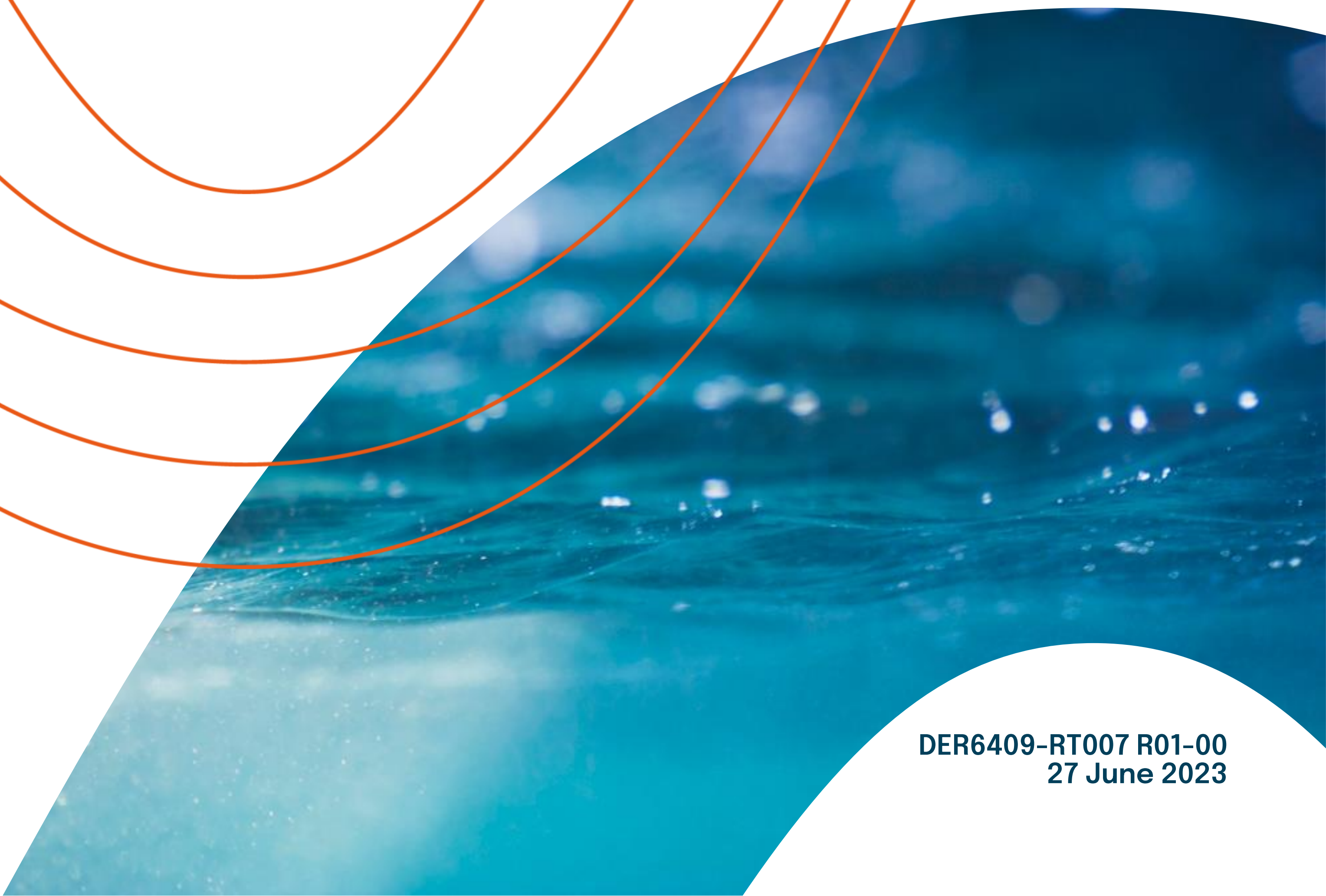
Beatrice Offshore Windfarm Ltd

hr wallingford

Beatrice Offshore Windfarm

Array Cable Monitoring: Non-Technical Report



DER6409-RT007 R01-00
27 June 2023

Document information

Document permissions	Unrestricted
Project number	DER6409
Project name	Beatrice Offshore Windfarm
Report title	Array Cable Monitoring: Non-Technical Report
Report number	RT007
Release number	01-00
Report date	27 June 2023
Client	Beatrice Offshore Windfarm Ltd

Executive summary

HR Wallingford were contracted by Beatrice Offshore Wind Ltd (BOWL) to prepare a standalone non-technical summary of the post-installation inter-array cable (IAC) monitoring at Beatrice Offshore Windfarm (BOWF). Presented in this report is a cable burial assessment of the 91 inter-array cables IACs utilising the 2019, 2020, 2021 and 2022 bathymetric and as-built cable survey data.

In this study we were tasked with analysing the cable burial along the IACs. We have compared data from the 2019, 2020, 2021 and 2022 post-installation surveys with the as-built cable levels to determine the presence of any cable exposures. These observations were verified using the 2022 ROV video footage.

The following observations were made:

- The majority of the IAC lengths are buried beneath the seabed or have rock protection berms covering them;
- There are 5 IACs which have had partial survey coverage and it is recommended to include these in future periodic monitoring surveys;
- Along some short sections of cable, in particular near the ends of sections protected by rock berms, the depth from the surrounding seabed level to the top of the cable is recorded to be less than the design minimum of 0.6 m. Along three cables (BE-G7-BE-G6, BE-G7-BE-J6 and BE-H11-BE-J12) more than 10% of the cable length is under this threshold of 0.6 m. These cables should be monitored in the future;
- The only documented cable exposures are at either end of the IAC where they exit the seabed and enter into the foundation J-tube. These sections of cable are designed to be exposed and are protected by Cable Protection Systems (CPS). No sections of exposed IAC have been identified between the two end burial points;
- The BOWF site is relatively benign in terms of seabed mobility and as a result, based on currently available information on seabed processes and site survey, we do not predict there to be any significant changes in the burial depths of the inter-array cables over the lifetime of the assets (25 years from 2018);
- The requirements of the PEMP for periodic risk-based monitoring should ensure any unexpected changes in the cable burial depths are identified by BOWL.

