4. MARINE SEDIMENTS

Summary of previous survey results

Most of the sites within the survey area had a seabed of coarse sand with some of medium sand. A few sites to the east and west of the survey area had a notable amount of silt. The coarse and medium sands were fairly evenly distributed over the survey area with no obvious inshore/offshore differences. There has not been a consistent pattern of change in dominant sediment type near and within the turbine array or along the cable route in 2004 with sediments at some sites becoming generally finer, others coarser and two sites remaining the same. As sites within the wind farm array and in control areas have shown both increases and decreases in coarseness, no apparent trend was identified.

4.1 GRAB SAMPLING

4.1.1 Introduction

An initial baseline benthic survey for the North Hoyle Wind Farm location and its surrounding sublittoral environment was undertaken during August 2001 by the Centre for Marine and Coastal Studies (then University of Liverpool, now CMACS Ltd). The baseline survey and subsequent annual monitoring have covered subtidal benthic ecology and marine sediments. Subtidal benthic ecology monitoring is described in Section 5; the following section describes the results of the sediment particle size analyses performed on benthic samples obtained through field survey by methods described in detail in Section 5 (Benthic Organisms). The positions of the monitoring location are shown in Figure 5.1.

4.1.2 Methods

The methods used for the 2005 post-construction grab survey were the same as those in the construction survey of 2003, pre-construction survey of 2002 and the initial baseline survey of 2001. This was to allow direct comparisons to be undertaken from results of all three surveys.

4.1.2.1 Laboratory Analysis

4.1.2.1.1 Sediment analysis

In the laboratory all sediment samples were dried to a constant weight using ovens at a set temperature of 70^{o}C. The sediments were then analysed chemically for Total Organic Carbon (TOC) and physically for particle size analysis (PSA).

4.1.2.1.2 Chemical Analysis - Total Organic Carbon (TOC)

To analyse the TOC content of the marine sediments at each of the survey locations samples were first processed through a series of sieves for particle size analysis and the < 1mm fraction subsampled. This fraction was sent to a commercial laboratory to be ashed at temperatures in excess of 550ºC. The TOC content of the marine sediments was analysed by calculating the loss on ignition from each sample.

4.1.2.1.3 Physical analysis - Particle size analysis (PSA)

Sediments were sieved using a set of Endecott BS 410 test sieves on the following sieve fractions;10mm; 5mm; 4mm; 2mm;1mm; 600µm; 425µm; 300µm; 212µm; 150µm; 63µm meshes. Results from sieving allowed the calculation of mean and median particle sizes and the determination of a sorting index by calculating the standard deviation of Phi. These indices were then used to determine the sediment type. The classification system used to distinguish sediment type and the sorting index were carried out in accordance with the methods of Buchanan (1984) (see Table 4.1 and Table 4.2). In addition, further classification was also made using the British Geological Survey Folk triangle classification system (see Figure 4.1).

Table 4.1 Classification used for defining sediment type (from Buchanan, 1984)

Wentworth Scale (mm)	Phi units	Sediment types
>256 mm	<-8	Boulders
64 - 256 mm	-8 to -6	Cobble
4 - 64 mm	-6 to -2	Pebble
2 - 4 mm	-2 to -1	Granule
1 - 2 mm	-1 to -0	Very coarse sand
0.5 - 1 mm	0 - 1	Coarse sand
250 - 500 µm	1 - 2	Medium sand
125 - 250 µm	2 - 3	Fine sand
63 - 125 µm	3 - 4	Very fine sand
<63 µm	>4	Silt

Table 4.2 Classification used defining degree of sediment sorting (from Buchanan, 1984)

Standard Deviation of mean Phi	Classification
<0.35	Very well sorted
0.35 - 0.5	Well sorted
0.5 - 0.71	Moderately well sorted
0.71 - 1	Moderately sorted
1 – 2	Poorly sorted
2 – 4	Very poorly sorted
>4	Extremely poorly sorted

