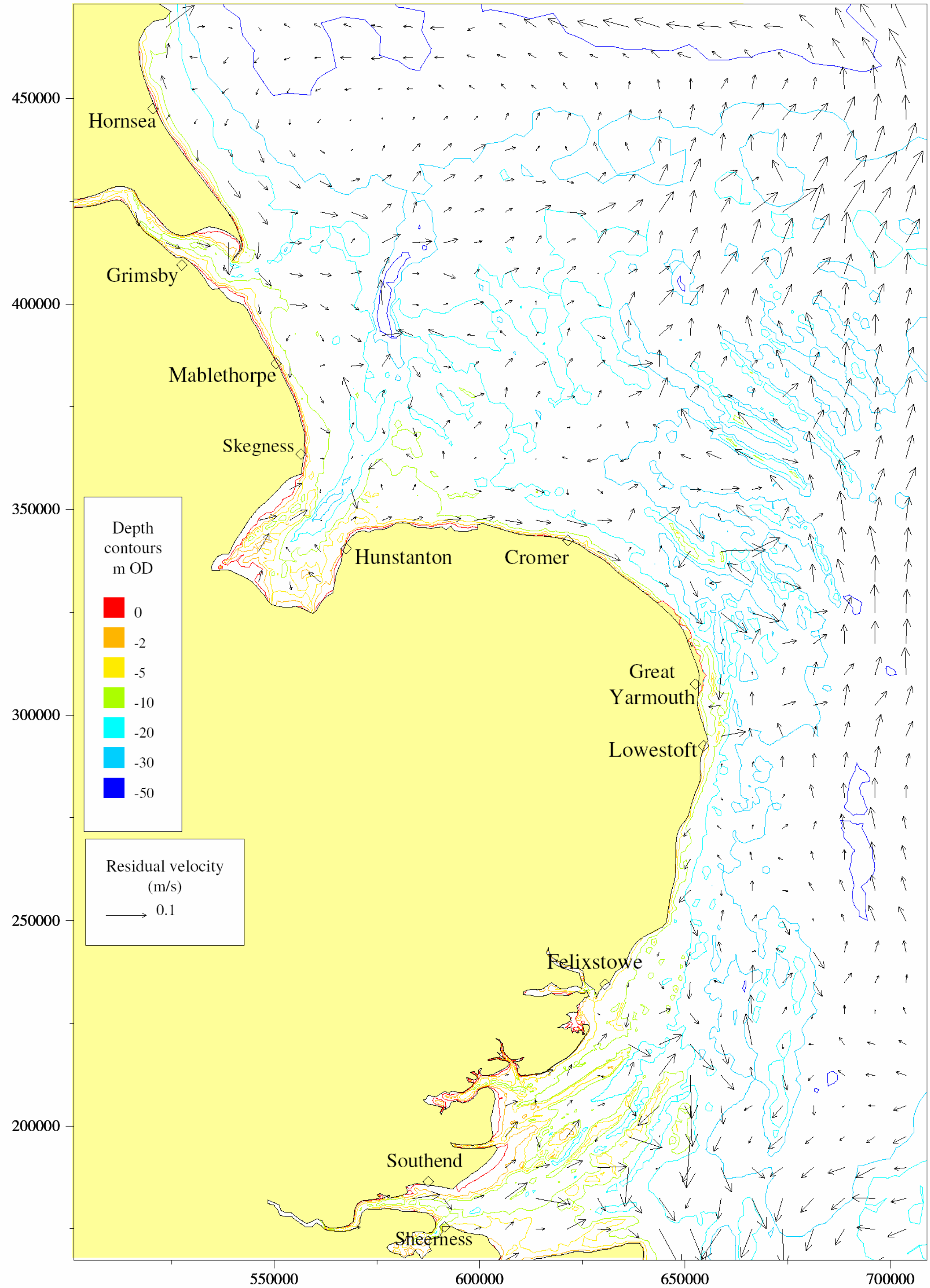
Measured and modelled tidal data undertaken to support design of the Port of Ramsgate extension in 1981 are available for the area immediately south of the Port including Pegwell Bay (HR Wallingford, 1981; HR Wallingford 1992). Currents run approximately parallel to shore i.e. west southwest to east northeast, with typical spring tide speeds of 0.5m/s on the westerly flood into the Bay, and 1.0m/s on the easterly ebb. Peak spring tide currents may be higher. These currents follow the Ramsgate navigation approach channel inside the Brake Bank. Currents within the inner part of Pegwell Bay are much slower, allowing an accretionary regime for fine sands and muds. **Figure 6.11** presents the peak flow contours from this modelling.

6.3.4 Waves

The Thanet site and export cable routes are exposed to northerly and easterly waves generated in the North Sea, as well as waves generated in the English Channel that can propagate from the south. Locally generated waves due to winds blowing across the Thames Estuary from west to northwesterly directions are also significant. It may be necessary to undertake site specific modelling to obtain reliable wave data to support the detailed engineering design, due to the complexity of the bathymetry and the varying fetch lengths for different directional sectors. However, for the purpose of the Environmental Impact Assessment, there are several acceptable data sources arising from site measurements and previous studies (Posford Haskoning, 2004; HR Wallingford, 1992; HR Wallingford 2002). These include offshore conditions at several locations and nearshore conditions at Ramsgate.

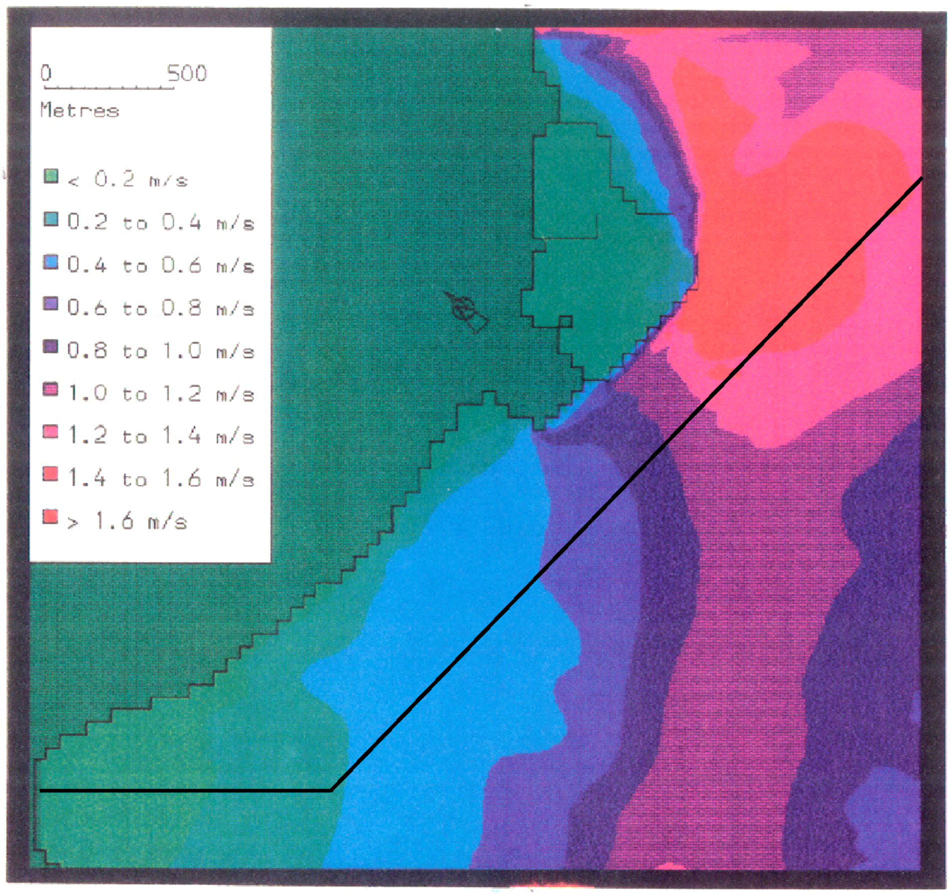
Measured offshore wave data from Kentish Knock (51.75°N, 1.54°E) are presented as a wave rose in **Figure 6.12**, which demonstrates that the prevailing wave direction is from the southwest, in terms of numbers of waves, but that the largest waves occur from the north to northeast directional sectors. The duration of the measurement period is not defined in the source, but it is assumed to be at least several years, giving a reasonable statistical distribution.

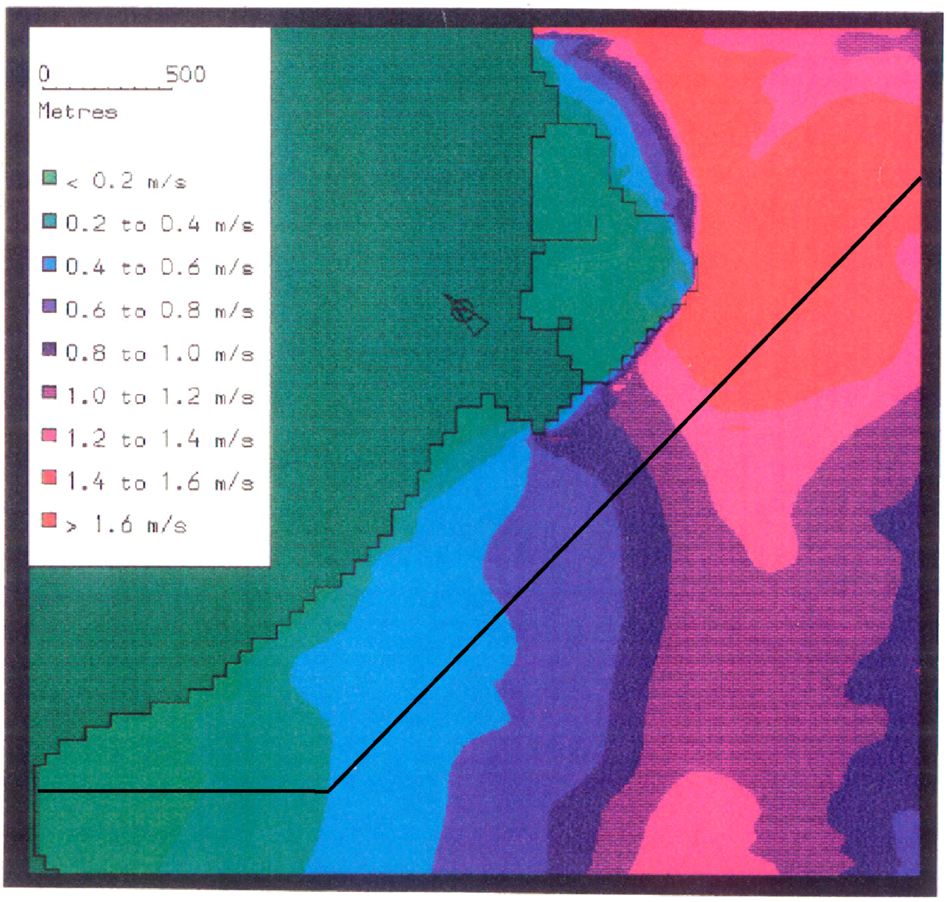
Wave data measured specifically for this project are available from Drill Stone Buoy, which was located adjacent to the Thanet site, for the period of February 2004 to December 2004. The wave rose for this site is presented as **Figure 6.13**. This dataset indicates a higher frequency of waves of all heights from the northeast quarter, and shows larger waves of up to 3.25m significant wave height (H_s) from both the northeast and southwest. The relatively short duration of the data reduces the statistical significance, but provides validation data for any subsequent modelling undertaken for detailed engineering design.



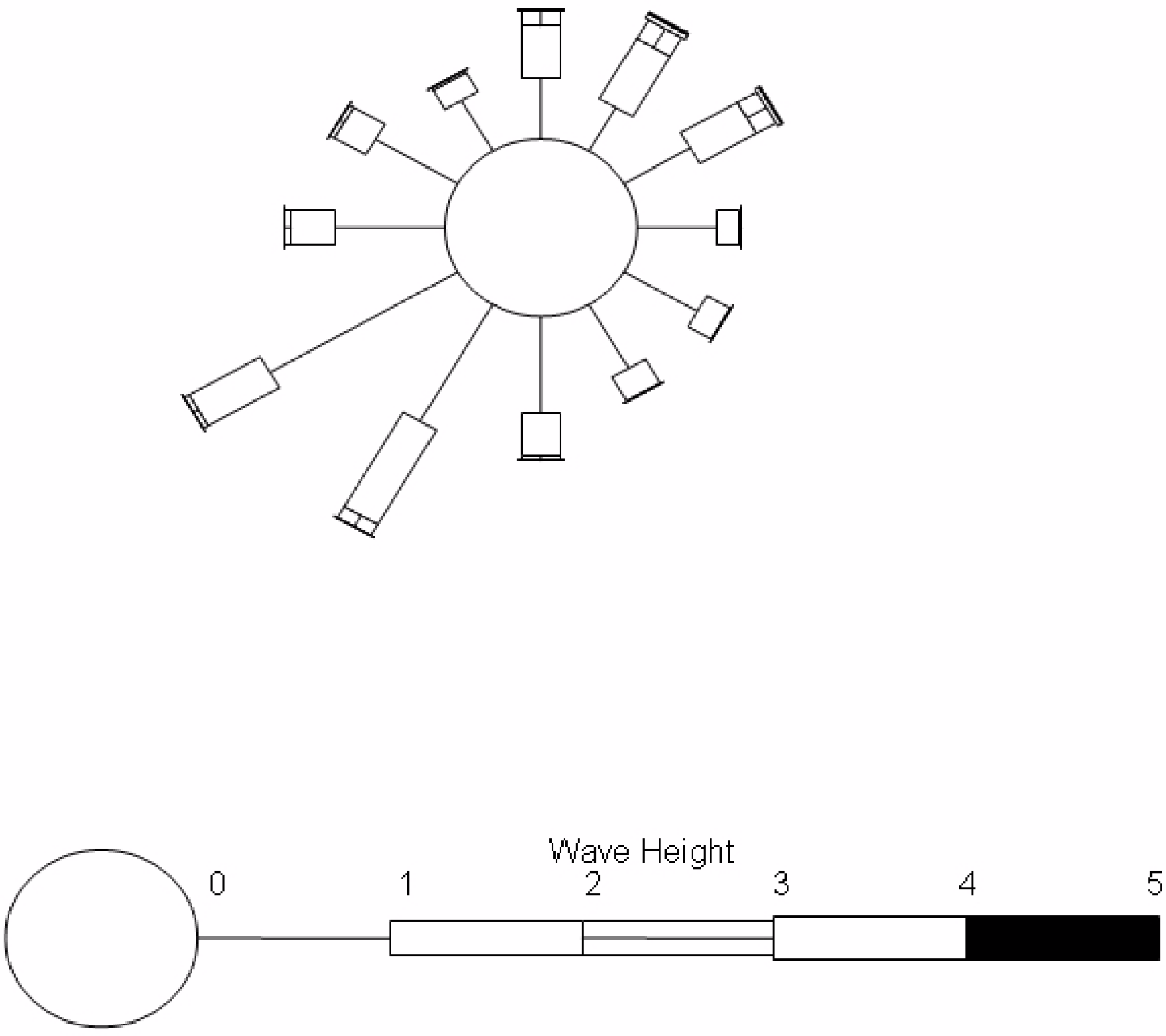
Spring tide
Residual Currents
Ks = 0.1

Drawing No : 9P5164/06/909	Scale : NOT TO SCALE	Source : HR Wallingford, CEFAS/UEA, Posford Duvivier, Dr B D'Olier, 2002	ROYAL HASKONING	Title : **SPRING TIDE DEPTH-AVERAGED RESIDUAL VELOCITY**
Date : 12/10/2005	Layout : SMG / Checked : JE			Project : **THANET OFFSHORE WIND FARM**
Figure : 6.10	Revision No : 001			Client : **THANET OFFSHORE WIND LTD**