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1 Introduction

HR Wallingford were contracted by Beatrice Offshore Wind Ltd (BOWL) to prepare a standalone non-technical summary of the post-installation inter-array cable (IAC) monitoring at Beatrice Offshore Windfarm (BOWF). Presented in this report is a non-technical cable burial assessment of the 91 IACs utilising the 2019, 2020, 2021 and 2022 bathymetric and cable survey data.

Figure 1.1 shows the boundaries of the wind farm lease site and the location of the 91 IACs. These are arranged in fourteen circuits (also referred to as strings) and there are six Wind Turbine Generators (WTGs) per string. The first WTG in a string is connected by an IAC to an Offshore Transmission Module (OTM). The circuits are cross-connected at the ends in pairs. The two OTMs and their associated IAC form part of the Offshore Transmission Assets and are not included within this study.

1.1 Abbreviations

BOWF	Beatrice Offshore Wind Farm
BOWL	Beatrice Offshore Wind Ltd
CPS	Cable Protection System
IAC	Inter-Array Cable
LAT	Lowest Astronomical Tide
MBES	Multieam Echo Sounder
MMO	Marine Management Organisation
MSL	Mean Sea Level
O&M	Operations and Maintenance
OTM	Offshore Transformer Modules
PEMP	Project Environmental Monitoring Programme
SHL	Seaway Heavy Lift
UKHO	United Kingdom Hydrographic Office
VORF	Vertical Offshore Reference Frame
WTG	Wind Turbine Generator

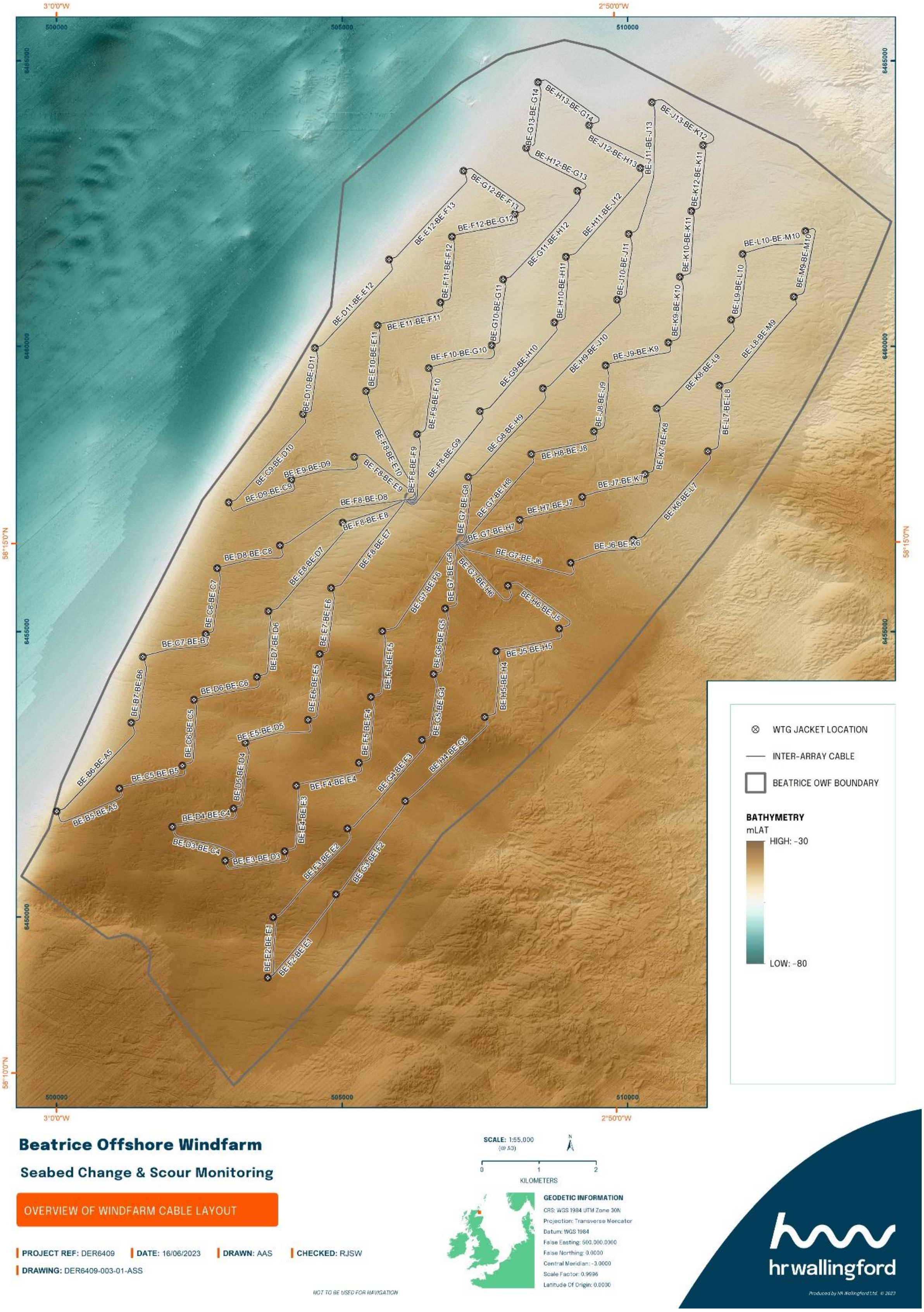

Figure 1.1: Beatrice Offshore Wind Farm location map

Source: HR Wallingford

1.1 PEMP requirements for cable monitoring

In 2020 BOWL prepared a Project Environmental Monitoring Programme (PEMP) to address the post-construction and operation and maintenance (O&M) requirements of Condition 27 of the Section 36 (S36) consent for the Beatrice Offshore Wind Farm. The PEMP outlines and defines the approach taken to monitoring of potential environmental impacts associated with post-construction and O&M. In section 13 of that document the monitoring plans for 'Seabed scour and local sediment deposition' are detailed.

In the PEMP, BOWL states that it considers that seabed scour and local sediment deposition is "an engineering issue and is not specifically linked to a sensitive environmental receptor". The MMO state that monitoring of scour should only be required in relation to the structural integrity of foundations or other associated infrastructure over the lifetime of an offshore wind farm project (MMO, 2014).

The lifetime of the BOWF assets is 25 years (service life) from installation in 2017/2018.