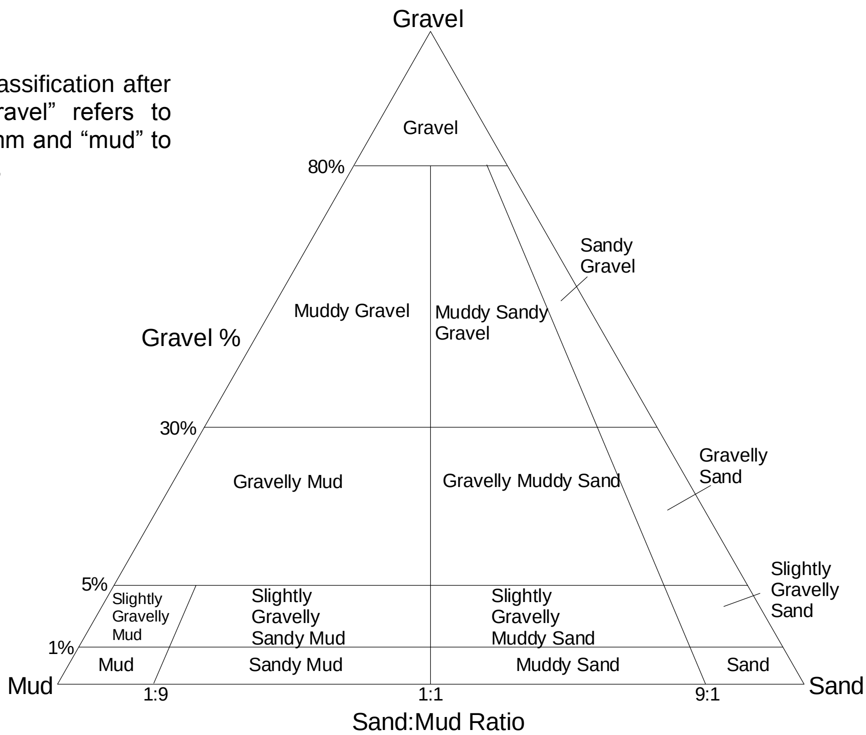

Figure 4.1 Sediment classification after Folk (1954), where "gravel" refers to particles greater than 2mm and "mud" to particles less than 63µm.

4.2 RESULTS

4.2.1.1 Sediments

Overall, the sea bed within and around the North Hoyle Wind Farm is characterised by fine and medium sands with varying amounts of coarser material. Eastwards from the array towards the mouth of the Dee estuary sediments are sandier, while coarser areas are found further offshore and to the west of the development. The original site survey carried out in July and August of 2001 described the area of the wind farm itself as highly variable over even quite short distances, but consisting largely of sand and sandy gravels with varying amounts of stone and minor clay/silt content, depending upon location (CMACS 2002; Fugro-UDI Ltd, 2001).

4.2.1.2 Particle Size analysis (PSA)

The results from the particle size analysis are provided in Table 4.3, which details the percentage of sediment retained on each sieve. This data was then analysed according to Buchanan's methods (Buchanan, 1984) to provide statistical data and sediment descriptions as displayed in Table 4.4.

Table 4.3 Summary statistics for sediment data date from 2005 surveys.

Site	Mean phi	Mean mm	+/- 1 std	Skewness	Kurtosis	Classification after Buchanan	Folk Triangles after BGS
1	1.44	0.37	0.38	-0.11	1.50	Well sorted medium sand	Sand
2	-0.03	1.02	2.27	-0.77	0.89	Very poorly sorted very coarse sand	Gravelly Sand
3	0.40	0.76	1.24	-0.30	0.82	Poorly sorted coarse sand	Gravelly Sand
4	-	-	-	-	-	-	-
5	-0.06	1.04	1.84	-0.23	0.75	Poorly sorted very coarse sand	Sandy Gravel
6	-0.35	1.28	2.35	-0.53	0.57	Very poorly sorted very coarse sand	Sandy Gravel
7	1.35	0.39	0.34	-0.13	1.03	Very well sorted medium sand	Sand
8	-0.01	1.00	2.53	-0.68	0.52	Very poorly sorted very coarse sand	Sandy Gravel
9	1.75	0.30	0.42	0.34	0.91	Well sorted medium sand	Sand
10	1.71	0.31	0.54	0.05	1.34	Moderately well sorted medium sand	Slightly Gravelly Sand
11	1.03	0.49	0.97	-0.41	1.11	Moderately sorted medium sand	Gravelly Sand
12	1.80	0.29	0.44	-0.03	1.01	Well sorted medium sand	Sand
13	1.72	0.30	0.42	0.35	0.94	Well sorted medium sand	Sand
14	1.42	0.37	1.06	-0.48	3.62	Poorly sorted medium sand	Gravelly Sand
15	1.35	0.39	0.43	-0.22	1.51	Well sorted medium sand	Sand
16	0.88	0.54	1.22	-0.12	1.00	Poorly sorted coarse sand	Gravelly Sand
17	1.89	0.27	0.36	-0.10	1.27	Well sorted medium sand	Sand
18	-1.08	2.11	1.77	0.16	0.86	Poorly sorted granule	Sandy Gravel
19	-0.79	1.73	1.72	0.22	0.91	Poorly sorted very coarse sand	Sandy Gravel
20	-1.03	2.04	1.62	0.11	1.04	Poorly sorted granule	Sandy Gravel

Table 4.4 Sediment descriptions for sediment data from 2002 to 2005.

