Morecambe Offshore Windfarm: Generation Assets

Environmental Statement

Volume 5

Appendix 15.1 Archaeological Assessment of Geophysical and Hydrographic Data

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Morecambe Offshore Windfarm

Archaeological Assessment of Geophysical and Hydrographic Data

Produced for Royal Haskoning DHV

MSDS Marine

MSDS Marine MSDS Heritage

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Morecambe Offshore Windfarm

Archaeological Assessment of Geophysical and Hydrographic Data

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1.0 Introduction

1.0.1 MSDS Marine Limited (MSDS Marine) have been contracted by Royal Haskoning DHV (RHDHV) to undertake an archaeological assessment of geophysical and hydrographic survey data collected within the windfarm site (generation assets) of Morecambe Offshore Windfarm in the Irish Sea, approximately 45 km south-west of the entrance to Morecambe Bay.

1.0.2 The survey was conducted by MMT during October and November 2021, and consisted of Sidescan Sonar (SSS), Multibeam Bathymetry (MBES), Magnetometer, and Sub-bottom Profiler (SBP). The assessment is being undertaken to inform the Environmental Impact Assessment (EIA) process.

1.0.3 This document forms the archaeological assessment of the geophysical and hydrographic survey data, and outlines the specification of the data, the method of archaeological assessment, the presentation of the results and recommendations for mitigation strategies. Prior to the commencement of the archaeological assessment of data, a data audit was undertaken the results of which are presented in Annex B.

2.0 Project location and status

2.0.1 The Project is a proposed offshore windfarm located in the east Irish Sea, this report pertains to the offshore generation assets, and the windfarm site. The windfarm was selected in early 2021 as part of The Crown Estate's Offshore Wind Leasing Round 4. The Project was secured by Flotation Energy plc (Flotation Energy) in February 2021 alongside their Spanish joint venture Partner Cobra (part of the ACS Group).

2.0.2 The windfarm site is situated in the vicinity of the South Morecambe Gas Fields (which are currently expected to cease production around 2027 (+/-2 years)). An factor in the windfarm site's selection was the potential for The Project to co-exist with oil and gas operations on previously developed seabed.

2.0.3 The Project will comprise an area of up to 125 km^2, located approximately 30 km off the Lancashire coast. The Project will include wind turbine generators (windfarm array), offshore substation(s) to convert generated power to a suitable voltage for transmission to shore, inter-array cables to connect wind turbine generators to the offshore substation(s), and possible platform link cables to connect offshore substations. When fully operational, The Project will have an anticipated nominal capacity of 480 megawatts (MW) and will have the potential to generate renewable power for over 500,000 homes in the United Kingdom (UK).

2.0.4 The Offshore Scoping Report[1] for the offshore generation assets, was submitted on the 23rd June 2022 in support of the request for a formal Scoping Opinion, a response from which was received in August 2022[2]

2.0.5 The location of Morecambe Offshore Windfarm is shown in Figure 1.

[1] RHDHV, 2022. *Scoping Report. Morecambe Offshore Windfarm. Generation Assets*. Reference: FLO-MOR-REP-0007

[2] The Planning Inspectorate, 2022. *Scoping Opinion. Proposed Morecambe Offshore Windfarm*. Case Reference EN010121 Available at https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010121/EN010121-000052-MORC%20-%20Scoping%20Opinion%20.pdf

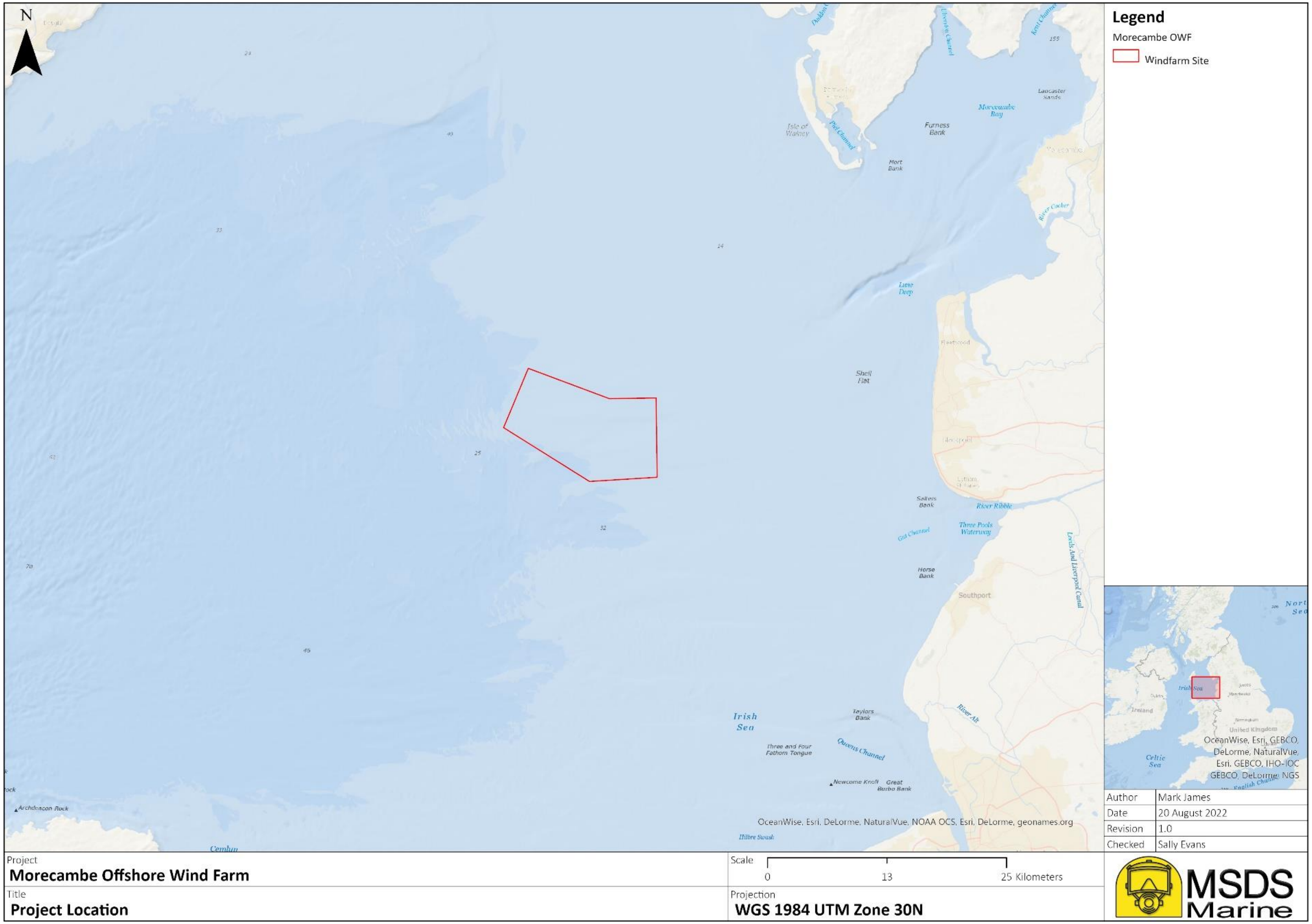

Figure 1: Location of Morecambe Offshore Windfarm

3.0 Aims and objectives

3.1 Archaeological review of geophysical and hydrographic data

3.1.1 The principle aim of the archaeological review of geophysical and hydrographic data is to establish the presence of material of potential archaeological significance on the seabed and the potential for submerged prehistoric remains laid down during different climatic and environmental conditions in the past. The identification of material and geological horizons allows for strategies to be recommended to mitigate against any negative effects that may be caused by the development process.

3.1.2 The objectives of the archaeological interpretation can be summarised as follows;

- To establish the presence of anthropogenic material of archaeological potential;
- To interpret the identified anomalies as to their potential to be of archaeological significance;
- To recommend mitigation strategies for the anomalies appropriate to their archaeological potential;
- To establish the palaeolandscape potential;
- To recommend mitigation strategies in relation to the palaeolandscape and palaeoenvironment; and
- To recommend further works that may be required and their specifications.

4.0 Existing infrastructure

4.0.1 The windfarm site encompasses the Calder gas field to the west and bisects the South Morecambe gas field to the north-east. Calder gas field was discovered in 1982 and started production in 2004, and South Morecambe was discovered in 1974 and started production in 1985. Both gas fields are still producing. Data was obtained from the North Sea Transition Authority[3] (NSTA) to identify the locations of infrastructure to ensure that it was not unnecessarily identified as of archaeological potential.

4.0.2 Infrastructure associated with the gas fields includes two platforms, Calder which is active and DP3 (in Morecambe South) which is not in use, the areas around which were excluded from the survey included pipelines, power cables, wells, well paths, and well bottom locations. The majority of infrastructure was visible either on the surface, or within the magnetometer data. The notable exception to this being the Calder to CPP1 power cable running north-east from the Calder platform. Where geophysical anomalies, in particular magnetic anomalies, were attributed to infrastructure they were removed from the dataset.

4.0.3 The locations are shown in Figure 2 and the type classified in Table 1 below

Infrastructure Type	Count	Notes
Pipeline	3	One active, two not in use
Power cable	4	Two active, two not in use
Well location	18	Associated with 17 well bottom locations and 17 well paths

Table 1: Infrastructure within the windfarm site

[3] https://www.nstauthority.co.uk/

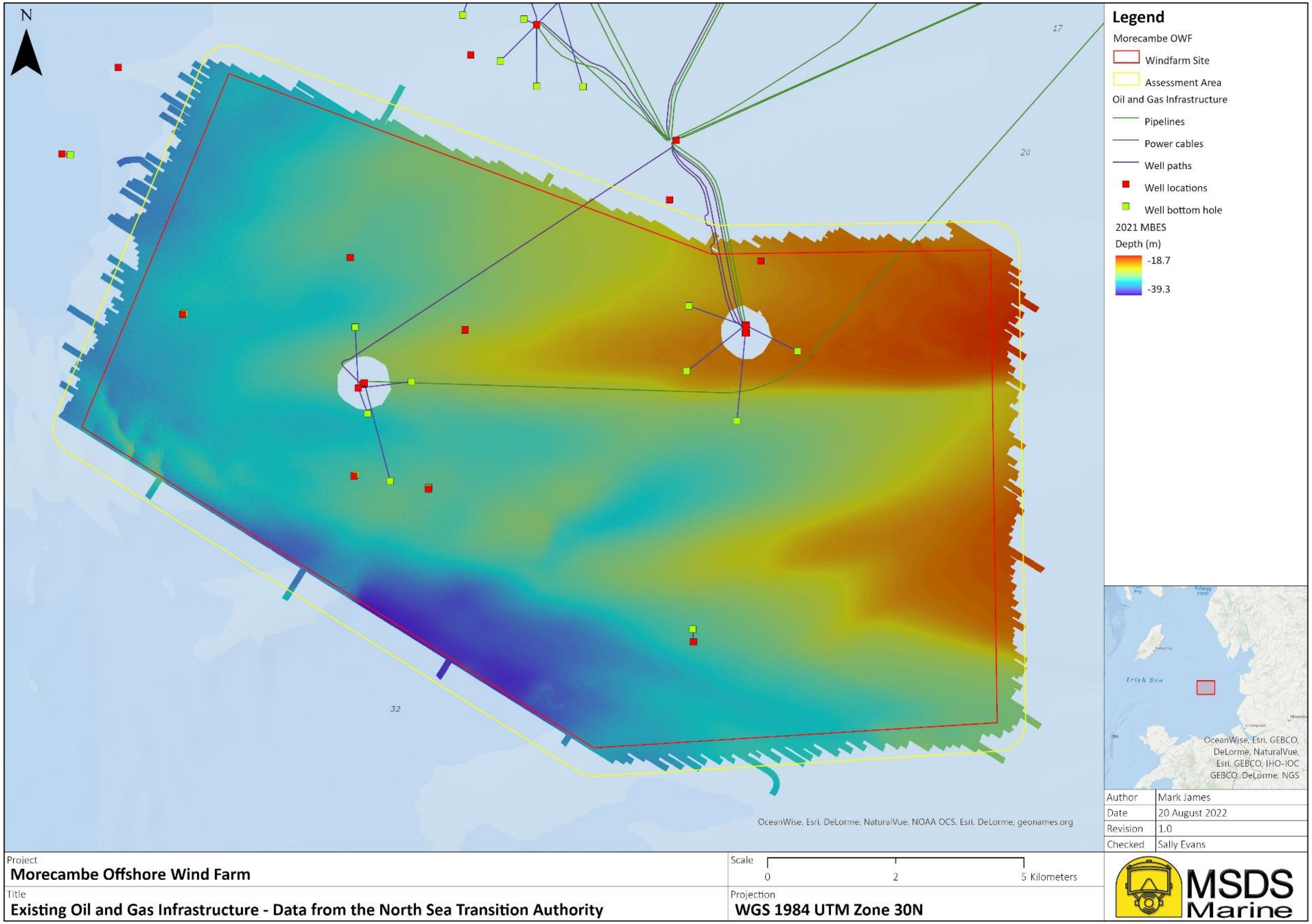

Figure 2: Existing infrastructure within the windfarm site

5.0 Methodology

5.1 Data collection

5.1.1 The survey was conducted by MMT during October and November 2021. The survey was undertaken using MV *Franklin*, a 55 m survey vessel owned and operated by MMT. The vessel was mobilised with a Multibeam Echo Sounder (MBES), a Sidescan Sonar (SSS), and two magnetometers configured as a Transverse Gradiometer (TVG). Two Sub-bottom Profilers (SBP) were also mobilised, a Parametric SBP and a Sparker.

5.1.2 The SSS and TVG were towed behind the vessel using a Remotely Operated Towed Vehicle (ROTV), the Sparker was towed behind the vessel, and the MBES and Parametric SBP were mounted to the hull of the vessel.

5.1.3 Survey operations were undertaken within a pre-defined boundary of approximately 126 km^2 referred to as the windfarm site within this report. Two gas platforms are present within the windfarm site, one active and one decommissioned. There is a notable absence of data within an 850 to 900 m radius of these structures.

5.1.4 The survey was planned with a line spacing of 85 m for the main lines, and 5 km for the cross lines. The line planning ensured 100% coverage of SSS data was achieved, including the nadir (@ 100 m range). The MBES swathe was set at 75° to produce 100 m coverage in the depth of water over the survey area. In addition, SBP and TVG data were collected along each of the survey lines, the TVG separation was 3.36 m, and the maximum altitude was 8 m with the typical altitude being 6 to 7 m. The survey navigation tracklines are presented in Figure 3, the SSS coverage in Figure 4, and the MBES coverage in Figure 5.

5.1.5 The survey achieved 100% SSS and MBES coverage of the windfarm site, with TVG and SBP collected to the line plan specification as outlined above, noting the data gaps around the gas platforms. The equipment specification shown in Table 2.

Sensor	Manufacturer	Model	Frequency
Sidescan Sonar	EdgeTech	2200	300 / 600 kHz 100 m range
Multibeam	Kongsberg	EM2040D	200 to 400 kHz
TVG (magnetometer)	Geometrics	G-882	10 Hz sample rate
Parametric SBP	Innomar	SES-2000 Medium	4 to 15 kHz Actual 8 kHz
Sparker SBP	GEO Marine Survey Systems	GeoSpark 200TIP	1.5 kHz

Table 2: Geophysical and hydrographic sensor specifications

5.1.6 The data were collected to a specification appropriate to achieve the following interpretation requirements:

- Sidescan Sonar: ensonification of anomalies > 0.5 m
- Multibeam Bathymetry: ensonification of anomalies > 1.0 m
- Magnetometer (TVG): 5 nT threshold for anomaly picking
- Sub-bottom Profiler (Parametric): penetration of 4 to 23 m was achieved
- Sub-bottom Profiler (Sparker): penetration of least 50 m was achieved

5.1.7 Towed sensors were positioned using an Ultra Short Baseline (USBL) positioning system to ensure positional accuracy throughout the survey. USBL ensures the actual position of the sensor is recorded, as opposed to when the position is estimated based upon the direction of the vessel and the amount of cable out (layback).

5.1.8 Although the accuracy of the USBL system is dependent on the angle, and the distance of the beacon from the transceiver, tolerances of between 0.5 m and 2.0 m can be achieved. Positional accuracy is further increased through the correlation of the SSS dataset with the MBES dataset.

5.1.9 Surface and sub-sea position sensors specifications are detailed below in Table 3.

Sensor	Manufacturer	Model	Accuracy
Surface positioning	Applanix	POSMV 320	Roll / pitch 0.01° Heave 5 cm or 5% Heading 0.02° Position 0.02 - 0.1 m
Sub-sea positioning	iXsea	GAPS II	0.2% slant range

Table 3: Position sensor specifications

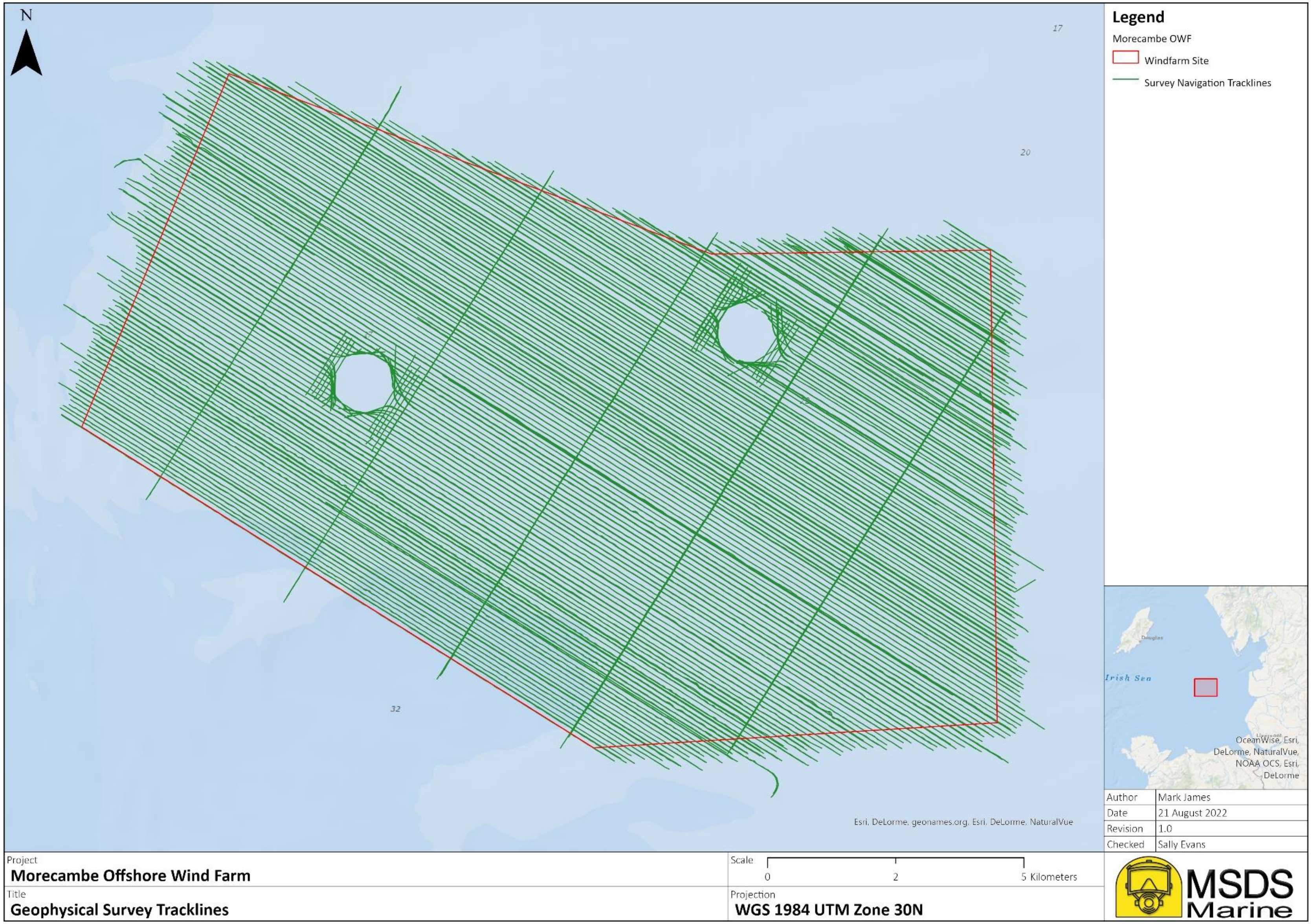

Figure 3: Geophysical survey tracklines

Figure 4: Sidescan Sonar coverage

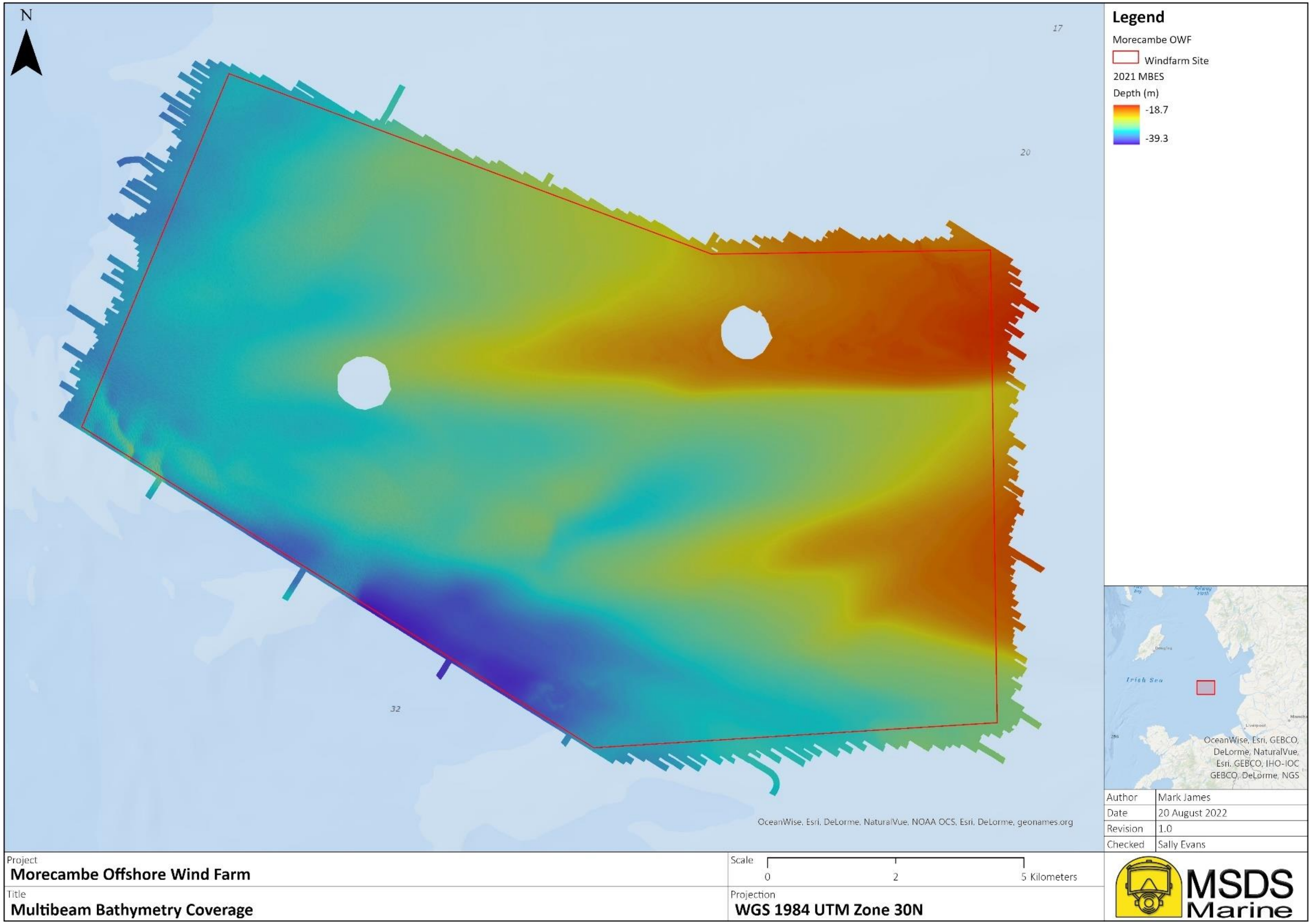

Figure 5: Multibeam Bathymetry coverage

5.2 Data deliverables to MSDS Marine

5.2.1 MSDS Marine were provided with the survey deliverables by Flotation Energy, including both raw and processed data, alongside interpretations and reports. The primary deliverables are detailed in Table 4 below.

Sensor	Data type	Format
Sidescan Sonar	Raw lines (LF and HF)	.jsf
	Processed lines (HF)	.xtf
	Mosaic (HF) 0.2 ppm	.tif
	Contacts	.csv, .shp
Sub-bottom profiler (both)	Raw lines	.sgy
	Processed lines	.sgy
	Grids	.dat
	Horizons	.dat
	Contours	.dxf
Magnetometer (TVG)	Raw lines	.txt
	Processed lines (individual)	.txt
	Processed lines (merged)	.csv
	Grids (residual and altitude)	.xyz
	Mosaic (residual and altitude)	.tif, .png
	Contacts	.csv, .shp
Multibeam bathymetry	Raw lines	.xyz
	Grids (at 0.2 m)	.txt
GIS	SSDM	.gdb
Reports	Survey report	.pdf
	Operations report	.pdf

Table 4: Data deliverables to MSDS Marine

5.3 Data quality and limitations

Sidescan Sonar (SSS)

5.3.1 With the exception of the areas around Calder and DP3 platforms (Section 4.0), the SSS data covered the extents of the windfarm site, providing 100% seafloor coverage including the nadir. The data were generally of good quality, with minimal interference or data degradation caused by environmental factors or the simultaneous use of different sensors. Some data degradation due to motion was noted, however this was not significant and does not affect the overall quality of the data and the suitability for archaeological interpretation.

5.3.2 Small offsets were noted in places between the SSS and MBES data, however this is usual and positions for medium and high potential anomalies were always taken from the MBES data.

Multibeam Bathymetry (MBES)

5.3.3 The MBES data covered the extents of the windfarm site, providing 100% coverage. A review of the un-gridded point cloud data shows that the quality is good with no significant height or positioning errors. The data density is good, and is able to be gridded to 0.2 m, increasing the ability to identify smaller features. Features identified within the MBES data correlate with those identified in the SSS data, although as detailed above small offsets were noted but within what is an acceptable tolerance.

Magnetometer (TVG)

5.3.4 The TVG data covered the extents of the windfarm site and was collected along the pre-defined survey line plan. The data were sampled at 10 Hz, at a maximum altitude of 8m (generally 6 to 7 m). The specification was designed to be able to detect the presence of ferrous materials >50 kg along the tracklines. Background noise levels generally did not exceed 2 nT, and that the data were suitable to identify anomalies with a peak-to-peak amplitude of 5 nT.