The aims and objectives of monitoring undertaken for seabed scour and local sediment deposition are:

- To monitor development, if any, of scour at WTG foundations; and
- To monitor any exposure of IACs.

The monitoring strategy for the IACs is as follows:

- Following installation, an assessment will be completed identifying areas of cable at potential risk of exposure in the future. Monitoring of these 'at-risk' areas will be conducted annually initially;
- Subject to the findings of the surveys, the frequency of these will be adapted to the appropriate level of risk exposure.

In relation to the impacts of cable, commitments were made by BOWL in the Environmental Statement that were highlighted within the PEMP. These include:

- "Monitoring of the effects from cable installation will be included as part of the overall benthic monitoring plan. Post construction surveys to validate predictions made regarding potential impacts on benthic habitats and their subsequent recovery";
- "Periodic and planned surveys of cable routes to monitor burial depths and seabed mobility for shipping and navigation purposes".

These two areas will not be directly addressed in this report, although the findings presented may be useful to BOWL in addressing these two commitments.

1.2 Description of survey location selection

Post-installation and rock placement documentation (Route Alignment Charts) provided by the Marine Installation Contractor based on post-installation geophysical surveys, were consulted by BOWL engineers when determining a selection of cables to survey during the first subsea survey and inspection campaign in late 2019, and subsequent campaigns in 2020, and 2021 and 2022.

Cable survey locations were selected to fulfil operational asset management obligations under the DNV manual (maritime asset risk management manual) and the O&M manual for BOWL (written by SHL, who were the construction Principal Contractor for BOWL)[1].

During the first year of O&M (2019) surveys were carried out at cable locations carrying highest asset management risk, i.e. those cables that if damaged, would result in higher loss of generation export capacity. In effect this meant the initial survey locations were on cables

[1] BOWF, pers. comm., 2023.

running from the OTMs to the terminal turbines in cable strings, as these cable sections would be transferring energy generated by all turbines in that string. In subsequent years, the next highest asset management risk locations were surveyed, such as cables protected with rock armour. At the end-of-warranty survey in 2022, the remaining (lower asset management risk) cable locations were surveyed.

The total numbers of inter array cables surveyed in each of the first four years of O&M were:

- In year 1 (2019) – 13 inter array cables surveyed;
- In year 2 (2020) – 14 inter array cables surveyed;
- In year 3 (2021) – 14 inter array cables surveyed;
- In year 4 (2022) – 65 inter array cables surveyed.

In future years, other potential asset management risk locations (such as cables in areas of higher third party activity) may be included as survey priorities.

2 Description of as installed cables

2.1 Cable lay and trenching

A small number of cables were laid and trenched in November 2017, with the majority installed between March and August 2018. Two different cables were used across the wind farm; a 300 mm^2 design with an outer diameter of 124 mm and a 630 mm^2 design with an outer diameter of 150 mm. Typically there was a gap of a few days between the laying and the trenching operations. After each trenching operation the seafloor was resurveyed. If the trenching operation was not successful then up to two rounds (passes) of further trenching operations took place. The trenching installation process used two different trenching systems a jet-trencher and I-trencher.

Based on the information set out in the Cable Burial Risk Assessment (not provided), BOWL aimed to achieve a depth from the original seabed level to the top of the inter-array cables of 0.6 m to 0.8 m, as this was deemed to be an attainable depth that provided adequate protection to cables from the identified hazards. In locations where the trenching did not achieve the lowering threshold of 0.6 m, rock protection was applied (discussed in Section 2.2).

2.2 Cable protection

Engineered rock berms were installed between October and November 2018 to protect cables that did not meet the minimum lowering requirement(0.6 m). For 44 of the IACs there was at least one section where rock protection was required. The rock berms installed were typically 0.6 m in height, but ranged between 0.4 and 0.8 m and had a toe width of approximately 6 m. Spot dump rock berms as short as 1 m length were installed. Some cables had in excess of 10 rock berms installed along their length, where the gaps between the rock berms could be shorter than 10 m. In total 253 rock berms were installed across the site.

After pull-in to the jacket foundation the cable touched down on the seafloor typically at 3 to 5 m from the exiting J-tube. Trenching operations could not be conducted in the immediate vicinity of the jacket and instead typically started at a distance of 17 to 18 m from the J-tube. This section of cable was protected using a Cable Protection System (CPS[2]), installed at the end of each IAC. We do not have any information on what this CPS comprises, though typically at wind farms a sheath of articulated plastic or metal casing is used. We can determine that the CPS extended from the J-tube out to approximately 16 to 20 m. Therefore, the cable was protected out to the distance where the trenching takes place. Figure 2.1 shows a still photograph from the

[2] Tekmar CPS (https://www.offshorewind.biz/2016/09/28/tekmar-cps-to-protect-beatrice-inter-array-cables/, accessed 26 June 2023)

2022 ROV survey of the cable exiting seafloor at the C5 end of the IAC-C5-B5 cable. Whilst Figure 2.2 and Figure 2.3 show the catenary (the section of cable in suspension) and the cable entering the J-tube for the same cable.

Figure 2.1: Burial point of IAC-C5-B5 at the C5 end

Source: RovCo 2022

Figure 2.2: Catenary of IAC-C5-B5 at the C5 end

Source: RovCo 2022

Figure 2.3: Bend-restrictor and bellmouth of J-Tube of IAC-C5-B5 at the C5 end

Source: RovCo 2022

3 Site setting

3.1 Geomorphology

The assessments that have been carried out by BGS and DTI (2004) and ABPmer (2012) in this region, provide a technical overview of the field site's bathymetric setting and seabed character.

The seabed configuration of the Moray Firth has been inherited from the effects of the ice sheets that covered the area during the last glaciation. Subsequent reworking of glaciogenic features developed further seabed variation (BGS and DTI, 2004). The input of new sedimentary material from the land into the Firth is limited (Barne et al., 1996).

Smith Bank is a distinct topographic platform. It is situated in the northwest of the Moray Firth and is associated with a geological fault block. It is approximately 35 km long and 20 km wide. The BGS and DTI (2004) estimates that the area of seabed on the Smith Bank that is in less than 50 m water depth is approximately 40 square km.