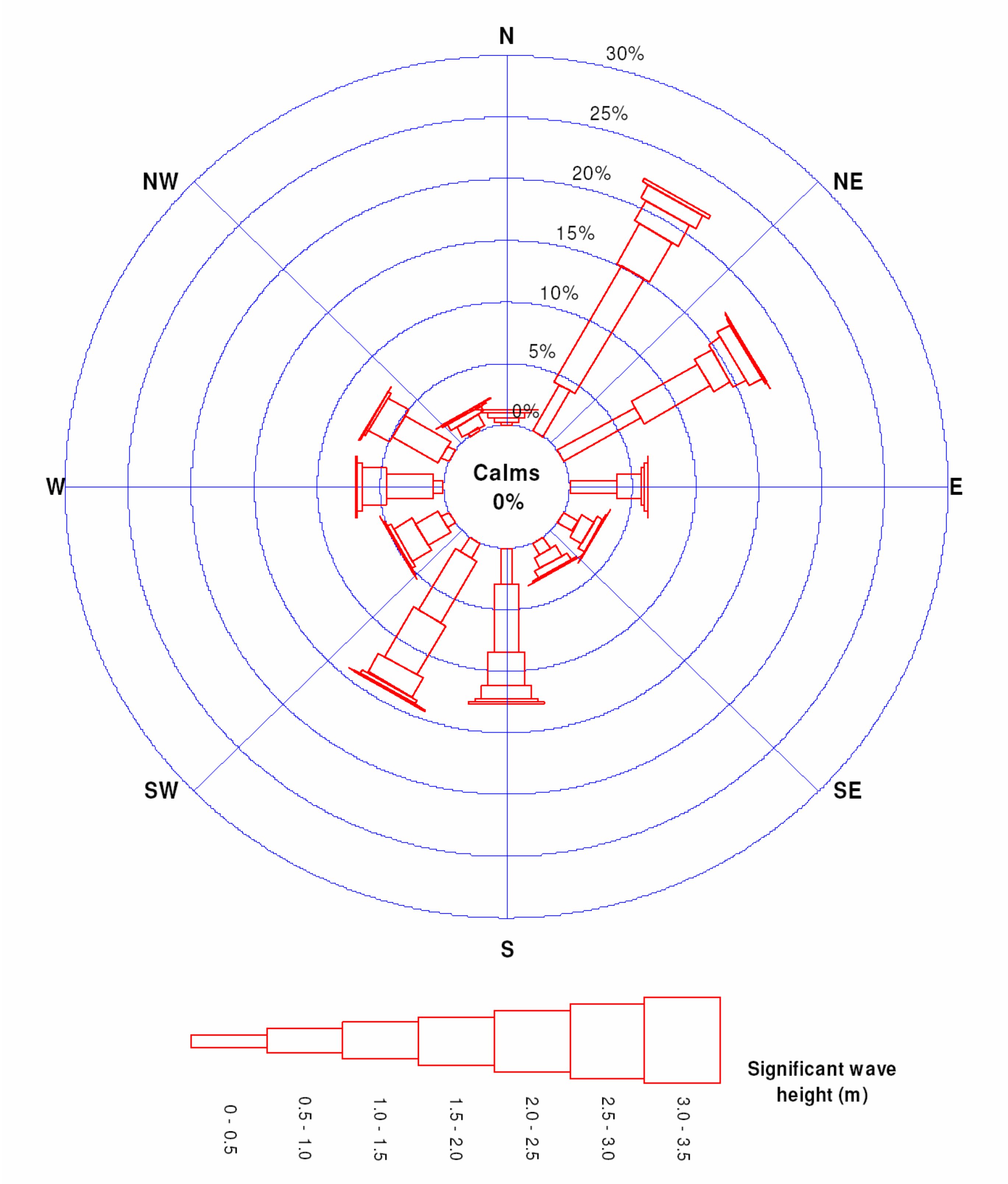




Drawing No : 9P5164/06/910	Scale : NOT TO SCALE		Source : HR Wallingford, 1981	Title : **PEAK SPRING AND HIGHEST ASTRONOMICAL TIDE FLOWS ALONG THE INNER CABLE ROUTE**
Date : 12/10/2005	Layout : SMG	Checked : JE		Project : **THANET OFFSHORE WIND FARM**
Figure : 6.11	Revision No : 001		ROYAL HASKONING	Client : **THANET OFFSHORE WIND LTD**



Drawing No : 9P5164/06/911	Scale : NOT TO SCALE		Source : Posford Haskoning, 2004	Title : **KENTISH KNOCK WAVE ROSE**
Date : 12/10/2005	Layout : SMG	Checked : JE		Project : **THANET OFFSHORE WIND FARM**
Figure : 6.12	Revision No : 001		ROYAL HASKONING	Client : **THANET OFFSHORE WIND LTD**



Drawing No : 9P5164/06/912	Scale : NOT TO SCALE	Source : London Array Limited Data February 2004 to December 2004	ROYAL HASKONING	Title : DRILL STONE WAVE ROSE
Date : 25/10/2005	Layout : SMG / Checked : JE			Project : THANET OFFSHORE WIND FARM
Figure : 6.13	Revision No : 002			Client : THANET OFFSHORE WIND LTD

Long term offshore data have also been derived from the UK Met Office European wave model for a point closer to the site at 51.5°N, 1.5°E (HR Wallingford, 2002). Although winds are strongest and most frequent from the southwest, the short fetch length limits wave generation from this direction. The secondary wind direction is from the north and northeast, which is also the direction of greatest fetch for wave generation. As with the measured data, the largest waves are from the north northeast sector, while westerly waves of up to 1m H_s are by far the most frequent, followed by southeasterly waves of up to 1m H_s.

Table 6.5 sets out extreme offshore conditions, based on these earlier studies including both modelling and monitoring, indicating a 100 year significant wave height of about 5.7m at the Thanet site (HR Wallingford, 2002) and therefore a maximum individual wave height of about 11m.

Table 6.5 Predicted extreme offshore wave conditions

Return period (years)	Hs (m)
1	3.9
10	4.9
100	5.7

(source: HR Wallingford, 2002)

Wave conditions along the export cable route are influenced by the reduced water depths and sheltering by the coast and Goodwin Sands. Northerly storm waves dominate along the cable route up to the Port of Ramsgate, after which the largest waves result from easterly winds. Limited data to define the wave conditions, are available from earlier HR Wallingford work for the Port of Ramsgate (HR Wallingford, 1981; HR Wallingford, 1992). In the area of the Port of Ramsgate, 2.2m H_s and 2.9m H_s waves from the east are considered to have 1 year and 10 return periods respectively. More extreme conditions will tend to be depth limited in the shallow waters of Pegwell Bay. Sediment transport within the inner Bay and along the coast to the south will be influenced by both the easterly storm waves and the more frequent southeasterly waves.

6.3.5 Joint probability events

There is a strong correlation between tidal surges and large wind waves within the southern North Sea, as they are generated by similar conditions (HR Wallingford, 2001). The coincident occurrence of a surge, causing water levels to be higher than the predicted tidal condition, and severe wave conditions can give rise to conditions that may influence structural design or sediment transport. For a given probability of joint occurrence, expressed in terms of return periods, the conditions may range from very high water levels with a modest wave condition to very severe waves with a modest water level.

In relation to the environmental impacts, events with severe wave conditions and high water levels can cause short term disturbance and may be important during construction or cable laying. They may also give rise to coastal erosion and flooding. However, they are infrequent and are therefore not significant to the longer term condition of the physical environment at the Thanet site or along the export cable route.

6.3.6 Future conditions

The Thanet project is assumed to have a design life of 40 years, during which time it is anticipated that the site conditions may vary due to the effects of global climate change. The important parameters in this case will be increasing sea level and the changes to the frequency and direction of strong winds.

Global sea levels have been rising over the past century, and rates are predicted to increase. Dixon and Tawn (1997) indicate a rate of sea level rise in the recent past of 1.7mm/yr for this area, approximately equal to the global average value. Mean sea levels will continue to increase due to continuing climate changes, particularly the increase in temperature of the world's oceans. Predictions from various numerical simulations of the world's atmosphere seem to agree that the present rate of increase in mean sea level will accelerate. It is necessary to anticipate higher tidal levels since this will occur over the expected lifetime of the wind farm. Global sea levels must be considered with local isostatic changes of ground levels to give relative water level change. At present, there is an assumption by the Department for Environment, Food and Rural Affairs (Defra) and the Environment Agency that relative sea level change along the southeast coast will be 6mm/year over the next 50 years, giving a total rise of 240mm over the assumed 40 year design life of the Thanet project. Ongoing work by several institutions will provide refinements to this accepted standard in the future.

The impacts of climate change on winds and waves have not reached a similar state of agreement. It is generally accepted that the design of coastal structures should consider the potential for increased storminess and changes to the dominant directions. The Thanet site is predominantly exposed to severe waves from the north to northeast due to the configuration of the North Sea and there is no reason to suppose that future extreme waves will arrive from a changed direction. Wave predictions in previous HR Wallingford studies within the southern North Sea and along the English Channel coast show variability in wave height from year to year, but no significant overall trend of direction or energy. However, the frequency of strong winds may increase, affecting both extreme wave heights and surge levels. In the absence of any certainty, it would be prudent to take a conservative approach and allow for design conditions at a higher level of predicted return period than would be the case if present conditions were assumed to continue.

6.3.7 Geology and geomorphology

The seabed sediments at and around the Thanet site and along export the cable routes have been sampled and a full bathymetric and geophysical survey has been completed (EGS International, 2005). Information has also been derived from Admiralty Charts, British Geological Survey and Joint Nature Conservation Committee (JNCC) publications, and a number of studies undertaken for Defra and the Local Authorities (Bomel Consultants, 2005; Lee and Ramster, 1981; British Geological Survey, 1987; JNCC, 1998; HR Wallingford, 1987; Halcrow, 1996; Halcrow, 2002).

Wind farm site

The near surface geology can be divided into three main units:

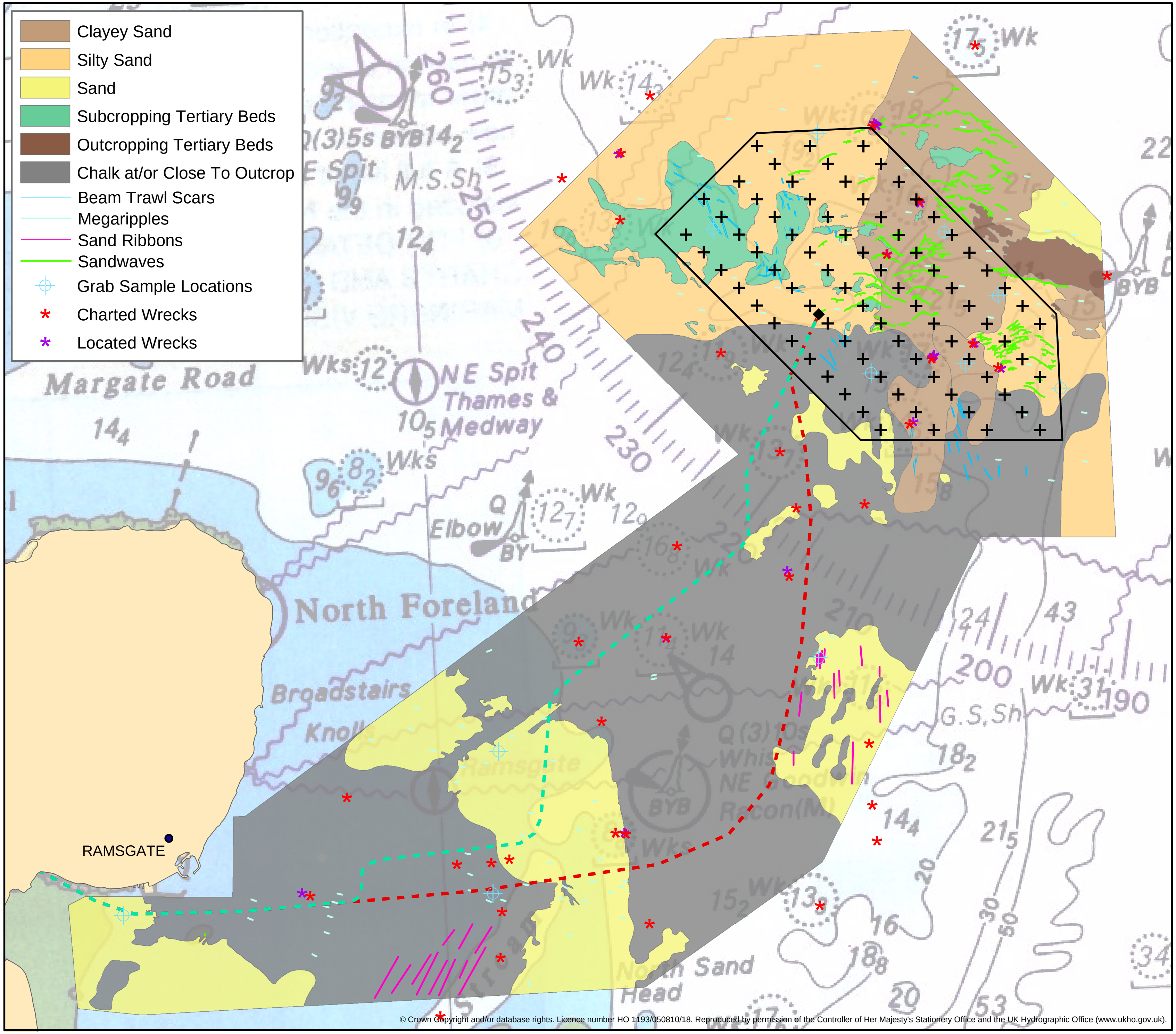
- Cretaceous chalk bedrock to the south, exposed in places, but dipping towards the north;
- Tertiary units, overlying the chalk, including Thanet Sand, Woolwich Beds and Harwich Formation exposed at the Drill Stone Reef and in several other places across the site; and
- Sand and gravel lag, including deposits in paleo-channels cut into the Tertiary units and chalk.

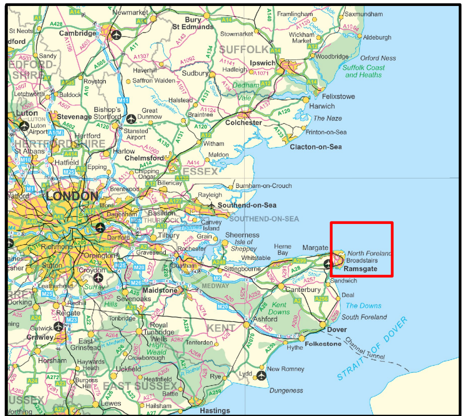
In terms of seabed sediments, the Thanet site can be divided into distinct regions, as shown on **Figure 6.14** and described below:

- The southern part of the site comprises chalk bedrock, covered in patches by a veneer of sand, generally less than 1m thick, but with a deeper infilled channel of up to 6m, running south from the centre of the site;
- The western part of the site is characterised by loose, clayey sand with megaripples that have wavelengths in the region of 5-7m and are less than 1m high. In the middle of this region there is a very thin layer of loose gravely sand overlying the Tertiary beds;
- In the central and northern parts of the site is an area of megaripples and 2-5m high sand waves, with asymmetry indicating north to south transport. Marine sediment thickness over the Tertiary beds reaches as much as 10m to the north of the site and in occasional pockets elsewhere; and
- The southeastern part of the site comprises mainly loose silty sand over the Tertiary beds with a further area of 2-4m high sand waves.

Immediately to the east of the Thanet site is the prominent sandstone outcrop, known as the Drill Stone Reef, which rises sharply from -24m CD to -13m CD. Along the northeast boundary of the site are further megaripples and sand waves of up to 7m in height, and greater depths of marine sand deposits overlying the Tertiary beds, providing a sediment source for southerly transport.

There is no reliable past survey data that will allow assessment of sand wave mobility within the Thanet site. Mobility rates for other North Sea sites that have been subject to detailed survey analysis indicate a variety of wave migration rates. Given this uncertainty, it would be appropriate to take a conservative view and assume that seabed elevations could vary by as much as the amplitude of the waves over the lifetime of the project.





