E.ON Climate and Renewables UK Limited

Humber Gateway Offshore Wind Farm: Benthic Monitoring Programme Annual Report

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1. Introduction

1.1 The Humber Gateway Offshore Wind Farm Development

Humber Gateway is a Round 2 offshore wind farm development, located in the northern part of the Greater Wash area. The site is located between 8km and 13.5km east of the Yorkshire coast, near the Humber Estuary in the north east of England. The Humber Gateway wind farm array covers an area of around 35 square kilometres of sea and will consist of 73 wind turbines, monopile foundations and inter-array cables. A single offshore substation platform will be mounted on a jacket type foundation.

Each wind turbine will be connected by 33kV inter-array cables to the offshore substation located at the north-west corner of the development site.

Humber Gateway Offshore Wind Farm (OWF) has been awarded full planning consent for construction and operation of the wind farm off the Holderness Coast. The Marine Licence issued to HWL in February 2013 (which replaces FEPA and CPA licences awarded in February 2011) requires HWL to undertake Benthic and Annex I survey during the preconstruction phase of the OWF development. This Preconstruction BMP Annual Report is a culmination of the works undertaken to fulfil the preconstruction Benthic and Annex I requirements of the Marine Licence.

Precision Marine Survey Limited (PMSL) has undertaken the Benthic and Annex I surveys on behalf of Humber Gateway Limited (HWL), in accordance with the requirements of the Marine Licence conditions for preconstruction ornithology.

A Benthic Monitoring Programme (BMP) was submitted to the MMO for approval in December 2011 (version 1), with a revised version issued dated May 2012 (version 2), where the latter included comments received from the MMO. A more detailed Annex I and Benthic Survey Methodology was issued to the MMO in August 2012, which detailed the location of the Annex I survey stations, which were based upon the results of the geophysical survey assessment.

The Benthic and Annex I surveys have followed the methodologies described in the Humber Gateway BMP. This BMP Annual Report summarises the Benthic and Annex I Preconstruction surveys undertaken in 2012, and discusses the results of these surveys.

The BMP and associated works consists of the following elements:

- Assessment of geophysical survey;
- Annex I Survey and Assessment; and
- Benthic Survey and Assessment.

A summary of each survey, including results and discussion is provided within this BMP Annual Report.

1.2 The Benthic Monitoring Programme

The Humber Gateway project has been subject to Environmental Impact Assessment (EIA). The resultant Humber Gateway Offshore Environmental Statement (ES) reported on a range of environmental parameters and identified potential impacts related to the construction and operation of Humber Gateway. Where impacts could not be overcome by embedded design changes, mitigation and monitoring measures were incorporated in the ES where appropriate, and agreed with statutory consultees. These mitigation and monitoring measures have been transposed into Marine Licence conditions, where the Marine Licence (L/2013/00012) was issued to HWL in February 2013, in accordance with the Marine and Coastal Access Act 2009. The Food and Protection Act (FEPA) Licence and Coast Protection Act (CPA) Licence previously issued to HWL have been consolidated into the Marine Licence and have therefore been repealed.

This BMP Annual Report is a culmination of the works undertaken to fulfil the preconstruction benthic and Annex I requirements of the Marine Licence.

On submission of this BMP Annual Report, HWL requires confirmation from the MMO, of the discharge of the Marine Licence conditions, as identified below, in relation to preconstruction benthic and Annex I activities.

The BMP issued to the MMO in December 2011 (and subsequently version 2 issued in May 2012) set out pre-construction benthic (seabed) habitats survey and monitoring objectives to fulfil Marine Licence conditions:

- The range of environmental monitoring (in relation to benthic and seabed habitats) proposed for the project;
- The specifications of the proposed monitoring in terms of approach and equipment;
- The provisional schedule for the proposed monitoring; and
- The proposed analysis and reporting requirements to present the findings of these surveys.

A full listing of the relevant Marine Licence conditions are provided **in bold** below, with a validation under each condition *in italic.*

Marine Licence Condition 3.1.10
The Licence Holder must carry out a pre-construction survey to determine the location and abundance of Annex 1 habitat in the vicinity of the array and cable route. Should Annex 1 be identified, the Licence Holder is required to undertake an assessment of the need to micro-site individual turbine structures, inter array cable or export cable. If micro siting is required, the Licence Holder must inform the Licensing Authority immediately. The results of the survey and assessment shall be submitted to the Licensing Authority and NE within one month of the completion of the survey. Construction must not commence without the written agreement of the Licensing Authority.

The Annex I survey was undertaken between August to October 2012, in accordance with the methodology provided in the BMP and the Detailed Annex I and Benthic Survey Methodology, August 2012. The results of the Annex I survey are reported within this BMP Annual Report. An Annex I Micrositing Assessment Report has been issued to the MMO in January 2013, with a revised version including comments received from MMO issued in April 2013. We therefore seek the discharge of condition 3.1.10.

Marine Licence Condition 3.1.11
The Licence Holder must submit a proposal for the specification of the pre-construction (baseline) monitoring as outlined in Annex 1, for the approval of the Licensing Authority in consultation with Cefas, and NE at least four months prior to the commencement of baseline survey works. Construction must not commence until the Licensing Authority has given its written acceptance of the baseline monitoring specification.

The BMP, setting out preconstruction Annex I and Benthic Monitoring was issued to the MMO in December 2011 (re-issued in May 2012 with amendments), where the survey results are detailed within this BMP Annual Report. We therefore seek the discharge of condition 3.1.11.

Marine Licence Condition 3.2.12
The Licence Holder must ensure that a pre construction (baseline) monitoring report is submitted to the Licensing Authority, in consultation with Cefas and NE two months prior to the commencement of construction. Construction must not commence until the Licensing Authority has agreed the baseline monitoring report is fit for purpose.

The submission of this BMP Annual Report fulfils the requirements of this condition. We therefore seek the discharge of condition 3.1.12.

Marine Licence Annex 1.1 Seabed Morphology and Scour
The Licence Holder must ensure that a pre and post construction bathymetry survey is undertaken to establish any changes in the shore profile to a defined point offshore and to locate any sediment build up that may occur as a result of reduction in sediment movement. As a minimum, monitoring data from the regional coastal monitoring programme must be used to help assess whether any changes have occurred. The results of this survey must be provided to the Licensing Authority in consultation with Cefas and NE in accordance with the details in the schedule referred to in Licence condition 3.1.1.

The preconstruction bathymetry survey was undertaken in 2011/2012 in order to advise the location of Annex I survey locations. An additional preconstruction bathymetry survey has been undertaken in 2012/2013. A summary of the 2012 bathymetry results are provided in this BMP Annual Report. We therefore understand that the requirements of this Annex 1.1 to be fulfilled in context of the preconstruction bathymetric survey.

Annex 1 2. Benthic Organisms
Prior to the commencement of any works the benthic ecology characterisation data must be reanalysed and reinterpreted to the satisfaction of the Licence Authority, in

consultation with Cefas and NE, in order to provide a robust baseline dataset against which the benthic monitoring data can be measured. 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). Sampling should involve a minimum of 3 replicates at each station and the number and location of stations 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 reference sites. NB. The sediment transport/deposition information and benthic data sets must be closely related.

The benthic ecology characterisation data was reanalysed and reinterpreted, as reported in Annex I of the BMP submitted in December 2011 (and re-issued in May 2012 with amendments), and approved by the MMO.

The benthic survey, planned for September 2012, was delayed significantly by the new requirement to apply for a Small Works Licence from the Crown Estate, in order to retrieve samples from the seabed. The application to the Crown Estate was made in August/ September 2012, and the Small Works Licence was issued in November 2012. The Small Works Licence held conditions which required the permission of seabed users for HWL to undertake benthic sampling. Permissions and/or small changes to Benthic Survey Sites took time to resolve, and compounded with poor weather conditions throughout winter 2012/2013, the benthic survey was delayed until February to April 2013. This has previously been communicated to the MMO.

As a result in the delayed Benthic Survey, Benthic Analysis is ongoing at the time of writing, where a benthic assessment report will be issued to the MMO in mid-May 2013, as a technical appendix to this BMP Annual Report. As a result, a debrief of the completed benthic survey, including the methodology, location of survey sites and sampling is provided within this BMP Annual Report, for the purposes of discharge of Marine Licence Annex 1.2 ahead of the commencement of construction activities. The benthic results analysis will be supplied to the MMO as a technical appendix by mid-May 2013.

2. Bathymetric Survey (Winter 2011/2012)

2.1 Reason for Survey

Prior to the issue of the Marine Licence, the FEPA Licence contained a condition (condition 9.40) that required pre and post construction bathymetric surveys:

The Licence Holder must undertake two (one winter and one summer) high resolution swath-bathymetric surveys per annum (including a pre-construction baseline) of the wind farm intra-array and export cable route to assess the extent of any changes to bedform morphology. Should additional cable protection be required (e.g. rock armour) a separate application must be made for Food and Environment Protection Act/Coast Protection Act consents.

The same condition has not been transposed into the Marine Licence, but nevertheless, a bathymetric survey was undertaken in 2011/2012 and again in 2012/2013, to fulfil this FEPA licence condition and to understand the geophysical environment which in turn informed determination of the detailed Annex I survey methodology, since the Annex I survey stations focussed on the intersections between the export and array cables with potential Annex I, indicative from bathymetric data assessment.

2.1.1 Annex 1.1 of the Marine Licence (Section 1.2 above) maintains a requirement to undertake pre and post bathymetric survey. Objectives

The objective of the preconstruction bathymetry surveys (and subsequent surveys) was to provide geophysical data and accurate bathymetry for the development area including a summary of the main sedimentary habitats (and distribution of man made objects).The distribution of man made objects (ie UXO and Archaeology) is not considered within this report. In consideration of Annex 1.1 of the Marine Licence (and previously FEPA clause 9.40) and the objectives of the BMP, the hypothesis to be tested following further post construction monitoring is as follows:

Establishment of the Humber Gateway Offshore Wind farm causes a significant alteration to the topography and sedimentary regime at the wind farm site.

The winter 2011/2012 bathymetric survey also included geophysical survey using sidescan sonar and together this information was used to inform the detailed methodologies including video drop sites of the subsequent Annex I and benthic surveys (Section 3).

2.2 Survey Methods

The winter 2011/2012 bathymetric survey was undertaken by Osiris Projects on behalf of HWL between 4th January and 27th March 2012 and included two components. The main survey of relevance to this BMP Annual Report was the acquisition of multibeam and sonar data across the offshore wind farm array and export cable corridor. This survey was undertaken using the survey vessel 'MV Lia' and data acquisition comprised of multibeam

and side scan sonar techniques at variable line spacings, in order to achieve 100% multibeam coverage and 200% sonar coverage.

The primary objectives were to locate and identify the following:

- Bathymetric data acquisition; and
- Annex I habitats including *Sabellaria spinulosa* and cobble reef structures.

Line spacing was initially set at 75m orientated 345° with a nominal number of cross lines for data QC, however line spacing was reduced in places to ensure that 100% multibeam coverage was achieved reducing the amount of infill required. Total side scan coverage of 200% was achieved and a total of 630.7km of data was acquired.

The second component included more detailed survey work for engineering purposes along the inter array cables, export route and turbine locations which was undertaken using the vessel 'MV Chartwell' as follows:

- Sub-bottom data acquisition along all inter array (turbine centre to turbine centre) and export cable centre lines for engineering purposes, with sparker and pinger sub-bottom data acquired in a single pass. Sub-bottom profiler data were required for jack-up leg penetration and cable installation purposes, to identify vertical/lateral extents of soil units and significant obstructions up to 15m below the seabed.
- UXO corridor expansion (north/south) from 120m to 300m to support foundation vessel placement at turbine design locations. Survey lines were acquired at 10m centres, towing a combination of two side scan sonar fish, over-the-side pinger and piggy-backed magnetometers, flown less than 3m above seabed at a 5m lateral separation.
- Inter array (east/west array corridors only) and export cable UXO corridors (nominal 50m corridor centred on cable) to support ploughing/trenching operations. Survey lines were acquired at 10m centres towing a combination of two side scan sonar fish, over-the-side pinger and piggy-backed magnetometers, flown less than 3m above seabed at a 5m lateral separation.

The equipment utilised for survey is summarised in Table 1.

Table 1. Equipment utilised for bathymetric and geophysical survey

Item #	Equipment Utilised	MV Lia	MV Chartwell
1	LEICA GX1230 Smartnet RTK	✓	✓
2	C-NAV 3050G dGPS	✓	
3	C-NAV 2050R dGPS		✓
4	HEMISPHERE VS1000 GPS Compass		✓
5	TSS Meridian Gyro Compass	✓	✓
6	QPS QINSy Navigation Software	✓	✓
7	APPLANIX POS MV 320 V4 Inertial Navigation System	✓	✓
8	RESON 7125 SV2 Multi Beam Echo Sounder	✓	
9	RESON SVP 15 (SN 73253)	✓	
10	RESON SVP 70 (SN 4709032)	✓	
11	VALEPORT Midas SVP (SN 23728)		✓
12	KLEIN 3000 Digital Dual Frequency Side Scan Sonar System	✓	✓
13	GEOMETRICS G882 Caesium Vapour Magnetometer		✓
14	GEOACOUSTICS GeoPulse Pinger		✓
15	GEORESOURCES GeoSpark 200 Sparker & Hydrophone		✓
16	SIMRAD EA400 Single Beam Echo Sounder	✓	
17	KNUDSEN 320M Single Beam Echo Sounder		✓
18	SONARDYNE Scout USBL System	✓	✓
19	SONARDYNE WSM Transponder	✓	✓
20	T-COUNT Cable Counter	✓	✓

2.3 Results of Winter 2011/2012 Bathymetric and Geophysical Survey

The full survey results were provided in the *Osiris report C12001 & C12002 - Humber Gateway Offshore Wind Farm UXO Extension and Winter Monitoring Survey volumes 1 – 3.*

The following sub-sections provide a brief overview of results in relation to bathymetry and seabed features (details on sub-bottom profiling and magnetometer survey are not included here, since they are not deemed to be of relevant to the Annex I and Benthic Environment, as per this BMP Annual Report).

2.3.1 Bathymetry

A chart showing the development layout (turbines, export route and array cables) overlaid with multibeam bathymetry results is provided in ***Figure 1***. Cable array layouts illustrated in these figures represent the most recent plan and correspond to those identified in the *Annex I Micrositing Assessment: Turbine Structures, Array Cabling, Export Cabling & Annex I Features* produced by HWL in January 2013 (reference HUM-ECH-ECF-PLA-0005_02) (which has been updated following receipt of comments from MMO and resubmitted in April 2013, reference HUM-ECH-ECF-PLA-0005_03).

Seabed levels within the export cable route corridor range from 'drying' heights of close to 0.0m CD at the inshore limits of the survey, to 16.3m below CD close to where the export cable corridor enters the offshore wind farm array area. Seabed levels inshore limits from 0.0m CD to 3.5m below CD at an average gradient of 1.6° with the exception of a NNW-SSE orientated ridge of sediment where seabed levels temporarily shoal to between 2.0m and 2.5m below CD. The seabed between the 4.5m below CD and 9.0m below CD contours is

very irregular with a large number of NNE-SSW orientated narrow seabed ridges. These features are near vertical in profile, with the largest features standing up to 2.0m higher than the surrounding seabed. Beyond the 9.0m contour is a flatter area approximately 150m – 200m wide which terminates abruptly at the base of a relatively narrow ridge orientated NNW – SSE which rises up to a minimum level of 5.9m below CD between the northern and southern cable route centre lines.

To the east of this feature, bed levels deepen generally towards the NNE across an undulating seabed a maximum depth of 16.3m below CD at the entrance to the development area. Within this area a number of more localised NNW – SSE orientated, ridges are present within the export cables corridor. These features generally stand up to 4.0m above the surrounding seabed and a number of these extend across both the southern and northern export routes.

Within the development site seabed levels are relatively consistent over much of the area ranging from 12m below CD to 18m below CD with an undulating seabed. A number of more elevated ridges are present in the area which are usually orientated NNW – SSE which may extend up to 1 to 2m above seabed. These range in size from tens of metres in width and <100m long to larger examples up to 50m wide and several 100m metres in length. In some areas these form a series of closely situated narrow linear ridges running through the site. Adjacent to these are often areas of slightly variable topography indicating slightly rougher ground sometimes with very small scale bands or ribbons of less elevated seabed (<0.5m above adjacent seabed). An area of somewhat elevated seabed (around is also present running NNE to SSW from the NE corner of the development site with seabed levels of between 12m to 14m below CD. Similarly shallow areas are also present along the southern edge of the development site. A number of jack-up spudcan depressions were also recorded adjacent to the substation and turbine locations a variety of large seabed scars were also noted some of which may have been left by the trailing legs of the jack-up rig during geotechnical surveys.

2.3.2 Seabed Features

Seabed features identified by sidescan sonar and multibeam bathymetric survey are provided in ***Figure 2*** which provides a summary of the assessment of the 2011/2012 geophysical data collected and analysed (excluding small scale features for clarity). To save any confusion, it is noted that the original outputs from the Osiris survey used a slightly different sediment nomenclature than utilised within this BMP Annual Report, where the nomenclature utilised within this Annual Report are deemed correct through drop down video ground truthing to confirm sediment classification. A calibration between the Osiris nomenclature and PMSL ground-truthed classification will be summarised in a separate addendum.

The side scan sonar data indicate that coarsely granular (Holocene) sediments are present at seabed level across most of the export cable route corridor and offshore wind farm array. These areas are largely characterised by extensive areas of (slightly muddy) mixed coarse sediment comprising of pebbles, gravelly sand and shell with frequent cobble and (generally) small boulders which in some areas appears to form a veneer over the

underlying boulder clay. This habitat is extensive and covers the majority of the area. Additionally, a large number of sonar contacts were recorded across the survey area which corresponds to boulders which have been frequently recorded throughout the site. Drop down video undertaken at the turbine locations in March 2011 prior to geotechnical surveys and the subsequent ground-truthing survey in May 2012 highlighted a degree of patchiness or variability in this habitat with some areas exhibiting increased *Modiolus* shell and others with increased cobble content.

As described previously, the majority of the development area lays between water depths of 13m and 16m below CD and aside from small scale features (individual boulders, debris, scar lines and jack-up spudcan depressions etc) the most obvious features are a series of elevated ridges running across the development site and at intervals along the export route usually orientated NNW to SSE. These features are thought to be remnant morainic deposits, which have been subsequently shaped by the existing current regime at the site and are up to 4m above adjacent seabed along the export route and up to 1 to 2m above seabed in the development site (although many of these features are smaller with much lower elevation). These ridges have been previously classified as gravel ridges (***Figure 2***) and subsequent assessment using drop down video in May 2012 (and earlier geotechnical surveys in 2011) have identified these as primarily cobble and small boulder. Other areas of slightly rougher ground with somewhat increased cobble content or with small scale patches or ribbons of cobble with modest elevation above adjacent seabed are also evident from the sidescan data and are scattered across the area usually adjacent to the main cobble ridges described earlier or in some areas at the periphery of the site.

A broader area of slightly elevated seabed is also present running SSE from the north east corner of the site. Sidescan data indicated that this may potentially include more gravelly sediment, although an assessment of the available video footage from this area did not appear to highlight a particular change in sediment in this region. Other notable habitats are the series of ridges at the inshore end of the export route. These are a complex system of elevated/exposed boulder clay ridges (see *Section 5.1.1*). Adjacent to these and further inshore are some areas of sand or mixed gravelly sand, (notably at the extreme inshore end of the export route) often interspersed with patches of boulder or cobble.

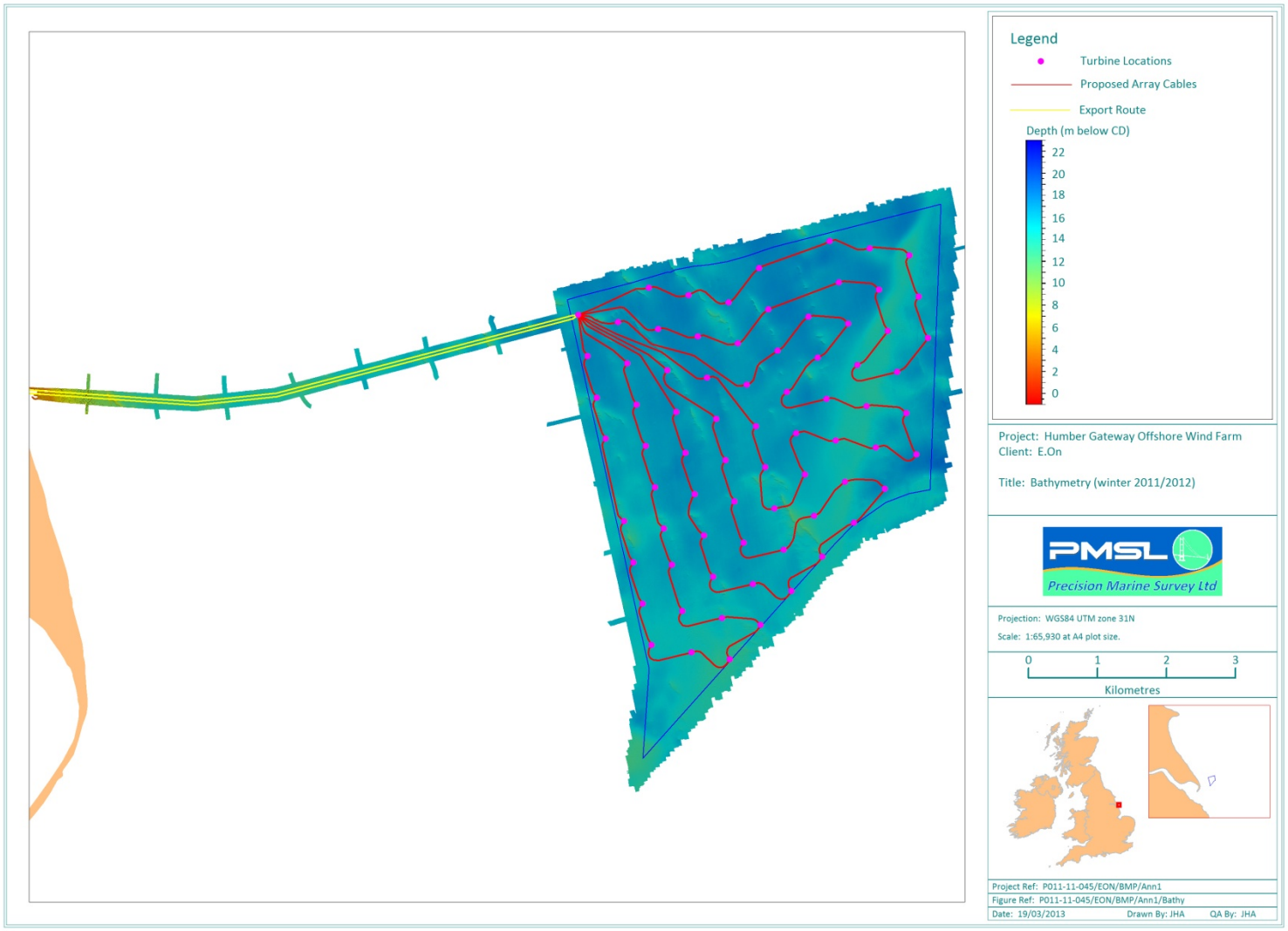


Figure 1. Site layout and bathymetry

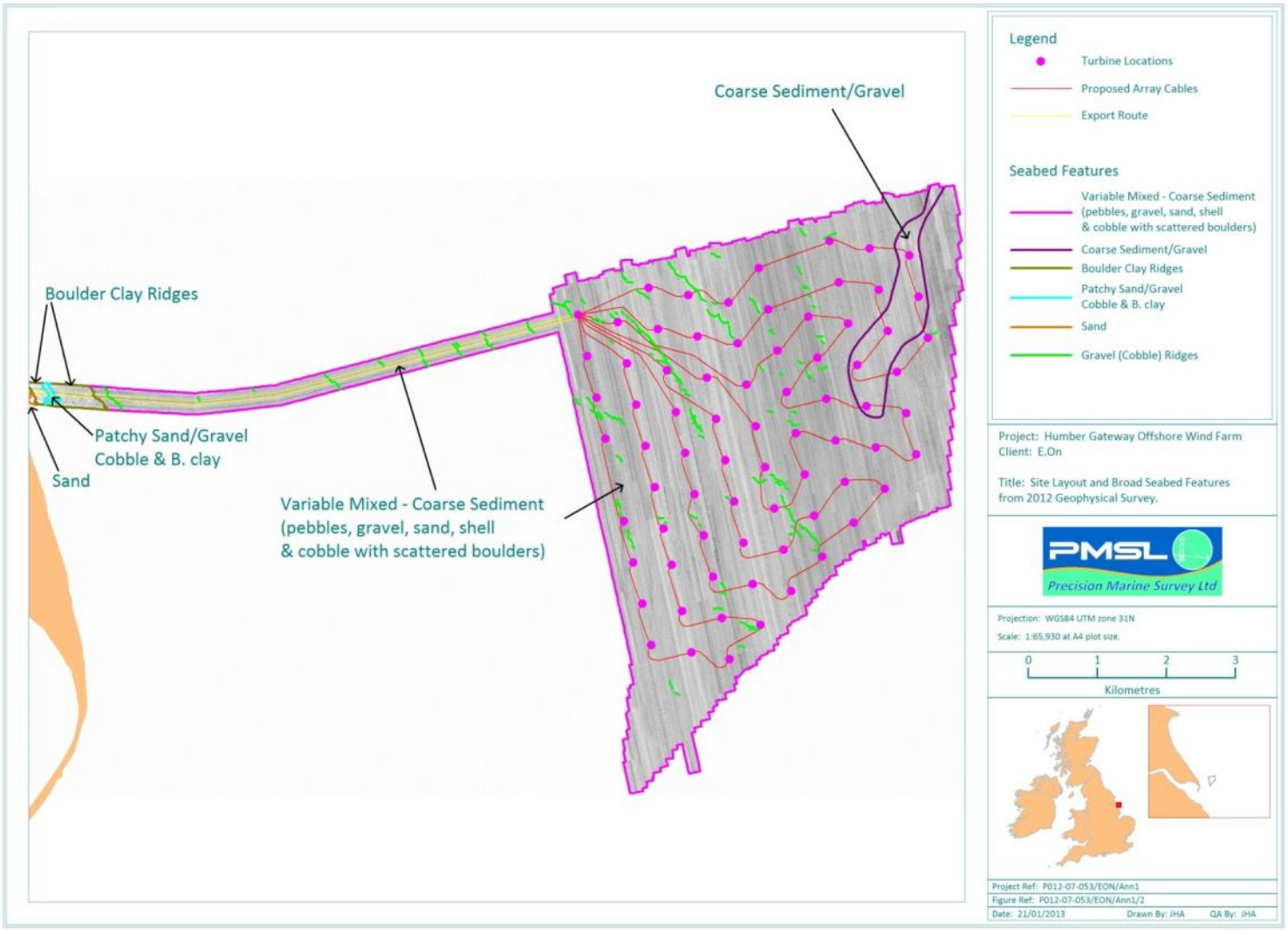


Figure 2. Broad seabed features

3. Annex I Survey Assessment

3.1 Reason for survey

The requirement for Annex I habitat survey is outlined in condition 3.1.10 of the Marine Licence (previously 9.33 of the FEPA licence) as follows:

The Licence Holder must carry out a pre-construction survey to determine the location and abundance of Annex 1 habitat in the vicinity of the array and cable route. Should Annex 1 be identified, the Licence Holder is required to undertake an assessment of the need to micro-site individual turbine structures, inter array cable or export cable. If micro siting is required, the Licence Holder must inform the Licensing Authority immediately. The results of the survey and assessment shall be submitted to the Licensing Authority and NE within one month of the completion of the survey. Construction must not commence without the written agreement of the Licensing Authority.

