



GUNFLEET SANDS 3 DEMONSTRATION PROJECT

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POST-CONSTRUCTION YEAR 1 – MARINE LICENCE
ENVIRONMENTAL MONITORING REPORT

DONG ENERGY GUNFLEET SANDS DEMO (UK) LIMITED

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AUDIT INFORMATION

This monitoring summary report has been prepared by DONG Energy as part of the Marine Licence monitoring program for the Gunfleet Sands 3 Demonstration Project, under Marine Licence L/2012/00100/7. This report describes the environmental monitoring completed during the first year post construction period running from July 2013 – July 2014, in line with the requirements of the Gunfleet Sands 3 Demonstration Project Marine Licence.

Individual technical surveys and studies form the basis for this monitoring summary report. Full copies of the technical reports may be obtained on request from:

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Appendix B – Letter from the MMO dated 9th October 2013 confirming the removal of the fish and ornithological monitoring conditions.

Appendix C – Export Cable and WTG Inspection Surveys – Gunfleet Sand 3 Windfarm October 2013.

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GLOSSARY OF TERMS

ALSF	Aggregate Levy Sustainability Fund
ANOSIM	Analysis of Similarity
BERR	Department for Business, Enterprise and Regulatory Reform
Cefas	Centre for Environment, Fisheries and Aquaculture Science
DDV	Drop Down Video
DEFRA	Department for Environment, Food and Rural Affairs
EIA	Environmental Impact Assessment
EMP	Environmental Monitoring Plan
ES	Environmental Statement
GFS	Gunfleet Sands
HDD	Horizontal Directional Drill
MBES	Multibeam Echosounder
MDS	Multidimensional Scaling
MMO	Marine Management Organisation
MNCR	Marine Nature Conservation Review
MW	Megawatt
PCA	Principal Components Analysis
PLA	Port of London Authority
PSA	Particle Size Analysis
PSD	Power Spectral Density
PTS	Permanent Threshold Shift
RMS	Root-Mean-Square
SIMPER	Similarity Percentage
SIMPROF	Similarity Profiles
SPL	Sound Pressure Level
TOC	Total Organic Carbon
WTG	Wind Turbine Generator

EXECUTIVE SUMMARY

Gunfleet Sands Demonstration Project (GFS3) is a two turbine development located approximately 8.5 km south east of Clacton-on-Sea. The development area is approximately 1 km² with two 6 Megawatt (MW) turbines connected by an inter-array cable and an export cable which runs 9 km to a landfall location just south of Clacton-on-Sea. GFS3 lies adjacent to the operational Gunfleet Sands 1 (GFS1) and Gunfleet Sands 2 (GFS2) wind farms which are located to the immediate northwest. The project has been wholly developed by DONG Energy.

Construction of the Gunfleet Sands Demonstration Project started in June 2012 with grid connection achieved in February 2013 and first power produced in April 2013. The first turbine was in operation in April 2013, followed by inauguration of the wind farm in November 2013.

Environmental monitoring was completed prior to the start of construction and subsequently throughout the construction period, with monitoring continuing during the initial operational phase as a condition of the Marine Licence granted for the project. This report provides a summary of the monitoring completed during the first year post construction period. The following paragraphs briefly summarise the findings of the main monitoring studies completed at the GFS3 site during this period (July 2013 – July 2014). It should be noted that the original Marine Licence requirement for post-construction fish and ornithological monitoring have subsequently been removed, and as such, these surveys have not been undertaken. These changes were approved by the Marine Management Organisation (MMO), with the removal of the need for fish and ornithological monitoring confirmed by letter on 9th October 2013 (MMO case reference 35027/101220 – Appendix B).

Bathymetry (Scour) Surveys

Scour effects are a normal response to the placement of structures in an area subject to tidal currents and/or wave action and where the seabed is composed of fine sediment, as is the case at GFS3.

Scour was predicted in the Environmental Statement (ES) prepared for GFS3. The GFS3 ES predicted the depth of scour to be between 10.35m and 13.8m, with scour extents within 69m of the monopile, in the absence of any scour protection. Scour protection has been placed around the turbine foundations to mitigate the risk of scour occurring. There has been some identified scour/erosion of the bed of up to 0.2m to the north of Wind Turbine Generator (WTG) F00. The rock armouring and surrounding bed elsewhere remains stable compared to the October 2013 survey. In the case of turbine F00, some accretion in the footprint left by the jack-up rig has been observed.

There has been some erosion on both the northern and southern edges of the Gunfleet sandbank. The track of the cable route has experienced greater erosion than the surrounding bed. Away from the WTGs, no other cable exposures were seen in the data. The exposed export cable and inter-array cable were also seen in the data. There has been no change in the extent of the exposed cable compared to the previous survey in October 2013.

Comparing the results of the bathymetric surveys over the pre- and post-construction survey periods suggests that no major changes to bathymetry and scour effects have occurred across the wider GFS3 site.

Benthic Ecology

Data collected within the baseline survey and the year one post construction monitoring revealed significant change was detected between survey periods in benthic infaunal communities, however this was seen at both reference and cable route sampling stations. As a result of this, the changes could not be attributed to the installation or operation of the export cable, suggesting instead that the changes detected were a result of natural fluctuations occurring on a greater scale than the cable route. The North Sea is a shelf sea characterised by seasonal fluctuations in environmental variables and inter-annual variation in benthic infaunal communities is a common characteristic of the region. It is concluded that the relatively small changes recorded within the study area are likely to be a result of natural fluctuations.

This assessment has validated predictions made within the ES and supporting addendum including the impact of temporary habitat loss/disturbance, increases in suspended sediment and sedimentation, and potential release of contaminants from adjacent sediments. All impacts were predicted to be of negligible significance. The results of the survey work conducted to date indicate that any impacts resulting from the installation and operation of the export cable route are within natural variation of the infaunal communities within the vicinity of the cable route.

Operational Noise

The survey results found that as a whole, the measured unweighted sound pressure levels show that the operational phase of the wind farm has had resulted in a minimal increase on the overall sound pressure levels in the vicinity of the wind farm. Indications are that the sound pressure levels from the F00 and G00 turbines tend to fall below the background noise level within 100m (background noise levels include noise from Gunfleet Sands 1 and 2 turbines and associated vessel traffic).

The measured underwater noise data has been interpreted using a number of metrics. All the unweighted measured levels were found to be significantly below any criteria in the literature that have been seen to cause fatality or physical injury.

The data has also been analysed in terms of the species specific dBht metric. In general, the sound pressure levels for fish and marine mammals were found to have increased but generally not exceeding the 50 dBht level, with the exception of harbour porpoise and striped dolphin for which dBht levels were found to be below 75 dBht. However, the levels remain well below the levels that which could be expected to cause significant disturbance.

M-Weighted sound exposure levels (SELs) were calculated by extrapolating measured levels over 24 hours. It was found that all the SELs fall well below the level at which permanent hearing damage is likely to occur for cetaceans and pinnipeds.

Conclusions

It is concluded that the first year of post-construction monitoring is considered fit for purpose and has ensured that the Gunfleet Sands project has fulfilled the requirements of the Marine Licence during the first year post-construction.

1. Introduction

1.1. Background

1.1.1. DONG Energy is one of the leading energy groups in the Nordic region. The company pioneered the offshore wind farm industry in Denmark with projects constructed in the 1990's. In 2002 and 2003 DONG Energy constructed the world's two largest offshore wind farms; Horns Rev and Nysted. In addition to the Gunfleet Sands 3 project, DONG Energy is involved in a number of Round 1, Round 2 and Round 2 extension and Round 3 offshore wind projects in the UK, as summarised below:

- the **Barrow project**, which went into operation in 2006;
- the **Burbo Bank project**, which was completed and went into operation in 2007;
- the **Burbo Bank extension**, which was granted development consent in September 2014 ;
- the **London Array project**, for which the first foundation was installed in March 2011 and which went into operation in March 2013;
- the **Walney project**, which was completed and went into operation in April 2012;
- the **Walney extension** which had an application for consents accepted in July 2013 with a decision expected in November 2014;
- the **West of Duddon project**, consented with construction started in May 2013;
- the **Westermost Rough project**, located in the Greater Wash region, for which the first foundation was installed in February 2014;
- the **Lincs project**, which is located off the coast of Skegness and was officially opened in August 2013;
- **Hornsea Project One**, 33.3% share acquired by DONG Energy in 2011, which had an application for consents accepted in September 2013 with consent granted in December 2014; and
- the **Gunfleet Sands I & II projects** which were completed and went into operation in Spring 2010.

1.1.2. The Gunfleet Sands (GFS) offshore wind farm, which is located approximately 8.5km south-east of Clacton-on-Sea in Essex, consists of the operational GFS 1 and GFS 2 projects. Consent was granted for GFS 1 in 2004 and for GFS 2 in 2008. The combined GFS 1 and 2 projects consist of 48 operational turbines, each of a maximum capacity of 3.6 MW. Generation capacity for the GFS projects is restricted and capped at 164 MW.

1.1.3. In August 2010, DONG Energy was awarded a demonstration lease by The Crown Estate for a site to the south-west of the GFS 2 array to construct two demonstration turbines (Figure 1). This is known as the Gunfleet Sands 3 - Demonstration Project (GFS 3). The majority of the GFS 3 site (approximately 80%) lies within the originally consented GFS 2 site.

1.1.4. Details of GFS3 project, including the construction process, are set out in Section 2 of this report.

Gunfleet Sands 3 Demonstration Project

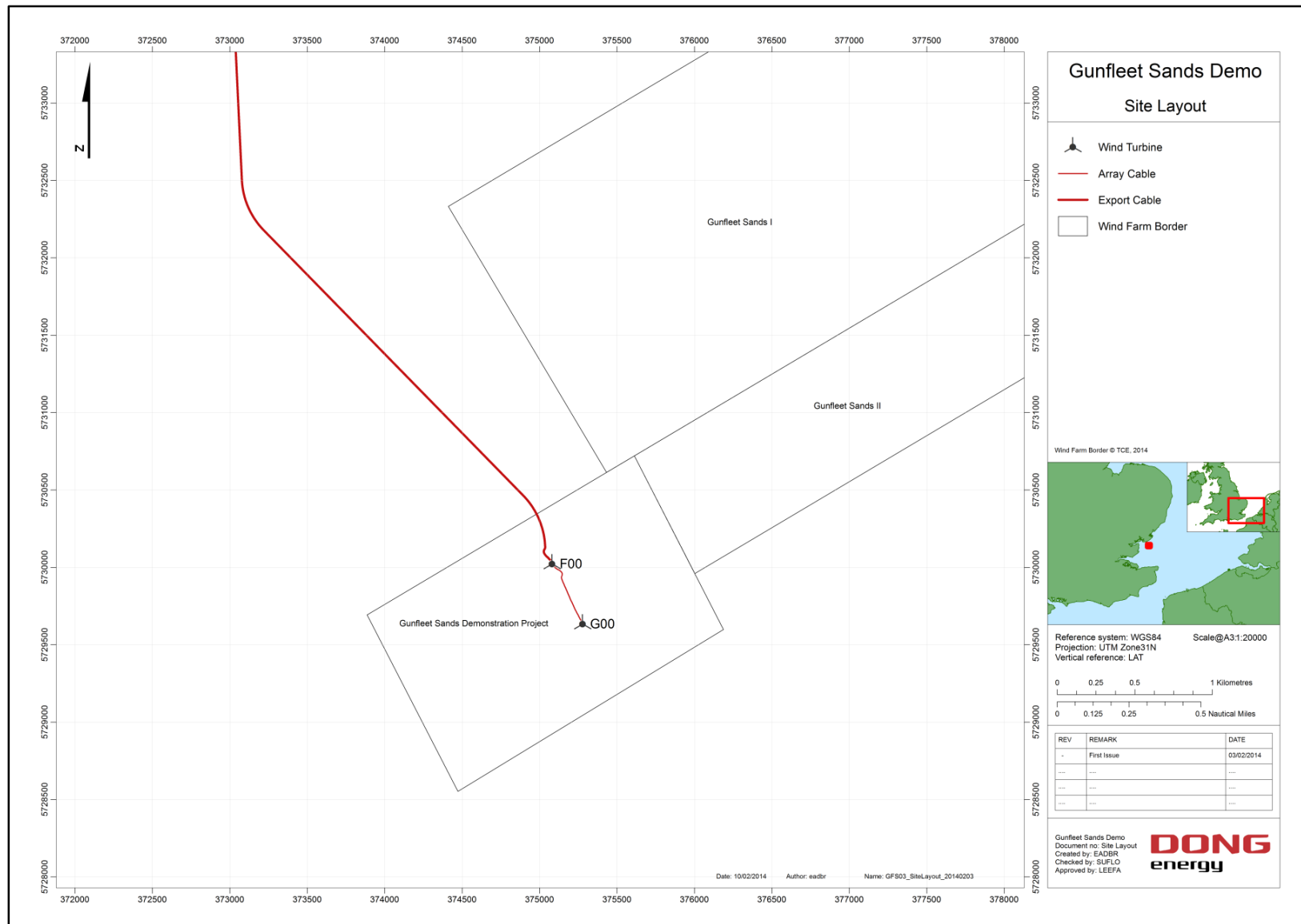


Figure 1 - Location and turbine layouts for the Gunfleet Sands3 Demonstration Project (as built layout).

1.2. Project Consents

- 1.2.1. On 16th December 2010, DONG Energy submitted an application to the MMO for the following in respect of GFS 3:
- consent under section 36 of the Electricity Act 1989 to construct and operate the GFS 3 project;
 - a declaration under section 36A of the Electricity Act 1989 to extinguish rights of navigation so far as they pass through the locations in the sea where GFS 3 is to be located;
 - a licence under part 2 of the Food and Environment Protection Act 1985 to deposit articles in the sea in connection with the GFS 3 marine construction works; and
 - consent under section 34 of the Coastal Protection Act 1949 to make provision for the safety of navigation in relation to the proposed construction works.
- 1.2.2. The GFS3 proposal to which the initial application related was for up to 2 offshore wind turbine generators with an aggregate maximum installed capacity of 20 MW together with associated inter-connecting cabling. The initial application was accompanied by an ES. At the time of the initial application the intention was to connect GFS 3 via the existing GFS 1 and GFS 2 offshore transformer and the offshore export cable.
- 1.2.3. On 6th April 2011, a new system of marine licensing replaced and consolidated the previous statutory regime for marine consents including the need for licences under part 2 of the Food and Environment Protection Act 1985 and consents under section 34 of the Coastal Protection Act 1949. From that point on, the application was then progressed by the MMO as an application for a Marine Licence together with a consent under section 36 and declaration under section 36A of Electricity Act 1989.
- 1.2.4. Subsequent to the initial application being submitted to the MMO, DONG Energy was advised that the current export cable constructed for GFS 1 and GFS 2 would not be sufficient to enable GFS 3 to produce power at maximum capacity. Accordingly, DONG Energy decided to amend the application so that it included a new export cable that would run directly from GFS 3 to the 33kV distribution network in Clacton-on-Sea to ensure that GFS3 would be able to operate at full capacity. This proposal was discussed at a meeting between DONG Energy and the MMO on 21st February 2011.
- 1.2.5. In a letter to DONG Energy dated 7th April 2011, the MMO confirmed that the proposed export cable for GFS 3 could not be treated as a separate application to the GFS 3 turbines themselves. The MMO advised DONG Energy that an addendum to the ES submitted with the Application would be required to cover the environmental implications of the revised scope of works for the entire GFS 3 project.
- 1.2.6. DONG Energy therefore produced two addendum reports together with an overarching non-technical summary to update the ES submitted with the application: one addendum covered the offshore section of the proposed export cable (the Offshore Addendum) and the other addendum covered the onshore section of the proposed export cable (the Onshore Addendum). Both the Offshore Addendum and the Onshore Addendum were submitted (together with the non-technical summary) to the MMO, who had to consider the environmental impacts of the GFS 3 project as a whole.
- 1.2.7. The following offshore consents were issued for GFS3 in March 2012:
- Marine Licence;
 - Section 36 consent; and
 - River Works Licence from the Port of London Authority (PLA).

1.2.8. As a result of the Marine and Coastal Access Act 2009 (MCAA), from 6th April 2011 the marine licensing system was consolidated and Marine Licences replaced previous statutory controls including:

- Licences under Part 2 of the Food and Environment Protection Act 1985;
- Consents under section 34 of the Coast Protection Act 1949;
- Consents under Paragraph 11 of Schedule 2 to the Telecommunications Act 1984; and
- Licences under the Environmental Impact Assessment and Natural Habitats (Extraction of Minerals by Marine Dredging) Regulations 2007.

Marine Licence

1.2.9. As part of the new marine licensing system, a Marine Licence for the works was issued in March 2012. The MMO Licence reference is L/2012/00100/7.

1.2.10. In keeping with licences issued for all existing UK offshore wind farms, the GFS3 Marine Licence set out conditions requiring a variety of environmental monitoring to be completed through the various phases of the development (pre-construction, during construction and post-construction). These monitoring studies were required as a check on the conclusions reached in the project ES and to ensure that no ‘unforeseen’ environmental impacts were occurring.

1.2.11. The Marine Licence includes a requirement for the developer to produce a monitoring plan for each phase of development setting out the proposed specification of the monitoring which is then subject to agreement with the Regulator (MMO), and their advisers (Centre for Environment, Fisheries and Aquaculture Science (Cefas) and Natural England).

1.2.12. All monitoring reports are required to be forwarded to the Licensing Authority and Natural England on an annual basis, or more frequently if the results trigger further monitoring work. In order to collate all of the environmental monitoring specifications an Environmental Monitoring Plan (EMP) was produced (NIRAS, 2014). The chronology of the preparation of the GFS3 EMP is set out in Table 1 below.

Table 1 - Development of the GFS3 Environmental Monitoring Plan.

Action	Date
Proposed EMP (Revision 01) submitted to the MMO	April 2012
Comments on proposed EMP received from the MMO (incorporating advice from Cefas, RSPB and Natural England)	June 2012
Proposal to amend scope for post-construction bathymetric survey was confirmed and approved for implementation by the MMO	23 June 2013
A proposal for amended scope for post-construction benthic survey was confirmed and approved for implementation by the MMO	10 July 2013
A proposal to vary Marine Licence L/2012/00100 and exclude post-construction fish monitoring was confirmed and approved for implementation by the MMO	28 August 2013
A proposal to vary Marine Licence L/2012/00100 and exclude post-construction ornithological monitoring was confirmed and approved for implementation by the MMO	9 October 2013
A proposal to postpone post-construction operational noise monitoring to the summer of 2014 was confirmed and approved for implementation by the MMO	20 September 2013

Action	Date
A proposal for postponing the year two post-construction benthic survey until 2015 was confirmed and approved for implementation by the MMO	20 May 2014
Variation order request for removing benthic monitoring condition sent to the MMO	27 October 2014
EMP Revision - version B submitted to the MMO	28 October 2014

- 1.2.13. It should be noted that the original Marine Licence requirements for post-construction fish and ornithological monitoring have subsequently been removed by the MMO and as such these surveys have not been undertaken. These changes were approved by the MMO following the submission of a letter (dated 12th August 2013 – Appendix A) which stated that high quality of data collected at Gunfleet Sands 1 and 2 allowed for a high degree of certainty in the conclusions that were made in the GFS3 ES.
- 1.2.14. In relation to ornithological monitoring, the EIA in respect of the GFS3 project drew benefit from the extensive dataset already available for the GFS 1 and 2 projects. The majority (80%) of the GFS3 lease areas sits within the boundary of the originally consented GFS2 site. The GFS2 environmental assessment incorporated a 22 turbine array, whilst only 18 turbines were constructed. Thus, the two GFS3 turbines lie partially within the envelope of assessment completed in respect of GFS2, which concluded no significant effects associated with that development. An Addendum to the GFS3 ES was issued for the GFS3 export cable route, and this also concluded no significant effects associated with these works.
- 1.2.15. The GFS3 ES concluded that in relation to the installation of the export cable, two turbines and the associated inter-array cable, there would be no significant impacts on fish and shellfish ecology associated with the site. The GFS3 ES drew primarily upon data and impact assessments from the GFS1 & GFS2 ES, due to both proximity of study sites and relevance of data. Extensive environmental monitoring of the GS1 and GS2 sites was undertaken prior to the start of construction and subsequently throughout the construction period, with monitoring continuing throughout two years of operation. The fish monitoring for GS1 & GS2 concluded that there had been no significant adverse effects on fish species as a result of the construction and operation of the GS1 and GS2 wind farms. Given the results of the monitoring conducted for GS1 and GS2, it was considered that fish monitoring at GFS3 was no longer justified.
- 1.2.16. The removal of the need for fish and ornithological monitoring was confirmed by letter on 9th October 2013 (MMO case reference 35027/101220 – Appendix B).
- 1.2.17. The pre-construction monitoring was undertaken in early 2012, prior to construction commencing. Construction monitoring started in Q2 2012, being completed by Q3 2012 (the timing of individual monitoring surveys within that timeframe depended on the purpose of that monitoring).
- 1.2.18. The monitoring specifications set out in the EMP and agreed with the regulator and their advisers that are relevant to the post-construction monitoring period are summarised in Section 3 of this report. Dates for the first year of post-construction surveys are summarised in Table 2 below.

Table 2 - Summary of the Year 1 post construction surveys.

Survey Type	Year 1 Post Construction Dates
Bathymetry	Multibeam Echosounder (MBES) surveys were undertaken on the following project components in Autumn 2013 (6 th and 7 th October) and Spring 2014 (10 th April and 16 th May): <ul style="list-style-type: none"> • a 50m wide corridor along the export cable route between WTG F00 and the Horizontal Directional Drill (HDD) exit point; and • around the WTG foundations and the inter-array cable.
Benthic ecology	Drop down video (DDV) and benthic grab surveys undertaken over 3 days in July 2013.
Underwater Noise	Operational noise modelling undertaken based on measurements taken on 29 th and 30 th July 2014.