Legend:

- Wind Farm Location
- Proposed Turbines x 83
- Offshore Substation
- Proposed Cable Route 1
- Proposed Cable Route 2

Title:

GEOLOGY, SURFACE SEDIMENT AND SEABED FEATURES WITHIN THE THANET SITE

Project:

THANET OFFSHORE WIND FARM

Source: Main Chart - Not to be used for navigation.
© Haskoning UK Ltd.
Inset Map -
Derived from MiniScale by Ordnance Survey.
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Licence number AL 100017728

Client:

THANET OFFSHORE WIND LTD

Drawn by:	Checked:	Drawing No:
SMG	SDG	9P5164/06/704

Date:	Figure:
25/10/2005	6.14

Scale:	Revision No:
0 0.5 1 1.5 2 Kilometres	004

ROYAL HASKONING

Export cable route

The underlying geology of the export cable routes comprises chalk, which is exposed over large areas. Surface sediments vary within the different hydrodynamic environments, as shown as **Figure 6.14**.

The intertidal area of Pegwell Bay comprises loose medium to silty sand overlying chalk to a depth exceeding 1m. Detailed comparison of the 1955 Admiralty Fair Chart and the recent export cable corridor survey indicates that the bathymetry has changed between the +1m CD and -1.5m CD contours in the Bay and in the area of the Port of Ramsgate extension, as shown on **Figure 6.15**. The major area of change, with accretion levels of up to 1.5m, appears to be associated with a southerly migration of the River Stour channel. The channel is known to have shifted historically in response to changes to the Goodwin Sands, Brake Bank and the shingle spit extending north from Deal, and may have shifted more recently in response to the port extension at Ramsgate. It is uncertain as to whether the surveyed change will be permanent, or will reverse in future, but further change to this area should be considered a possibility.

Beyond the Port of Ramsgate, the preferred northern export cable route passes across the dredged navigation approach channel approximately 4km east of the port, and then runs northeast to the wind farm, crossing an area with patches of loose surface sand over chalk, including occasional megaripples.

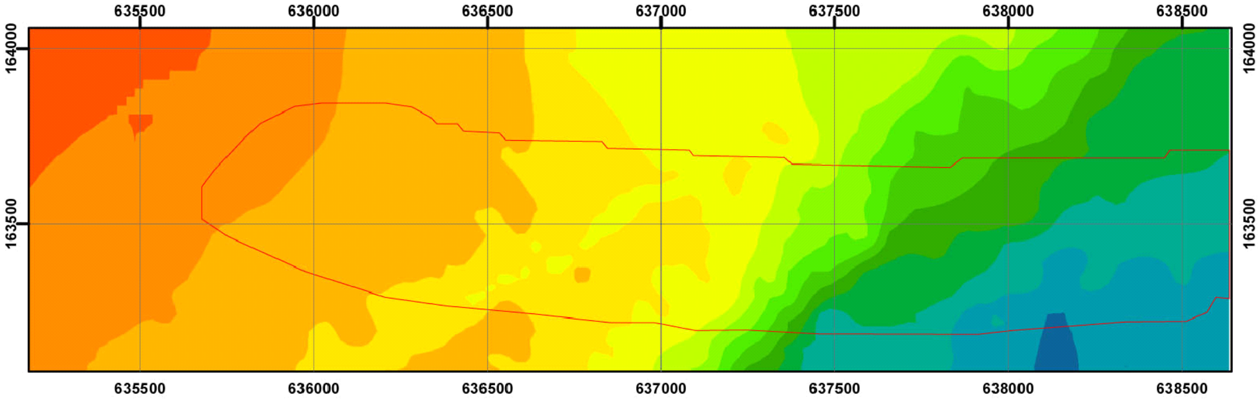
The alternative southern cable route runs parallel to the Ramsgate navigation approach channel for about 8km, crossing patches of loose surface sand over chalk with occasional megaripples orientated northeast to southwest. The route passes over the northern end of the Goodwin Knoll sandbank, with a sand depth of up to 8m, sand waves of up to 4m and surface megaripples oriented north to south. The route then swings northeast towards the Thanet site, encountering further large patches of loose sand over chalk, including areas of sand ribbons oriented north to south.

Detailed comparison of Admiralty surveys from 1960, 1970, 1973, 1980 and 1997 with the 2005 EGS survey indicates that the area has varied in elevation by as much as 5m. Changes are due to north to south and east to west migrations of the sandbank as shown in **Figures 6.16** and **6.17**. Future changes are uncertain but, as with the Pegwell Bay area, large scale instability should be anticipated.

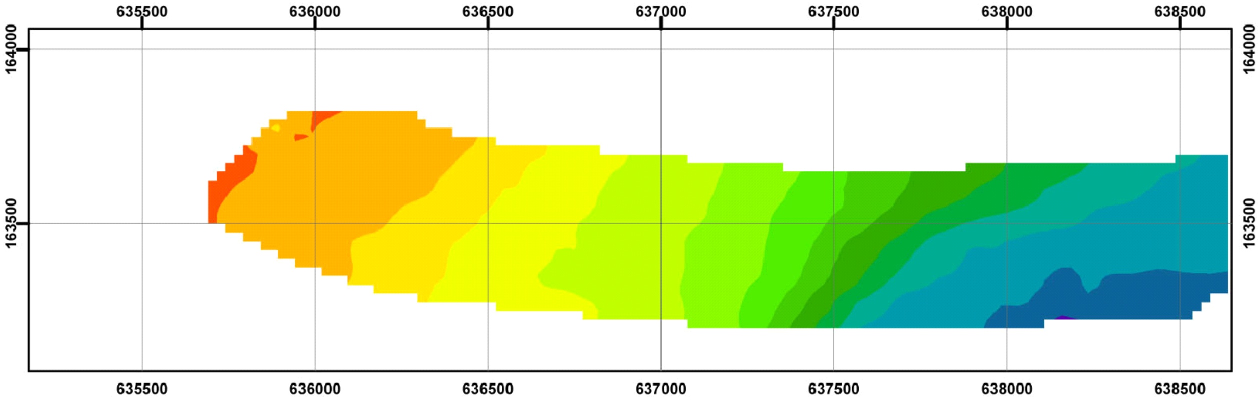
Coastline

The coastline adjacent to the Thanet site, from Margate to Ramsgate, is highly indented and dominated by near-vertical Cretaceous chalk sea cliffs ranging from 20-30m in height. The chalk is jointed and faulted and these structural weaknesses have been exploited by wave action, leading to the creation of arches and undermining of the cliff base, causing block falls and leaving behind stacks. Built defences protect most of the cliff toe south from North Foreland, so rates of erosion are much reduced. The foreshore consists of a wave-cut chalk platform, varying in width up to 250m, covered by a thin and highly mobile layer of sand and shingle deposits. Sand deposits are generally retained within the small embayments created within the cliffs. The upper beach widens towards Ramsgate, where the harbour breakwaters halt the natural southerly drift.

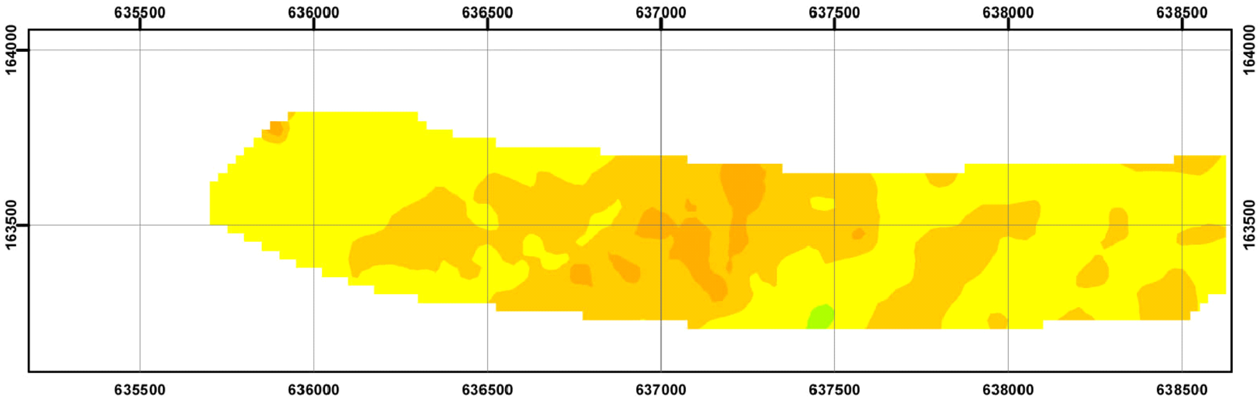
Map 1. Seabed Bathymetry - 1955



Map 2: Seabed Bathymetry - 2005



Map 3: Difference in Depth between 1955 and 2005 Datasets



1:18,000

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www.hrwallingford.co.uk

Seabed Bathymetry - Pegwell Bay

Coordinate System: British National Grid

Notes:
1. Depth soundings are reduced to 2.58m below Ordnance Datum and interpolated using an ordinary kriging algorithm with a search radius of 12 points. Grid resolution is 25 metres
2. Difference grids have been mapped to indicate Negative values as Erosion, and Positive values as Accretion

Depth (m)
- 3.1 - 5.0
- 2.1 - 3.0
- 1.1 - 2.0
- 0.6 - 1.0
- 0.1 - 0.5
- -0.4 - 0.0
- -0.9 - -0.5
- -1.4 - -1.0
- -1.9 - -1.5
- -2.4 - -2.0
- -2.9 - -2.5
- -3.4 - -3.0
- -3.9 - -3.5
- -4.3 - -4.0

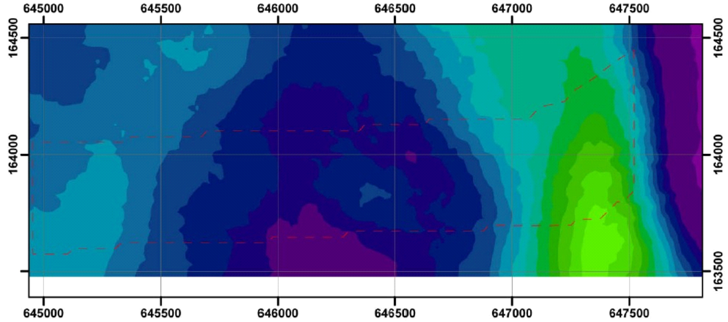
Legend applies to maps 1 and 2

Depth Change (m)
- 0.6 - 1.0
- 0.1 - 0.5
- -0.4 - 0.0
- -0.9 - -0.5
- -1.4 - -1.0

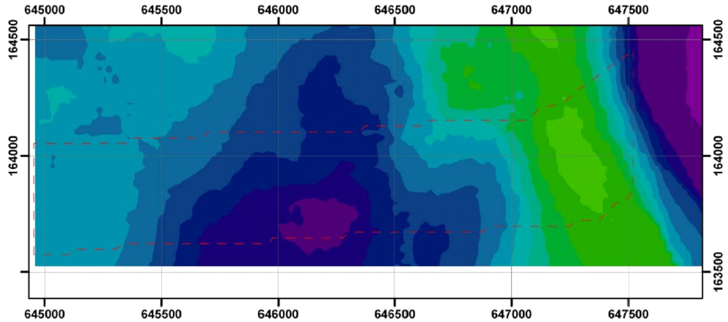
Legend applies to map 3

Drawing No : 9P5164/06/913	Scale : NOT TO SCALE		Source : HR Wallingford, 2005	ROYAL HASKONING	Title : BATHYMETRY OF THE CABLE ROUTE INTO PEGWELL BAY FROM 1955 AND 2005 SURVEYS, PLUS DEPTH DIFFERENCE PLOT
Date : 12/10/2005	Layout : SMG	Checked : JE			Project : THANET OFFSHORE WIND FARM
Figure : 6.15	Revision No : 001				Client : THANET OFFSHORE WIND LTD

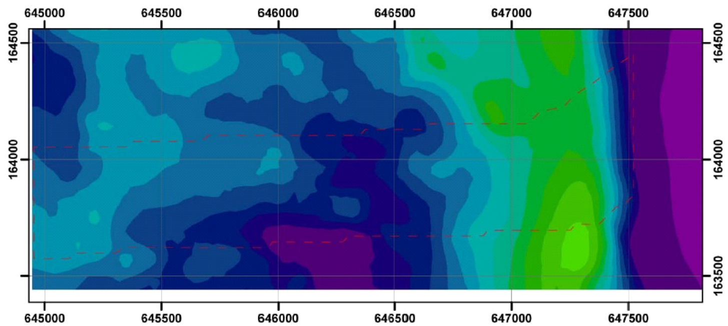
Map 1: Seabed Bathymetry - 1960



Map 2: Seabed Bathymetry - 1970



Map 3: Seabed Bathymetry - 1973



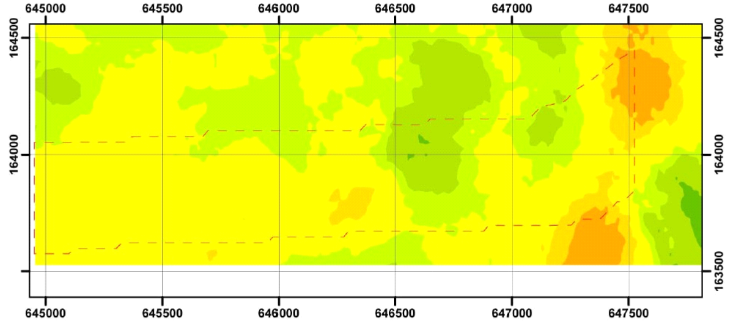
Depth (m)

- 2.6 - 3.0
- 3.1 - 3.5
- 3.6 - 4.0
- 4.1 - 4.5
- 4.6 - 5.0
- 5.1 - 5.5
- 5.6 - 6.0
- 6.1 - 6.5
- 6.6 - 7.0
- 7.1 - 7.5
- 7.6 - 8.0
- 8.1 - 8.5
- 8.6 - 9.0
- 9.1 - 9.5
- 9.6 - 10.0
- 10.1 - 10.5
- 10.6 - 11.0
- 11.1 - 11.5
- 11.6 - 12.0
- 12.1 - 12.5
- 12.6 - 13.0
- 13.1 - 15.0
- > 15.0

Map 4: Difference in Depth between 1960 and 1970 Datasets

Depth Change (m)

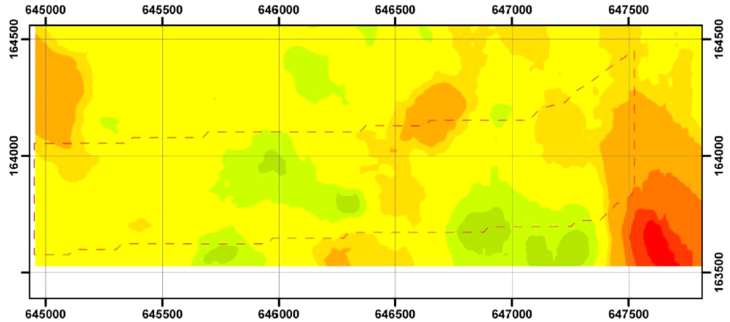
- 3.1 - 4.0
- 2.1 - 3.0
- 1.1 - 2.0
- 0.6 - 1.0
- 0.1 - 0.5
- -0.4 - 0.0
- -0.9 - -0.5
- -1.9 - -1.0



Map 5: Difference in Depth between 1970 and 1973 Datasets

Depth Change (m)

- 1.1 - 2.0
- 0.6 - 1.0
- 0.1 - 0.5
- -0.4 - 0.0
- -0.9 - -0.5
- -1.9 - -1.0
- -2.9 - -2.0
- -3.9 - -3.0
- -4.9 - -4.0
- -5.9 - -5.0



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Seabed Bathymetry - Goodwin (1960-1973)

Coordinate System: British National Grid

HR Wallingford

Notes:
1. Depth soundings are reduced to 2.58m below Ordnance Datum and interpolated using an ordinary kriging algorithm with a search radius of 12 points. Grid resolution is 25 metres
2. Difference grids have been mapped to indicate Negative values as Erosion, and Positive values as Accretion

Drawing No : 9P5164/06/914	Scale : NOT TO SCALE		Source : HR Wallingford, 2005
Date : 12/10/2005	Layout : SMG	Checked : JE	
Figure : 6.16	Revision No : 001		