Sub-bottom profiler

5.3.5 The SBP data covered the extents of the windfarm site, along the pre-defined survey line plan. Penetration of the Parametric system was between 4 m and 23 m, with a vertical resolution of 0.3 m. The Sparker achieved a minimum penetration of 50 m with a vertical resolution in the upper section of 0.3 m. The Innomar and Sparker data were reviewed, and good vertical and horizontal correlation of reflectors were observed between the datasets. Boundaries were clearest within the Sparker data and for that reason all interpretation was based on this dataset. Five stratigraphic seismic units were identified within the data, and the data was of good quality.

Suitability for archaeological interpretation

5.3.6 The windfarm site seabed is characterised across a significant area by mobile sands, manifesting as sandwaves of various sizes. These sandwaves can cause obstructions to the sonar data, in particular the SSS, the data from which is collected closer to the seabed. Obstructions cause acoustic shadow, i.e., areas of no data, which can hide smaller features of potential anthropogenic origin. This can cause uncertainty as to whether all features have been identified. However, the SSS data achieved 100% coverage, including the nadir, this translates to 200% coverage across most of the data. With the data collected in opposite directions this largely mitigates this uncertainty. The collection of a high resolution MBES data set also aids in the interpretation where features might be masked in the SSS data.

5.3.7 Magnetometers work by detecting changes in the earth magnetic field, the further away from the sensor the lower the reading will be. The survey was specified to identify ferrous material of >50 kg along the tracklines of the sensors. Therefore, the further the distance from the tracklines, the larger the minimum detection size will be.

5.3.8 SBP data is collected directly beneath the sensor, in general terms, and outside the identification of the palaeolandscape, SBP is not suited to the prospection for buried material of potential anthropogenic origin due to the wide line spacing. It can however be useful for corroboration of other datasets where a trackline passes directly over a magnetic anomaly or a potentially buried feature visible in the SSS or MBES data.

5.3.9 The depth of penetration achieved by the Sparker was 50 m. However, interpretation of the data indicates that the windfarm site is underlain by Triassic bedrock ranging from 3 – 43 m indicating that the Sparker achieved full penetration of the Quaternary sequence across most of the site. Seabed multiples affected the identification of the top of the bedrock in restricted areas though for the majority of the site the data were clear and suitable for archaeological interpretation.

Summary

5.3.10 The data collected across the windfarm site is of good quality overall, and in the case of SSS and MBES provided 100% coverage. SBP data were collected to a pre-determined line plan, providing suitable coverage and penetration for the interpretation of the palaeoenvironment. The TVG data were collected to pre-determined line plan suitable for the identification of ferrous material >50 kg along the tracklines, with the minimum detection size increasing with distance from the tracklines.

5.3.11 The data is considered of an appropriate specification, coverage, and quality, to undertake a robust archaeological assessment to inform the EIA process.

5.4 Archaeological assessment of data

5.4.1 The archaeological assessment of data was undertaken by a qualified and experienced maritime archaeologist with a background in geophysical and hydrographic data acquisition, processing, and interpretation.

5.4.2 Following delivery of the required datasets, an initial review was undertaken to gain an understanding of the geological and topographic make-up of the survey area. Within the extent of the survey area the potential for variations in the seabed are high and can affect the interpretation of anomalies.

5.4.3 The interpretation report considers the full extents of the survey data which includes full coverage of the windfarm site. The assessment of United Kingdom Hydrographic Office (UKHO) and National Record of the Historic Environment (NRHE) data was undertaken within the windfarm site and a 0.5 km buffer.

5.4.4 Whilst some of the data extends beyond the windfarm site, the purpose of the assessment is to characterise the historic environment and therefore data from the wider area were considered. The focus of the mitigation measures is, however, on anomalies within the windfarm site, or where mitigation measures would impact within the windfarm site. The assessment area is presented in Figure 6.

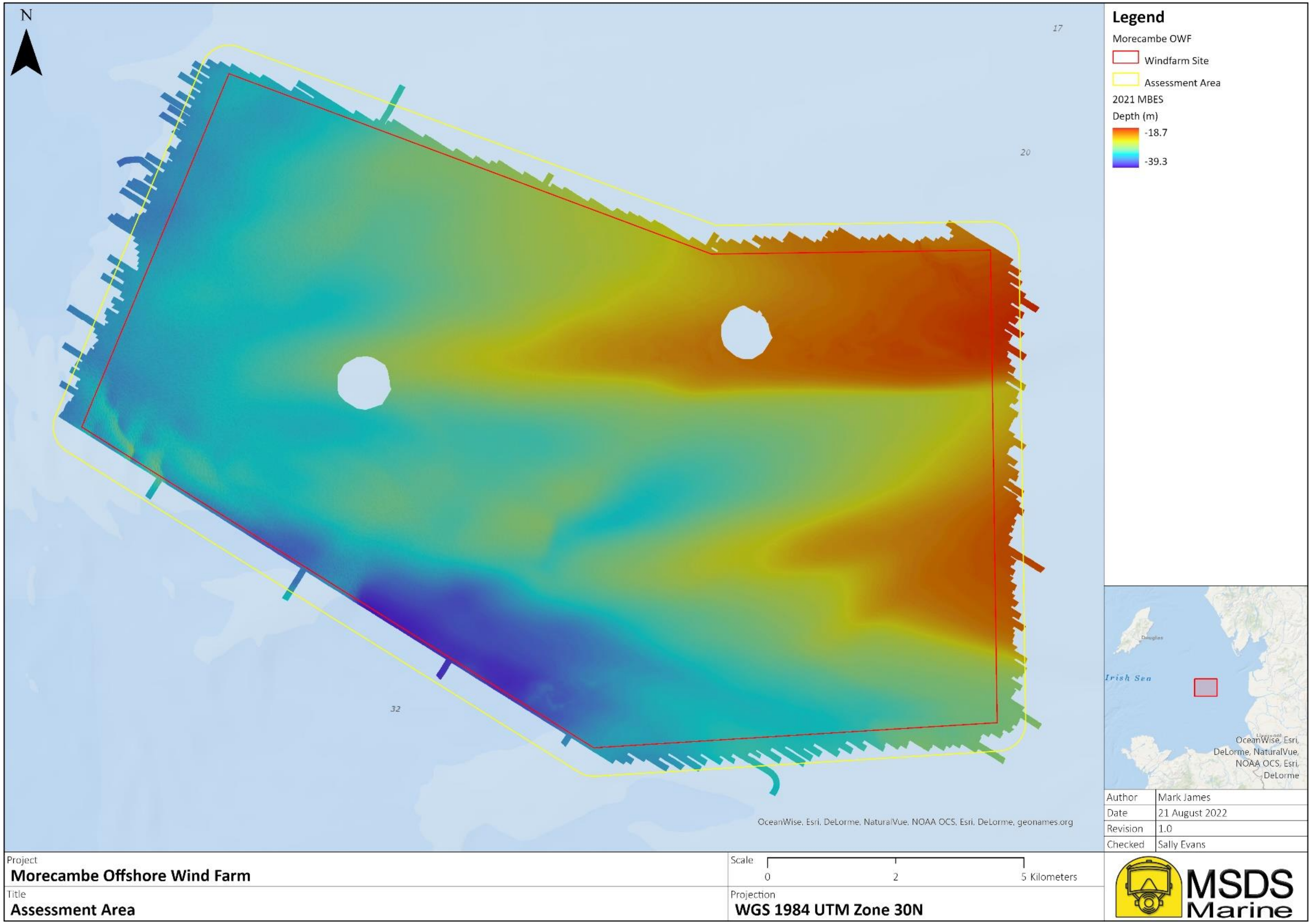

Figure 6: Assessment Area

Sidescan Sonar

5.4.5 SSS is considered the best tool for the identification of anthropogenic anomalies on the seabed due to the ability to ensonify small features and as such forms the basis of any archaeological assessment of data. SSS data in .xtf format were imported into Chesapeake SonarWiz 7.9 software, navigation and positioning were checked and corrected where required, and optimal gains were applied to ensure the consistent presentation of data.

5.4.6 Data were reviewed on a line-by-line basis, and all anomalies of potential anthropogenic origin identified and recorded. Records include at a minimum an image of the anomaly, dimensions, and a description. Whilst typically only images of medium and high potential anomalies are presented with the assessment report, images of all anomalies are recorded as interpretations can change as the data assessment progresses. A rating of archaeological potential was assigned to the anomaly following the criteria outlined in Table 5 below.

5.4.7 Following assessment of the individual lines, a mosaic was created and a Geotiff exported to allow for the checking of positional accuracy against the MBES data and to identify the extents of any anomalies that may have extended past the limits of individual lines.

Magnetometer

5.4.8 Magnetometer data indicates the presence of ferrous, and thus usually anthropogenic, material both on, and under the seabed. Where line spacing allows, typically to a specification for the detection of UXO, magnetometer data can provide accurate positions of buried ferrous anomalies. The survey line spacing for Morecambe Offshore Windfarm is c.85 m which is too great for the accurate positioning of magnetic anomalies at distances away from the tracklines but can indicate areas of archaeological potential. Where possible, magnetic anomalies were correlated with anomalies visible on the seabed.

5.4.9 Magnetometry data were provided as .xyz files and as a gazetteer detailing all anomalies greater than 3 nT. An assessment was made by MSDS Marine as to the suitability of the gazetteer for archaeological interpretation. Where required the .xyz magnetometer data was imported into either Geometrics MagPick or Chesapeake SonarWiz 7.9 software where the data was smoothed, and a 'baseline' identified and removed from the data to highlight ferrous anomalies whilst taking into account geological variations in the data.

5.4.10 Magnetic anomalies identified within the data had the position, intensity and dimensions recorded. A rating of archaeological potential was assigned to the anomaly following the criteria outlined in Table 5 below. The data were gridded to visually identify areas where the distribution of anomalies may represent a wider feature such a buried but dispersed wreck, or modern features such as buried cable or chain.

Multibeam Bathymetry

5.4.11 Due to the minimum anomaly detection size of MBES data being larger than that of SSS data, the primary use during archaeological assessment, outside of seabed characterisation, is the corroboration of anomalies identified within other datasets and the visualisation of anomalies that may otherwise be obscured by shadow.

5.4.12 Navigation corrected, but unprocessed, MBES data were provide to MSDS Marine as .xyz files, the data were imported into QPS Fledermaus where it was gridded and a hill-shaded surface applied, shading was adjusted to ensure the optimal presentation of data. The resulting 3-

Dimensional image was viewed on a block-by-block basis, and all anomalies of potential anthropogenic origin identified and recorded.

5.4.13 Records include, at a minimum, an image of the anomaly, dimensions, and a description. A rating of archaeological potential was assigned to the anomaly following the criteria outlined in Table 5 below. Where the interpretation of an anomaly was unclear, the data were imported into point cloud visualisation software such as Cloud Compare, in order to view the un-gridded data. The gridded surface image was exported as a Geotiff to allow further assessment alongside other datasets.

Potential	Criteria
Low	An anomaly potentially of anthropogenic origin but that is unlikely to be of archaeological significance – Examples may include discarded modern debris such as rope, cable, chain, or fishing gear; small, isolated anomalies with no wider context; or small boulder-like features with associated magnetometer readings.
Medium	An anomaly believed to be of anthropogenic origin but that would require further investigation to establish its archaeological significance – Examples may include larger unidentifiable debris or clusters of debris, unidentifiable structures, or significant magnetic anomalies.
High	An anomaly almost certainly of anthropogenic origin and with a high potential of being of archaeological significance – high potential anomalies tend to be the remains of wrecks, the suspected remains of wrecks, or known structures of archaeological significance.

Table 5: Criteria for the assessment of archaeological potential

Combined assessment

5.4.14 Following the assessment of all datasets the results were loaded into ESRI ArcGIS Pro 3.0, a Geographical Information System (GIS), and reviewed alongside each other, along with Geotiffs of the SSS and MBES. The concurrent review allows the amalgamation of duplicate anomalies, the assessment of the wider context, and an understanding of the extents of a feature that may be partially buried, or span across two or more lines of data.

5.4.15 Data from the United Kingdom Hydrographic Office (UKHO), including the positions of wrecks and obstructions, and the relevant Historic Environment Records (HER) as well as all other relevant data such as third-party assets were assessed to ensure that any additional information is drawn upon, but also that anomalies are not unnecessarily identified as having archaeological potential when the origination can be identified. The resultant remaining anomalies assessed as having archaeological potential were compiled into a gazetteer and a shapefile.

5.4.16 The interpretation of geophysical and hydrographic data is, by its very nature, subjective. However, with experience and by analysing the form, size, and characteristics of an anomaly, a reasonable degree of certainty as to the origin of an anomaly can be achieved.

5.4.17 Measurements can be taken in most data processing software, and whilst largely accurate, discrepancies can be noted due to a number of factors. Where there is uncertainty as to the potential of an anomaly, or its origin, a precautionary approach is always taken to ensure the most appropriate mitigation for the historic environment.

5.4.18 It should be noted that there may be instances where an anomaly may exist on the seabed but not be visible in the geophysical data. This may be due to being covered by sediment or being obscured from the line of sight of the sonar. The use of both SSS and MBES data mitigates this by visualising anomalies from multiples angles, including from above. Anomalies were named following the standard MSDS Marine convention, [PROJECTYEAR_ID], e.g., MC22_XXX.

5.5 Palaeolandscape and Sub-bottom Profiler sources

5.5.1 A number of data sources were used for the assessment. The principal sources which were reviewed and assessed are set out below, while other published sources are referred to in-text. Data sources have been identified within a 2 km buffer around the windfarm Site, this area is referred to as the study area throughout this report.

5.5.2 The data available for the site includes:

- MBES Data
- Sub-bottom profiler data:
  - Innomar
  - Sparker
- Boreholes and cores recorded by the BGS;
- Ground model outputs including:
  - MMT (2022) Morecambe Offshore Windfarm Offshore Geophysical Survey. Report for Offshore Wind Ltd.
- Research papers and publications including:
  - Jackson et al. (1995) United Kingdom Offshore Regional Report: The geology of the Irish Sea.
  - Mellett et al. (2015) Geology of the seabed and shallow subsurface: The Irish Sea.

5.5.3 A total of one borehole and six cores have been taken within the study area by the BGS, the data for which was available for review as part of this assessment. Seismic surveys of the area were also undertaken by the BGS in order to feed into the Offshore Regional Report (ORR) for the area (Jackson et al. 1995). The findings of the ORR have been included within this assessment.

5.5.4 A number of other studies have taken place in the vicinity of the site, including the West Coast Palaeolandscape Survey (WCPS) (Fitch et al. 2011) which focussed in part on the Upper Palaeolithic and Mesolithic landscapes of the Liverpool Bay area, including the site.

5.5.5 The locations and extents of these previous investigations are detailed in Figure 7

5.6 Palaeolandscape and Sub-bottom Profiler interpretation

5.6.1 Whilst the interpretation of the palaeolandscape is based upon the archaeological review of geophysical and hydrographic data, the method of assessment, the assessment criteria and the best practise mitigation strategies differ from those presented in the preceding sections and thus it is detailed separately for clarity.

5.6.2 Sub-surface data acquired from seismic and geotechnical surveys is key to understanding the palaeolandscape potential of the windfarm site. These data are available for the site (see below for data sources) and have been assessed to identify ground conditions within the site. The interpretations of the data feed into the ground model, which incorporates both geological modelling and engineering conditions, knowledge of which is necessary for development design. Sedimentary units have been identified within the seismic data based on their seismic character and likely depositional environment, and tentatively correlated with known geological formations in the area based on the available data (MMT 2022). Ground truthing with geotechnical data will be necessary to confirm the current interpretations. The base of each sedimentary unit has been mapped to feed into the ground model, and grids have been exported from the ground model for this assessment. From an archaeological perspective the ground model provides insight into the potential geological formations within the site, and their likely depositional environment. This feeds into the assessment of the palaeolandscape through time, and corresponding archaeological potential.

5.6.3 Sedimentary unit grids and geological maps derived from the interpretation of sub-surface data and the current seabed derived from MBES data were assessed alongside existing studies which contribute to the understanding of the palaeolandscape and prehistoric archaeological potential within the area. An archaeological review of the geophysical survey assessments and ground model covering the windfarm site was conducted by MSDS Marine. This included a review of geophysical survey data reports, select seismic profiles and ground model outputs including mapped horizons and grids. These sources were reviewed in order to establish an understanding of the geological make-up of the site, formations present and their palaeoenvironmental and archaeological potential. Information about the wider area has also been used to better contextualise the various environments experienced in the area during the Pleistocene and Holocene.

5.6.4 The site is within the Irish Sea region (Figure 1). The British Geological Survey (BGS) reports relating to the Irish Sea (Jackson et al. 1995; Mellett et al. 2015) have been used here in conjunction with the results of geophysical surveys undertaken by MMT as part of the preliminary site investigation for Morecambe Offshore Windfarm to identify deposits present within the site. The sources are listed below.

5.6.5 Geological formations and their archaeological potential have been discussed within Section 10.0 of this report.

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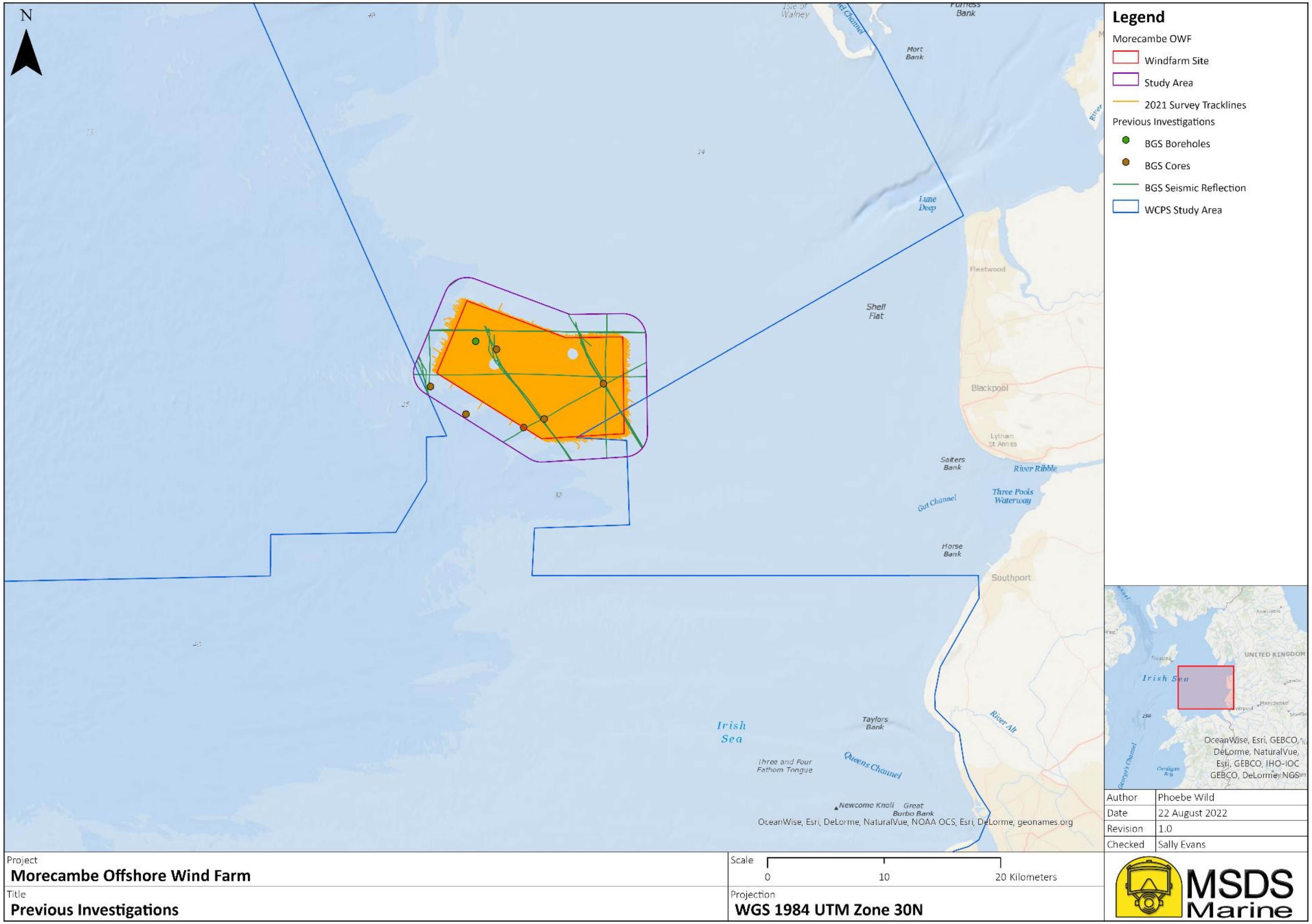

Figure 7: Previous investigations within the study area

5.7 Mitigation

5.7.1 The following section discusses the archaeological mitigation strategies which are considered for The Project, the proposed mitigation is presented in Section 11.0.

Surface anomalies

5.7.2 To ensure the most appropriate and robust mitigation for the historic environment, whilst being proportional to the requirements of the development, mitigation recommendations are determined on an anomaly-by-anomaly basis, and consider all available data including;

- Potential significance;
- Size;
- Seabed type;
- Seabed dynamics;
- Development type; and
- Potential negative impacts.

5.7.3 Mitigation strategies have been based on the criteria in Table 6 below.

Potential	Criteria
Low	No archaeological significance interpreted. Maintain an operational awareness of the anomaly's location and reporting through the agreed protocol should material of potential archaeological significance be encountered.
Medium	Avoidance of the anomaly's position and where appropriate an archaeological exclusion zone may be recommended. Ground truthing of the anomaly through the use of divers or an ROV would establish the archaeological potential.
High	Archaeological exclusion zones will be recommended based on the size of the anomaly, any outlying debris and the seabed dynamics as interpreted from the SSS and MBES data.

Table 6: Mitigation criteria for archaeological anomalies

5.7.4 Where an anomaly is visible in the MBES data, that position will generally be used for the implementation of mitigation recommendations. The position obtained from the MBES data is generally more accurate due to the sensor and the GPS receiver being fixed to the vessel in known planes. SSS and magnetometer sensors are towed, and thus the margin for error is greater even with USBL, as the positional tolerance can be between 0.5 m and 2.0 m.

5.7.5 A phased approach to mitigation is proposed for Morecambe Offshore Windfarm, corresponding with the planned future survey strategy. The survey specification was designed for the purposes of consenting and Front End Engineering Design (FEED) to determine the most appropriate area for development. Future surveys will likely combine an increase in resolution, and the addition of magnetometer data with tighter line spacing (as determined by the pUXO risk), within the development area. With the data resolution and coverage set to increase, the confidence in interpretation and appropriateness of mitigation strategies will also increase.

Following the archaeological assessment, recommendations have been made as to the coverage and specification of future surveys to ensure a robust archaeological assessment of the development area at all stages of the development process.

5.7.6 At this phase, differentiation has made between anomalies that are visible and identifiable in the survey data (e.g., SSS and MBES anomalies), and potential anomalies that have not been identified in the survey data but are likely to exist on the seabed (e.g., Live UKHO records).

5.7.7 The mitigation strategies detailed in Table 7 have been used.

Potential	Criteria
Archaeological Exclusion Zones (AEZs)	For archaeologically significant anomalies that are clearly identifiable in the survey data and where the extents are largely known, Archaeological Exclusion Zones (AEZs) will be recommended. AEZs will remain for the life of The Project or until ground truthing or higher resolution data determines a reduction in potential, significance, or extents.
Temporary Archaeological Exclusion Zones (TAEZs)	Where an anomaly is not visible in the survey data but likely to exist on the seabed at a known position or where the extents of an anomaly are not fully identifiable, Temporary Archaeological Exclusion Zones (TAEZs) will be recommended. TAEZs have been identified as highly likely to be altered following higher resolution or full coverage data assessment, however, they will remain in place until alterations have been formally agreed.
Areas of Archaeological Potential (AAP)	Areas of Archaeological Potential (AAP) are primarily reserved for magnetic anomalies where, due to line spacing, positions are not accurately known. AAPs demonstrate that there is potentially an anomaly of archaeological significance around the given position. The anomaly is likely to be identified following higher resolution or full coverage data assessment but as the nature and position is not precisely known, no formal exclusion zone is recommended but instead a general awareness of the position is considered appropriate at this phase.

Table 7: Archaeological mitigation strategies

Palaeolandscape

5.7.8 Dependant on the assessed potential, the process of mitigation in relation to the palaeolandscape and palaeoenvironmental remains typically follows a staged approach of continued assessment aligning with the engineering requirement to undertake geotechnical works. The staged process is broadly outlined within The Crown Estate (2021) guidance on Archaeological Written Schemes of Investigation for Offshore Wind Farm Projects and COWRIE (Gribble and Leather 2011) guidance on Offshore Geotechnical Investigations and Historic Environment Analysis.

5.7.9 Archaeological input into geotechnical core locations can allow for the greatest insights into the palaeolandscape, such as through the sampling of stratified channel deposits, deposits likely to contain organic remains or un-eroded surfaces. Typically, this process involves close collaboration with the Site Investigation team. Round-table discussions and the review of seismic profiles tends to be a conducive method of allowing engineering and archaeological requirements to be taken into consideration when micro-siting geotechnical cores.

5.7.10 Following the collection of geotechnical cores, they will undergo a staged program of geoarchaeological assessment and analysis. In brief the process is as follows;

- Stage 1: Geoarchaeological review of core logs;
- Stage 2: Geoarchaeological recording;
- Stage 3: Geoarchaeological assessment;
- Stage 4: Geoarchaeological analysis, and;
- Stage 5: Final reporting and publication.

6.0 Results of surface geophysical anomalies

6.0.1 For the avoidance of confusion, the results of magnetic anomalies with no surface expression are presented in Section 7.0, UKHO records in Section 8.0, HER records in Section 1.0, and the palaeolandscape assessment in Section 10.0.

6.0.2 A total of 38 anomalies of potential archaeological interest were identified within the extents of the survey data, 32 of which fall within the windfarm site, and six within the 0.5 km assessment area. The anomalies are categorised by potential in Table 8.

Potential	Windfarm site	0.5 km buffer	Total
Low	26	6	32
Medium	6	0	6
High	0	0	0
Total	32	6	38

Table 8: Distribution of archaeological anomalies by potential

6.0.3 The distribution of anomalies is shown in Figure 8, as can be noted the distribution is fairly uniform across the surveyed area. The ratios of medium and low potential anomalies are relatively consistent with a typical archaeological assessment of data. It is, however, notable that no high potential anomalies were identified within the data.