In consideration of Marine Licence condition 3.1.10 and the objectives set out above, the Annex I surveys and subsequent post construction monitoring will aim to test the following hypothesis:

Establishment of the Humber Gateway Offshore Wind farm causes a significant alteration to the extent and status of Annex 1 reef features at the wind farm site.

The Annex I survey has identified locations of confirmed Annex I features, with particular reference to the wind turbine locations, array and export cables and the assessment also provides an indication of the distribution of potential Annex I habitat and features elsewhere within the geophysical survey boundaries in the development site. The Annex I Micrositing Assessment report (reference HUM-ECH-ECF-PLA-0005_03) sets out methodology undertaken to avoid Annex I features, where possible, through micrositing. Micrositing was not possible in every case, due to engineering, planning and physical constraints therefore, a residual number of Annex I features are affected by the development, which are identified and detailed within the Annex I Micrositing Assessment report.

Together, these Annex I survey results and the Annex I Micrositing Assessment report are issued to the MMO and Statutory Consultees to discharge Marine Licence condition 3.1.10 (as previously contained in FEPA licence as condition 9.33).

3.2 Annex I Reef Habitat Definitions

Reefs are one of the UK marine habitats defined under Annex 1 of the EC Habitats Directive to be protected by the designation of Special Areas of Conservation (SACs). The definition of the term 'reef' in the context of the Habitats Directive is given in the Interpretation Manual of European Union Habitats (CEC, 1999) and subsequent revisions in 2007 (CEC, 2007). These provide a definition of reef as "*submarine, or exposed at low tide, rocky substrates and biogenic concretions, which arise from the sea floor in the sublittoral zone*

but may extend into the littoral zone where there is an interrupted zonation of plant and animal communities. These reefs generally support a zonation of benthic communities of algae and animal including concretions, encrustations and corallogenic concretions" The revised definitions from 2007 provide further detail regarding habitats further offshore as follows: "*Reefs can be either biogenic concretions or of geogenic origin. They are hard compact substrata on solid and soft bottoms, which arise from the sea floor in the sublittoral and littoral zone. Reefs may support a zonation of benthic communities of algae and animal species as well as concretions and corallogenic concretions*"

The 2007 interpretation manual further clarifies the terms used in the reef definition as follows:

1. Biogenic concretions are defined as concretions, encrustations, corallogenic concretions and bivalve mussel beds originating from dead or living animals, i.e. biogenic hard bottoms which supply habitats for epibiotic species.
2. Geogenic origin means reefs formed by non biogenic substrata.
3. Hard compact substrata are rocks (including soft rock, e.g. chalk), boulders and cobbles (generally > 64 mm in diameter).
4. Arise from the sea floor means the reef is topographically distinct from the surrounding seafloor.
5. Sublittoral and littoral zone means the reefs may extend from the sublittoral uninterrupted into the intertidal (littoral) zone or may only occur in the sublittoral zone, including deep water areas such as the bathyal. Such hard substrata that are covered by a thin and mobile veneer of sediment are classed as reefs if the associated biota is dependent on the hard substratum rather than the overlying sediment. Where an uninterrupted zonation of sublittoral and littoral communities exists, the integrity of the ecological unit should be respected in the selection of sites. A variety of subtidal topographic features are included in this habitat complex such as: Hydrothermal vent habitats, sea mounts, vertical rock walls, horizontal ledges, overhangs, pinnacles, gullies, ridges, sloping or flat bed rock, broken rock and boulder and cobble fields.
6. Examples of animals forming biogenic reefs in the North Atlantic including North Sea: Polychaetes (e.g. *Sabellaria spinulosa*, *Sabellaria alveolata*, *Serpula vermicularis*), bivalves (e.g. *Modiolus modiolus*, *Mytilus* sp.) and cold water corals (e.g. *Lophelia pertusa*).

The classification of Annex I reef has been further refined by the UK statutory nature conservation agencies purposes to assist in the identification of reef habitat (Johnson, 2002) which provides further information on substratum, height boundaries, depth, topography and size. Whilst no minimum size for Annex I reef is stated in the definitions the UK statutory nature conservation agencies maintain that reefs should be of sufficient size to "maintain its structure and function" and the interpretation for biogenic reef in coastal waters from the UK Marine SAC Project derived by Holt *et al.* (1998) includes the following definition "*Solid, massive structures which are created by accumulations of organisms, usually arising from the seabed or at least clearly forming a substantial, discrete community or habitat which is very different from the surrounding seabed. The structure of the reef may be composed almost entirely of the reef-building organism and its tubes or shells or it may to some degree be composed of sediments, stones and shells bound together by the organism*".

This definition was based on a number of criteria namely that a biogenic reef " *should be substantial in size (generally of the order of a metre or two across as a minimum, and somewhat raised, mainly in order to disqualify nodule like aggregations such as may be formed by S. spinulosa and scattered small aggregations such as occurs with many of the species under consideration)*", and "*should create a substratum which is reasonably discrete and substantially different to the underlying or surrounding substratum, usually with much more available hard surfaces and crevices on and in which other flora and fauna can grow*".

In UK coastal and inshore waters the most common biogenic reefs are those comprised of *Sabellaria alveolata*, *S. spinulosa*, *Mytilus edulis*, *Modiolus modiolus* and *Serpula vermicularis* whilst geogenic reefs include bedrock reef and stony reef.

In the context of the Humber Gateway, the main Annex I reef feature of interest which are considered to have a potential presence within the development area include *Sabellaria* reef and stony reef both of which have been recorded in some areas off the mouth of the Humber and in the vicinity of the Humber Gateway development site. *S. spinulosa* is a commonly recorded species in coastal waters off the east coast whilst *S. alveolata* has also been recorded in nearshore habitats off the Holderness coast just north of the Humber estuary. Some areas of stony were also been identified within the development site during the 2011 geotechnical surveys.

3.2.1 *Sabellaria* Reef

The two species of *Sabellaria* vary somewhat both in terms of distribution and reef morphology. *S. alveolata* is predominantly an intertidal species although it may extend into the shallow sublittoral and UK represents the northern extremity of this species. As such it is primarily found on the south and west coast of the UK (between Lyme Regis and the Solway) although it has also been recorded off the east coast including off the Humber Estuary. This species can form extensive reef structures up to 1m high in which the tubes of the worms form tightly packed concretions on cobble, pebble or bedrock with a characteristic honeycomb appearance. *Sabellaria spinulosa* has a somewhat wider distribution and is primarily found in the shallow sublittoral and is widespread around the UK and common off the east coast and in particular in the Humber and Greater Wash region. This species tends not to form extensive reef formations but instead is either solitary or found in low-lying aggregations of tubes in mixed sediment or sometimes encrusting cobbles and pebbles. However, in some areas (e.g. the Wash and adjacent waters) this species may form more extensive reef structures which cover large areas of seabed and some areas of reef have also been recorded off the mouth of the Humber.

In terms of *Sabellaria*, in addition to Annex I reef protected under the Habitats Directive, statutory protection in the UK for intertidal examples of *S. alveolata* may be achieved through SSSI designation and both species of *Sabellaria* may occur as sub-features of non-reef Annex 1 habitats (e.g. 'intertidal mudflats and sandflats' or 'Sandbanks which are slightly covered by seawater all the time'). Biodiversity Action Plans (BAPs) have also been defined for both *Sabellaria alveolata* and *S. spinulosa* and *S. spinulosa* reefs are also listed as a threatened and/or declining habitat under the Convention for the Protection of the

Marine Environment of the North-East Atlantic (OSPAR Convention) (OSPAR Commission, 2008a).

The OSPAR description of *S. spinulosa* reef habitat (OSPAR Commission, 2008b) distinguishes two sub-types of reef namely *S. spinulosa* reefs on rock (EUNIS code: A4.22; CR.MCR.CSab under the National Marine Habitat Classification for UK and Ireland), and *S. spinulosa* reefs on mixed (sediment) substrata (EUNIS code: A5.611; SS.SBR.PoR.SspiMx). The OSPAR definition states that such reefs should have a minimum area of 25m^2 and that "*Sabellaria* covers 30% or more of the substrata and needs to be sufficiently thick and persistent to support an associated epibiota community which is distinct from surrounding habitats".

Criteria for *Sabellaria* reef have also been defined by Gubbay (2007) which provides a guide to 'reefiness' to assist in the classification of reef from survey data as described in Section 4.

3.2.2 Stony Reef

Stony reefs are geogenic reef forms which include bedrock reef and stony or cobble reef where bedrock or stable boulders and cobbles arise from the surrounding seabed creating a habitat that is colonised by a variety of reef flora and fauna. Cobble reefs are considered to be a sub-type of stony reefs, which also include those reefs formed by boulders and also some areas of iceberg ploughmarks. Stony (cobble) reef are comprised of sediments which are between 64mm and 256mm in diameter. Such habitats may include other (finer) sediments with the cobbles either matrix or clast supported. Criteria for stony reef are as per Irving (2009) and given in Section 4.

3.3 Objectives

As outlined in the BMP, the Annex I survey methodology utilised geophysical survey data from the winter 2011/2012 bathymetric and geophysical survey within the turbine array and export cable route (Section 2) to identify areas of potential Annex I habitat (*Sabellaria* reef and cobble reef). This information, in addition to information of potential reef distribution gained from previous surveys (Section 3.4), were used to define a series of Annex I survey sites.

The survey sites were selected to target those areas where potential Annex I habitat intersected or were in close proximity to the proposed wind turbine, array and export cable locations. In such areas, drop down video survey was undertaken following standard methodologies, as described in the BMP, to identify Annex I as well as the extent and status of the Annex I features.

The assessment of reef type/status used guidance within Hendrick and Foster-Smith (2007) for *Sabellaria* reef and Gubbay (2007) and Irving (2009) for stony reef to classify areas of potential reef.

3.4 Previous Surveys

Data from a number of surveys undertaken during the development phase of Humber Gateway were used to provide additional information on the potential distribution of Annex

I reef and provide contextual information on potential habitat distribution. A number of these surveys have been referred to in relation to the Annex I survey, as follows:

- 2004 Benthic Characterisation Survey: Benthic survey reported in the Humber Gateway Environmental Statement. This also incorporated some drop down video for Annex I assessment.
- 2011 Geophysical Survey: Multibeam and sidescan undertaken prior to geotechnical works & UXO assessment within 120m boxes around proposed turbine sites and Cone Penetration Testing (CPT) sites along the export route. Undertaken in late spring/summer 2011.
- 2011 Annex I survey: Drop down video survey at turbine and CPT sites undertaken prior to geotechnical investigations undertaken in March 2011.
- 2011/2012 winter Geophysical Survey: Multibeam and sidescan undertaken across the full development site to fulfil BMP and cable routing requirements.
- 2012 Export route video survey: Drop down video survey undertaken along the export route for Annex I assessment with regard to export routeing options.
  2012 Annex I groundtruthing survey: Drop down video survey undertaken along the export route and array cables to assess potential Annex I habitat in relation to geophysical data.

3.5 Annex I Assessment Process

As described in the BMP, the protocol for Annex I habitat assessment followed the process:

1. Geophysical Survey (multibeam and sidescan) - this was carried out in winter 2011/2012 during the bathymetric survey as a required component of the BMP;
2. Analysis & Interpretation of geophysical data, groundtruthing and calibration;
3. Identification of potential Annex I from geophysical survey results and selection of survey sites based on the potential Annex I locations;
4. Provision of detailed survey scope to Licensing Authority;
5. Annex I drop down video survey;
6. Analysis & Assessment of Annex I survey results, including positive identification of location, extent and grading of any Annex I;
7. Consultation with Licensing Authority (via Annex I Micro Siting Assessment Report (reference HUM-ECH-ECF-PLA-0005) and Annex I survey report).

As outlined in Section 2, the bathymetric and geophysical survey included multibeam (swathe) bathymetry and sidescan sonar across the entire development site and export route.

The outputs from the geophysical survey were then examined in conjunction with:

- existing video data obtained during previous Annex I survey data undertaken at turbine locations in 2011 (as part of the geotechnical investigations);
- additional Annex I survey along the export cable route (November 2011 & May 2012)
- groundtruthing video survey undertaken in May 2012.

This process identified discrete areas of seabed which differed in topography from the adjacent seabed (e.g. gravel ridges) and/or those areas with sidescan data suggesting harder/rougher ground which may have comprised of cobble/boulder or include areas with *Sabellaria* reef potential. This information was then reviewed in order to assess likely areas of potential reef and to design a series of survey sites for approval of the Licensing Authority, described in the detailed Annex I and Benthic Survey Methodology report (reference HUM-ECH-ECF-PLA-0005_03).

In terms of Annex I habitats, the detailed drop down video survey of turbine locations (including sites 100m to the north, south, east and west) and Cone Penetration Testing (CPT) sites in the vicinity of the export corridor undertaken in March 2011, recorded Annex I reef (stony reef) at turbine site G60 with one other area recorded 100m east of turbine site 19 and also an area at CPT site 5 just to the north of the current the export route. Assessment of these areas in relation to geophysical survey data indicated that these corresponded to the areas of gravel ridges described in Section 2.3.2. Subsequently, a groundtruthing exercise was undertaken in May 2012 at a number of these habitats which indicated that the majority of these ridge features are likely to qualify as Annex I stony reef with the boundaries of these features corresponding closely to areas of elevated seabed.

Adjacent to these features are often areas of seabed with somewhat higher cobble content but or patchy small scale collections of cobbles with limited elevation and such habitats were patchily distributed across the development site as indicated by areas of slightly rougher seabed from multibeam and sidescan data usually forming a narrow area immediately adjacent to the main ridges. During the assessment and review of the 2011 video survey data with Natural England, such habitats were not considered reef and are considered transitional or borderline habitats.

The 2011 geotechnical surveys did not identify any areas of *Sabellaria* reef at the turbine locations or CPT sites although it is known from the 2004 benthic characterisation survey and previous video surveys that *Sabellaria* is widespread throughout the area (notably *S. alveolata* inshore and *S. spinulosa* offshore) in non-reef form with low to moderate abundances within the sediments or patchy encrustation on harder substrata. For the most part *Sabellaria* populations off the Yorkshire coast and Humber region appear to form aggregations within mixed sediment or thin patchy crusts on larger substrata and generally do not form reef structures. Previous video survey as part of the 2004 benthic characterisation study identified two potential Annex 1 *Sabellaria* reef areas but these were well outside the development boundary. No specific areas were identified from the 2011/2012 geophysical data which were considered likely to specifically correspond to *Sabellaria* reef, although areas of elevated/rougher ground described above for stony reef were also considered to have potential to provide a suitable habitat for the formation of such features and as such these were included for consideration within the Annex I drop down video survey methodology.

A chart showing the Annex I classification at the sites surveyed by drop down video during 2011 and the coverage of video groundtruthing sites surveyed in 2012 is provided in ***Figure 3***. It was considered that the main areas of potential Annex I habitat in the development area would be stony/cobble reef features which are likely to correspond to the cobble

ridges in those areas with pronounced elevation. *Sabellaria* reef was considered to be less likely but those areas of rougher ground or with variable or elevated topography (usually adjacent to gravel ridge areas) particularly closer inshore also warranted assessment. Consequently, these areas were those targeted during the pre-construction Annex I survey. For survey purposes, some provisional boundaries for these features were derived using bathymetric contours and available groundtruthing video data and sidescan to allow planning of survey sites.

The Annex I survey followed methodologies outlined in Section 3 of the BMP and given the wide distribution of features with potential Annex I status, the survey targeted those areas of potential reef along the cobble ridges in close proximity (<150m) to the proposed array cables and export route.

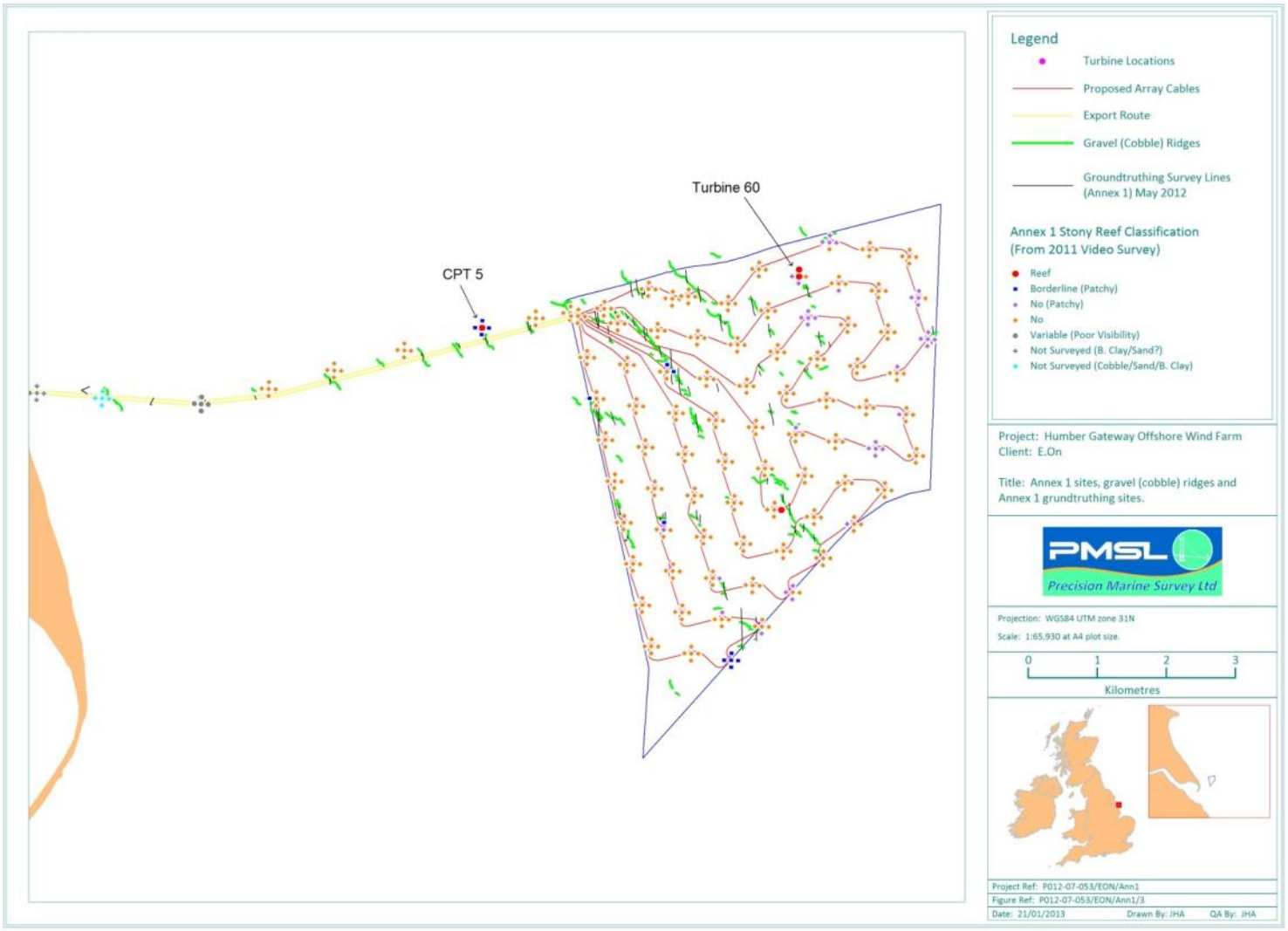


Figure 3. Cobble ridges, Annex I records from 2011 DDV survey and May 2012 groundtruthing sites

4. Annex I Survey Method

The survey method utilised during the Annex I survey followed that provided in the BMP, modified as appropriate to take into account the size and orientation of the Annex I features whilst physically undertaking the survey.

The survey incorporated the use of pre-determined drop down video to assess seabed features identified during geophysical survey as having potential for Annex I habitats following standard procedures outlined in Goggan *et al* (2007), Limpenny *et al* (2010) and other appropriate guidance e.g. Marine Monitoring Handbook procedural guidance 3.5, MALSF Guidelines for the Conduct of Benthic Studies at Marine Aggregate Extraction Sites (Ware and Kenny, 2011).

The Annex I survey utilised an Imenco drop down video and digital stills camera (14 megapixels minimum with HD video recording) with appropriate lighting system and strobe flash. The drop down stills/video system was linked by umbilical to the surface to allow a real-time video feed to the surface for SD video recording with a GPS overlay. A surface PC monitored the vessel position overlain on geophysical data (multibeam/sidescan) to allow fine tuning of survey sites and appropriate lengths of video drifts. The video system was set to allow an oblique view and a camera height to allow optimum images to be obtained given that visibility in this area is often relatively poor (particularly during ebb/flood tides). Digital stills were also taken at representative habitats at each site the video system incorporating a laser scaling system (or physical scale bar) to allow an assessment of scale for sedimentary/biological features. The groundtruthing survey undertaken in May 2012 utilised a Kongsberg 14-208 drop down video/stills camera system. Video was recorded digitally and archived on external hard drive/DVD for further analysis.

The Annex I survey was undertaken during appropriate tides/weather conditions to allow optimum video capture, although given the number of sites to be surveyed, the survey covered periods of ebb/flood tides in addition to the slack water period. At each survey site the immediate survey area was checked for obstructions e.g. static gear before the camera was deployed. Survey positioning was undertaken with an Ashtech Promark GPS system with GPS antenna mounted above the video deployment boom. The drop down video camera system undertook short drifts (50-100m) over the survey site (as guided by real time monitoring of the vessel position in relation to features identified in the 2011/2012 geophysical data) with the video frame occasionally allowed to rest on the seabed to allow still photographs to be extracted as tides permitted. The video camera was kept as close to the seabed as possible to allow for a clear representation of the sea bed and faunal type to be recorded with periodic drops to the seabed for stills. Sites were surveyed along or across the features identified from geophysical survey with sufficient drift to capture boundaries of reef features, adjacent habitats and potential array cable intersections.

The methodology described in the BMP for Annex I survey specified the standard cruciform approach with sites surveyed at a centre point and 100m to the north, south, east and west but also allowed for modifications to this approach depending on the nature of the reef habitats whilst in the field. Given that the majority of the features identified from geophysical survey appear to be relatively narrow, linear features the Annex I survey

targeted sites along the feature at approximately 100m separation yet undertaken at a sufficient drift across these sites such that the edge of the feature (and adjacent habitats) could be mapped in one drop rather than using separate deployments 100m either side or employing an arbitrary 100m cruciform approach (which has the potential to miss boundaries or reef features). Additional drifts to the east or west (or north/south) were surveyed as required, if reef extended beyond the initial deployment which allowed the standard cruciform approach to be applied as appropriate (guided by assessment of geophysical data during the survey). Given that the target features were well defined by bathymetric data, the current survey targeted those features in the immediate vicinity of the array cables or export routes in accordance with Marine Licence condition 3.1.10 and as such targets areas within 150 - 200m of proposed array cables and export routes. Potential Annex I areas outside this zone were generally not surveyed although some of these features were covered as part of the May 2012 groundtruthing survey.

130 stations were targeted for Annex I survey (***Figure 4***) with survey locations along more extensive reef features separated at approximately 100m intervals. Smaller reef features were usually surveyed by a single drift across the features to identify boundaries and assess whether they correspond to provisional boundaries identified from the geophysical data. Survey coverage was also supplemented by the geophysical groundtruthing video survey undertaken in May 2012 and additional Annex I related video obtained during the benthic survey in April 2013.

A map showing the survey lines of each drift in the vicinity of the proposed array cables and export route is provided in ***Figure 5*** along with positions of survey lines from the May 2012 groundtruthing survey and supplementary information gathered in April 2013. These show the areas covered by video in the vicinity of the survey stations described in ***Figure 4*** The survey was undertaken in on the 10th, 11th, 12th and 13th September and the 4th October 2012 onboard the PMSL vessel 'Precision 1'.

An assessment of video footage was made *in-situ* to assess the potential for Annex I habitats (*Sabellaria* reef or stony/cobble reef). These assessments were undertaken using the currently available guidance notes i.e. Gubbay (2007) for potential *Sabellaria* reef, and Irving (2009) for potential stony/cobble reef. The criteria for these reef features are summarised below in ***Table 2*** and ***Table 3.***

The quality of the reef was determined by drop down video drifts across the reef feature and assessed with reference to the 'reefiness' criteria defined in Irving (2009) (and subsequent assessment of Humber Gateway reefs discussed with Natural England in 2011). The reefs were assessed in terms of overall cobble content and patchiness, elevation/distinctness from adjacent habitats, clast vs. matrix supported cobble and coverage by epibiota (reef fauna/flora) as per Irving (2009). These give a general resemblance to reef rather than quality *per se* so this information was also combined with a qualitative assessment of the diversity of the features to provide an overall quality.

For example, reefs which ranged from low to medium resemblance on the various reefiness criteria but were moderately diverse were classed as medium grade. Similar reefs with more diverse fauna/flora were classed as high grade if at least two of the reef resemblance

criteria were high. Reefs with low or medium resemblance criteria but were particularly patchy or with very sparse epibiota were generally classified as low grade.

The extent and grade of the reef was assessed by drop down video across the reef feature in conjunction with geophysical data. This was carried out by monitoring vessel/camera position overlain over the geophysical data in real time during survey and during subsequent analysis to assess the position of the video in relation to potential reef features. The primary reef features (topographically distinct with high levels of cobble) showed good agreement with the geophysical data which enabled reef boundaries to be interpolated using a combination of geophysical data and boundaries derived from video. As such the main reef areas along the more elevated cobble ridges (clast supported) could be delineated with a relatively high level of accuracy taking into account positional variability of the camera in relation to GPS which is within the region of +/- 5m as a conservative estimate.

However, whilst many of the reefs are relatively small, given their linear distribution they are often quite extensive and as such there is a limit as to video coverage possible for a given feature so geophysical data was required to derive full boundaries. However as the main reef habitats - i.e. those with distinct elevation/topographic distinctness and significant (clast supported) cobble content appear to correspond close to geophysical data the extent of reefs should have a relatively high level of accuracy even taking into account their natural variability. The grade of reef takes into account variability of habitat observed during survey but inevitably it is not possible to get 100% coverage of the reefs so relatively broad quality assessments were used to allow for inherent variability.

Where possible, video drifts were undertaken which traverse the entirety of the reef to the opposing side and also cover adjacent non reef habitat either side. Where reefs are in close proximity to each other a video drift which crossed from one reef to the next was usually employed (tides permitting) or a separate video drop was used to cover the intervening area. If video evidence and geophysical evidence suggested that the reefs were separate then boundaries have been drawn as such – those with some uncertainty (e.g. those which comprise of several reef ridges which grade into each other) are typically indentified as one feature - albeit with some likely variation along their length. As there was close agreement between the boundaries of the main reefs identified from video and geophysical data this should allow reasonable confidence in separation of two reefs in close proximity.