	Descriptions after Buchanan				Folk Triangles after BGS			
Site	2002	2003	2004	2005	2002	2003	2004	2005
1	Moderately sorted medium sand	Well sorted medium sand	Moderately well sorted medium	Well sorted medium sand	Slightly Gravelly Sand	Sand	Slightly Gravelly Sand	Sand
2	Poorly sorted coarse sand	Very poorly sorted Very coarse sand	Well sorted medium sand	Very poorly sorted very coarse sand	Gravelly Sand	Sandy Gravel	Slightly Gravelly Sand	Gravelly Sand
3	Poorly sorted coarse sand	Poorly sorted granule	Poorly sorted coarse sand	Poorly sorted coarse sand	Gravelly Sand	Sandy Gravel	Gravelly Sand	Gravelly Sand
4	Poorly sorted granule	Well sorted medium sand	Moderately well sorted medium sand	-	Gravel	Sand	Slightly Gravelly Sand	-
5	Poorly sorted Very coarse sand	Poorly sorted pebble	Poorly sorted coarse sand	Poorly sorted very coarse sand	Sandy Gravel	Gravel	Gravelly Sand	Sandy Gravel
6	Poorly sorted medium sand	Very well sorted medium sand	Very poorly sorted Very coarse sand	Very poorly sorted Very coarse sand	Gravelly Sand	Sand	Sandy Gravel	Sandy Gravel
7	Very well sorted medium sand	Very well sorted medium sand	Poorly sorted Very coarse sand	Very well sorted medium sand	Sand	Sand	Sandy Gravel	Sand
8	Poorly sorted granule	Very poorly sorted very coarse sand	Very well sorted medium sand	Very poorly sorted Very coarse sand	Gravel	Sandy Gravel	Sand	Sandy Gravel
9	Well sorted fine sand	Well sorted fine sand	Moderately sorted medium sand	Well sorted medium sand	Sand	Sand	Slightly Gravelly Sand	Sand
10	Poorly sorted coarse sand	Poorly sorted very coarse sand	Poorly sorted Very coarse sand	Moderately well sorted medium sand	Sandy Gravel	Sandy Gravel	Sandy Gravel	Slightly Gravelly Sand
11	Poorly sorted granule	Well sorted medium sand	Well sorted medium sand	Moderately sorted medium sand	Sandy Gravel	Sand	Sand	Gravelly Sand
12	Very well sorted medium sand	Well sorted fine sand	Well sorted medium sand	Well sorted medium sand	Slightly Gravelly Sand	Sand	Sand	Sand
13	Moderately well sorted medium sand	Well sorted medium sand	Very poorly sorted coarse sand	Well sorted medium sand	Slightly Gravelly Sand	Slightly Gravelly Sand	Gravelly Sand	Sand
14	Moderately sorted pebble	Very poorly sorted granule	Well sorted fine sand	Poorly sorted medium sand	Gravel	Sandy Gravel	Sand	Gravelly Sand
15	Moderately well sorted medium sand	Moderately well sorted medium sand	Moderately sorted medium sand	Well sorted medium sand	Slightly Gravelly Sand	Slightly Gravelly Sand	Slightly Gravelly Sand	Sand
16	Moderately sorted medium sand	Well sorted medium sand	Moderately sorted fine sand	Poorly sorted coarse sand	Slightly Gravelly Sand	Slightly Gravelly Sand	Gravelly Sand	Gravelly Sand
17	Moderately well sorted medium sand	Well sorted medium sand	Moderately well sorted medium sand	Well sorted medium sand	Slightly Gravelly Sand	Sand	Sand	Sand
18	*	Poorly sorted very coarse sand	Poorly sorted very coarse sand	Poorly sorted granule	*	Sandy Gravel	Sandy Gravel	Sandy Gravel
19	*	Poorly sorted granule	Moderately sorted medium sand	Poorly sorted very coarse sand	*	Sandy Gravel	Gravelly Sand	Sandy Gravel
20	*	Poorly sorted granule	Very poorly sorted very coarse sand	Poorly sorted granule	*	Sandy Gravel	Sandy Gravel	Sandy Gravel

* = Not sampled

RWE Group

4.2.1.3 Comparison with Previous Surveys

Although site 4 (classified in 2002 as “gravel”) was not sampled, this was due to there being a high proportion of stones which prevented the grab from operating properly; indicating that the seabed at this site was clearly gravelly.