The site bathymetry (Figure 1.1) shows that seabed levels range from 35 m below Lowest Astronomical Tide (LAT) in the south-western corner to 68 m below LAT in the north-western corner of the site. Apart from a very gentle (maximum 2.6°) slope along the margin of Smith Bank to the north, numerous raised ridges and associated narrow troughs were identified by Osiris (2011) across approximately 75% of the central and southern part of the site. These ridges are up to 1.2 m high and 50 to 70 m apart. Osiris interpreted that finer grained sand material is present on the ridges and more gravelly sand within the troughs.

The sediment type varies across the region, characterised by muddy sand, sand, gravelly sand and gravelly sand (BGS, 2004). Grab samples from Smith Bank (EMU, 2011) are dominated by gravelly and slightly gravelly sands. ABPmer (2012) describe these samples as poorly - very poorly sorted which indicates low sea-bed mobility. Further, previous BGS surveys of the Moray Firth reveal the seabed is not widely populated by large scale bedforms, suggesting that the region is characterised as low energy due to limited bedload sediment transport having taken place. ABPmer (2012) also describe the tidal regime within the Moray Firth as 'benign', which indicates that when sediment transport does occur it is likely to do so in association with low-frequency and high energy storm events. This interpretation is further supported by the trend of decreasing sediment grain size with increasing water depth (BGS and DTI, 2004) as it indicates the importance of wave action involved in sediment transport within the Moray Firth.

Offshore sediment transport is directed from the north towards the southwest into the Moray Firth (Reid and McManus 1987; ABPmer, 2012). The dominant direction of sediment transport within the Firth broadly corresponds to the tidal flow axis in the region. Sediment is thought to exit the Moray Firth in the southeast as sediment transport is noted along the southern coast of the Firth in association with east - west tidal currents (Reid and McManus, 1987).

3.2 Soil conditions

The surficial sediment across the site can be broadly grouped into three classes: medium to coarse SAND, medium to coarse SAND and GRAVEL and till which comprises gravelly CLAY, with cobbles and boulders. The distribution of these three classes is shown in Figure 3.1.

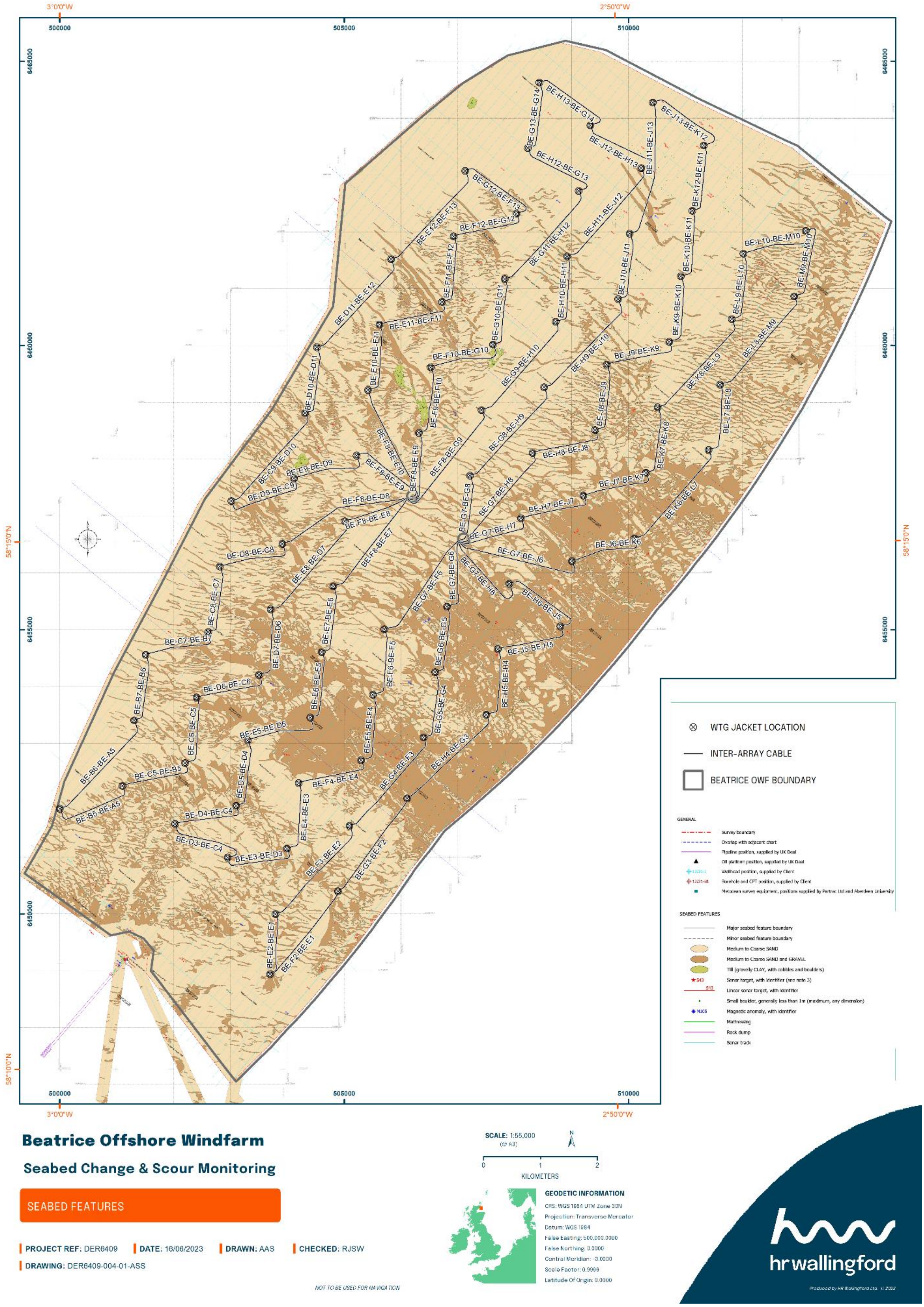

Figure 3.1: Seabed surficial sediment and features map

Source: HR Wallingford using data provided by Osiris

Soil profiles have been extracted from Atkins (2016). Within the top 3 m of the surface the units listed in Table 3.1 are found. Geological stratums are listed from youngest I (Upper Quaternary) to oldest IV (Early Cretaceous). The relative strength of the soils increases with age.

Particle Size Distribution (PSD) analyses indicate that the material in stratum I-Gr is generally a well-graded fine to medium SAND. The other granular strata i.e. stratum II-Gr, stratum III-Gr and stratum IV-Gr encountered generally contain high percentages of fines. The PSD tests indicate that all the cohesive strata across the site contain high percentages of clays, silts and sands.