6.0.4 The distribution of anomalies within the geophysical data shows a consistent approach to the assessment. The low and medium potential anomalies are discussed below according to their assessed potential.

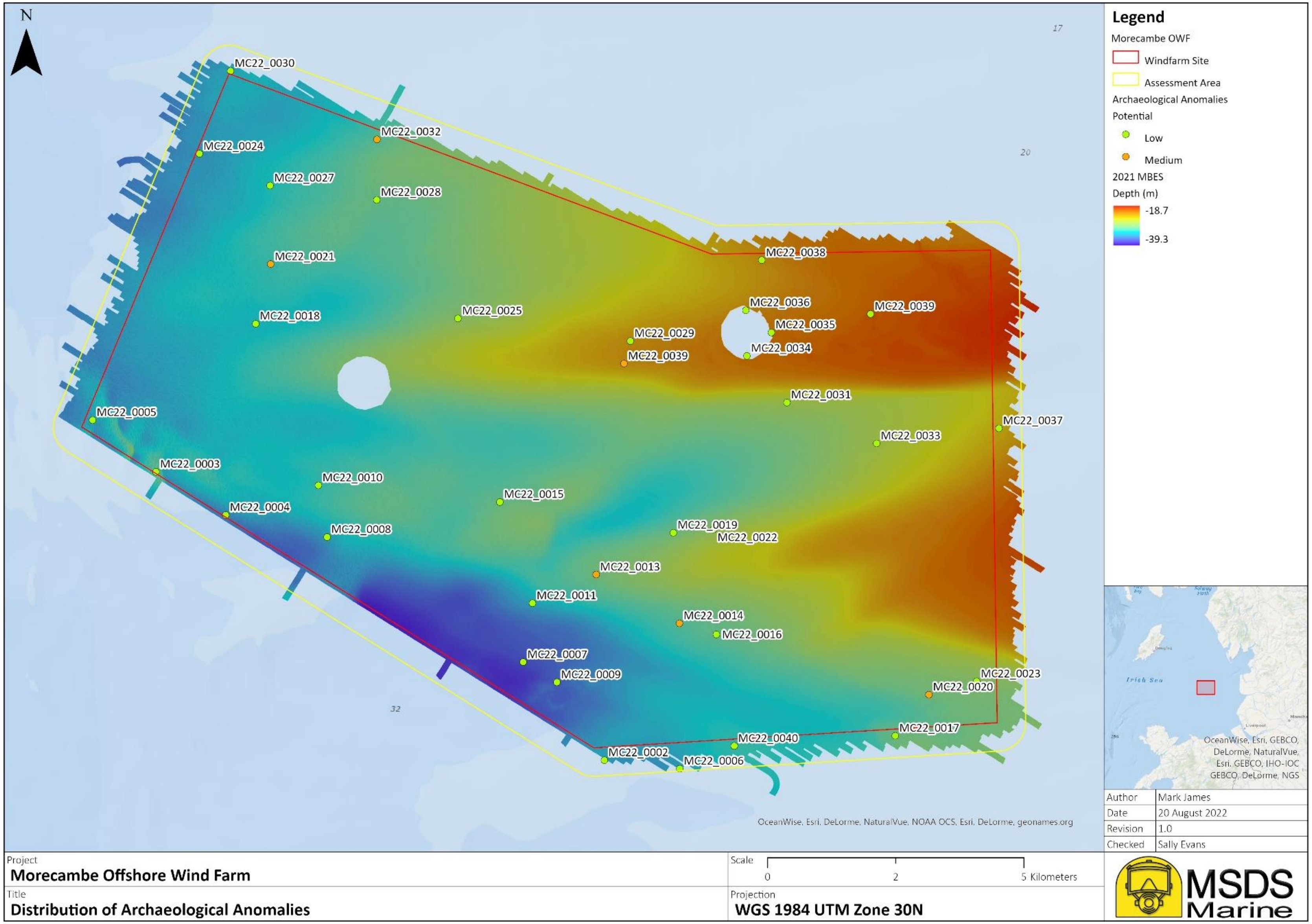

Figure 8: Distribution of Archaeological Anomalies

6.1 Low potential anomalies

6.1.1 32 anomalies interpreted as of low archaeological potential were identified within the Morecambe Offshore Windfarm survey extents, 26 of which fall within the windfarm site and six within the 0.5 km assessment area. The anomalies can be categorised as follows in Table 9.

Anomaly category	Windfarm site	0.5 km buffer	Total
Chain, cable, or rope	9[4]	0	9
Likely geological	8[5]	2[6]	10
Potential debris	4[7]	3[8]	7
Unidentified debris	5[9]	1[10]	6
Total	26	6	32

Table 9: Low potential anomaly categories

6.1.2 The anomalies interpreted as of low archaeological potential (see Table 5) are a mixture of small features, often boulder-like, or likely to represent modern debris such as chain, cable, or rope or small items of debris with no features indicating archaeological potential. Each anomaly was reviewed and interpreted to be of low archaeological potential. A further review was undertaken following the assessment of the survey area extents.

6.1.3 Low potential anomalies have been assessed against all available evidence and are deemed unlikely to be of archaeological significance and as such are not discussed further within the results section of this report. The identification of an anomaly as of low archaeological potential is commensurate with the mitigation for this category - *Maintain an operational awareness of the anomaly's location and reporting through the agreed protocol should material of potential archaeological significance be encountered*.

6.1.4 The distribution of low potential anomalies is shown in Figure 9. Further information regarding mitigation can be found in Section 11.0, and a gazetteer of low potential anomalies, including positions and dimensions, can be found in Annex A – *Anomalies of archaeological potential*.

[4] MC22_0005, MC22_0007, MC22_0010, MC22_0024, MC22_0027, MC22_0031, MC22_0033, MC22_0034, and MC22_0035
[5] MC22_0004, MC22_0008, MC22_0015, MC22_0018, MC22_0022, MC22_0023, MC22_0028, and MC22_0041
[6] MC22_0017, and MC22_0040
[7] MC22_0009, MC22_0011, MC22_0016, and MC22_0025
[8] MC22_0002, MC22_0006, and MC22_0030
[9] MC22_0003, MC22_0019, MC22_0029, MC22_0036, and MC22_0038
[10] MC22_0037

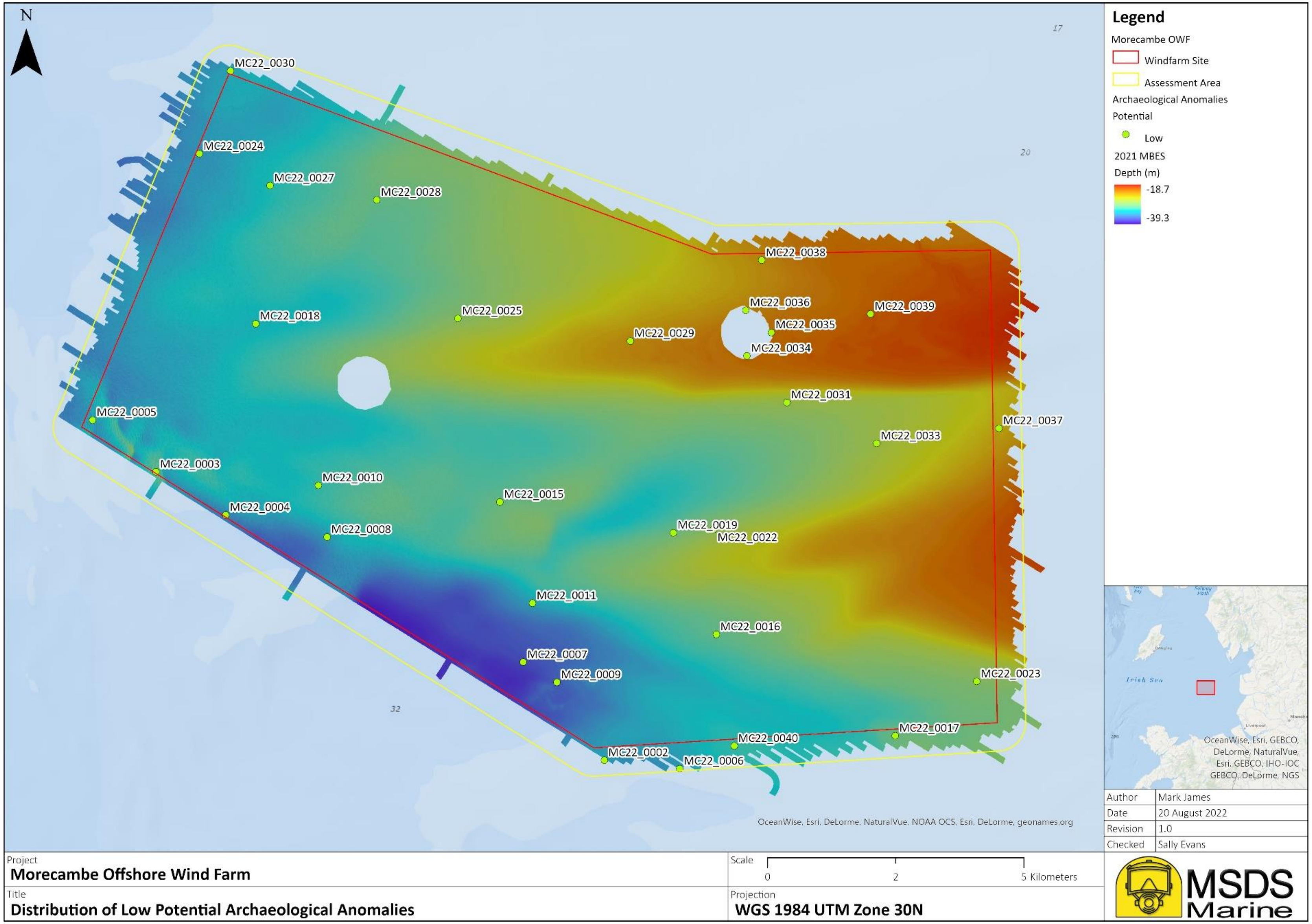

Figure 9: Distribution of Low Potential Archaeological Anomalies

6.2 Medium potential anomalies

6.2.1 Six anomalies interpreted as of medium archaeological potential were identified within the Morecambe Offshore Windfarm survey extents, all of which fall within the windfarm site. The anomalies can be categorised as follows in Table 10, the distribution is presented in Figure 10.

Anomaly category	Windfarm site
Potential debris	1
Unidentified debris	5
Total	6

Table 10: Medium potential anomaly categories

6.2.2 The anomalies interpreted as of medium archaeological potential have characteristics that indicate a likelihood of representing anthropogenic debris that has the potential to be of archaeological interest.

6.2.3 The identification of an anomaly as of medium archaeological potential is commensurate with the mitigation for this category - *Avoidance of the anomaly's position and where appropriate an archaeological exclusion zone may be recommended. Ground truthing of the anomaly through the use of divers or an ROV would establish the archaeological potential*.

6.2.4 Each medium potential anomaly is discussed, along with an image, within this section of this report. Further information regarding mitigation can be found in Section 5.7, and a gazetteer of medium potential anomalies, including positions and dimensions can be found in Annex A – *Anomalies of archaeological potential*.

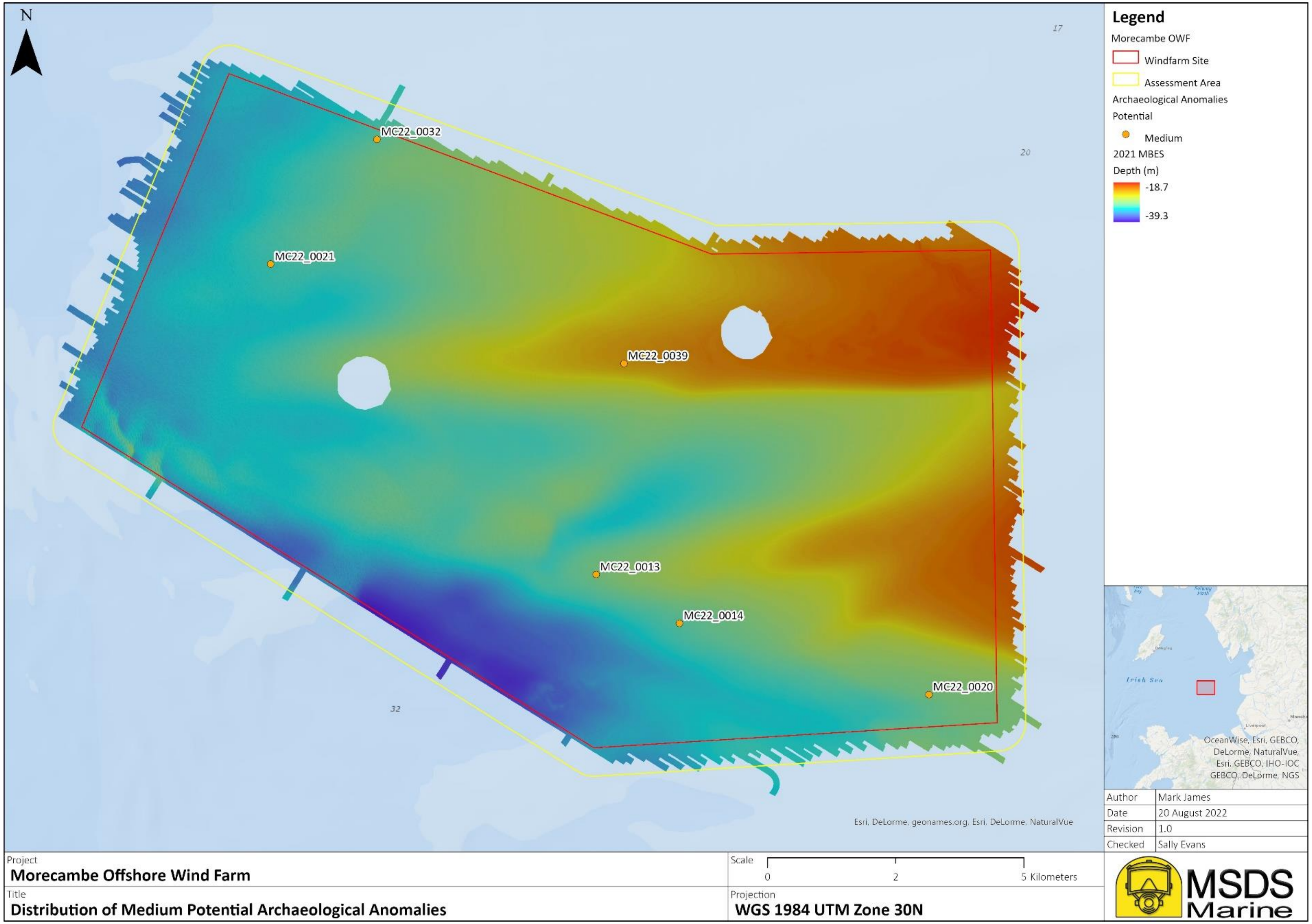

Figure 10: Distribution of Medium Potential Archaeological Anomalies

MC22_0013

6.2.5 MC22_0013 (Figure 11) lies approximately 3.0 km north of the southernmost corner of the windfarm site. The anomaly is only visible within the SSS data, with no associated magnetic anomaly. The position does not correspond with any UKHO or NRHE records.

6.2.6 The anomaly is visible as a curvilinear feature in association with a small area of seabed disturbance, and two further distinct features, covering an area 12.4 m x 7.3 m with a maximum height above seabed of 0.2 m. The anomaly is largely incoherent, but the form of the features may indicate anthropogenic origin.

6.2.7 The assessment of the anomaly as medium potential is precautionary, based primarily on the visible size. The anomaly lies within an area of stretched data caused by movement of the SSS towfish which can alter the form and dimensions, it is also not visible within the other datasets which may cast doubt as to the true interpretation. Further assessment of new geophysical data, or by Remotely Operated Vehicle (ROV) would be required to better understand the archaeological potential.

MC22_0014

6.2.8 MC22_0014 (Figure 12) lies approximately 2.7 km north-east of the southernmost corner of the windfarm site. The anomaly is visible within the SSS and MBES data, with no associated magnetic anomaly. The position does not correspond with any UKHO or NRHE records.

6.2.9 The anomaly is visible in the SSS data as two prominent, and joined, curvilinear features over an area 6.6 m x 1.9 m with a measurable height of 0.3 m. Within the MBES data the anomaly lies within a slight depression, likely caused by scour, with a number of irregular features. The overall form of the anomaly indicates anthropogenic debris, although the origin cannot be determined. The form does not indicate the remains of a wrecked vessel; thus, a medium potential rating is considered appropriate.

MC22_0020

6.2.10 MC22_0020 (Figure 13) lies approximately 1.3 km north-west of the south-eastern corner of the windfarm site. The anomaly is visible within the SSS and MBES data, with no associated magnetic anomaly. The position does not correspond with any UKHO or NRHE records.

6.2.11 Within the SSS data the anomaly appears as a boulder-like feature measuring approximately 2.0 m x 1.5 m with irregular scour extending north-east, south-west. Within the MBES data the anomaly appears irregular with a prominent, roughly linear, feature orientated north-east, south-west measuring 3.9 m x 1.7 m. Up to 1.4 m to the north-east smaller features are visible. Scour is evident all around the anomaly, but most prominent to the east.

6.2.12 The form of the anomaly is indicative of anthropogenic debris, although the origin is not clear. The prominence of the associated scour may suggest a large object, or a number of smaller solid objects. There is no evidence in the immediate vicinity to indicate that the anomaly may be part of a larger, buried feature.

Figure 11: Medium Potential MC22_0013

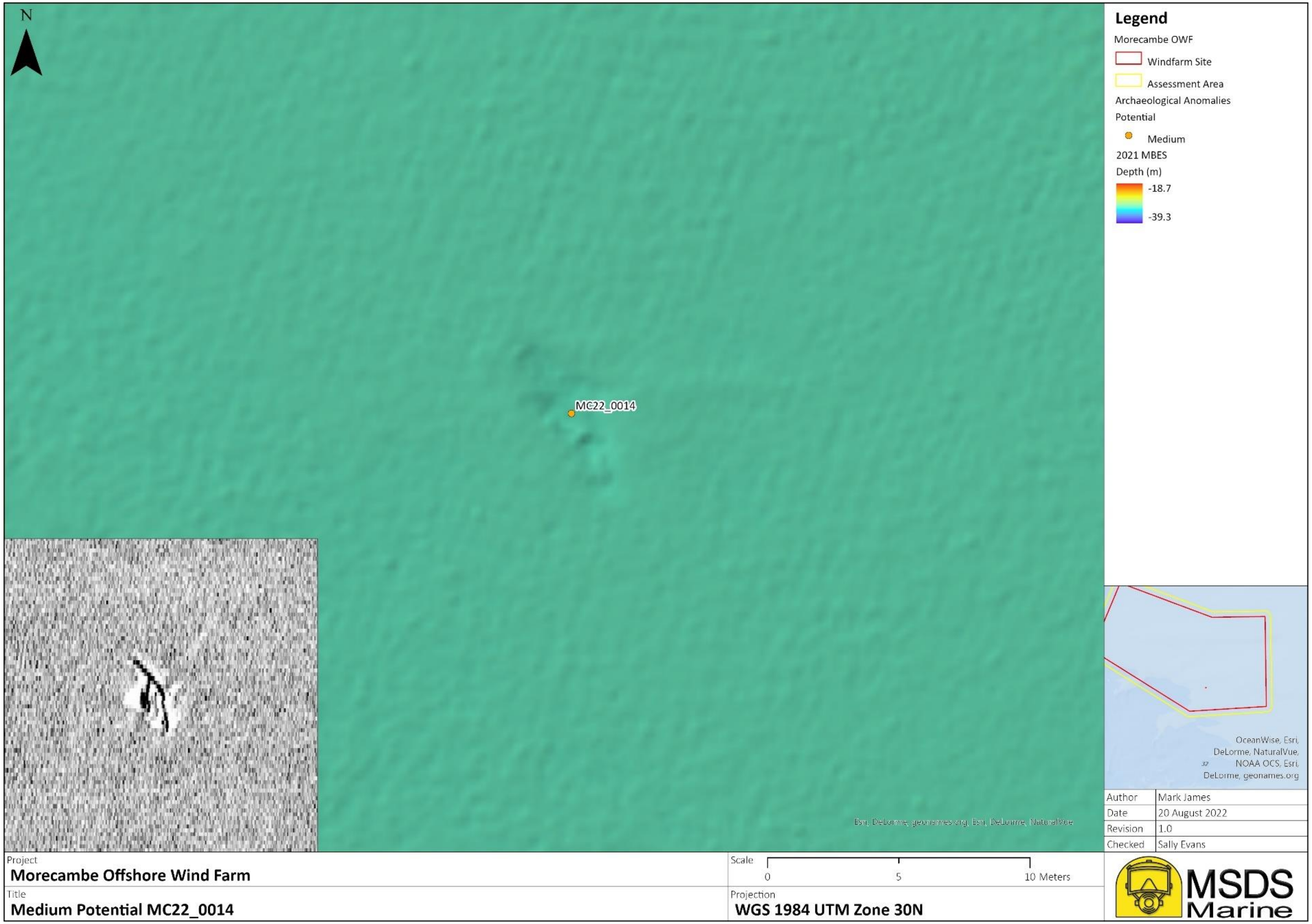

Figure 12: Medium Potential MC22_0014

Figure 13: Medium Potential MC22_0020

MC22_0021

6.2.13 MC22_0021 (Figure 14) lies approximately 3.4 km south of the north-west corner of the windfarm site. The anomaly is visible within the SSS and MBES data, with no directly associated magnetic anomaly. The position does not correspond with any UKHO or NRHE records.

6.2.14 The anomaly is primarily identifiable within the SSS as an ovular patch of low lying reflectors measuring approximately 6.0 m x 4.0 m. The presence of low lying reflectors can indicate a patch of geological features such as small boulders, equally it can represent anthropogenic debris. Two further smaller features of similar form are visible approximately 13.0 m to the north-east, the MBES data shows a sand wave separates them from the main feature which may indicate they are connected but partially buried. Overall, the feature measures 21.7 m x 8.8 m.

6.2.15 Within the MBES data only the south-west part of the overall feature is visible and appears as a slight disturbance in the seabed with slight scour to the south-west alongside another sand wave. There is no indication the feature extends to the south-west beneath the sand wave.

6.2.16 Whilst no magnetic anomalies directly correlate with the anomaly it falls mid-way between parallel lines of data which show a small magnetic anomaly of 9.9 nT to the south and 8.5 nT to the north. There is potential for the magnetic anomalies to be related to the anomaly suggesting ferrous content.

6.2.17 The form of the anomaly is unusual within the surrounding area, and due to the extents could indicate material of anthropogenic origin and of archaeological interest, given the form, and the potential correlation with the magnetic anomalies there is potential for this to represent a wrecked vessel. Equally however, there is potential for the anomaly to represent a geological feature. Further investigation would be required to determine the archaeological significance; therefore, a medium potential rating is considered appropriate.

MC22_0032

6.2.18 MC22_0032 (Figure 15) lies approximately 170 m south of the northern boundary of the windfarm site, 2.8 km south-east of the north-west corner. The anomaly is visible within the SSS and MBES data, with no directly correlating magnetic anomaly. The position does not correspond with any UKHO or NRHE records.

6.2.19 The anomaly is visible in the SSS data as a line of multiple small features, some angular, extending 13.3 m x 2.2 m with a measurable height of 0.2 m, and running north, south, parallel with a sand wave. Within the MBES the form is less clear and appears as a small mound (2.1 m x 1.2 m) with two smaller features to the south forming a triangle. The MBES data does appear to show that the anomaly has disrupted the sandwave, with possible slight scour extending to the east-north-east.

6.2.20 Three small magnetic anomalies lie within 100 m of the anomaly, the closest being 20.5 m to the east, due to the line spacing of the magnetometer there is potential for the closest magnetic anomaly to be related thus suggesting some ferrous content. The two southerly anomalies, and another to the east, form a line potentially indicative of a cable, or pipe.

6.2.21 The form of the anomaly appears to indicate anthropogenic debris, although the origin is not clear. The size of the anomaly may suggest the potential to be of archaeological interest although further investigation would be required to establish the archaeological significance, therefore a medium potential rating is considered appropriate.

MC22_0039

6.2.22 MC22_0039 (Figure 16) lies approximately 2.5 km south-west of the northern corner of the windfarm site. The anomaly is visible within the SSS and MBES data, with a correlating magnetic anomaly of 437.7 nT. The position does not correspond directly with any UKHO or NRHE records, however UKHO record 8299 lies 280 m to the north-east. It is not believed the anomaly and the UKHO record are related, but it is noted for completeness. Further information regarding UKHO record 8299 can be found in Section 8.1.

6.2.23 The anomaly is visible in the SSS data as a small feature within a sandwave, quite boulder like, and measuring 1.5 m x 1.4 m with a measurable height of 0.1 m. Within the MBES data the anomaly is visible as a small break in the sand, with a slight mound and a shallow depression.

6.2.24 The anomaly has been identified primarily due to the associated large magnetic anomaly. Whilst the form of the anomaly, and the data in the surrounding area, does not suggest further buried material the magnetic anomaly indicates ferrous, and thus anthropogenic, material. The archaeological significance is not clear, the anomaly could represent modern debris, or potential Unexploded Ordnance (pUXO). Thus, further investigation would be required to establish the archaeological significance and a medium potential rating is considered appropriate.

6.3 High potential anomalies

6.3.1 No anomalies interpreted as of high archaeological potential were identified within the Morecambe Offshore Windfarm survey extents.