Table 2. Criteria for *Sabellaria* reef (Gubbay, 2007)

Characteristic	Not a reef	'Reefiness'		
		Low	Medium	High
Elevation (cm) (average tube height)	< 2	2-5	5-10	> 10
Extent (m^2)	< 25	25-10,000	10,000 - 1,000,000	> 1,000,000
Patchiness (% cover)	< 10	10-20	20-30	> 30

Table 3. Criteria for stony/cobble reef (Irving, 2009)

Characteristic	Not a stony reef	'Resemblance' to being a stony reef		
		Low	Medium	High
Composition	< 10%	10-40% Matrix supported[1]	40-95%	> 95% Clast supported[2]
Notes: Diameter of cobbles being greater than 64 mm. Percentage cover relates to a minimum area of 25 m^2. The 'composition' characteristic therefore also includes 'patchiness'.				
Elevation	Flat seabed	< 64 mm	64 mm - 5 m	> 5 m
Notes: Minimum height (64 mm) relates to minimum size of constituent cobbles. This characteristic could also include 'distinctness' from the surrounding seabed.				
Extent	< 25 m^2	←	> 25 m^2	→
Biota	Dominated by infaunal species			> 80% of species present composed of epifaunal species

[1] Implies that there is finer sediment surrounding each cobble.
[2] Implies that the cobbles are touching each other.

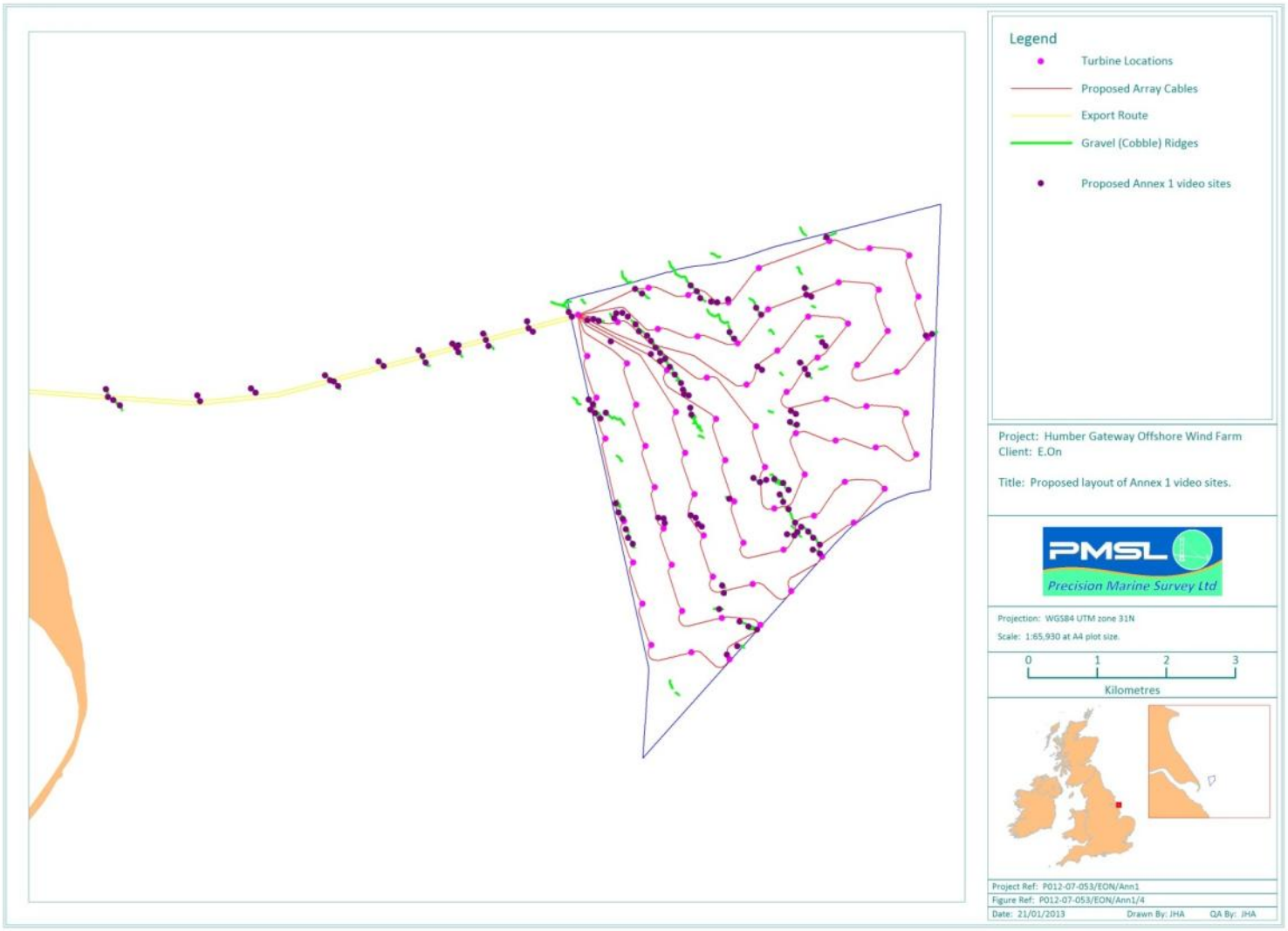


Figure 4. Indicative layout of targeted Annex I survey sites

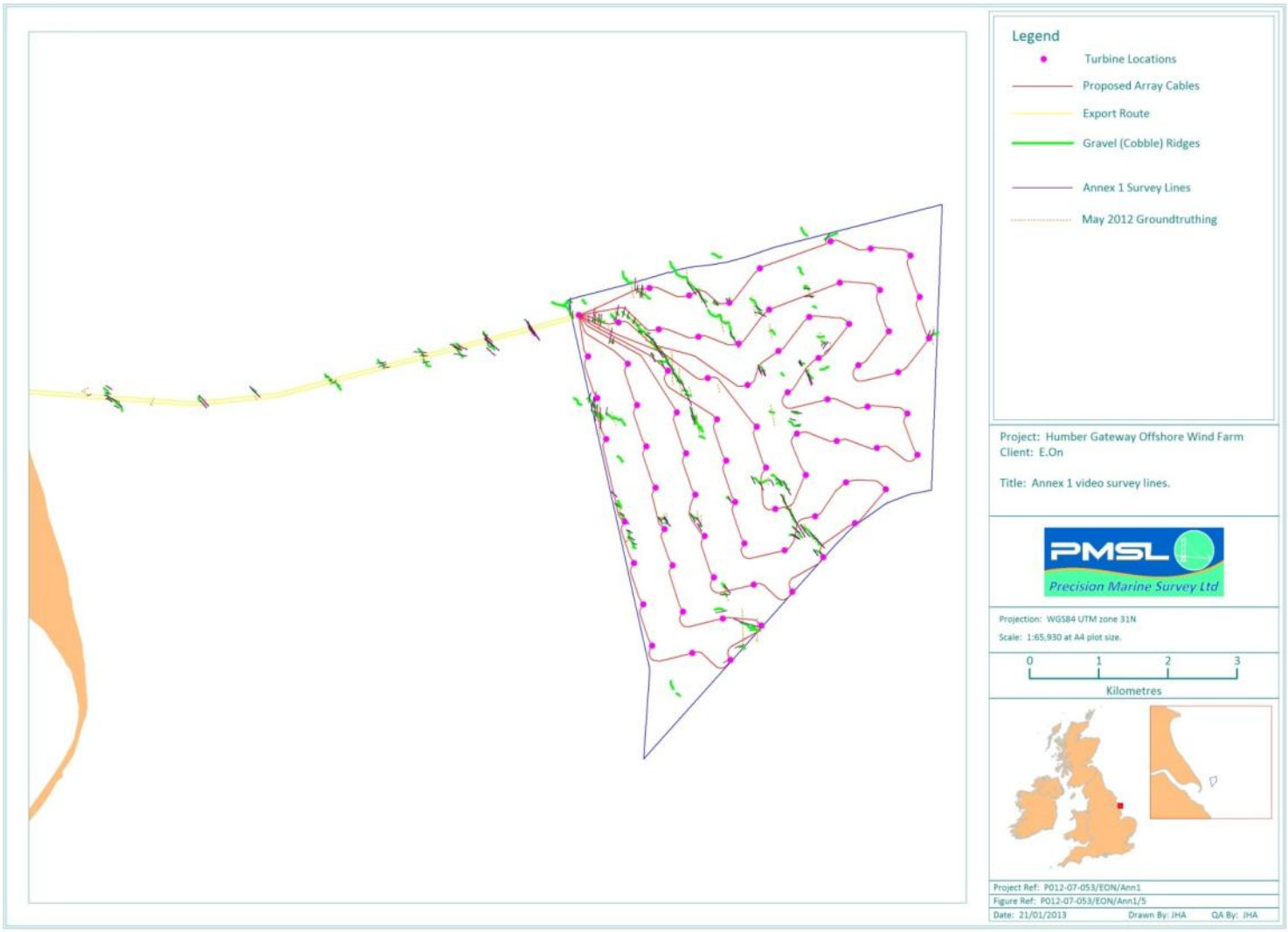


Figure 5. Annex I survey lines (including groundtruthing surveys from May 2012)

5. Results

An assessment of the video data obtained during the Annex I survey has been used in conjunction with the geophysical data obtained for the project to derive boundaries for Annex I features within the development site. Derivation of boundaries were based on drop down video records of Annex I along the video transects; where a good match between video data and geophysical data was present, the bathymetric / sidescan records were used to interpolate estimated boundaries for a given feature. Provisional Annex I boundaries were also derived based on geophysical data for those areas not covered by video survey i.e. those areas distant from array cables/turbine sites. Larger reef features with distinct/elevated cobble ridges include boundaries for the main (clast supported) reef ridge in addition to the overall Annex I boundary. Small scale cobble features (including discrete transitional cobble habitats) have also been identified and mapped where possible from video and geophysical data. The identified reef features are often adjacent to variable transitional habitats with increased cobble content. These transitional habitats are often present immediately adjacent to the main reefs and whilst these areas may exhibit increased cobble content or include smaller patches/ribbons of cobble interspersed with less cobbly habitat these are too patchy or small scale to be considered reef. As such the boundaries shown in here represent core cobble reef habitats which are sufficiently distinct and consolidated to meet the reef criteria (Irving, 2009).

Reef features along the export route have only been mapped as far as existing geophysical or video data allows and these boundaries represent a more refined version of the Annex I risk zones utilised in the Annex I Micrositing Assessment report (Report HUM-ECH-ECF-PLA-0005_03). A summary map showing the distribution of Annex I habitat is provided in ***Figure 6***.

The results of the Annex I survey have been summarised for the development site, with the export route summarised in Section 4.1 and the offshore wind farm in Section 4.2. Given the large number of features within the development site, the offshore wind farm area has been divided into a series of zones to simplify reporting. Each sub-section provides an overview of the Annex I features present within these zones, with emphasis on those which intersect construction areas (array or export cables) together with representative stills of the feature for each area provided.

5.1 Export Route

Along the export route, ten areas of Annex I reef have been identified (***Figure 7***). All of these features correspond to areas of gravel (cobble) ridges and as such have been classified as geogenic stony (cobble) reef. No areas of biogenic reef (e.g. *Sabellaria* reef) were recorded.

Within the export route, sediments adjacent to Annex I features were mixed coarse sediments comprising pebbles, gravel, shell and cobble with occasional boulder and occasional areas of exposed boulder clay ridges (known locally as clay huts) at the inshore end of the export route. The extreme inshore end of the export route includes a dense area

of these exposed boulder clay ridges (See section 5.1.1). The exposed boulder clay ridges do not themselves constitute Annex I habitat.

Features conforming with the definition of Annex I existed as stony reef habitats comprising of medium to large cobble or occasionally small boulder forming ridges ranging from 10m to 50m in width and 100m to 300m in length, although a number of these are likely to extend some distance beyond the survey area as illustrated by historic records of gravel ridges from earlier geophysical surveys (**Figure 7**). Habitats vary from well defined and elevated medium grade stony reef features which are primarily clast supported (e.g. reefs 1, 6 and 8) to narrower ribbons or bands of cobble which are less well defined and more transitional or patchy in nature with less elevation and vary from matrix supported to clast supported. Inshore examples of these reef habitats along the export route or those within the influence of the Humber plume (and particularly less well defined or less elevated examples) tend to exhibit a degree of siltation and the reefs are generally characterised patchy coverage by a variety of epifauna, notably barnacles, patchy or sparse hydroids and bryozoans (e.g. *Flustra foliacea*) and occasional patches of calcareous red algae and ascidians such as *Dendrodoa grossularia*.

These features are in close proximity to the export route and with the exception of reef 3 which is just outside the export route they either cross the proposed export route (reefs 1, 6, 7, 8 and 9) or intersect the margins (reefs 2, 4, 5 and 10). These features (with the exception of reef 3) have been addressed in relation to export cables route in the *Annex I Micrositing Assessment: Turbine Structures, Array Cabling, Export Cabling & Annex I Features* produced by HWL in January 2013, and updated in April 2013 (reference HUM-ECH-ECF-PLA-0005_03). A summary of each reef feature with representative stills is provided in ***Table 3***, which may be cross referenced to the relevant feature reported in the Annex I Micrositing Assessment report (Report HUM-ECH-ECF-PLA-0005_03).

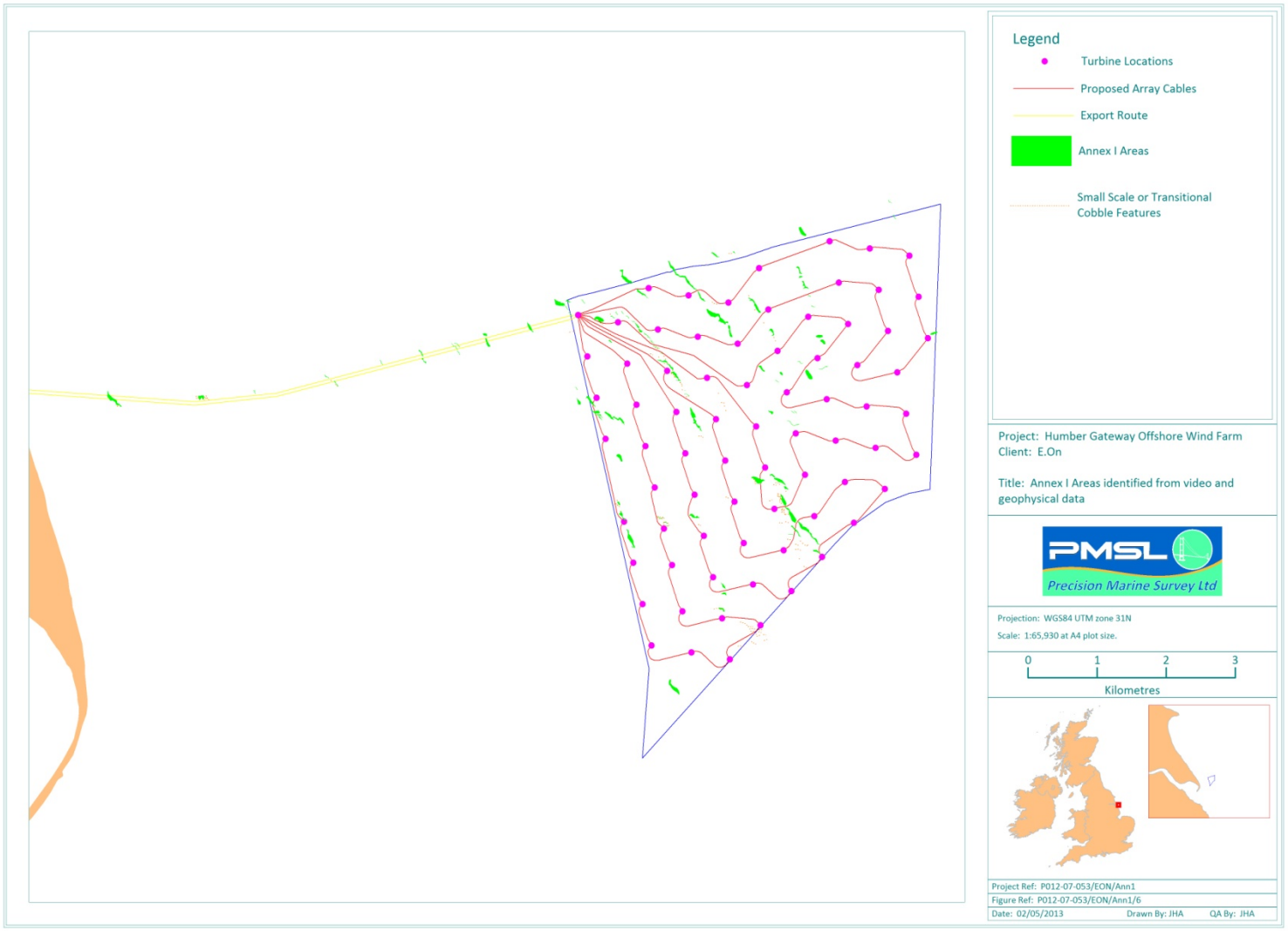
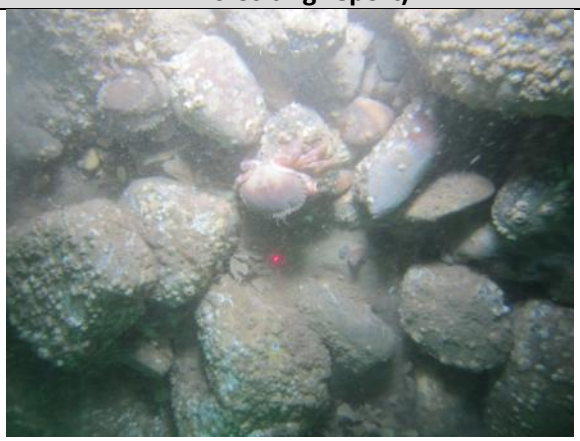
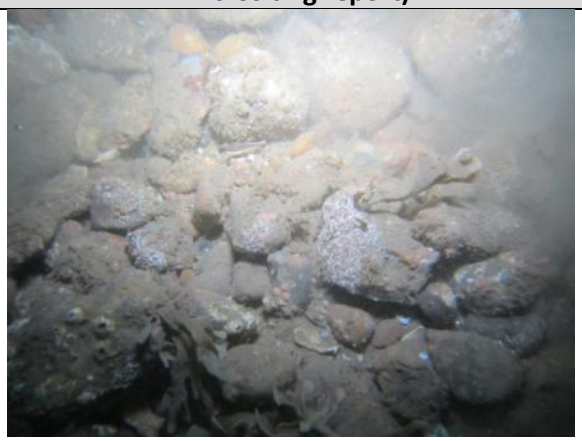
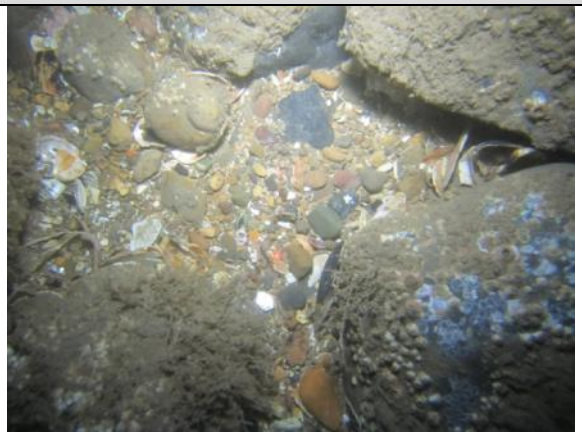
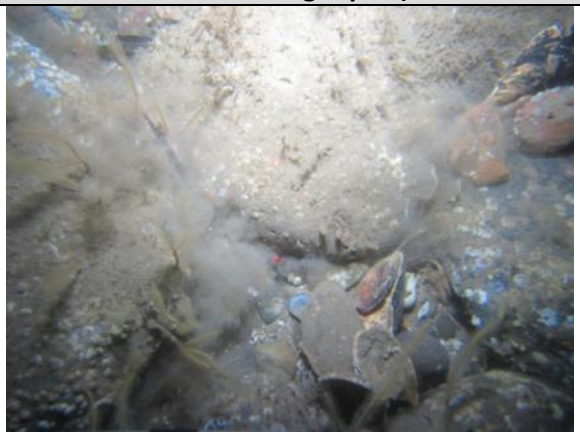


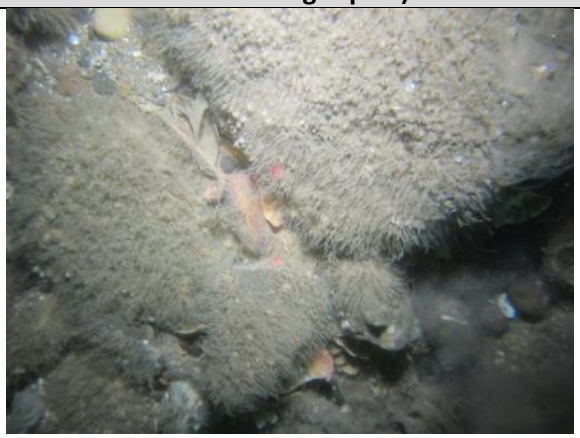
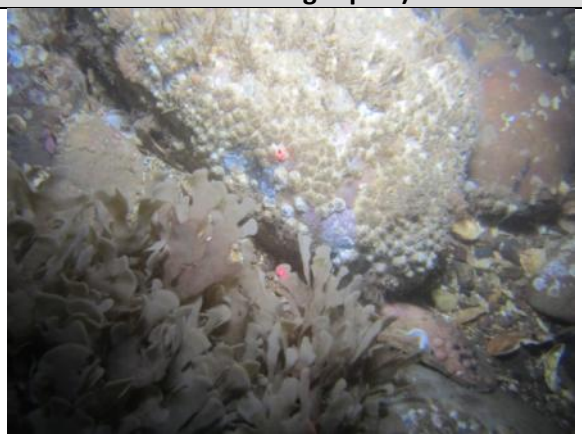
Figure 6. Distribution of Annex I reef features

Figure 7. Annex I features along the export route (including 2008 cobble ridges)

Table 4. Summary of Annex I reef along the export route

Reef Area 1 (reference Ex_A in Annex I micrositing report)	Reef Area 2 (reference Ex_B in Annex I micrositing report)
	
Quality: Medium Distinct & elevated cobble reef (up to 50m in width) crossing full extent of the export route and extending ≥100m to North >150m to South. Areas of more transitional cobble, boulder and mixed sediment or variable narrow bands of cobble are present to the north and west.	Quality: Medium-Low (Variable/Patchy) Variable/patchy area of cobble reef which extends 70m to the North. Situated adjacent to the northern edge of the export route with some narrow bands of cobble habitat intersecting the edge of the export route. Other areas of transitional cobble habitat are present adjacent to this and further north and west.
Reef Area 3 (does not intersect the export route so not included in the Annex I micrositing report)	**Reef Area 4 (reference Ex_C in Annex I micrositing report)**
	
Quality: Medium-Low (Variable/patchy) Narrow bands of cobble (<10m width) in transitional habitat situated 20-30m to the north of the export route. An area of variable (transitional) cobble is also present in the export route but is not considered reef.	Quality: Low to Borderline (Variable/Patchy) Narrow band (<10m width) of cobble habitat on either side of the export route extending at least 100m to the north and to 140m to the south. Variable quality ranging from borderline to low grade with better examples recorded at furthest extent from the export route. Cobble habitat also present in the export route but not reef.

Reef Area 5 (reference Ex_D in Annex I micrositing report)	**Reef Area 6 (reference Ex_E in Annex I micrositing report)**
	
Quality: Low to Medium Narrow band (<10m) of stony reef extending at least 100m to the north. This habitat just reaches the boundary of the export corridor but does not appear to extend further into the export route.	Quality: Medium Two bands of elevated cobble reef 15m in width running to the north and south of the export route & extending at least 100m to the north and 130m to the south. Only the northern area appears to extend into the export route but does not cross the entire extent.
Reef Area 7 (reference Ex_F&G in Annex I micrositing report)	**Reef Area 8 (reference Ex_H in Annex I micrositing report)**
	
Quality: Low to Borderline Two narrow bands (<10m width) of relatively poorly defined cobble reef running into and across the export route and extending up to 50m north. A second reef is present to the south of the export route which extends at least 130m to the south of the corridor.	Quality: Medium Distinct band of elevated cobble reef up to 20m wide running across the majority of the export route and at least 80 to 100m to the south. Another area of reef is present 30m to the north of the export route and extends at least 140m further north.

Reef Area 9 (reference Ex_I in Annex I micrositing report)	Reef Area 10 (reference Ex_J in Annex I micrositing report)
	
Quality: Medium to Low Narrow band of cobble reef (up to 15m width) running across the export route and extending at least 70m north and 50m south.	Quality: Low to Borderline (Transitional) Ephemeral band of variable cobble habitat which just intersects the export route (up to 10m intrusion) and extends 50 to 80m to the north. Patchy and generally poorly defined with better examples of cobble reef habitat further north.

5.1.1 Exposed Boulder Clay Ridges

Whilst not part of the main Annex I survey video work undertaken as part of this study, the results of drop down video (including the May 2012 ground truthing survey) identified an area of exposed boulder clay ridges as described in Section 2.3.1 and 2.3.2. The exposed boulder clay is not Annex I habitat, but it is worth noting, for the engineering challenge it represents to the installation of the export cable. The exposed boulder clay exists in the inshore area (approximately 500m off the intertidal zone extending 500-600m offshore) and is found across the entire north to south extent of the Section 36 consent export corridor, and extends some distance north and south beyond the boundaries of the consent.

There is anecdotal evidence that these features are present further north along the coast and also slightly further offshore. Exposed clay is present off Easington and as far north as Aldbrough (based on historic grab/video sampling) although these tend to be exposed sheets of clay (often with piddocks) in areas where the surface sand/gravel has been scoured away.

The exposed boulder clay exists in relatively shallow water (<10m CD) and is characterised by a dense series of tightly packed exposed boulder clay ridges or mounds, where each ridge or mound can be up to 1m to 2m high, up to 100m long and sometimes several metres wide. These features can be a few metres apart in some areas whilst elsewhere more extensive gaps are present which are characterised by gravels, sand, and patchy cobble or boulder.

The location and topography of these features is provided in ***Figure 8.***

Some representative stills of these features is provided in ***Table 5*** and video survey indicates that many of these features have relatively little epibiota, although it is noted that some of these clay ridges have a sparse and patchy coverage by hydroids, or occasionally crustose algae or sponge. It is considered that the ridges may sometimes provide shelter for local shellfish populations. These features also often have numerous holes or pits which are presumably formed by boring bivalves such as piddocks, which tend to inhabit exposed boulder clay in the shallow sub-tidal all along the Holderness coast.