- 1.2.19. The Marine Licence issued for GFS3 project also includes conditions related to the reporting of the monitoring results. The relevant conditions are detailed in Table 3 below.

Table 3 - Summary of Marine Licence reporting requirements.

Marine Licence Condition	Description
3.3.14	The Licence Holder must submit environmental monitoring reports to the Licensing Authority, Cefas and Natural England by the date specified in accordance with the Monitoring Programme as referred to in condition 3.1.13 and scheduled in accordance with condition 3.1.1 in order to allow the Licensing Authority to consider if any action may be required to mitigate or correct any adverse environmental effects which may be mitigated.
Annex 1	The reports should include data, interpretation, assessment, conclusions and an executive summary. All data must be submitted within the reports - processed and unprocessed. All monitoring surveys should be based on a clear and reported rationale and robust hypotheses should be established for each survey. The interpretation and reporting of the monitoring required in this annex must be undertaken so as to ensure that all inter-relationships are appropriately assessed.

1.3. Objectives of this Report

- 1.3.1. This document provides a summary of the Marine Licence monitoring completed during the first year post construction for the GFS3 project. This document is set out to achieve the following objectives:

- Provide a brief summary of the need for and approach to the monitoring required during the post construction period;
- Provide a brief summary of the methods and results of the monitoring studies during the first year of post-construction monitoring;
- Draw brief conclusions on the results of the monitoring studies with reference to baseline data;

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- Relate the findings of the current study to the predictions reported in the original environmental statements to validate the outputs of the Environmental Impact Assessment (EIA); and
- Integrate and compare, where relevant, the results from individual studies to provide a description of the wider environmental effects.

1.3.2. The document contains results and conclusions from the following first year post construction phase Marine Licence monitoring studies completed at the GFS3 site:

- Bathymetry;
- Benthic ecology; and
- Operational noise.

1.3.3. Note that this report is intended to provide a summary of the monitoring only; full details of each of the monitoring studies are available in the individual monitoring reports referenced in this report and previously submitted separately to the licensing authorities and their advisers.

2. Construction and Operation of the Gunfleet Sands 3 Demonstration Project

2.1. Introduction

- 2.1.1. This section summarises the construction process and operational activities for GFS3, focusing on the offshore works. Table 4 shows the construction program for the GFS3.
- 2.1.2. A description of the construction activities is provided in the following sections.

2.2. Offshore construction

- 2.2.1. The offshore construction work included:

- Two monopiles piled in the sea bed at the offshore site;
- Installation of 2 wind turbine generators;
- 33kV subsea inter array cables installed and terminated;
- 33 kV subsea cable installed between the shore and the WTG; and
- 33 kV onshore cable jointed to the 33 kV subsea cable.

Monopile foundation installation

- 2.2.2. The main purpose of the foundations is to support the weight, wind and wave loads on the turbines. Each monopile foundation consisted of a welded cylindrical steel monopile with total length of 46 m and penetrated the seabed up to circa 30-34 m. The detailed design process revealed that scour protection around the monopiles was necessary. As such, scour protection was installed to prevent seabed erosion locally around the piles.
- 2.2.3. The monopiles installed at the GS3 site have an outer diameter of 5.95 m and a total weight circa 355 tonnes. After installation, a painted steel transition piece was mounted on top of each monopile. The transition piece weighs circa 370 tonnes, has an outer diameter of 5 m, and a total length of 23.81 m which results in a top level of 18.15 m above LAT (Lowest Astronomical Tide) and an overlap between the monopile and the transition piece of 8.5 m. The transition piece was fastened to the monopile by means of a high strength grout material. The grout forms a permanent connection after hardening.
- 2.2.4. The transition piece is coloured yellow from HAT (Highest Astronomical Tide) to the height of the marine aids to navigation lights (the equivalent height on the unlit structures) and included pre-installed boat landings.
- 2.2.5. The monopiles were delivered to site by the floating crane “Svanen”. The Svanen then lifted the monopile into position, with the pile fixed and guided by the pilegripper before being piled to target penetration depth using a large hydraulic hammer. The transition piece was placed on the monopile and levelled before being grouted together with the monopile using a high strength grout material.
- 2.2.6. Scour protection of gravel and rock was applied around both turbine foundations.

Gunfleet Sands 3 Demonstration Project

Table 4 - Gunfleet Sands 3 Demonstration Project construction program.

	2012												2013											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Construction Permit Award																								
Onshore cable installation																								
Onshore substation																								
Foundation installation																								
Turbine installation																								
Offshore cable installation																								
Grid Connection																								
First power generated																								
Commercially operational																								

Wind turbine installation

- 2.2.7. The turbines installed at the GS3 site are the Siemens 6 MW. These have a hub height of 83.6 m above mean high water spring (MHWS) and a rotor diameter of 121 m.
- 2.2.8. The wind turbines were mounted on the foundations in the following sequence:
1. Lower and upper tower section (the first tower section mounted on the foundation transition piece);
 2. The nacelle containing the gearbox, transformer and generator; and
 3. The three blades, mounted one by one.
- 2.2.9. The installation of the wind turbines was undertaken by the “Sea Installer”. The ancillary works such as cable connections, installation of j-tubes, and commissioning and start-up of the turbines were undertaken by smaller vessels operating out of Brightlingsea.
- 2.2.10. The wind turbines were installed following foundation installation. The installation of wind turbines was completed in January 2013. The project was fully operational in November 2013.

Array and export cables

- 2.2.11. A cable of approximately 9.5km length connects the turbines to the landfall point. An additional array cable was installed between the two turbine positions; the distance between the two positions being approximately 0.5km.
- 2.2.12. The cable installation was carried out by the simultaneous lay and burial of the cable, using a cable plough towed by an anchored barge. The simultaneous lay and burial ensured that the construction vessel only had to make one ‘pass’ along the cable route. The cable was then pulled through the duct at landfall location from the cable laying vessel to shore. The burial of the cable also ensured that the cable is protected from natural and man-made hazards, such as anchors being dragged on the seabed.

3. Environmental Monitoring Specifications

3.1. Introduction

3.1.1. The following sections provide a brief overview of the specifications of the Marine Licence monitoring studies completed during the first year post construction period and summarised in this report. The specifications for these studies have been previously agreed with the licensing authorities and their advisers and are set out in greater detail in the EMP (NIRAS, 2014) (see Section 1.2 above). More detail on the methodology and timings employed for each monitoring study are included in the subsequent summaries presented under Section 4.

3.2. Marine Licence Monitoring

3.2.1. The monitoring required by the project Marine Licences during the first year post construction is as follows:

- Bathymetry;
- Benthic ecology; and
- Operational noise.

3.2.2. The relevant licence conditions and a brief summary of the proposed monitoring approach are set out in Table 5.

3.3. Monitoring program

3.3.1. The Marine Licence environmental monitoring program covering the pre, during and post-construction periods is summarised in Table 6. The construction period is bordered by a dotted line, with completed surveys in light green.


Table 5 - Summary of first year post-construction GF3 monitoring.


Monitoring	Marine Licence Condition	Summary of Agreed Monitoring
Bathymetric Surveys	3.3.2	The Licence Holder must undertake a 100% coverage bathymetric survey of the turbines, area and export cable route within three months following completion of construction of the wind farm to assess scour. The area of seabed surveyed must be agreed with the Licensing Authority in consultation with Cefas and Natural England. The survey must be repeated at six monthly intervals for a period of at least two years for turbines and three years for the export cable. This shall specifically address the need for additional scour protection around the turbine pylons and associated cables. The Licence Holder must submit the data in the form of a report to the Licensing Authority, including proposals for scour protection measures by the date specified in the schedule required under condition 3.1.1. The necessity for further surveys will then be reviewed and where necessary extended.
	3.3.3	The Licence Holder must carry out similar surveys as in condition 3.3.2 in the event of any major storm events likely to result in significant sediment movements (i.e. greater than a 1 in 10 year wave event at this site in terms of wave height). Wave data is currently available free from http://www.cefas.co.uk/wavenet/default.htm .
	Annex 1, Point 1	Appropriate monitoring must be undertaken at Gunfleet 3 during the operational phase of the wind farm to address any potential impact from scour. Condition 3.3.2 refers.
Benthic Surveys	Annex 1, Point 2	<p>Sample locations for ongoing monitoring must be determined by factors such as precise foundation locations, location of cables. Sample locations must also take full account of factors such as coastal process modelling outputs (for sediment transport / deposition information) and geophysical surveys (to ensure adequate coverage of sea bed habitats). The sample locations must be the same as the baseline to ensure data is comparable pre and post construction.</p> <p>Sampling should involve a minimum of three replicates at each sample location and the number and locations should be determined making use of the data used to characterise the site as part of the Environmental Statement. This monitoring should include a suitable baseline data set and make adequate use of control sites.</p> <p>The Licence Holder must complete post construction benthic surveys along the cable route for a period of three years. The frequency will be reviewed in discussion with the Licensing Authority at the end of the first year of monitoring.</p> <p>NB. The sedimentary and benthic data sets must be closely related. Please refer to the ALSF paper: 2nd Edition Best Practice Guidelines.</p>


		(http://cefas.defra.gov.uk/alsf/projects/mitigation-and-management/08p75/2nd-edition-best-practice-benthic-guidelines.aspx)
Operational Noise Monitoring	3.3.4	The Licence Holder must undertake post construction noise monitoring. The specifications for these measurements must be agreed with the Licensing Authority in consultation with Cefas and NE prior to the commencement of the monitoring.
	Annex 1, Point 5	<p>Detailed during construction monitoring is required as per condition 3.2.17. Details are to be agreed with Cefas prior to construction. Post construction monitoring is required for a period of one year. Data must be collected on the frequencies and magnitudes of underwater noise produced by this offshore wind farm. This is required for a variety of purposes, including:</p> <p>In combination with the biological aspects of the monitoring programme proposed in Annexes 1, the data would help to elucidate any interactions between noise generation and the provision of new habitat and fish aggregation effects of the turbine support structures.</p> <p>Determining the effects of distance depth and background sources on noise propagation.</p> <p>Any potential marine mammal and fish disturbance.</p>

Table 6 - Gunfleet Sands 3 Demonstration Project Environmental Monitoring Programme

Survey	2012				2013				2014				2015				2016			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Construction Period (Offshore)																				
Post-construction period																				
Pre-construction debris survey																				
Post-construction bathymetry survey (Year 1)																				
Post-construction bathymetry survey (Year 2)																				
Post-construction bathymetry survey (Year 3)																				
Post-construction benthic survey																				
Marine mammal mitigation programme																				
Marine mammal construction survey (as part of ornithological monitoring)																				
Construction (piling) noise monitoring																				
Ornithological monitoring (boat based – during construction)																				
Operational noise monitoring																				

 Proposed survey periods

 Completed surveys periods

 Duration of key project stages

4. Offshore Environmental Monitoring

4.1. Introduction

4.1.1. The following sections provide an overview of the key findings arising from the environmental monitoring completed at GFS3 during the first year post construction as required by the Marine Licence conditions.

4.1.2. The results of all of the Marine Licence monitoring conducted during the first year post construction are summarised, specifically the following monitoring studies:

- Bathymetric surveys;
- Benthic surveys; and
- Operational noise monitoring.

4.1.3. The topic specific survey reports have been appended to this report. The reports comprise the following documents:

- Appendix C: Bathymetry (Scour) Survey – Export Cable and WTG Inspection Surveys – Gunfleet Sand 3 Windfarm October 2013.
- Appendix D- Bathymetry (Scour) Survey – Export Cable and WTG Inspection Survey – Gunfleet Sands 3 Windfarm April-May 2014.
- Appendix E: Benthic Ecology Survey – Gunfleet Sands Demonstration Project Year 1 Post-Construction Export Cable Monitoring Report.
- Appendix F: Operational Noise Survey - Monitoring and Assessment of Operational Subsea Noise of Gunfleet Sands 3 – 16th October 2014.

4.1.4. The relationship between the different variables subject to monitoring is explored where relevant as required by the Marine Licence conditions. In addition, the relevant conclusions for each subject from the GFS3 ES (DONG Energy, 2010) and the associated Offshore Addendum (DONG Energy, 2011) are briefly summarised and compared to the findings of the monitoring conducted during the construction and post construction periods.

4.2. Bathymetry (Scour) Surveys

Summary of Licence Conditions and Proposed Approach

4.2.1. Conditions relating to monitoring of bathymetry and scour effects are set out in the Marine Licence for GFS3. The specific Marine Licence conditions are set out in Table 5 of this document. The findings in this report represent the first and second bathymetric scour monitoring surveys.

Monitoring Methods

4.2.2. The post-construction surveys presented here were conducted on 6th to 7th October 2013 (Year 1 - Autumn surveys), and 10th April 2014 & 16th May 2014 (Year 1 - Spring surveys), with surveys following on from the previous bathymetric surveys. The works incorporated the following scope of works:

- MBES survey of 50m wide corridor along the export cable route between WTG F00 and the HDD exit point (Figure 2);
- MBES survey of WTG foundations F00 and G00 and the inter-array cable (Figure 2); and
- Difference surface models at both turbine sites and along the export cable route.

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- 4.2.3. Full details of the equipment and methodology used are provided in the survey report (PLA, 2014 – Appendices C and D).

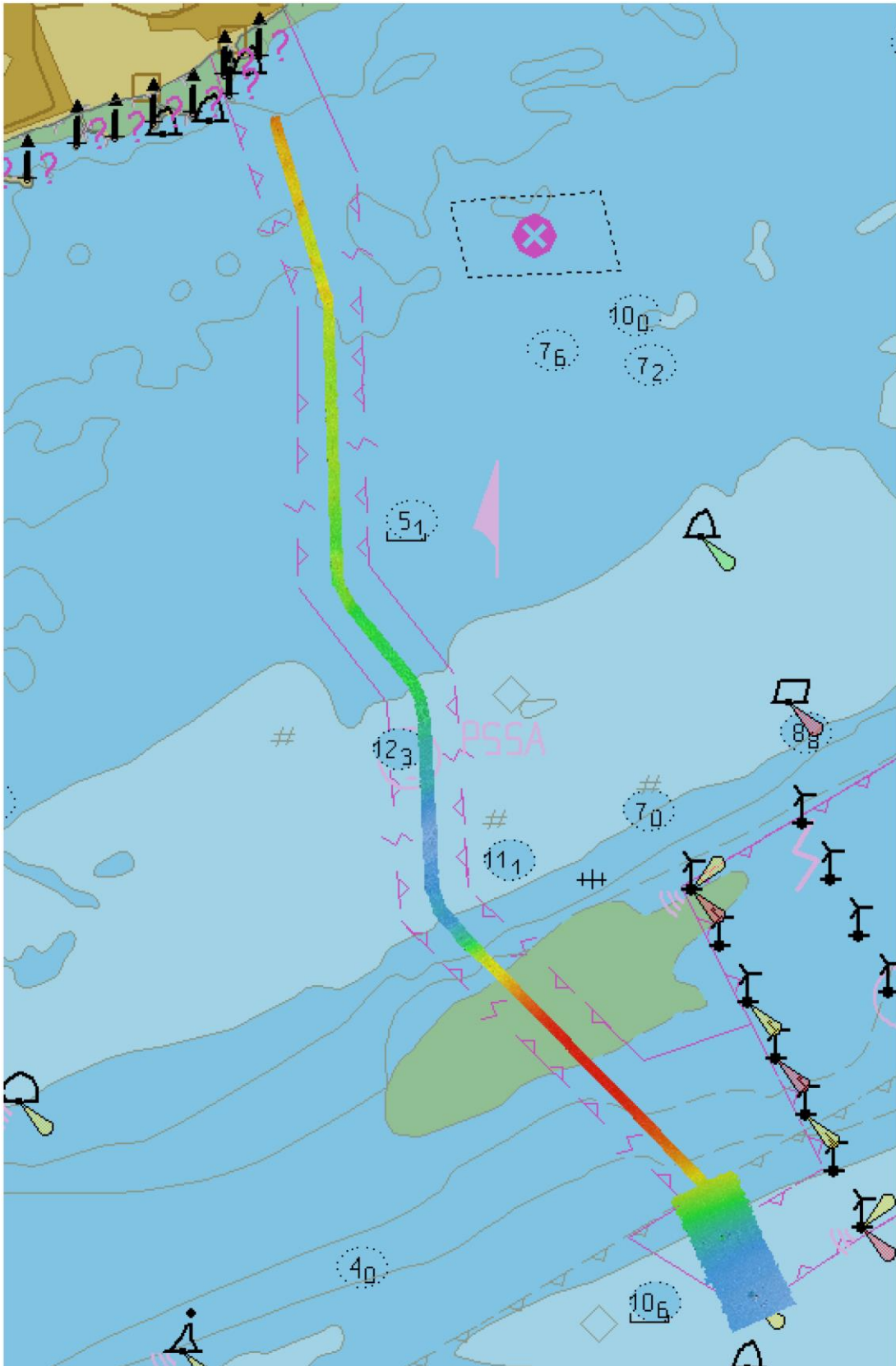


Figure 2 - Survey area along export cable route between the wind turbines and the HDD exit points, and the inter-array cable route between turbines F00 and G00 (PLA, 2014).

4.2.4. All first year post-construction surveys were carried out using the Port of London’s survey vessel ‘Yantlet’ (Figure 3), with bathymetric data collected using a hull-mounted Reson SeaBat 8125h MBES. The location of the survey areas is shown in Figure 2.



Figure 3 - PLA survey vessel ‘Yantlet’ (PLA, 2014).

Results

Export cable route scour

4.2.5. The status of the export cable route is described in Table 7.

Table 7 - Cable route status

Kp value	Cable Route
Kp 0.810 – 0.853	Mattresses
Kp 0.853 - 5.125	Trench
Kp 5.125 - 5.9	Shallow Trench <5cm
Kp 5.9 - 6.3	Trench
Kp 6.3 – 6.7	Shallow Trench <5cm
Kp 6.7 -7.2	Trench
Kp 7.2 -8.825	No trench seen. Flat seabed.
Kp 8.825-8.870	Trench up to 20cm deep
Kp 8.870 - 9.3	No trench seen. Flat seabed.
Kp 9.3 - 9.4	Shallow Trench
Kp 9.4 - 9.434	Exposed Cable
Kp 9.434 - 9.440	Span to WTG F00

- 4.2.6. Along the survey corridor, the seabed is disturbed in several areas with drag marks believed to be associated with cable laying operations (Table 7). The survey corridor is also crossed by shallow pairs of trawl marks, possibly due to fishing activity. An example of a cable laying drag mark and pair of trawl marks is shown in Figure 4. It is important to note that drag marks do not have any consequence to cable integrity and as such, no remedial action is proposed.

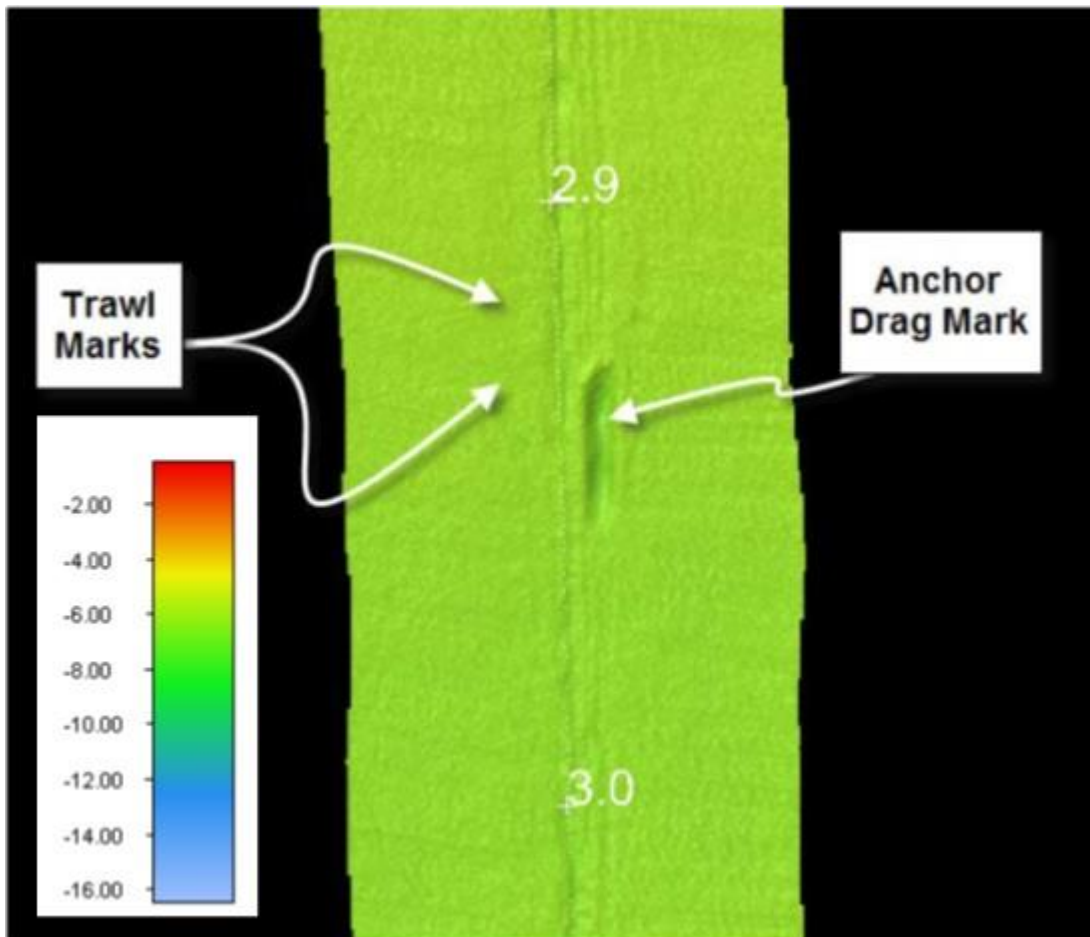


Figure 4 - Drag mark and trawl marks (kp 2.9 - kp3.0) (PLA, 2014).