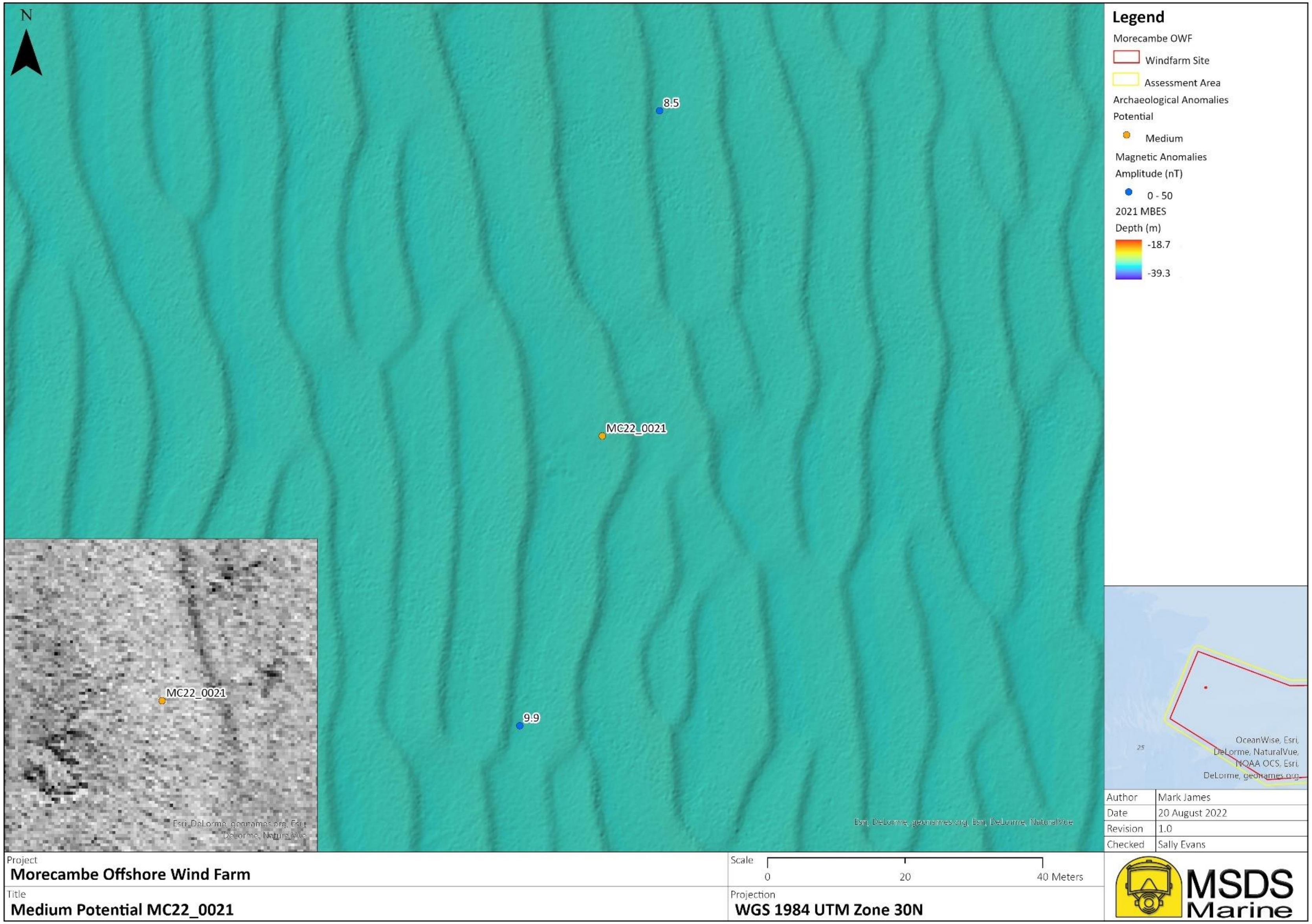

Figure 14: Medium Potential MC22_0021

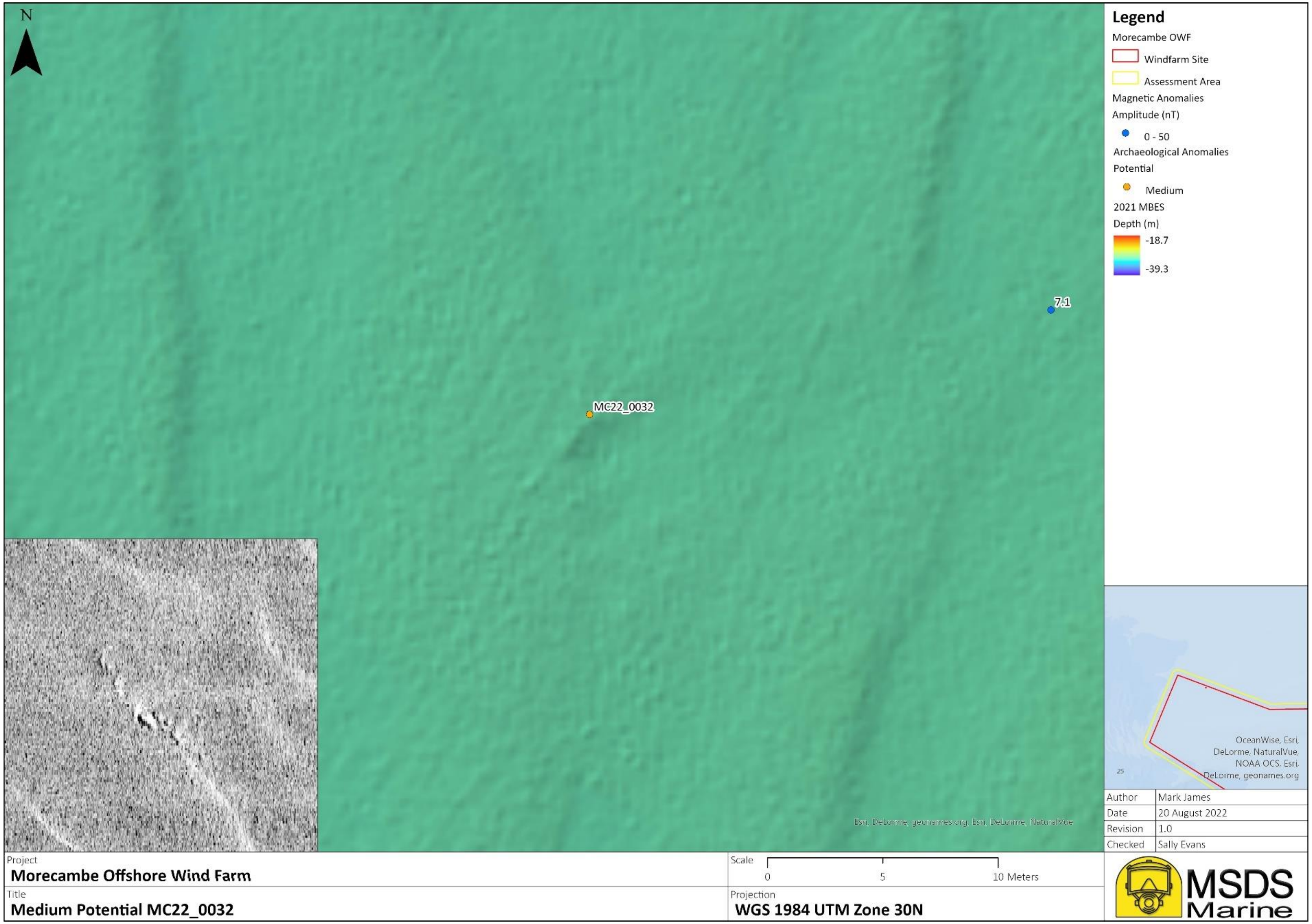

Figure 15: Medium Potential MC22_0032

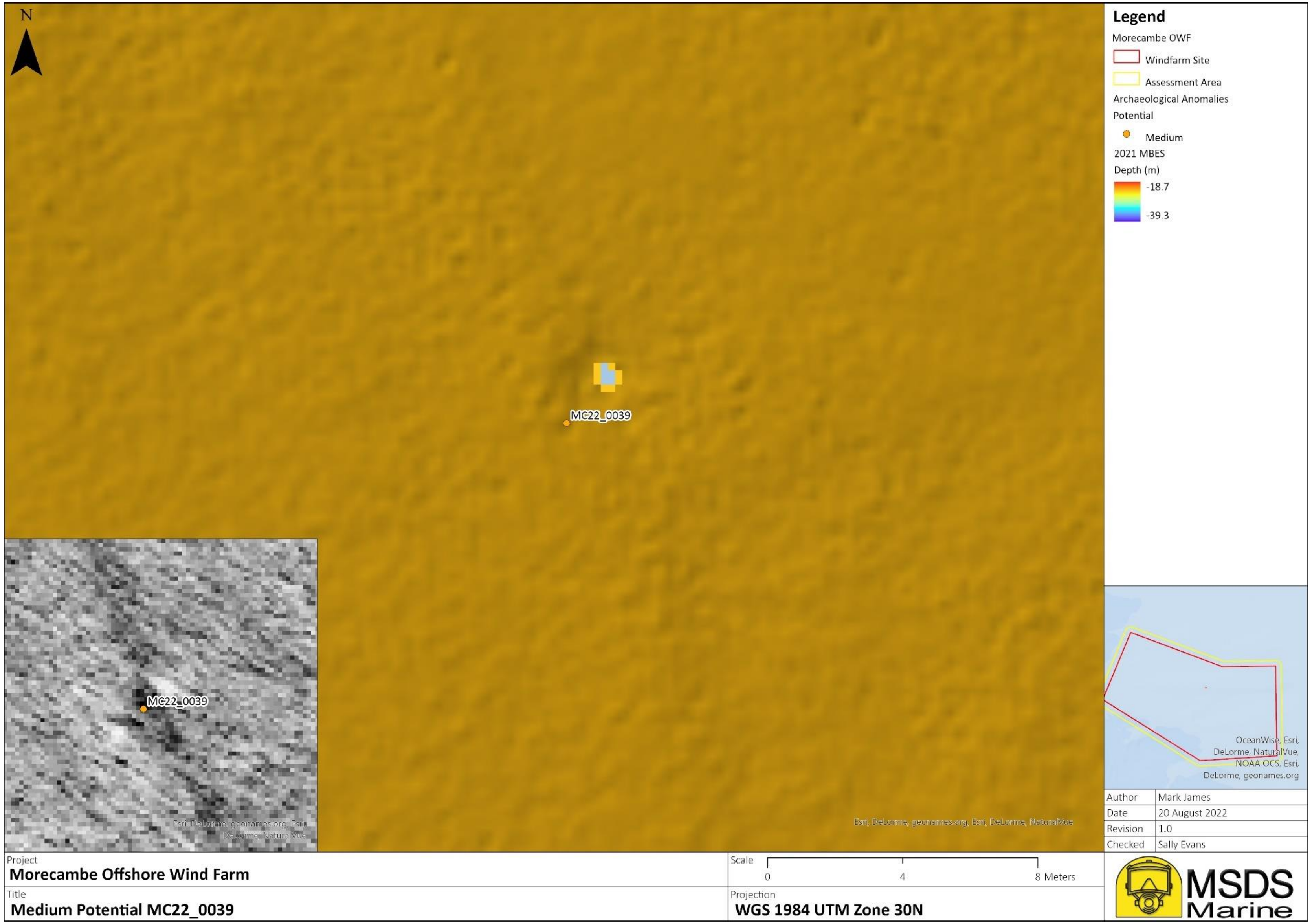

Figure 16: Medium Potential MC22_0039

7.0 Magnetic anomalies

7.0.1 301 magnetic anomalies ranging between 2 nT and 1,806 nT were identified within the data extents, of these 71 do not correlate with known, or visible, features or infrastructure. To note, only one magnetic anomaly correlated directly with an anomaly identified as of archaeological potential, this is likely due to the line spacing of the magnetometer data. 68 magnetic anomalies fall within the windfarm site, and three within the 0.5 km buffer. The distribution of anomalies by amplitude is shown below in Table 11 with their spatial distribution presented in Figure 17.

Intensity (nT)	Windfarm site	0.5 km buffer	Total
5 to 50	65	3	68
50 to 100	2	0	2
100 to 200	0	0	0
200 +	1	0	1
Total	68	3	71

Table 11: Magnetic anomalies

7.0.2 Anomalies identified from the magnetometer data are ferrous and thus generally anthropogenic in origin although they can be associated with geological features, however there is no visual interpretation as with other geophysical data.

7.0.3 The magnetometer data collection methodology across the Morecambe Offshore Windfarm survey area was to run lines concurrently with the SSS and MBES, thus the line spacing is not sufficient for the detailed assessment of small, ferrous features on or below the seabed. The position for a magnetic anomaly can only be determined from directly below a single sensor, or where lines are run close enough together to be able to confidently position an anomaly seen on two, or more, lines. However, in combination with SSS and MBES data the magnetometer specification is considered sufficient to develop a broad understanding of the potential of the survey area, and to identify larger features of potential archaeological significance.

7.0.4 The positions of magnetic anomalies were viewed in the available datasets and where there was a strong correlation with a seabed anomaly, they were assessed for archaeological potential. All remaining anomalies have been included within this section.

7.0.5 All isolated magnetic anomalies of 50 nT or less are considered to be of limited potential to be of archaeological significance.

7.1 Large magnetic anomalies

7.1.1 One large magnetic anomaly (>100 nT) was identified within the magnetometer dataset, MC22_MAG_0254, a complex anomaly of 739.4 nT. The anomaly is isolated with no corresponding seabed anomaly identified within the other datasets, the most likely explanation is that the anomaly is buried, or potentially very low lying as to not be visible within the surface datasets. The anomaly is not visible on the adjacent lines of magnetometer data, which are approximately 75.0 m each side (Figure 18). Due to the size of the anomaly, and the visibility on adjacent lines, it is likely it is largely contained at the location.

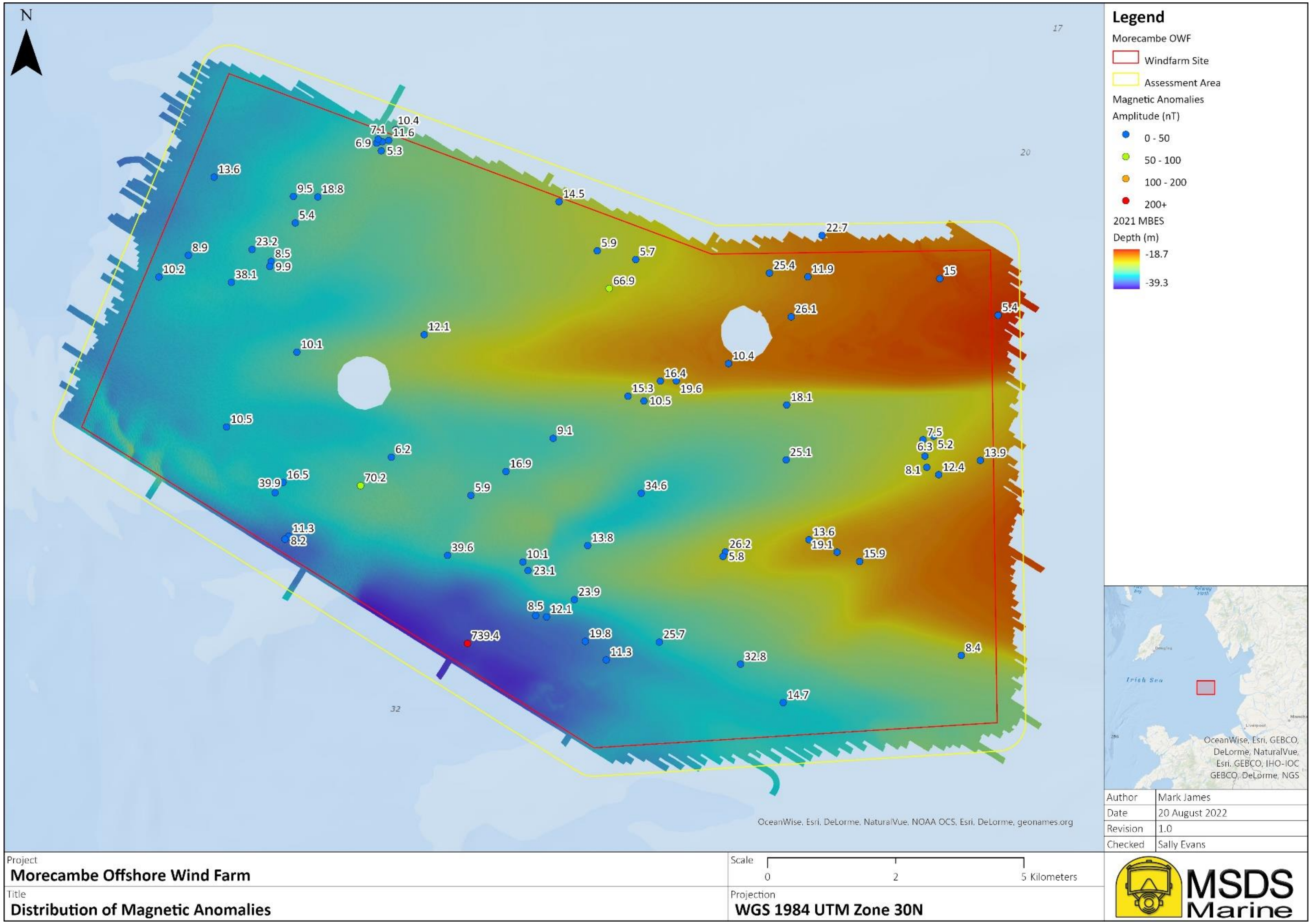

Figure 17: Distribution of isolated magnetic anomalies

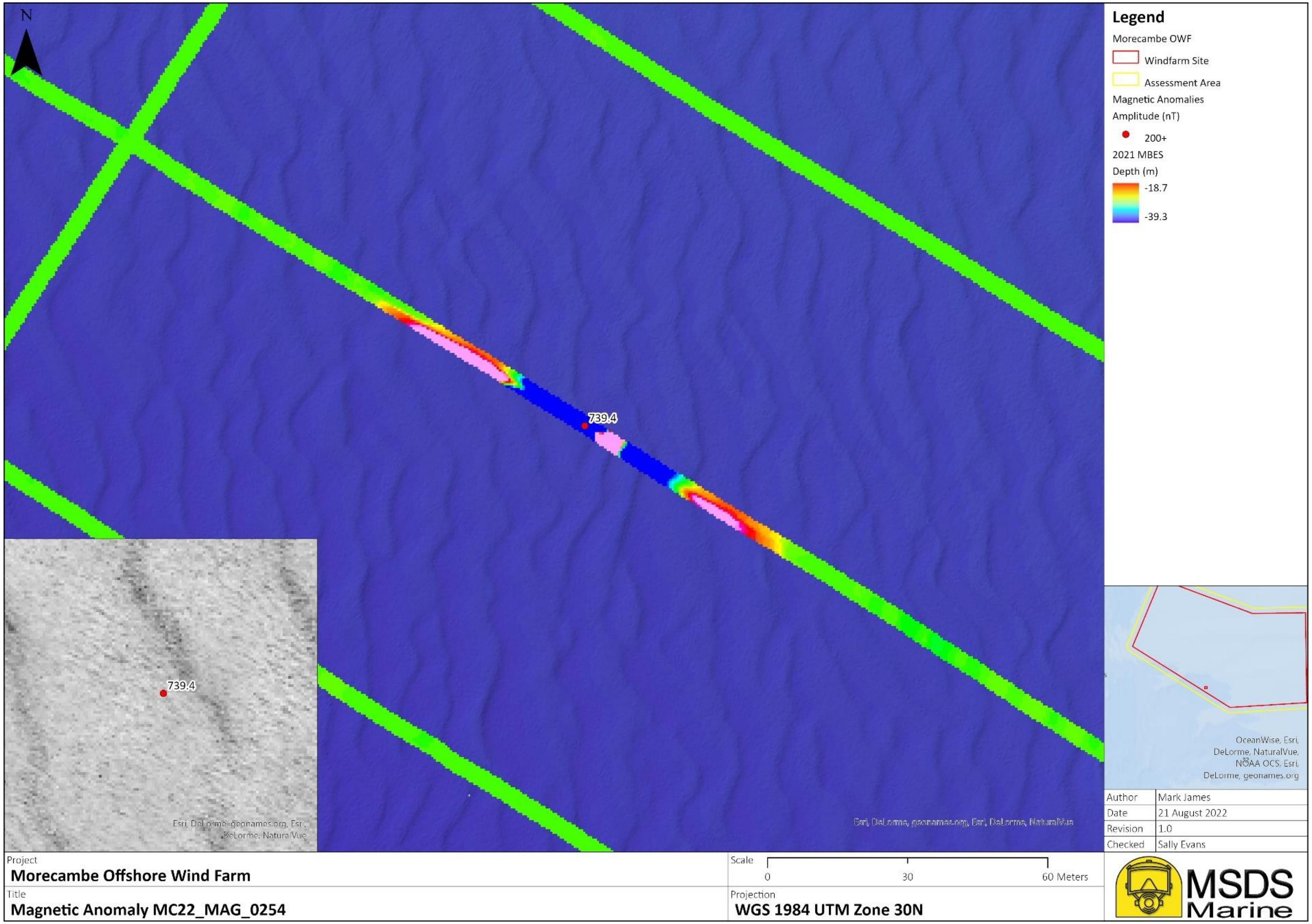

Figure 18: Magnetic Anomaly MC22_MAG_0254

8.0 United Kingdom Hydrographic Office (UKHO) Data

8.0.1 United Kingdom Hydrographic Office (UKHO) data from 2022 was obtained for the assessment area for correlation with anomalies identified within the geophysical data, and the establishment of TAEZs.

8.0.2 Five UKHO records were identified within the extents of the Morecambe Offshore Windfarm survey data, three within the windfarm site and two within the 0.5 km buffer. No further records were identified within the windfarm site or the assessment area.

8.0.3 The categories of records, along with record counts, are detailed in Table 12, and the distribution presented in Figure 19.

Record type	Windfarm site	0.5 km buffer	Total
Foul ground	2	0	2
Wreck	1	2	3
Total	2	2	5

Table 12: UKHO records by type within the Morecambe Offshore Windfarm assessment area

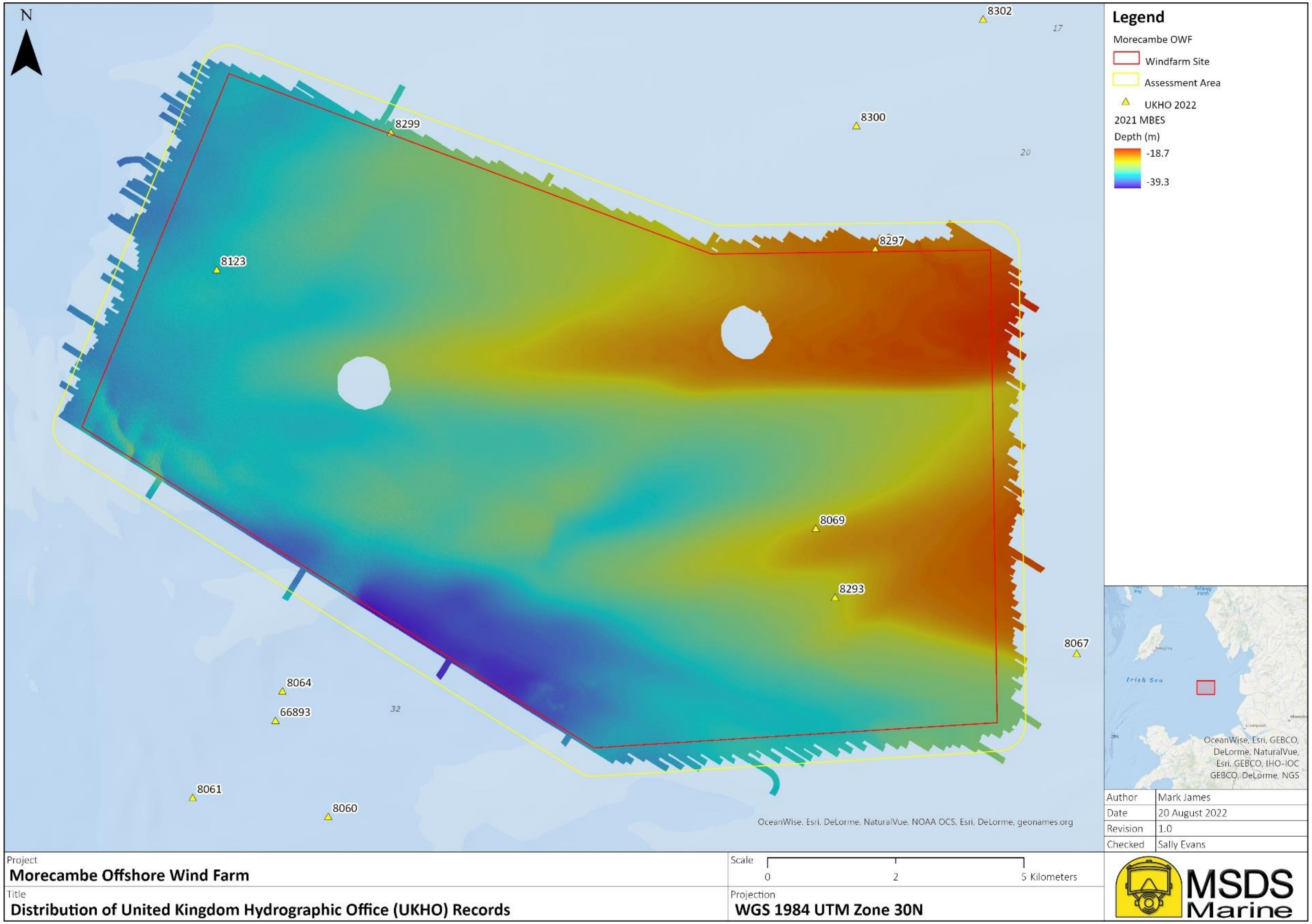

Figure 19: Distribution of United Kingdom Hydrographic Office (UKHO) Records

8.1 UKHO Records of Wreck

8.1.1 Of the five UKHO records identified, three are records of wrecks. UKHO data typically, where known, lists information about the wreck, the circumstances of its loss, surveying details, and whether the record is considered live or dead. A dead record is one which has *not been detected by repeated surveys, therefore considered not to exist*[11]. Whilst the decision to amend a wreck to dead is based on data available from repeat surveys, records can be amended for a number of reasons including:

- Deterioration of the wreck to such a degree that it no longer exists on the seabed;
- Continual burial of the wreck so that the presence is not detected over repeat surveys;
- The identification of the wreck as a natural feature; or perhaps most commonly,
- The wreck not existing at the listed location due to inaccurate reporting or positioning at the period of identification.

8.1.2 The position of the UKHO records were reviewed in the data and an assessment made as to whether they were visible, or likely to exist on the seabed. The UKHO records relating to wreck are presented in Table 13, and a description of each wreck provided below.

Record	Status	Name	Date sank	Date recorded	Last detected	Visible in data
8123	Dead	*Sontiire*	1982	1982 Observed	Not detected	Not visible
8297	Dead	Unknown	Unknown	1996	Not detected	Not visible
8299	Dead	Unknown	Unknown	1996	Not detected	Not visible

Table 13: UKHO records of wreck within the Morecambe Offshore Windfarm assessment area

UKHO record 8123

8.1.3 UKHO record 8123 lies in the west of the windfarm site, approximately 1.1 km from the western boundary and relates to the wreck of the *Sontiire*, a merchant cruiser that was observed sinking on 10th August 1982 whilst on passage from Hesketh to Douglas. Two passengers were rescued, and the position noted as 257° and 11 miles from the Morecambe buoy. The location was surveyed in 1996, the vessel was not located, and the record subsequently amended to dead.