The typical median grain size (d_{50}) for stratum I-Gr is between 0.117 and 0.416 mm with a mean value of 0.27 mm. The typical range for stratum II-Gr is between 0.065 and 0.345 mm with mean of 0.155 mm.

The design soil classification is a simplification of the ground conditions and some variability should be expected within individual strata. This is demonstrated by the wide range of particle sizes within each of the strata.

Table 3.1: Soil classification within upper 3.5 m of profile

Geological stratum	Description	d50 range (mm)	Mean d50 (mm)	Clay range (%)	Silt range (%)	Sand range (%)	Gravel range (%)
I-Gr	Upper Quaternary sands and gravels	0.117 – 0.416	0.27	0 – 6	1 –13	56 – 99	0 – 42
II-Co	Quaternary cohesive			10 – 55	22 – 60	6 – 59	0 – 7
II-Gr	Quaternary non-cohesive	0.065 – 0.345	0.155	<10 -– 11	1 – 41	51 – 98	0 – 8
III-Gr	Disturbed bedrock			<10 – 22	4 – 50	49 – 96	0 –10
IV-Gr	Largely intact bedrock			<10 – 18	8 – 31	53 – 92	0 – 14

Source: Data extracted from Atkins 2016

3.3 Metocean conditions

Metocean conditions are provided for two locations: BOWL Inner (water depth approximately -37 mLAT), at the very south of the wind farm lease site and BOWL Outer (water depth approximately -49 mLAT) at the very northeast of the site (ABP, 2012).

The tidal range at the BOWF site is 3.2 m on spring tides and 1.6 m on neaps and Mean Sea Level (MSL) is +2.31 m above LAT.

The BOWF site is exposed to waves approaching for the northeast, southeast and to a lesser extent the southwest (Figure 3.2). Larger wave heights are observed at the seaward (northeastern) extent of the site. Here 1 in 1 year significant wave heights are 8.0 m and have associated periods of 13 s (Table 3.2). Extreme significant wave heights increase marginally with longer return periods. For example the 1 in 50 year significant wave height is 9.4 m.

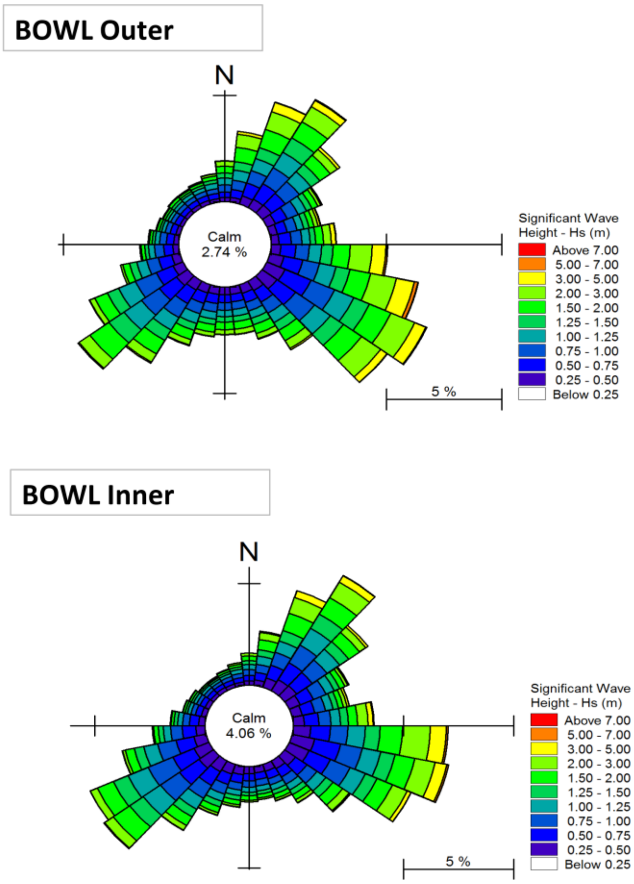

Figure 3.2: Wave roses for BOWL outer and inner

Source: ABP 2012

Table 3.2: Extreme omni-directional wave height and associated parameters for BOWL outer

	1 in 1 year	1 in 5 year	1 in 10 year	1 in 50 year
Significant wave height (m)	8.0	8.7	8.9	9.4
Peak wave period, central estimate (s)	13.0	13.6	13.8	14.1

Source: HR Wallingford using information from ABP 2012

Tidal currents are strongly rectilinear and aligned with the ebb towards north-northeast and flood towards south-southwest (Figure 3.3). Flow speeds are faster in the outer parts of the site.

Tidal currents are relatively weak reaching a peak of 0.55 m/s in the outer site area. By comparison storm surge currents are stronger, even for the 1 in 1 year return period. The storm surge component is strongly unidirectional and acts in a southerly direction.