- 4.2.7. A new target has been identified at kilometre point (kp) 4.235 (Figure 5), 40m east of the cable route. The target is located at 372596.3E, 5734334.8N, length 5m width 0.75m and a height of 0.3m above the surrounding bed. The least depth on the target is 8.4m. The target does not have consequence to cable integrity and therefore, no further action is proposed.

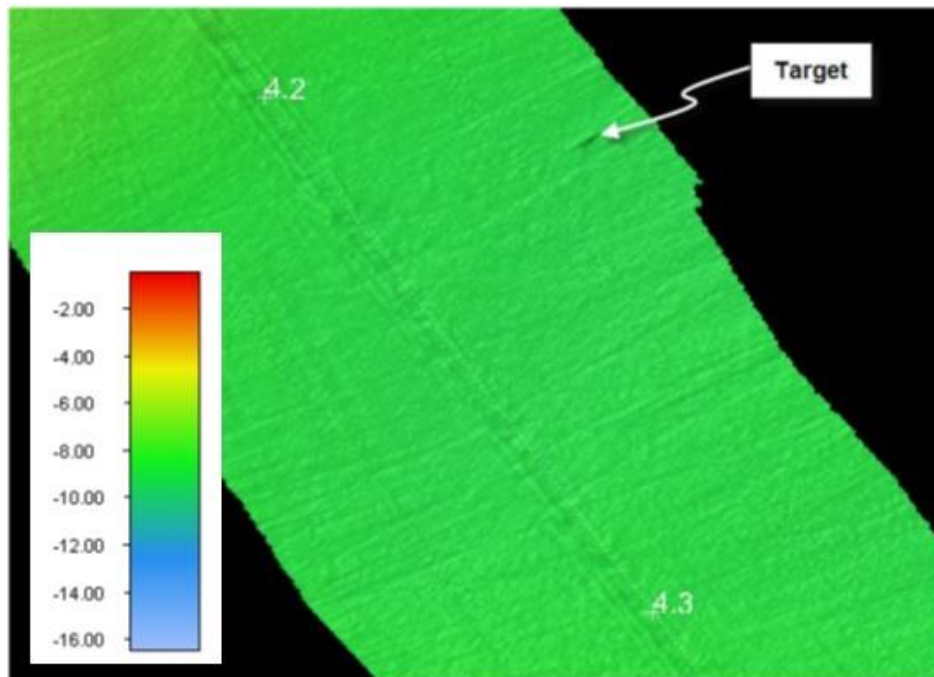


Figure 5 - Target (kp4.2 - kp4.3) (PLA, 2014).

4.2.8. Table 8 provides descriptions of the bedforms present along the export cable route from the April 2014 surveys. There has been little notable change from kp0.8 to kp6.55 between October 2013 and April 2014. On the north of the bank, there has been some erosion on the slope between kp6.55 and kp7.2 (as described in Table 8), with some of the erosion shown in Figure 6 (kp6.7 – 6.9). The difference model shows the slope continuing to be cut away. In this area, the trench along the charted kp has deepened by approx. 0.1m compared to the surrounding bed. Between kp 8.3-kp 8.9 there has been up to 0.3m of erosion. At kp8.85, the erosion is concentrated over the charted cable route (Figure 7).

Table 8 - Bedform descriptions

Kp value	Bed description
0.9-4.1	Shallow bedforms wavelength 1-3m, height 0.1m
4.1-4.55	Smooth seabed with some scarring
4.55-5.15	Bed forms orientated NE-SW (in flow direction). 0.1m height
5.15-5.85	Flat seabed
5.85-6.1	Sandwaves 5-10m wavelength, height 0.5m
6.1-6.3	Sandwaves 3-5m wavelength, height 0.2m
6.3-6.55	Small bedforms and mounds
6.55-7.2	Slope on to sandbank ridges carved in to slope.
7.2-8.5	Smooth seabed
8.5-8.85	Various bedforms/areas of erosion.
8.85-9.4	Smooth seabed.

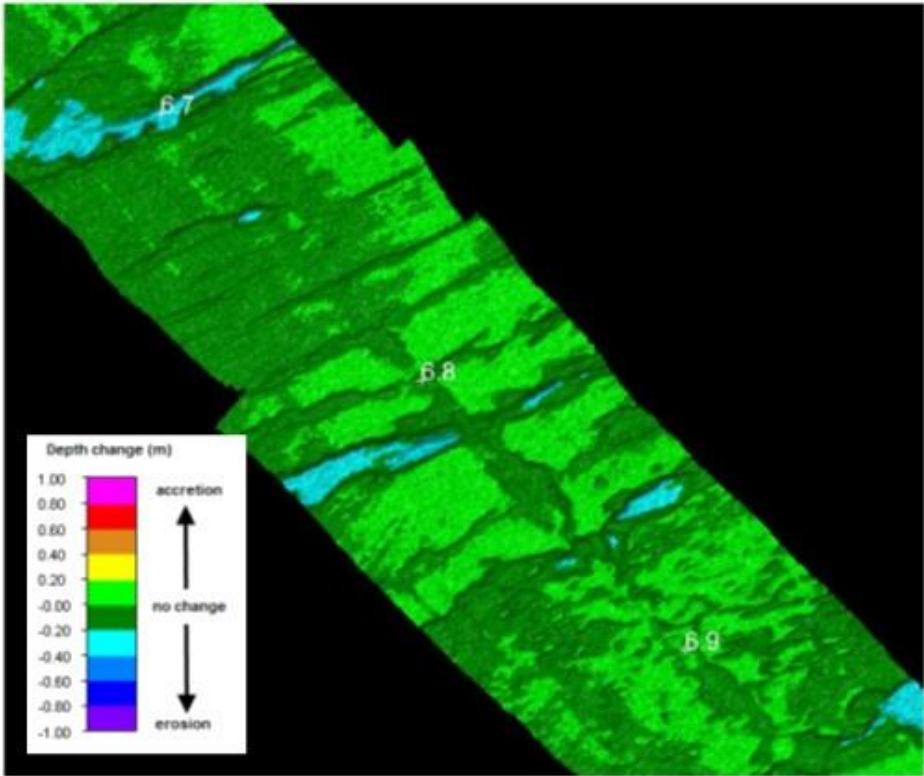


Figure 6 - Difference model comparing April 2014 with October 2013 data between kp6.7 and kp6.9 (PLA, 2014).

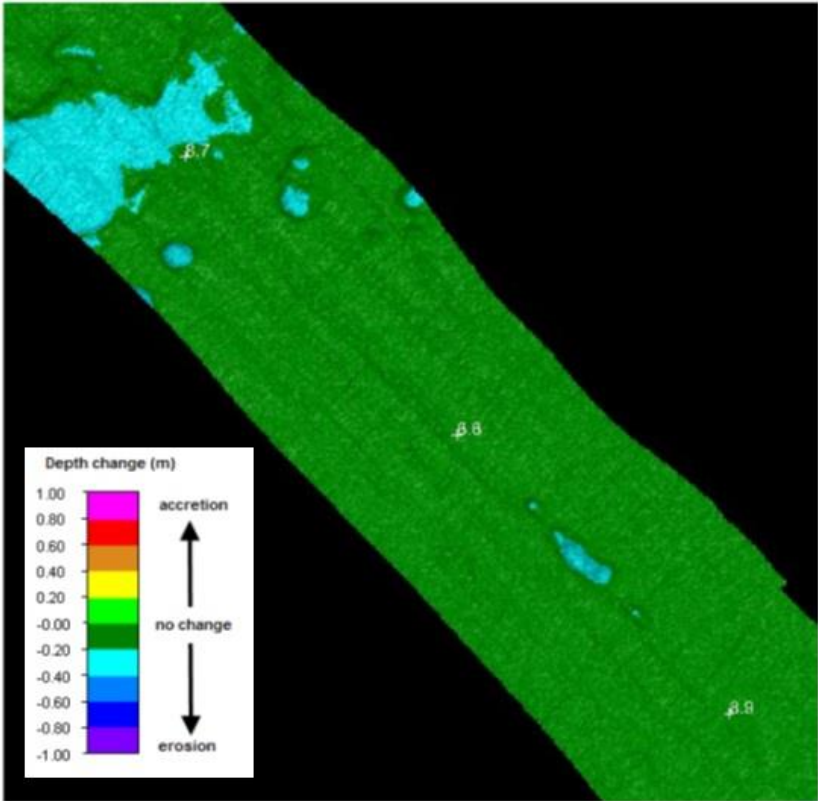


Figure 7 - Difference model comparing April 2014 with October 2013 data between kp8.7 and kp8.9 (PLA, 2014).

Wind turbine and inter-array cable scour

4.2.9. Figure 8 shows the export cable running north out of WTG F00. The cable appears to span across the ridges of the rock armouring and as the cable descends off the rock armouring. This is also seen at the southern side of F00 and at G00. There also appears to be a span where the bed has scoured around the cable, close alongside the rock armour. The extents of the cable exposures and spans (as they enter the monopile) are detailed in Table 9. There are similar scour features under the cables close alongside the rock armouring at the southern side of F00 and at G00. These smaller spans have not been detailed in in Table 9.

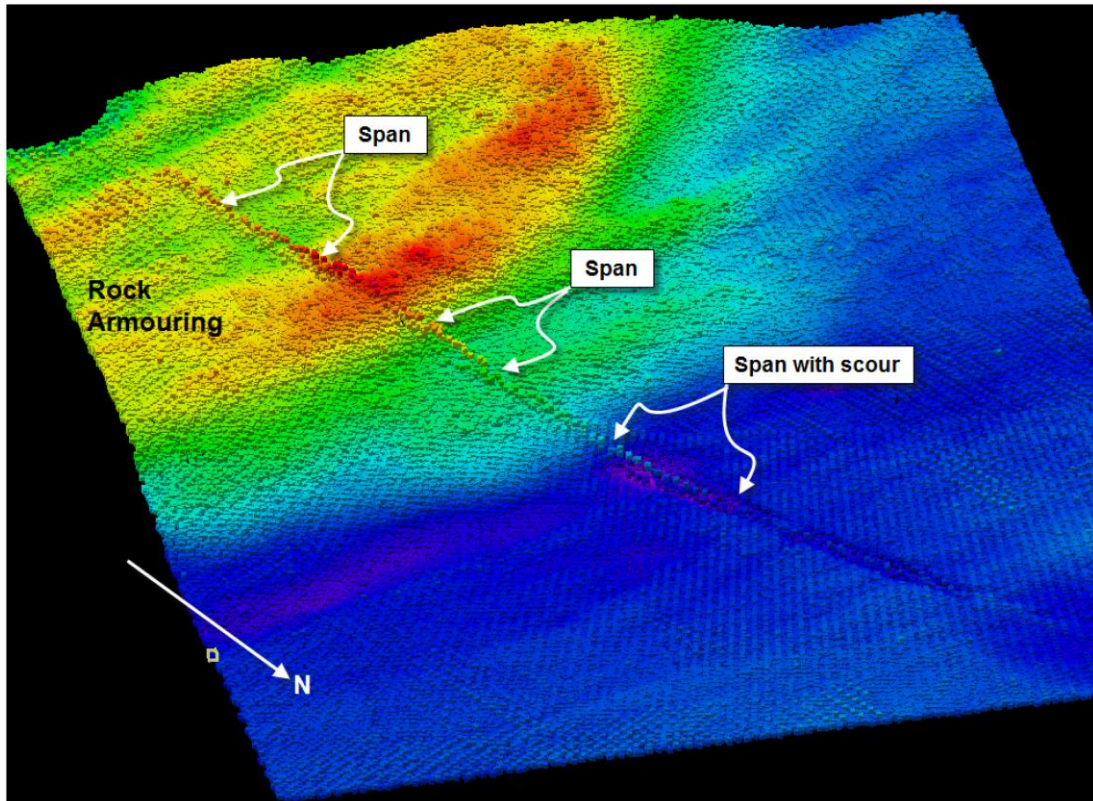


Figure 8 – Export cable span at WTG F00 (PLA, 2014).

Table 9 – Cable exposure and spans at the WTG foundations

WTG	Description	Start		End	
		Easting	Northing	Easting	Northing
F00	Cable exposure 1	375058.2	5730056.5	375077.7	5730029.2
F00	Cable span 1	375077.5	5730029.8	375079.7	5730025.7
F00	Cable span 2	357081.9	5730020.3	375084.4	5730017.4
F00	Cable exposure 2	375084.4	5730017.4	375122.2	5729985.0
G00	Cable exposure 3	375264.4	5729658.5	375272.9	5729643.4
G00	Cable span 3	375272.9	5729643.4	375276.2	5729637.4

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- 4.2.10. The exposed export cable and inter-array cable can be seen in Figure 9 to Figure 13. The extent of the exposed cables was to a maximum of 54m to the south of F00. There has been no change in the extent of the exposed cable since the previous survey in October 2013.
- 4.2.11. The occurrence of the cable span in the vicinity of the foundation is due to the need for the cables to surface close to the scour protection to enter onto the scour protection. As this cable span is intentional and occurred during the installation process, no remedial action is proposed.

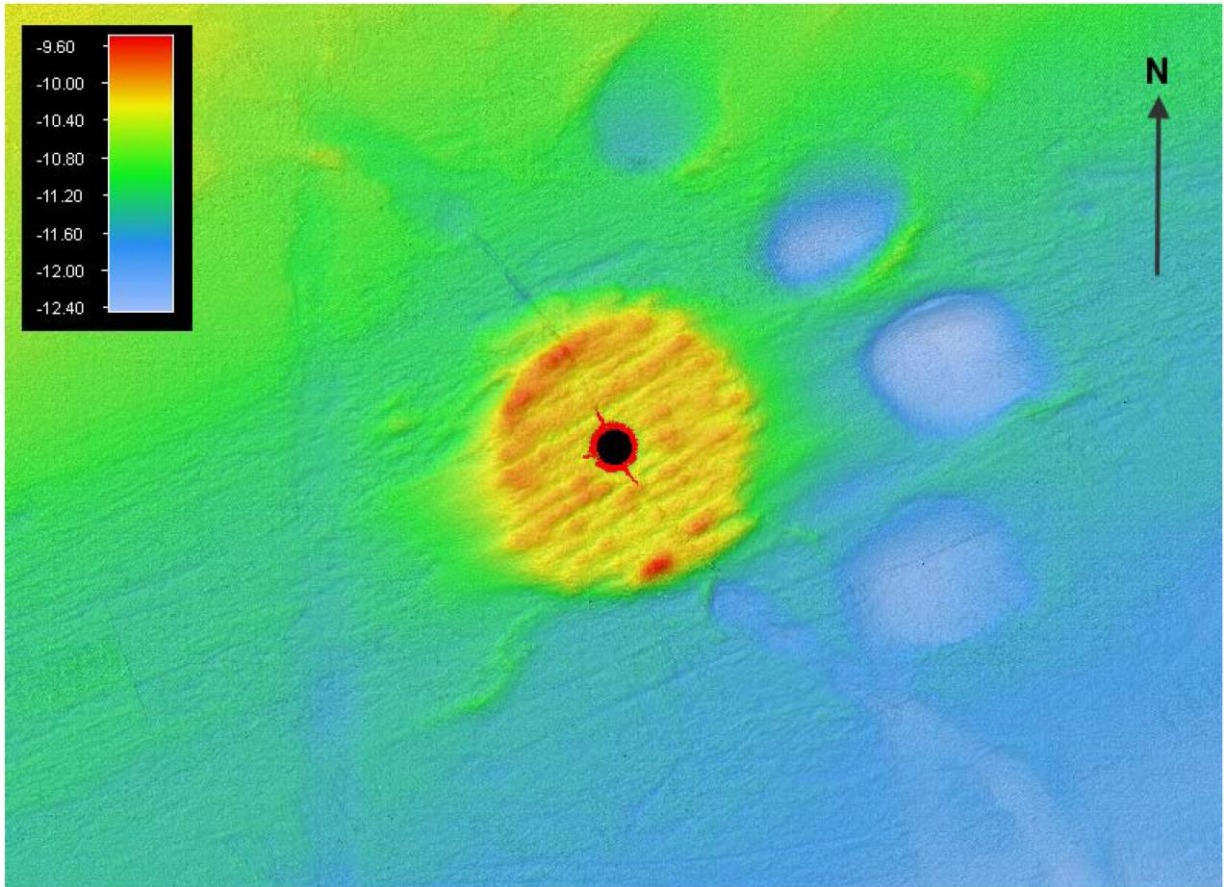


Figure 9 – Digital Terrain Model – WTG F00 (PLA, 2014).

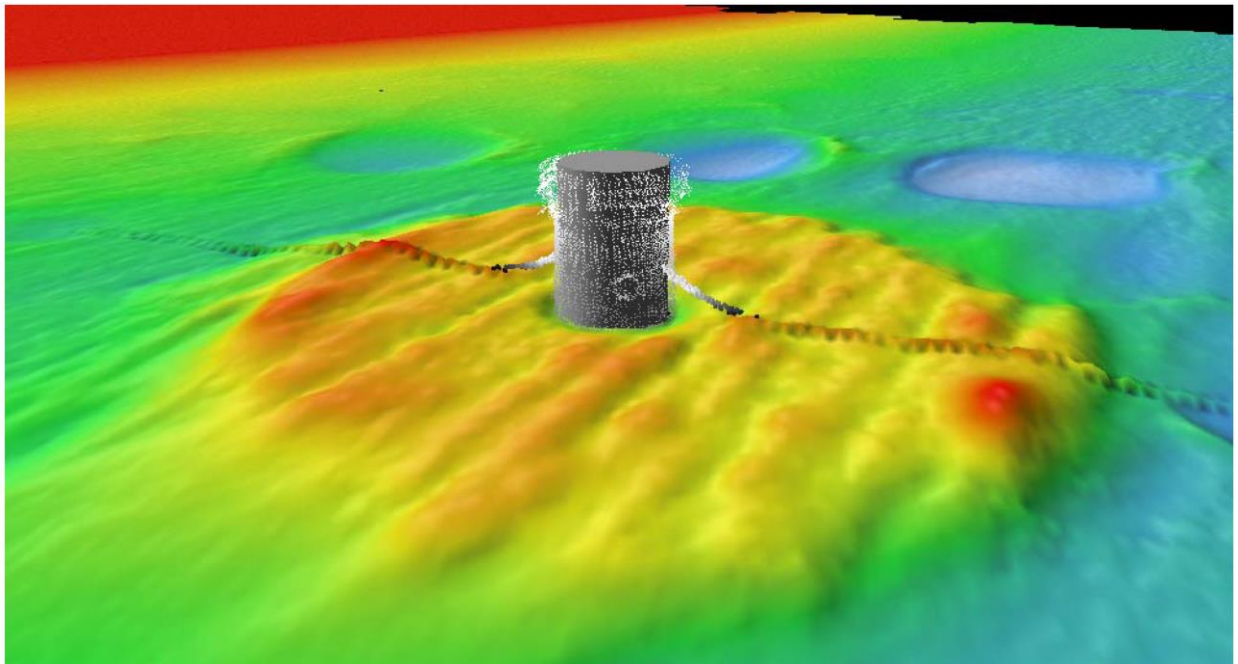


Figure 10 – Point Cloud – WTG F00 (PLA, 2014).

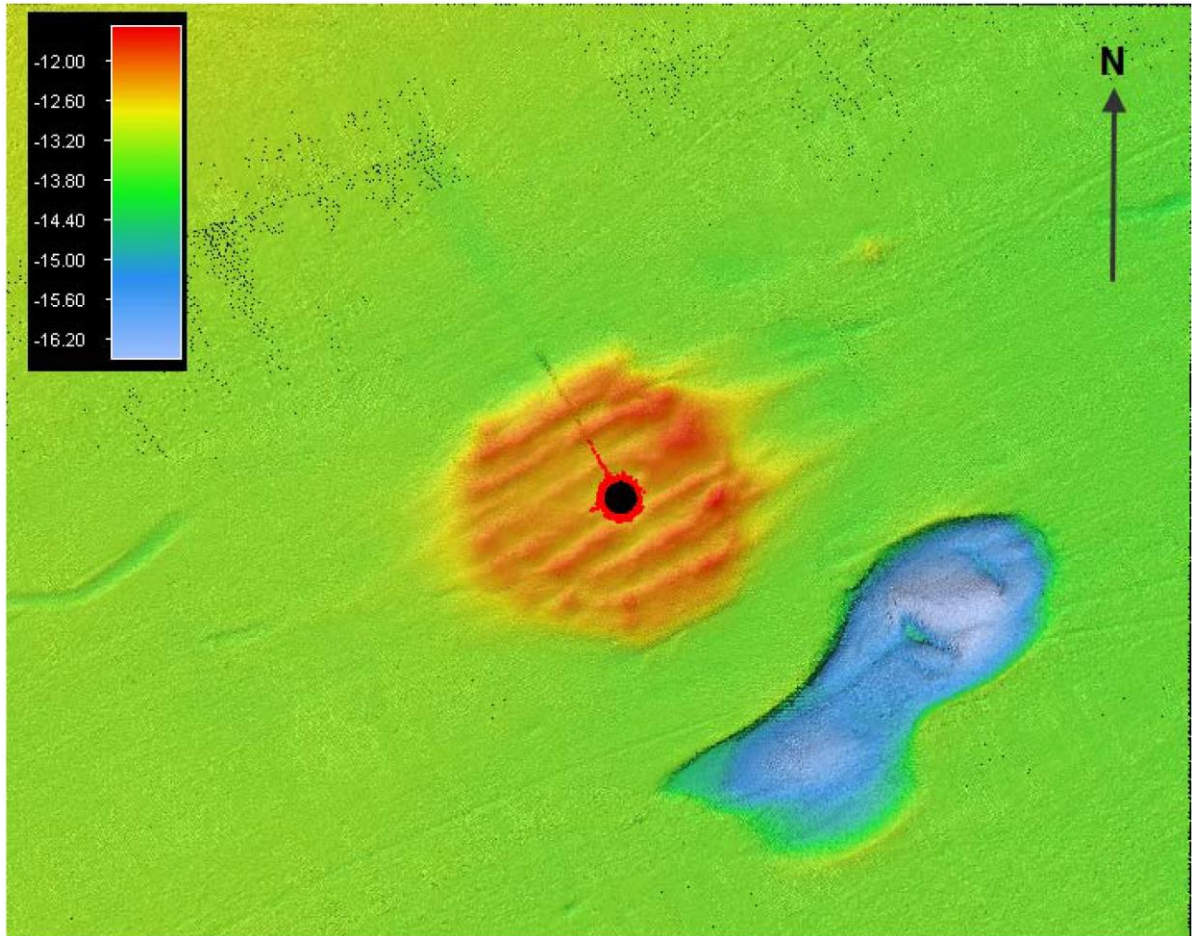


Figure 11 - Digital Terrain Model – WTG G00 (PLA, 2014).