In 2005 the sediments at most sites were very similar in nature to 2002. The biggest differences between 2002 and 2005 were at sites 10 and 14, both of which are well outside of the wind farm. Site 10 has previously been consistently classified as sandy gravel, but in 2005 had a much reduced gravel content and was classified as slightly gravelly sand. Site 14 has shown a high degree of variability, from gravel in 2002 to gravelly sand in 2005 (sandy gravel in 2003 and sand in 2004). At sites 1, 3, 4 and 5, which are the sites within the wind farm, there was very little apparent difference in the nature of the sediments in 2005 compared to 2002 (in the case of site 4 this being based on the observation that the site was gravelly in 2002 and clearly remains gravelly in 2005, though it could not be properly sampled).

Sites 18, 19 and 20 have been consistently coarse, being classified as sandy gravel in all cases, except for site 19 in 2004, which had a slightly lower gravel content and was thus classified as gravelly sand. Sites 1, 3, 9, 12, 15, 16 and 17 have also been fairly consistent in the nature of their sediments. Of these, the first two are within the wind farm site, while the others are outside. Ten sites, (2, 4, 5, 6, 7, 10, 11, 12, 14) have shown considerable fluctuations in the nature of the sediments. Again, however, there appears to be no link with the wind farm, with sites 2 and 4 being within the wind farm, while the others are outside. There is also no apparent link with distance offshore, depth, or any other geographical or hydrographic factor. Such variability would be expected to be a normal feature of this sort of fairly wave exposed, shallow-water environment.

4.2.1.3.1 Total organic carbon (TOC)

The 2005 TOC analysis results are presented in Table 4.5 alongside the results from the previous surveys. Sites 18, 19 and 20 were new sites for 2003 and therefore no data was available for 2002.

Overall the TOC levels for 2005 were considerably increased compare to those levels found during the previous surveys, with site 7 showing a considerable decrease and all others considerable increases.

However, excepting sites 4 (where there was no sample in 2005) site 7 (where there was an unusually high TOC in the 2002 survey) and sites 18, 19 and 20 (where there was no survey in 2002), the values for 2005 are between 26 and 60 times higher than in 2002. Values for sites 18, 19 and 20 are approximately 14 – 100 times higher than values for 2003 and 2004.

Table 4.5 Total Organic Carbon (%) results for 2005 with comparison to 2004, 2003 construction survey and the 2002 baseline.

Site no.	%TOC 2002	%TOC 2003	%TOC 2004	%TOC 2005
1	0.04	0.01	0.04	0.28
2	0.06	0.04	0.05	0.39
3	0.08	0.04	0.07	0.41
4	0.55	0.02	0.04	no sample
5	0.07	0.01	0.04	0.41
6	0.08	0.06	0.07	1.55
7	1.02	0.01	0.12	0.21
8	0.02	0.16	0.05	1.20
9	0.17	0.04	0.07	0.44
10	0.07	0.04	0.05	0.37
11	0.05	0.01	0.04	0.45
12	0.07	0.03	0.04	0.37
13	0.12	0.01	0.06	0.35
14	0.09	0.05	0.05	0.50
15	0.02	0.03	0.04	0.47
16	0.04	0.01	0.09	0.46
17	0.12	0.06	0.06	0.49
18	*	0.07	0.05	0.98
19	*	0.01	0.07	1.01
20	*	0.04	0.05	0.95

* = not surveyed in 2002

4.2.1.4 Summary

Particle size analysis for 2005 grab samples revealed a heterogeneous sea-bed of fine and medium sands with varied amounts of gravel, the gravel sometimes being dominant. Gravels and sands were fairly evenly distributed over the survey area with no obvious inshore/offshore differences. There has not been a consistent pattern of change in dominant sediment type near to or within the turbine array or along the cable route between 2002 and 2005. As sites both within the wind farm array and in control areas have shown both increases and decreases in coarseness during this period there is no trend present that would suggest that wind farm construction, cable burial or adjustment of hydrodynamic forces due to the presence of the piles in the seabed are responsible for changes in sediment characteristics at each site. The original geophysical survey of 2001 described several areas of rippled and megarippled seabed and it is possible that there are different sediment types on the crests and in the troughs of these ripples. Such small scale variation is indicated by some of the faunal results, where significant differences occasionally occur between replicate samples taken from within a few metres of each other. It is also plausible that the grab is sampling from different pockets of sea bed type which change as a result of natural variation over the course of the year. Finally, chance variation in the number of stones picked up in any one sample, even where sediments are actually quite evenly distributed, could conceivably result in noticeable changes in the sediment as described by particle size analysis.