8.1.4 Given the vagaries of the given location, the difficulties in obtaining an accurate position for a sinking vessel, no identification during the 1996 survey, and the lack of any evidence of the wreck within the geophysical data, it is highly likely the wreck does not lie at the given location. There is potential for the wreck to lie within the windfarm site, potentially relating to anomalies identified as of archaeological potential, however, there is no strong correlation between the description of the wreck and any material identified on the seabed. The closest anomaly of archaeological potential is medium potential MC22_0021 which lies approximately 0.9 km to the east. A relationship between UKHO record 8123, and MC22_0021 was considered, however, whilst the UKHO record does not list dimensions the description as a merchant cruiser may suggest a size that does not correspond to the anomaly visible on the seabed.

[11] https://www.wrecksite.eu/ukhoAbbrev.aspx

Furthermore, the sinking in 1982 is likely to indicate a ship of steel construction, which would likely be associated with a much larger magnetic anomaly and more pronounced remains on the seabed given the relatively short timeframe from sinking.

UKHO record 8297

8.1.5 UKHO record 8297 lies to the east, outside of the windfarm site 61 m north of the northern boundary. The record originated in 1996 (source unknown) as the identification of a non-dangerous wreck, the location was recorded with DECCA. The location was surveyed in 1997 with no wreck being located, the record was subsequently amended to dead. The survey report noted an area of high reflectivity, in the current datasets an area of high reflectivity measuring 5.8 m x 5.1 m is noted 75 m to the east. There is the potential that this is the featured referred to in the UKHO record. Based on the available data this area has been interpreted as geological in origin.

8.1.6 Based on the available evidence, it is highly likely that there is no wreck at the given location. Furthermore, it is highly likely that the record originated from the identification of a natural feature, and thus is unlikely to represent the presence of anthropogenic remains within the windfarm site.

UKHO record 8299

8.1.7 UKHO record 8299 lies to the west, outside of the windfarm site 43 m north of the northern boundary. The record originated in 1996 (source unknown) as the identification of a non-dangerous wreck, the location was recorded with DECCA. The location was surveyed in 1997 with no wreck being located, the record was subsequently amended to dead. There is no evidence of anthropogenic material at the location of the record. However, medium potential anomaly MC22_0032 lies 280 m to the south-west, along with two small magnetic anomalies 232 m and 160 m to the south/south-west. Whilst the form of the anomalies do not indicate a wrecked vessel, there is potential that they may have resulted in the original creation of the record although due to the small size of the remains on the seabed, it seems unlikely that they would have been interpreted as wreck.

8.1.8 Based on the available evidence, the position being obtained with DECCA, no evidence within the 1996 survey, and no evidence within the current dataset, it is highly likely that there is no wreck at the given location.

8.2 UKHO Records of Modern Features

8.2.1 No records of modern features were identified within the assessment area.

8.3 UKHO Records of Non Submarine Contacts (NSC)

8.3.1 No records of Non Submarine Contacts (NSC) were identified within the assessment area.

8.4 UKHO Records of Obstructions and Foul Ground

8.4.1 Obstructions and foul ground are records of seabed features which in the case of the former present a danger to safe navigation. The scope of the category can be broad and can, in practise, represent features from large pieces of debris through to large geological features. The records can originate from a number of sources including hydrographic survey (including sweeps), geophysical survey, or from reported fisherman's fasteners. To note; fisherman's fasteners are records of net snags identified during the course of fishing activity.

8.4.2 Of the five records identified within the assessment area, the UKHO record two as foul ground originating from fisherman's fasteners. Both the records are within the windfarm site to the south-east and are considered dead.

8.4.3 UKHO record 8069 was created in 1971 and disproved and amended to dead in 1997. UKHO record 8293 was created in 1996 and disproved and amended to dead in 1997. No evidence of any anthropogenic material, or geological, that may have resulted in a net snag is visible at either location, or within the vicinity.

General note about obstructions and foul ground

8.4.4 Whilst the foul records within the windfarm site are now considered dead there remains the possibility in some instances that material may remain on the seabed, either buried, not visible in the geophysical data, or having been moved through, for example, fishing nets snagging.

9.0 National Record of the Historic Environment

9.0.1 Data were obtained from the National Record of the Historic Environment (NRHE) in England for the assessment area. These records were used for correlation with anomalies identified within the geophysical data, in particular where the identity of an anomaly may be subject to uncertainty.

9.0.2 58 NRHE records were returned within the assessment area, 49 of which are within the windfarm site. All the returned records derive from fisherman's fasteners, with the following description *Unidentified seabed obstruction reported by fishermen. Possibly indicative of wreckage or a submerged feature.* All the records were created in 1999. The distribution of records is shown in Figure 20.

9.0.3 With the exception of NRHE record 909448 which correlates with UKHO record 8069 (foul ground derived from a fisherman's fastener) no NRHE records correlate with any archaeological anomalies, or UKHO records, and none relate to reported losses. It should be noted that NRHE records make no differentiation between records considered live or dead.

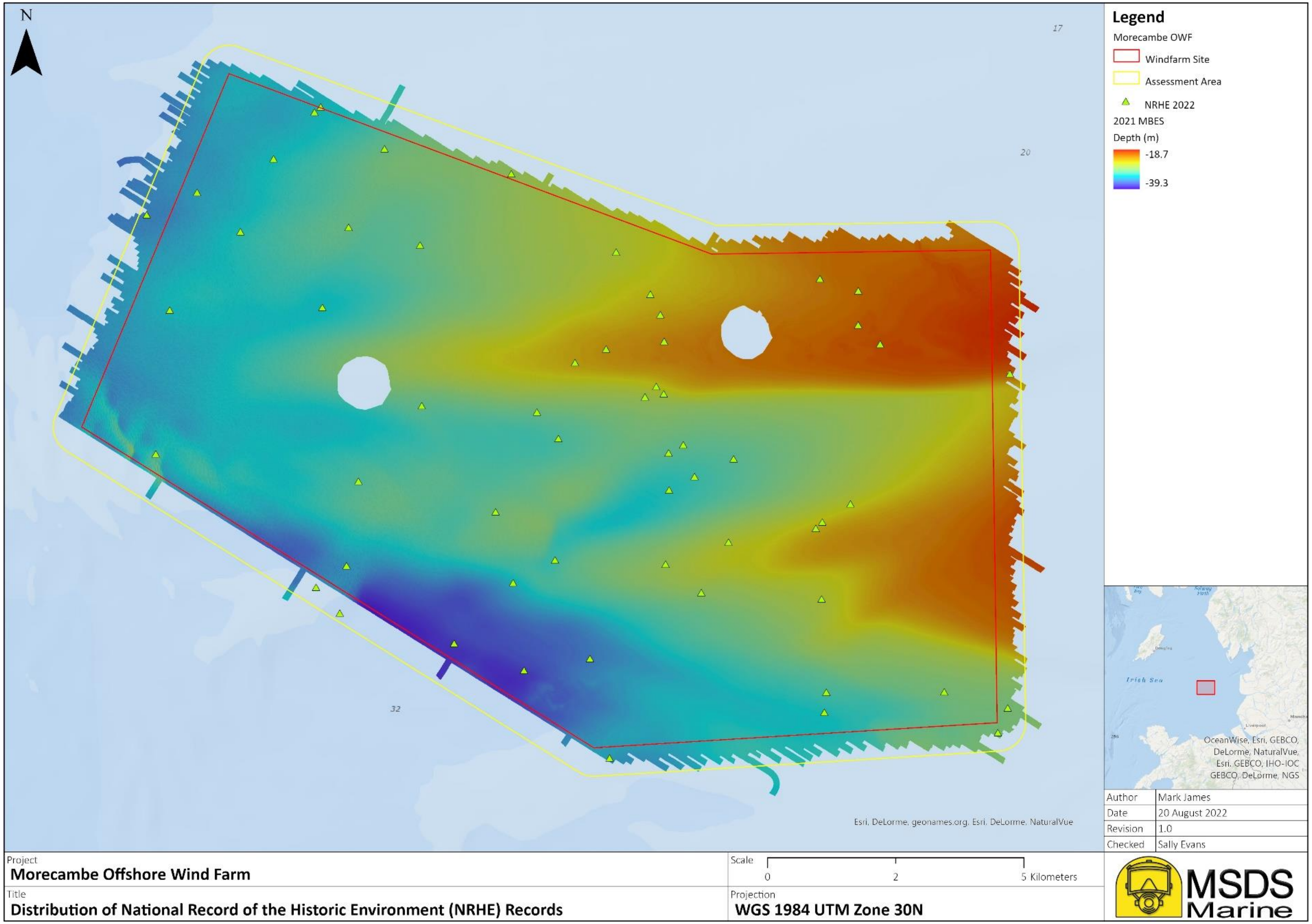

Figure 20: Distribution of National Record of the Historic Environment (NRHE) Records

10.0 Palaeolandscapes

10.0.1 This section provides a geological summary and assessment of the palaeoenvironmental and prehistoric archaeological potential of the site, taking into account the depositional environment, date, nature, and post-depositional processes of the Quaternary sequence within the site, which may have influenced this potential. Unit names follow those set out within MMT's (2022) report.

10.1 Quaternary Sequence

10.1.1 The Quaternary sequence within the site is set out within Table 14 and is discussed in detail below. As discussed in Section 0 correlations between units identified within the site and deposits known in the wider area are preliminary at this stage, and further investigation is required to confirm the correlations. These investigations will take place as part of the site investigations programme associated with the pre-construction surveys for the Morecambe Offshore Windfarm (MMT 2022).

Unit	Base	Lithology	Correlated Formation	Correlated Member	Age	Depositional Environment	Archaeological potential
1	H17	Marine silty sand	Western Irish Sea (A)	Mud Facies	Devensian to early Holocene	May be deep water glaciomarine to shallow marine, though other interpretations are possible (see text)	Some potential identified though further investigation required (see text)
2	H40	Sand	Western Irish Sea (A)	Prograded Facies	Devensian	Deltaic to glaciomarine	Limited but potential cannot be ruled out (see text)
3	H45	Silty sand	Western Irish Sea (A)	Mud Facies	Devensian	Deep water glaciomarine to shallow marine	Limited due to adverse conditions
			Western Irish Sea (B)	Mud Facies (Upper Tabular Stratified Member)	Devensian	Glaciomarine to marine	
4	H50	Till	Cardigan Bay Formation	Upper Till Member	Devensian	Glacial	Limited due to adverse conditions
				Lower Till Member	Wolstonian	Glacial	
5	N/A	Mudstone and halite	Triassic Bedrock	N/A	Triassic	N/A	N/A

Table 14: Quaternary Sequence

Note: dotted lines indicate the divide between multiple possible interpretations for each unit where a single interpretation is not given

10.2 Thickness of Quaternary Deposits

10.2.1 Analysis of seismic data collected as part of the current application has found that Quaternary deposit thickness varies across the site; in the east deposits extend to at least 43 m thick, whereas in the south and west they are c.5 m and c.25 m respectively (MMT 2022). This interpretation broadly correlates with the findings of BGS sampling and seismic data within the site and study area, although the BGS indicate that some parts of the study area extend to > 50 m (BGS 2014), and a BGS borehole taken within the site (ID: 71/40) (see Figure 7) indicates a thickness of at least 63 m of Quaternary material above bedrock. Large-scale deep incisions into bedrock filled with Quaternary material are common across the Irish Sea area (Jackson et al. 1995) and interpretation of sub-bottom data collected for The Project identified areas of greater thickness within channel-like features (see Figure 21**Error! Reference source not found.** for an example), accounting for the areas of thickest Quaternary sediment.

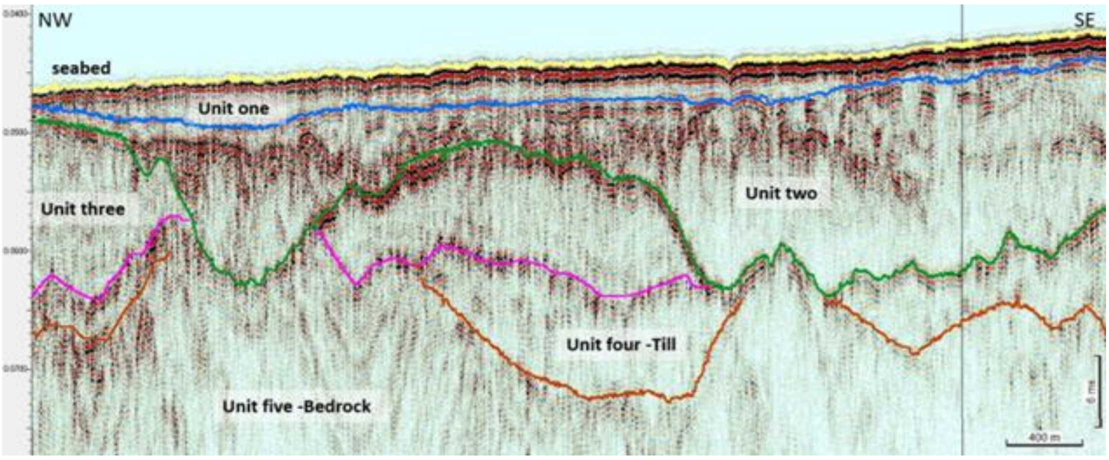

Figure 21: Glacial channels within Unit 2 and Unit 5 (MMT 2022)

10.3 Pre-Quaternary Bedrock

10.3.1 Bedrock was described in the ground model report as Unit 5:

- Unit 5 comprises mudstone and halite and is present across the entire site. It is part of the Mercia Mudstone Group. The base of this unit was not identified and as such its total thickness is unknown (see Figure 22 for depth to top of Unit 5). Its upper surface is erosional and is overlain unconformably by Unit 4, and Unit 3 where Unit 4 is absent (MMT 2022). The top of the bedrock was not mapped in full as seabed multiples affected the data in some areas (MMT 2022: 42)

10.3.2 This deposit predates the Quaternary period and is not of archaeological interest. It is not discussed further.

10.4 Quaternary deposits and formations

- Unit 4 overlies Unit 5 (bedrock). It is seismically chaotic, varies in thickness and is discontinuous across the site, being absent in some areas. The base of this unit is represented by horizon H50 which is also the top of the bedrock, Unit 5 (see Figure 23). The deposit infills large possible tunnel valley features incised into Unit 5 in the east of the site. Unit 4 has been correlated with a till member of the Cardigan Bay Formation. Till members include an Upper Till Member and Lower Till Member. The deposits within the Cardigan Bay formation were laid between MIS 6 to MIS 2 (specifically 180.6 ka BP – 13.9 ka BP) (BGS 2020). The Upper Till Member is a Devensian glacially-derived till deposit comprising stiff or hard clay with inclusions ranging from cobbles to large boulders. The Lower Till Member comprises very stiff diamicton dating to the Wolstonian (Mellett et al. 2015; Jackson et al. 1995). Both interpretations indicate glacial deposition.

- Unit 3 comprises silty sand and is present across most of the site, although it is absent in the centre of the site and other small areas. Seismically, the unit is well bedded towards the base, but moving away from the base the unit becomes more chaotic. This unit overlies Unit 4, but also directly overlies the bedrock in places. The base of this unit is represented by horizon H45 (see Figure 24). The base of the deposit is between 1 m and 29 m below seabed level. In the central north part of the site, Unit 3 is at its thickest and deepest. Unit 3 has been interpreted a Mud Facies deposit of the Western Irish Sea Formation, specifically either the Mud Facies of the Upper Tabular Stratified member of the older 'B' division (WIS-B), or the Mud Facies of the younger 'A' division (WIS-A). The WIS-B Mud Facies comprises silts with sand and patches of boulders and cobbles. It has been interpreted as glaciomarine to marine (Mellett et al. 2015). The WIS-A Mud Facies has "near-transparent acoustic character with parallel, sub-horizontal reflectors forming tabular-stratified units" and comprises black to greenish grey, shelly silts, and sands with patches of boulders and cobbles interpreted as mostly cold-water deposits with some evidence of ameliorative stages (Jackson et al. 1995; Mellett et al. 2015). This Mud Facies is deep water marine to glaciomarine deposit shifting to a shallower marine deposit (Jackson et al. 1995). Both interpretations indicate deposition in a marine or glaciomarine environment.

- Unit 2 is present across much of the site but absent in some areas. Its base (horizon H40) has been found between 1 m and 23 m below the seabed (see Figure 25). Unit 2 has a variable seismic character; with prograding clinoforms in places and chaotic character in others. The unit is thought to hold a high proportion of sand and has been correlated with a Prograded Facies of the late Devensian WIS-A (MMT 2022). This comprises wedges of fine to medium sand with rare to absent microfossils (Jackson et al. 1995). The Prograded Facies deposition has been suggested to be deltaic to glaciomarine laid in a period of ice retreat at the end of the LGM (Mellett et al. 2015; MMT 2022). This deposit infills channels incised into the underlying Units 3 and 4. The channels are generally present in the western part of the site and are aligned north-south. They may represent tunnel valleys (MMT 2022: 51).

- Unit 1 comprises silty sands interpreted as a recent marine deposit present continuously across the site. Its base is represented by horizon H17 which has been identified between 1 m and 10 m below seabed level (see Figure 26). Unit 1 is characterised by acoustically well bedded parallel and laterally continuous reflections which show onlapping sequence stratigraphy (MMT 2022). The unit is overlain by a thin veneer of sand that has been interpreted as surficial sands. Unit 1 has been correlated with the late Devensian WIS-A (MMT 2022), specifically the deep water glaciomarine to marine Mud Facies deposit. The wider BGS studies suggest that the WIS-A Mud Facies was deposited in a cold deep water environment, shifting to a more temperate shallow marine environment (Jackson et al. 1995; Mellett et al. 2015). Although Unit 1 has been correlated with a marine deposit, the seismic character of the unit may indicate a variety of depositional environments; the well-bedded nature may indicate alluvial deposition, and the evidence of onlapping within the deposit could indicate that it was deposited in a transgressive environment. As discussed below, the timing and processes surrounding the Holocene transgression are debated; some authors suggest that the site was terrestrial, bordering a floodplain with multiple fluvial channels during this period, rather than the marine environment described in BGS sources (Fitch et al. 2011; Brooks et al. 2011). As such Unit 1 requires further investigation and geoarchaeological interpretation to confirm its depositional environment.

10.5 Seabed Sediments

10.5.1 The seabed sediments were interpreted as gravelly sand, sand and clayey sand based on SSS imagery (MMT 2022). The main seabed features include megaripples caused by sediment movement and trawl marks caused by historic bottom fishing, and there is an isolated area of sand waves in the south-western corner of the site.

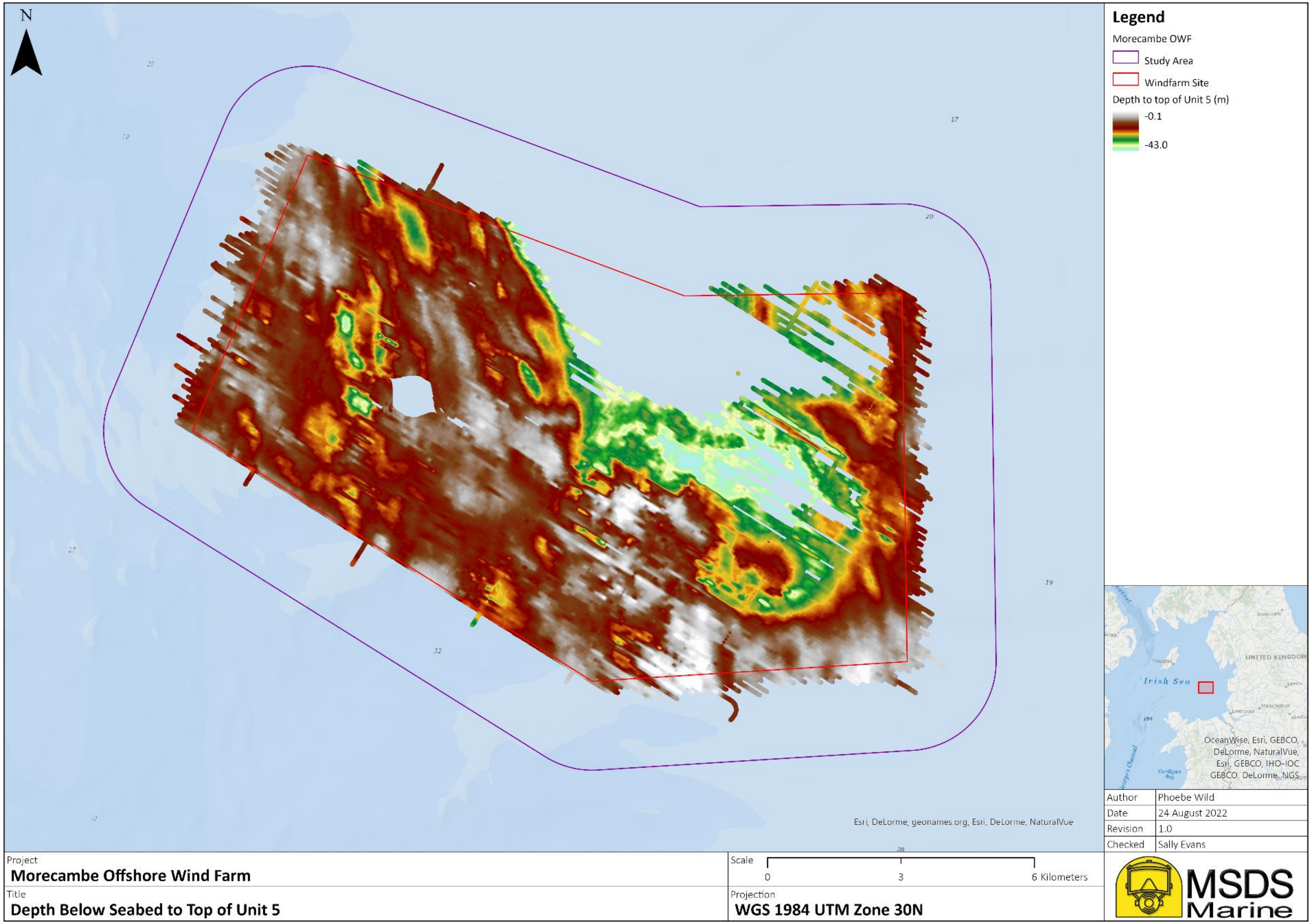

Figure 22: Depth below seabed to top of Unit 5 (bedrock)