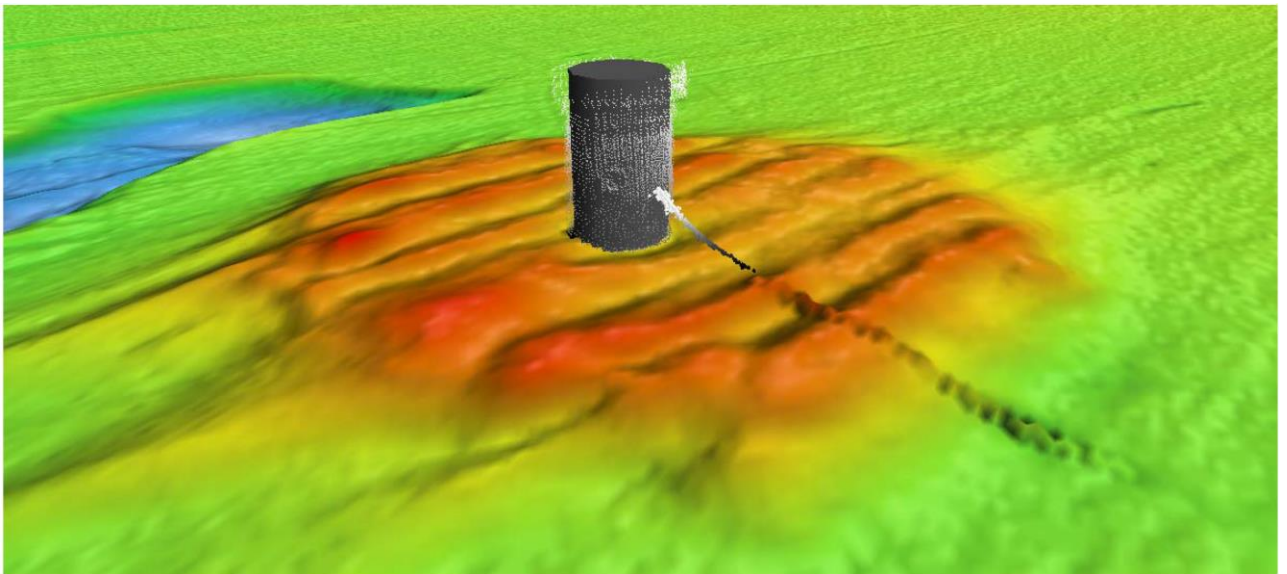


Figure 12 - Point Cloud – WTG G00 (PLA, 2014).

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- 4.2.12. From the difference model and the difference surface charts which both compare the data from April 2014 with data from October 2013 (Figure 13 - Figure 14), it can be seen that jack-up footprints seen in the previous data have continued to infill (seen as accretion).
- 4.2.13. The difference model also shows there has been up to 0.3m deepening 100-150m north of WTG F00 (Figure 13). There does not appear to be any change in depth over the rock armouring or around the exposed cables. Figure 14 shows no significant change in the vicinity of WTG G00.

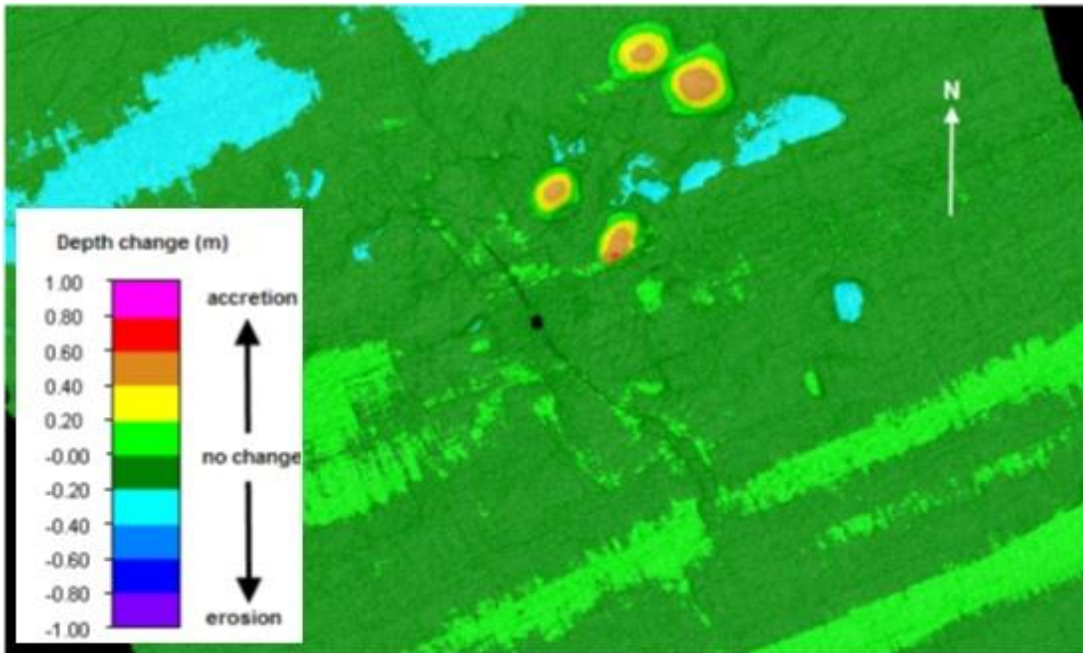


Figure 13 – WTG F00, Difference Model (April 2014 – October 2013) (PLA, 2014)

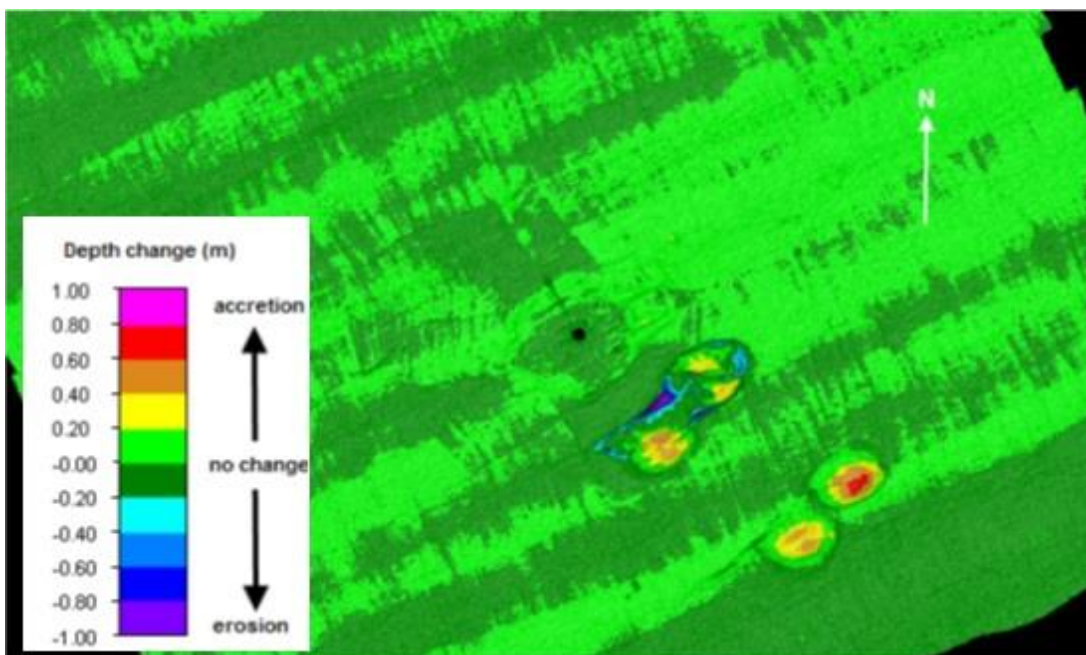


Figure 14 - WTG G00, Difference Model (April 2014 – October 2013) (PLA, 2014)

- 4.2.14. The cross-sections in Figure 16, Figure 17, Figure 19, and Figure 20 show profiles of the bed depth in the vicinity of the base of turbines F00 and G00. The cross-sections are cut at 45° intervals including along the expected scour direction. The cross section locations are shown in Figure 15 and Figure 18 below. It can be seen that there has been some erosion of the seabed over the wider area surrounding the scour protection (predominantly in the ENE-WSW direction). Since installation, there has been some build-up of material immediately adjacent to the scour protection.

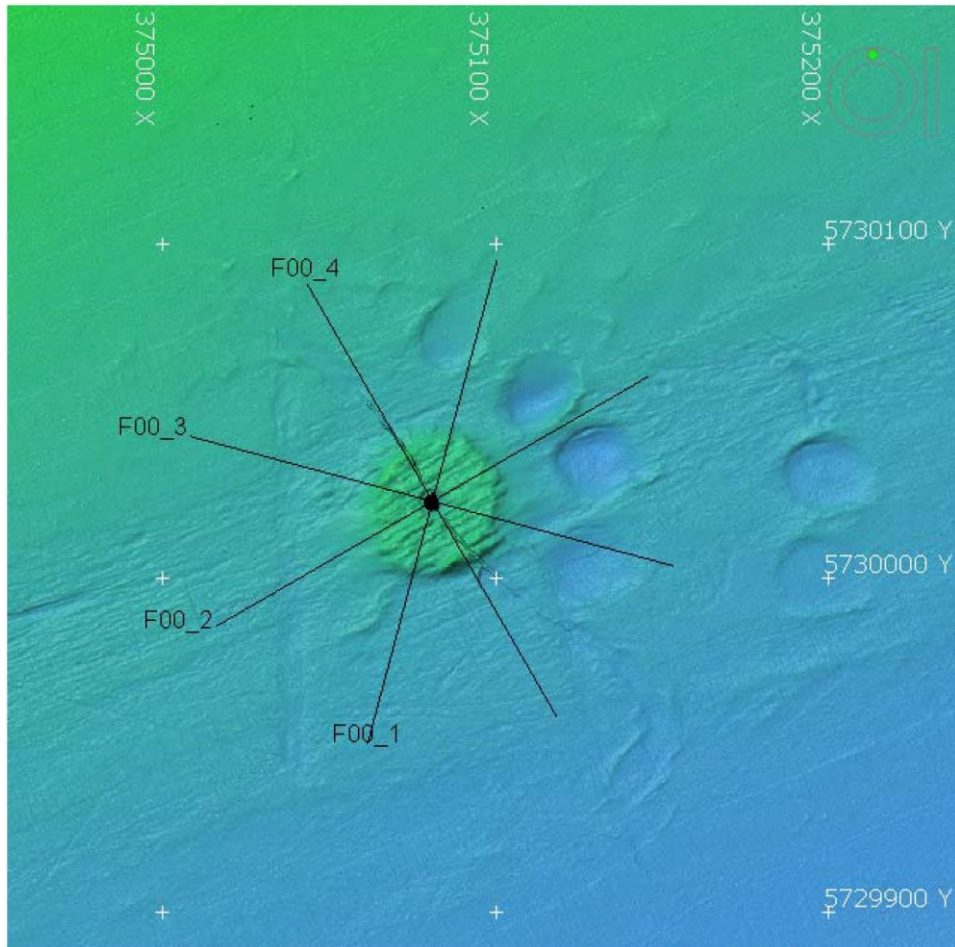


Figure 15 - Cross section locations at turbine F00 (PLA, 2014).

- 4.2.15. The rock armour around the WTG F00 remains stable. Cross-section F00_1 (Figure 16) shows some accretion in the footprint left by the jack-up rig. Cross-section F00_3 (Figure 17) shows up to 0.2m erosion to the northwest of the scour protection. These depressions occurred during construction, as shown by the green line which represents the first survey since construction, and the depressions have shown accretion since that time.

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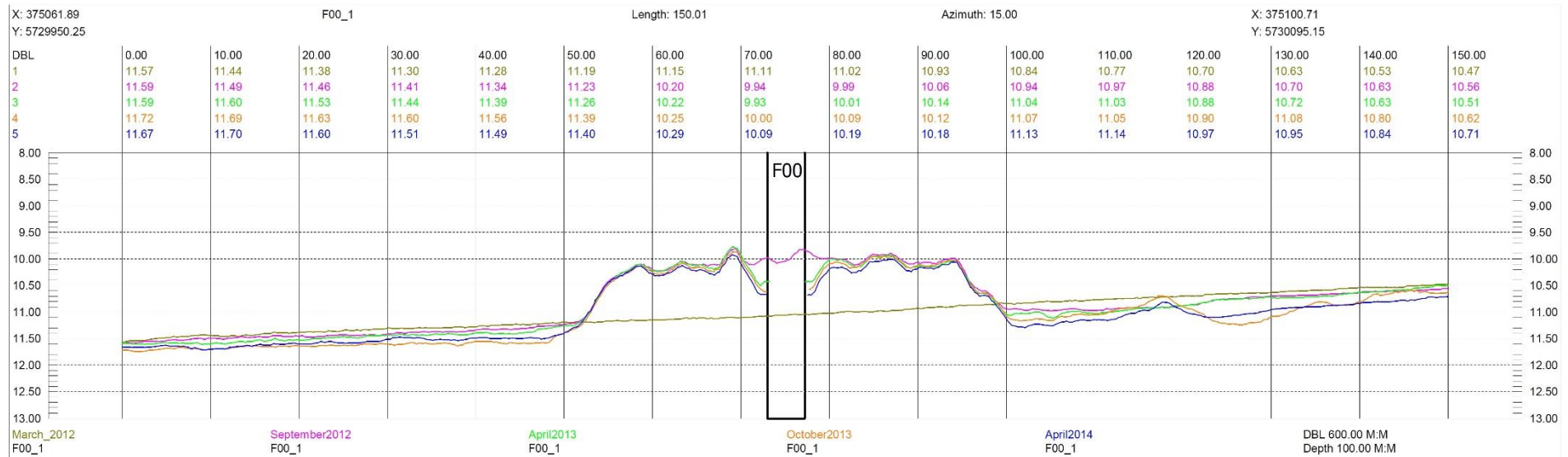


Figure 16 - Cross section at turbine F00: Position 1 (PLA, 2014).

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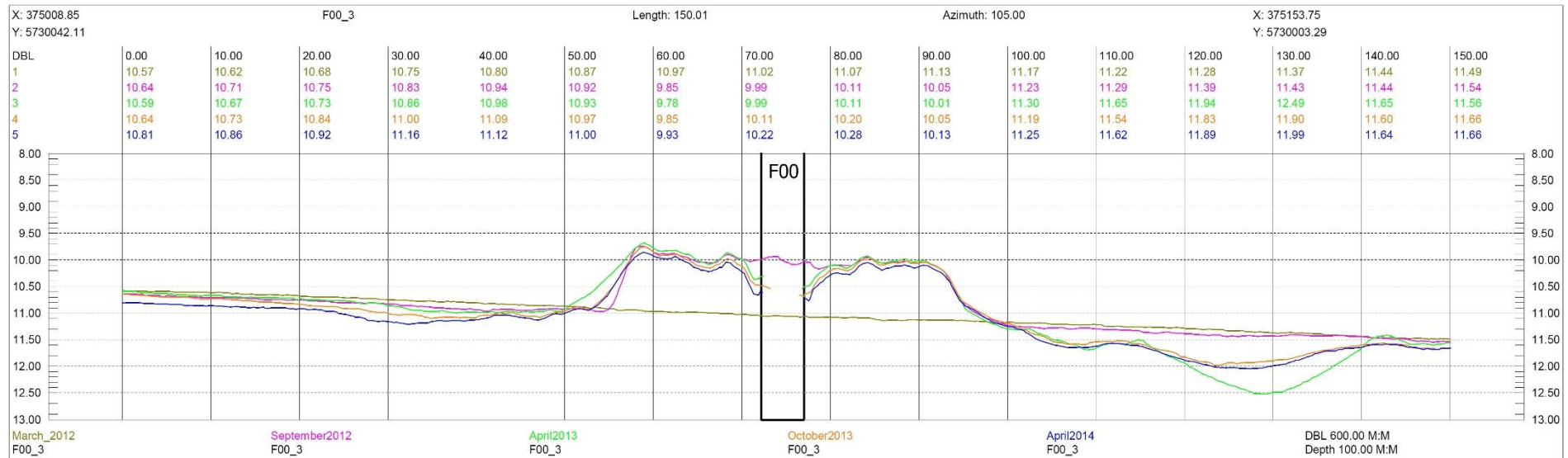


Figure 17 - Cross section at turbine F00: Position 3 (PLA, 2014).

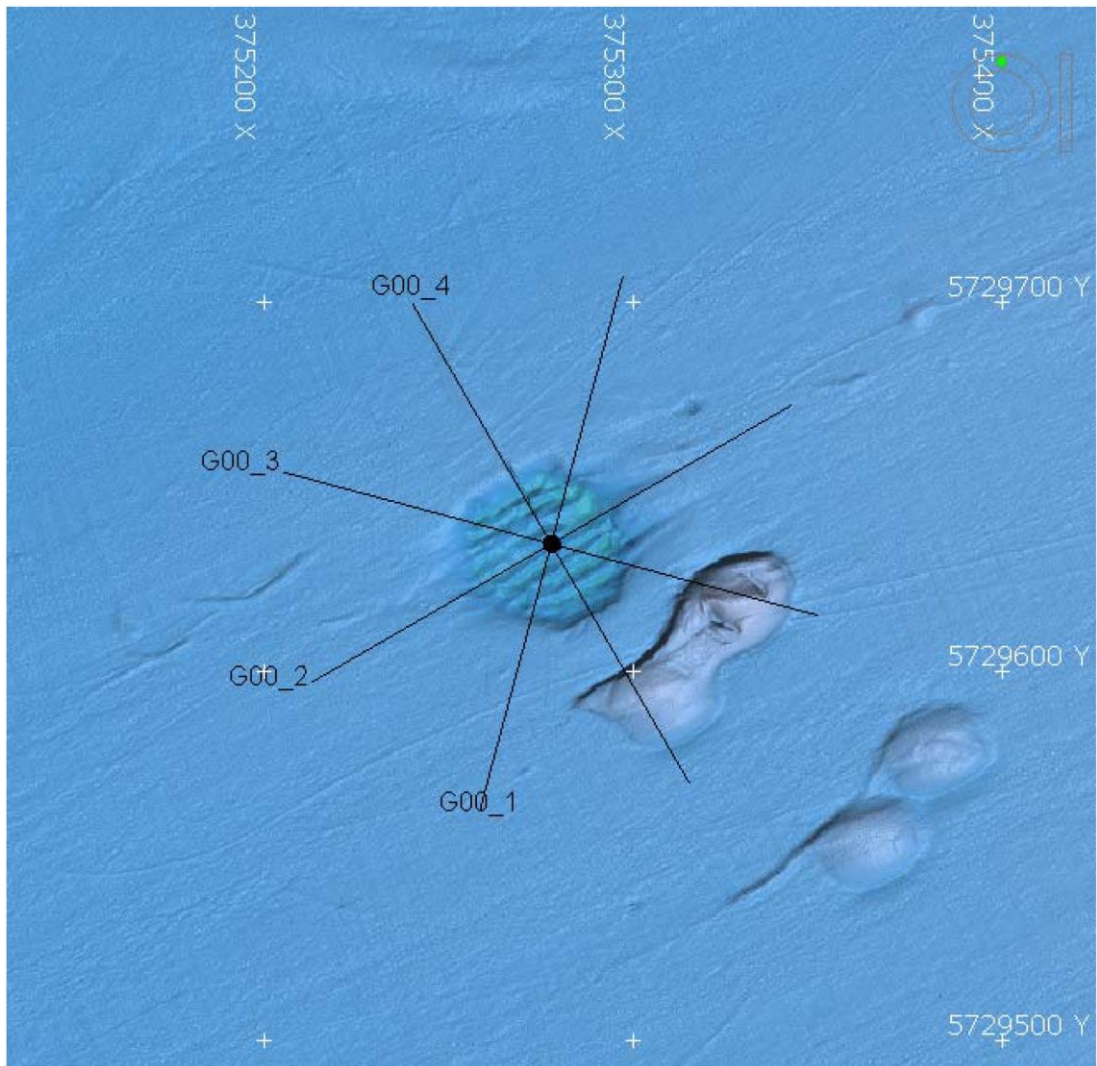


Figure 18 - Cross section at turbine G00 (PLA, 2014).

- 4.2.16. The cross-sections (Figure 19 and Figure 20) show that the rock armour is stable and there has been no significant change on the surrounding seabed since the previous survey October 2013.