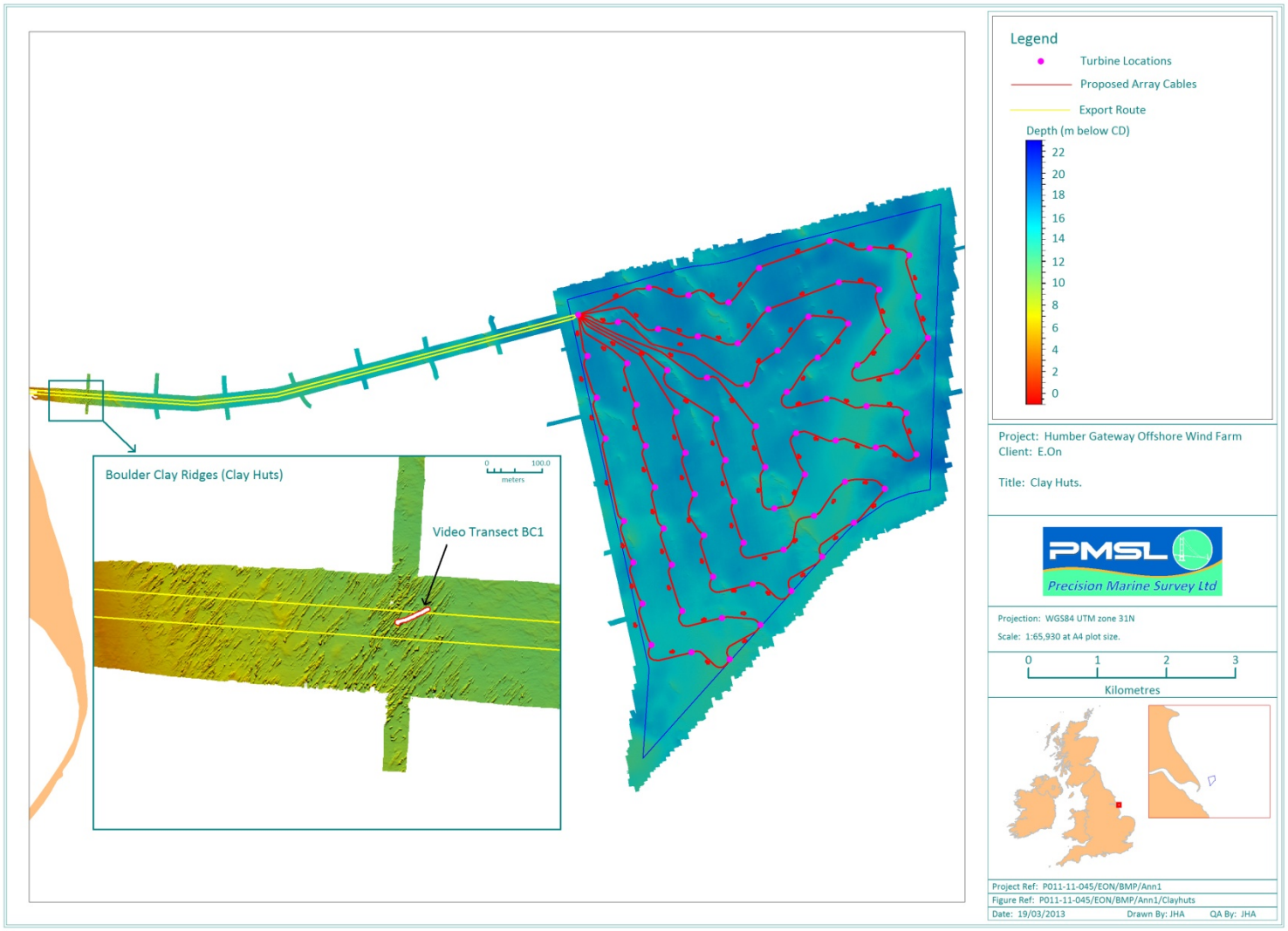
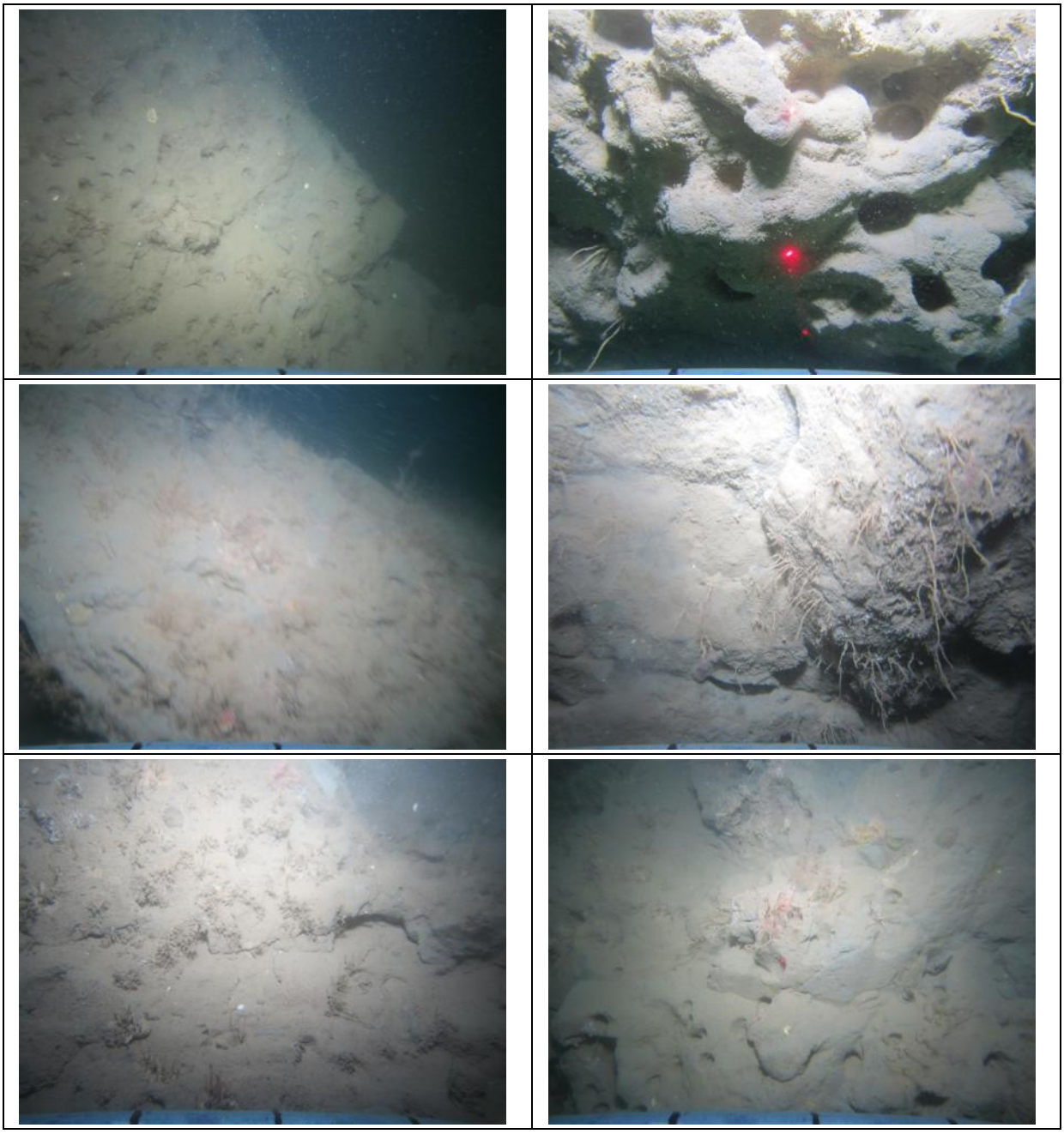


Figure 8. Location of exposed boulder clay ridges (known locally as clay huts)

Table 5. Example stills of boulder clay ridges taken along transect BC1



5.2 Offshore Wind Farm Area

Within the development site approximately 120 discrete cobble ridges were identified and these range from discrete ribbons or bands of reef to larger, often linear reef areas (***Figure 10***). The boundaries identified have attempted to delineate between separate reef features based on geophysical data and drop down video although in some areas they tend to comprise a series of ridges which grade into each other and in such cases they have been incorporated into a single reef feature (unless video evidence suggests otherwise).

The results of the Annex I video survey indicated that these features comprise of similar habitats to those outlined for the export route i.e. areas of cobble habitat which often form elevated linear stony/cobble ridges which are classified as Annex I stony/cobble reef. No areas of *Sabellaria* reef were recorded during the survey although the species was recorded in low abundances, in some locations.

As described in Section 5 the identified reef features are often adjacent to highly variable transitional habitats which may include increased cobble content in relation to habitats further afield. These transitional habitats which are often present immediately adjacent to the main reefs often have variable cobble content and may include smaller patches/bands of cobble but are too patchy or small scale to be considered reef and as such the boundaries shown here represent core cobble reef habitats which are sufficiently distinct and consolidated to meet the reef criteria (Irving, 2009).

In order to summarise the results of the distribution of these features across the offshore wind farm area, the area has been divided into 11 zones as identified in ***Figure 9*** and are summarised below in sections 4.2.1 to 4.2.21. Where these areas include reef which intersects, or is in very close proximity to the cable array, examples of seabed habitat at these intersection points have also been described.

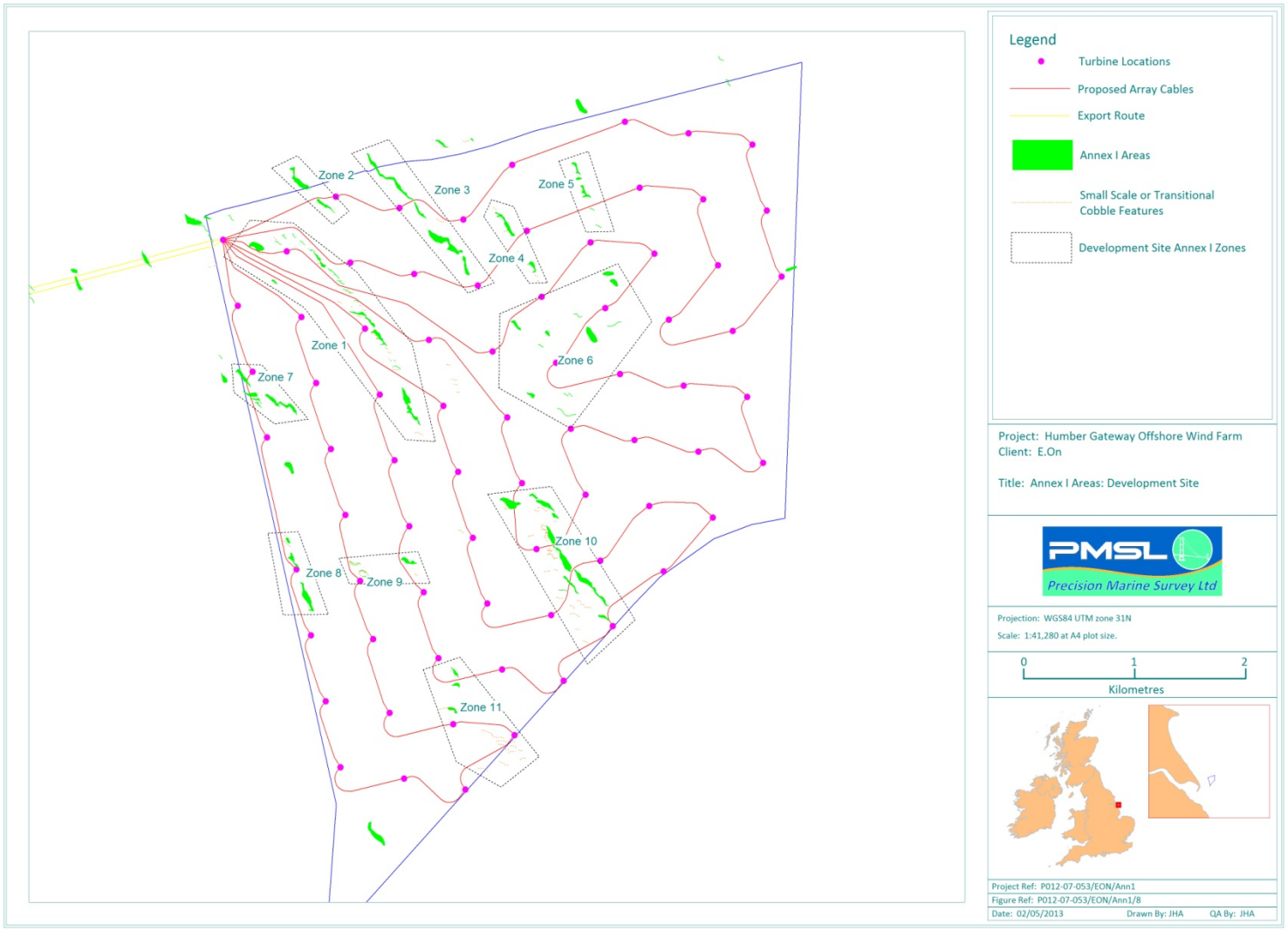


Figure 9. Annex 1 assessment zones within the development site

5.2.1 Zone 1

Zone 1 located to the north west of the offshore wind farm development site includes the area around the sub-station (HGOS) and adjoining array cable string to turbines B04, C04, C05, C06, D05 and D06 (***Figure 10***).

In this zone, a series of over 30 narrow linear reef features are present, predominantly running NW to SE. The majority of these features comprise of narrow ribbons of medium to large cobble or small boulders with reefs around 10m in width and 50m to 100m in length. These features tend to be relatively low lying and transitional between matrix supported and fully clast supported and are generally considered low to medium grade reef. The reefs are characterised by moderate coverage by barnacles and other encrusting epibiota, primarily hydroids and bryozoans and occasional patches of ascidians or encrusting sponge. Representative photographs of a number of these features are provided in ***Table 6.***

In addition to these smaller scale reef features, several larger reefs are also present as highlighted by photographs Z1a and Z1b along the array cable between HGOS and turbine B04 and also photographs Z1l to Z1n to the east of turbine C05. These features are up to 50m wide and include more clast supported cobble and small boulder with increased elevation. Larger reef features are predominantly medium grade as they are increasingly clast supported with a greater elevation usually several cobbles thick (i.e. within the 64mm to 5m category outlined in Irving, 2009) with elevation up to a metre above adjacent seabed. Similar epibiota is present in these areas although many of the larger cobbles appear to have a scoured appearance with old barnacle scars and pink encrusting algae. These habitats have moderate diversity with a range of epifauna, although coverage is generally quite patchy.

The majority of these features are situated 20m to 60m away from adjacent array cables and do not intersect the array cable routes. Those features which intersect the array cables or in extremely close proximity (<10m) are highlighted in Section 4.2.2 (and are pre-identified within the Humber Gateway Annex I Micrositing Assessment report).

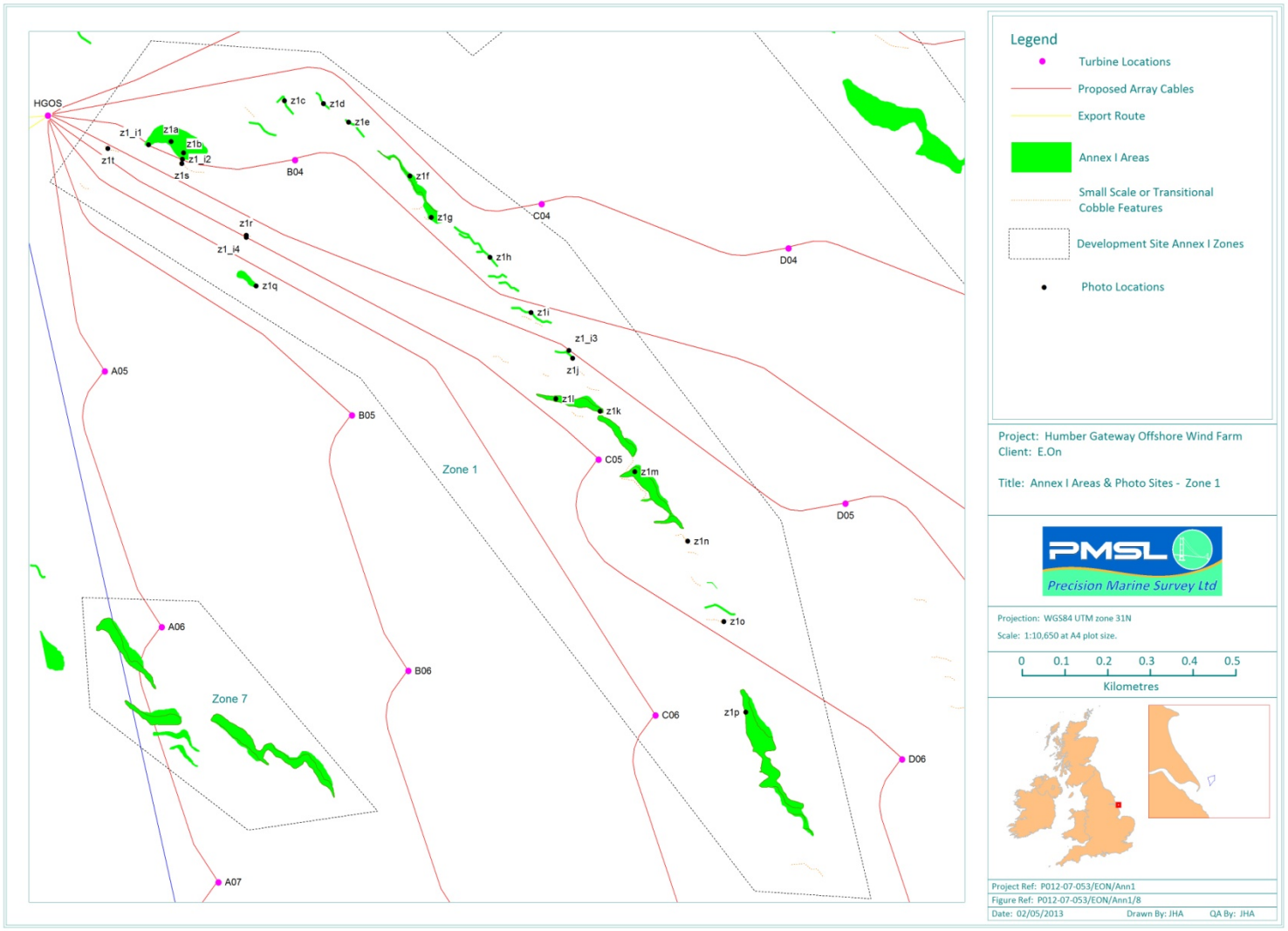
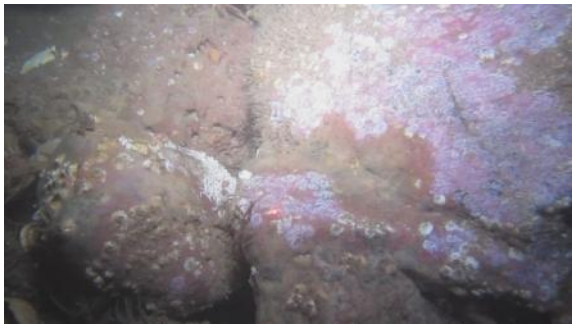
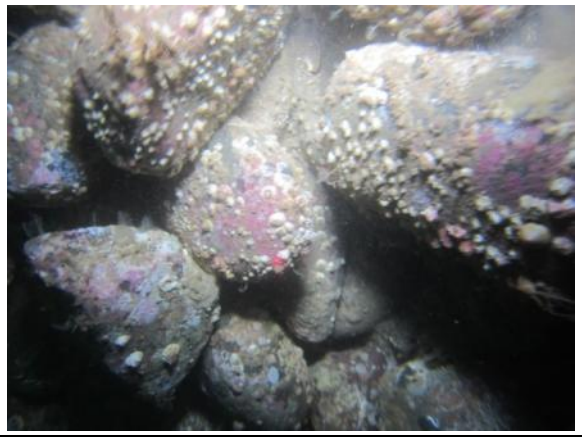


Figure 10. Zone 1 and associated Annex I features with locations of reported photographs

Table 6. Representative photographs from reefs in zone 1.

Z1a	Z1b
	
Z1c	Z1d
	
Z1e	Z1f
	
Z1g	Z1h
	

Z1i	Z1j
	
Z1k	Z1l
	
Z1m	Z1n
	

Z1o	Z1p
	
Z1q	**Z1r**
	
Z1s	**Z1t**
	

5.2.2 Zone 1 Array Cable and Annex I feature Intersections

Annex I features within Zone 1 which intersect array cable routes are identified in the Humber Gateway Annex I Micrositing Assessment Report. Two areas are identified within the Report named as AR_G1 and AR_G2 in the Report, which correspond to points Z1_i1 and Z1_i2 as shown in ***Table 7*** below. At these areas the array cable intersects the edge of a single reef feature at two areas (Intersections Z1_i1 and Z1_i2) which are located along array cable named HGOS-B04 where the array cable route intersects the edge of a larger medium grade reef feature in an area where it starts to grade into transitional or low grade reef.

In addition, two other areas have been identified (Z1_i3 and Z1_i4) where the array cables do not intersect Annex I features but are in close proximity (approximately 10m) although these are not referenced in the E.On Micrositing report as they do not intersect. Areas Z1_i3 and Z1_i4 are located outside two small medium to low grade reef features although the seabed at the array cable location is characterised by transitional, patchy (non-reef) cobble and mixed sediments. No Annex I *Sabellaria* reef was recorded in this zone.

Table 7. Representative photographs from habitats in the vicinity of array intersections within area Zone 1

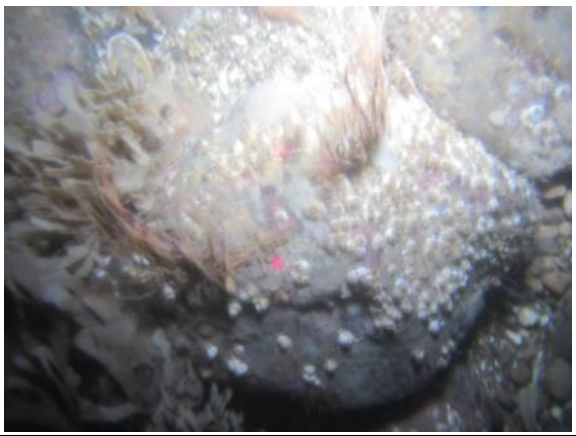
Z1_i1 (AR_G1)	Z1_i2 (AR_G2)
	
Z1_i3	Z1_i4
	

5.2.3 Zone 2

Zone 2 is situated to the north of the wind farm development area and includes two large Annex I reef features to the north and south of array cable between HGOS and turbine C03.

The northern feature is approximately 260m long and up to 50m wide whilst the southern feature is 250m long and 30m to 40m wide. This feature is characterised by medium grade stony/cobble reef comprising of predominantly clast supported large cobble and small boulders. Representative stills from these features are provided in ***Table 8*** with a chart showing the distribution of photographs given in ***Figure 12***. These features exhibit moderate elevation with the reefs several cobbles thick in places although in terms of epifauna they are somewhat sparse/patchy and primarily characterised by patches of barnacles and encrusting polychaetes, calcareous/crustose pink algae, patchy hydroids or bryozoans such as *Flustra foliacea* and occasional ascidians and appear relatively tideswept. No areas of *Sabellaria* reef were recorded in this area.

Table 8. Representative photographs from reefs in area Zone 2

Z2a	Z2b
	
Z2c	Z2d
	

D2e	
	

5.2.4 Zone 2 Array Cable and Annex I feature intersections

The southern Annex I reef within Zone 2 intersects array cable HGOS-C03 at its northern extremity (intersection Z2_i1) in an area of slightly transitional low grade reef where the main reef begins to grade into adjacent non-reef mixed/coarse sediment habitats. An example of seabed habitat at this intersection is provided in ***Figure 11***. The northern reef is some 800m from the cable array.

Figure 11. Seabed at array intersection Z2_i1 (HGOS-C03)

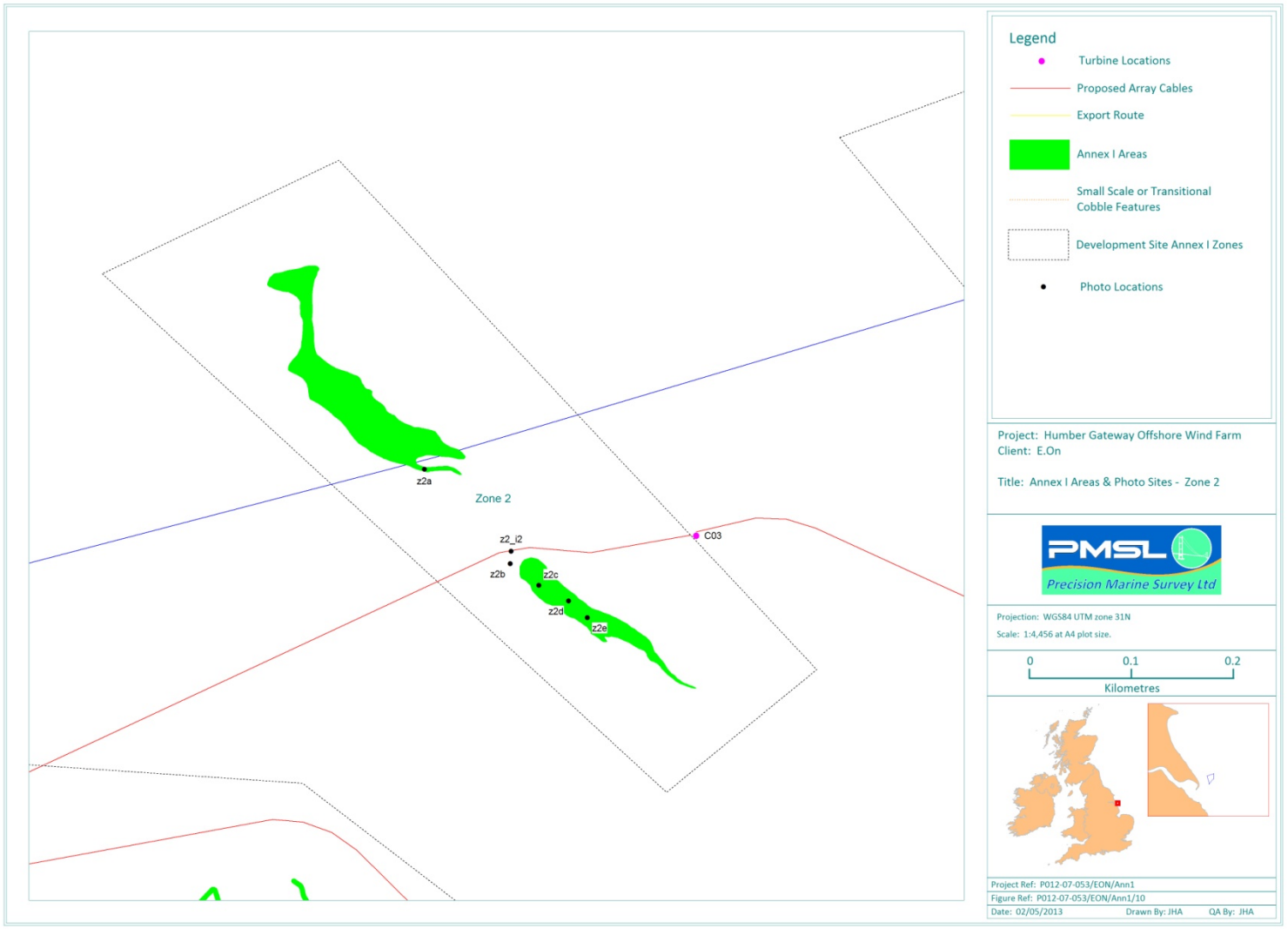


Figure 12. Annex I features in Zone 2 and locations of photographs

5.2.5 Zone 3

Zone 3 is located at the northern end of the wind farm development area, in the vicinity of array cables D03-E04 and D04-F04. In this area, four large linear Annex I reef features are present running NW to SE. Two reefs are present to the north and south of array D03-E04, where the northern reef extends approximately 600m to the north and is around 40m to 50m wide. The reef to the south of array D03-E04 is approximately 200m long and around 20m to 30m wide. Neither of these reefs intersect the proposed array cable which runs across a narrow band of non reef habitat (mixed coarse sediment).