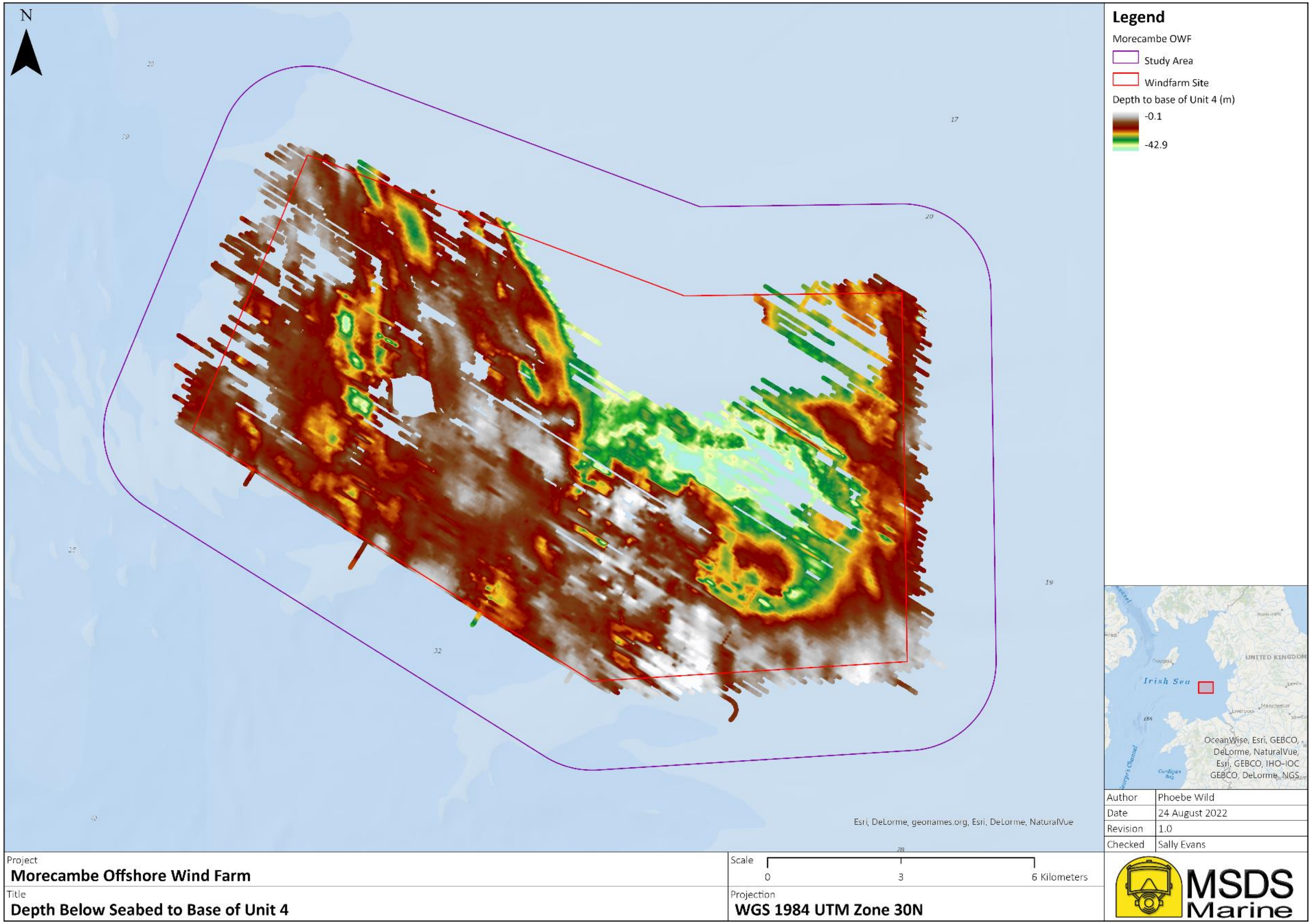

Figure 23: Depth below seabed to base of Unit 4

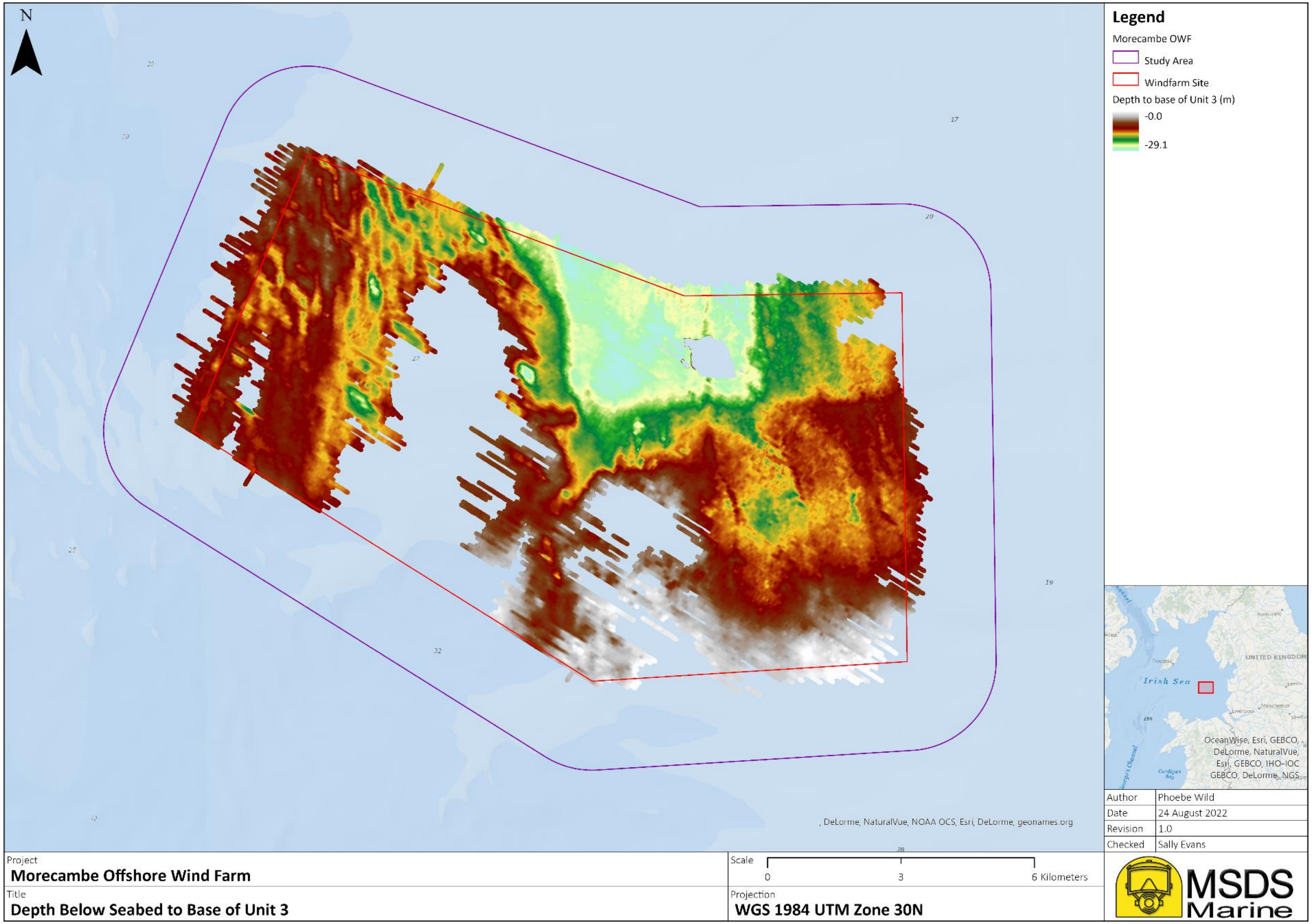

Figure 24: Depth below seabed to base of Unit 3

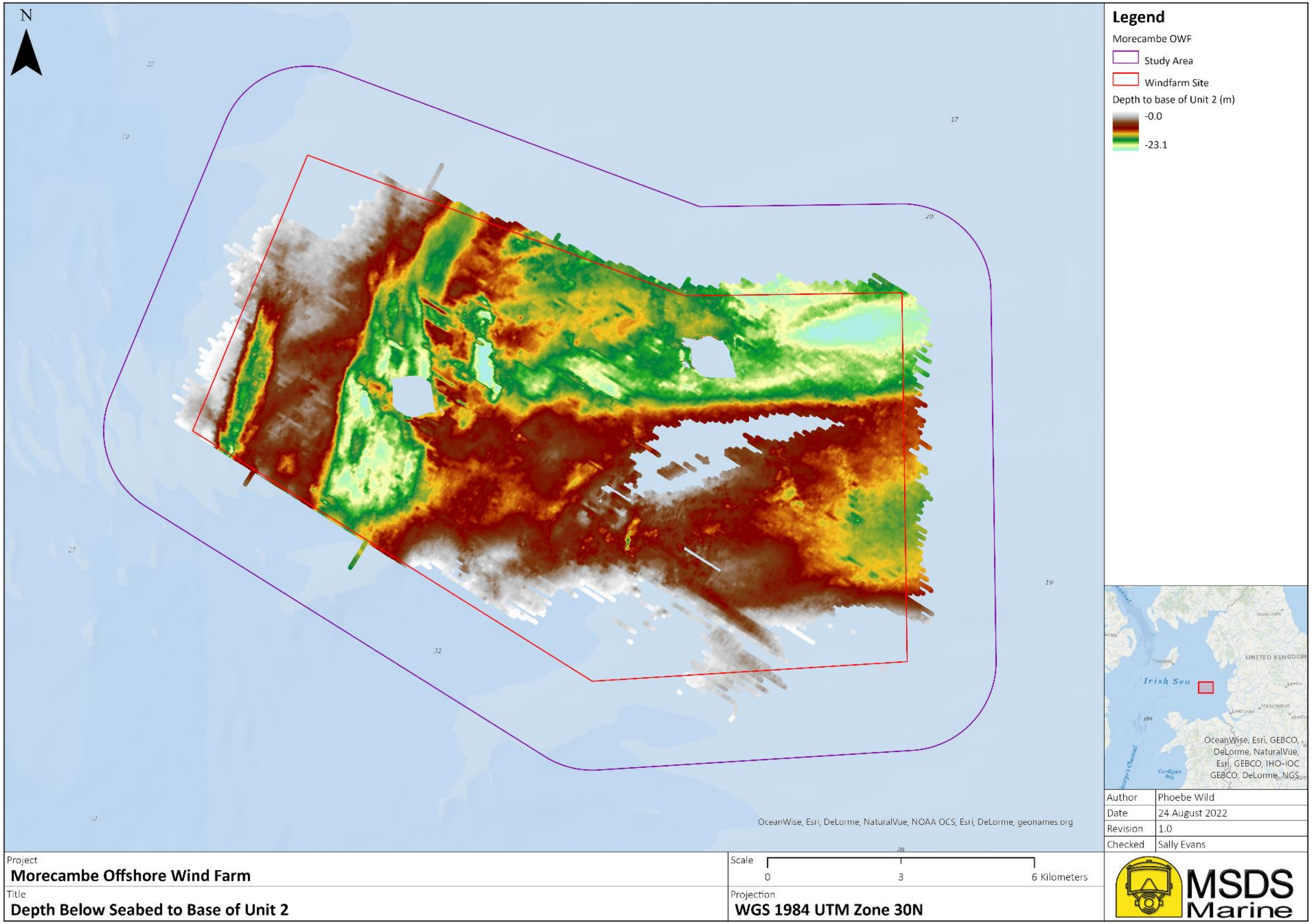

Figure 25: Depth below seabed to base of Unit 2

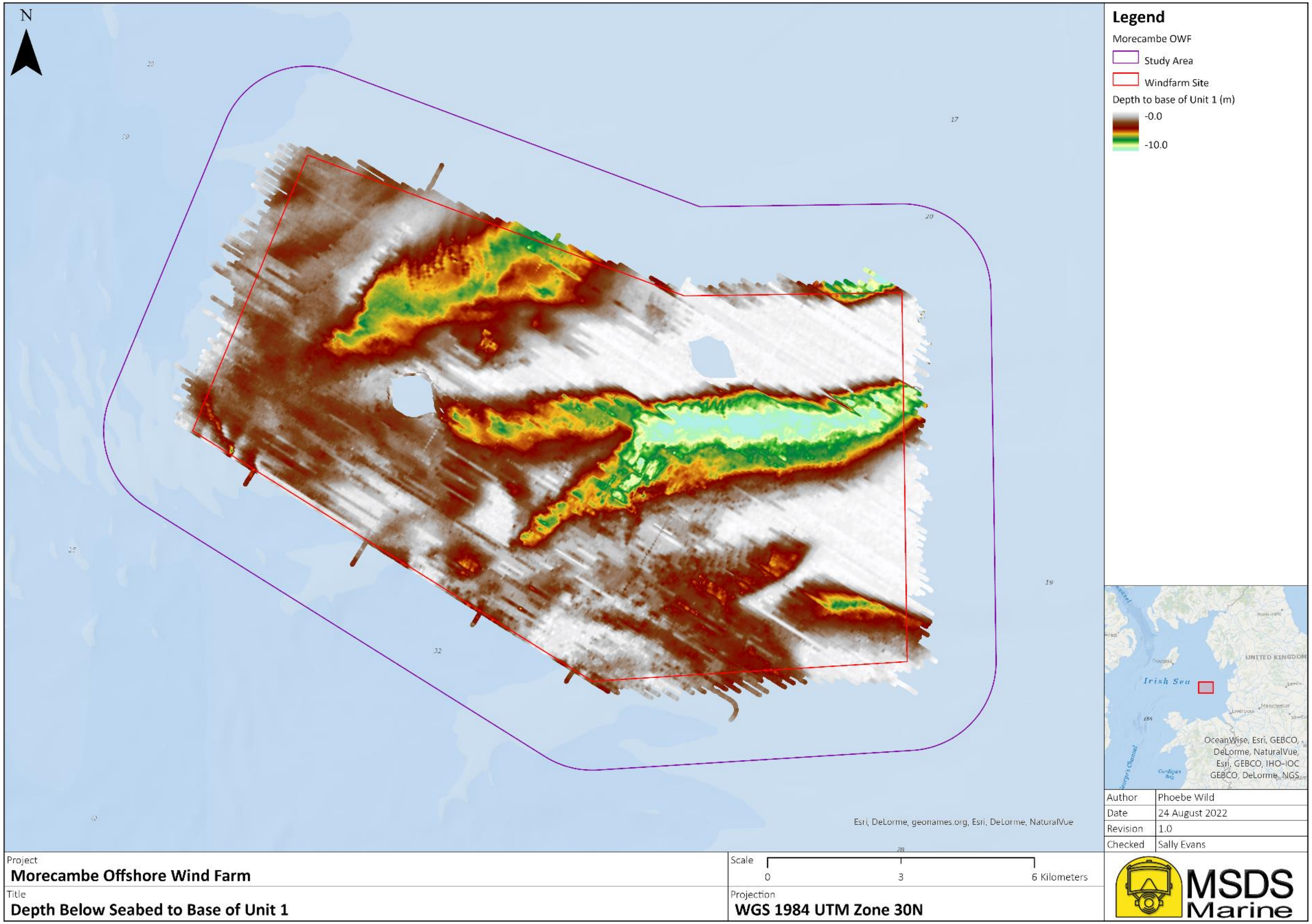

Figure 26: Depth below seabed to base of Unit 1

10.6 Geomorphology

10.6.1 The site has been subject to varied conditions during the Quaternary with a number of erosive events that have affected the geomorphology of the area. Large-scale valleys, up to several kilometres in width, have been incised into the weak Mercia Mudstone bedrock (Unit 5) and within Prograding Facies of WIS-A (Unit 2) (MMT 2022). The larger channels in the east of the site are incised into the bedrock and are interpreted as subglacial tunnel valleys infilled predominantly with Unit 4, although where this is absent Unit 3 overlies the bedrock. The smaller channels in the site are tentatively interpreted as tunnel valleys infilled by the deltaic to glaciomarine Unit 2.

Sea level data

10.6.2 There are limited Sea Level Index Points (SLIPs) offshore in the Irish Sea. The majority of SLIPs are present along the current coastline and date to after the maximum extents of the Devensian glaciation (Last Glacial Maximum (LGM)). These indicate that the site was periodically submerged as the coastline fluctuated following the LGM, however, the exact date of submergence of this area is debated and different models of submergence exist (e.g., Brooks et al. 2011; Fitch et al. 2011; Jackson et al. 1995; Mellett et al. 2015; Shennan et al. 2018).

10.6.3 The two main geological sources that cover this area were produced by the BGS (Jackson et al. 1995; Mellett et al. 2015). These sources include differing interpretations of geological formations laid during the Devensian/Holocene transition resulting in different interpretations of contemporary palaeolandscape evolution. The sources agree that the site was subject to subglacial to glaciomarine conditions during the Devensian. Following ice retreat at the end of the LGM Jackson et al. (1995) suggest the deposits which survive with the area represent subglacial, glaciomarine, prodeltaic and full marine environments, indicating a lack of deposits representing subaerial exposure. Mellett et al. (2015) instead suggest that the site was subject to subglacial to glaciomarine to deltaic conditions and thus potentially indicating sub aerial exposure prior to full marine inundation. Neither sources provide definitive dating for these landscape changes. These differences principally relate to how the Western Irish Sea (A) formation is interpreted, and in particular the Prograded Facies, interpreted as Unit 2 within the site.

10.6.4 Landscape models by Brooks et al. (2011) and Fitch et al. (2011) present alternative theories for landscape evolution during this period suggesting that the site was terrestrial to intertidal at various points. Brooks et al. (2011) indicate that the site was coastal and intertidal at 18 ka BP and fully terrestrial by 16ka BP (see Figure 27). Modelling by Fitch et al. (2011) supports this theory, this study postulates that the site was situated on a floodplain adjacent to fluvial channels suggesting a deltaic environment at c.18ka BP. The Brooks et al. (2011) model then shows the site transitioning from intertidal (13 ka BP), to offshore/coast adjacent (10 ka BP) to fully offshore (8 ka BP) (see Figure 27). These dates indicate marine transgression occurring from the Loch Lomond Stadial to the onset of the Holocene. However, data from the WCPS suggests that the site was terrestrial at 10ka BP, during the Mesolithic (Holocene) (Fitch et al. 2011) (see Figure 29).

10.6.5 Shennan et al. (2018) have produced a recent and extensive study of relative sea level in Britain and Ireland since the LGM. Their study, incorporating over 2,000 data points including sea level index points along with marine and terrestrial limiting data, provides regional insights into RSL across the UK. Sea level data for the Isle of Man and Morecambe Bay indicate sea level rise coinciding with the Windermere interstadial (14.7-12.9 ka BP), a subsequent fall during the Loch Lomond stadial (12.9-11.7 ka BP), and finally a relatively swift period of sea level rise attributed to the Holocene transgression (Shennan et al. 2018). Supporting this scenario of sea level change are data from Cumbria which indicate relative sea levels were at least +2 m OD in the Windemere Interstadial (Lloyd et al 2013), while data from North Wales demonstrates lower sea levels during and following the Loch Lomond stadial (between -29 m and -24 m OD from c. 12.6k BP to 11.1k BP) (Roberts et al 2011). Data from around the Morecambe Bay area of the Irish Sea demonstrates later sea level rise (Shennan et al. 2018). The data points for the north-west are clustered around the current coastline, however, they indicate periods of marine lowstand during which the site may have been aerially exposed, particularly during the Loch Lomond Stadial and early Holocene. It is thought that the current coastline of the Liverpool Bay area was established in around 6 ka BP, as such the site was likely to have been subject to marine conditions considerably before this with Brook et al (2011) indicating submergence of the site by at least 10 ka BP, though Fitch et al (2011) suggest a later date.

10.6.6 Further evidence on the timing of the transgression is required to determine when the site was finally submerged. Units 1 and 2 may have been deposited during these periods and may hold evidence relating to the transgression and palaeolandscape changes.

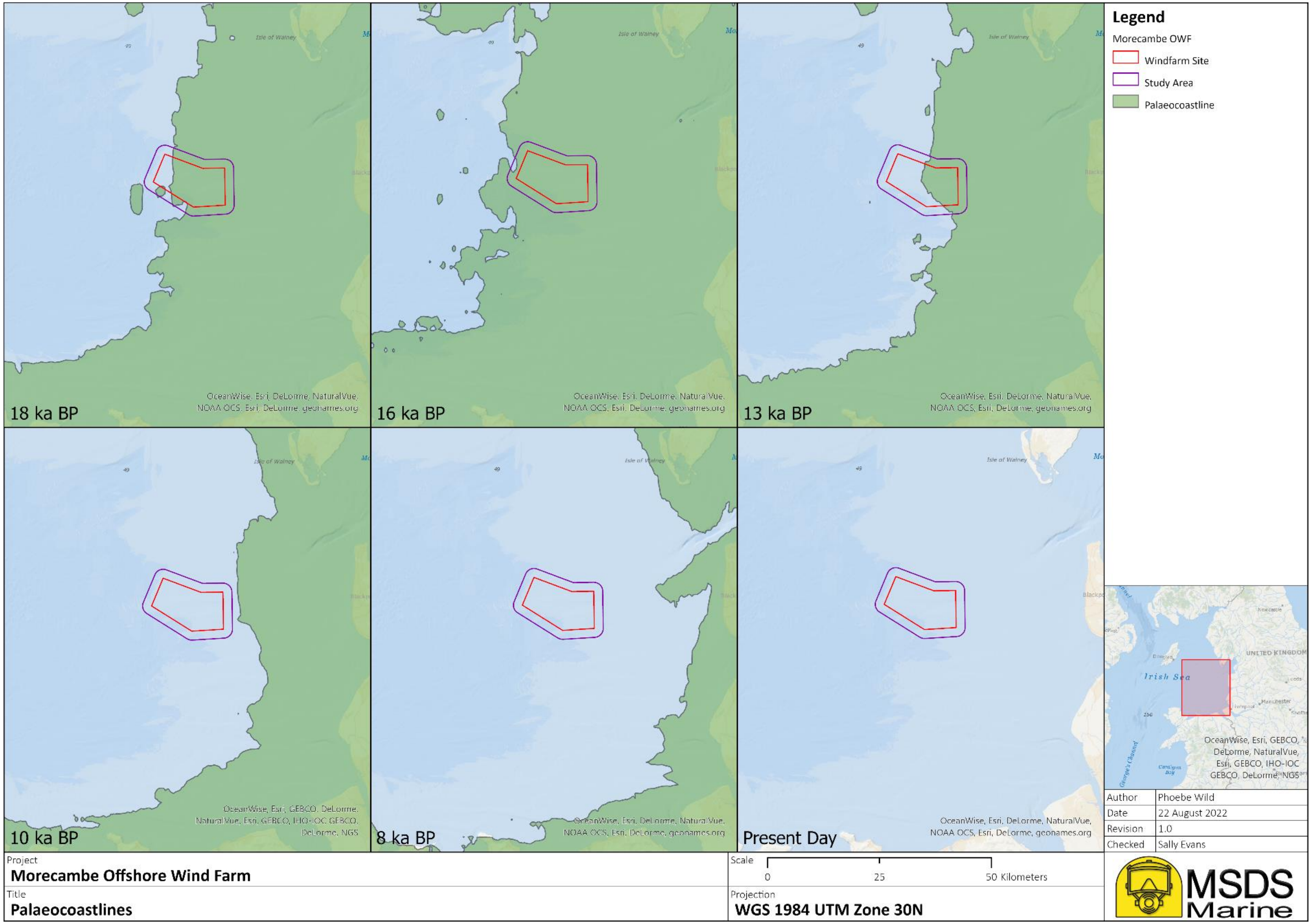

Figure 27: Palaeocoastlines as modelled Brooks et al. 2011; EMODnet

10.7 Palaeolandscape assessment and Prehistoric Archaeological Potential

Lower Palaeolithic

10.7.1 This section considers the potential for submerged prehistoric remains, including archaeological sites, palaeolandscape elements and palaeoenvironmental evidence, to be present within the site.

10.7.2 The prehistoric archaeological record of the UK covers the period from the earliest hominin occupation, potentially as far back as 970,000 BP, to the end of the Iron Age and the Roman invasion of Britain by Claudius in AD 43. The coastline of the UK changed drastically during this period and large tracts of what is now the seabed were once subaerially exposed.

10.7.3 The UK has been affected by several glacial events over the last 1 million years; including the Anglian (480-430 ka BP), the Wolstonian (350-132 ka BP), and the Devensian (122-10 ka BP), and intervening marine transgressions all of which have influenced archaeological potential (see Figure 28). The potential is inferred from the presence of prehistoric landscapes within the Irish Sea, discussed in a variety of published reports and grey literature (see below). Potential palaeolandscape and palaeoenvironmental remains associated with the site are further investigated here.

10.7.4 Prehistoric archaeological potential is gauged with reference to evidence for human activity in the UK during each period, and the contemporary environment within the site. Depositional environment and post-depositional factors are also key to understanding potential, and as such geological deposits present within the site form an important consideration in understanding archaeological, palaeoenvironmental and palaeolandscape potential. Deposits with potential for prehistoric archaeological remains, or palaeoenvironmental information are generally those laid during periods of aerial exposure or by fluvial process, rather than sub-glacial or marine deposits (though these may include remains capable of providing dates for different environmental conditions, and constraining time periods of potential suitability for habitation). However, there is also potential for archaeological material to be redeposited or reworked within secondary contexts as a result of fluvial erosion or glacial processes (Hosfield and Chambers 2004), this will be taken into consideration when potential is assessed.

10.7.5 Review of the geological stratigraphy of the site within the ground model report indicates that the Quaternary deposits likely post-date the late Wolstonian (MIS 6), with the majority likely originating in the Devensian and Holocene periods. Thus, the following discussion will only relate to the archaeological and palaeoenvironmental potential of deposits laid during the late Wolstonian onwards.

Late Middle Palaeolithic (186-45 ka BP, MIS 6-3)

10.7.6 While most deposits within the site are thought to relate to the Devensian and Holocene periods (MIS 3-1), a number of origins for Unit 4 are possible. Unit 4 is described as stiff or hard clay and is thought to represent a diamicton deposited as a glacial till (MMT 2022). The unit has been correlated with a till member of the Cardigan Bay Formation. The till members within this formation include the Upper Till and Lower Till. The Lower Till dates to the late Wolstonian (MIS 6), while the Upper Till dates to the late Devensian (MIS 2-1). Glacial tills represent inhospitable environments and have very limited archaeological potential as such the potential for archaeological remains to be present within the site from the Late Middle Palaeolithic is very low.

10.7.7 Although the following interglacial stage, the Ispwichian (126-116 ka BP, MIS 5e) climatic amelioration may have allowed the development of environments which were more conducive to human activity than the preceding glacial phase, no such activity has been identified within the UK dating to this period (Marshall et al. 2020).

Upper Palaeolithic (45-10 ka BP, MIS 3-1)

10.7.8 The Devensian (122-10,000 BP, MIS 5d-1) glaciation which directly followed the Ipswichian interglacial was the last glaciation to affect the UK. The maximum extents of the glaciation reached c.250 km south of the site between 26 ka BP and 14.7 ka BP (see Figure 28). Within the wider area, deposits described by the BGS indicate predominantly glacial conditions during the Devensian: the Upper Till Member of the Cardigan Bay Formation, also tentatively correlated to Unit 4, is a glacial till that forms the base of the Quaternary sequence across much of the Irish Sea (Jackson et al. 1995). The overlying Western Irish Sea Formation, elements of which have been correlated to Unit 3, Unit 2, and Unit 1 represents glaciomarine, deltaic, and finally deep-water glaciomarine to shallow marine deposits. These indicate a shifting environment following climatic changes towards the end of the Devensian and onset of the Holocene.

10.7.9 Seismic, and limited geotechnical, data from the site indicates that late Devensian material was mostly laid in a glaciomarine to marine environment, limiting archaeological potential. However, Unit 2 has been correlated with Prograding Facies of the WIS-A Formation which may represent a deltaic environment at the Postglacial/Holocene transition (see discussion in Section 10.6). Seismic data also indicates that Unit 2 infills relic glacial tunnel valleys incised into the underlying deposits.

10.7.10 Different models for landscape changes in the area during the Upper Palaeolithic to Mesolithic have been put forward; a number of studies suggest that the offshore part of the Irish Sea basin was subject to marine conditions for the majority of this period, while other studies (particularly the WCPS) suggest that it was a terrestrial environment dominated by fluvial systems and related floodplains, connected with glacial meltwater systems (see Figure 28) (Brooks et al. 2011; Jackson et al. 1995; Mellett et al. 2011; Fitch et al. 2011) (see section 10.7). Sea level data recently collated by Shennan et al. (2018) indicate sea level rise coinciding with the Windermere interstadial (14.7-12.9 ka BP), a subsequent fall during the Loch Lomond stadial (12.9-11.7 ka BP), and finally a relatively swift period of sea level rise attributed to the Holocene transgression. The information indicates periods of marine lowstand during which the site may have been aerially exposed, particularly during the Loch Lomond Stadial and early Holocene.

There is currently no evidence of human activity in the UK during the Loch Lomond stadial, though early Holocene evidence is recorded. While sub aerial exposure of the site is possible during this period the area is likely to have been dominated by glacial landforms and meltwater river systems (Fitch et al. 2011). It is possible that deltaic or infill deposits associated with Unit 2 may have been laid down in association with these landscapes described by the WCPS (see Figure 28). The climate was still likely to have been cold during this period and landscapes dominated by glacial meltwater systems are not likely to have been hospitable environments for settlement, however, the conditions may not have been prohibitive for human activity and the area could have been used for resource exploitation (Fitch et al. 2011).

10.7.11 As such, there is some archaeological potential within this unit during the early Holocene as the climate would have been cool but not prohibitive to human activity, and the environment may have been suitable for hunting and resource exploitation. There is also potential for this unit to contain redeposited remains. Remains tend to survive in sheltered locations such as cave sites, and more exposed areas have undergone heavier erosion associated. This erosion is likely to favour the preservation of more durable remains in redeposited settings. The Holocene transgression is likely to have eroded and reworked Unit 2, further affecting the potential for archaeological or palaeoenvironmental remains.