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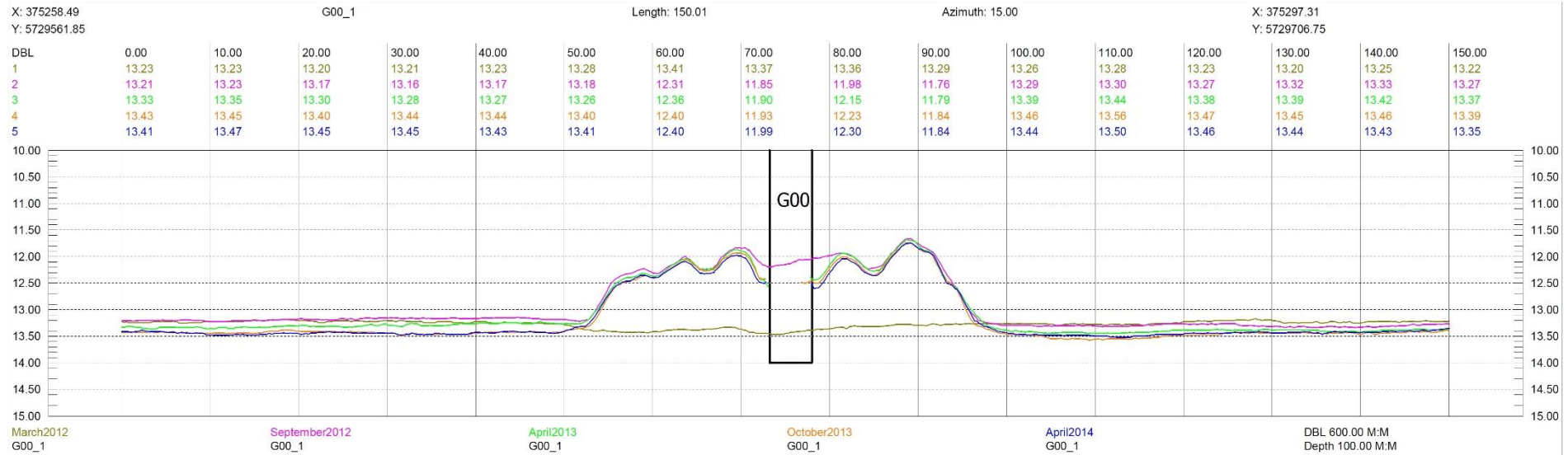


Figure 19 - Cross section at turbine G00: Position 1 (PLA, 2014).

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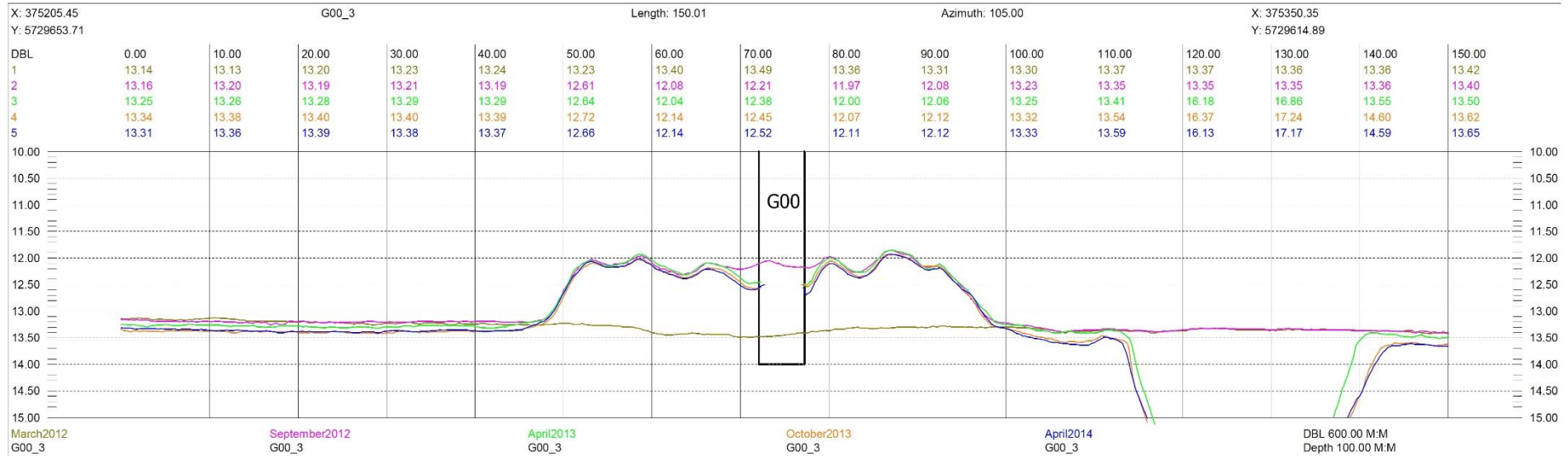


Figure 20 - Cross section at turbine G00: Position 3 (PLA, 2014).

Conclusions

- 4.2.17. Scour effects are a normal response to the placement of structures in an area subject to tidal currents and/or wave action and where the seabed is composed of fine sediment, as is the case at GFS3.
- 4.2.18. Scour was predicted in the ES prepared for GFS3. The GFS3 ES predicted the depth of scour to be between 10.35m and 13.8m, with scour extents within 69m of the monopile, in the absence of any scour protection. Scour protection has been placed around the turbine foundations to mitigate the risk of scour occurring. There has been some identified scour/erosion of the bed of up to 0.2m to the north of WTG F00. The rock armouring and surrounding bed elsewhere remains stable compared to the October 2013 survey. In the case of turbine F00, some accretion in the footprint left by the jack-up rig has been observed.
- 4.2.19. There has been some erosion on both the northern and southern edges of the Gunfleet sandbank. The track of the cable route has experienced greater erosion than the surrounding bed. Away from the WTGs, no other cable exposures were seen in the data. The exposed export cable and inter-array cable were also seen in the data. There has been no change in the extent of the exposed cable compared to the previous survey in October 2013.
- 4.2.20. Comparing the results of the bathymetric surveys over the pre- and post-construction survey periods suggests that no major changes to bathymetry and scour effects have occurred across the wider GFS3 site.
- 4.2.21. Further post-construction scour surveys at the GFS turbines and along the export cable route, in line with the requirements of the Marine Licence, will act as a check on the stability of the scour and the development of scour wake effects.

4.3. Benthic surveys

Summary of Licence Conditions & Proposed Approach

- 4.3.1. Conditions relating to monitoring of the benthic ecology are set out in the Marine Licence for GFS3. The specific Marine Licence conditions are set out in Table 5 of this document.
- 4.3.2. The Environmental Monitoring Plan (NIRAS, 2014) states that post-construction benthic surveys along the cable route for a period of three years following the completion of the works. The frequency of the post construction monitoring will be reviewed in discussion with the Licensing Authority at the end of the first year of monitoring.

Monitoring Methods

- 4.3.3. Full details of the methods used to monitor the benthic ecology at GFS3 post-construction are given in the Year 1 post construction benthic monitoring report (Natural Power, 2013 – Appendix E), with a summary provided here. The survey was undertaken in response to the Marine Licence conditions highlighted above, in particular that benthic sampling should be undertaken in order to investigate possible changes in marine benthic communities along the export cable route.
- 4.3.4. A drop down video (DDV) and benthic grab survey was carried out over a 3 day period in July 2013. A total of 20 sampling stations were identified and sampled for monitoring purposes: 15 along the export cable route and five reference sites. These sampling stations incorporated the 15 pre-construction survey sites sampled in 2011 for the GFS3 characterisation study and an additional five stations sampled as part of the monitoring programme at GFS 1 and 2. Sampling sites are shown in Figure 21.
- 4.3.5. The DDV camera was hand-hauled and incorporated a Sony bullet camera that provided live viewing capabilities via an umbilical tethered to the haul line and a high definition digital camera. The camera system also had two video flood lights and a laser visual scale system. In accordance with the EMP three still images were randomly selected along each transect from the high definition digital camera transects for subsequent analysis. Full video tows were also observed as the moving video image is useful to aid identification and provide additional information on the three dimensional structure of biota.
- 4.3.6. Day grab samples were collected in accordance with the most recent and relevant advice relating to benthic seabed monitoring (Ware & Kenny, 2011) and Natural Power's standard operating procedures. Once the sample was deemed adequate a sub-sample of approximately 500 ml volume was taken for Particle Size Analysis (PSA) and total organic carbon (TOC) measurements. The sample was then passed through a 1 mm sieve to remove the finer fractions of the sediment. The sediment and fauna collected on the sieve was then placed in a labelled sample pot and fixed for processing in the laboratory.
- 4.3.7. Where possible, all macrofauna were identified to species level and enumerated, with a variety of univariate and multivariate statistics used to investigate the results.
- 4.3.8. Full details of the equipment and methodology used are provided in the survey reports (Natural Power, 2013).

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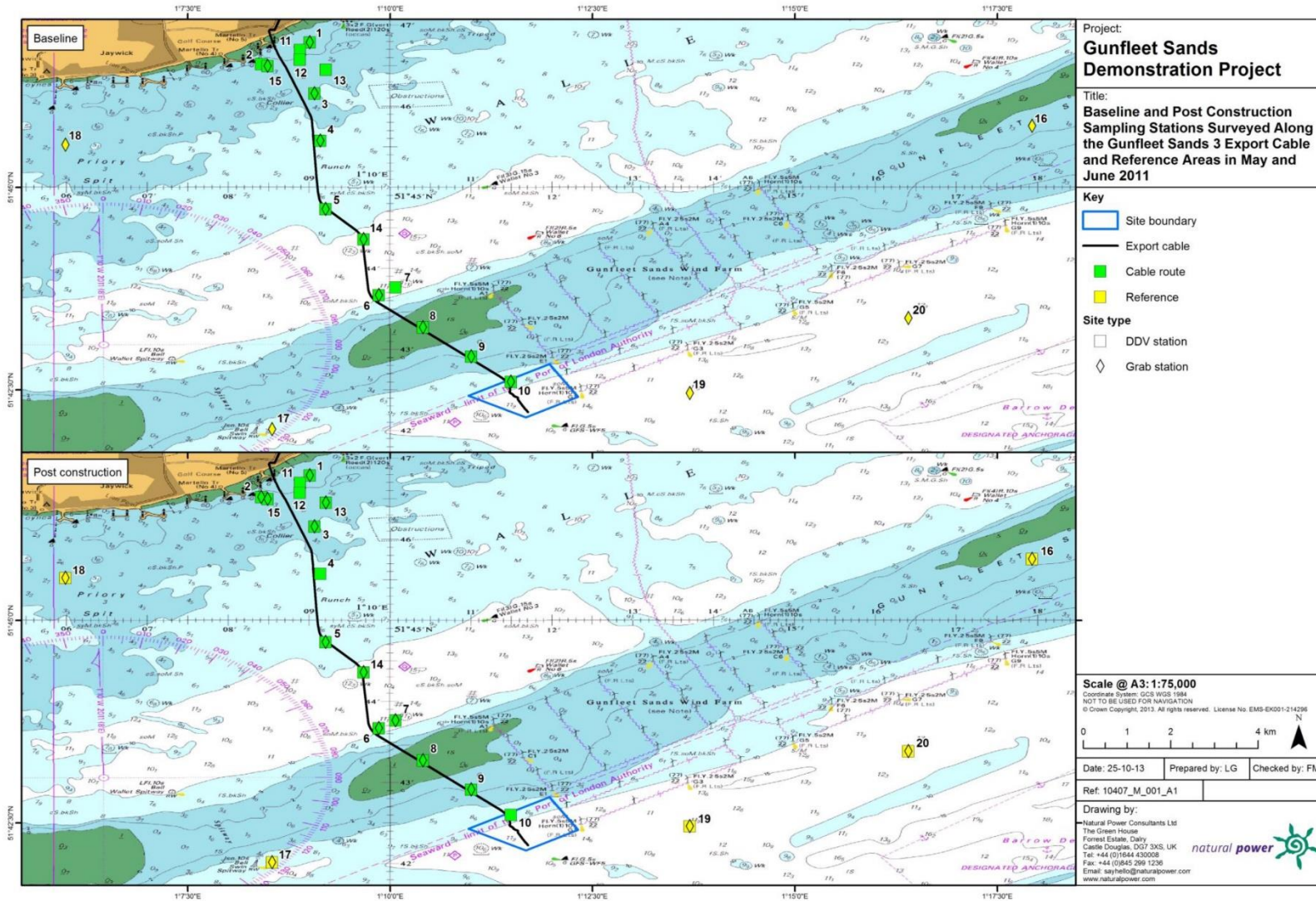


Figure 21 - Baseline and post-construction Year 1 sampling stations along the GFS3 export cable (Natural Power, 2013).

Results

- 4.3.9. Surveys were carried out between 15th and 18th of July 2013 using the Arie Dirk. The DDV survey was completed on the 15th and 16th of July 2013 and the grab survey was completed on the 17th and 18th of July 2013.

DDV surveys

- 4.3.10. Initial observations of the video clips showed that the key substrate in this area is mud. At a few sites some pebbles and gravel also featured but this was minimal. There were no distinctive sediment features observed throughout the video survey. The biota present appeared characteristic of shallow water mud, including polychaetes, *Macoma* spp., *Ophiura albida*. In total 20 taxa were observed during the DDV survey, 14 of which were identified to genus or species level.
- 4.3.11. Based on DDV surveys, two biotopes were assigned along the cable route during the post construction survey. The two level 2 biotopes assigned were *Sublittoral cohesive mud and sandy mud communities* (SS.SMu) and *Sublittoral sands and muddy sands* (SS.SSa).
- 4.3.12. Biotopes assigned from the DDV data during the year 1 post construction survey and the baseline cable route survey were found to be slightly different, with the two biotopes assigned along the cable route in the baseline survey comprising *Infralittoral mobile clean sand with sparse fauna* (SS.SSa.IFiSa.IMoSa), and *Flustra foliacea and Hydrallmania falcata on tide-swept circalittoral mixed sediment* (SS.SMx.CMx.FluHyd).
- 4.3.13. During the baseline surveys areas of *Sabellaria spinulosa* crust were observed along the cable route. None of the areas of *Sabellaria spinulosa* observed were topographically distinct from the surrounding substrate or extensively distributed and therefore are not judged to represent areas of Annex I habitat as outlined within Gubbay (2007). In the post construction DDV survey no *Sabellaria spinulosa* colonies or individuals were observed.

Benthic grab surveys

- 4.3.14. Between the baseline and post construction surveys there has been marked increase in the number of individuals (N) recorded at each station (Figure 23), with increases in the number of individuals at stations across the entire survey area including reference stations. The number of species (S) (Figure 24) and the species richness (d) have also increased between the baseline and post construction periods for both the reference sampling stations and the cable route sampling stations.
- 4.3.15. The increases in the indices relating to the number of individuals (N) and species (S & d) were found to be statistically significant between baseline and post construction surveys. No significant differences were found between treatment areas during these sampling occasions, with the exception of species richness which was consistently higher at the cable route stations compared to the reference stations (Figure 22). As the increase in species richness was seen at both the cable route and reference stations alike, with richness being found to be consistently higher in the cable route stations in both the baseline and post-construction surveys, it can be assumed that there has been no change from baseline species richness at either treatment areas.
- 4.3.16. The Shannon-Weiner (H') diversity index was calculated to provide an indication of the diversity recorded at each station. Although there were increases in Shannon diversity (H') over time, these differences were not found to be significant. There was however a significant difference found between treatment areas.

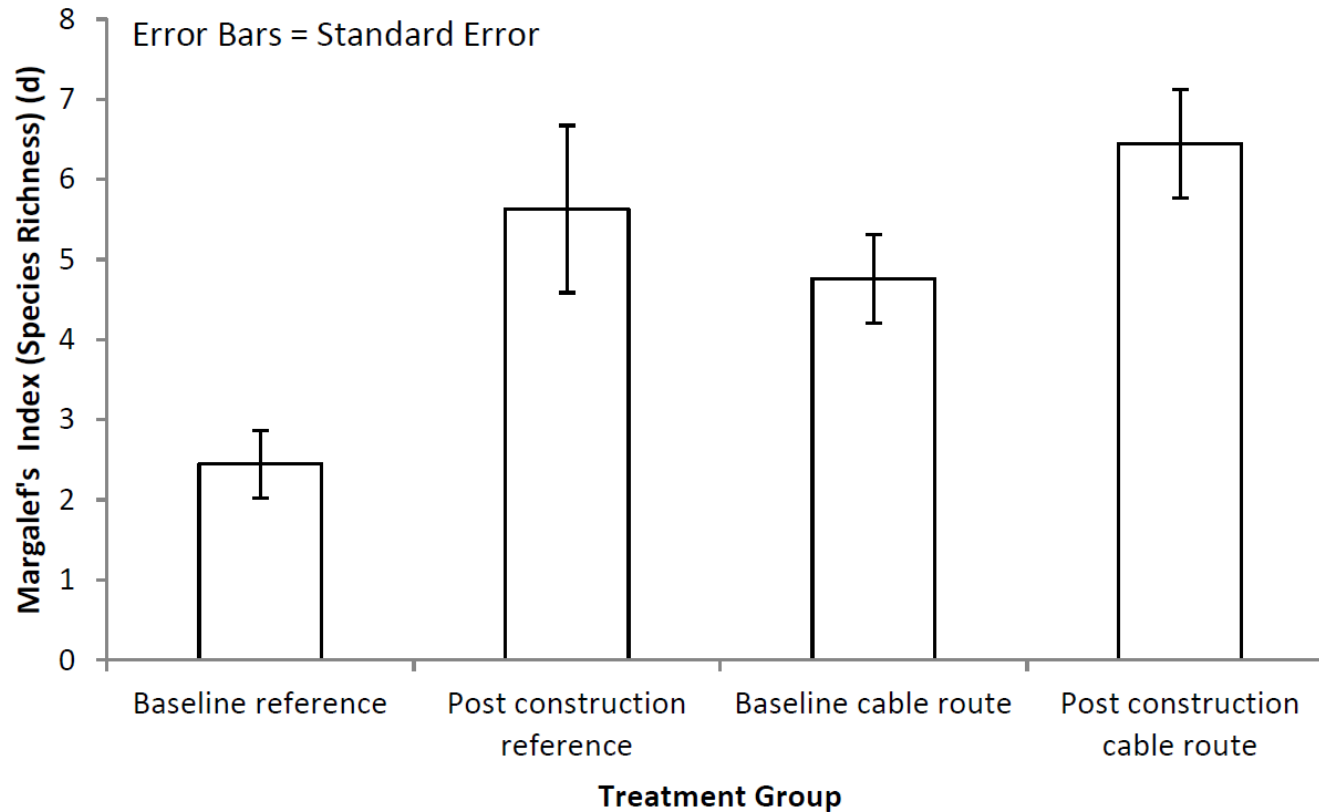


Figure 22 - Mean Species Richness (per grab) per location (cable route or reference station) and sampling occasion (baseline and post construction) (Natural Power, 2013).

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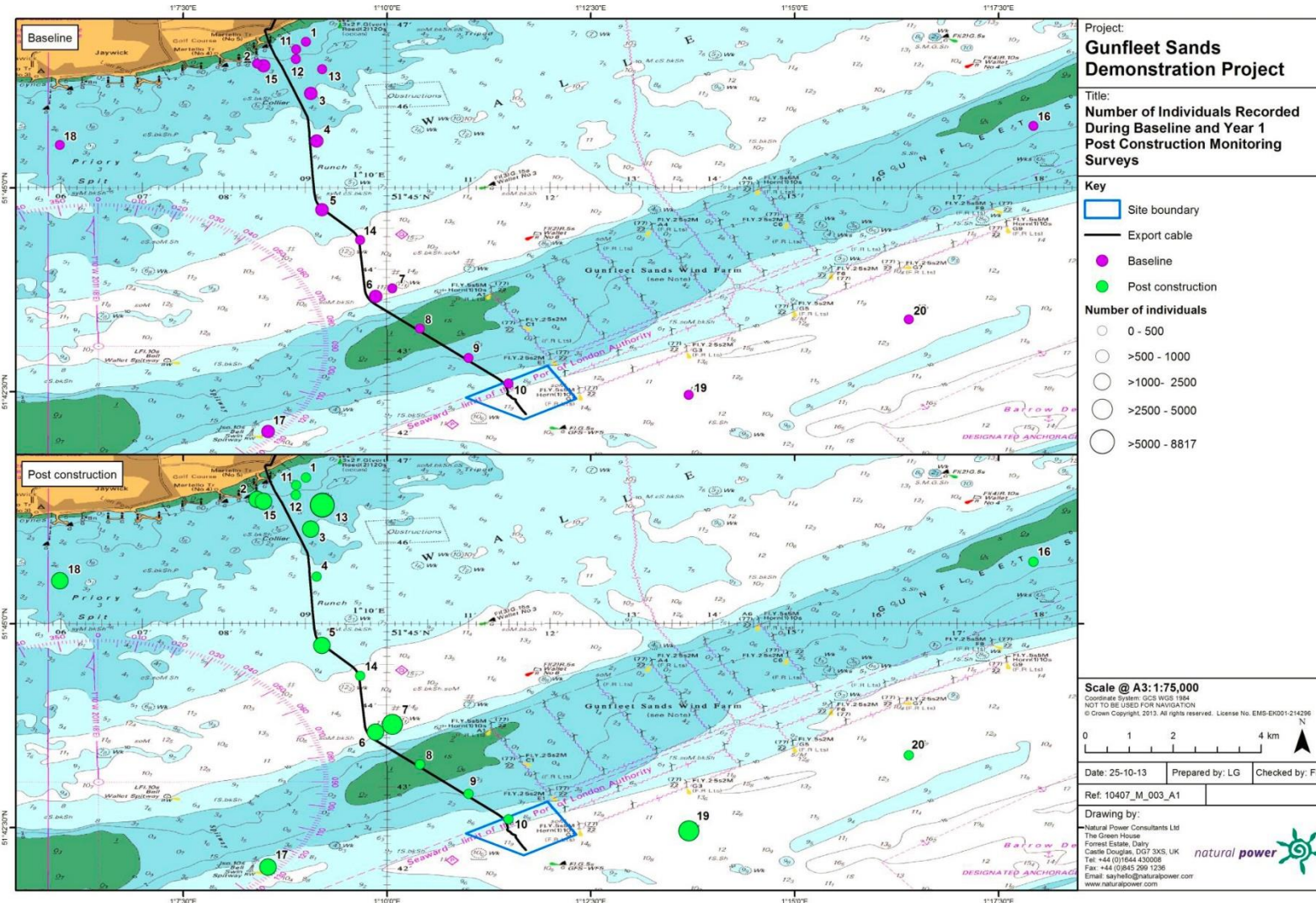


Figure 23 - Total number of individuals recorded at each station during the baseline and post-construction surveys (Natural Power, 2013).