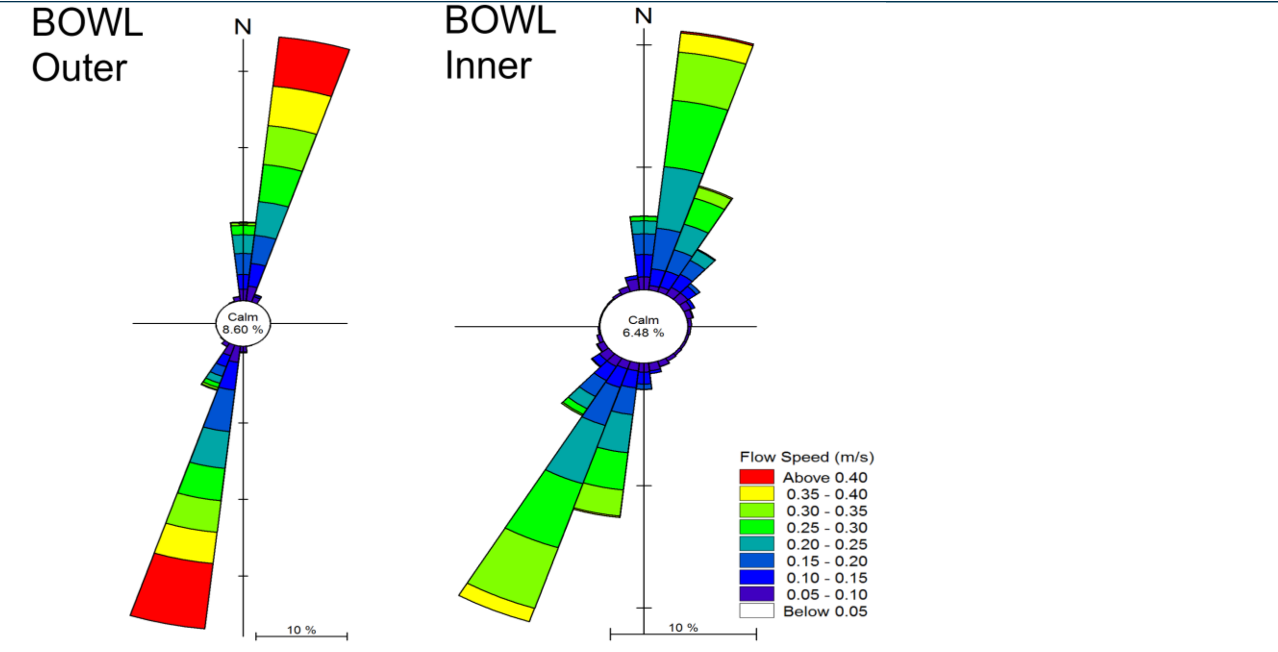

Figure 3.3: Tidal current roses for BOWL outer and inner

Source: ABP 2012

Table 3.3: Extreme tidal and surge currents for BOWL inner and outer

	BOWL inner			BOWL outer		
Return period (year)	Tidal component (m/s)	Surge component (m/s)	Total current (m/s)	Tidal component (m/s)	Surge component (m/s)	Total current (m/s)
1 in 1	0.45	0.50	0.94	0.55	0.50	1.05
1 in 10	0.45	0.64	1.09	0.55	0.64	1.19
1 in 100	0.45	0.75	1.19	0.55	0.75	1.29

Source: ABP 2012

4 Survey specification

4.1 Survey methodology

Table 4.1 summarises the Multibeam Echo Sounder (MBES) bathymetric data use for this IAC monitoring assessment.

Table 4.1: Summary of bathymetric data used in this study

Year	Month	Surveyor	Coverage	Geographical projection	Vertical datum	Resolution of data provided
2016		Fugro	Site wide	WGS84 UTM 30N	Not specified	0.5 m
2019	October	Fugro	10 WTG, 2 OTM, 13 inter-array cables, sections of export cables	WGS84 UTM 30N	VORF LAT	0.25 m
2020	October - November	RovCo	16 foundations,	WGS84 UTM 30N	LAT (method	Raw and 0.25 m*

Year	Month	Surveyor	Coverage	Geographical projection	Vertical datum	Resolution of data provided
			14 inter-array cables, inter-connector, sections of export cable		not specified)	
2021	July	RovCo	10 foundations, 14 inter-array cables	WGS84 UTM 30N	VORF LAT	0.25 m
2022	April	RovCo	70 foundations, 65 inter-array cables	WGS84 UTM 30N	VORF LAT	0.25 m

Source: HR Wallingford

*Note: *whilst these data were provided gridded to 0.25 m a grid resolution of 0.5 m is more appropriate for the spacing of the data (i.e. the data were too sparse to create a 0.25 m grid)*

4.2 Vertical datums

We have compared the differences in bathymetric surface across the site using the 2016 (the most recent site-wide survey) as a baseline (Table 4.2). In each case the distribution of values is relatively tight about a mean and when visually inspecting the surfaces the offsets appear relatively homogenous across the site. For this reason we have applied the fixed offsets provided in Table 4.2 to vertically align the surveys to the level of the 2016 pre-installation surface. No offset was applied to the 2021 or 2022 data given its close agreement with the 2016 survey.

Table 4.2: Average difference between each bathymetric surface and the 2016 Fugro

	Average (m)	Standard deviation
Fugro 2016	N/A	N/A
Fugro 2019	-0.07	0.12
RovCo 2020	-0.68	0.13
RovCo 2021	0.02	0.13
RovCo 2022	-0.02	0.12

Source: HR Wallingford

Note: N/A not applicable as this was used as baseline

4.3 Data quality

RovCo did not report any estimates for the total propagated uncertainty of the multibeam bathymetry data. However, it is stated in the survey reports (RovCo, 2021a; 2021b; 2023) that the surveys were conducted to meet UKHO Special Order requirements. For a water depth of 40 m (representative of the depths found across the windfarm) UKHO special order specifications require a total horizontal uncertainty of less than 2 m and a total vertical uncertainty of less than 0.4 m.

From our review of the data quality and the vertical offsets between the different surveys we recommend using an uncertainty of ±0.2 m when comparing any two bathymetric surfaces.

5 Data collected during surveys

5.1 Data coverage

HR Wallingford were provided with as-laid and trenched cable listings. Given all cables have been trenched the as-trenched listings provide a good estimation of the present-day positions of the cables (assuming there has been no movement of the cables, which is a reasonable assumption).

Table 5.1 details the coverage of the 91 IACs in the 2019, 2020, 2021 and 2022 surveys. The naming convention for the IAC is such that the first WTG listed is where the cable laying started (presumably first-end pull in) and the second WTG is where the cable was laid to (presumably second-end pull in).

Thirteen (13) cables were surveyed in 2019. Fourteen (14) cables were surveyed in 2020, however, six (6) of these were only partial coverage, fourteen (14) cables were surveyed in 2021 and sixty-five (65) cables were surveyed in 2022.

We note the following cables have only been partially surveyed since installation:

- BE-B06-BE-A05;
- BE-F09-BE-F10;
- BE-F10-BE-G10;
- BE-G12-BE-F13;
- BE-H09-BE-J10.