Further south, two large areas of Annex I reef are located between array cables D03-E04 and D04-F04 measuring approximately 375m in length and up to 60m wide whilst the other reef measures 200m by 30m. A smaller reef feature to the east of these is also present forming a narrow ribbon of cobble habitat which is approximately 80m long by 10m wide.

These features are all characterised by cobble and small boulders and have been classified as stony/cobble reef with no areas of *Sabellaria* reef present. The larger reef features include a mixture of medium to large cobble and small boulder on mixed coarse sediment and are primarily clast supported and clearly elevated above seabed. Coverage by cobble varies somewhat within these features with some more matrix supported areas present within the reef particularly towards the margins where they grade into more transitional low grade reef. Adjacent to these features are transitional mixed coarse sediments comprising of pebbles, stones, shell and cobble with patchier areas of higher cobble content which are usually too small to constitute reef but are transitional habitats with small scale low grade/borderline cobble habitat.

The Annex I reefs appear consistent with other areas within the development site and characterised by somewhat tideswept large cobble encrusted with barnacles and patches of calcareous/crustose red algae and a patchy hydroid/bryozoan turf. Characteristic still photographs for the reefs in this area are provided in ***Table 9*** and a map showing the location of stills is given in ***Figure 13.***

Table 9. Representative photographs from reefs in area Zone 3

D3a	D3b
	

Z3c	Z3d
	
Z3e	Z3f
	
Z3g	
	

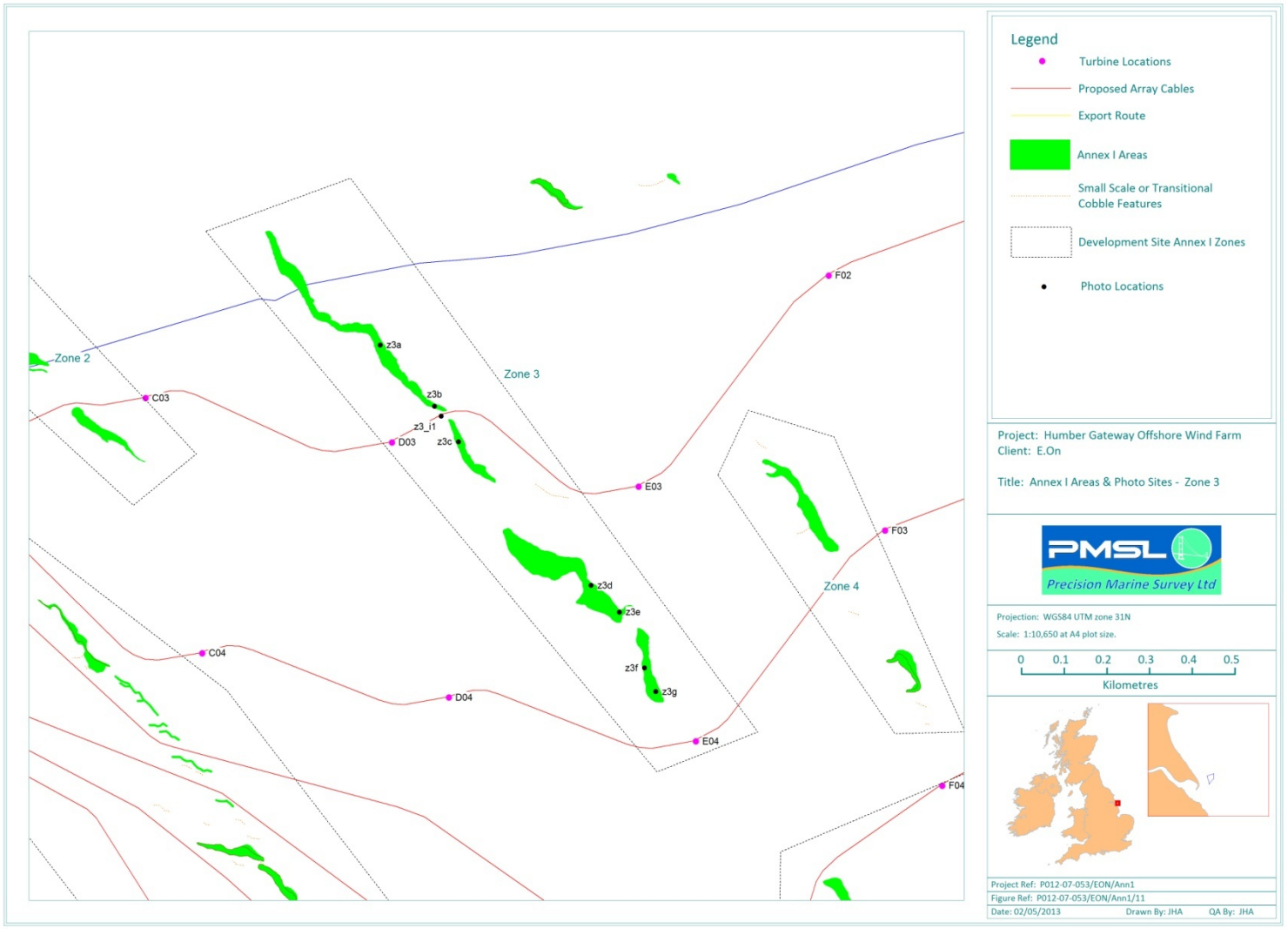


Figure 13. Annex I features in Zone 3 and locations of photographs

5.2.6 Zone 3 Array Cable Intersections with Annex I features

The array cable D03-E03 runs between the two northern reefs in Zone 3 with the main reefs located within 10m of the array cable. Cable routing options through this Zone have been discussed in the Humber Gateway Annex I Micrositing Report (reference Intersection Ar_H in the Report) and a representative still of the seabed in this area is shown in ***Figure 14*** below. The array cable runs through an area of non reef habitat just off the main southern reef which comprises of mixed stones, gravel, shell and cobble with patchy hydroids and *Flustra* on larger cobble along with occasional barnacles or other encrusting fauna.

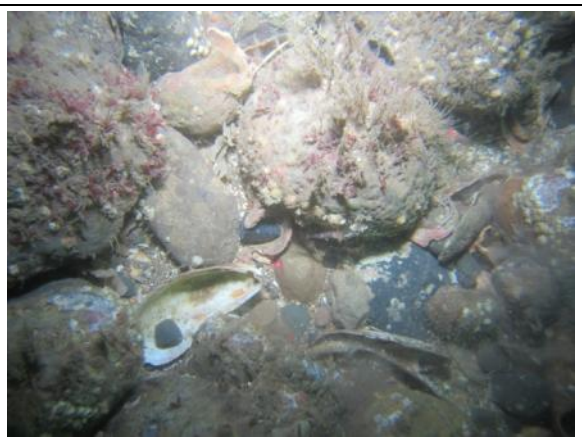
Figure 14. Seabed at array intersection Z3_i1 (D03-E03)

5.2.7 Zone 4

Zone 4 covers reefs either side of cable array E04-F03 at the northern end of the wind farm development area. This Zone contained two main Annex I reef areas to the north and south of the cable array and one smaller band of Annex I reef. The larger reef area to the north is approximately 270m long by 35m wide orientated NW to SE, whilst the reef to the south measures around 100m in length and 10-35m in width. There is also a smaller band or reef to the south of the array cable which is around 10m wide and 30m long. These features have been classified as stony/cobble reef and no examples of *Sabellaria* reef were recorded in this area.

The reef features in this area were somewhat variable medium or medium to low grade reef comprising of cobble and small boulder on coarse mixed substrata. There was a degree of patchiness in these features with some areas of borderline matrix supported cobble but the main reef areas which had significant elevation above seabed were usually clast supported large cobbles with a variable epifaunal which primarily consisted of barnacles, patches of hydroids and bryozoans such as *Flustra foliacea* and also sporadic patches of sponge and occasionally stunted patches of red algae. Representative still photographs from these reefs have been provided in ***Table 10***, whilst a chart showing the locations of these photographs is provided in ***Figure 15.***

Table 10. Representative photographs from reefs in area D4.

Z4a	Z4b
	
Z4c	Z4d
	

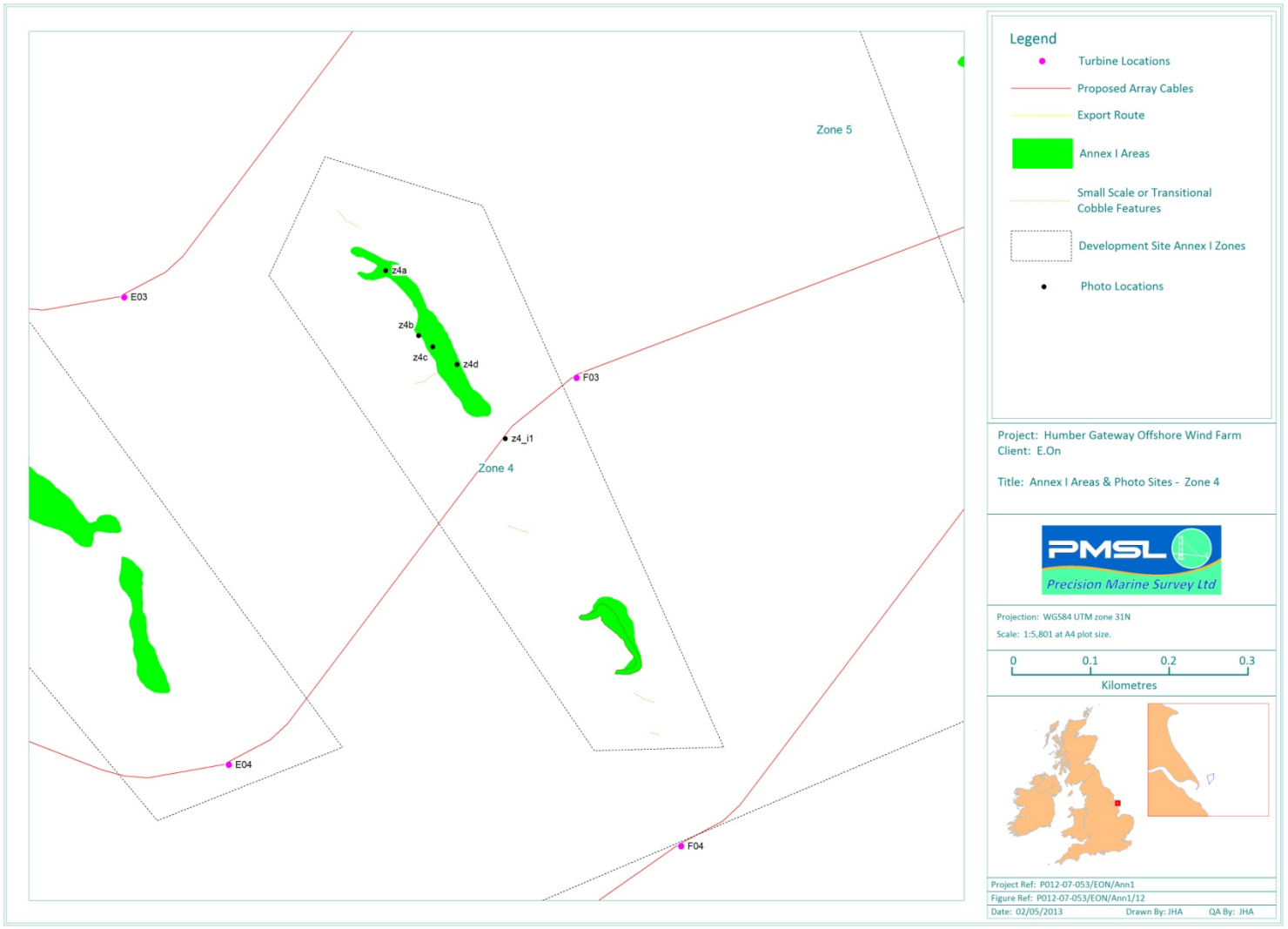


Figure 15. Annex I Zone 4 and locations of photographs

5.2.8 Zone 4 Array Cable and Annex I feature Intersections

None of the cable arrays in Zone 4 pass through any of the reported reef features with the nearest reef approximately 40-50m from the array. However, an example of seabed in the vicinity of array cable E04-F03 is provided for information in ***Figure 16.*** Sediments in this area are primarily shell and gravel/pebbles with occasional cobble.

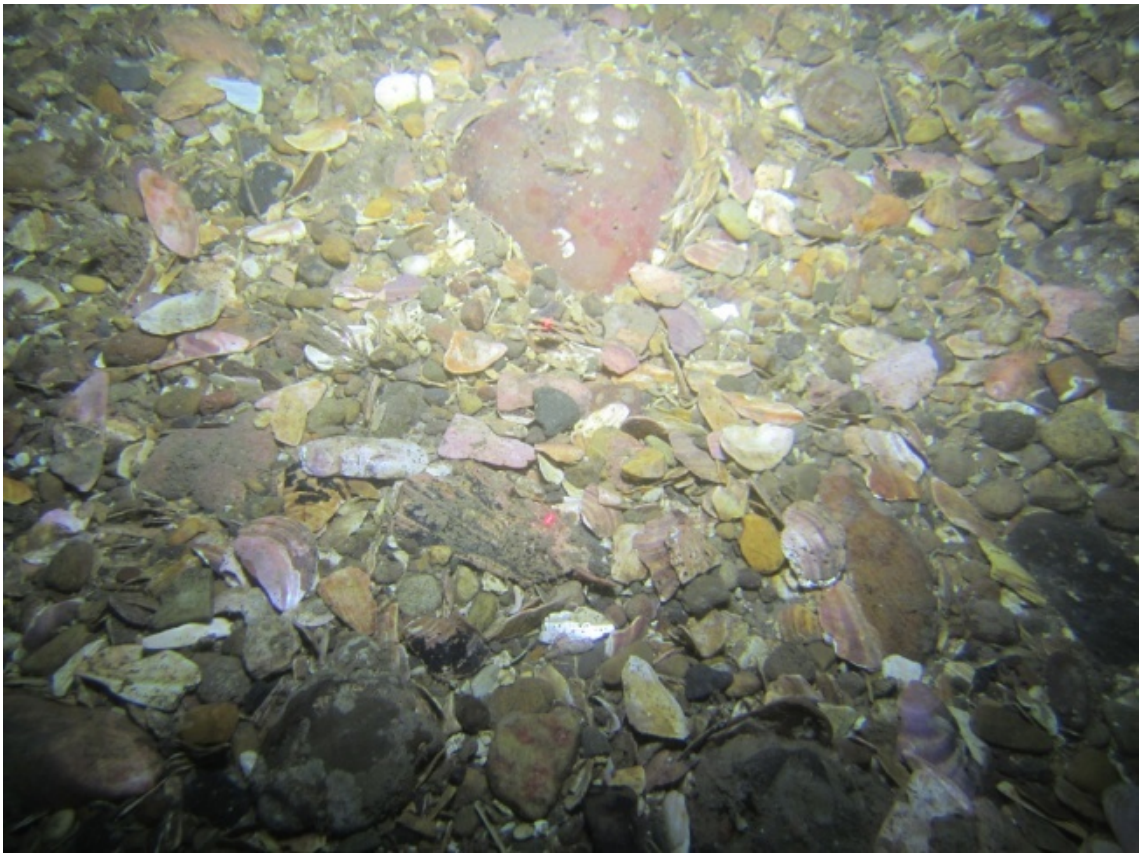


Figure 16. Seabed at array intersection Z4_i1 (E04-F03)

5.2.9 Zone 5

Zone 5 is situated to the north of the development site either side of array cable F03-H02. In this Zone, there are two main reef areas to the north of the array and two smaller bands of reef to the south. No areas of *Sabellaria* reef were identified in this Zone and the reefs identified have been classified as cobble reef overlaying mixed coarse sediments.

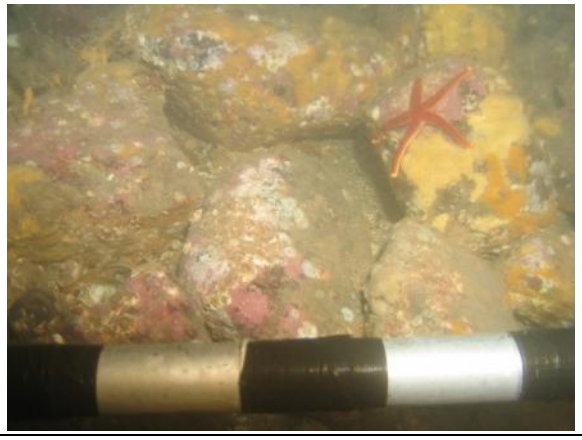
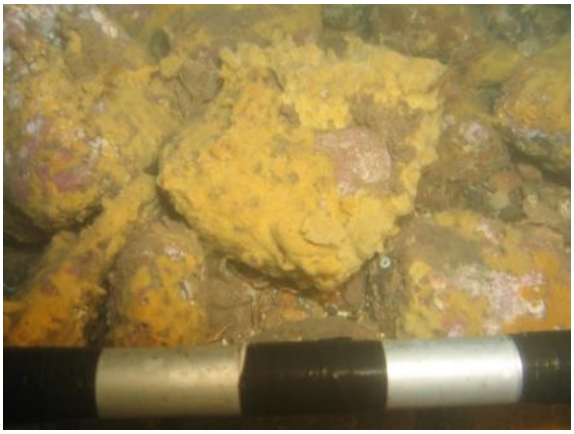
The northern feature nearest the array comprises of a two bands of cobble reef which grade into each other with a smaller area just to the north. This reef area extends around 100m north to south with the bands of reef 15m to 20m wide. A second area of reef is also present forming a linear feature running N-S further north at the location of an abandoned turbine location. This area was distant from proposed array cables so was not surveyed during the 2012 surveys area but was surveyed in March 2011 as part of the Annex I geotechnical surveys (site G60). Annex I cobble reef was identified at this location resulting in the removal of this turbine location. This area forms a linear cobble reef approximately 150m long and 15m to 40m wide. Two smaller ribbons of reef running east to west are also present to the south of array cable F03-H02 which are approximately 10m wide and 50m long.

Cobble reef in this area comprises medium to large cobble and small boulder forming narrow bands or ridges of medium grade reef which are primarily clast supported but grade into matrix supported transitional or lower grade reef between the cobble ridges in adjacent sediments. Smaller scale patches of reef type habitat associated with these bands are often quite patchy and grade in and out of reef formation in the in areas immediately adjacent to the main reefs. Typical fauna included dense patches of barnacles, calcareous/crustose pink algae, patchy hydroids and clumps of *Flustra* with patches of sponge or ascidians. The reef in the vicinity of the abandoned turbine at G60 had particular dense coverage by sponges in some areas.

Representative photographs from some of these features are provided in ***Table 11*** and a map showing the location of these is given in ***Figure 17***.

Table 11. Representative photographs from reefs in Zone 5

Z5a	Z5b
	

Z5c	G60a
	
G60b	G60Na
	
G60Nb	
	

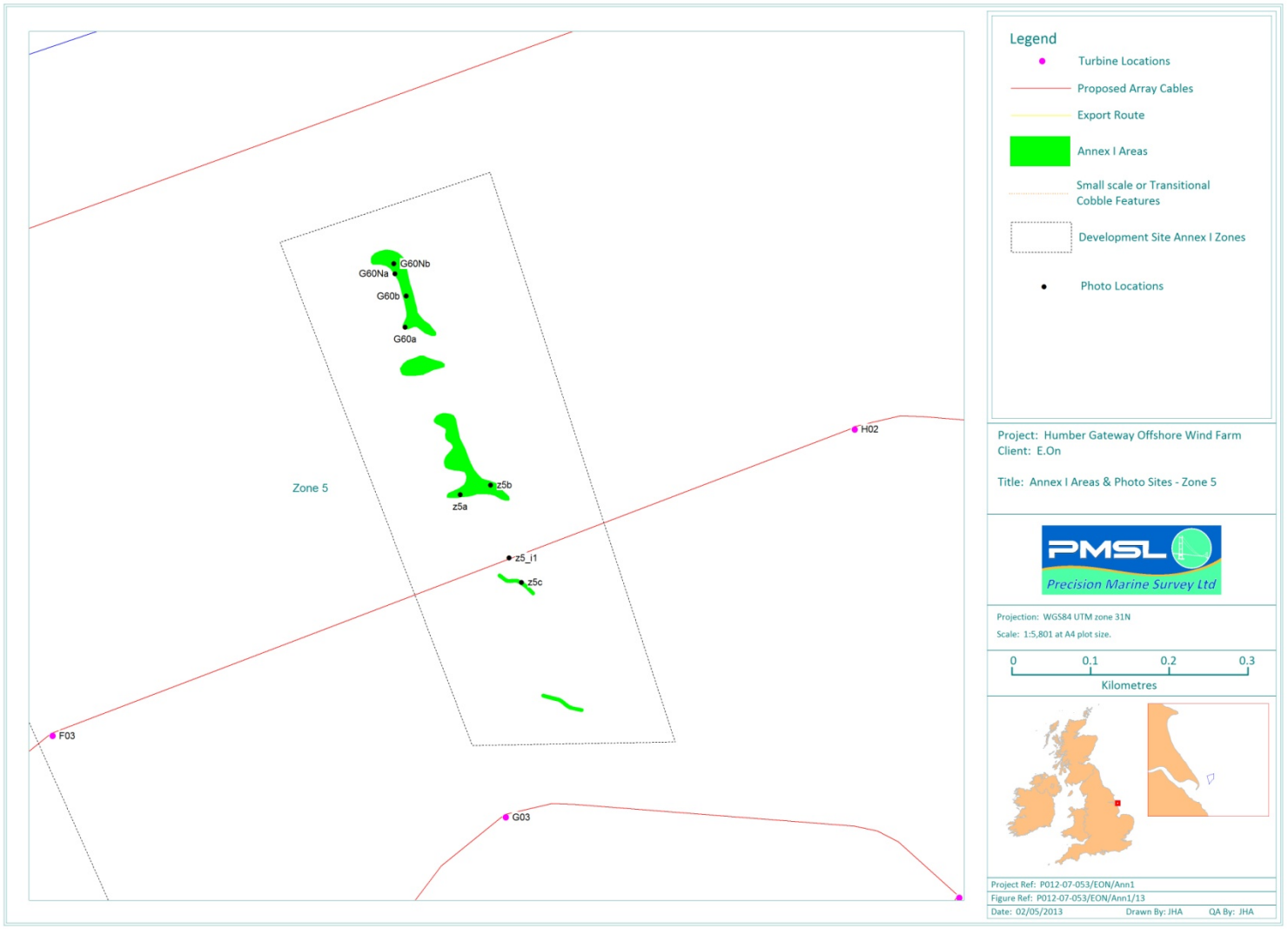


Figure 17. Annex I area Zone 5 and locations of photographs

5.2.10 Zone 5 Array Cable and Annex I feature Intersections

The array cables within Zone 5 do not pass through any of the recorded reef features although a small band of cobble reef is present 30m to the south of array cable F03-H02. However, in the vicinity of the proposed array cable the sediments are comprised of mixed pebbles, gravel and shell with patchy cobble with no reef forms recorded (***Figure 18***).

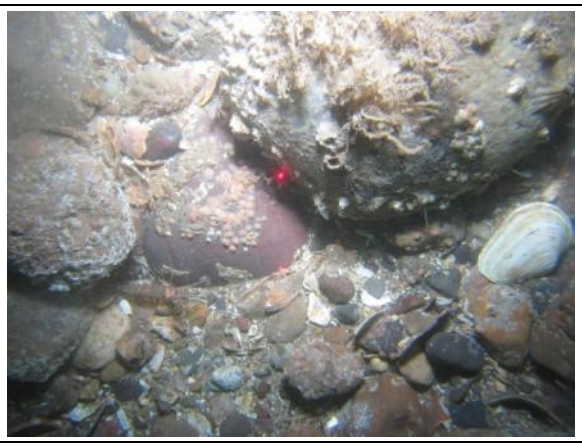
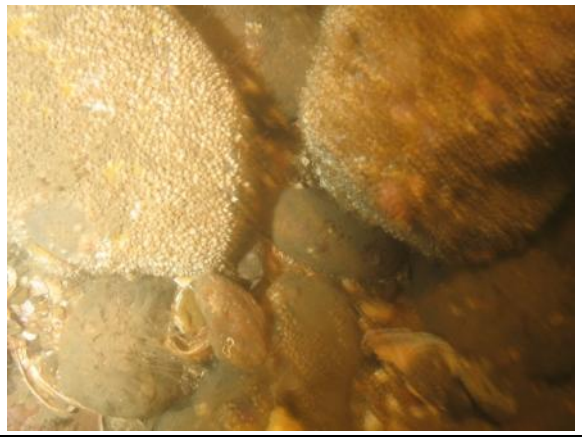
Figure 18. Seabed at array intersection Z5_i1 (F03-H02)

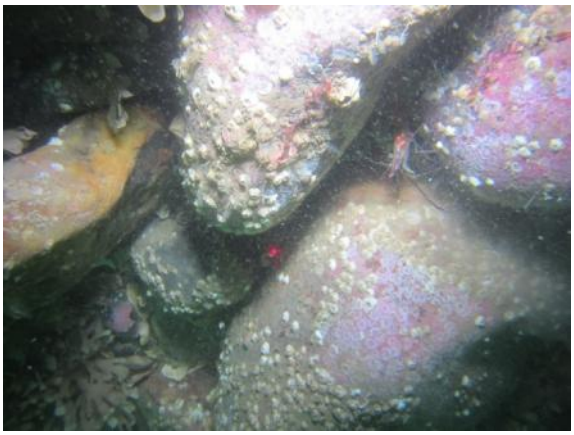
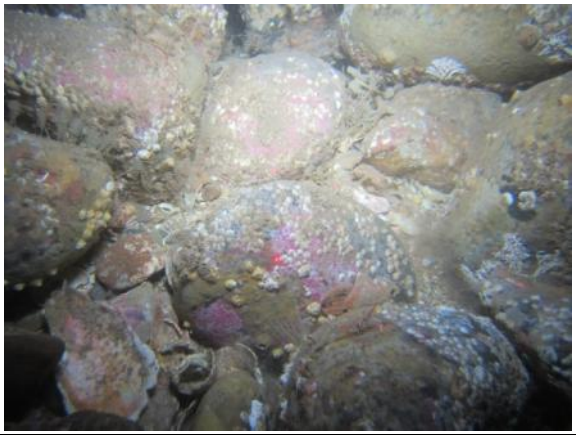
5.2.11 Zone 6

Zone 6 is situated toward the centre of the development site around array cables E05-F04, G05-F05-G04 and F04-G03-H03-G04. Twelve disparate reef features were recorded in this area comprising of cobble/stony reef with no Annex I *Sabellaria* reef recorded. These features tended to be scattered smaller scale features usually comprising of medium-low grade bands or narrow ridges of cobble 50m to 120m long and around 10m wide. Two slightly larger reef areas were also recorded with one just to the south of array E05-F04 (120m x 25m) and another just south of array F05-G04 (140m x 50m). These features tended to be comprised of lower lying beds of cobble which ranged from matrix supported to slightly more elevated clast supported cobble and small boulder at the centre of the ridge.

These features tended to be somewhat tideswept barnacle dominated features with a relatively sparse or patchy hydroid/bryozoan turf and occasional patches of pink crustose/calcareous algae or stunted forms of red algae. Representative stills of reefs in this area are shown in ***Table 12*** and the positions of these are shown in ***Figure 19***.