Gunfleet Sands 3 Demonstration Project

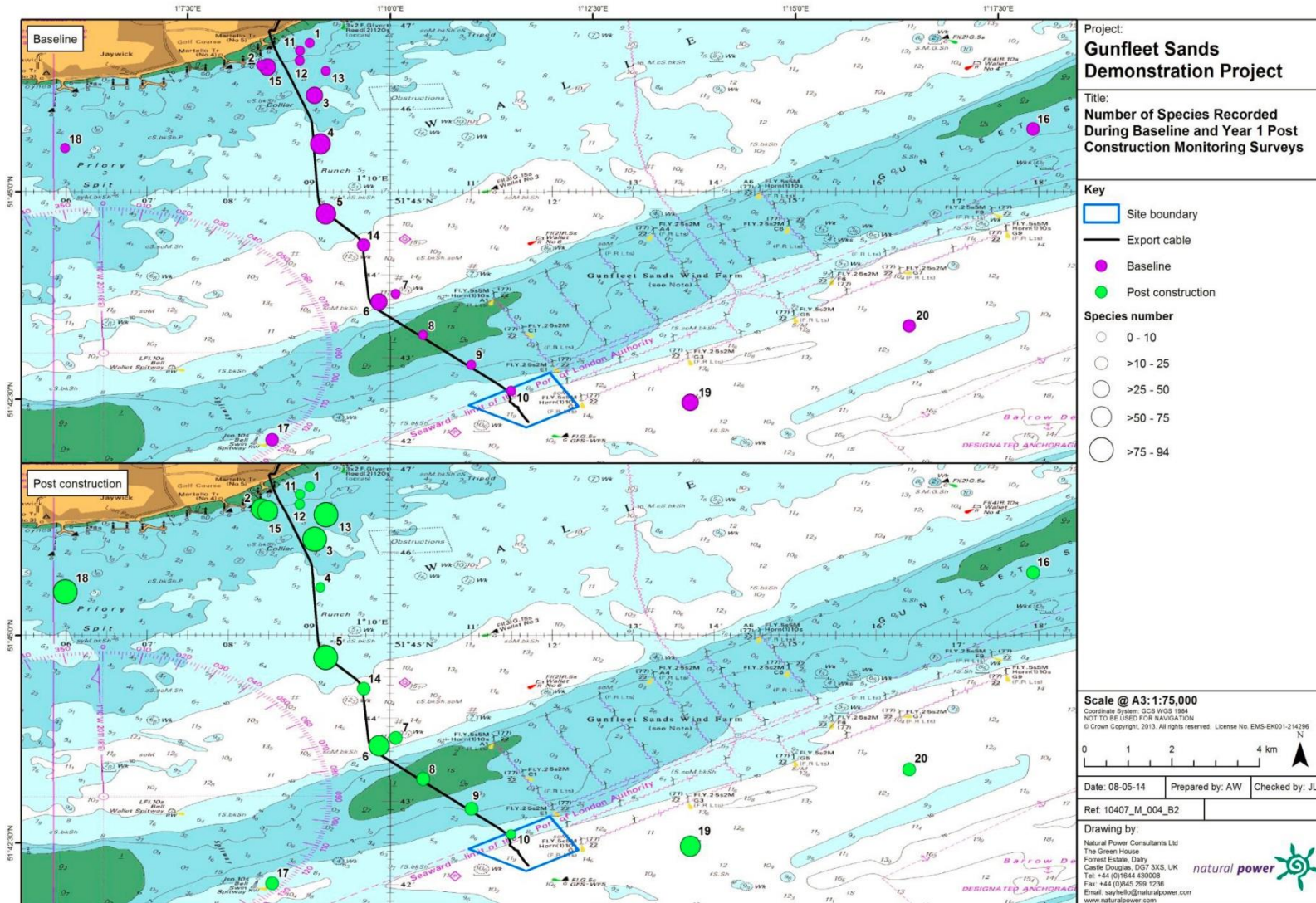


Figure 24 - Number of species per sampling station recorded at each station during the baseline and post-construction surveys (Natural Power, 2013).

- 4.3.17. Pielou's Evenness (J') was slightly lower during the post construction surveys compared to baseline. This difference was found to be significant although no significant differences were identified between treatment areas i.e. reference and cable route sampling stations. Evenness has declined, indicating that the assemblages sampled may have become represented by more individuals of fewer species (i.e. dominant species) in some of the samples. This slight decrease in evenness can be attributed to the increase in species richness between baseline and post-construction surveys (see Figure 22 and paragraph 4.3.15) with diversity remaining broadly similar over time.
- 4.3.18. The dendrogram produced using the CLUSTER process (Figure 25) illustrates clear patterns with regards to the level of similarity between replicates. Some similarities are seen between the sampling stations. At around 50% similarity the majority of these replicates split and are separated into baseline and post construction groups. However, there are still some cable route replicates that do not fall into this grouping. Half of the replicates exhibit a low level of similarity and are grouped towards the right half of the dendrogram.
- 4.3.19. Similar to the dendrogram, the ordination plot shows the majority of replicates to be clustered together in a two dimensional plot (Figure 26). There is some clear separation of sampling stations, however, the distribution of sampling station sampled during baseline and post construction exhibit a similar distribution in multivariate space following an arc with the baseline replicates orientated closer towards the top of the plot. Nonetheless, there still remains a degree of overlap between stations from the two sample periods. The stress value is relatively low indicating that the ordination of data points in two dimensional space is likely to be a good representation of the differences in species composition recorded at each station.
- 4.3.20. Similarity Percentage (SIMPER) outputs revealed the top five species contributing to dissimilarity between each pairwise comparison resulting in a significant difference. *Abra alba*, *Nucula nucleus*, *Nucula nitidosa* and *Ensis* juveniles are consistently in the top five species, and in many cases are the top three species contributing to dissimilarity between all pairwise comparisons.
- 4.3.21. A one-way Analysis of Similarity (ANOSIM) was used to determine any changes that have occurred between PSA data collected along the cable route and reference locations before and after construction. The ANOSIM test produced a low Global R-value and a p-value greater than the critical value (ANOSIM, $R=0.038$, $p = 0.255$). It is therefore concluded that there has been no change in PSA between any treatment groups.
- 4.3.22. A principal components analysis (PCA) was undertaken on average values to visualise the distribution of sampling stations in relation to the environmental variables (Figure 27). The majority of sampling stations ordinate towards the right side of the PCA plot. The environmental variable associated with this distribution are the two particle size groups associated with very fine sand (63 to 125 μm) and fine sand (125 to 250 μm) and to a lesser extent silt (less than 63 μm) and medium sand (250 to 500 μm). Both the cable route and the reference stations show the shift to smaller particle sizes in comparison to the pre-construction sampling.

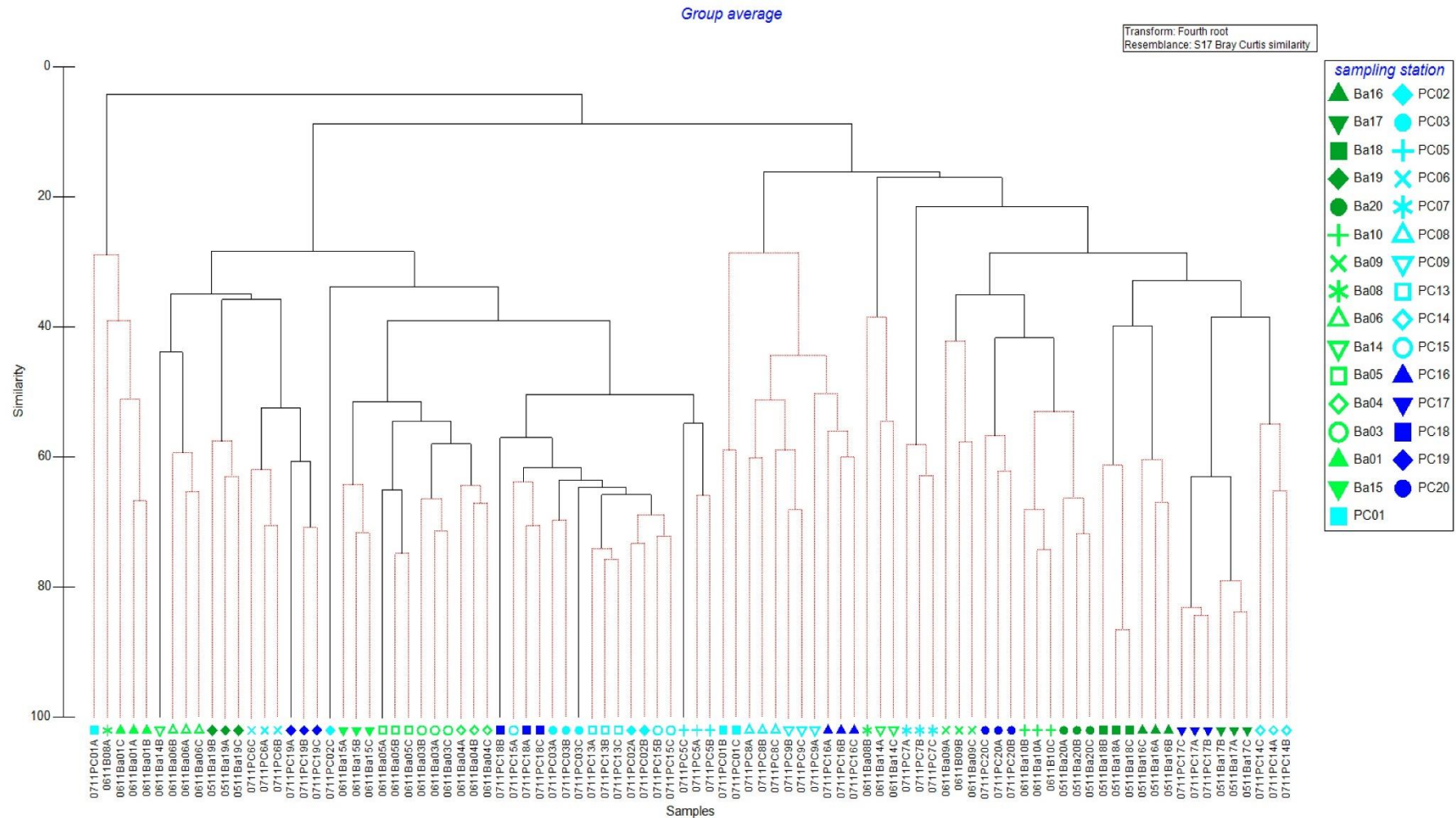


Figure 25 - Baseline and post-construction benthic survey cluster dendrogram (all replicates). Green = baseline, Blue = post construction (dark = reference and light = cable route sites) (Natural Power, 2013).

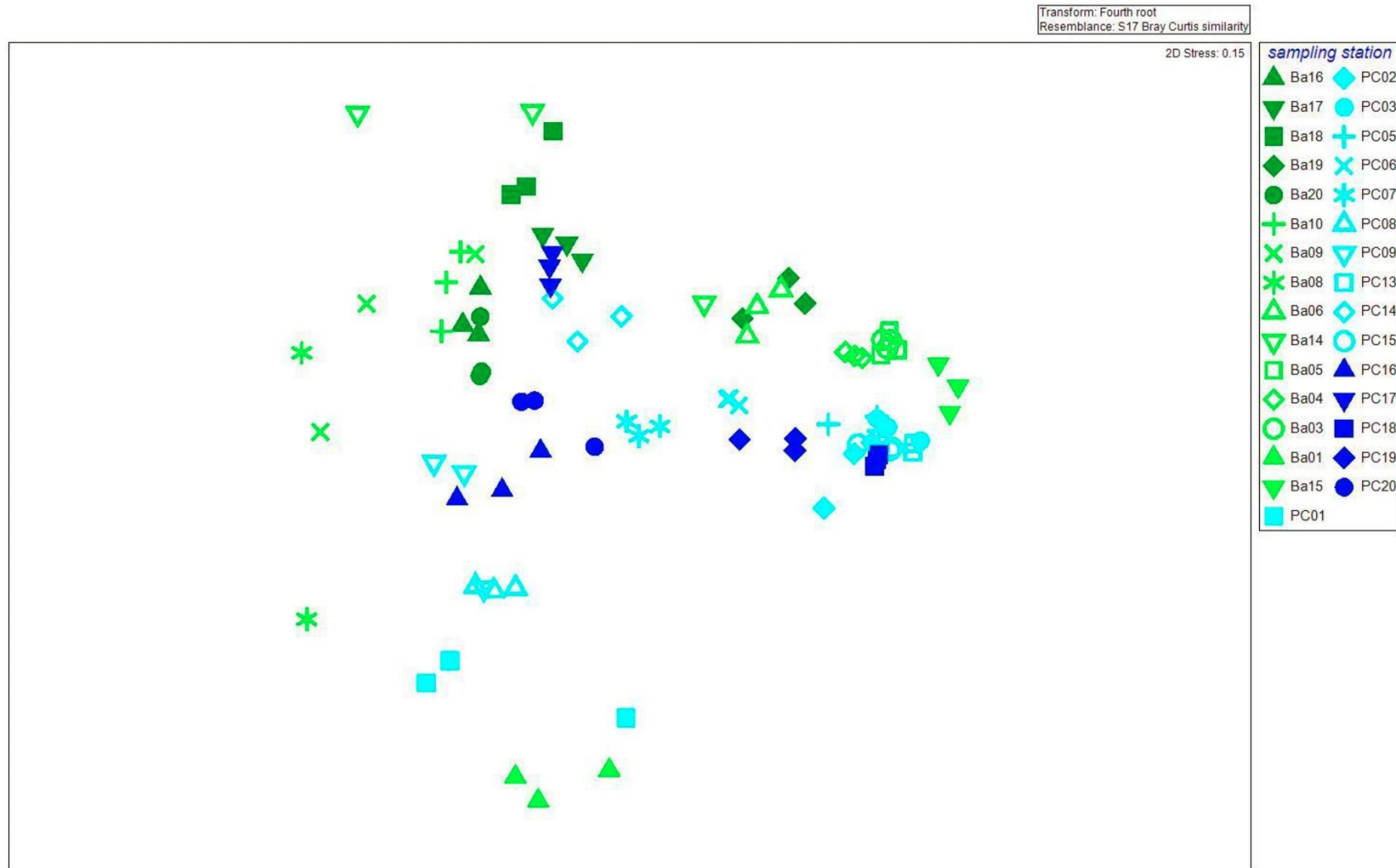


Figure 26 - Baseline and post-construction benthic survey Multidimensional Scaling (MDS) ordination plot (all replicates). Green = baseline, Blue = post construction (dark = reference and light = cable route sites) (Natural Power, 2013).

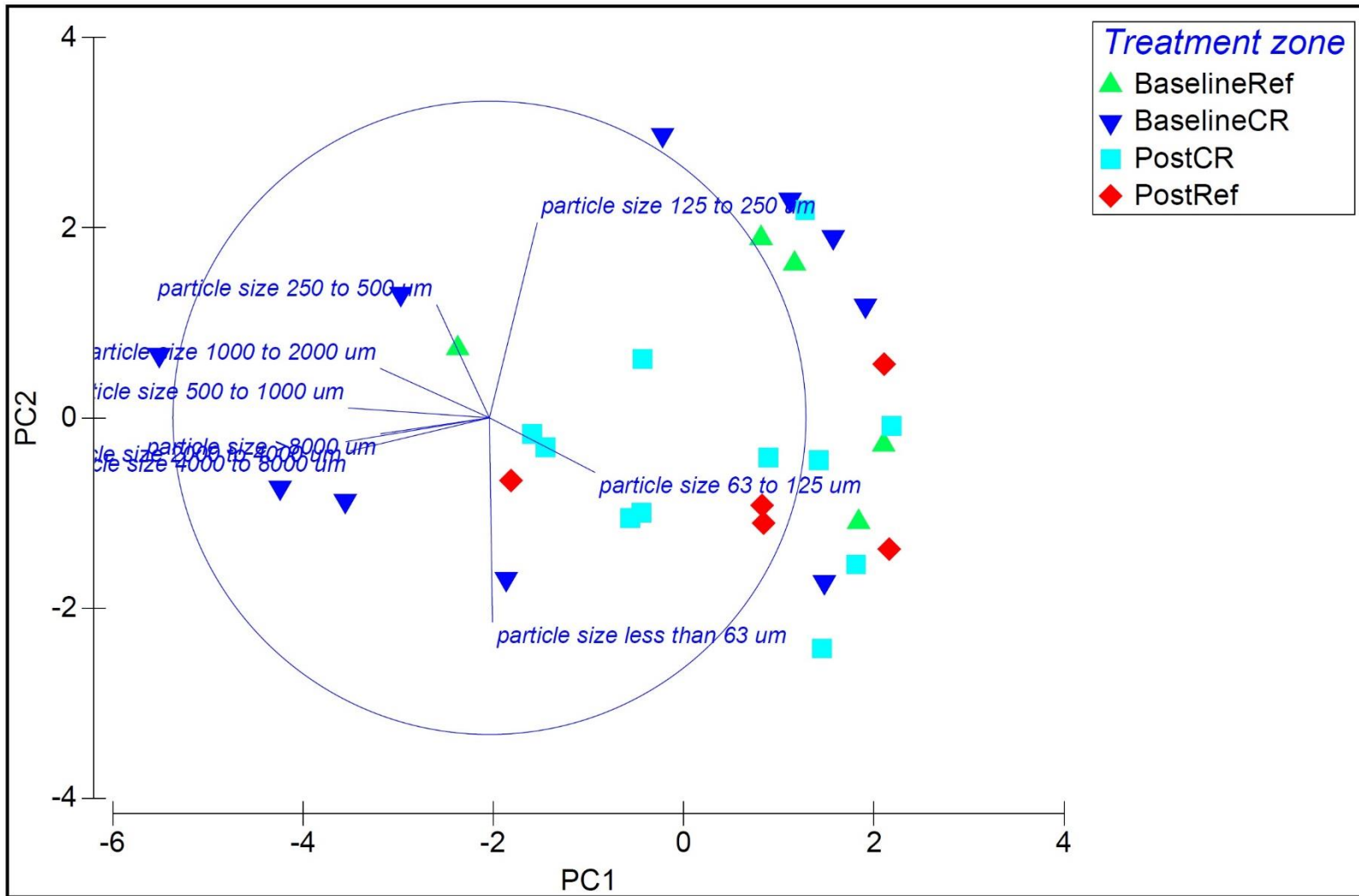


Figure 27 - Grouping of stations sampled during each treatment group from Principal Components Analysis. The environmental variables comprise of the Wentworth scale PSA groupings (Natural Power, 2013).

- 4.3.23. Similarity Profile tests (SIMPROF) identified 13 significantly different groups with a probability ≤ 0.05 and five stations were also identified as distinct from the groupings. Using these groupings to assign factors SIMPER identified the key species within each grouping. The SIMPROF groupings observed at the $p < 0.05$ level mostly pertain to groupings within sample station replication. By adding a similarity line on the graph at 50% and using lower level groupings, clusters were apparent. In order to allow these patterns to be seen more clearly the averages of these are presented in Figure 28, where four clusters can be seen.
- 4.3.24. The characteristic of these groups is described below. In order to provide interpretation of the infaunal assemblages into mappable units, biotopes were assigned based on the best fit biotopes listed in the MNCR review (Connor *et al.*, 2004). Biotopes were assigned using infaunal data supplemented with DDV data.
- 4.3.25. The stations were broadly similar between the baseline and post construction surveys. The biotopes *Infralittoral mobile clean sand with sparse fauna* (SS.SSa.IFiSa.IMoSa), *Sabellaria spinulosa* and *Polydora spp. on stable circalittoral mixed sediment* (SS.SBR.PoR.SspiMx) and *Abra alba* and *Nucula nitidosa* in circalittoral muddy sand or slightly mixed sediment (SS.SSa.CMuSa.Aalb.Nuc) were the most common across the survey area and were observed at 6, 12 and 8 stations respectively. The biotope *Lagis Koreni* and *Phaxas pellucidus* in circalittoral sandy mud (SS.SMu.CSaMu.LkorPpel) was observed only once during the baseline reference station survey. In contrast the biotope *Nephtys cirrosa* and *Bathyporeia spp. in infralittoral sand* (SS.SSa.IFiSa.NcirBat) was observed during the post construction surveys only. There is no obvious pattern between the baseline and post construction surveys with respect to the distribution of infaunal biotopes (Figure 29).