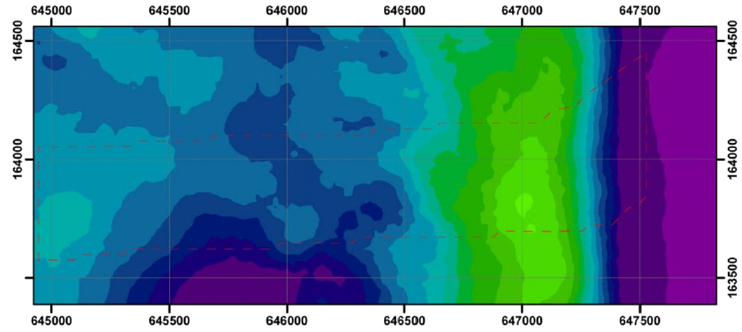
ROYAL HASKONING

Title : **BATHYMETRY OF THE CABLE ROUTE OVER GOODWIN KNOLL FROM 1960, 1970 AND 1973 SURVEYS, PLUS DEPTH DIFFERENCE PLOTS**

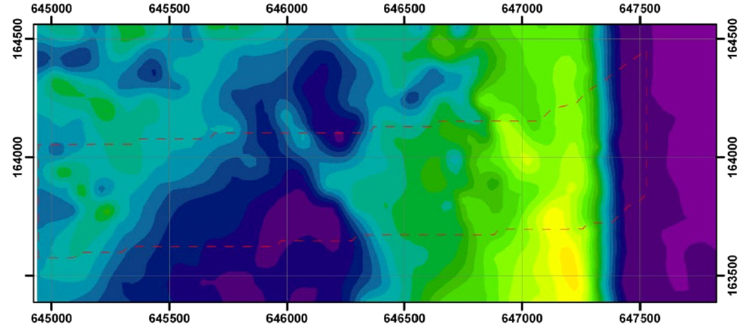
Project : **THANET OFFSHORE WIND FARM**

Client : **THANET OFFSHORE WIND LTD**

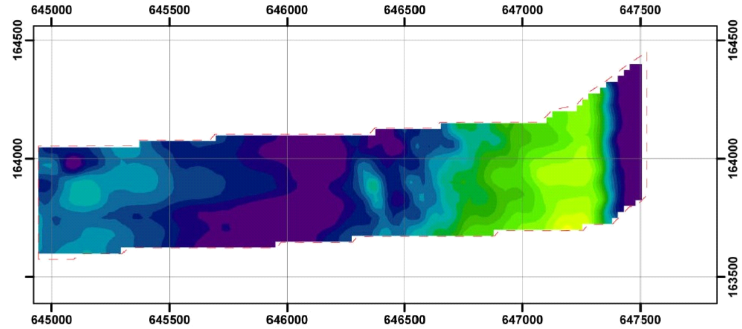
Map 1: Seabed Bathymetry - 1980

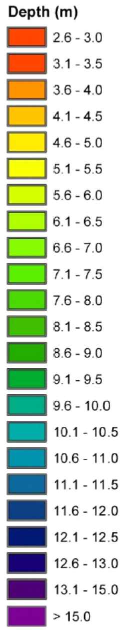


Map 2: Seabed Bathymetry - 1997

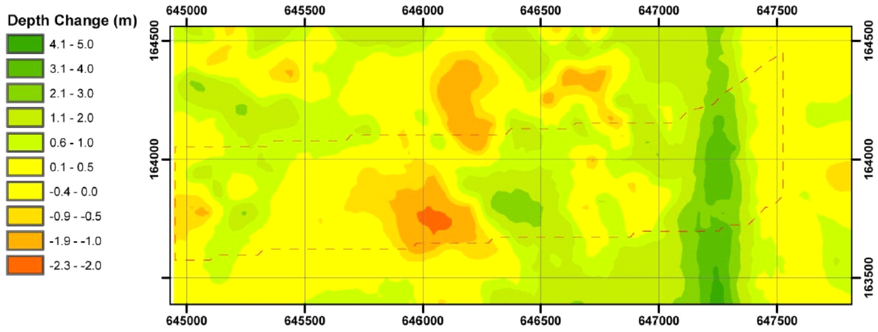


Map 3: Seabed Bathymetry - 2005

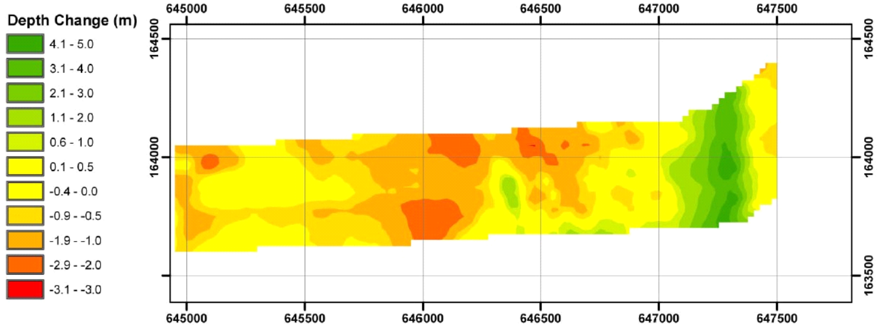




Map 4: Difference in Depth between 1980 and 1997 Datasets



Map 5: Difference in Depth between 1997 and 2005 Datasets



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Seabed Bathymetry - Goodwin (1980-2005)

Coordinate System: British National Grid

HR Wallingford

Notes:
1. Depth soundings are reduced to 2.58m below Ordnance Datum and interpolated using an ordinary kriging algorithm with a search radius of 12 points. Grid resolution is 25 metres
2. Difference grids have been mapped to indicate Negative values as Erosion, and Positive values as Accretion

Drawing No : 9P5164/06/915	Scale : NOT TO SCALE		Source : HR Wallingford, 2005	Title : BATHYMETRY OF THE CABLE ROUTE OVER GOODWIN KNOLL FROM 1980, 1997 AND 2005 SURVEYS, PLUS DEPTH DIFFERENCE PLOTS
Date : 12/10/2005	Layout : SMG	Checked : JE		Project : THANET OFFSHORE WIND FARM
Figure : 6.17	Revision No : 001		ROYAL HASKONING	Client : THANET OFFSHORE WIND LTD

The chalk cliff beyond Ramsgate gives way to sandstone Thanet Beds, which dip down below the fine grained Holocene sediment of the River Stour valley. Further south, the coast comprises a shingle ridge beach, topped in places by dunes. The beach is fed by northward drift from South Foreland, but is now tending to erode, as various shoreline works to the south have reduced natural drift.

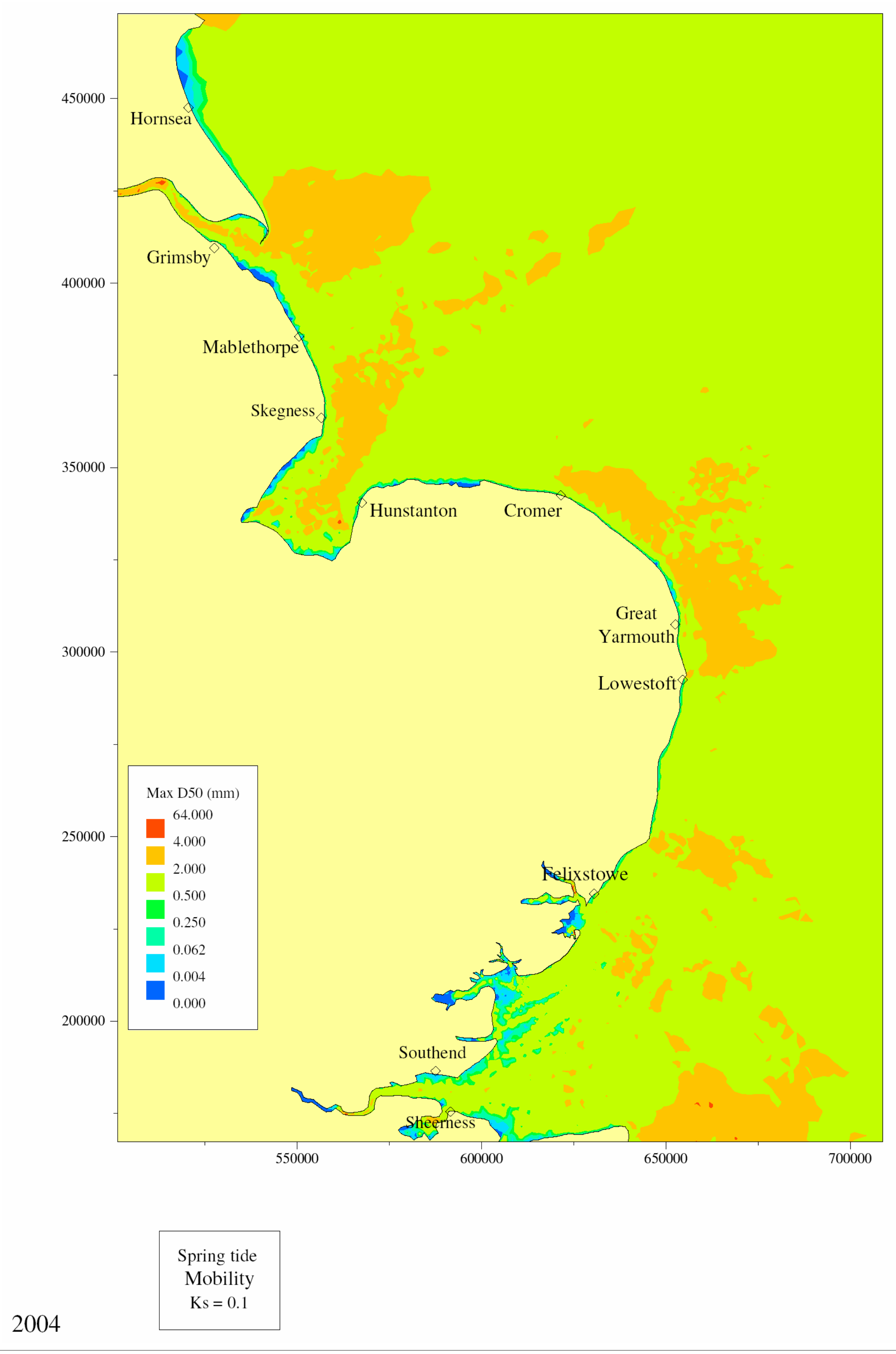
6.3.8 Seabed processes

Seabed transport is driven by tidal currents combined with waves, and is a function of the type and availability of seabed sediment. The relative importance of waves and tidal currents varies depending on local conditions, with the effect of waves dependent on the wave height and period relative to the depth of water. Seabed transport pathways for the Thanet area have been investigated by various studies, and are considered at a regional level by the Southern North Sea Sediment Transport Study (SNSSTS) (HR Wallingford *et al*, 2002). This important work made use of all available field information, combined with numerical modelling to derive a coherent image of seabed transport pathways.

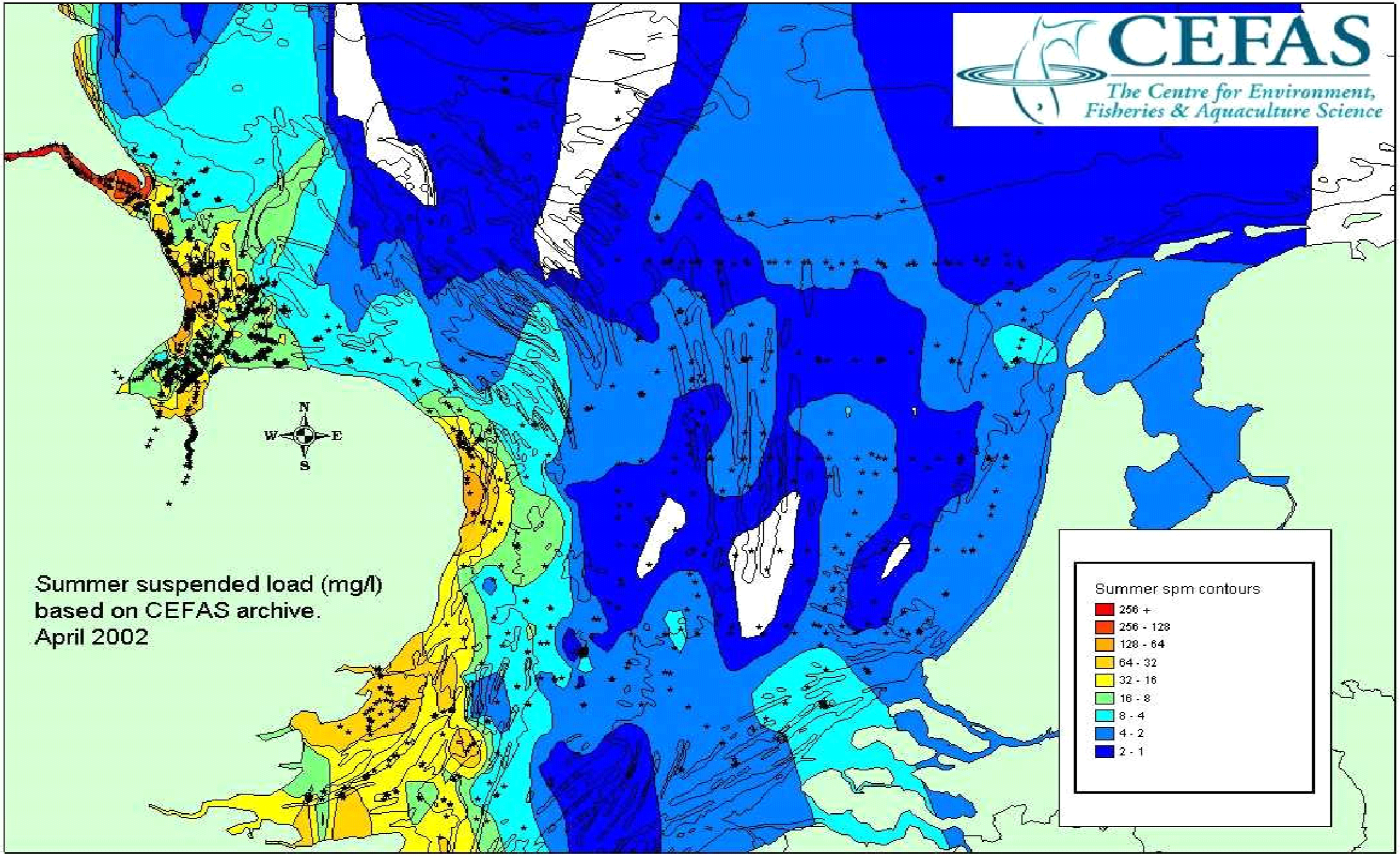
The existing sediment transport regime for the southern North Sea was simulated using the HR Wallingford TELEMAC, SANDFLOW and COSMOS models. The results of that work provide an indication of the transport regimes at the Thanet site and the export cable routes. The tidal currents can mobilise coarse sand and fine gravels of up to 4mm size under normal spring tide conditions (see **Figure 6.18**), while suspended loads vary from typical summer values of 16mg/l to 30mg/l to typical winter values of up to 60mg/l (see **Figures 6.19** and **6.20**). Tidal current residuals, and therefore nett transport vectors, vary from the shore to the outer limits of the Thanet site giving significant differences in rate and direction.

Model results from HR Wallingford *et al* (2002) varied considerably depending on assumptions about sediment size, seabed roughness, wave stirring, wind stresses and tidal state. These differences reflect the natural variability of sea conditions. By combining the model results and seabed indicators such as sand wave asymmetry, megaripple patterns, sand ribbons, sandbanks, etc, the SNSSTS built up a relatively comprehensive and authoritative picture of bed transport. **Figures 6.21** and **6.22** indicate net fluxes for fine sand under neap and spring tides, without wave or surge conditions.