There also continues to be little evidence that the distribution of drill cuttings over the sea bed during construction has acted to noticeably increase the coarseness of sea bed sediments at the wind farm site with most of the wind farm sites (1, 3, 4 and 5) having the same, or very similar, sediment classification in 2003, 2004 and 2005 as in 2002 (prior to any construction activity). Although site 4 (classified in 2002 as “gravel”) was not sampled in 2005, this was due to the high proportion of stones which prevented the grab from operating properly; thus the seabed at this site was clearly still very gravely.

TOC values in 2003 and 2004 suggested little obvious pattern between sites, nor was there any clear trend when those results were compared to results from the 2002 survey, and it was previously thought likely that any differences in those years represented natural variations. However, 2005 results are clearly high; if these results truly represent increased values they are also presumably caused by natural variations since there is no relation between the amount of increase in TOC and the wind farm or cable route, nor is there any clear relationship with possible hydrographic factors such as depth, distance offshore or east–west position. Although the analytical method has changed since the 2002 surveys (when a Carlo Erba analyser was used), loss on ignition analyses have been performed on all PSA samples since 2003. It is common for organic content of sediments to be closely linked with the fine fraction, but review of results for particle size fractions shows clearly that in this case these apparent increases are NOT related to the amount of very fine (<63µm) material in the samples.

4.3 SUSPENDED SEDIMENT MONITORING

Suspended sediment concentration (SSC) monitoring was carried out during the construction phase. Further to discussion with the Licensing Authority, CEFAS and CCW, it has been agreed that no further SSC monitoring is required during wind farm operation. The results of SSC monitoring was presented in the Annual FEPA Monitoring Report for 2003-4 (June 2005*).*

4.4 SCOUR

Summary of previous survey results

Very minor scour was interpreted in Autumn 2004 at 3 out of 30 turbine positions with very minor scour interpreted in Spring 2005 from placement of rock over J-tube ends (rock was placed for operational reasons, not due to scour development). The maximum scour development seen to date is entirely less than 0.5m depth, and hence it is concluded that no widespread scour has occurred. Furthermore, these difference are within the natural scale of variation for the seabed types present.

4.4.1 Introduction

The purpose of this section is to summarise the monitoring for potential scour effects and from the results interpret how the actual scour effects around the foundations relate to the expected scour and how this may impact on structural integrity of the monopiles and also on the benthic environment. The full scour report for Spring 2006 has been submitted to the Licensing Authority under separate cover.

Condition 9.15 of the Food and Environment Protection Act Licence (FEPA) 1985: Part II, licence 31579/05/0 (as amended) to NWP Offshore Ltd. For the North Hoyle Offshore Wind Farm specifies:

> *"The Licence Holder must undertake a bathymetric survey around a sample of adjacent turbines (minimum of 4) within 3 months of completion of the construction of the wind farm to assess changes in the bathymetry within the array. The survey is to be undertaken immediately after construction is complete and repeated at 6 monthly intervals for a period of 3 years. This shall specifically address the need for (additional) scour protection around the turbine pylons. The Licence Holder must submit the data in the form of a report to the Licensing Authority, including proposals for scour protection measures."*

Further to that quoted above, Condition 9.16 adds:

> *"If the monitoring results carried out under condition 9.15 indicate that scour protection is not required…., the Licence Holder must seek approval from the Licensing Authority for the change in the works previously notified to the Licensing Authority. "*

Scour monitoring has been undertaken for all 30 turbine structures at regular intervals since the monopile foundations were installed, between July and October 2003, to present.

The original scope of work required the main contractor on the project, the North Hoyle Consortium (NHC), to back-fill any scour holes that were predicted to develop at the base of the monopile foundations with rock armour to stabilise the seabed. No rock protection was deployed due to the lack of scour hollows.