Table 5.1: Cable route multibeam echosounder data availability for 2019, 2020, 2021 and 2022 surveys

Cable ID	Fugro 2019	RovCo 2020	RovCo 2021	RovCo 2022
BE-B05-BE-A05				Yes
BE-B06-BE-A05		Partial (B06 half)		
BE-B07-BE-B06				Yes
BE-C05-BE-B05				Yes
BE-C06-BE-C05				Yes
BE-C07-BE-B07			Yes	
BE-C08-BE-C07				Yes
BE-C09-BE-D10				Yes
BE-D03-BE-C04			Yes	
BE-D04-BE-C04				Yes
BE-D05-BE-D04				Yes
BE-D06-BE-C06				Yes
BE-D07-BE-D06				Yes
BE-D08-BE-C08				Yes
BE-D09-BE-C09		Yes		
BE-D10-BE-D11				Yes
BE-D11-BE-E12				Yes
BE-E02-BE-E01		Yes		
BE-E03-BE-D03				Yes
BE-E04-BE-E03				Yes
BE-E05-BE-D05		Yes		
BE-E06-BE-E05			Yes	
BE-E07-BE-E06				Yes
BE-E08-BE-D07				Yes

Cable ID	Fugro 2019	RovCo 2020	RovCo 2021	RovCo 2022
BE-E09-BE-D09				Yes
BE-E10-BE-E11				Yes
BE-E11-BE-F11				Yes
BE-E12-BE-F13				Yes
BE-F02-BE-E01				Yes
BE-F03-BE-E02				Yes
BE-F04-BE-E04			Yes	
BE-F05-BE-F04			Yes	
BE-F06-BE-F05				Yes
BE-F08-BE-D08				Yes
BE-F08-BE-E07				Yes
BE-F08-BE-E08				Yes
BE-F08-BE-E09		Yes		
BE-F08-BE-E10				Yes
BE-F08-BE-F09			Yes	
BE-F08-BE-G09				Yes
BE-F09-BE-F10		Partial (mid-section)		
BE-F10-BE-G10		Partial (G10 end)		
BE-F11-BE-F12			Yes	
BE-F12-BE-G12				Yes
BE-G03-BE-F02				Yes
BE-G04-BE-F03		Yes		
BE-G05-BE-G04				Yes
BE-G06-BE-G05				Yes
BE-G07-BE-F06				Yes
BE-G07-BE-G06	Yes			Yes
BE-G07-BE-G08			Yes	
BE-G07-BE-H06				Yes
BE-G07-BE-H07				Yes
BE-G07-BE-H08				Yes
BE-G07-BE-J06				Yes
BE-G08-BE-H09				Yes
BE-G09-BE-H10				Yes
BE-G10-BE-G11				Yes
BE-G11-BE-H12				Yes
BE-G12-BE-F13		Partial (G12 end)		
BE-G13-BE-G14		Yes		Yes
BE-H04-BE-G03		Yes	Yes	
BE-H05-BE-H04		Yes		
BE-H06-BE-J05	Yes			Yes
BE-H07-BE-J07				Yes
BE-H08-BE-J08	Yes			Yes
BE-H09-BE-J10		Partial (J10 end)		
BE-H10-BE-H11				Yes
BE-H11-BE-J12	Yes			Yes
BE-H12-BE-G13			Yes	
BE-H13-BE-G14				Yes
BE-J05-BE-H05				Yes

Cable ID	Fugro 2019	RovCo 2020	RovCo 2021	RovCo 2022
BE-J06-BE-K06	Yes			Yes
BE-J07-BE-K07				Yes
BE-J08-BE-J09			Yes	
BE-J09-BE-K09	Yes	Partial (J09 end)		
BE-J10-BE-J11			Yes	
BE-J11-BE-J13				Yes
BE-J12-BE-H13	Yes			Yes
BE-J13-BE-K12	Yes			Yes
BE-K06-BE-L07	Yes			Yes
BE-K07-BE-K08				Yes
BE-K08-BE-L09	Yes			Yes
BE-K09-BE-K10				Yes
BE-K10-BE-K11				Yes
BE-K12-BE-K11			Yes	
BE-L07-BE-L08			Yes	
BE-L08-BE-M09	Yes			Yes
BE-L09-BE-L10	Yes			Yes
BE-L10-BE-M10	Yes			Yes
BE-M09-BE-M10				Yes

Source: HR Wallingford

Note: Some cables may have data available at the ends of the cables due to the survey coverage from the foundation scour survey, these are not included within this table

6 Results

6.1 Areas of IAC where no action is required

A minimum Depth of Lowering for protection from fishing and anchoring of smaller vessels (deemed the most likely threat) was set at 0.6 m (BOWL, 2016). Most sections of cable where this depth was less than 0.6 m were covered by rock berms to provide protection. Where rock berms have been installed this depth is no longer relevant, since the rock provides protection instead of the lowering afforded just through trenching.

There have been no natural large scale (>0.2 m in the vertical (z) direction) seabed changes at site since installation (2016 to 2022) along the cable routes, and hence the cables remain lower than the surrounding seabed. Sediment ripples were visible in the 2019 and the 2022 bathymetry data. The symmetry and linearity of these bedforms indicate that they have formed under wave dominated activity. These ripples are unlikely to be associated with net migration of material.

The impact of wind farm infrastructure on seabed is minimal. Scour has been observed at the WTG jacket legs, but there is no obvious development of scour along the berms at present. Rock berms are likely to reshape with time, but will still likely provide sufficient coverage given their installed base width of approximately 6 m on the otherwise generally stable seabed within the wind farm.

We note that the post-installation backfill level in the trench can be variable. As a result some cables have limited cover (e.g. <0.4 m). Due to the relatively benign morphology of the site it is not anticipated that any trenches that were partially backfilled will fill in due to natural sediment transport processes.

6.2 Areas of IAC where cover level is at a threshold where monitoring is recommended

Typically the sections with a depth of less than 0.6 m are at the ends of the cables (where the cable is protected with CPS, Section 2.2) and at the ends of the rock berms.

Those cables with more than 10% of their total length not conforming to this depth (of 0.6 m) include: BE-G7-BE-G6, BE-G7-BE-J6 and BE-H11-BE-J12:

- BE-G7-BE-G6: Minimum depth from cable to original seabed level not met at start and ends of rock berms. Minimum is 0.5 m;
- BE-G7-BE-J6: Minimum depth from cable to original seabed level not met at start and ends of rock berms. Short section of 0.2 m depth;
- BE-H11-BE-J12: Minimum depth from cable to original seabed level not met at start and ends of rock berms. Minimum is 0.4 m.