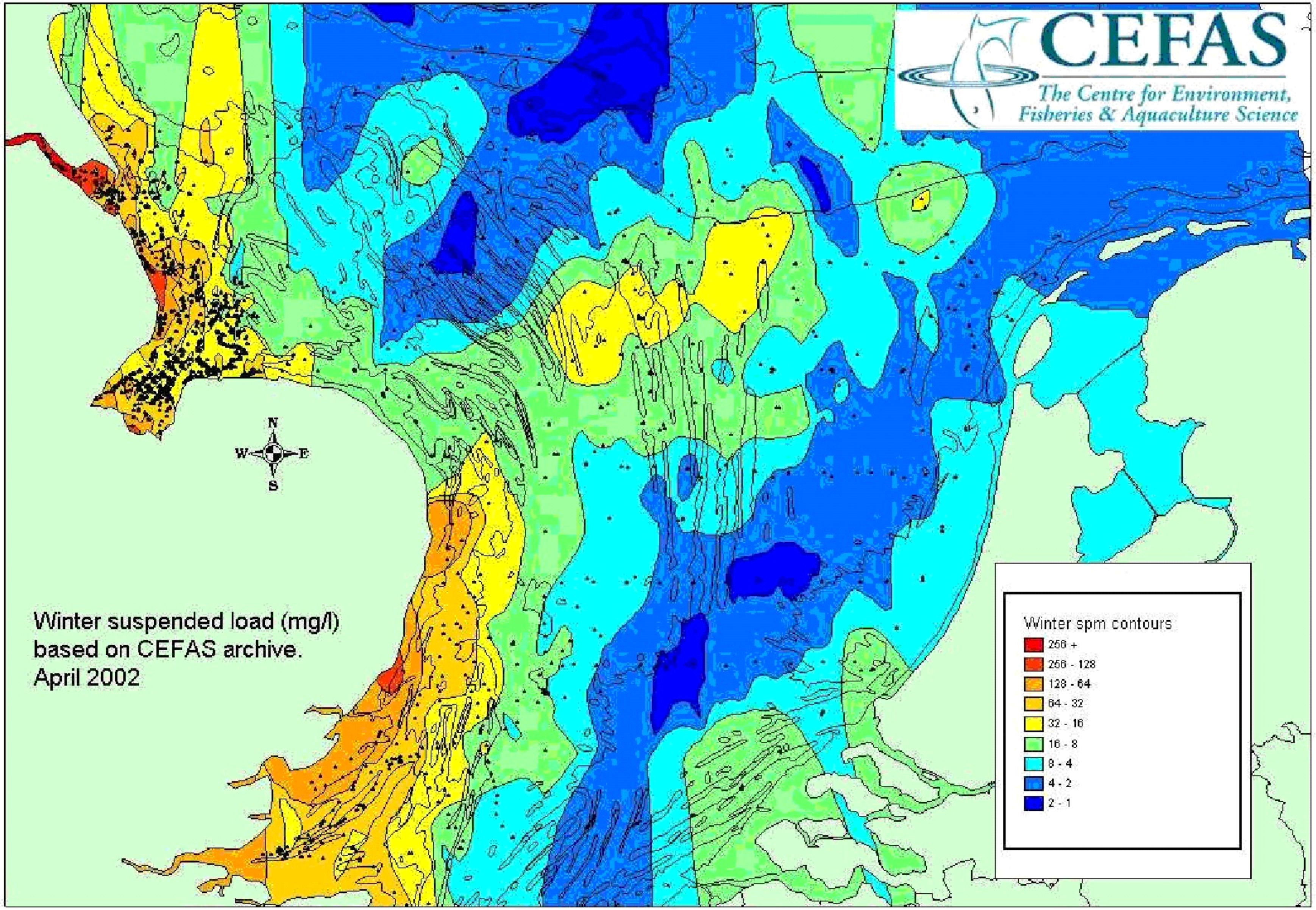
The dominant driver for sediment transport over most of the site area is tidal current. The effects of unbroken waves in the relatively deep water of the site are limited mainly to a stirring effect whereby the entrainment process is enhanced, particularly during periods of higher wave activity. Wave action can increase the magnitude of the suspended sediment concentration by this process, but the transport pathways are unaltered.



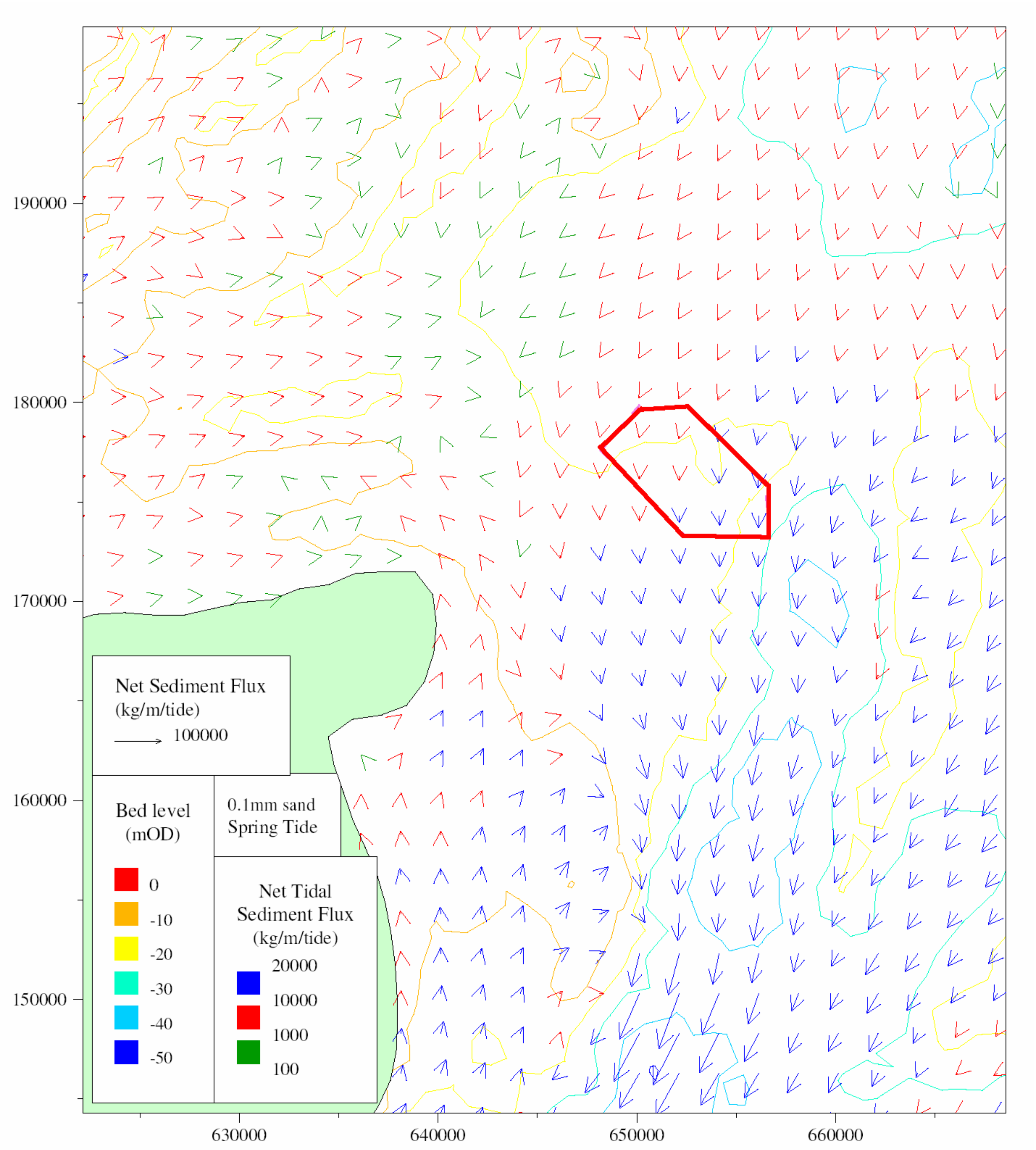
Drawing No : 9P5164/06/916	Scale : NOT TO SCALE	Source : HR Wallingford, CEFAS/UEA, Posford Duvivier, Dr B D'Olier, 2002	ROYAL HASKONING	Title : **SEABED MOBILITY: MAXIMUM MOBILE GRAIN SIZE UNDER SPRING TIDES**
Date : 12/10/2005	Layout : SMG / Checked : JE			Project : **THANET OFFSHORE WIND FARM**
Figure : 6.18	Revision No : 001			Client : **THANET OFFSHORE WIND LTD**



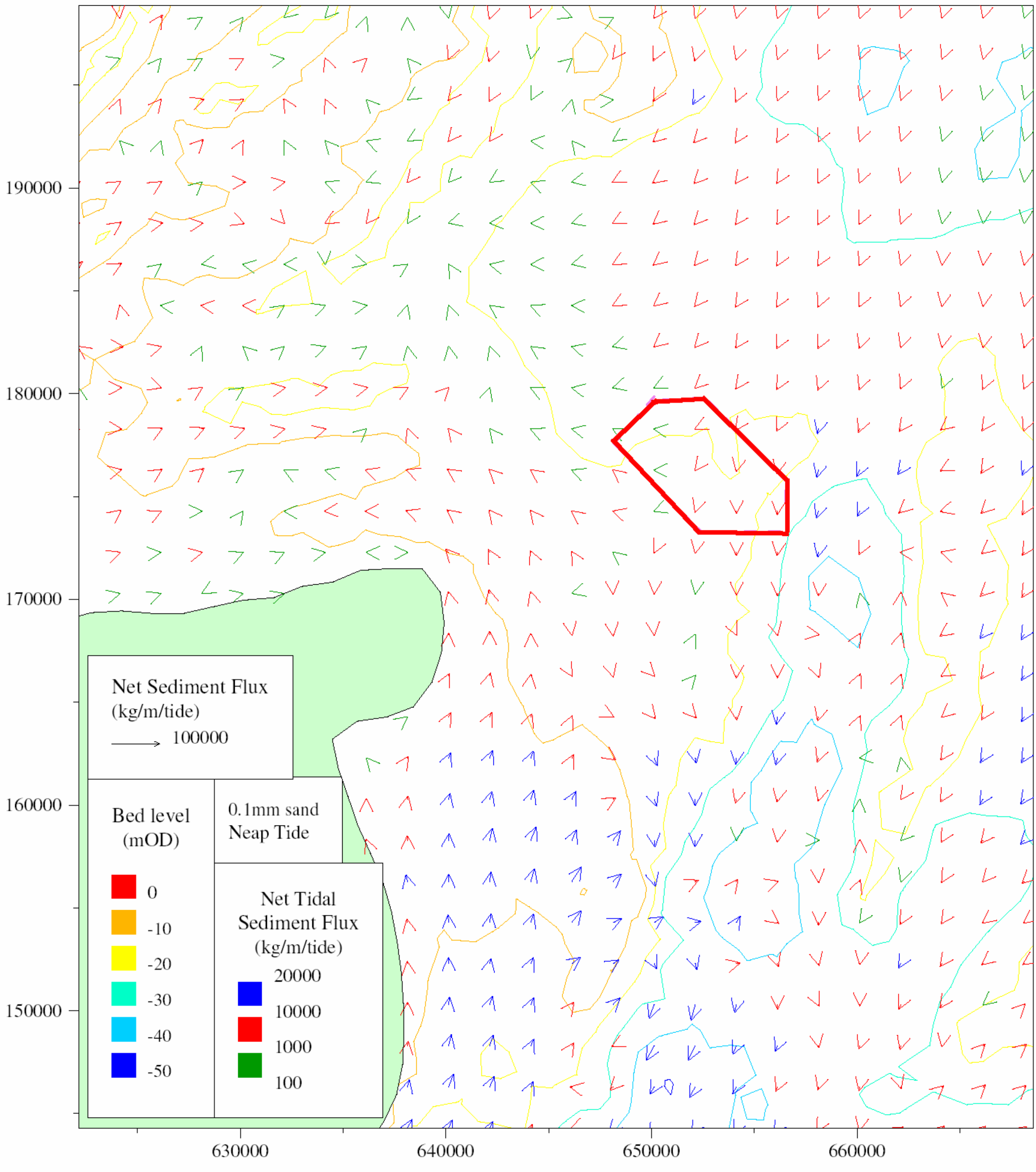
Drawing No : 9P5164/06/917	Scale : NOT TO SCALE		Source : HR Wallingford, CEFAS/UEA, Posford Duvivier, Dr B D'Olier, 2002	Title : "CLIMATE MEAN" SUMMER SUSPENDED SEDIMENT CONCENTRATIONS (UNITS: mg/l)
Date : 12/10/2005	Layout : SMG	Checked : JE		Project : THANET OFFSHORE WIND FARM
Figure : 6.19	Revision No : 001		ROYAL HASKONING	Client : THANET OFFSHORE WIND LTD



Drawing No : 9P5164/06/918	Scale : NOT TO SCALE		Source : HR Wallingford, CEFAS/UEA, Posford Duvivier, Dr B D'Olier, 2002	ROYAL HASKONING	Title : "CLIMATE MEAN" WINTER SUSPENDED SEDIMENT CONCENTRATIONS (UNITS: mg/l)
Date : 12/10/2005	Layout : SMG	Checked : JE			Project : THANET OFFSHORE WIND FARM
Figure : 6.20	Revision No : 001				Client : THANET OFFSHORE WIND LTD



Drawing No : 9P5164/06/919	Scale : NOT TO SCALE	Source : HR Wallingford, CEFAS/UEA, Posford Duvivier, Dr B D'Olier, 2002	ROYAL HASKONING	Title : NET POTENTIAL SEDIMENT FLUX FOR FINE SAND UNDER MEAN SPRING TIDE CONDITIONS
Date : 12/10/2005	Layout : SMG — Checked : JE			Project : THANET OFFSHORE WIND FARM
Figure : 6.21	Revision No : 001			Client : THANET OFFSHORE WIND LTD



Drawing No : 9P5164/06/920	Scale : NOT TO SCALE	Source : HR Wallingford, CEFAS/UEA, Posford Duvivier, Dr B D'Olier, 2002	Title : NET POTENTIAL SEDIMENT FLUX FOR FINE SAND UNDER MEAN NEAP TIDE CONDITIONS
Date : 12/10/2005	Layout : SMG / Checked : JE		Project : THANET OFFSHORE WIND FARM
Figure : 6.22	Revision No : 001	ROYAL HASKONING	Client : THANET OFFSHORE WIND LTD

Large waves in relatively shallow waters cause wave breaking that generates an additional driving force, and this process does alter the direction of sediment transport. However, for the Thanet site, the seabed levels are generally greater than -15m CD. The onset of wave breaking due to depth limitation occurs when the wave height exceeds a factor of the water depth of between 0.55 and 0.8. This range criterion indicates that only the most extreme individual waves of over 8m would break over the Thanet site at lowest tide levels, while at high tide levels only waves above about 10m would be likely to break. Waves of this size would only occur during extreme conditions, with an occurrence probability less frequent than 1 in 1 or even 1 in 10 years. Consequently, it is appropriate to focus attention on the potential impact of the wind turbine foundations on the sand transport patterns due to tidal currents alone, enhanced by non-directional wave disturbance.

The tidal currents are capable of mobilising sand and fine gravel at the Thanet site under normal spring tidal conditions. Tidal current residuals, and therefore net transport vectors, vary considerably between the coastline and the wind farm site. This indicates significant differences in the rate and direction of sediment transport across the area of interest. The conditions are sufficiently dynamic to prevent deposition across most of the shallow exposed chalk and to create mobile bed forms such as sand ribbons, megaripples, sand waves and sandbanks, where water depths or sediment supply are large enough. The orientation of the bedforms indicates that sediment transport occurs in a north to south direction across the Thanet site.

The transport direction along the export cable route close to Ramsgate is influenced by both tidal residuals and wave breaking in shallower waters during more severe northeasterly events. The resultant transport directions are in opposition, giving a dynamic and uncertain situation. The geophysical survey team observed that the surface sediment along both export cable routes is very mobile, with depths and bedforms changing within the winter survey period due to currents and wave disturbance (EGS, 2005).