In 2004 the decision was taken to apply rock protection to all J-Tubes and cable bights (the section of cable running from the J-Tube at seabed level to full burial depth) to a distance of up to 12m from each turbine as a precautionary measure not from scour, but to reduce mechanical damage to the J-Tubes from tidal current action and to protect shallow laid cables as they approached the J-Tubes.

Between July and October 2004 rock dumping took place at all 30 turbines. A total of 4187m^3 of rock was placed during 2004 around the J-tubes.

In August 2005 a 5m section of cable near WTG 30 was covered with 200 25kg grout bags to cover a free cable span approximately 18m from the bellmouth at WTG30.

Previous Predictions of Scour Development

The North Hoyle Project Method Statement (June 2003) predicted; through results of assessments, and evidence from subsea inspections of the met mast structure, that scour would be prevalent at the site. It also predicted that scour holes would develop up to a maximum of 5.2m in depth (assuming no scour protection was installed), the scour depth being governed in this instance by tidal currents. A truncated cone shaped hole was also predicted to extend laterally up to 3 pile diameters (12m). These calculations are now thought to represent large over-estimations in scour development at North Hoyle.

Evidence from physical processes experts support the principle that scour at North Hoyle is primarily driven by tidal currents from ebb and flow tides and that this process occurs year round peaking during maximum tidal streams at spring tides.

For a one year period, Gislason (2003) estimated that the scour depth developed by repeated action of strong currents may obtain a depth of 0.52m. A strong current with recurrence period of 50 years (0.8 m/s) will in its short duration at the peak of a tidal cycle be able to develop a scour hole of 0.66m (assuming 50 year extreme significant wave height of 6.05m).

If rock used for scour protection has a 50th percentile rock diameter (D_{50}) of 4mm, the local scour around the pile will vary from time to time, depending on strength of current and wave climate, direction etc. This is because rock of this size or below will be mobilised from time to time thus creating scour. For coarser rock material the variation in the scour depth would clearly be less.

For large waves, Gislason (2003) states that 4 mm material will be mobilised on the seabed. A scour hole from the wave action does not, however, develop to great depths, because the horseshoe vortex is weaker. For instance, a maximum 1 year wave, in combination with maximum spring tidal current, will develop a scour hole of 0.4 m.

Hence, based on the predictions of Gislason, it can be speculated that scour is unlikely to develop beyond 0.7m in depth under severe storms and generally never more than 0.5m.

4.4.2 Scour Surveys

The main contractor issued an as-built survey report number HBC-750-NH-R002 (Dec 2003) to assess the development of scour by presenting 3D plots of each turbine foundation base and the surrounding seabed surface to 10m. No appreciable scour pits were identified in the survey carried out between August and October 2003 when each monopile had been installed for at least 30 days. The design assumption was that if scour were to develop, it would most probably do so within 14 days of installation.

The main contractor deemed that, shortly after installation, no significant scour was developing and thus no rock armour was required.

The main contractor subsequently followed this report with a visual diver inspection at each foundation between April and May 2004 to satisfy themselves as designers that no scour had since developed over the previous winter period.

Osiris Projects Ltd were then commissioned to carry out scour monitoring surveys covering all 30 turbine structures at the North Hoyle development site in 2004, 2005 and 2006. The first year of surveys were conducted in both Spring and Autumn, however, following submission of the Autumn 2004 scour survey results, DEFRA confirmed that scour monitoring was only necessary once a year and hence it wasn't deemed necessary to carry out further Autumn monitoring surveys unless future scour became evident.

The surveys were carried out over 100m square boxes, centred at each monopile location, with high-resolution swath bathymetry data (see example in Figure 4.2) acquired by running a series of parallel survey lines at 50m centres. The primary objective of the surveys was to accurately map localised variations in seabed topography, in order to monitor the effects of tidal current scour around the monopile structures, including two met mast locations at the site.

The scour surveys carried out between 2004 and 2005 identified no obvious or significant scour around any of the 30 monopiles. None of the quoted scour had developed beyond 0.5m depth and upon review of the two and three dimensional bathymetry plots for each turbine, many of the features considered to be scour pits were not immediately apparent. This result is considered negligible compared to the predicted scour pit development of up to 2 pile diameters (i.e. 8m) in the North Hoyle Project Method Statement (June 2003).

Between the 2004 and 2005 surveys rock placement took place as a rolling programme to rock dump around J-Tubes bellmouths to protect surface laid cables in transition to full burial. This was reflected by localised changes in seabed levels seen at many of the turbine locations during the Spring 2005 survey.