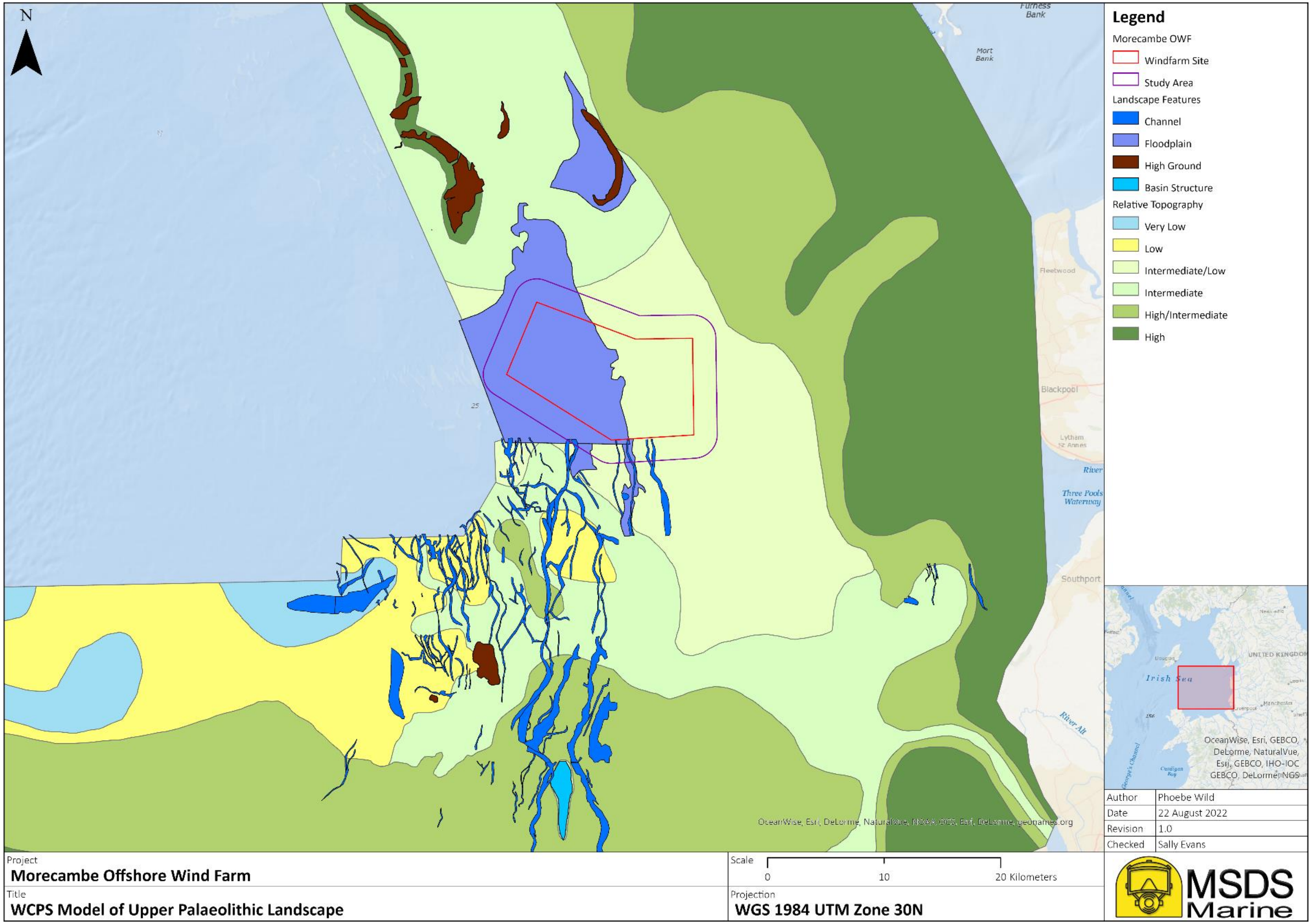

Figure 28: Upper Palaeolithic landscape modelled by the WCPS (Broad) (Fitch et al. 2011)

Mesolithic (10-6 ka BP, MIS 1)

10.7.12 Sea level studies lack consensus on the date of inundation for this part of the Irish Sea which influences the assessment of potential for this period (see Section 10.6). Shennan et al. (2018) indicate a rapid transgression during the Holocene and earlier studies indicate that the site was submerged by the start of the Mesolithic at 10 ka BP (Brook et al. 2011), though others indicate that the site may have remained sub-aerially exposed during the early Mesolithic (Fitch et al. 2011; Jackson et al. 1995). The timing of the transgression is therefore key to understanding the potential for Mesolithic remains. If submerged, as in the models by Brook et al. (2011) there is no potential for in situ Mesolithic material. However, if all or parts of the site remained exposed (e.g., Fitch et al. 2011), as the climatic conditions ameliorated during the onset of the Holocene, Mesolithic communities could have thrived in the Liverpool Bay area (Fitch et al. 2011). Woodland would have developed, and the seaward zones (potentially including the site) may have become brackish fenland. Indeed, the landscape modelling undertaken by the WCPS suggests the majority of the site was terrestrial, a low lying plain on the landward edge of the intertidal zone. Two river channels are modelled in the north of the study area (see Figure 29). The environment described in the WCPS would have been conducive to human exploitation; available resources would have increased as the local flora and fauna became more diverse, and the range of environmental conditions would have presented more varied opportunities for exploitation. Relic glacial tunnel valleys, such as those infilled by Unit 2, may have remained active during the Mesolithic (Fitch et al. 2011) and could have formed foci for human activity (Ward and Larcombe 2008).

10.7.13 While the date of the Holocene marine transgression is debated, all sources agree that the area around the site had been inundated by at least the middle of the Mesolithic period (Brooks et al. 2011; Fitch et al. 2011; Ransley et al. 2013; Sturt et al. 2013; Shennan et al. 2018).

10.7.14 Unit 1, correlated to the WIS-A Mud Facies, is thought to have been laid during the final marine transgression of the Irish Sea (MMT 2022; Mellett et al. 2015). Studies indicate that alluvial deposits and floodplains may have been present in the Liverpool Bay area just prior to inundation (Fitch et al. 2011). While the general character of the unit is thought to represent marine sediments, limiting archaeological potential, the well-bedded and onlapping composition would not rule out an alluvial transgressive environment. Frequent gas blanking identified within the Mud Facies elsewhere in the Irish Sea may be indicative of decaying organic remains (Schroot and Schüttenhelm 2003), however, no gas blanking was identified within the seismic survey of the site limiting the palaeoenvironmental potential of the unit identified within the site. Further investigation is required to determine the archaeological potential of Unit 1; if the unit does include alluvial/transgressive deposits then it may have archaeological potential, although if it is entirely marine then the potential is diminished. The unit may also contain earlier archaeological and palaeoenvironmental material reworked by marine erosion caused by the Holocene transgression. Any such remains may shed light on the dating and processes of the Holocene transgression, which remains a key research question for the area.

10.8 Summary of Submerged Prehistoric Potential

10.8.1 In summary, there is limited archaeological potential from the Quaternary Units 4 and 3 within the site due to the adverse subglacial and marine conditions they represent which would be unsuitable for human activity and yield minimal paleoenvironmental material.

10.8.2 Unit 2 is thought to represent a glaciomarine to deltaic environment, laid down after the LGM, while Unit 1 is thought to represent glaciomarine to marine deposits, though the seismic character would not rule out an alluvial or transgressive environment. There is some palaeoenvironmental potential within Unit 2 due to its potentially deltaic nature, and uncertainty in the interpretation and date of the unit and its correlated formation between geological sources (Jackson et al. 1995; Mellett et al. 2015). Archaeological potential is more limited but cannot be ruled out. Unit 2 is also likely to have been affected by marine erosion caused by the Holocene transgression, this will have affected the potential of the unit.

10.8.3 Unit 1 is thought to be primarily marine in nature, limiting archaeological potential though it is possible that this unit also represents the transgression there may also be potential for archaeological and palaeoenvironmental remains within Unit 1, suggested by a possible interpretation of its seismic character and subsequent deposition environment. However, there is no evidence of organic material within this deposit which limits its palaeoenvironmental potential. Further investigation of these units, through coring and geoarchaeological analysis is required to address these gaps in understanding.

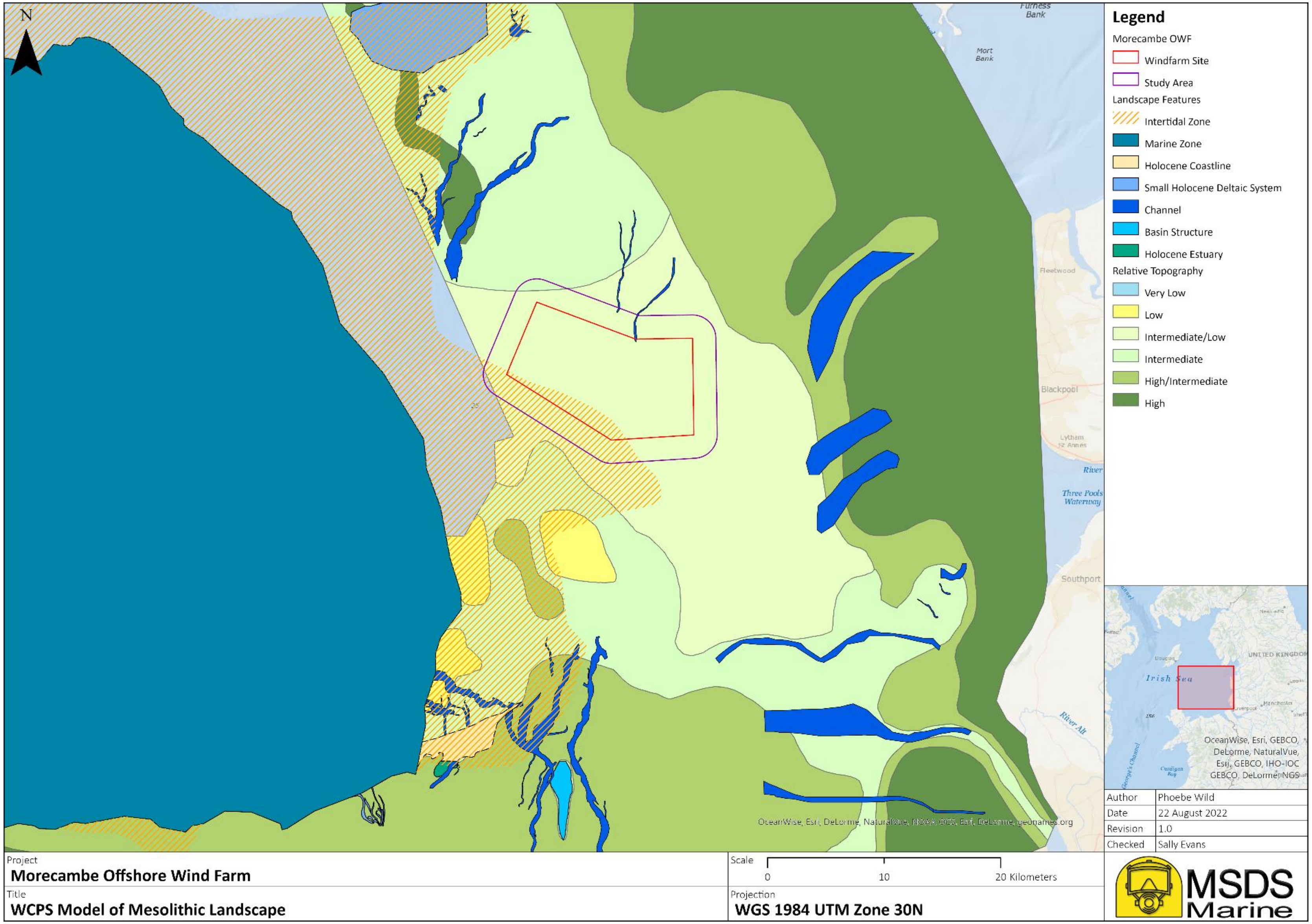

Figure 29: Mesolithic landscape modelled by the WCPS (Broad)(Fitch et al. 2011)

11.0 Mitigation

11.0.1 This section provides recommendations for the robust, but proportional, mitigation of impacts to the historic environment for low, medium, and high potential anomalies, and magnetic anomalies, identified within the geophysical dataset. As outlined in Section 5.7 recommended mitigation for these anomalies will be through the implementation of AEZs, TAEZs and AAPs.

11.0.2 The mitigation strategies recommended within this report are based on the available data, which includes full coverage MBES and full coverage high frequency SSS. Magnetometer data was collected at the same line spacing as the SSS and MBES which means there is potential for smaller items of buried material of archaeological interest to be present within the assessment area that is not visible within the current dataset, or for magnetic anomalies to not be represented in their true position.

11.0.3 However, the data serve to characterise the potential of the area with respect to the requirement for exclusion zones. Mitigation will be developed through each phase of survey works as detailed within Section 12.0.

11.0.4 The data extents do not fully cover the assessment area, with the exception of the areas around the gas platforms, they do however cover the entirety of the windfarm site. Whilst UKHO and NRHE records have been identified outside of the windfarm site, only those records falling within, or close to, the boundary have been assessed for mitigation as no development, and thus impact, is planned outside this area.

11.1 Low Potential Anomalies

11.1.1 Low potential anomalies, and small magnetic anomalies, have been identified as potentially anthropogenic in origin but unlikely to be of archaeological significance and no exclusion zones are recommended for these anomalies. Should material of potential archaeological significance be identified during the course of pre-development and development works they should be reported under an appropriate protocol for archaeological discoveries such as the *Crown Estates Protocol for Archaeological Discoveries: Offshore Renewables Projects*[12] or a project specific protocol that considers the individual requirements of The Project.

11.2 Archaeological Exclusion Zones (AEZ)

11.2.1 No high potential anomalies have been identified within the dataset. Medium potential anomalies have been identified as likely to be of anthropogenic origin and potentially of archaeological significance, within the dataset six anomalies were interpreted as of medium potential. The anomalies have been recommended AEZs based on the size of the anomaly, the extents of any debris, the potential significance of the anomaly, the potential impact of the development and the seabed dynamics within the area.

11.2.2 Dependant on the form of anomalies, AEZs will either be recommended as a radius from the centre point of the anomaly or as a distance from the extents. Particularly in the case of shipwrecks, which tend to be longer in length than width, the use of a circle provides unequal

[12] The Crown Estate, 2014. *Protocol for Archaeological Discoveries: Offshore Renewables Projects*. Wessex Archaeology on behalf of the Crown Estate.

protection around the extents. This not only impacts the protection afforded but does not represent proportional mitigation.

11.2.3 In total six AEZs relating to medium potential anomalies have been recommended within the windfarm site. Anomalies and their recommended exclusion zones are detailed in Table 15 and the distribution presented in Figure 30. Note, where discrepancies exist between the position within different datasets, the position deemed to be most accurate has been used, typically that derived from the MBES data.

Anomaly ID	Description	Potential	WGS84 Z30N		AEZ (m)
			X	Y	
MC22_0013	Unidentified debris	Medium	460388.2	5958939.3	30 radius
MC22_0014	Unidentified debris	Medium	461851.3	5958082.3	15 radius
MC22_0020	Potential debris	Medium	466231.1	5956833.2	15 radius
MC22_0021	Unidentified debris	Medium	454675.9	5964387.8	25 extents
MC22_0032	Unidentified debris	Medium	456543.3	5966579.2	25 radius
MC22_0039	Unidentified debris	Medium	460876.8	5962642.2	15 radius

Table 15: Archaeological Exclusion Zones within the windfarm site

11.3 Temporary Archaeological Exclusion Zones (TAEZ)

11.3.1 One TAEZ has been recommended within the windfarm site. TAEZs are recommended where an anomaly is not visible in the dataset but is known to exist, where the position cannot be determined with enough accuracy for refined exclusion zones, or where the extents are not fully known. They are often larger than AEZs but are identified as temporary as they are highly likely to be altered following higher resolution or full coverage data assessment, however, they will remain in place until alterations have been formally agreed.

11.3.2 The TAEZ relates to magnetic anomaly MC22_MAG_0254, a large complex anomaly of 739.4 nT. The form may indicate a wider extent of material, and/or multiple elements potential indicating archaeological interest. The size of the TAEZ takes into consideration the TVG line spacing. Anomalies and their recommended exclusion zones are detailed in Table 16 and the distribution presented in Figure 30.

Anomaly ID	Description	Amplitude (nT)	WGS84 Z30N		TAEZ (m)
			X	Y	
MC22_MAG_0254	Magnetic	739.4	458129.8	5957731.9	50 radius

Table 16: Temporary Archaeological Exclusion Zones within the windfarm site

11.4 Area of Archaeological Potential (AAP)

11.4.1 No AAPs have been identified within the windfarm site.

11.5 Notes on Exclusion Zones

11.5.1 Exclusion zones have been recommended based on the available evidence as interpreted by an experienced and qualified maritime archaeologist, they are to be agreed between The Project, the archaeological curator, and the regulator. Exclusion zones are implemented to protect, in-situ, potentially archaeologically significant material.

11.5.2 Where an exclusion zone has been implemented, no development work impacting the seabed is to take place within the prescribed area. Should an exclusion zone impact the development program it is recommended that a program of ground truthing be undertaken to establish the identity of an anomaly in order that the potential archaeological significance can be assessed by a qualified and experienced archaeologist. Following identification and assessment, the exclusion zone can be re-assessed to ensure mitigation is appropriate to the archaeological significance of the anomaly.

11.6 Protocol for Archaeological Discoveries

11.6.1 An appropriate protocol for archaeological discoveries such as the *Crown Estates Protocol for Archaeological Discoveries: Offshore Renewables Projects*[13] should also be applied across the scheme. Such protocols provide a means of identifying previously unidentified archaeological remains and are an important part of the mitigation process.

[13] The Crown Estate, 2014. *Protocol for Archaeological Discoveries: Offshore Renewables Projects*. Wessex Archaeology on behalf of the Crown Estate.

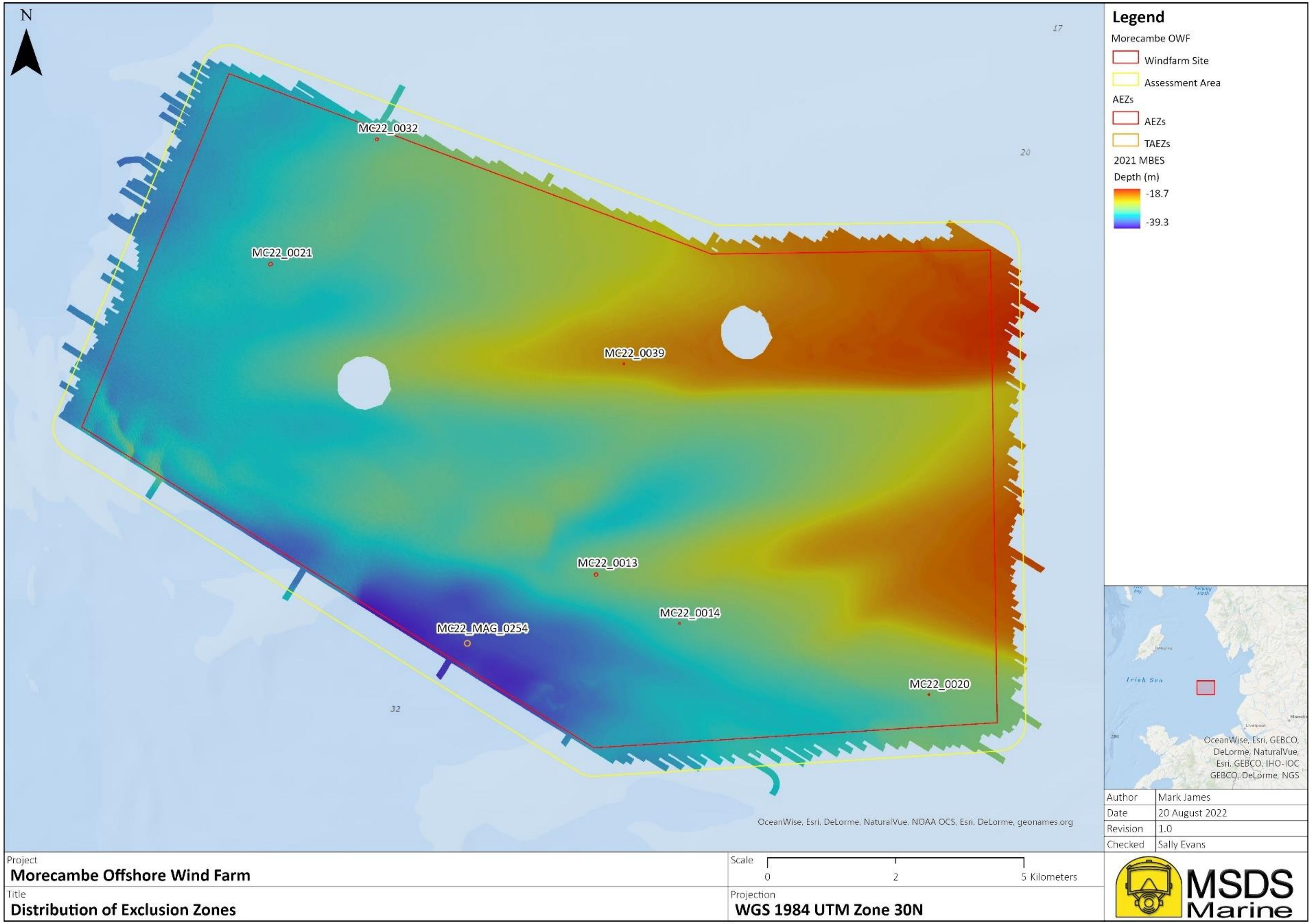

Figure 30: Distribution of Exclusion Zones

11.7 Prehistoric Archaeology and Palaeoenvironmental Remains

11.7.1 This report has outlined areas of prehistoric archaeological and palaeoenvironmental potential in particular associated with Units 1 and 2. The key mitigation in relation to the palaeolandscape and palaeoenvironmental remains follows a staged approach of geoarchaeological assessment aligned with the engineering requirement to undertake geotechnical works. Typically, this process involves close collaboration with the Site Investigation team. Archaeological input into geotechnical core locations can allow for the greatest insights into the palaeolandscape, such as through the sampling of stratified channel deposits, deposits likely to contain organic remains or un-eroded surfaces. Round-table discussions and the review of seismic profiles tends to be a conducive method of allowing engineering and archaeological requirements to be taken into consideration when micro-siting geotechnical cores.

11.7.2 Following the collection of geotechnical cores, it is recommended that they undergo a staged program of geoarchaeological assessment and analysis as the primary means of ground-truthing the potential identified in this report, and of mitigating impacts to remains. In brief the process is as follows;

- Stage 1: Geoarchaeological review of core logs;
- Stage 2: Geoarchaeological recording;
- Stage 3: Geoarchaeological assessment;
- Stage 4: Geoarchaeological analysis, and;
- Stage 5: final reporting

11.7.3 This work should be undertaken by a trained geoarchaeologist. Each stage should inform the scope of the next, and work may cease at any point where no recommendations for further work are made. This would be the case if, for example, cores were determined to hold no geoarchaeological potential at the end of Stage 2.

11.7.4 This geoarchaeological assessment and analysis should aim to deliver conclusions on the prehistoric archaeological and palaeoenvironmental remains within the area. Further mitigation may be required based on the results of this assessment.

12.0 Recommendations for Future Work

12.1 Archaeological Assessment of Geophysical Data

12.1.1 The archaeological interpretation of the geophysical data collected at the pre-application stage, to which this assessment pertains, fits within a wider framework of planned geophysical survey for Morecambe Offshore Windfarm. The survey specification was designed for the purposes of consenting and Front End Engineering Design (FEED) to determine the most appropriate area for development. Future surveys will likely combine an increase in resolution, and the addition of magnetometer data with tighter line spacing (as determined by the pUXO risk), within the development area. With the data resolution and coverage set to increase, the confidence in interpretation and appropriateness of mitigation strategies will also increase.

12.1.2 All geophysical data collected as part of The Project will be assessed for archaeological potential by a qualified and experienced maritime archaeologist where relevant to the development. It is recommended that the archaeologist have a demonstrable background in both the collection and processing of geophysical data as well as the archaeological review of data.

12.1.3 The archaeological review of data at these stages is considered necessary, not only for the robust assessment of the historic environment and archaeological potential but also for development planning. As the planned surveys increase in coverage and resolution but decrease in area, it is beneficial to be aware of any potential archaeological mitigation that may be required to ensure minimal re-planning.

12.1.4 Prior to any impact on the seabed pUXO specification data will be made available to, and reviewed by, the archaeologist. This includes, but is not limited to, cable laying operations, WTG installations, jack up barge positioning, anchor positions, UXO and boulder clearance and geotechnical works.

12.1.5 The methodology for the archaeological interpretation of data will follow that on which this review is based but will be subject to the preparation and agreement of a separate method statement. Whilst it is anticipated that methodologies will not vary a great deal between phases of work it is important to draw upon previous results to ensure the method proposed is both robust but practical.

Survey Specification

12.1.6 Survey specifications will vary dependent on a number of factors including, water depth, vessel, and equipment, however, certain recommendations can be made such as coverage, size of anomaly to be ensonified and positional accuracy.

12.1.7 Of particular relevance is the specification for pUXO surveys which are undertaken to a specification suitable to reduce the UXO risk to As Low As Reasonably Practical (ALARP). In almost all instances data collected for UXO assessment is highly suitable for archaeological assessment. General specifications are detailed below;

- Sidescan Sonar: data should be high frequency (at least 400-600 kHz), collected with a minimum of 200% coverage and the fish should be flown at an optimal altitude (typically c.10% of range). The fish should be positioned with a correctly calibrated USBL system and layback recorded as a backup. The data should be of a quality and resolution to identify seabed anomalies >0.3 m.

- Sub-bottom Profiler: data should be collected at a frequency and power appropriate to the seabed type and the required penetration, vertical resolution should be <0.3 m where possible and the data should be heave corrected. Sub-bottom data are only collected below the sensor; therefore, data should be collected on all magnetometer lines as these are generally the tightest spacing.

- Multibeam Echo Sounder: for archaeological interpretation multibeam data are used for general seabed characterisation and quality control for the positioning of anomalies identified in the sidescan data. Data should be high resolution (typically 300-400 kHz) and acquired within IHO Special Order specifications , this includes full coverage data and a requirement to detect features >1.0 m on the seabed.

- Magnetometer: the method for magnetometer surveys will vary between multiple close survey lines or multiple magnetometers in an array and wider survey lines. Magnetometer surveys for UXO identification should aim for full coverage with a blanking distance of 2.5 m, a target positioning accuracy of +/-2.5 m and an absolute accuracy of <2 nT. The fish should be flown between 2.0 m and 4.0 m above seabed and positioned with a correctly calibrated USBL system and layback recorded as a backup.

Reporting

12.1.8 Reporting following each phase of survey and archaeological assessment will be submitted to the curator and the regulator no later than three months following the end of the survey campaign and no later than one month prior to the start of construction works or any pre-construction impacts to the seabed.

12.2 Geoarchaeological Assessment

12.2.1 This report has outlined areas of prehistoric archaeological and palaeoenvironmental potential (summarised in Section 10.8). While marine and glacially derived units are unlikely to hold archaeological potential, some areas of potential have been identified associated with uncertainties in the interpretation of Units 1 and 2. It is therefore recommended that geoarchaeological assessment should accompany any geotechnical work undertaken within the site to investigate this potential further and provide an opportunity to mitigate impacts to the palaeolandscape. The assessment should follow the staged process outlined in Section 11.7 of this report.

12.3 Protocol for Archaeological Discoveries (PAD)

12.3.1 A suitable protocol for archaeological discoveries is a key element of the mitigation procedures, particularly for anomalies identified as low archaeological potential. A suitable protocol should also be implemented during any works that may visually inspect the seabed or recover material to deck.