6.3.9 Coastal morphology and processes

This section describes the existing coastal situation and the predicted future evolution assuming no further onshore or offshore development. The frontage considered extends along the maximum area over which the Thanet project, including the export cable route, could potentially influence the coastal processes. Given the dominant wave directions, tidal currents and known sediment transport routes, there is no potential for impacts beyond Margate to Deal on the Kent coastline. There must be a clear understanding of the existing processes within this area to assess the potential impacts, and the likely future evolution of the coast, including an understanding of the temporal and spatial variability, and the level of uncertainty.

The coastal area was assessed for the UK Macro-Review in 1987 and the Shoreline Management Plan process in 1996, and much of the available information has been collated and summarised within the Future Coast 2002 document (HR Wallingford, 1987; Halcrow, 1996; Halcrow, 2002). The accepted management plan is to maintain the existing shoreline position through active construction and management, apart from the length from Foreness Point to North Foreland where the present eroding cliffs may be allowed to recede naturally to a new position, and within Pegwell Bay where the foreshore is building up and new saltmarsh is forming.

The coast of this region is characterised by chalk cliffs, gravel and sand beaches, low dunes and marshes. Much of the coast to the east of Margate around North Foreland and on to Cliffs End in Pegwell Bay consists of near vertical chalk cliffs, fronted by a wide, intertidal wave-cut chalk platform. Small bays, sea stacks and arches have formed. Further to the south, there is the wide silty sand foreshore and gravel upper beach around Pegwell Bay. The shoreline beyond the Bay is formed by a series of curved spits, covered in part by sand dunes. The sand and shingle beaches front low lying land as far south as Deal, after which the chalk cliffs start to rise again towards South Foreland.

In terms of coastal processes, the area of interest can be divided into two regions:

- The Isle of Thanet (Margate to Ramsgate); and
- East Kent (Pegwell Bay to Deal).

The Isle of Thanet forms a relatively resistant chalk headland that has exerted major controls on the evolution of the area, both as a point of stability along the southern boundary of the Thames Estuary and as a result of its influence upon the tidal flows that operate between the North Sea and the English Channel. The chalk cliffs are primarily eroded along faults and joints at the base, resulting in uneven erosion and the formation of bays and headlands. The frontage is exposed to moderately severe wave conditions from the north, east and south, with the level of exposure reducing westwards from Foreness Point, and southwards from North Foreland.

The drift direction along the north coast is westwards and the foreshore sediments vary from predominantly shingle in the east to predominantly fine sand in the west. There is no evidence of sediment exchange around North Foreland. The drift is southerly from North Foreland to Ramsgate, with significant shingle beaches found only within the small bays cut into the chalk cliffs. The beach widens and becomes sandier at Ramsgate, where the port breakwaters halt the drift. It is uncertain as to whether there is any significant offshore movement, but nearshore bedforms suggest that material does move off, possibly being carried north again on the nearshore residual tidal current. There is no evidence of material entering the port via the dredged navigation approach channel, which apparently does not require any maintenance to keep the charted depth of -7.5m CD.

Structural defences comprising concrete seawalls and groynes exist from Margate to Foreness Point, and seawalls from North Foreland to Ramsgate. In contrast, the chalk cliffs between Foreness Point and North Foreland are unprotected, with the exception of localised defences in Kingsgate Bay. The foreshore has progressively become squeezed between a rising sea level and static backshore defences due to the presence of defences throughout the majority of the cliff frontage. There has been a nett loss of beach material, because drifting sediment has not been replaced at the same rate by the input of material from offshore or released from sea cliffs erosion. The progressive loss of foreshore sediment leads to slow rates of shore platform lowering, which can be assumed to continue in the future. This has reduced the natural ability of the foreshore to moderate incoming wave energy and leaves the existing shoreline subjected to higher wave action.

The East Kent frontage south of Ramsgate is geologically influenced by the presence of chalk headlands at South Foreland and the cliffs at Ramsgate. The shoreline of Sandwich Bay is predominantly characterised by a shingle ridge, which has grown progressively northwards from Deal up to the mouth of the River Stour. The lower foreshore widens northwards from Deal, forming Sandwich Flats and then the wide fine sand and mud intertidal flat within Pegwell Bay.

The position of the shingle ridge varies over time in response to changes in the extent and elevation of the Goodwin Sands and the Brake Bank. These large scale nearshore banks provide shelter to Sandwich Bay and Pegwell Bay, but are known to change over time.

Pegwell Bay is accreting sand and fines from the adjacent shorelines and from offshore. Tidal currents are weak locally, allowing deposition of suspended load, and the area is sheltered from significant wave disturbance. The inner Bay is sufficiently stable for saltmarsh to have become established along the shoreline. Further north and east, close to the Port of Ramsgate, there is an area of apparent instability where surveys indicate changes of bed elevation of up to 1m over the past decade. Future change may be influenced by changes to the Goodwin Sands and Brake Bank, or further development of the port.

The landfall site is in the northwest of the Bay, to the north of the reclaimed ground formerly used as a hoverport (as shown in **Figure 1.2** in **Section 1, Introduction** and **Plate 6.1** below). The upper foreshore comprises pioneer growth of saltmarsh backed by a low gravel and shell beach that is vegetated along its crest. There is a low rock revetment around the disused hovercraft base, which cuts across the line of the natural upper beach. The general situation is indicative of long term stability and accretion, although it could be disturbed under southeasterly storm conditions, particularly if water levels were above normal.

Plate 6.1 Disused Hoverport: Pegwell Bay

(source: Halcrow, 2002)

6.4 Impacts during Construction

6.4.1 Impact of sediment transport - suspended sediment

Fine sediment brought into suspension due to scour around the foundations or construction operations would be transported up-drift, with the distance dependent on the hydrodynamics at the time of disturbance and on the settling velocity of the sediment. Coarse sediments such as sand and gravel, would settle almost immediately, but finer silt and clay material may be carried for considerable distances, and may not settle until a different hydrodynamic regime is encountered.

Short term increases in the level of suspended sediments and subsequent deposition could be an issue with regard to fisheries and benthic communities. The increase would depend on the foundation construction and cable laying methods, and wave / tidal conditions during the period of disturbance. The significance of the impact would depend on the sensitivity of the communities during the construction period. Assessment of ecological impacts should take account of the moderately high background levels of suspended sediment throughout the area of up to 30mg/l in summer and up to 60mg/l in winter (see **Figures 6.19** and **6.20**). Driving monopiles would cause considerably less suspended sediment than drilling, as the spoil from drilling operations would remain on the seabed for sufficient time to allow tidal currents to transport material as bed load or in suspension. Gravity base foundations would also cause short term disturbance as some form of bed levelling is likely to be required prior to placement and significant excavation could require spoil disposal elsewhere (see **Section 2, Project Details**).

Sediment transport would also be influenced by the method of cable burial. Regardless of burial method, bed sediment would be disturbed causing increased suspended loads during laying operations and increased potential for subsequent re-suspension. As with foundation construction, the impacts would depend on the construction method employed, composition of the seabed and the sensitivity of the natural environment during the construction period. Sand and coarser sediment would only be dispersed over a short distance, typically metres for coarse sand and up to a few hundred metres for very fine sand, while fines such as silt and chalk would be carried in suspension over the full distance of the tidal excursion, which is about 10km for the main site and export cable route. The volume of material put into suspension per metre run of cable length would be small relative to the normal baseline suspended sediment concentrations in the area, so impacts would be **negligible**. Chalk fines would cause the seawater to become visibly milky over a wide area, even at low concentrations.

Ploughing is considered to cause the least disturbance, as excavated bed material is largely returned as the cable is laid. Jetting is not appropriate in areas of exposed chalk and sandstone. Trenching creates the greatest disturbance and depends on natural processes to backfill. Backfill rates depend on the local currents, seabed type and availability of suitable mobile sediment. Given the availability and mobility of the surface sands across most of the Thanet site, it is likely that natural infill would be rapid. However, trenching the exposed chalk along the export cable route could leave an open trench, and imported backfill could be required to provide protection to the cable. If so, the material would be specified to minimise the potential for future re-suspension or bed load transport.

The potential dispersion of disturbed silt and chalk arising from burial to a target depth of 1m can be estimated using standard principles outlined in Fischer *et al* (1979) along with unpublished industry information on seabed disturbance during ploughing or trenching.

It is assumed that about 0.02m^3 of sediment per metre of cable run would be put into suspension by ploughing in silty sand or chalk. Trenching would put as much as 0.3m^3 of sediment into suspension per metre. Re-suspended chalk or silt would be rapidly distributed throughout the water column and would be carried by the daily tidal excursion for up to 10km. The spatial differences in tidal currents, both through the water column and with distance offshore would result in shear dispersion of the plume, resulting in the growth of the size of the plume and reduction of concentrations of chalk or silt within the plume.

Assuming that trenching proceeds at 0.1m/s in a water depth of 20m, then the suspended sediment concentration within the plume is conservatively estimated to be in the order of 2mg/l to 15mg/l, depending on current speeds. Even at the higher estimate, the concentration is below the typical summertime background concentration of less than 30mg/l (see **Figure 6.19**). Ploughing could proceed more rapidly, at perhaps 0.3m/s, but would release much less sediment, giving peak concentrations of only about 3mg/l. These short term increases to the background concentrations are unlikely to be significant, but should be considered in relation to any sensitive communities (see **Section 9, Marine Ecology**).

It is likely that disturbed chalk would be clearly visible as a milky plume. Concentrations would reduce with a half-life of the order of a few tides to a week, depending primarily on tidal conditions, and the plume would drift with the residual current (**Figures 6.8** and **6.9**). The effects on water quality is discussed in **Section 7, Marine and Coastal Water Quality**. The settling velocity of chalk is negligible and so there would not be any temporary or permanent deposition on the seabed. Silt would settle during slack water, but is likely to be re-suspended as currents increase through the tidal cycle.

Induced sediment transport is likely to be highest during the winter months, due to the enhancement of tidal current activity by large waves and storm surges. Any potential impacts on the transport regime, including local scour and suspended sediment dispersion, would be minimised by undertaking seabed disturbance activities in the summer months. This requirement would have to be balanced against other environmental and practical considerations.

Driving monopile foundations would minimise the local increase in suspended sediment. Drilling and grouting piles would release sediment for transport as bed load and in suspension, but the volumes released would have a **negligible** impact on the general sediment regime. Levelling bases for gravity base structures would cause greater disturbance and sediment dispersion, but even this activity is not considered to be significant in terms of increased suspended load or sediment deposition, except locally during the period of work on each base. Consideration would be given to the phasing of this work to minimise exposure to severe wave conditions and any seasonal sensitivities of the natural environment.

The significance of the effect of suspended sediment is assessed in **Section 7** and **Section 9** as discussed above.

6.5 Impacts during Operation

6.5.1 Localised impacts on waves

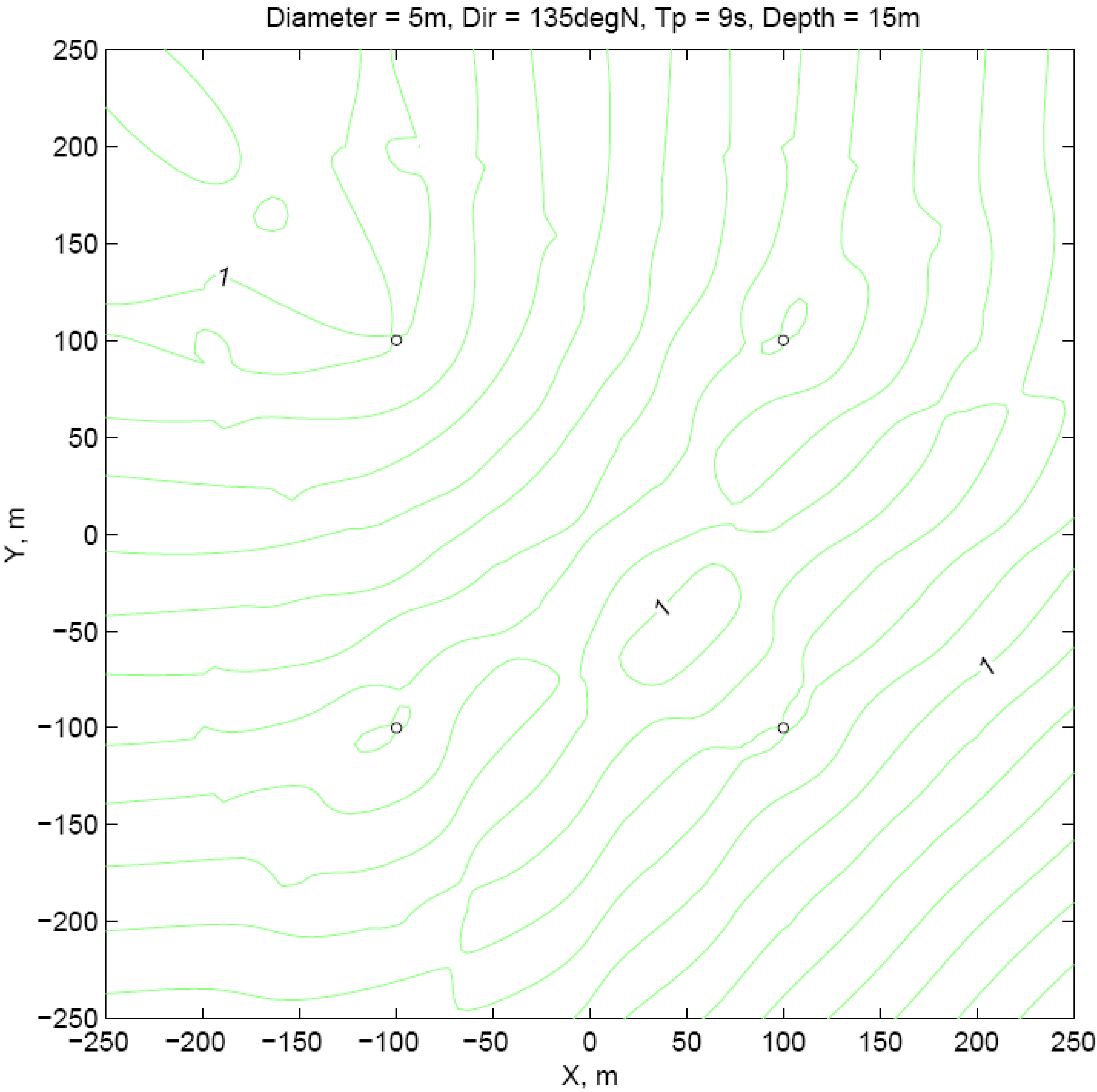
Waves would be modified in the immediate vicinity of the wind turbine foundations due to diffraction and reflections. Methods for assessing the potential impacts of monopiles and simple gravity base structures are well established. It was assumed for this study that the large diameter base plates of the possible gravity base structures would have a sufficiently low profile, relative to the water depth, that they would have minimal impact on wave transformation and would not cause breaking (see **Figure 2.8** in **Section 2**). The low, narrow cable crossing structures used for the crossing of the two in-service telecommunications cables would have a similar minimal impact. This assumption is valid for all but the largest storm waves occurring during low water periods, when under these infrequent conditions, very localised wave refraction and shoaling could occur.

The proposed monopiles and the upper cylinder of the gravity base structures are considerably narrower than the typical wavelength of most waves affecting the study area, and therefore it is considered that the direct impact on waves would be small, other than immediately around each structure, and there would be no discernible interaction between the structures. The reasons for these conclusions are set out below.

Waves are disturbed by the presence of cylindrical structures when the diameter, D, becomes large relative to the wavelength, L. A value of $D/L \geq 0.2$ is generally taken as the regime in which wave scattering becomes important. A reflected wave is generated when it hits a large cylinder and moves outwards from it. On the sheltered side of the cylinder there would be a shadow zone where wave fronts are bent around the cylinder. These waves are diffracted and, combined with the reflected waves they are referred to as the scattered waves.