The Spring 2006 survey took place between 5th April and 16th April 2006. Osiris were requested to calculate volumetric comparisons with the previous surveys to establish if wider seabed levels were changing.

Table 4.6 shows the volumetric changes in seabed at each of the thirty 100 by 100m survey areas since 2004. Between 2005 and 2006 half the turbines showed a net increase in overall sediment volume. The range of volume in boxes showing an increase (142.5-1662m^3) was comparable to the range of boxes showing a volume decrease (33.3-1219m^3). However, it is evident that the maxima (highest gains and highest losses) are higher in magnitude than those of the previous year. The sum difference between total volumetric increase and volumetric decrease for all turbines showed a net increase of approximately 2400m^3. This compares with a net loss of 700 m^3 the previous year between 2004 and 2005. Both met masts exhibited a loss in sediment in the last year (albeit negligible in the case of Met Mast 1).

Comparing overall volume changes since 2004 (over a 2 year period) a total of 17 turbines showed a net increase in overall sediment volume compared to the remaining 13 showing a net decrease in sediment volume. The range of volume in boxes showing an increase (32-1831m^3) was comparable to the range of boxes showing a volume decrease (5-1554m^3). It is evident that Met Mast 2 100m x 100m box has exhibited a loss in sediment for two consecutive years. However, negligible losses have occurred adjacent to the structure. The result here suggests that Met Mast 2 is situated in a more dynamic sedimentary environment than Met Mast 1.

The sum difference between total volumetric increase and volumetric decrease for all turbines between 2004 and 2006 showed a net increase in sediment of approximately 1700m^3. This demonstrates that in the three years this analysis has taken place, the net volumes across all survey boxes are in the same order of magnitude as individual box volume changes and therefore suggests it is within the range of natural inter-annual variability.

Turbine / Met Mast No.	Net Volume Change (m³)		Overall Volume Change (m^3)
	Autumn '04 to Spring '05	Spring '05 to Spring '06	Autumn '04 to Spring '06
1	+169.5	+ 1662.0	+ 1831.5
2	+392.5	+ 1003.9	+ 1396.4
3	+145.0	+ 1189.8	+ 1334.8
4	-108.0	+ 1118.0	+ 1010.0
5	-107.0	-420.7	-527.7
6	-102.0	+ 142.5	+ 40.5
7	-138.0	-49.1	-187.1
8	+263.0	-295.7	-32.7
9	-171.5	-160.0	-331.5
10	-253.5	-930.7	-1184.2
11	+304.5	+ 409.5	+ 714.0
12	-12.5	-1004.8	-1017.3
13	-345.0	-1209.0	-1554.0
14	+65.5	-33.3	+ 32.2
15	+408.5	-1190.1	-781.6
16	-198.5	-457.8	-656.3
17	+474.5	-138.1	+ 336.4
18	+401.5	-134.3	+ 267.2
19	-54.5	-367.4	-421.9
20	-313.0	-1219.0	-1532.0
21	-119.5	+ 699.3	+ 579.8
22	-267.0	+ 336.4	+ 69.4
23	-430.0	-377.9	-807.9
24	+100.0	+ 639.2	+ 739.2
25	+261.5	-57.5	+ 204.0
26	-205.5	+ 878.1	+ 672.6
27	-393.5	+ 388.4	-5.1
28	-171.0	+ 413.8	+ 242.8
29	-293.5	+ 1394.4	+ 1100.9
30	-22.5	+ 177.8	+ 155.3
Met Mast 1	+24.0	-19.9	+ 4.1
Met Mast 2	-607.0	-652.3	-1259.3

Table 4.6 Summary of Seabed Volume Changes between 2004 and 2006.

There is no particular pattern to explain these changes in seabed volume except to say that, when mapped out; the trend lines across the wind farm array appear to be in a SW-NE orientation, suggesting that the changes reflect natural sediment movement across the site from linear features such as sand waves and megaripples.

A forthcoming 2007 survey will provide further data to support the evidence that appreciable foundation/ rock placement scour has not developed at North Hoyle.

4.4.3 Results Interpretation

Following submission of the Autumn 2004 scour survey results, DEFRA confirmed that no scour monitoring was deemed necessary in Autumn 2005.

In 2005, the operations and maintenance contractor identified a section of exposed cable from Turbine 30 and this was addressed by covering the free span with grout bags. The side scan for this particular survey box has highlighted an area of increased volume which corresponds to area that was covered in grout bags, but no associated scour is apparent.