12.3.2 The protocol will take the form of the Crown Estates *Protocol for Archaeological Discoveries: Offshore Renewables Projects*[14] or a project specific protocol that considers the individual

[14] The Crown Estate, 2014. *Protocol for Archaeological Discoveries: Offshore Renewables Projects*. Wessex Archaeology on behalf of the Crown Estate.

requirements of The Project. The protocol will be agreed with the curator and the regulator prior to any impact on the seabed.

12.4 Ground Truthing

12.4.1 Should archaeological exclusion zones impact on the proposed development works it is recommended that a program of ground truthing is undertaken to establish the identity of the anomalies so that further archaeological assessment can be undertaken, and interpretations revised as appropriate.

13.0 Sources consulted and bibliography

13.1 Sources Consulted

- BGS Offshore GeoIndex
- BGS Lexicon of Named Rock Units
- West Coast Palaeolandscapes Survey
- EMODnet Geology Portal

13.2 Bibliography

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14.0 Annex A – Anomalies of Archaeological Potential

Name	Potential	Description	Mag (nT)	Length (m)	Width (m)	Height (m)	AEZ (m)	AEZ Type	X	Y
MC22_0002	Low	Potential debris		2.1	0.2	0.2			460532.5	5955683.2
MC22_0003	Low	Unidentified debris		9.4	0.1	0.1			452664.1	5960742.7
MC22_0004	Low	Likely geological		5.5	2.0	0.4			453890.0	5959984.7
MC22_0005	Low	Chain, cable, or rope		7.9	0.2	0.0			451551.6	5961653.6
MC22_0006	Low	Potential debris		1.2	0.2	0.9			461857.3	5955532.8
MC22_0007	Low	Chain, cable, or rope		4.5	0.4	0.0			459111.0	5957402.5
MC22_0008	Low	Likely geological		2.3	1.5	0.2			455668.2	5959598.2
MC22_0009	Low	Potential debris		1.5	0.3	0.3			459700.9	5957048.8
MC22_0010	Low	Chain, cable, or rope		8.1	0.6	0.2			455516.1	5960505.2
MC22_0011	Low	Potential debris		4.4	0.4	0.3			459271.6	5958437.8
MC22_0013	Medium	Unidentified debris		7.3	12.4	0.2	30 radius	AEZ	460388.3	5958939.3
MC22_0014	Medium	Unidentified debris		6.6	1.9	0.3	15 radius	AEZ	461851.3	5958082.3
MC22_0015	Low	Likely geological		4.1	1.5	0.8			458699.5	5960213.9
MC22_0016	Low	Potential debris		2.4	1.0	0.2			462497.3	5957889.9
MC22_0017	Low	Likely geological		5.1	2.8	0.3			465638.9	5956111.4
MC22_0018	Low	Likely geological		2.8	1.4	0.4			454416.5	5963344.1

MC22_0019	Low	Unidentified debris		4.3	0.3	0.3			461746.5	5959673.3
MC22_0020	Medium	Potential debris		4.6	2.0	0.9	15 radius	AEZ	466231.1	5956833.2
MC22_0021	Medium	Unidentified debris		21.7	8.8	0.2	25 extents	AEZ	454675.9	5964387.8
MC22_0022	Low	Likely geological		7.4	3.8	0.5			462448.6	5959733.2
MC22_0023	Low	Likely geological		4.8	0.7	0.0			467069.2	5957065.7
MC22_0024	Low	Chain, cable, or rope		15.1	0.2	0.0			453426.5	5966325.2
MC22_0025	Low	Potential debris		3.7	0.8	0.0			457966.1	5963436.4
MC22_0027	Low	Chain, cable, or rope		6.9	0.1	0.0			454668.2	5965765.6
MC22_0028	Low	Likely geological		4.1	2.1	0.1			456540.9	5965518.2
MC22_0029	Low	Unidentified debris		6.6	0.3	0.3			460989.3	5963039.5
MC22_0030	Low	Potential debris		5.5	0.3	0.0			453974.3	5967781.5
MC22_0031	Low	Chain, cable, or rope		8.1	0.1	0.1			463737.6	5961959.5
MC22_0032	Medium	Unidentified debris		13.3	2.2	0.2	25 radius	AEZ	456543.3	5966579.2
MC22_0033	Low	Chain, cable, or rope		9.3	1.2	0.3			465312.2	5961242.3
MC22_0034	Low	Chain, cable, or rope		53.5	0.2	0.0			463035.9	5962777.9
MC22_0035	Low	Chain, cable, or rope		23.8	11.0	0.0			463463.7	5963189.8
MC22_0036	Low	Unidentified debris		5.1	4.1	0.4			463016.5	5963581.5
MC22_0037	Low	Unidentified debris		10.8	0.4	0.0			467458.2	5961507.2
MC22_0038	Low	Unidentified debris		2.4	2.3	0.2			463294.6	5964457.5

MC22_0039	Medium	Unidentified debris	437.7	1.5	1.4	0.1	15 radius	AEZ	460876.8	5962642.2
MC22_0040	Low	Likely geological		1.9	0.9	0.3			462809.2	5955930.8
MC22_0041	Low	Likely geological		4.7	2.1	0.0			465206.1	5963515.0

15.0 Annex B – Audit of Geophysical and Hydrographic Data

Morecambe Offshore Wind Farm

Audit of Geophysical and Hydrographic Data

Produced on behalf of Royal Haskoning DHV

MSDS Marine

2022/MSDS22219/1

Morecambe Offshore Wind Farm

Audit of Geophysical and Hydrographic Data

Project Name	Morecambe Offshore Wind Farm: Audit of Geophysical and Hydrographic Data
Client	Royal Haskoning DHV
Client Project Number	PC1165
MSDS Marine Project Number	MSDS22219
Author and contact details	Name: Mark James Email: [redacted]@msdsmarine.co.uk Telephone: [redacted]
Origination date	30/05/2022
Reviser (s)	
Date of last revision	
Quality Assurance Approval	Sally Evans
Version number:	1.1
Summary of changes	Addressing client comments

Contents

Figures

Tables

1.0 Introduction

1.0.1 MSDS Marine Limited (MSDS Marine) have been commissioned by Royal Haskoning DHV (RHDHV) to undertake an archaeological assessment of geophysical and hydrographic data in relation to the known and unknown archaeological environment for Morecambe Offshore Wind Farm (MOWF).

1.0.2 The aim of the archaeological assessment of geophysical data is to develop an understanding, and provide a description, of the known archaeological environment, including locations of (palaeo) environmental remains, buried archaeology and maritime and aviation sites, over the windfar.

1.0.3 This reports sets outs the geophysical and hydrographic data collected, and received, by MSDS Marine, the coverage, quality, and the appropriateness for archaeological assessment to inform the Environmental Impact Assessment (EIA) process. This report has been informed by an initial data audit by MSDS Marine, and the results presented in the MMT Operations Report[15] and MMT Survey Report[16]

2.0 Survey Details

2.1 Operational details

2.1.1 The survey was conducted by MMT during October and November 2021. The survey was undertaken using MV *Franklin*, a 55 m survey vessel owned and operated by MMT. The vessel was mobilised with a Multibeam Echo Sounder (MBES), a Sidescan Sonar (SSS), and two magnetometers configured as a Transverse Gradiometer (TVG). Two Sub-bottom Profilers (SBP) were also mobilised, a Parametric SBP and a Sparker,

2.1.2 The SSS and TVG were towed behind the vessel using a Remotely Operated Towed Vehicle (ROTV), the Sparker was towed behind the vessel, and the MBES and Parametric SBP were mounted to the hull of the vessel.

2.1.3 Survey operations were undertaken within a pre-defined boundary of approximately 126 km^2. The survey area will be referred to as the scoping area/boundary throughout this report. Two platforms are present within the area, one active and one decommissioned, there is a notable absence of data within a 850 – 900 m radius of these structures.

[15] MMT, 2022. *Operations report: Offshore geophysical survey. Morecambe Offshore Windfarm*. Unpublished report for Offshore Wind Ltd.

[16] MMT, 2022. *Survey report: Offshore geophysical survey. Morecambe Offshore Windfarm*. Unpublished report for Offshore Wind Ltd.

2.2 Sensor specification

2.2.1 Geophysical and hydrographic sensor specifications are detailed below in Table 2.

Sensor	Manufacturer	Model	Frequency
Sidescan Sonar	EdgeTech	2200	300 / 600 kHz 100 m range
Multibeam	Kongsberg	EM2040D	200 – 400 kHz
TVG (magnetometer)	Geometrics	G-882	10 Hz sample rate
Parametric SBP	Innomar	SES-2000 Medium	4 – 15 kHz Actual 8 kHz
Sparker SBP	GEO Marine Survey Systems	GeoSpark 200TIP	1.5 kHz

Table 17: Geophysical and hydrographic sensor specifications

2.2.2 Towed sensors were positioned using an Ultra Short Baseline (USBL) positioning system to ensure positional accuracy throughout the survey. USBL ensures the actual position of the sensor is recorded, as opposed to when the position is estimated based upon the direction of the vessel and the amount of cable out (layback).

2.2.3 Although the accuracy of the USBL system is dependent on the angle, and the distance of the beacon from the transceiver, tolerances of between 0.5 m and 2.0 m can be achieved.

2.2.4 Surface and sub-sea position sensors specifications are detailed below in Table 3.

Sensor	Manufacturer	Model	Accuracy
Surface positioning	Applanix	POSMV 320	Roll / pitch 0.01° Heave 5 cm or 5% Heading 0.02° Position 0.02 - 0.1 m
Sub-sea positioning	iXsea	GAPS II	0.2% slant range

Table 18: Position sensor specifications

2.2.5 All data were collected, and referenced, relative to WGS84 UTM Zone 30.

2.3 Coverage and line spacing

2.3.1 The survey was planned with a line spacing of 85 m for the main lines, and 5 km for the cross lines. The line planning ensured 100% coverage of SSS data was achieved, including the nadir (@ 100 m range. The MBES swathe was set at 75° to produce 100 m coverage in the depth of water over the survey area. In addition, SBP and TVG data were collected along each of the survey lines, the TVG separation was 3.36 m, and the maximum altitude was 8 m with the typical altitude being 6 – 7 m. The survey navigation tracklines are presented in Figure 31, the SSS coverage in Figure 32, and the MBES coverage in Figure 33.

2.3.2 The survey achieved 100% SSS and MBES coverage of the Morecambe windfarm site, with TVG and SBP collected to the line plan specification as outlined above.

Figure 31: Survey navigation tracklines

Figure 32: Sidescan Sonar coverage

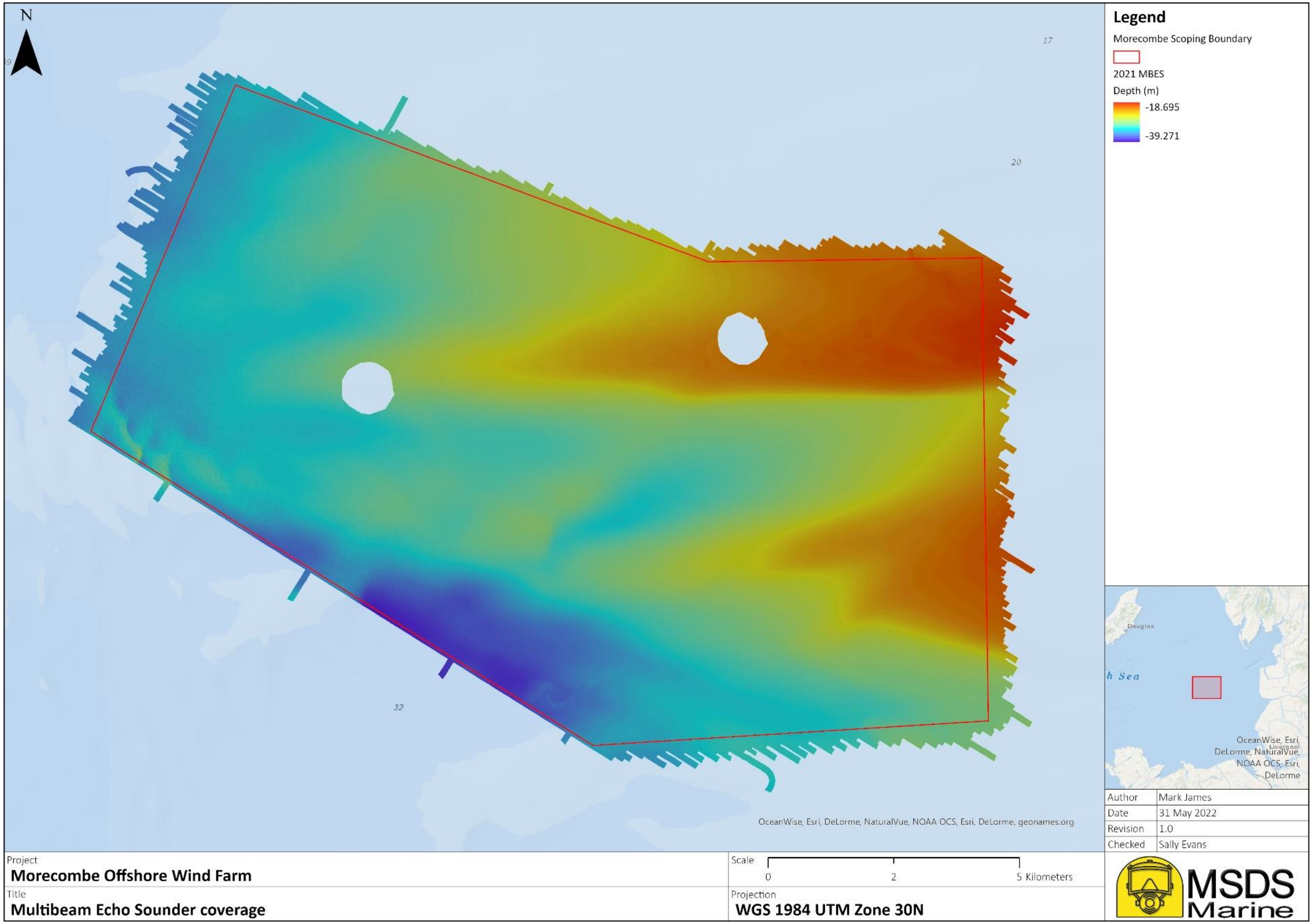

Figure 33: Multibeam Echo Sounder coverage

3.0 Deliverables to MSDS Marine

3.0.1 MSDS Marine were provided with the survey deliverables by Flotation Energy, including both raw and processed data, alongside interpretations and reports. The primary deliverables are detailed in Table 4 below.

Sensor	Data type	Format
Sidescan Sonar	Raw lines (LF and HF)	.jsf
	Processed lines (HF)	.xtf
	Mosaic (HF) 0.2 ppm	.tif
	Contacts	.csv, .shp
Sub-bottom profiler (both)	Raw lines	.sgy
	Processed lines	.sgy
	Grids	.dat
	Horizons	.dat
	Contours	.dxf
Magnetometer (TVG)	Raw lines	.txt
	Processed lines (individual)	.txt
	Processed lines (merged)	.csv
	Grids (residual and altitude)	.xyz
	Mosaic (residual and altitude)	.tif, .png
	Contacts	.csv, .shp
Multibeam bathymetry	Raw lines	.xyz
	Grids (at 0.2 m)	.txt
GIS	SSDM	.gdb
Reports	Survey report	.pdf
	Operations report	.pdf

Table 19: Data deliverables to MSDS Marine

4.0 Data quality and suitability for archaeological interpretation

4.1 Sidescan Sonar (SSS)

4.1.1 The SSS data covered the extents of the windfarm site, providing 100% coverage, including the nadir. An initial review of the data indicates that the quality is good, with data extending to the full 100 m range. Seabed features line up across multiple lines, and correlate with those visible in the MBES data.

4.1.2 Although each line of data has not been reviewed at this stage, MMT report that the data is of sufficient resolution to identify boulders >0.5 m and other features >1.0 m in size. A limited review of data established that the data meets the detection parameters presented by MMT. Some data degradation due to motion was noted within the data, however this was not significance and does not affect the overall quality of the data and the suitability for archaeological interpretation. An example of the SSS date is shown in Figure 34.

4.2 Multibeam Bathymetry (MBES)

4.2.1 The MBES data covered the extents of the windfarm site, providing 100% coverage. An initial review of the un-gridded point cloud data indicates that the quality is good with no significant height or positioning errors. The data density is good, and is able to be gridded to 0.2 m, increasing the ability to identify smaller features. Features identified within the MBES data correlate with those identified in the SSS data. An example of the MBES is shown in Figure 35.

4.3 Magnetometer (TVG)

4.3.1 The TVG data covered the extents of the windfarm site and was collected along the pre-defined survey line plan. The data were sampled at 10 Hz, at a maximum altitude of 8m (generally 6-7 m). The specification was designed to be able to detect the presence of ferrous materials >50 kg along the tracklines. Each line of data has not been reviewed, but MMT report that the background noise levels generally did not exceed 2 nT, and that the data were suitable to identify anomalies with a peak to peak amplitude of 5 nT.

4.4 Sub-bottom profiler

4.4.1 The SBP data covered the extents of the windfarm site boundary, along the pre-defined survey line plan. Penetration of the Parametric system was between 4 m and 23 m, with a vertical resolution of 0.3 m. The Sparker achieved a minimum penetration of 50 m with a vertical resolution in the upper section of 0.3 m. A full review of the data has not been undertaken; however, five stratigraphic seismic units were identified within the data, and the data examples provided within the survey report appear to be of good quality. An example of the SBP data is shown in Figure 36. Note, the figure has not been produced by MSDS Marine.

Figure 34: Sidescan Sonar data example

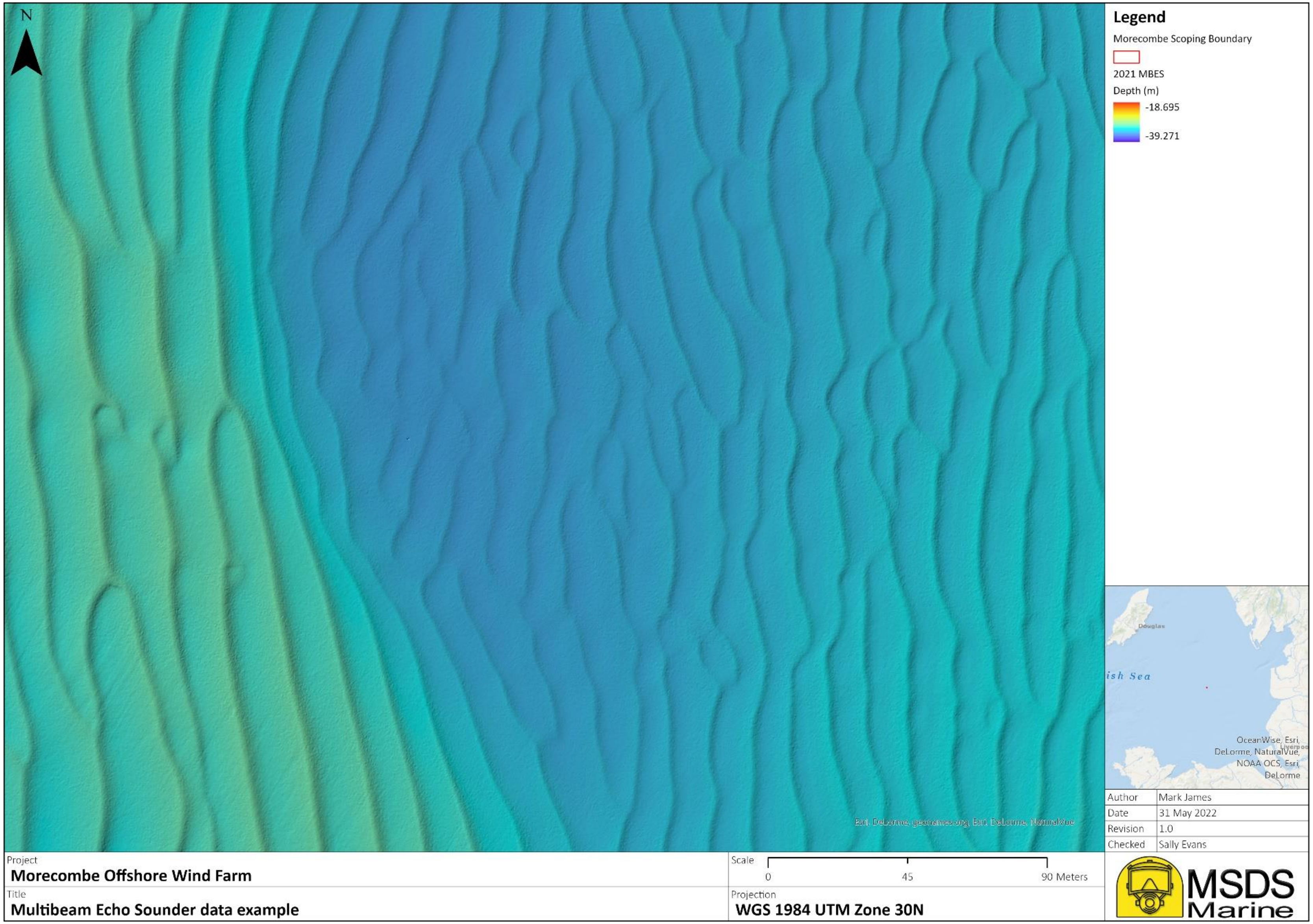

Figure 35: Multibeam Echo Sounder data example

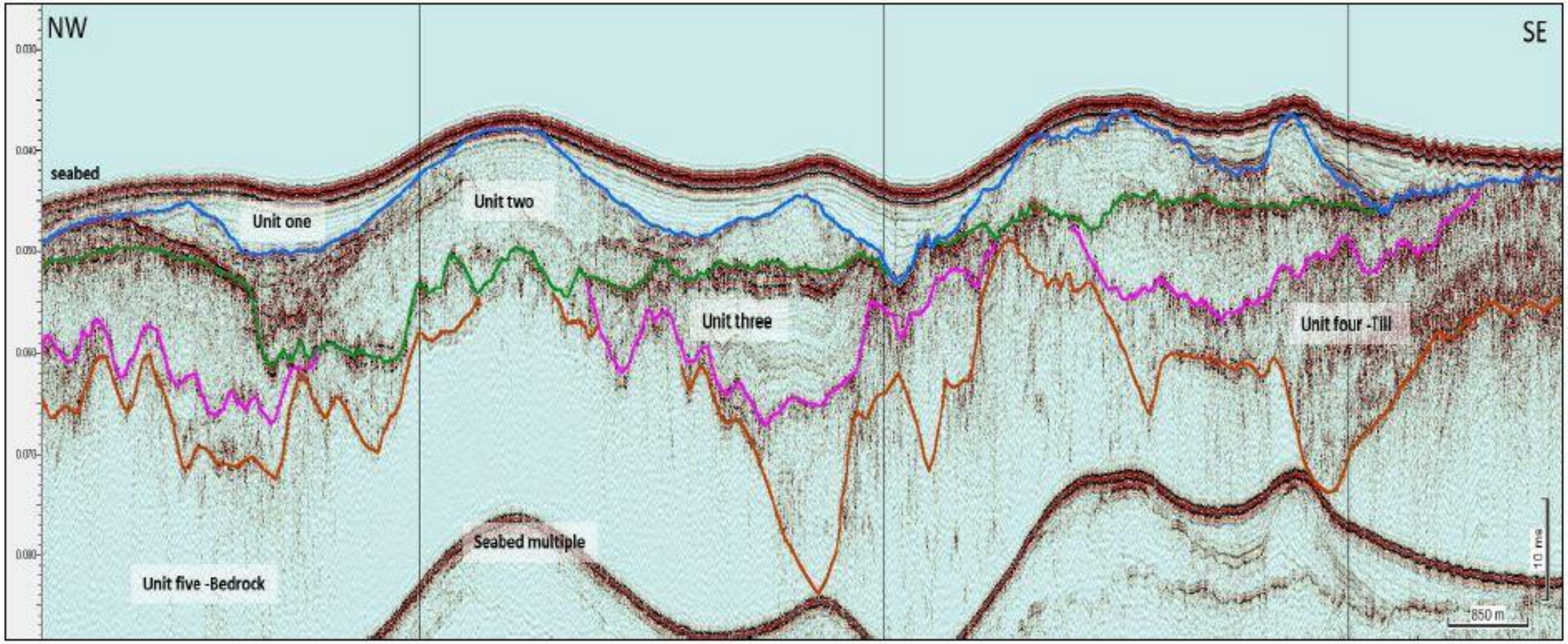

Figure 36: Sub-bottom Profiler (Sparker) data example

4.5 Limitations

4.5.1 The Morecambe windfarm siteseabed is characterised across a significant area by mobile sands, manifesting as sandwaves of various sizes. These sandwaves can cause obstructions to the sonar data, in particular the SSS, the data from which is collected closer to the seabed. Obstructions cause acoustic shadow, i.e. areas of no data, which can hide smaller features of potential anthropogenic origin. This can cause uncertainty as to whether all features have been identified. However, the SSS data achieved 100% coverage, including the nadir, this translates to 200% coverage across most of the data. With the data collected in opposite directions this largely mitigates this uncertainty. The collection of a high resolution MBES data set also aids in the interpretation where features might be masked in the SSS data.

4.5.2 Magnetometers work by detecting changes in the earth magnetic field, the further away from the sensor the lower the reading will be. The survey was specified to identify ferrous material of >50 kg along the tracklines of the sensors. Therefore, the further the distance from the tracklines, the larger the minimum detection size will be.

4.5.3 SBP data is collected directly beneath the sensor, in general terms, and outside the identification of the palaeolandscape, SBP is not suited to the prospection for buried material of potential anthropogenic origin due to the wide line spacing. It can however be useful for corroboration of other datasets where a trackline passes directly over a magnetic anomaly or a potentially buried feature visible in the SSS or MBES data.

4.5.4 The depth of penetration achieved by the Sparker was 50 m. However, interpretation of the data indicates that the windfarm site area is underlain by Triassic bedrock ranging from 3 – 43 m. The Triassic period predates earliest hominid activity and is therefore of no archaeological interest.

5.0 Summary

5.0.1 The data collected across the Morecambe windfarm site is of good quality overall, and in the case of SSS and MBES provided 100% coverage. SBP data were collected to a pre-determined line plan, providing suitable coverage and penetration for the interpretation of the palaeoenvironment. The TVG data were collected to pre-determined line plan suitable for the identification of ferrous material >50 kg along the tracklines, with the minimum detection size increasing with distance from the tracklines.

5.0.2 The data is considered of an appropriate specification, coverage, and quality, to undertake a robust archaeological assessment to inform the EIA process.