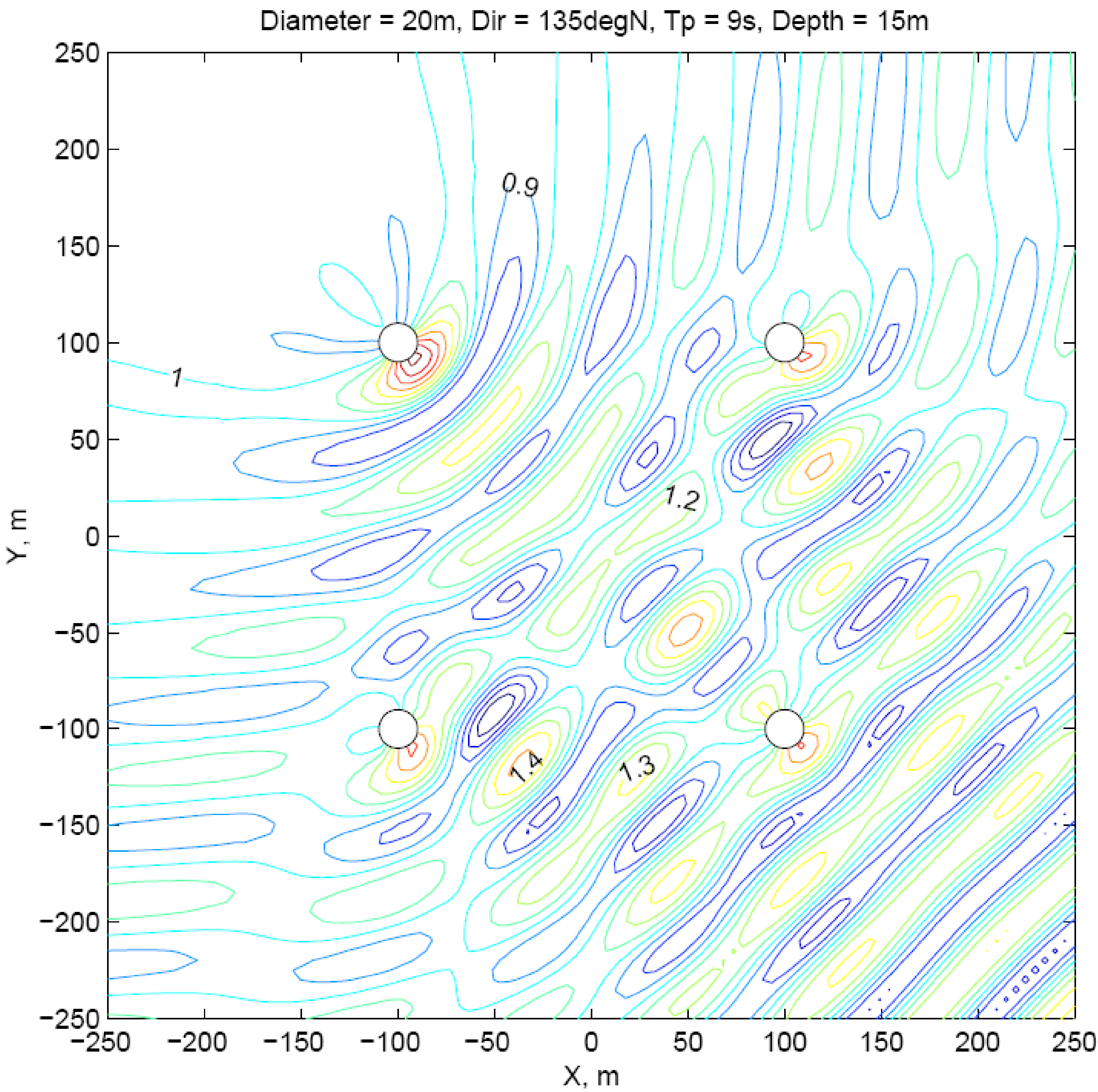
The wave climate for the area around the Thanet site includes short period waves likely to be influenced by the foundations for a significant percentage of the time. However, these short period waves have low heights and therefore the resulting scattered and diffracted waves would be small. Monopiles and simple gravity base structures could be considered to act independently, as the scattered waves would decay to an insignificant wave height when they reach the nearest adjacent foundations.

Several approaches to simulating wave diffraction and scattering are available. Recent published research from Oxford University (Ohl *et al,* 2001) clearly supports the view that assuming the range of configurations likely for the Thanet site, the scattered waves created by interactions with any one foundation would be negligible before reaching the nearest adjacent foundation. Sample results are set out in **Figures 6.23** and **6.24** using 5m and 20m diameter cylinders at only 200m spacing. The contour values of increased wave energy indicate that there are no areas with greater than a 10% change using 5m diameter piles, but there are areas of 40% increase/decrease with the 20m cylinders. Even with the larger cylinders, the downstream effect is negligible outside the area of the piles. These results are only a simple example with one wave condition, but show clearly that there is no potential for significant cumulative impacts with 6m diameter foundations spaced at a minimum distance of 700m in the prevailing north to south dominant flow direction.



Drawing No : 9P5164/06/921	Scale : NOT TO SCALE		Source : derived from: Ohl, C.O.G., Taylor, P.H., Eatock Taylor, R., Borthwick, A.G.L., 2001	Title : **WAVE SCATTERING FROM 5M DIAMETER CYLINDERS AT 200M SPACINGS: + - 10% WAVE ENERGY CONTOUR INTERVALS**
Date : 12/10/2005	Layout : SMG	Checked : JE		Project : **THANET OFFSHORE WIND FARM**
Figure : 6.23	Revision No : 001			Client : **THANET OFFSHORE WIND LTD**

ROYAL HASKONING



Drawing No : 9P5164/06/922	Scale : NOT TO SCALE		Source : derived from: Ohl, C.O.G., Taylor, P.H., Eatock Taylor, R., Borthwick, A.G.L., 2001	ROYAL HASKONING	Title : WAVE SCATTERING FROM 20M DIAMETER CYLINDERS AT 200M SPACINGS: + - 10% WAVE ENERGY CONTOUR INTERVALS
Date : 12/10/2005	Layout : SMG	Checked : JE			Project : THANET OFFSHORE WIND FARM
Figure : 6.24	Revision No : 001				Client : THANET OFFSHORE WIND LTD

Even under likely worst case conditions, as simulated using a simplified numerical wave model for a shallow sandbank under the recently completed CEFAS/Defra research project (Halcrow, 2003), the cumulative impact of closely spaced turbines has been shown to reduce incident wave heights by no more than 5%, with no influence on wave period. More realistic non-linear, random wave modelling using the turbine spacing for the Thanet project show that the cumulative impact of the wind farm on the wave conditions would be negligible. This conclusion has been independently reached by HR Wallingford during a number of Round One offshore wind farm studies, the recent DTI funded generic research project (ABPMer, 2005) and recently completed wave monitoring undertaken by CEFAS at the Scroby Sands offshore wind farm (report not yet published).

Future sea level rise or increased storminess would allow larger waves to reach the site, but the influence of the structures on the wave conditions would remain negligible.

6.5.2 Localised impacts on currents

Currents would also be modified in the immediate vicinity of the wind turbine foundations and cable crossing structures. Tidal currents in the area are essentially rectilinear with normal velocities up to 1m/s. There would be a flow separation zone and downstream turbulence in the immediate lee of the proposed wind turbine foundations. Standard design guidance (Lamb, 1932) suggests that this zone typically extends 6-10 structure diameters i.e. 36m to 60m for a 6m diameter monopile, and within this zone there is likely to be generation of turbulence that is greater than normal, especially during peak flood and ebb conditions. There could also be some shedding of turbulent vortices that extend beyond this main zone of influence. Only the upper cylinder of the gravity base structure is considered for the purposes of depth averaged flow impacts (see **Figure 2.8** in **Section 2**). The foundation base is addressed within the scour section. As the structures would be separated by a minimum distance 450m along each row and by at least 700m in the direction of the dominant north-south tidal flows, then it can be assumed that there is no significant interaction between structures with respect to flows. This conclusion has also been reached for Round One offshore wind farm sites and by the recent DTI project (ABPMer, 2005).

The export cable crossing structures would also cause downstream flow separation with some locally increased turbulent shear stress. The turbulent wake would extend downstream, increasing the potential for scour. As with vertical cylinders, it is assumed that the area of significant impact would be limited to about 10 times the structure elevation, or less than 15m down-drift.

6.5.3 Localised impact on scour

The potential impact of the wind turbine foundations, cable crossing structures or any exposed cable on the sediment transport would depend on the local modifications to the waves and currents, as described above, and the availability of potentially mobile sediment. The local acceleration of the tidal currents and generation of down-drift turbulence, together with wave activity, would tend to scour sediment from around the structures and from beneath the cables on both the flood and ebb tide, and deposit it down-drift.

A best estimate for the depth of scouring of monopiles and simple gravity base structures for Environmental Impact Assessment purposes can be based on existing literature (Whitehouse, 1998; Whitehouse *et al*, 2004; Den Boon *et al*, 2004; Zaaijer, 2003; DNV, 2004; Sumer and Fredsøe, 2002; Whitehouse, 2004; Hoffmans and Verheij, 1997), unpublished research from the DTI Suction Caisson programme, recent commercial wind farm physical modelling projects, and the recent monitoring experience from the Scroby Sands offshore wind farm (CEFAS research report, in preparation).

The scour extent and depth around a cable or turbine foundation is dictated by the hydraulic and sediment conditions. For the purposes of considering the worst case situation for the Environmental Impact Assessment, it is assumed that there is sufficient current to cause scour and that the surface sediment is non-cohesive, homogeneous and unlimited. In reality, it is known that the sediment distribution across the site is variable, with the areas of sand waves giving a potential mobile depth of up to 10m in places, while the areas of patchy mobile layers over chalk or sandstone would limit scour to the depth of surface cover. Further work on the scour potential at each turbine location would be carried out for the detailed engineering design.

The results of the scour assessment under approximate worst case conditions for the wind farm site and cable corridor are as follows outlined below.

Case 1: Wind farm monopiles

Table 6.6 Case 1: Wind farm monopiles: assumed parameters

Monopile:	**Diameter = 6m**
Water depth:	h = 18m to 28m at times of peak current
Waves:	H_s = 3.0m; T_p = 6 sec
U_{orb} at bottom:	U_{orb} = 0.5m/s
Current:	U = 1.0m/s
Sediment:	d_{10} = 0.010mm; d_{50} = 0.220mm; d_{90} = 0.450mm
Threshold of motion:	U_{crit} = 0.5m/s

The steady velocity required to initiate sediment transport is approximately 0.5m/s, while the minimum wave height needed to mobilise the sediment is approximately 0.9m. This indicates that under peak flow conditions the tide alone is capable of moving sediment and causing scour around the structure, even in the absence of any waves. The scour hole due to tidal currents alone has the potential to extend approximately 4D horizontally from the pile and up to approximately 1.5D vertically, where D is the monopile diameter. Given D=6m, then scour could extend approximately 24m from the outside of the structure and about 9m in depth. The presence of waves would tend to speed up the rate at which the scour occurs, although the presence of storm waves with H_s greater than 3m could inhibit the scour depth and extent.

This assessment assumes an unlimited depth of potentially mobile, homogeneous fine sand. This is a reasonable assumption for the sand wave areas of the Thanet site, but gives an overestimate for those areas with coarser, mixed grain size sediment or exposed chalk. It is likely that some scour would occur in all situations over the life of the development, but the depths and horizontal extent would be considerably less, and in the case of undisturbed chalk would be negligible.

Given the potential for scour, further studies prior to detailed engineering design would be undertaken to determine the requirement for placement of a rock scour apron around the foundations. Further site investigations would determine detailed geotechnical information at the turbine locations where there is a thick cover of potentially mobile sediment, to determine with greater certainty the potential depth of scour and the significance with respect to detailed engineering.

Case 2: Wind farm gravity bases

Table 6.7 Case 2: Wind farm gravity bases: assumed parameters

Base plate dimensions:	**Diameter = up to 35m**
Elevation:	= 4m
Water depth:	h = 18m to 28m at times of peak current
Waves:	H_s = 3.0m; T_p =6 sec
U_{orb} at bottom:	U_{orb} = 0.5m/s
Current:	U = 1.0m/s.
Sediment:	d_{10} = 0.010mm; d_{50} = 0.220mm; d_{90} = 0.450mm
Threshold of motion:	U_{crit} = 0.5m/s

The wide base plate protects the seabed from intense flows around the base of the central monopile. However, local flow acceleration and vortex action would occur around the wall of the foundation, causing scour. Flow over the foundation would generate a recirculating zone downstream akin to flow separation over a rearward step and the reattachment point downstream would be a point of high turbulent shear stress (Whitehouse, 2004).

If the seabed behaves as fine, non-cohesive sediment of unlimited depth, the predicted scour depth for a 35m diameter plate would be up to 2.1m, extending to a width of approximately 8m. It is assumed that scour of chalk or coarse mixed sediment would be slower to occur and less deep, as with the monopiles.

Regardless of the predictions, it is assumed that some scour would occur on all seabed types and that this would be a potential risk with respect to gravity base structure stability. Therefore, a scour apron would be placed for protection (see **Section 2**). The apron is likely to be formed from rock or slate, placed to a width of 5-10m around the base plate perimeter.

Case 3: Wind farm export cables

Table 6.8 Case 3: Wind farm export tables: assumed parameters

Cable:	**Diameter = 0.25m**
Water depth:	as Case 1
Waves	as Case 1
Current:	as Case 1
Sediment:	as Case 1
Threshold of motion:	as Case 1

(NB. assumed not buried and normal to maximum flow direction)

The tide alone is capable of moving sediment and causing scour for unburied cables, even in the absence of any waves. After cable laying in non-cohesive fine sediment, a scour hole could quickly develop to a depth of approximately 0.15m underneath the cable and this could grow to around 0.70m after 10 to 15 tidal cycles, assuming that flows are approximately perpendicular to the cable. Parallel flows would cause less scour. The scour could extend up to 20m either side of the cable. If the cable sags, the depth of the hole may be as large as 1m underneath the initial cable position.

Burial to 2–3m is likely to be required for areas with sand waves or other mobile bedforms, although a depth of 1m would normally be acceptable in areas of exposed chalk or sandstone, which includes much of the export cable route. The exact requirement regarding burial depth would be determined during the detailed design stage and would depend on localised seabed conditions.

A scour hole could quickly develop if the buried cable is exposed following installation due to large scale bed movements. The cable must always remain buried below the seabed to avoid scour. Consideration would be given to the areas of large sand waves and megaripples within the Thanet site, or the shifting sandbank at Goodwin Knoll on the southern export cable route. As these areas are potentially mobile at short and long term timescales, the cable would either be diverted to less active corridors, or buried to such a depth that it is always below the troughs of the seabed features, ensuring that the bed forms move over the cable without risking exposure (Whitehouse *et al*, 2000).

Case 4: Cable crossing structures

The cable crossing structures are assumed to be low i.e. approximately 1m above the existing bed and narrow crested. Increased local turbulence due to both wave and current interactions with the structure is anticipated to have an impact on sediment processes, causing some localised instability. The nature and extent of this instability is not certain, and could result in both scour and deposition. Available guidance suggests that the area of impact would extend approximately 10h, where h is the structure elevation, giving a footprint of disturbance of less than 15m either side of the structure (Whitehouse, 1998). The significance of this disturbance depends on the local sensitivity of the benthic community, which is discussed in **Section 9**.

The wind turbine foundations could suffer some local scour of the mobile surface sediment. The maximum extent of scour is predicted to be up to 9m depth and up to 24m away from each monopile, assuming sufficient mobile sediment depth. Simple gravity base structures would cause less scour. Sediment released by scour is considered unlikely to have any significant effect on general sediment distribution or seabed levels, and therefore scour aprons are not required to prevent environmental impacts. The requirement for aprons for both monopiles and gravity base structures to provide structural stability, reduction of fatigue and to prevent damage at the cable / foundation interface will be determined during the detailed design stage.

A number of scour protection options can be considered:

- Rock backfill;
- Concrete unit mattresses; and
- Sand or grout filled geotextile bags.

Regardless of method used, the protection layer would extend over the predicted scour area to provide adequate protection. A suitable filter layer, usually quarry run stone and/or geotextile layer, can be placed between the protection layer and the seabed material to prevent settlement. Scour of fine mobile sediment can be expected within a few tides after installation of the foundations and it may be possible to utilise the initial scour hole within the scour mitigation design. Seabed levels adjacent to the foundation will be monitored before and after installation to determine the amount of scour.