Table 12. Representative photographs from reefs in Zone 6

Z6a	Z6b
	
Z6c	Z6d
	

Z6e	Z6f
	
Z6g	Z6g2
	
Z6h	Z6i
	

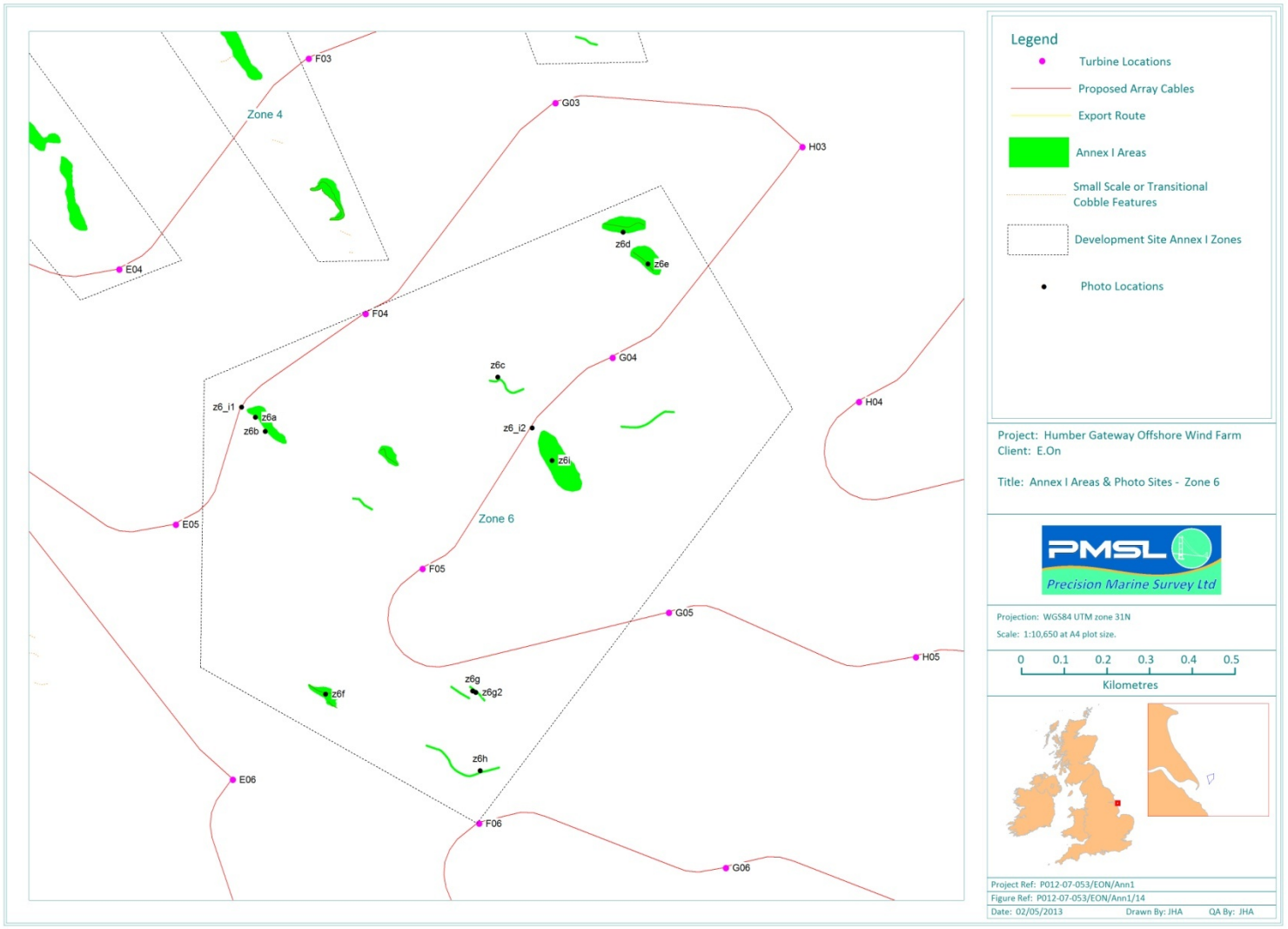


Figure 19. Annex I Zone 6 and locations of photographs

5.2.12 Zone 6 Array Cable and Annex I feature Intersections

The majority of the reef features in Zone 6 are some distance from the proposed array cables although the two larger features are 10-20m the south of arrays E05-F04 and F05-G04 respectively. Examples of seabed habitat at the proposed array cable route in these areas are shown in ***Table 13*** which indicates that the array cables are positioned in non reef habitats comprising of mixed coarse sediments with pebbles, shell, gravel and patchy cobble.

Table 13. Seabed at array intersections Z6_i1 & Z6_i2 (E05-F04 and F05-G04)

Z6_i1	Z6_i2
	

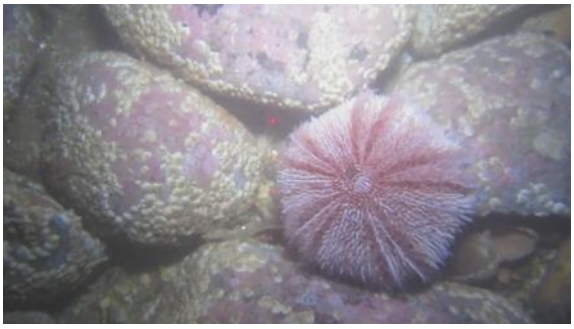
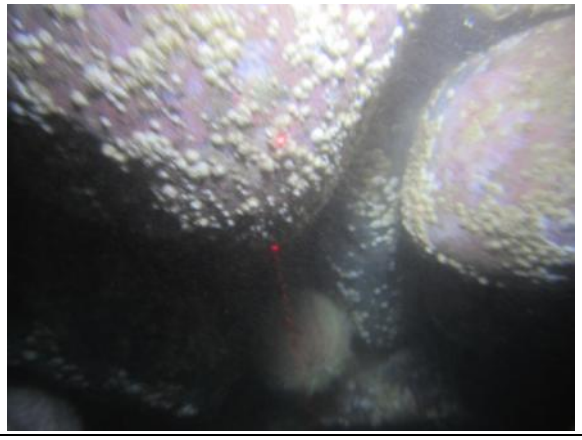
5.2.13 Zone 7

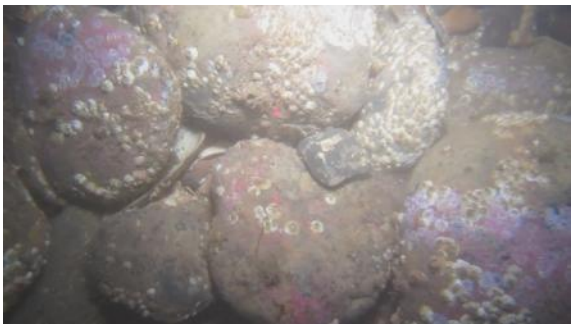
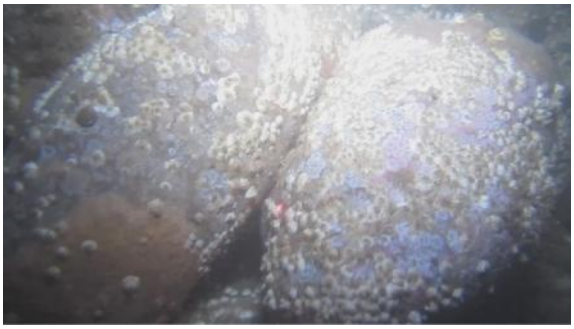
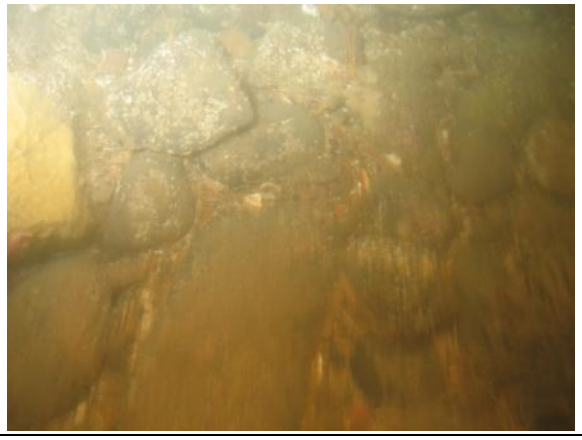
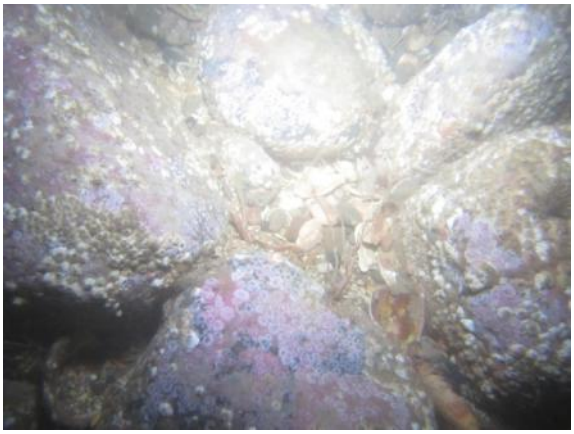
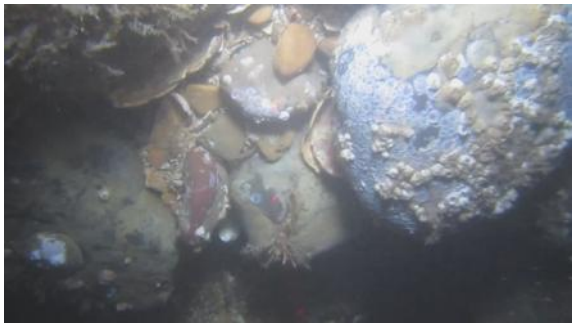
Zone 7 covers an area either side of the array cable string A06-A07 to the east of the offshore wind development site. This zone includes five areas of large linear reef features which are generally orientated NW to SE with a number of these crossing the array cable route. These features have been classified as stony/cobble reef with no areas of *Sabellaria* reef recorded.

The main reef features include a cluster of quite extensive linear features ranging from 80m to 200m in length and 10m to 30m in width which run across the array cable route and another large linear feature up to 400m long and 35m in width to the east of the array cable. Three of these features which run alongside and/or across the array cable are relatively close together and separated by narrow areas of more transitional (but generally non reef) mixed coarse sediments with variable or patchy cobble content. Within these features the main reef area tends to form a central clast supported cobble ridge with large cobble and small boulders forming medium grade Annex I reef with areas of more transitional or lower grade partially matrix supported reef distributed within or toward the periphery of the ridge.

The more elevated reef areas are characterised by barnacles with occasional patches of crustose pink algae and a relatively sparse tide swept epifaunal community including hydroids and bryozoans, small sponges or ascidians and occasional echinoderms (primarily *Echinus esculentus*). Representative stills from these areas and a map showing their locations are provided in ***Table 14*** and ***Figure 20.***

Table 14. Representative photographs from reefs in area Zone 7

Z7a	Z7b
	

Z7c	Z7d
	
Z7e	Z7f
	
Z7g	Z7h
	

Z7i	Z7j
	

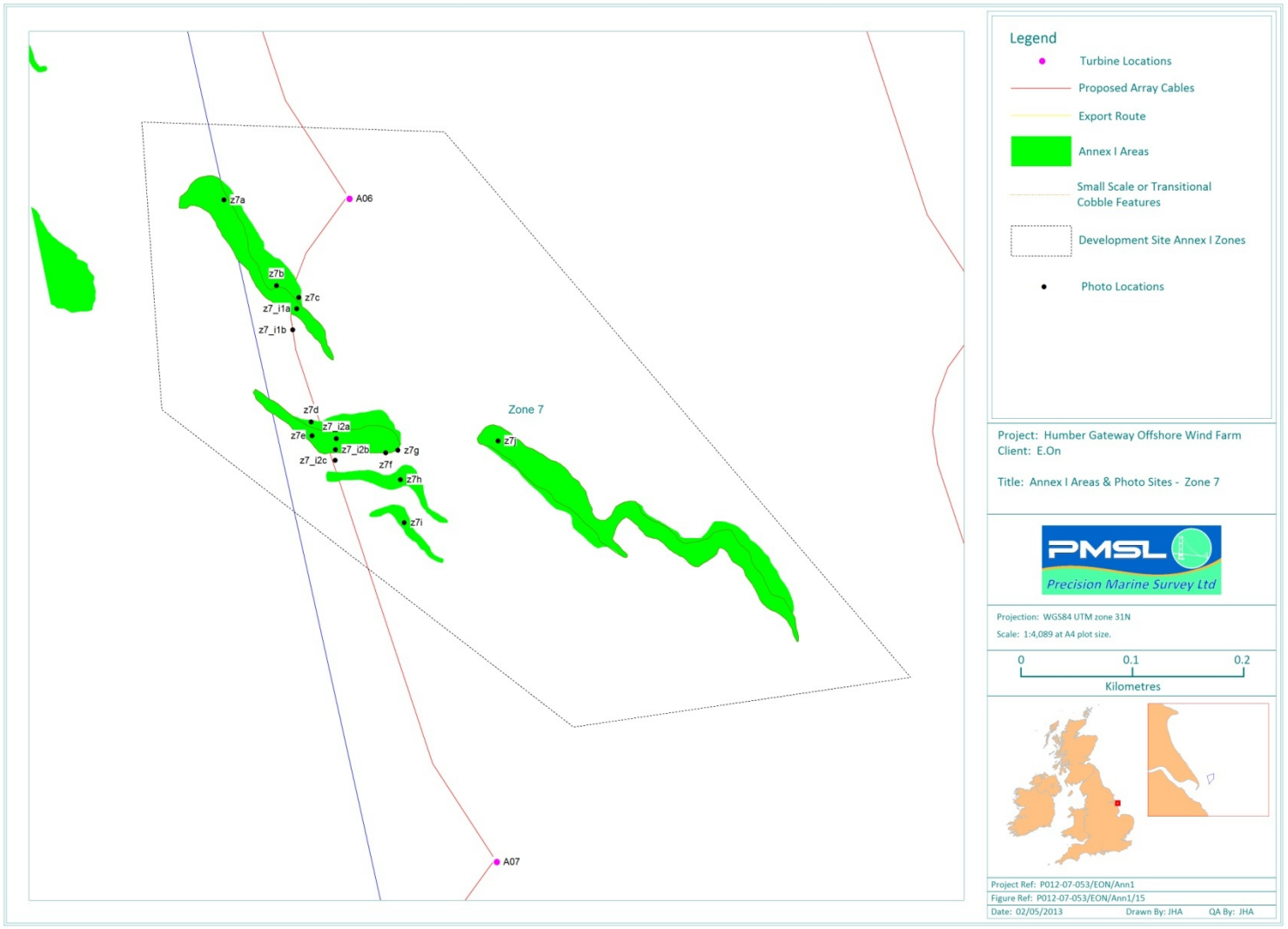


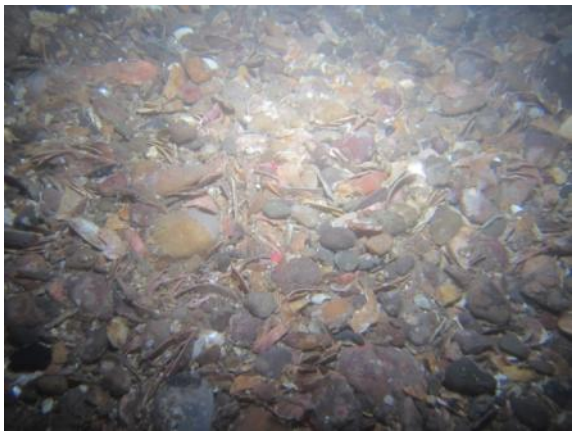
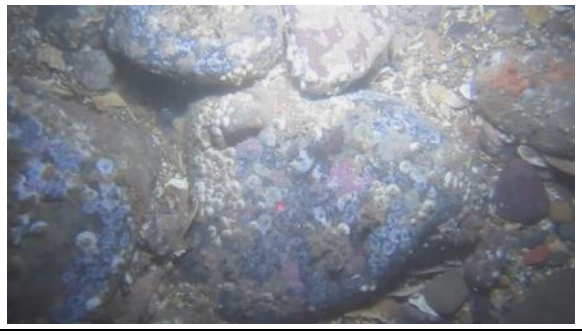
Figure 20. Annex I Zone 7 and locations of photographs

5.2.14 Zone 7 Array Cable and Annex I feature Intersections

The proposed cable array A06-A07 crosses through two of the main reefs within Zone 7 and also intersects the edge of a third reef feature 20m further south. This intersection has been discussed with regard to array cable routeing options in the Humber Gateway Annex I Micrositing Assessment Report under intersection Ar_A. No Annex I *Sabellaria* reef was recorded in zone 7.

With no other alternatives, owing to engineering and physical constraints, the intersections are routed across the body of the reef, including examples of medium grade cobble reef as highlighted in ***Figure 20***. Additional stills along the cable array in this area are provided in ***Table 15*** which also highlights the slightly variable nature of the reef in this area which also includes patchier lower grade matrix supported cobble reef. An example of seabed habitat along the array cable just outside the main reefs is also given (photograph Z7_i1b) which highlights the adjacent (non reef) sediments comprising of pebbles and shell with occasional cobble.

Table 15. Seabed at array intersections Z7_i1 to Z7_i2c (A06 to A07)

Z7_i1a	Z7_i1b
	
Z7_i2a	Z7_i2b
	

Z7_i2c	
	

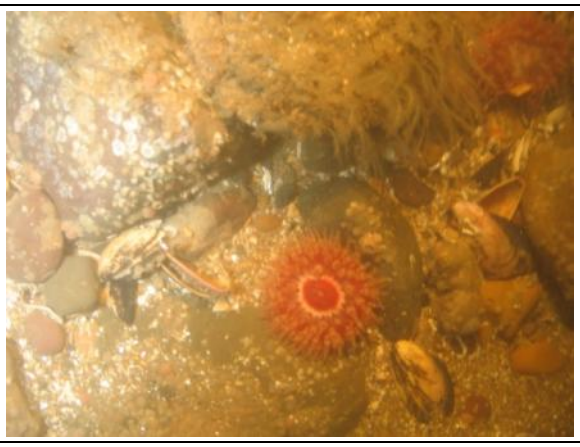
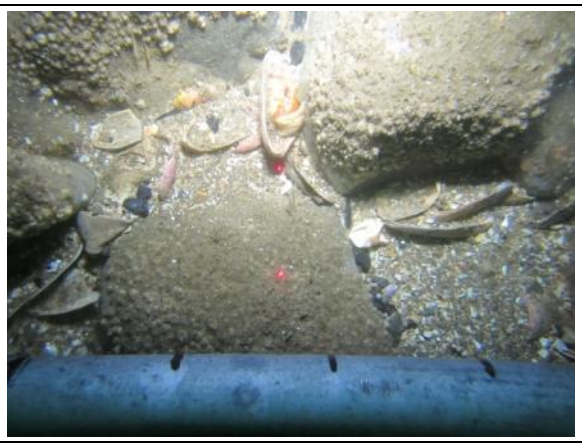
5.2.15 Zone 8

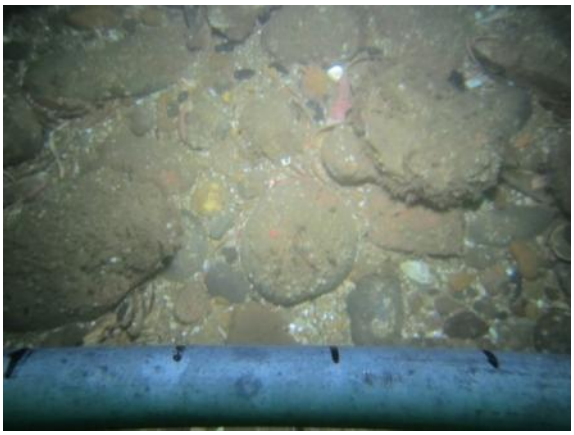
Zone 8 is situated on the western edge of the development site along array cable strings D08-D09-D10. This area includes two main areas of reef just to the north and south of turbine D09 which measure approximately 130m by 30m wide and 280m by 40m respectively. There are also smaller reef areas further north to the east of array string D08-D09. These features are characterised by similar habitats to those in Zone 7 i.e. linear cobble ridges which are classified as Annex I cobble reef with no *Sabellaria* reef or other biogenic reef recorded. The cobble ridges vary from clast supported large coble and small boulder along the main ridges which grade into areas of less elevated (lower grade) matrix supported cobble reef along the margins and in the smaller less well defined reefs.

The reefs have a similar composition to other reefs in this area and primarily characterised by abundant barnacles with a relatively sparse or patchy coverage by other epibiota which included some calcareous encrusting pink algae, and hydroids/bryozoans with occasional anemones in gravel between cobbles in matrix supported reef areas.

Representative photographs from these reefs are provided in ***Table 16*** and their locations given in ***Figure 21.***

Table 16. Representative photographs from reefs in Zone 8

Z8a	Z8b
	
Z8c	Z8d
	

D8e	D8f
	
D8g	
	

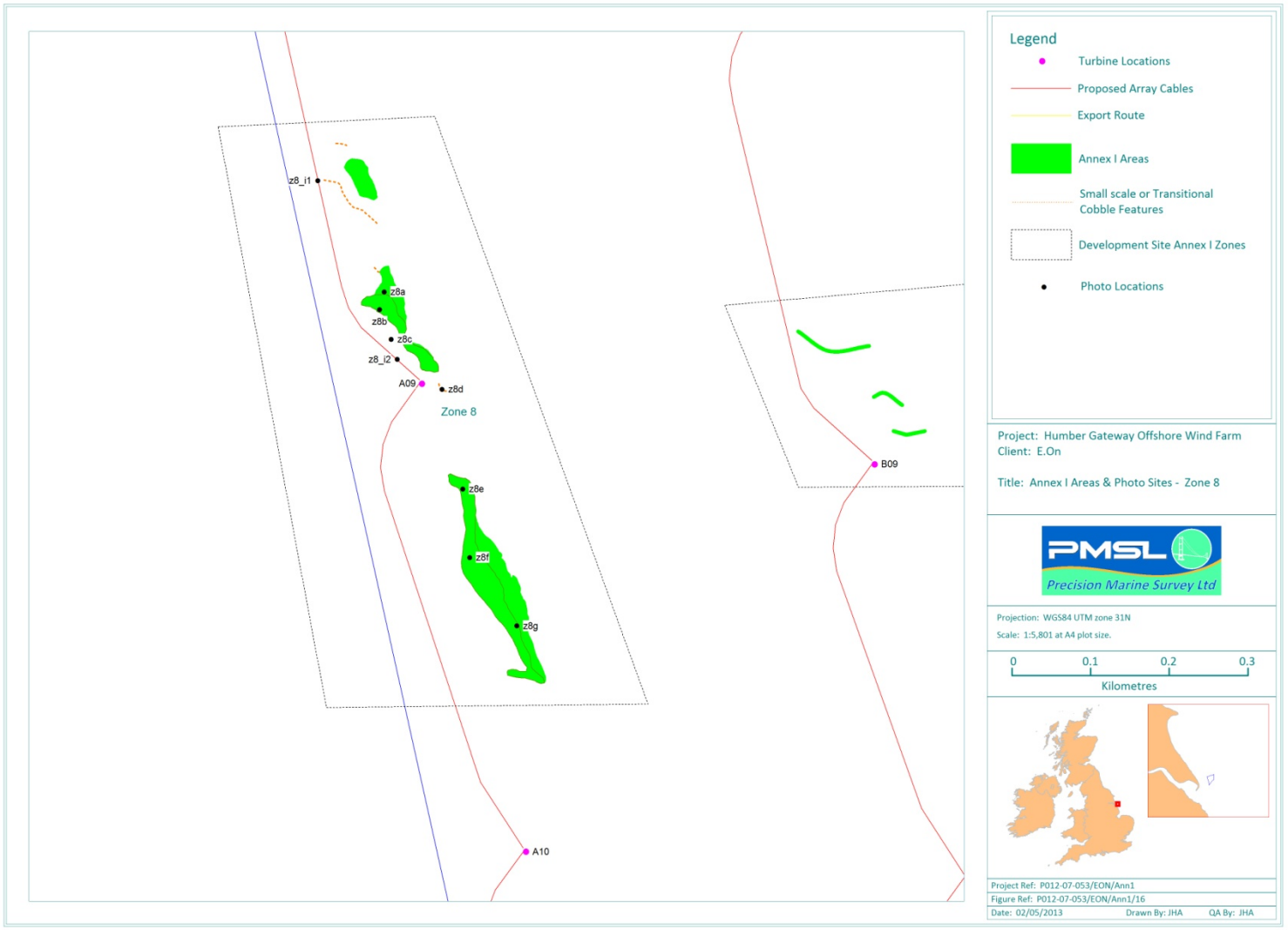


Figure 21. Annex I Zone 8 and locations of photographs

5.2.16 Zone 8 Array Cable Intersections with Annex I

The array cable string D08-D09-D10 is situated just to the west of the main reef with the northern reef around 15m to 20m from array D08-D09 whilst the reef south of D09 is located 60m to the east of the cable array. The smaller bands of reef further north include one area around 10m from array D08-D09. None of the reefs intersect the proposed cable array but representative photographs of seabed on the array route adjacent to the reefs are provided in ***Table 17,*** for information. These indicate that seabed along the cable array is comprised of mixed coarse sediment including stones, shell, gravel and patchy cobble and no Annex I stony reef of *Sabellaria* reef were recorded in this area.

Table 17. Seabed at array intersections Z8_i1 & Z8_i2 (A08 to A10)

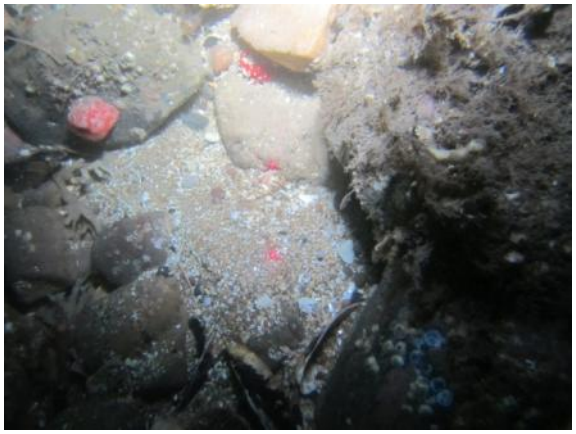
Z8_i1	Z8_i2
	

5.2.17 Zone 9

Zone 9 is located to the west of the development site along the proposed array cables B08-B09 and C08-C09. The main reef located in this area is just to the east of array C08-C09 and is approximately 120m by 20m with a few other smaller reef areas or linear features usually less than 100m in length and under 10m in width. These features have been classified as medium to low grade cobble reef and comprise of discrete cobble ridges with clast supported medium to large cobble interspersed with matrix supported cobble on gravel and pebbles (lower grade reef) on the margins of larger, more elevated reef features or in the smaller less well defined bands of reef (e.g. at points D9a and b). No Annex I *Sabellaria* reef was recorded in Zone 9.