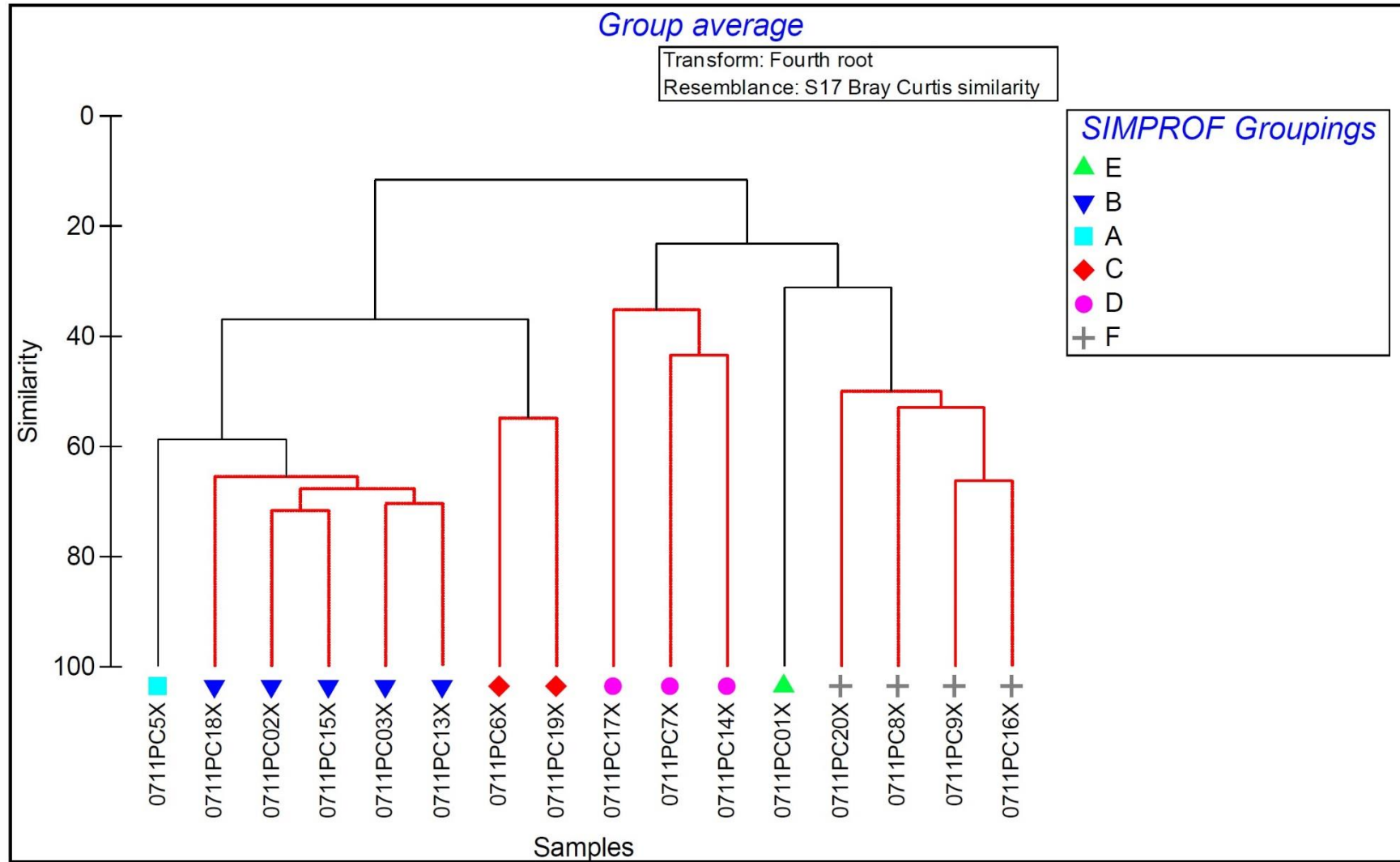


Figure 28 - Cluster dendrogram of the post-construction year 1 survey SIMPROF test (station averages, probability value of <math><0.05</math>). Red legs = significantly distinct group (Natural Power, 2013).

Gunfleet Sands 3 Demonstration Project

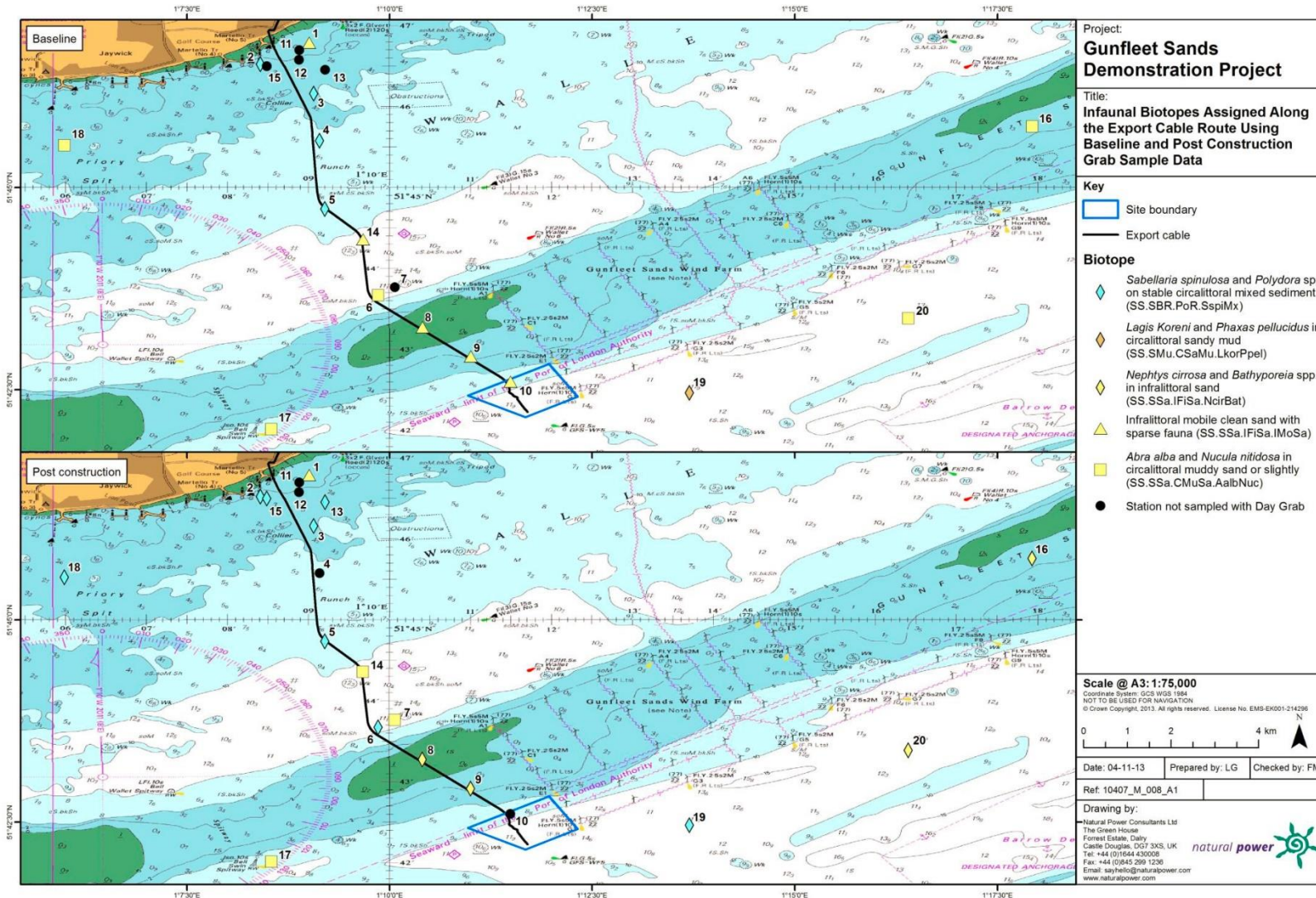


Figure 29 - Baseline and post-construction infaunal biotopes assigned based on the benthic grab data along the export cable route (Natural Power, 2013).

Conclusions

- 4.3.26. The results of the univariate statistics suggest that there have been changes to community structure between the baseline and post construction surveys, however as the majority of these were seen at both the cable route and reference stations alike, this strongly suggests that the driver for these changes was not related cable installation.
- 4.3.27. The increase in individuals may be attributed to the increase in juveniles found in the post construction survey samples, as there were significantly higher numbers of juveniles found during the post construction surveys than during baseline surveys. Significant differences were also seen between locations i.e. cable route and reference sampling stations, with significantly more being found at reference stations. The presence of an increased number of juveniles is attributable to the time of year the surveys were undertaken indicating high numbers could be partially attributable to recruitment induced seasonal variation as reported elsewhere in the North Sea (Reiss & Kröncke, 2005).
- 4.3.28. Temporary habitat loss/disturbance from cable laying activities was predicted to have a negligible effect due to the extent and temporary nature of the activity. Whilst sampling was not undertaken within the area of direct disturbance, the results of this survey strongly suggest that no effects were detected on the wider scale. Impacts may occur beyond the footprint of the cable area from anchoring, however, there was no evidence of any disturbance at the cable route. It is likely that the absence of any effects is a result of the localised nature of any impact and/or the recovery to baseline conditions following cessation of construction activity. The results suggest that the above impacts result from temporary habitat loss or disturbance within the levels predicted within the ES Addendum.
- 4.3.29. Increases in suspended sediment and sedimentation were predicted to have a negligible effect on benthic communities and habitats in the vicinity of the cable route. Although 90% of the re-suspended sediment was predicted to settle within 1 m of the cable route, there was potential for sediment to travel up to 165 m, defining the area of impact. Therefore, the sampling stations collected as part of the year 1 post construction monitoring programme were within the potential area of impact. As stated previously no impacts on the benthic community can be directly attributed to the cable installation since significant impacts were detected at cable route and reference stations alike, between surveys. Furthermore, there was no significant change in the particle size composition between any of the treatment groups.
- 4.3.30. Multivariate investigation of the PSA data suggests that there has been a sample-wide shift towards finer materials since construction, although the one-way ANOSIM confirmed that the PSA data recorded along the cable route has not changed significantly before or after construction. This indicates the both the cable route and reference areas have been subject to the same effects as the wind farm. The data also suggest that fine sand fractions within the sediment have a moderately strong relationship in shaping the benthic community. This has been supported by previous benthic studies which found that infaunal communities were influenced by the silt content of the sediment, and depth (Buchanan *et al.*, 1978). The changes affecting benthic infaunal communities could therefore be a result of a number of additional factors.
- 4.3.31. The release of contaminants from adjacent sediments was concluded to be negligible in the environmental statement addendum as contaminants were not found to be present at levels that are likely to cause an effect. While no contaminated sediment sampling was undertaken during this post construction survey (as per Marine Licence requirements), the fact that no

impacts could be found that were attributable to cable installation supports the assumption this prediction was accurate.

4.3.32. It is therefore concluded that the impacts on benthos from the export cable installation and operation fall within the predicted outcomes reported in the environmental statement.

4.3.33. Statistical analysis has indicated that changes in the benthic assemblages in and around the GFS3 export cable route cannot be attributed to the installation or operation of the cable, but rather are a result of broader scale natural fluctuations. This is in line with the findings of studies undertaken for a number of UK offshore wind farms which indicate that the disturbance to seabed sediments during cable burial operations are likely to be short term and relatively localised (BERR, 2008). The lack of evidence of any impacts on benthic communities as a result of the construction and operation of an offshore wind farm (and associated works such as cable installation and operation) is in line with the findings of other benthic monitoring programmes conducted both in the UK and across Europe. The strategic review of offshore wind farm monitoring undertaken by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) in 2010 (Walker and Judd, 2010) concluded:

“To date none of the benthic monitoring has identified any detrimental effects”.

4.3.34. Furthermore, in a geographical sense, the results obtained from the GFS 1 and 2 post construction year three monitoring detail no major changes have been observed over the survey period and that communities remain dominated by a few key groups (annelids, crustacea and molluscs (CMACS, 2012)). This was supported by SIMPER analysis which suggests the fauna in the wind farm area is somewhat sparse (as it has throughout all survey years), compared with the near field and reference sample stations. Finally, the general conclusion is that statistical evidence suggests that there has been no effect of windfarm construction on benthic fauna in the wind farm area (CMACS, 2012). The findings presented in this report indicate that the GFS3 export cable has not had a significant impact on benthic communities and any observed differences have been attributed to natural variability.

4.3.35. It is therefore recommended that no further studies of the benthic assemblages in the vicinity of the GFS3 export cable are necessary.

4.4. Operational Noise

Summary of Licence Conditions & Proposed Approach

- 4.4.1. Conditions relating to monitoring of operational noise are set out in the Marine Licence for GFS3. The specific Marine Licence conditions are set out in Table 5 of this document.
- 4.4.2. The monitoring specification set out in the GFS3 EMP (NIRAS, 2014). States the following:

The Licence Holder proposes that post-construction noise monitoring will be measured via low-noise hydrophones deployed from vessels, as per the methodology employed at GFS1. This method has been adopted by the Licence Holder on another of their Round 1 offshore wind farms (Barrow Offshore Wind Farm) and has provided good quality results. The hydrophones will be attached to an anti-heave buoy, which will trail behind the boat. The hydrophones will be calibrated and sound recordings will be continually backed-up to laptop computer. Navigational information (and other metadata, e.g. sea state, temperature) will be acquired alongside noise data.

'Background' noise measurements will be obtained on a calm day during the construction stage between measurements that will be undertaken for the pile driving operations. 'Ambient' noise levels during the operational phase will be collected at a distance of 1-3km away from the wind farm.

- 4.4.3. GFS3 operational noise monitoring was due to commence in summer 2013. However, as the turbines were still undergoing testing and not operating consistently at the time the survey was postponed to the summer of 2014. A proposal to postpone post-construction operational noise monitoring to the summer of 2014 was confirmed and approved for implementation by MMO on 20th September 2013.

Monitoring Methods

- 4.4.4. The underwater operational noise monitoring is presented in detail in Subacoustech Environmental (2014 – Appendix F) and summarised in the following sections. The data includes considerably more analysis than presented here, given the summary nature of the current report, with numerous additional plots included in the Subacoustech Environmental report (2014).
- 4.4.5. The measurements have been taken to characterise the level of noise produced by the turbines under typical operating conditions. They are presented in terms of sound pressure levels and interpreted with respect to the potential impact of underwater sound from the turbines on marine species in the region.
- 4.4.6. Underwater noise was recorded using specialist equipment developed by Subacoustech Environmental Ltd., which measured underwater sound to levels well below sea state zero noise and over the frequency range required to characterise anthropometric noise in the ocean, including the hearing response range of species of fish and marine mammals. Measurements were undertaken on transects with the turbine as an end-point, either travelling towards or away from the turbine, from a range of 30 m from an operational turbine, up to 1620m. Figure 30 identifies the approximate measurement transects taken.

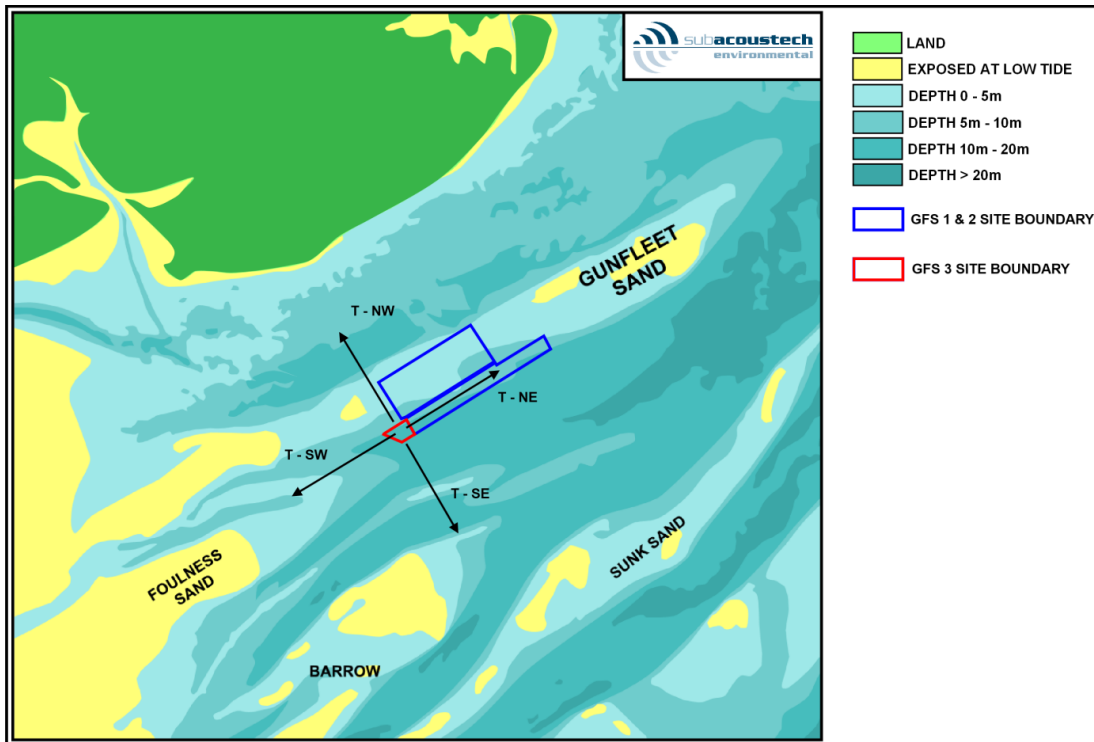


Figure 30 – Location of the GFS3 site and boundaries, and measurement transect directions (Subacoustech, 2014).

- 4.4.7. The operational underwater noise survey at Gunfleet Sands 3 site was undertaken on 29th and 30th July 2014. The survey was undertaken from a boat, Sophie Lea, which was boarded in Brightlingsea harbour on each day before heading out to the Gunfleet Sands wind farm site.
- 4.4.8. All underwater sound vessel based measurements conducted as part of this study were undertaken using a Brüel and Kjær Type 8106 low noise hydrophone, which is able to measure underwater sound to levels well below sea state zero noise.
- 4.4.9. The Brüel and Kjær Type 8106 hydrophone has a linear sensitivity to underwater sound over the frequency range from 7 Hz to 80 kHz. The calibration chart for the transducer, traceable to International Standards, is provided in Appendix A. However, Brüel and Kjær also provide sensitivity data outside of the linear range, from 0.25 Hz to 150 kHz, so that useable acoustic data can be extended well beyond the linear frequency range specified above. A benefit of this broad, well specified frequency calibration is that an inverse filter can be applied to flatten the response of the hydrophone.

Results

- 4.4.10. An underwater noise survey was undertaken prior to GFS3 being made operational. The survey was undertaken on 13th and 14th March 2013 (Subacoustech Environmental Ltd report no. E419R0102). Measurements were undertaken along four transects (in a North East, South East, South West and North West direction) extending out from the two turbines.
- 4.4.11. It was observed that almost all the average levels on the first day of the survey were found to be between 105.0 and 117.6 dB re 1 µPa. In general the average levels on the second day were measured to be lower and were found to be between 104.3 and 112.9 dB re 1 µPa. The wind speed was reported to be between 7 and 9 m/s on 13th March and between 2 and 7

m/s on 14th March. The wave height was observed to be up to 0.5 m high on 13th March with very little swell on 14th March with wave height less than 0.4 m. The weather conditions on 14th March 2013 are seen to be similar to that for the operational noise survey and hence the measurements from this day will be used to compare to the operational noise measurements.

- 4.4.12. Measurements of underwater noise were taken at various distances from the two turbines at GFS3 in order to determine the extent of the sound propagation from the operational turbines. Figure 31 presents a power spectral density (PSD) plot of several measurements each at a different range from the turbines as well as a background measurement from March 2013. The PSD taken from the background measurements show that on 29th July 2014 measurements only exceeded the previously measured background levels across the frequencies at a range of less than 300 m from the operational turbines.

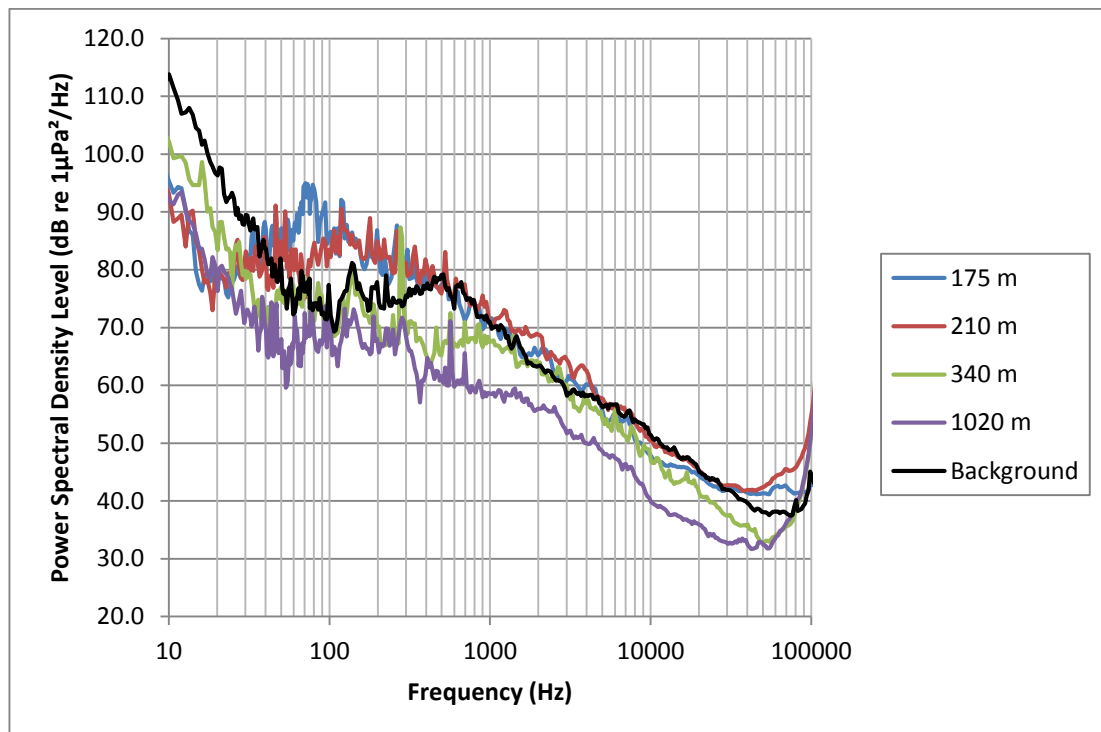


Figure 31 - PSD level plots of measurements taken at increasing distances from the wind turbines on 29th July 2014 (Subacoustech, 2014)

- 4.4.13. The data measured along all 6 transects extending from operational turbines were analysed to provide an indication of the variation in noise level with range which can be used to estimate the likelihood of any environmental impact.
- 4.4.14. Figure 32 to Figure 37 show what the measured Sound Pressure Level (SPL) was at a specific range. It is observed that for all the presented data below, very few of the data points exceed the maximum background level measured on each transect in March 2013. Measurement transects were undertaken in order to determine the source level and transmission loss of the propagating noise from the operational turbines. However transmission loss curves have not been fitted to the data because the measured levels are all very similar to the background measurements making it difficult to identify the noise produced purely by the GFS3 turbines. This suggests that the operational noise from the turbines F00 and G00 have minimal impact on increasing the overall sound pressure levels in and around GFS3.