There is a potential risk of exposure of cables at the ends of rock berms. Typically the cables are less deeply buried along these transition sections (hence the requirement for the rock berm along neighbouring sections). Monitoring should continue as per the monitoring plan outlined in the consent plan. It is recommended that for annual surveys a small subsample of the IACs surveyed are kept the same, so that any ongoing trends in erosion or deposition can be captured.

6.3 Identified areas of exposed IAC

Figure 6.1 shows locations where the IACs are exposed on the seabed. At either end of the cable is a short section (on average 14 m from the jacket leg and as much as 24 m) where the cable exits the seabed from burial and joins up to the foundation through the J-tube. Along all of these sections the cable is in CPS (as shown in Section 2.2). These exposures are part of the design and are not of concern and do not require additional monitoring.

No sections of exposed IAC have been identified between the two end burial points.

These findings were supported by the analysis of the 2022 RovCo ROV footage at 65 IACs, in which no exposures were recorded between the two end burial points.

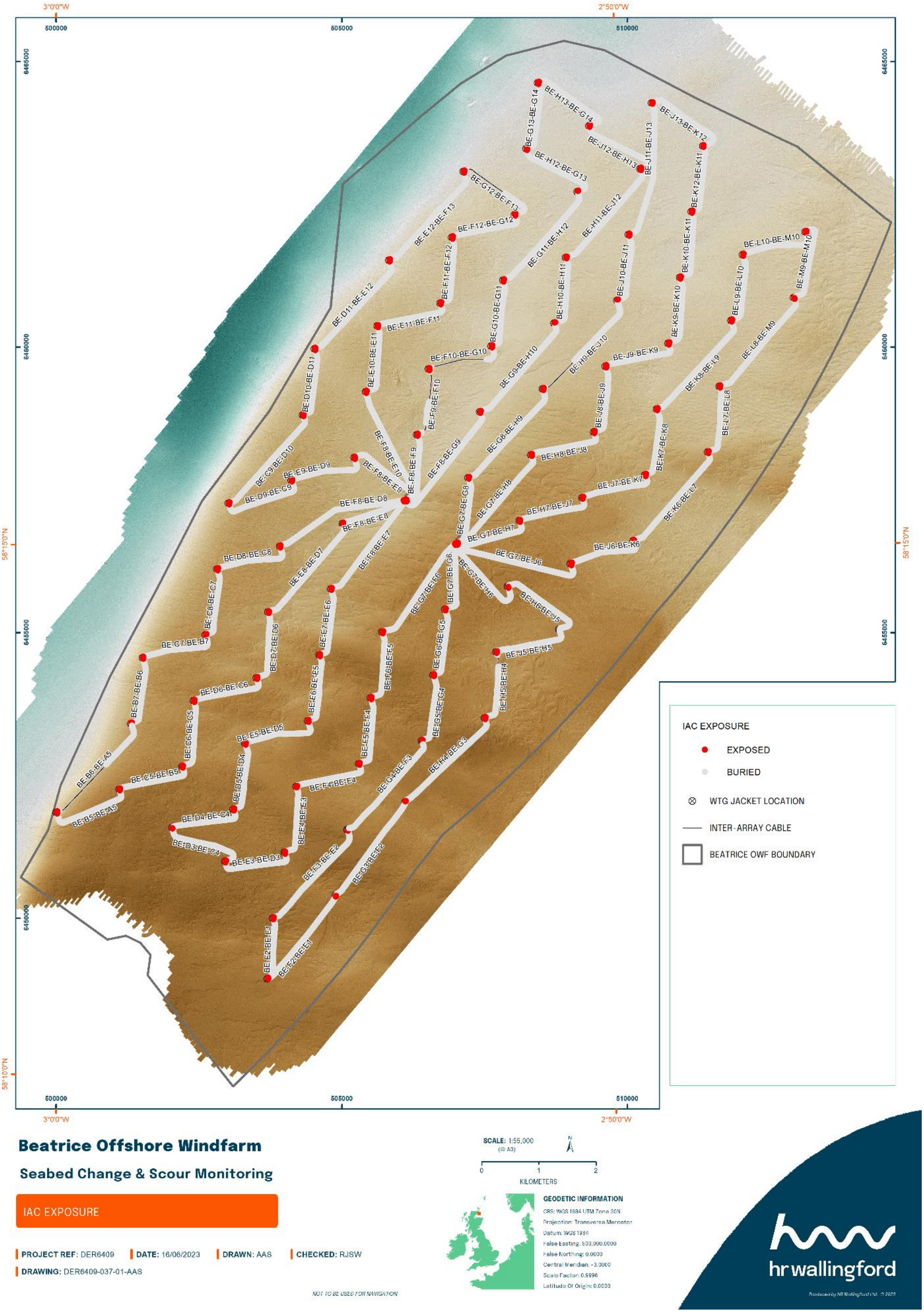

Figure 6.1: Locations of cable exposures using the 2019, 2020, 2021 and 2022 bathymetric data

Source: HR Wallingford

7 Conclusions

The following observations were made based on the analysis of IAC cables at Beatrice Offshore Wind Farm (BOWF):

- The majority of the IAC lengths are buried beneath the seabed or have rock protection berms covering them;
- There are 5 IACs which have had partial survey coverage and it is recommended to include these in future periodic monitoring surveys;
- Along some short sections of cable, in particular near the ends of sections protected by rock berms, the depth from the surrounding seabed level to the top of the cable is recorded to be less than the design minimum of 0.6 m. Along three cables (BE-G7-BE-G6, BE-G7-BE-J6 and BE-H11-BE-J12) more than 10% of the cable length is under this threshold of 0.6 m. These cables should be monitored in the future;
- The only documented cable exposures are at either end of the IAC where they exit the seabed and enter into the foundation J-tube. These sections of cable are designed to be exposed and are protected by Cable Protection Systems (CPS). No sections of exposed IAC have been identified between the two end burial points;
- The BOWF site is relatively benign in terms of seabed mobility and as a result, based on currently available information on seabed processes and site survey, we do not predict there to be any significant changes in the burial depths of the inter-array cables over the lifetime of the assets (25 years from 2018);
- The requirements of the PEMP for periodic risk-based monitoring should ensure any unexpected changes in the cable burial depths are identified by BOWL.

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HR Wallingford
Howbery Park
Wallingford
Oxfordshire OX10 8BA
United Kingdom

+44 (0)1491 835381

info@hrwallingford.com

www.hrwallingford.com