Burial of all cables would reduce any potential problems, with the added benefit of protection from anchors and fishing gear. The depth of burial required would vary, but would be sufficient to minimise the likelihood of future re-exposure. There is potential for interactions with numerous other active and disused cables depending on the design method of the crossings. The cables would be designed and laid in such a way that possible future uncovering and subsequent exposure to the strong tidal currents does not compromise their integrity, and a long term monitoring and management programme would be developed as part of the design process. The recommended burial depths set out below are indicative only and will be confirmed during detailed design engineering.

Cabling across the intertidal area of Pegwell Bay to the landfall would require burial to a depth of approximately 1m. As the area is open to the public, it is important that future cable exposure does not occur. The area is generally considered stable or accreting, but is subject to some localised change due to the movement of intertidal drainage channels and potential erosion of the upper beach during severe wave conditions. Disturbance of the foreshore during burial could result in drainage channels shifting to follow the cable route until the sediment cover stabilises.

There is an area of potential instability around the low tide level of Pegwell Bay due to migrations of the River Stour channel. The cables would be buried in this area to 2m or until the chalk bedrock is reached.

Thereafter, the preferred northern cable route to the wind farm site is mainly across exposed chalk, with occasional patches of mobile sand. The cables would be buried to approximately 1m within the chalk, and approximately 2m in the mobile sand areas. The current navigation approach channel is understood to have a reference elevation of -

7.5m CD and it is a requirement that the installed export cables have a reference elevation of -11.0m CD. By installing the cables to this reference elevation they would be protected from any future planned dredging operations along the channel (see **Section 2**).

The alternative southern export cable route crosses the Goodwin Knoll at the end of the navigation approach channel. This area has been identified as unstable, with seabed elevation changes measured at up to 5m over the past 50 years. The cable would be buried to a depth of at least 3m to reduce the risk of exposure, along with a management commitment to ensure long term monitoring and reburial as required. It is recommended that this route is not used unless there are substantial benefits arising from other design criteria, as there is a recognised risk of cable exposure.

Cables within the Thanet site would be buried to at least 1m across areas of exposed chalk or sandstone, and up to 3m in the areas of sand waves to reduce the risk of future exposure within sand wave troughs.

There would be a need for ongoing monitoring and management following construction of the turbines and placement of the cables to ensure that scour depths, or cable exposure, do not exceed the design limits. Monitoring will be particularly important in the area of potentially mobile sand waves within the Thanet site, with several years data on mobility required to inform a cable management plan.

The following further work would be undertaken during the detailed engineering design:

- Consider potential scour and scour protection in more detail, particularly if gravity base structures are proposed in preference to monopiles;
- Develop a monitoring and management programme, to ensure that any future seabed mobility does not increase risks to the turbine foundations or cables, which would include swathe bathymetry to allow assessment of sand wave migration and localised scour around foundations; and
- Determine detailed metocean conditions for the design and installation of the turbines and cables.

6.5.4 Impact of sediment transport – bed load

Assuming a final spacing between turbines of at least 700m in the dominant north - south tidal flow direction, it is considered unlikely that there would be any overall sheltering effect that could give rise to broad scale accretion or erosion of sand or gravel over the Thanet site. The generic industry modelling review, undertaken for the DTI (ABPMer, 2005), supports the view that broad scale effects are unlikely for a situation with similar characteristics to the Thanet site. More recent, but still unpublished, work has been undertaken by CEFAS at Scroby Sands offshore wind farm in which repeated swathe bathymetry surveys showed no evidence of interturbine or broad scale seabed change as a result of the wind turbines, although there was clear evidence of localised scour at each monopile and extended ‘tails’ of sediment disturbance at some.

6.5.5 Far-field and coastal impacts on waves

As discussed above, wave effects are limited to the immediate vicinity of the foundations, with no significant or measurable interactions between structures, and therefore no significant cumulative effect is envisaged. Given the nature and depth of the seabed at the Thanet site, it is considered that the structures would not significantly modify the seabed in a more general sense, either by large scale erosion due to an increase in turbulence, or large scale accretion due to sheltering. In the absence of any general seabed level changes, there would be no significant impacts on areas outside the Thanet site, including at the coastline. This conclusion is in line with industry research (ABPMer, 2005), and recent unpublished work by CEFAS on wave measurements at Scroby Sands that concludes far-field impacts due to foundation influence on the wave climate would be **negligible** for situations with similar characteristics to the Thanet site.

6.5.6 Far-field and coastal impacts on currents

Currents are dominated by tidal processes at the Thanet site and along the export cable route, with enhanced currents due to storm surges or wave breaking under high wave conditions along the shallow sections of the export cable route and near the landfall. Other than in the immediate vicinity of the foundations, currents are considered unlikely to be modified to a discernible extent by the project, and therefore there would be a **negligible** impact on adjacent areas. This conclusion is also supported by industry research (ABPMer, 2005).

6.5.7 Far-field and coastal impacts on nearshore sediment transport

The analysis described for the localised impacts anticipates that the impact of the foundations on sediment transport is likely to be restricted to localised areas around the structures and along the export cable route during burial and the immediate post-burial recovery period. It is considered that the Thanet project would have a **negligible** and unmeasurable impact on the general sediment transport regime or morphology of the area.

6.5.8 Far-field and coastal impacts on coastal processes

There is the potential for shoreline processes to be affected at the cable landfall in Pegwell Bay, depending on the design and construction approach. There is no significant drift to cause concern, due to the orientation and stable form of the upper beach within the Bay (**Plate 6.1**). At present, it is assumed that the landfall would be achieved by trenching or ploughing across the foreshore and through the upper beach. If this were the case, then there would be a **negligible** impact on the shoreline, apart from short term impacts during construction. Impacts during construction would be **negligible** provided that the upper beach and foreshore levels are reinstated using the trenched material immediately following cable laying.

It is considered that the impact of the Thanet project on wave and current regimes, and therefore nearshore transport, would be **negligible** and unmeasurable away from the immediate vicinity of the turbines. Waves incident on monopile or gravity base foundations would mainly be scattered, rather than dissipated. In relation to the total energy passing through the site, any potential loss is considered **negligible** and therefore there would be no significant impact on the shoreline at any point.

Future sea level rise, and possible increased storminess, would allow slightly larger waves to reach the exposed shoreline of Thanet. The Thanet project would have **no impact** on these conditions. The only area of concern could be at the landfall, where there could be potential for increased upper beach erosion. However, Pegwell Bay is a depositionary area, as shown by the developing saltmarsh, and it is assumed that deposition across the intertidal area would keep pace with rising sea levels. This local process would limit the potential for larger waves reaching the shoreline and therefore long term erosion would be minimised.

6.6 Impacts during Decommissioning

Methods for decommissioning have not been defined, but it is assumed that buried cables would be left in place while turbine foundations are removed to 2m below seabed level. Under this situation there would be no broad scale or long term impacts on seabed or coastal processes. Locally, scour pits may fill approximately back to the surrounding seabed level and there would be short term increases in suspended loads due to any required seabed disturbance. Any exposed or potentially exposed cables in areas of seabed mobility may need to be cut and removed, but again this would not be expected to cause anything but temporary and local disturbance.

6.7 Cumulative Impacts

The Thanet site is located in the Thames Estuary Strategic Environmental Assessment (SEA) area along with several other consented and planned wind farms (see **Figure 1.1** in **Section 1**), most notably the Kentish Flats site that has recently completed construction and the London Array site that has recently submitted a consent application. There are also a number of active and disused cables, shipping channels and navigation dredging areas, plus aggregate dredging to the north, as shown in **Figure 17.1** in **Section 17, Other Human Activities**, which shows the existing licensed areas of the outer Thames Estuary. The potential for interactions and cumulative impacts during the life of the Thanet project have been considered.

A number of existing telecommunications cable routes emanate from the Thanet shoreline and extend across the Channel to Europe. Three telecommunications cables cross the export cable routes. There is no evidence to suggest that any of the existing cables have any ongoing impact on seabed processes. Each crossing would need to be considered separately during detailed engineering design and construction, but it is assumed that low, narrow crested crossing structures would be installed and that seabed processes would only be influenced locally.

The discussions for the localised and far-field and coastal impacts above have asserted that turbine foundations spaced at the distances proposed would have no significant or measurable cumulative impact on waves, currents or sediment transport, either within the wind farm site or over a wider area. If individual structures do not have an influence on adjacent structures, then there is no potential for one wind farm having a cumulative impact with a neighbouring wind farm or other activity at several kilometres distance.

The northern export cable route passes through the dredged navigation approach channel to Port of Ramsgate. It is understood that the channel is kept clear by natural processes and by the propeller disturbance of larger vessels. Assuming no change to this situation, then the export cables should have **no impact**. However, it is possible that maintenance or capital dredging would be required in the future, putting both the cables and dredger at risk. This potential 'in-combination' impact can be mitigated by locally increasing the cable burial depth and ensuring that the export cables are sufficiently covered to prevent future impact damage from dredging, possible vessel grounding or anchor drag. The Harbour Master has been consulted regarding present and future operations, and cable burial to -11.0m CD has been agreed in principle.

6.8 Summary

A desktop study of the hydrodynamics and geomorphological processes was undertaken to set out the existing state of knowledge and to assess the potential impact of the development, in accordance with the CEFAS Guidance Notes 2004 (HR Wallingford, 2005). No new modelling has been undertaken to support this work, however geophysical and geotechnical survey information has been derived from the recent work undertaken by EGS International (2005). The report also builds on the earlier Environmental Scoping Report prepared by Royal Haskoning (Posford Haskoning, 2004).

The Thanet site lies in water depths of between 15m and 27m below Chart Datum (CD) and is exposed to severe wave conditions generated within the southern North Sea and the eastern English Channel. The prevailing southwesterly winds blow off the Kent coast and therefore have a relatively short effective fetch length, but waves are enhanced by swell entering from the English Channel. The most severe conditions are generated by northerly and northeasterly winds blowing across the full extent of the North Sea. The tidal range is around 4.5m on spring tides and the area is subject to tidal currents of approximately 1m/s offshore, increasing to above 1.6m/s along the export cable route, east of Ramsgate before dropping within Pegwell Bay. Tidal surges are relatively common with the 50 year level reaching up to 2.5m above the predicted tides.

The seabed at the Thanet site mainly comprises a thin veneer of silty sand overlying chalk to the south and sandstones to the north. There are areas of exposed rock, sand waves and megaripples within the site, consistent with the active physical processes and varying availability of sediment. The export cable routes encounter superficial sands lying over chalk through the offshore section, giving way to thicker sand and silty sand over chalk and then sandstone within Pegwell Bay.

The adjacent coast comprises the chalk cliffs of the Isle of Thanet from Margate to Ramsgate, after which the chalk cliffs give way to lower sandstone cliffs, which dip down to shingle ridge beaches and developing saltmarsh in Pegwell Bay. The chalk cliffs are mainly protected by a variety of defences, but the unprotected lengths are slowly eroding. The cliffs are fronted by narrow sand and shingle beaches above a wide wave-cut chalk platform. The entire coastline and the nearshore area are designated for environmental protection, including Sites of Special Scientific Interest (SSSI), Special

Area of Conservation (SAC) and Special Protection Area (SPA) sites, as well as National and Local Reserves, with a particular focus on the chalk cliffs and Pegwell Bay.

It is considered that the Thanet project would have some localised impact on the waves, currents and corresponding sediment transport regime in the immediate vicinity of the Thanet site and export cables, but is unlikely to have any significant or measurable far-field impacts in relation to the existing natural variability of the dynamic environment. The proximity to the other wind farm sites, cables and dredged areas in the Thames Estuary would not result in any cumulative impacts. This general conclusion concurs with the findings for the already consented Round One wind farms set within similar nearshore situations and with the recently published generic research on wind farm impacts (ABPMer, 2005).

Localised issues of concern are limited to:

- Increased suspended sediments, including chalk fines, during construction and cable laying, possibly impacting on the natural environment within the plume dispersion area;
- High scour potential around the wind turbine foundations on parts of the site, possibly requiring protection measures;
- The potential for future cable damage due to dredging or other activities within the Port of Ramsgate navigation approach channel on the northern cable route;
- High potential for exposure of cables due to sand wave activity within the Thanet site and large scale seabed mobility across the Goodwin Knoll bank on the alternative southern cable route; and
- Potential for exposure of cables due to changing seabed levels in the subtidal area of Pegwell Bay to the southwest of the Port of Ramsgate.

The potential for broad scale changes to the seabed as a result of the combined effect of all the wind turbines is considered to negligible, assuming monopile or gravity base structure foundations with the dimensions and spacing proposed. The foundations can be considered as independent of each other in respect of the impact on the currents and waves. This conclusion also indicates that there would be no potential cumulative impacts arising from the adjacent wind farms or in combination with other infrastructure and activities.

The potential sediment transport rate is moderate to high at the Thanet site, and there is potential for localised scour around the base of each structure. Some scour around the structures should be anticipated due to peak currents of up to about 1m/s, combined with a moderately high energy wave regime. The extent of scouring has been estimated at up to 9m depth for monopiles, or approximately 2.1m for gravity base structures, depending on assumptions regarding sediment characteristics and the type of foundation. The greatest potential for scour is in the areas of sand waves through the central and northern parts of the site, where scour depths could reach the maximum depth and horizontal extent. Foundations in other areas are likely to suffer less scour, due to the presence of coarser surface material or less easily eroded sub-layers, but some scour should be anticipated for all areas, including exposed chalk.

The export cable routes pass through areas of active sediment transport, therefore the cables would be buried to sufficient depth to prevent future uncovering. The preferred northern export cable route has areas of mobile bedforms lying over chalk, but the generally shallow depth of mobile sediment limits the potential for vertical change over the life of the development to less than 2m. The alternative southern cable corridor passes through an area of large scale mobility in the area of the Goodwin Knoll, where vertical change of up to 5m has been observed over the past 50 years and should be anticipated in the future. The corridor leading towards the landfall in Pegwell Bay passes through a further area of long term instability due to the shifting channel of the River Stour, therefore an elevation change of up to 1m should be anticipated.

It has been demonstrated that the background levels of suspended sediment concentration at the Thanet site, and along the export cable routes, are naturally moderately high, so that the transient impact of plumes arising from the cable burial process are unlikely to be significant. If construction of the wind turbine foundations requires significant seabed disturbance then there would be locally high, but short term, suspended sediment loads. The export cable routes cross large areas of exposed chalk and chalk fines would be released during laying operations, creating a milky plume of suspended fines. Any potential environmental impacts would depend on the season and the likely sensitivity of the natural environment, but are unlikely to be significant against the natural background of suspended sediment concentrations.

The shoreline at Pegwell Bay is subject to only very weak potential drift and the wide intertidal area is considered stable or accreting, so there is no cause for concern regarding the impacts on physical processes at the landfall. Cable trenching through the existing upper beach and any artificial revetment would be undertaken with care to avoid unnecessary disturbance, and the condition of the foreshore would be reinstated on completion to ensure minimal environmental impacts.

Decommissioning by removal of exposed cables and foundations to seabed level or below is not expected to cause anything but temporary and local disturbance. Rapid seabed recovery to the ambient conditions would be expected.

The Thanet site is located in the same Strategic Environmental Assessment (SEA) area as several consented and planned wind farms. There are also a number of active and disused telecommunications cables, shipping channels and navigation dredging areas, plus aggregate dredging to the north.

Turbine foundations, spaced at the proposed distances, have no significant or measurable cumulative impact on waves, currents or sediment transport, either within the Thanet site or over a wider area. Therefore, there is no potential for one wind farm having a cumulative impact with a neighbouring wind farm, or other activity at several kilometres distance.

There is no evidence to suggest that any of the existing cables have any ongoing impact on seabed processes. Each cable crossing would be considered separately during design and construction, but it is assumed that low, narrow crested crossing structures would be installed and that seabed processes would only be influenced locally.