These reef features include barnacle dominated larger cobble and patchy areas of hydroid/bryozoan turf most notably *Flustra foliacea*, particularly in areas of patchier matrix supported reef areas. A variety of other epibiota is also present including a variety of echinoderms, anemones and occasional patches of crustose pink algae, sponges or ascidians. A chart showing the location of these areas and representative photographs from a selection of these reefs is provided in ***Table 18*** and ***Figure 22.***

Table 18. Representative photographs from reefs in area Zone 9

Z9a	Z9b
	
Z9c	**Z9d**
	

Z9e	Z9f
	

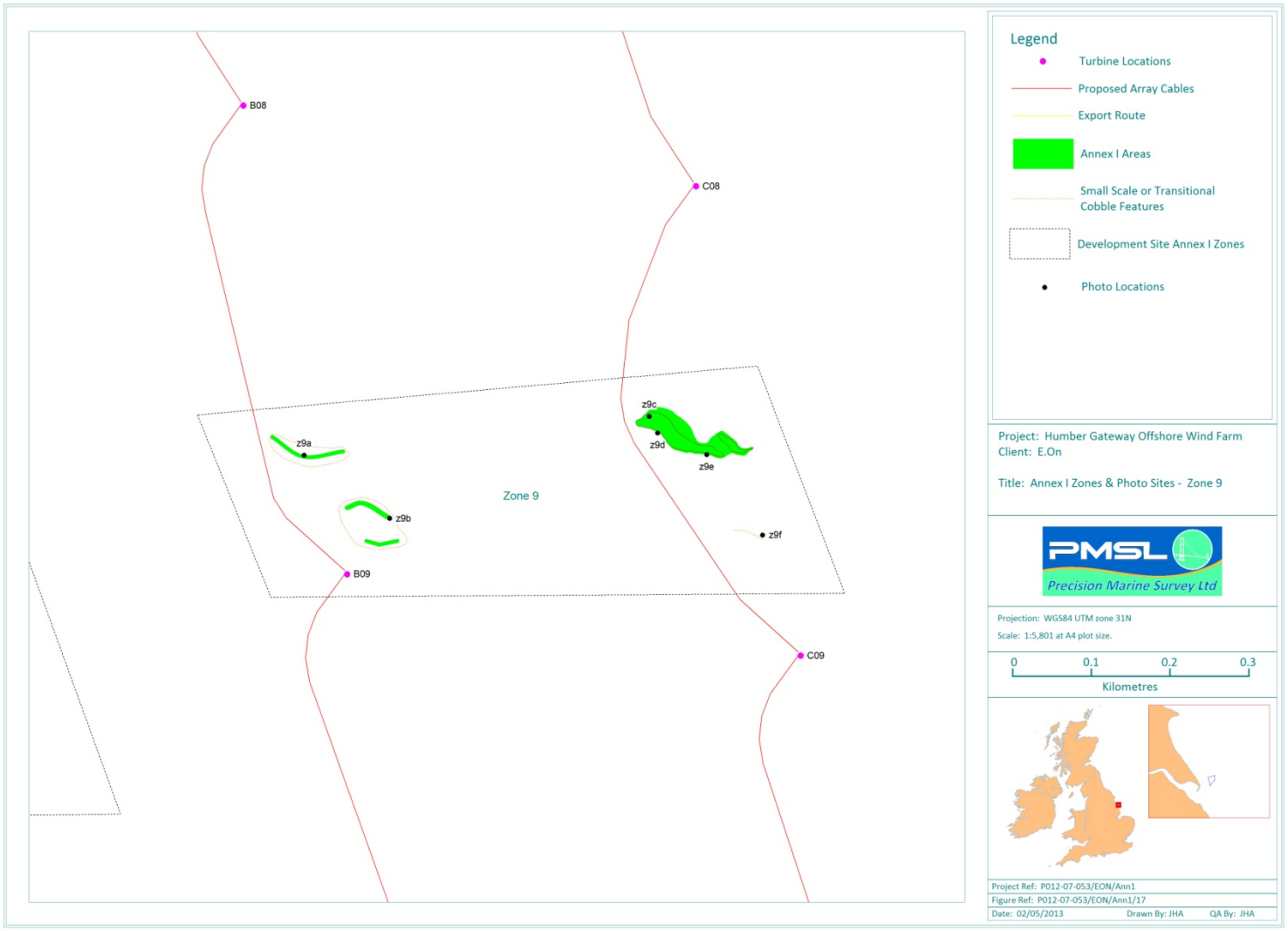


Figure 22. Annex I area Zone 9 and locations of photographs

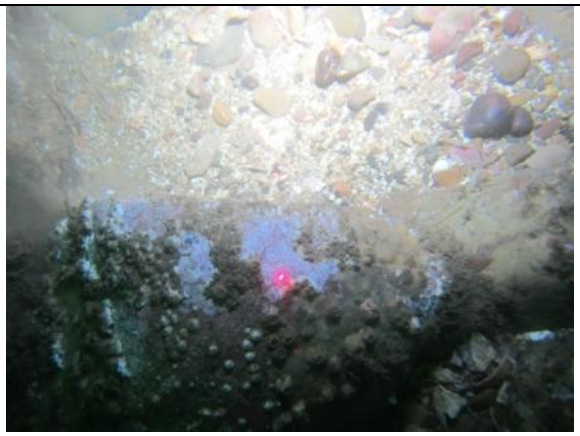
5.2.18 Zone10

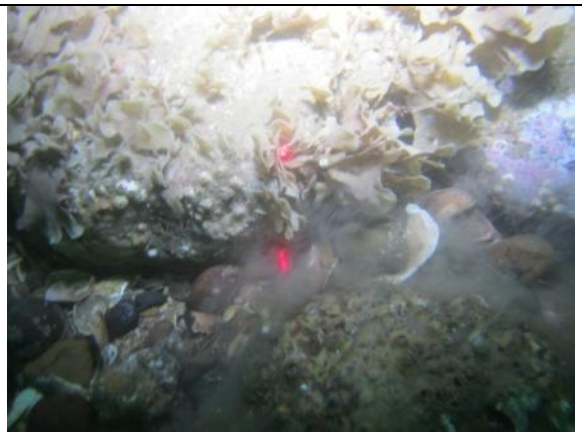
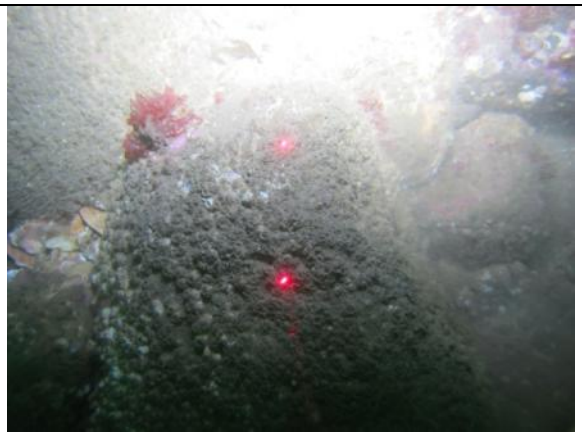
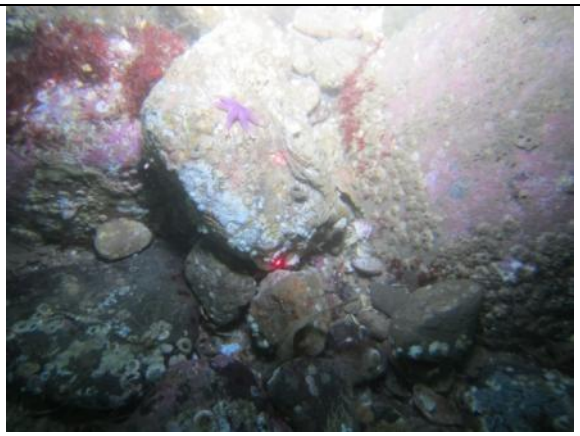
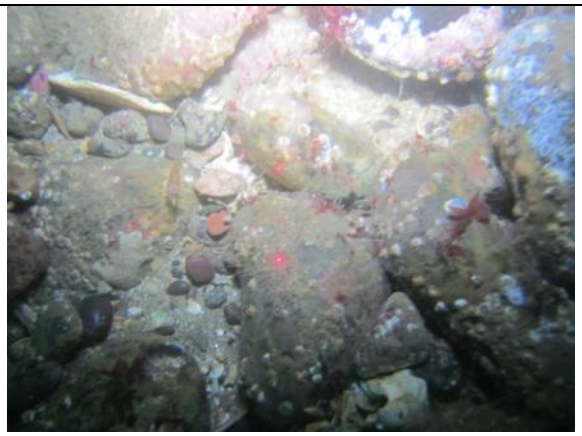
Zone10 is situated at the southern end of the development site and includes a number of quite extensive reef systems which vary from elevated large scale cobble ridges up to 500m long and 50m wide to smaller areas or narrow bands of less elevated cobble. These cover areas between array cable strings E07-E08-F07, E09-F08 and F09-G08. Five main reefs are present in close proximity to the cable arrays notably either side of E08-F07 and to the north of F09-G08 with smaller reefs further north adjacent to E07-E08.

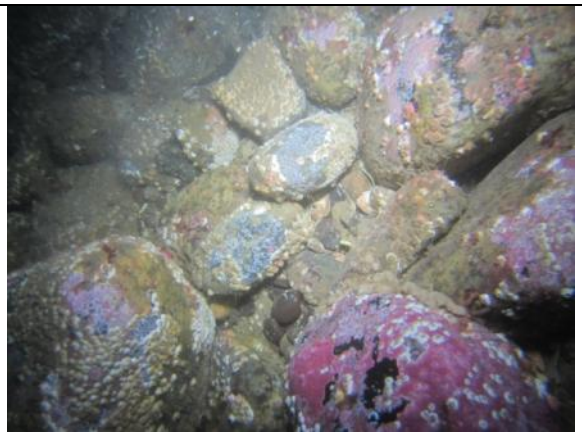
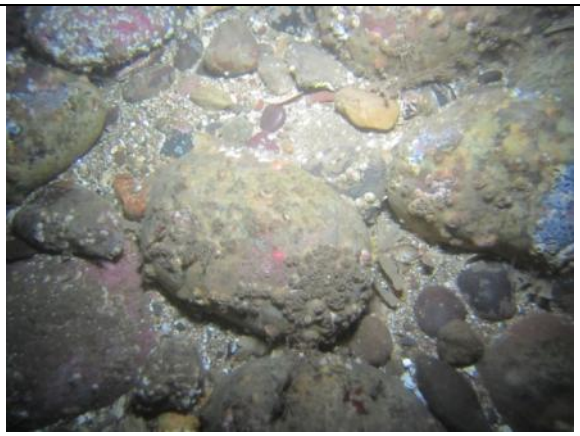
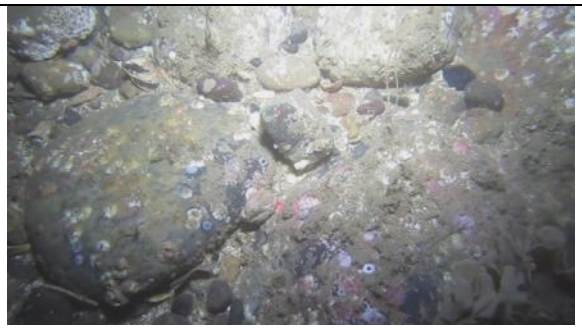
These features include some particularly large cobble ridges with elevations up to 1m above seabed comprising of clast supported large cobble and small boulder forming medium to high grade cobble reef along with smaller linear cobble reef features which are less elevated and form matrix or partially clast supported cobble reef on mixed coarse sediment. To the west of the main series of reefs which run north to south between E08 and F09 are areas of transitional habitat which includes more discrete, smaller patches or ribbons of cobble amongst areas of quite cobbly mixed sediment which are generally too patchy or small scale to de defined as reef but include transitional/borderline cobble habitats. The main reef between E08 and F09 is also bordered to the west by sandy gravelly sediment which grades into the reef itself forming areas of matrix supported reef on the north-west margin of this large reef feature. Smaller reefs in area Zone10 tend to be medium or medium to low grade cobble reef as recorded elsewhere on the development site. No areas of *Sabellaria* reef were recorded in this area.

Many of the reefs are characterised by similar fauna to the other survey areas namely barnacle encrusted cobbles with a sparse or patchy epifaunal assemblage of hydroids, bryozoans (including some denser patches of *Flustra foliacea*), crustose pink algae and other encrusting fauna such as tube building polychaetes (e.g. *Pomatoceros* spp.). The larger reef feature running from E08 and F09 also has areas of sponge, ascidians such as *Dendrodoa grossularia* and patches of red algae and a wider variety of hydroids. Representative stills from a variety of locations in this area have been provided in ***Table 19*** and ***Figure 24.***

Table 19. Representative photographs from reefs in zone 10.

Z10a	Z10b
	

Z10c	Z10d
	
Z10e	Z10f
	
Z10g	Z10h
	

Z10i	Z10j
	
Z10k	Z10l
	
Z10m	Z10n
	

Z10o	
	

5.2.19 Zone 10 Array Cable Intersections with Annex I

A number of the reefs recorded in Zone 10 cross the proposed array cables or are in close proximity and these areas and respective cable routing options have been discussed in the Humber Gateway Annex I Micrositing Assessment Report. A number of representative stills have been provided for these areas and other array locations in areas adjacent to reef habitats (***Table 20***).

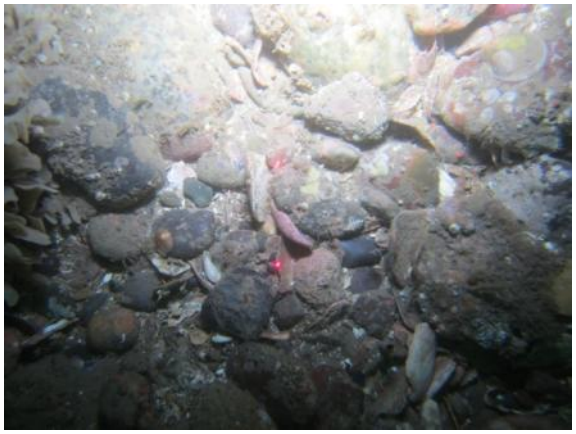
Intersection Zone 10_i1 is near to a small reef area to the north which is identified as intersection Ar_E in the Humber Gateway Annex I Micrositing Assessment Report. This reef is characterised by medium to low grade cobble reef but the array intersection is situated just off the reef in adjacent (non reef) sediments which form transitional habitats comprising of pebbles, shell and gravel and patchy cobble. Intersection Z10_i2 runs between two larger reef features along array cable E08 to F07, reported in the Humber Gateway Annex I Micrositing Report as Ar_F. In this area the adjacent reefs are medium to high grade cobble reef but the array intersection passes through a narrow gap between the main reefs comprising of mixed stones, shell, gravel and variable or patchy cobble which is not classified as reef but represents a somewhat transitional and patchy mixed coarse sediment/cobble habitat. Video evidence (supported by geophysical data) highlighted a gap between these reefs with a narrow area of non reef sediment.

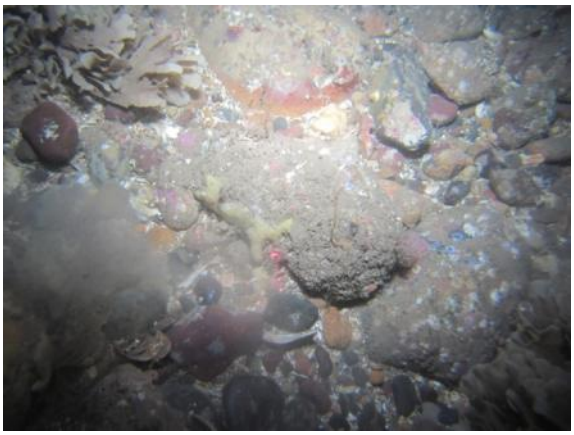
Intersection Zone 10_i3 is between two large medium or medium/high grade cobble reefs immediately either side of array E08-F07 with a further intersection across this array cable by a smaller reef 80m to the south (Z10_i4) and a smaller band of cobble just adjacent to the array (within 10m) 65m further south (Z10_i5a and b). This area of intersections is reported in the Humber Gateway Annex I Micrositing Assessment Report as Intersection Ar_D. Intersection Zone 10_i3 which lays between the two main reefs is located in an area of somewhat transitional and patchy mixed coarse sediment and cobble habitat which whilst moderately cobbly differs from the adjacent main reefs and too patchy to be considered reef. The intersection at Z10_i4 crosses a narrow area of medium-low grade cobble reef and further south the seabed along the array string E08-F07 runs adjacent to a

small band of reef which is characterised by borderline low grade reef (Z10_i5a). To the south at Z10_i5b the sediments in the vicinity of the array route are characterised by non reef forming mixed coarse sediments.

Intersection Z10_i6 to the south of Zone 10 is adjacent to a small reef area of medium to low grade cobble reef alongside array cable F09-G08, as reported in the Humber Gateway Annex I Micrositing Assessment Report as intersection Ar_C. This reef (which grades into borderline low grade reef at its eastern extent) is just to the east (<10m) of the array cable which crosses through a mixed coarse sediment habitat of cobble, pebbles and mixed sediment which is a transitional reef area with patchy low grade cobble reef.

Table 20. Seabed at array intersections Z10_i1 to Z10_i6

Z10_i1	Z10_i2
	
Z10_i3	Z10_i4
	
Z10_i5a	Z10_i5b
	

Z10_i5c	Z10_i6
	

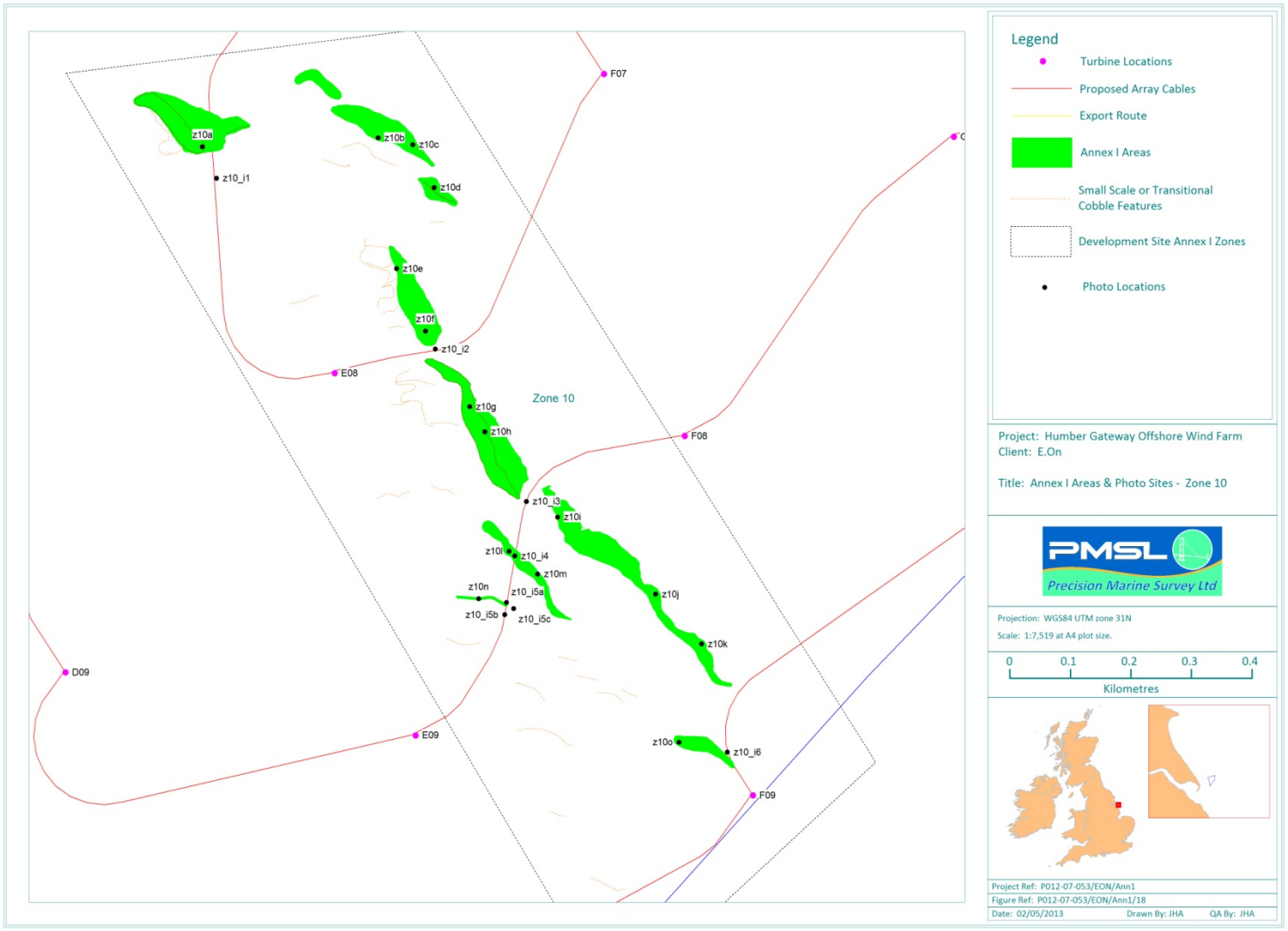


Figure 23. Annex I Zone 10 and locations of photographs

5.2.20 Zone 11

Zone 11 is located at the south western end of the development site in the vicinity of array cables C10-D10 and C12-D11. Four small reef areas are present to the north of Zone 11 adjacent to array cable string C10-D10 which are characterised by relatively narrow cobble ridges with limited elevation approximately 70m long by 20m wide. These features are classified as medium to low grade cobble reef and include areas of variable matrix supported reef on gravelly sand and smaller bands of more clast supported medium-large cobble along the central ridge of the reef features. These areas of reef are generally characterised by barnacles and patches of slightly silted hydroid/bryozoan turf with clumps of *Flustra foliacea* and occasional patches of crustose pink algae.

To the southern end of Zone 11 is an area adjacent to array cable string C12-D11 which has a transitional mixed coarse sediment habitat with variable cobble content including a number of small ribbons of matrix supported cobble often embedded in gravel and pebbles. This area is similar to some of the transitional mixed/coarse sediment recorded elsewhere and not considered as cobble reef although there are numerous small scale patches of more consolidated cobble with limited elevation. For the most part this area is classified as mixed coarse sediment which grades in and out of small areas of transitional/borderline cobble habitats or small scale cobble features which don't fully qualify as cobble reef. Sediments are quite variable in this area with some areas of exposed boulder clay or more gravelly sediments often overlying or supporting patchy cobble along with frequent boulder which are occasionally colonised by patches of encrusting sponge.

No areas of *Sabellaria* reef or other biogenic reef were recorded in Zone 11. Representative photographs from reefs and transitional habitats in Zone 11 are shown in ***Table 21*** and ***Table 22*** and locations of photographs mapped in ***Figure 24.***

Table 21. Representative photographs from reefs in area D11

Z11a	Z11b
	

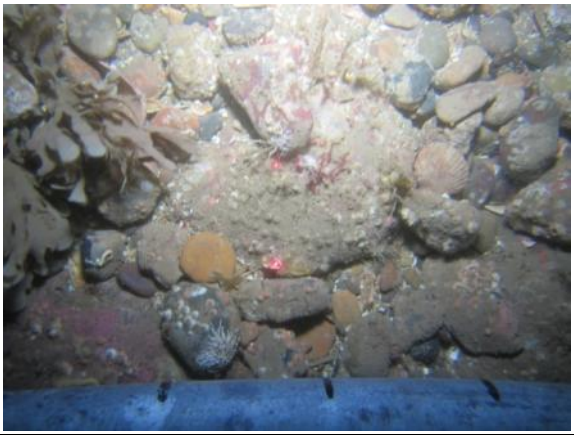
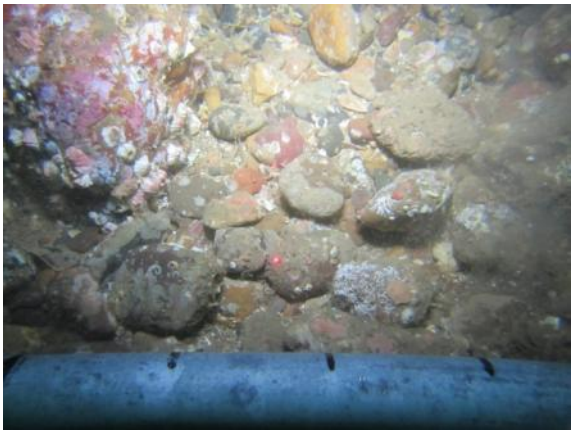
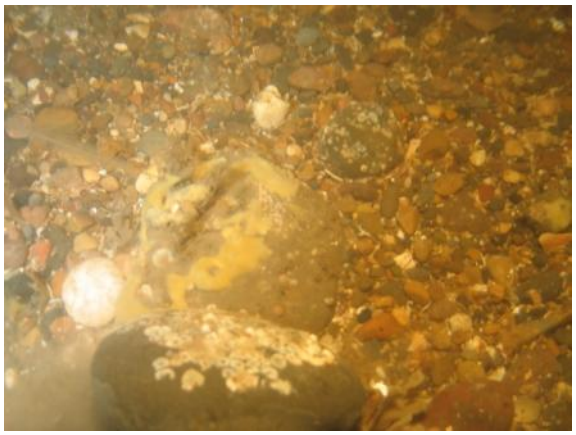
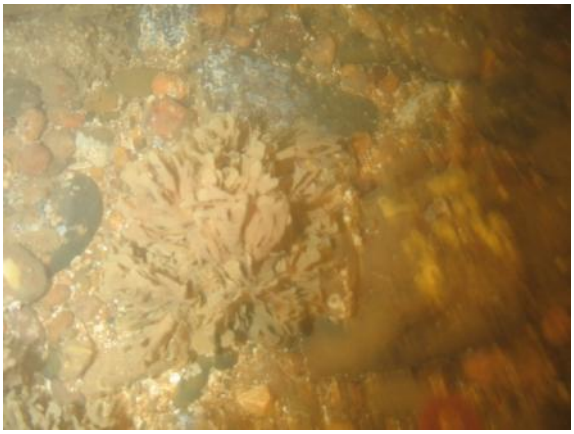
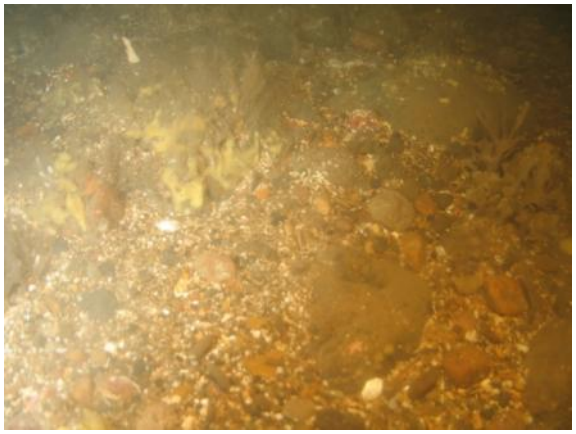
Z11c	Z11D
	
Z11e	
	

Table 22. Representative photographs from transitional habitats in area D11

Z11_T1	Z11_T2
	

Z11_T3	Z11_T4
	
Z11_T5	Z11_T6
	
Z11_T7	Z11_T8
	

Z11_T9	Z11_T10
	
Z11_T11	Z11_T12
	

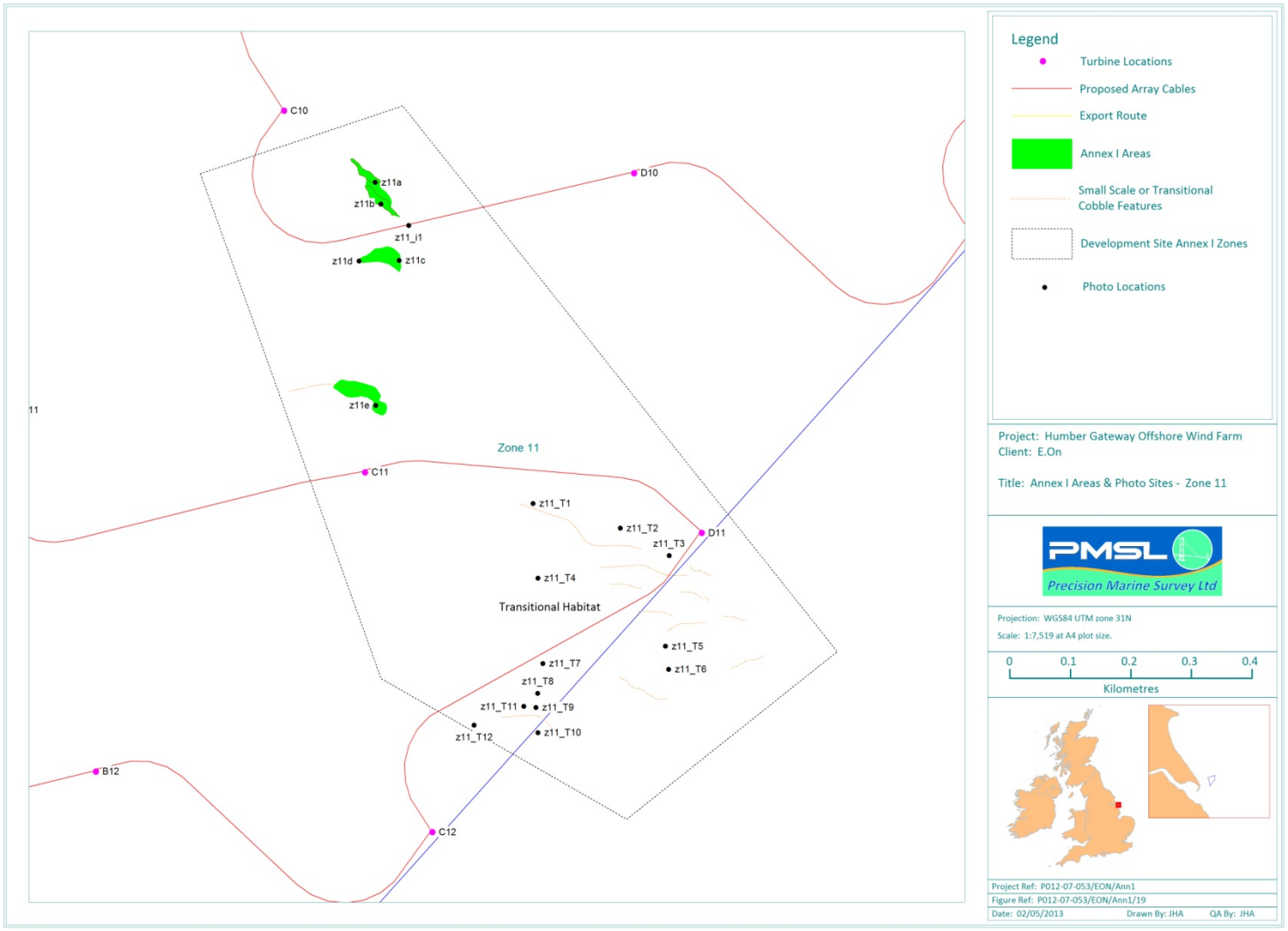


Figure 24. Annex I Zone 11 and locations of photographs

5.2.21 Zone 11 Array Cable Intersections with Annex I

Array cables in Zone 11 do not intersect any of the main reefs identified to the north of the area but the cable array string C10-D10 passes between two reefs at a distance of approximately 20m. An example of seabed habitats in this area is shown in ***Figure 25*** which indicates the presence of non reef habitat comprising of pebbles and occasional cobble in gravelly sand.