The previous surveys had confirmed the stability, form, volume and content of the rock armour and confirmed that scouring had remained below the design estimate at less than 0.5m. This most recent study has further confirmed that scouring from both turbine structures and rock placement largely absent and where scour is apparent it is less than 0.5m.

The data from the Osiris Spring 2006 survey indicates that movement of sediment is occurring for the majority of the turbine survey boxes. However, it is thought that the predominant process occurring across the wind farm array is that of sediment movement attributable to natural coastal processes and the changes in seabed levels found in the recent study are likely to be the result of these processes.

From an analysis of the 2006 volume comparison plots, minor scour development within a 10m radius of the foundation structures may have occurred (up to circa $2m^3$) at the following turbines: 19 and 20, with less obvious decreases at 04, 08, 12, 15, 18, 24, 26, 28. Turbines 25, 29 and 30 may also show some secondary scour around the placement of rock armour. However for all of these positions, general movement of sediment is occurring across the survey box and changes in seabed levels could equally be attributable to natural sediment processes.

Thresholds for sea bed mobility indicate that currents alone only create live bed conditions for the sandy material, with large storms required to exceed thresholds for both sands and gravels. The largest gravels are immobile and are generally regarded as a lag deposit.

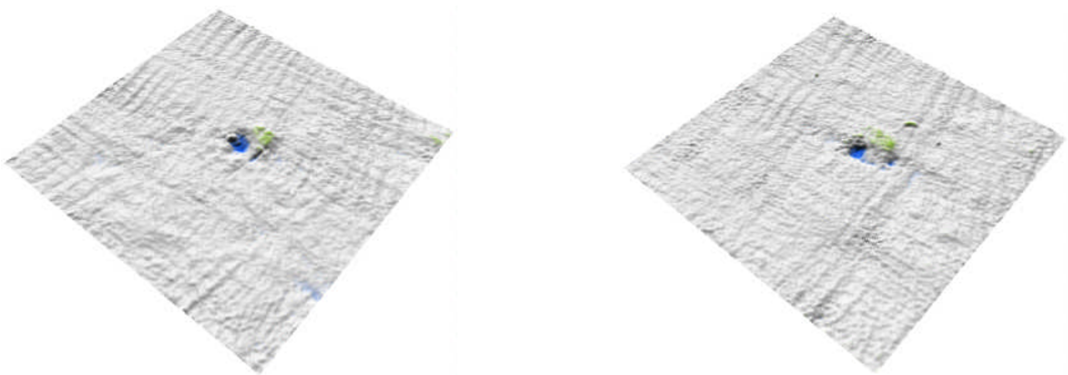

Figure 4.2 3D side scan image of WTG 19 (left) and WTG30 (right) with corresponding changes in seabed volume between Spring 2005 and Spring 2006.

The next scheduled survey will be in Spring 2007.

4.4.4 Summary

From the North Hoyle Environmental Statement and The Project Method Statement Rev 2 (June 2003) it has been widely recognised that the dominant factor in mobilising soft reworkable surface sediment (i.e. sands) at North Hoyle was the action of tidal current (ebb and flood tides). Based upon surveys and subsequent assumptions, backed by coastal processes expert opinion, and from the latest set of surveys; it can be concluded that, to date, no long term scour is developing at the North Hoyle Offshore Wind Farm.

Bomel (Jan 2004) modelled ultimate limit state analysis for 2 typical monopile structures using the assumption that 2m depth scour pits will develop during the course of the wind farm design life. Bomel (2004) concluded that the North Hoyle monopiles for both mudstone and sandstone substrates, based on the design basis, would have an acceptable performance in respect of axial capacity, lateral response and loading-induced stresses. Hence, given the maximum scour development seen to date is less than 0.5m depth, scour is unlikely to affect the structural integrity of the monopile foundations.

Scour development is less than that anticipated / predicted in the Project Method Statement and in line with the design assumptions made by LIC.

Based upon bottom and side scan sonar survey pre- and post-construction, followed by a repeat survey in Spring 2006, there has been no perceptible global scour or change in seabed bathymetry. Bathymetry depth change trends across the wind farm array, from Osiris 2004-5 surveys, appear to be in a SW-NE orientation, suggesting that the changes reflect natural sediment movement across the site from linear features such as sand waves and megaripples and not influenced by the installation of the wind farm.

Environmental implications on the regional sediment transport regime are effectively negligible as no distinct scour pits have developed. Placement of rock around the J-Tubes has generally remained in-situ with potential movement occurring at only 3 locations.