4.4.15. Figure 32 to Figure 34 all show the measured data to have a spread which ranges between the maximum and minimum background levels without showing any clear drop in level with range.

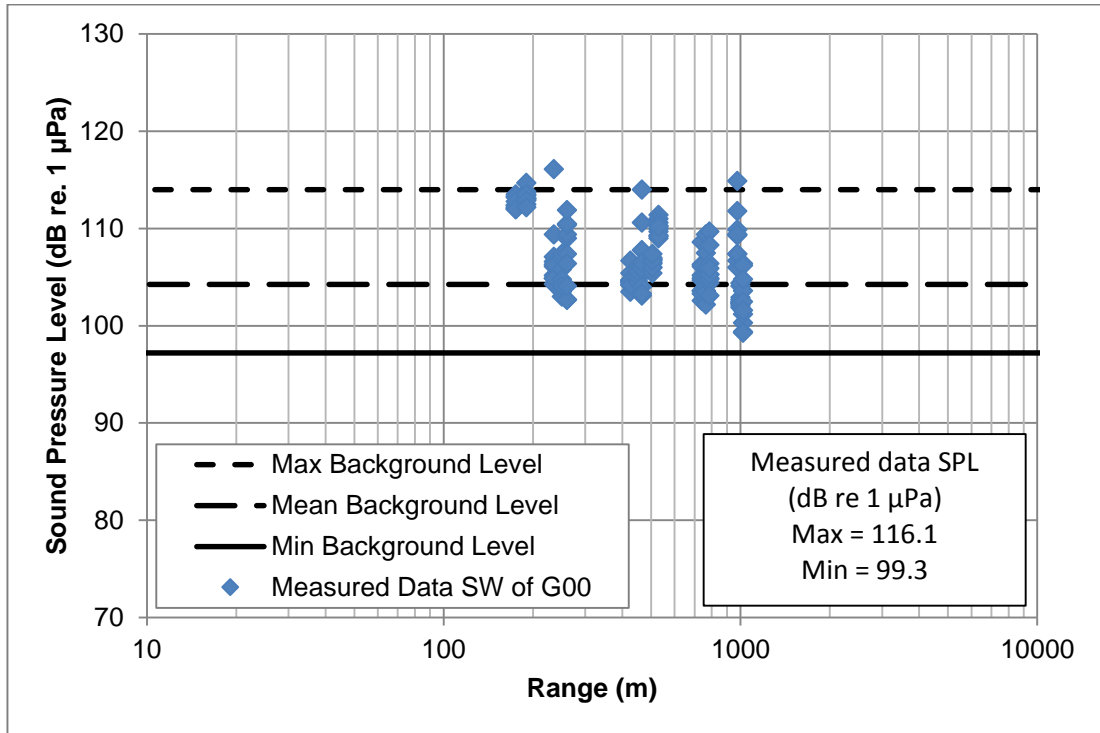


Figure 32 - Level versus range plot of data measured along the South West transect from G00 turbine on 29th July 2014 (Subacoustech, 2014)

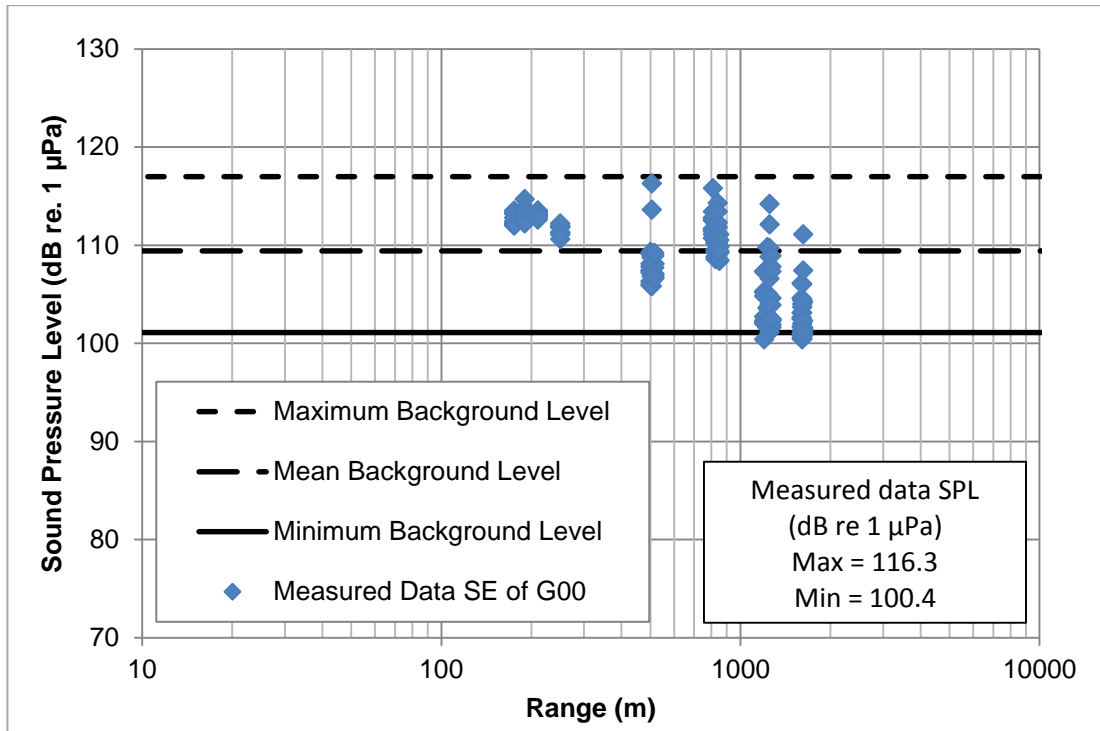


Figure 33 - Level versus range plot of data measured along the South East transect from G00 turbine on 29th July 2014 (Subacoustech, 2014)

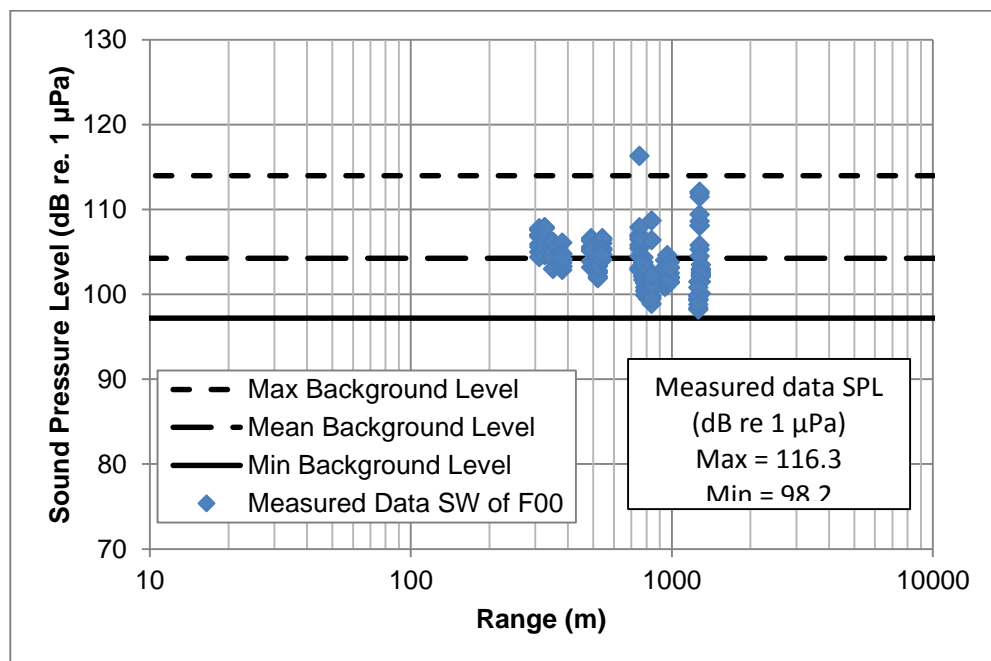


Figure 34 - Level versus range plot of data measured along the South West transect from F00 turbine on 30th July 2014 (Subacoustech, 2014)

4.4.16. Figure 35 shows the measured data on the south east transect, where measurements were taken at a distance less than 100 m to the wind turbine. These are greater than the mean background level along the south east transects from G00. These data points exhibit an indication of reduction in level with range which may be due to the propagating operational turbine noise. However, at distances beyond 100 m the majority of measurements are seen to be below the mean background level and show no signs of any further reduction in level.

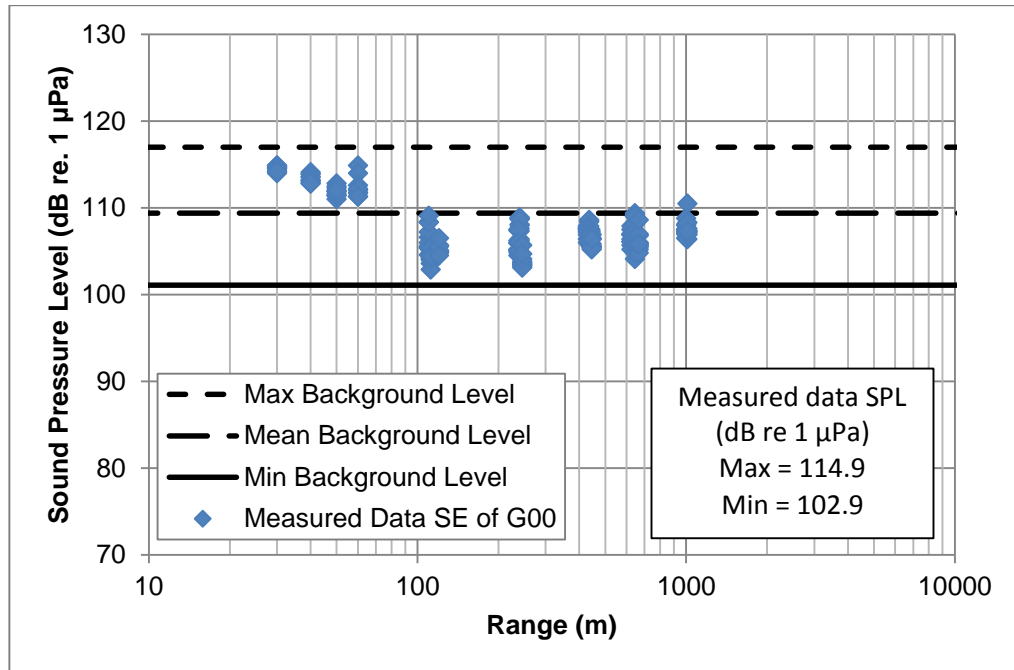


Figure 35 - Level versus range plot of data measured along the South East transect from G00 turbine on 30th July 2014 (Subacoustech, 2014)

4.4.17. Similarly, Figure 36 illustrates that virtually all the measured data on the north east transect from F00, all taken at a range beyond 100 m from the turbine, were recorded to be below the mean background level. It was noted that the background measurements undertaken along the north east transect were dominated by vessel noise within Gunfleet Sands 1 and 2.

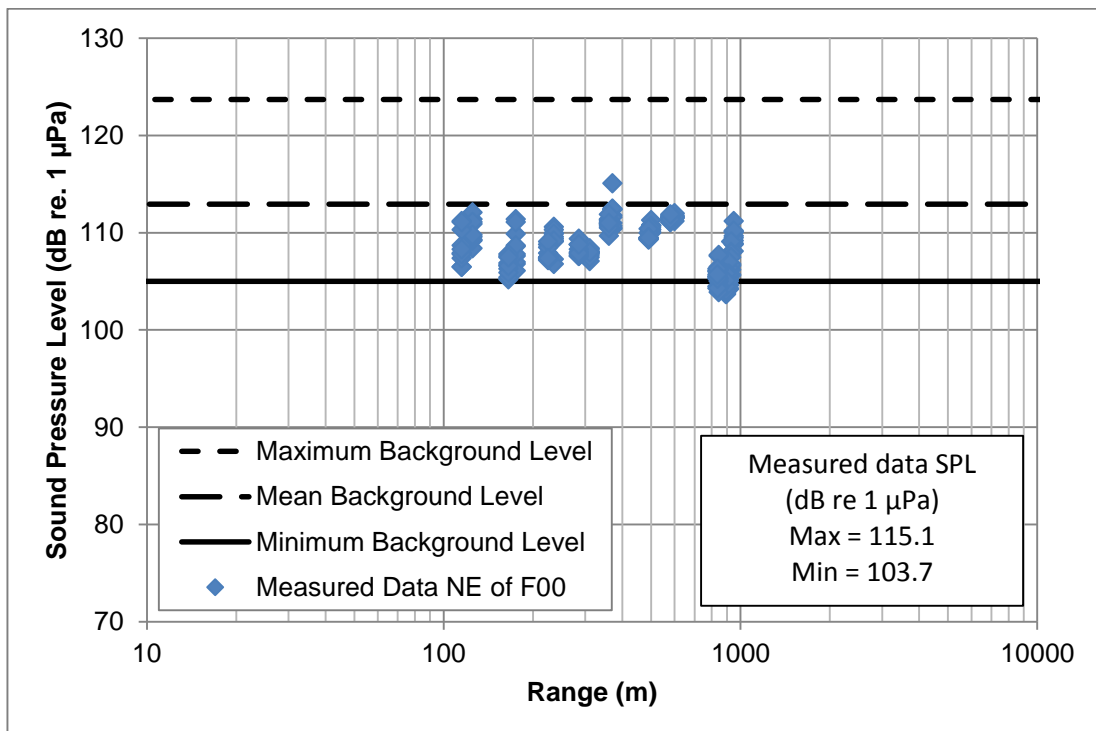


Figure 36 - Level versus range plot of data measured along the North East transect from F00 turbine on 30th July 2014 (Subacoustech, 2014)

4.4.18. All the measured data along the south west transect from G00 presented in Figure 37 are seen to be equal or greater than the mean background level previously measured along that transect. The measurements at a range less than 100 m again exhibit a reduction in level with range. Conversely, the measurements taken at a distance greater the 100 m do not appear to fall below the previously measured mean background level and indeed some measurements are seen to be higher in level than the measurements close in to the turbine. This further supports the view that the noise being measured is unlikely to be attributable to the particular turbines at these distances.

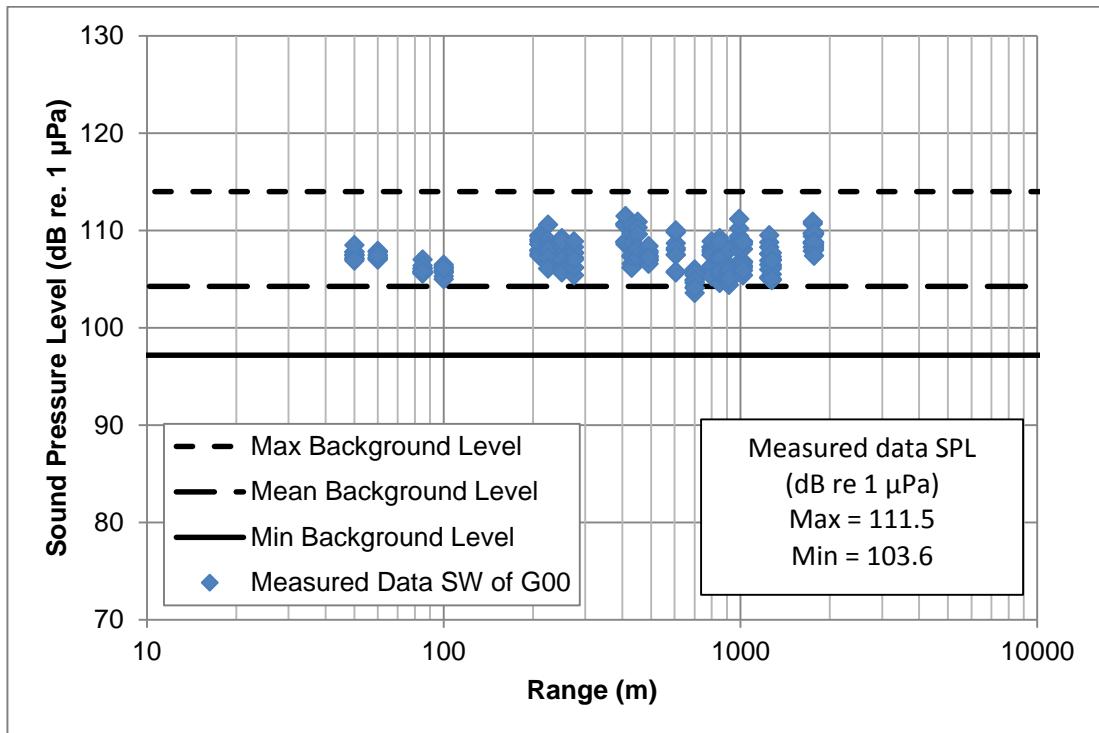


Figure 37 - Level versus range plot of data measured along the South West transect from G00 turbine on 30th July 2014 (Subacoustech, 2014)

- 4.4.19. All the data have been analysed to obtain noise levels in terms of the dBht (Species) metric. This method of presenting noise data indicates the likely perception by an animal of the underwater sound, and thereby provides a measure that can be used to assess the potential for the underwater sound cause a behavioural effect.
- 4.4.20. The data has been analysed in terms of the hearing abilities of fish including cod, dab and herring. All the measured dBht levels for fish were found to be below 50 dBht, the level below which there is a low likelihood of avoidance.
- 4.4.21. When comparing the fish dBht levels with the background noise measurements undertaken in March 2013, it was observed that the dBht levels for cod have increased but are still considerably lower than levels in which behavioural reactions are thought to occur, however dBht levels for dab and herring the measured levels are more variable.
- 4.4.22. The data has been analysed in terms of the hearing abilities of bottlenose dolphin, harbour porpoise, harbour seal and striped dolphin. All the measured dBht levels for marine mammals were found to be below 75 dBht, the level which some avoidance by the majority of

individuals may occur. The maximum dBht levels were found to be measured for harbour porpoise, which were found to be in excess of 50 dB--ht by 16 to 18 dB.

- 4.4.23. When comparing the marine mammal dBht levels with those measured in the background noise survey undertaken in March 2013 it is observed that the dBht levels for bottlenose dolphin, harbour porpoise and striped dolphin have increased. For harbour seal the measured operational levels are comparable with the background levels.
- 4.4.24. Analysis has been carried out on the recorded data in terms of M-Weighted SELs (Southall et al., 2007). The criteria states that if a receptor receives over a specific level of noise over a 24 hour period then permanent hearing damage (Permanent Threshold Shift, PTS) is likely to occur. The criteria states that PTS is likely to occur at 215 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$ (M) for marine mammals in the low, mid and high frequency cetacean hearing groups and at 203 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$ (M-pw) for pinnipeds (in water) group for noise categorised as a 'non pulse'.
- 4.4.25. The measurements undertaken have been extrapolated over a 24 hour period since they were taken over a short period. For a worst case scenario it has been assumed that the receptor stays stationary, at the same distance from the noise source, over the entire 24 hour period.
- 4.4.26. All the M-Weighted SELs were found to be significantly below the criteria at which PTS is likely to occur. The maximum level based on the measured data was found to be 178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$ (M-hf-) for the high frequency cetaceans.

Conclusions

- 4.4.27. The survey results found that as a whole, the measured unweighted Root-Mean-Square (RMS) sound pressure levels show that the operational phase of the wind farm has had minimal increase on the overall sound pressure levels in the vicinity of the wind farm. Indications are that the sound pressure levels from the F00 and G00 turbines tend to fall below the background noise level within 100m. (Background noise levels include noise from Gunfleet Sands 1 and 2 turbines and associated vessel traffic.)
- 4.4.28. The measured underwater noise data has been interpreted using a number of metrics. All the unweighted measured levels were found to be significantly below any criteria that have been seen to cause fatality or physical injury in the literature.
- 4.4.29. The data has also been analysed in terms of the species specific dBht metric. In general, the RMS dBht sound pressure levels for fish and marine mammals were found to have increased but generally not exceeding 50 dBht, except for harbour porpoise and striped dolphin for which dBht levels were found to be below 75 dBht. However, the levels remain well below the levels that which could be expected to cause disturbance.
- 4.4.30. M-Weighted SELs were calculated by extrapolating measured levels over 24 hours. It was found that all the SELs fall well below the level at which permanent hearing damage is likely to occur for cetaceans and pinnipeds.

5. Discussion and Conclusions

- 5.1.1. This report has set out in brief the offshore construction process and program that has been completed at the GFS3 site over the period July 2013 to July 2014. The post-construction environmental monitoring required by the GFS3 Marine Licence has been summarised based on a review of the detailed, individual monitoring reports and/or data sets.
- 5.1.2. The monitoring has acted to confirm the predictions made by the GFS3 ES with regard to the nature, extent and significance of the environmental effects arising from the development of the wind farm.
- 5.1.3. Comparison of scour estimates from the GFS3 ES, to the data derived from the post-construction surveys show that scour extent for both turbines are well within the range predicted. The export and inter-array cables were found to be well-defined but with no significant scour observed.
- 5.1.4. Benthic ecology surveys and subsequent analysis indicated that changes in the benthic assemblages in and around the GFS3 export cable route could not be attributed to the installation or operation of the cable, but rather are a result of broader scale natural fluctuations.
- 5.1.5. The operational noise monitoring revealed that there has been negligible increase in the sound pressure levels compared to the levels measured prior to the turbines being made operational.
- 5.1.6. In summary, the post-construction monitoring has been proven to have been fit for purpose and has ensured that the GFS3 project has fulfilled the requirements of the Marine Licence during the first year post-construction. Post-construction monitoring will continue to act as a check to confirm that the predictions made in the GFS3 ES are correct. The post-construction survey work will continue to be reported annually by DONG Energy in a monitoring report for the remaining two years of the three years post construction monitoring period specified in the Marine Licence.

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