Figure 25. Seabed at array intersection Z11_i1

6. Benthic survey

6.1 Objectives

The benthic survey aimed to provide an assessment of the status of benthic communities, biotopes and associated sediment parameters within the wind farm array and adjacent habitats including those potentially subject to construction related disturbance. This entailed survey by grab sampling and drop down video using appropriate techniques to define benthic communities and sediment parameters in the vicinity of the development and to allow a comparison of temporal trends for any future (post construction) monitoring.

The following survey components were undertaken to fulfil this component:

- Benthic sampling using appropriate sampling gear (section 6.3.1)
- Drop down video (in addition to that undertaken for the Annex I survey) to provide additional information on the epibenthic assemblage, at the benthic sampling sites
- Sediment sampling and Particle size analysis (PSA)
- Faunal preservation, processing and enumeration

6.2 Survey Design

The benthic survey design utilised a stratified random layout as outlined in the HWL Benthic Monitoring Programme (BMP) in which the benthic sampling stations were sited in each of the main benthic habitats/biotopes within and adjacent to the development site.

The numbers of survey stations within each of the main habitats took into account the spatial coverage of the main benthic communities and, where possible, utilised sites previously sampled during the EIA Benthic characterisation survey. The sites covered approximately 1 tidal excursion either side of the development area in order to allow assessment of direct and secondary impacts relating to construction related sediment disturbance and suspended sediment movement. As agreed with the Licensing Authority (and outlined in the BMP) the survey design incorporated a combination of single samples and replicate sampling which allowed sampling over a wider range of communities including more discrete variants of the main assemblages.

The benthic sample locations were chosen to provide a robust baseline and to allow suitable locations of any agreed ongoing monitoring, post construction. These locations were determined by factors such as precise foundation locations and location of export and array cables. The sample locations also took account of coastal processes and geophysical surveys, which ensured adequate coverage of sea bed habitats.

A proposed survey design was included within the BMP which comprised of 42 sites including 18 sites with triplicate sampling and 24 sites with single samples to extend coverage giving a total of 78 samples. The BMP (version 2, as re-issued in May 2012), including this benthic survey design were approved by the MMO and consultees.

As per the Marine Licence Annex 1.2 requirement, triplicate sampling was undertaken at survey sites, although during consultation of the benthic survey design within the BMP, triplicate sampling was agreed at just 18 sites rather than every sample site. This was considered appropriate, given the breadth of sample sites targeted.

It is noted that the benthic survey design outlined in the BMP, and which was subsequently deployed, also took account of the reanalysis and reinterpretation of the EIA benthic characterisation data, as contained in Appendix A of the BMP dated December 2011, and approved by the MMO and Consultees.

After receiving approval on the BMP from the MMO and consultees in August 2012, HWL was informed of a new requirement to obtain a Crown Estate Small Works Licence and conflict check required by the Crown Estate (TCE), as required for the removal of sediments from the seabed for the benthic survey. As such, a Small Works Licence was applied for by HWL, and which was awarded in October 2012.

Following receipt of TCE Small Works Licence, a number of benthic sampling sites were noted by TCE to be within 250m of existing infrastructure, where, if these sample sites were retained, would have required the permission of the identified asset holders for HWL to undertake benthic sampling at those given locations. Permissions were requested by HWL to the identified asset holders, however no permissions (nor objections) were received. In order to proceed with the benthic survey without any further delay to the benthic survey programme presented within the BMP and as to not run the risk of delaying the 2013 construction programme owing to the need to obtain the necessary approvals to discharge planning conditions, the benthic survey commenced in November 2012, with the following acceptable modifications to the benthic sampling design:

1. Sites 33 and 34 within Aggregate Dredging area 102 – sites omitted.
2. Site 32 within 250m of the York Gas pipeline – site relocated.
3. Sites 6, 7, 26 and 27 within 250m of the Amethyst A2d to Easington Gas pipeline – sites relocated.

In addition, following an assessment of the proposed export and array cable layout a number of minor adjustments were made to the sampling design to ensure that sites were at least 100m from proposed export and array cable routes to allow for more readily accessible post construction monitoring sites, particularly after the possible transfer of the export cable to the OFTO owner.

As a consequence of this decision, sites 6, 7, and 26 (which were within 250m of the Amethyst A2d to Easington Gas pipeline) were moved south of the export route and minor adjustments (<50m) were made to sites 1, 3, 8, 17 and 41 to keep them >100m of the proposed export and array cables.

It is important to note that all relocated sites were positioned in similar depths/seabed habitats to those originally proposed sites within the BMP and the revised survey design of 40 sites is provided in the chart in ***Figure 26***.

The two sites that had been proposed within the Aggregate Dredging area 102 were omitted entirely, since permission to undertake the benthic survey from the seabed user was not received. It was deemed acceptable to omit these two survey sites, since the area is regularly dredged, it is considered that the area is not representative of benthic habitat surrounding the Humber Gateway development site. It is considered that the resultant modified benthic survey design provides a robust baseline of benthic communities and discrete assemblages within and surrounding Humber Gateway, and is now also a more appropriate baseline for comparison with any future post construction monitoring sample locations, through modification of the benthic sample locations.

It is noted that despite the benthic survey commencing in November 2012, extremely bad weather and sea conditions prevailed over the winter period which greatly hindered progress of the benthic survey, and therefore the benthic survey was not completed until end of March 2013. This has meant a delay to the benthic sample assessment and completion of the benthic data assessment component of the BMP Annual Report, which will be submitted in due course as an Addendum to this report. Furthermore, the epibenthic video drop downs have continued throughout March and April 2013, at the survey sites presented in ***Figure 27***, to ensure that the resultant video images were visible owing to more favourable sea conditions during these latter months.

6.3 Benthic Survey Methods

The benthic survey was carried out following standard procedures e.g. Marine Monitoring Handbook procedural guideline 3-9, MALSF Guidelines for the Conduct of Benthic Studies at Marine Aggregate Extraction Sites (Ware and Kenny, 2011) and as specified in the BMP. The survey utilised a 0.1m^2 Hamon grab for sampling coarser marine sediments with sediment sieved *in-situ* through a 1mm sieve and an additional sample taken at each site for Particle Size Analysis. An inspection of seabed habitats was undertaken at each site using an underwater stills/video camera to document the presence of any Annex I habitats at the sample sites and provide additional information on epibenthic communities in addition to highlighting any underwater hazards.

The surveys were undertaken using the survey vessel *Precision 1* on the 10th and 17th January, 3rd, 5th and 6th March and 11th April 2013. Water quality and tidal conditions were not ideal for video survey during the benthic survey so for purposes of providing additional information on epibenthic communities drop down video survey was repeated during neap tides on the 20th to 22nd April 2013. Benthic samples were collected at all sites and a map showing the location of samples collected is provided in ***Figure 27***. As noted earlier, benthic sample processing and analysis is currently ongoing, with data, analysis and interpretation to be provided in an Addendum to this BMP Annual Report, in due course.

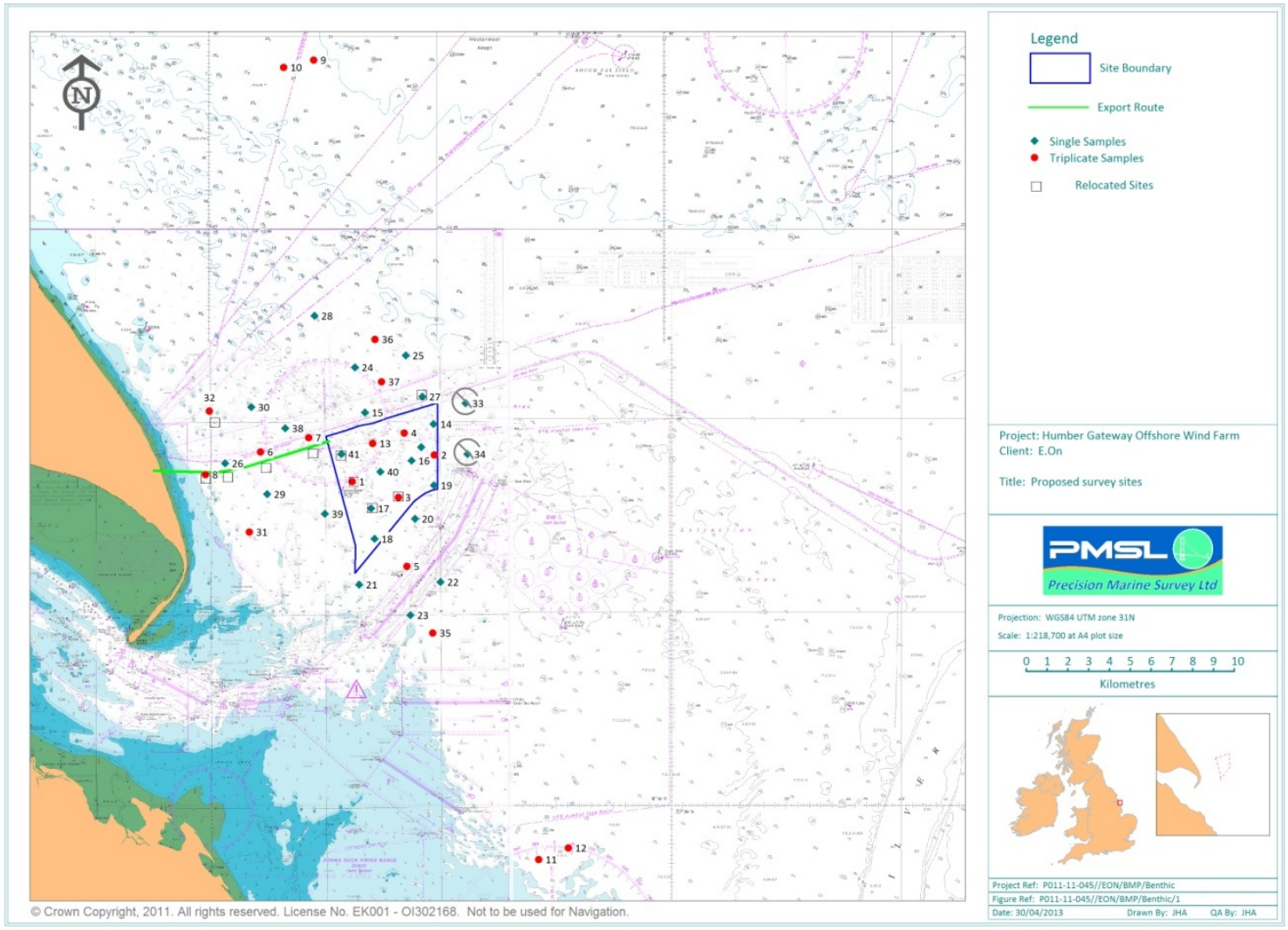


Figure 26. Original survey design showing modifications

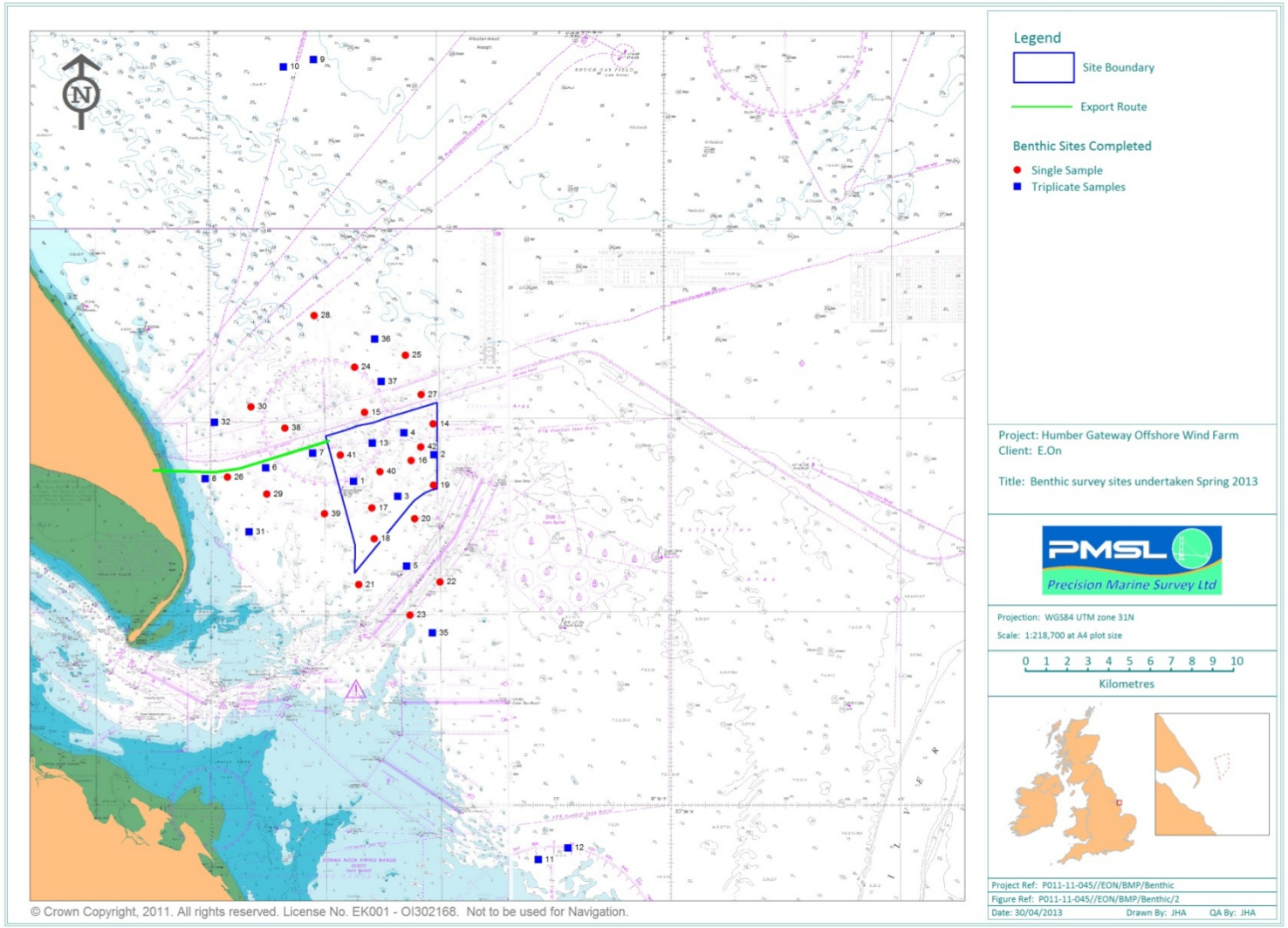


Figure 27. Benthic Sites surveyed spring 2013

6.3.1 Sample Collection

Drop down video utilised a similar methodology outlined in Section 4 for the Annex I surveys and employed an Imenco HD video and stills camera with lights and strobe flash with HD video recorded to SD card within the camera and SD video recorded to mini DV tape on board the vessel. Drifts undertaken over each site (typically 50m to 100m in length) with the camera positioned as close as possible to the seabed and occasionally set down to allow stills to be extracted.

Following an assessment of the site by drop down stills camera the vessel was repositioned at each site upon which the vessel was taken out of gear and the 0.1m^2 Hamon grab lowered by winch into the water. The winch was then used to lower the grab to the seabed at a rate of approximately 1 m/s and the winch slowed as the length of warp indicated it was approaching the seabed. Once the grab had landed, as evident by the slackening of the winch wire, the winch was stopped and the position of the grab was taken from the GPS along with time and water depth and recorded on the grab logsheet. The winch was then used to raise the grab off the seabed and docked into the retrieval frame on board the survey vessel and slowly bought aboard and lowered onto a metal frame with a sample box placed beneath.

With the grab resting on the frame, the grab was inspected to assess whether it had deployed correctly and the winch cable was then slackened to allow the lifting arm to be raised and the sample deposited into the plastic box positioned beneath the frame with the grab scoop checked to ensure all sediment has been released. The grab arm was then cocked ready for the next deployment and the grab wire held under tension to avoid triggering the grab.

Once the sample box was removed from the grab frame, the volume of sediment was assessed to check whether it met minimum requirements (5 litres) and the sediment description was recorded on the grab logsheet. A minimum of five attempts were made at each station to collect an adequate sample if volumes were below 5 litres. If required the vessel was repositioned slightly (within 50m) to allow additional attempts. In the instance that low sample volumes were collected then all samples were kept and the best/most representative one used for the faunal sample. Details of failed attempts were recorded on the grab logsheet.

Once a valid sample had been collected (or the most representative sample if the volume was below 5 litres) then the sample details were entered onto the logsheet and the sample box transferred for processing with the sample label/container within the sample box. The grab was then washed out with water ready for the next deployment. The collected sample was transferred to the sieving area and excess water emptied into the 1mm sieve. The raw sample was then photographed with the labelled bucket lid visible and the sample volume measured using the graduated sample container.

The remainder of the sample was then transferred to the sieve table for processing. The sample was gently washed through either a 1mm sieve or a 5mm sieve over the hopper or large sample box using a low pressure seawater hose. If a 5mm sieve was used first (where

coarser sediments were collected) the sieved water/sediment passing through the 5mm sieve was collected in the hopper and then passed through a 1mm sieve. Care was taken not to allow sieves to overfill and if required sieves were puddled in seawater to allow finer sediments to pass through without damaging any fauna. The residue left in the sieves was then photographed with a label and the residues transferred to a sample bucket. If there was a significant 5mm fraction this was put into a separate bucket labelled '>5mm fraction' otherwise the full residue (>1mm fraction) was transferred to a single bucket. In this process any larger or delicate animals were picked out using forceps and transferred to the sample bucket and the remaining residue gently transferred to the bucket with back-washing over a sample box (to collect any spillage) used to ensure all residue was collected and using a wide funnel to help transfer residue as required. The sieves(s) were then checked and any animals caught in the sieve mesh extracted using forceps.

The sample buckets (usually 2.5 litres) were then checked to make sure they had the correct labels which included the project title, date, survey reference and station number, sample type (PSA or Faunal) and sieve fraction as appropriate. Sample details were written on both the lid and the bucket side with an adhesive label also attached to the lid. A labelled tag was also placed inside the bucket which was then topped up with 10% buffered formalin solution with the volume of formalin equal or greater than the volume of sediment. The bucket lid was then secured onto the bucket and placed into a fish box for storage. The sample details for each sample were then entered onto the logsheet.

As per the BMP a PSA sample was also taken at each site whereby sediment was removed from a grab sample using a plastic scoop to extract a representative sub-sample of the sediment from the full depth and surface area of the sediment and including some water content. Around 500 ml was usually taken for PSA although a larger sample was used if particularly coarse sediments were obtained. The sediment samples was then transferred to a labelled plastic bag and then placed into a labelled plastic tub. Labels were checked against the logsheet and details entered as appropriate before the sample was transferred to a freezer for storage prior to analysis.

6.3.2 Laboratory Methodology

All laboratory methodologies were based on best practice and follow tried and tested method statements within the industry (Marine Monitoring Handbook procedural guideline 3-9; Ware and Kenny, 2011 and Worsfield *et al* 2010). Laboratory analysis was undertaken by experienced marine biologists/taxonomists and PMSL are members of the National Marine Biological and Analytical Quality Control scheme (NMBAQC). A standard sample tracking procedure was followed throughout the analysis period.

Sorting

The sorting methodology followed standard procedures as follows:

Each sample was sieved in freshwater water and then rinsed with running tap water through a nest of 20cm diameter 5mm and 1mm stainless steel sieves with larger sieves used as appropriate to separate cobbles etc. The sieve contents were then backwashed

over a white tray (to catch any potential spillage) into pre-labelled 5 litre plastic storage buckets or other suitable containers.

Each sample was then be re-washed through a through a nest of sieves, with the smallest mesh aperture of 1mm, to remove the preservative and partition the sample for ease of sorting. The residue from each sieve was then be gently washed into separate white trays. Water was added to the trays and the contents agitated and immediately after agitation, the light fraction is decanted to another tray. This procedure was repeated up to three times, and each tray of light fraction will be examined separately to the heavy fraction.

The trays were marked with the appropriate sample code (relating to the client, date, specific site, sample and replicate no) and all fractions were then examined as a monolayer under water in white trays, both by eye under a fluorescent bench light and 1.5x illuminated magnifier to remove larger animals with the remaining residue from the light and heavy fractions decanted into petri dishes for further sorting by binocular microscope stereo microscope (6x to 10x magnification). The fauna and residue derived from this process were then retained and stored by group in appropriately labelled containers. Each fraction was decanted into separate 100mm petri dishes and examined under a stereoscopic microscope with 20x eyepieces giving a maximum magnification of up to 80x. The fauna derived was added to the retained containers, preserved and stored ready for identification. Each petri dish was checked for a final time by another member of staff.

Taxonomic Identification

Identification was carried out using binocular zoom microscopes with 10x and 20x eyepieces, giving a maximum magnification of up to 80x. An additional 2x objective were also used as appropriate used to increase the potential magnification to 160x. Compound microscopes were also used for further magnification, up to 800x.

Identification of infaunal samples was undertaken to the lowest possible taxonomic level (i.e. species) and during identification, all individuals were initially separated into families, with part animals being assigned to families where possible. The macrofaunal animals were identified to species level using standard taxonomic keys, low and high power stereoscopic microscopes and dissection, when necessary, for identification. Incomplete animals without anterior ends were recorded as individuals to be included in the quantitative dataset but were identified where possible and recorded as present. Similarly, colonial sessile epibenthic taxa were recorded as present and not included within the infaunal quantitative data set.

Infauna were identified using standard taxonomic literature including the most up to date taxonomic keys and other more recent taxonomic publications or workshop (NMBAQC) proceedings and reporting nomenclature used the World Register of Marine Species (WoRMS) database (Appeltans, 2011).

Biomass

Biomass analysis was be performed by wet weight (tissue blotted) and carried out either for each taxa. Each item to be weighed was placed on blotting paper for a minimum of 30

seconds to allow absorption of preservative into the blotting paper after which the individuals are placed on the microbalance and the reading taken. Animals with shells were weighed with shells attached and for bivalves any fluid was drained off prior to weighing whilst echinoids were punctured and drained before weighing. The macrofaunal organisms were then placed back in their respective pots and stored. Biomass calculations included all identifiable fragments and calculated to ± 0.1mg with all biomass data will be recorded in grams or fractions thereof.

Particle Size Analysis

Particle Size Analysis was carried out as per NMBAQC guidelines and undertaken using a combination of dry sieving and laser granulometry methods as appropriate. Upon processing each of the sediment samples was mixed thoroughly until homogeneity is reached. Sub-sampling is used to split the coarse and fine fraction with sediments passed through a 1mm mesh sieve to remove the fine fraction which can then analysed by laser granulometry. The homogenised sample was dried for 48 hours at 84˚C to remove all moisture and weighed. The sample is then rehydrated and passed through a 1mm sieve by wet sieving. The <1mm fraction is retained and allowed to settle, the >1mm fraction is dried for 48 hours at 84˚C and then passed through a series of sieves at 0.5 phi fractions from 0 to -6.5 phi on a sieve shaker. Each sample was sieved for a minimum of 20 minutes and material retained on each sieve fraction weighed.

The data generated from the analysis of both the coarse and the fine fractions was combined to produce a complete particle size distribution for each sample for further analysis using the software programme Gradistat. Each sample was assigned a description based on the Folk classification system (Folk, 1974) and/or the Wentworth classification system (Wentworth, 1922). Statistics relating to particle size distribution including mean/median grain size, skewness, kurtosis, sorting coefficient and bulk sediment classes (e.g. % silt, sand & gravel) were also calculated using the Gradistat software.