Spiorad na Mara Offshore Wind Farm

Offshore Project

Environmental Impact Assessment Report

Annex 15.1.3: Stage 1 Geoarchaeological Review of Geotechnical Data, Volume 2c

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1 INTRODUCTION

1.1 OVERVIEW

1.1.1.1 This annex of the Environmental Impact Assessment Report (EIAR) presents the geoarchaeological review of the geotechnical data acquired in support of the proposed Spiorad na Mara Offshore Windfarm (hereafter referred to as 'the Offshore Project') with respect to the geoarchaeological potential of the geological deposits. This annex accompanies **Appendix 15.1: Marine Archaeology Desk Based Assessment, Volume 2c** and **Chapter 15: Offshore Archaeology and Cultural Heritage, Volume 2a** of the EIAR.

1.1.1.2 This annex should be read in conjunction with the project description provided in **Chapter 3: Project Description, Volume 1a** and the relevant parts of the following chapters and appendices:

- **Chapter 15, Volume 2a;**
- **Appendix 15.1, Volume 2c;**
- **Annex 15.1.1: Historic Environment Gazetteer, Volume 2c;**
- **Annex 15.1.2: Archaeological Assessment of Geophysical and Hydrographic Data, Volume 2c;**
- **Outline Offshore Written Scheme of Investigation, Volume 3**.

1.1.2 PROJECT BACKGROUND

1.1.2.1 Spiorad na Mara Limited (hereafter referred to as 'the Applicant') is proposing to develop the Project. The Project is an offshore wind farm (OWF) that will consist of up to 60 fixed-bottom wind turbine generators (WTGs).

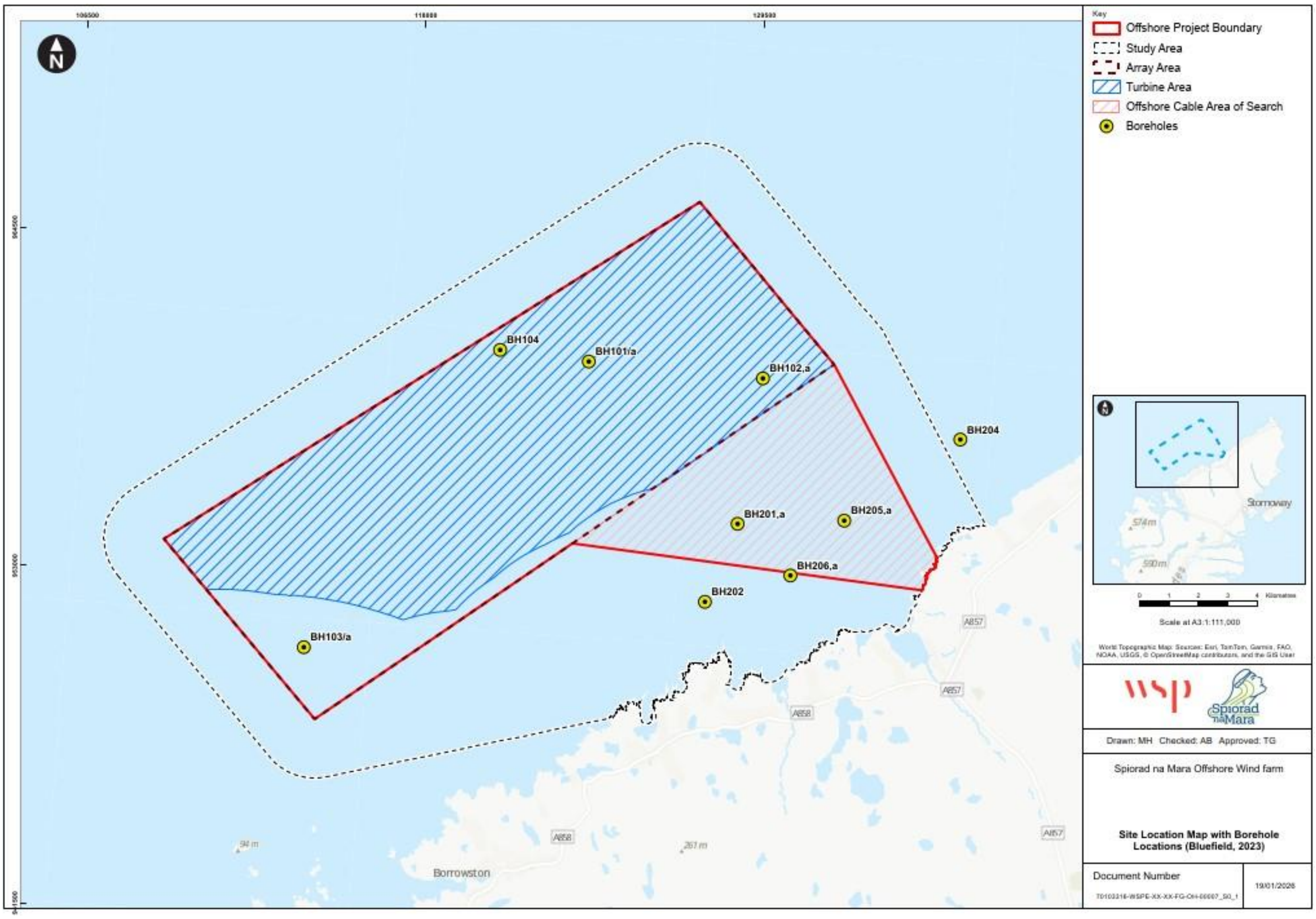
1.1.2.2 The Project will include both offshore and onshore infrastructure. This EIAR supports the application for the offshore components of the Project as outlined in **Chapter 1: Introduction, Volume 1a**. The offshore components of the Project (the Offshore Project) includes all infrastructure and activities located seaward of Mean High Water Springs (MHWS) within the Array Area and Offshore Cable Area of Search (OCAS) (**Figure 1.2: Offshore Project Location, Volume 1c**). Further detailed information is provided in **Chapter 3, Volume 1a**.

1.1.2.3 The Offshore Project is situated off the northwest coast of Isle of Lewis/*Eilean Leòdhais* and the Array Area is located approximately 5-13 km offshore and is approximately 161 km^2 in size. It will comprise WTGs, foundations, Offshore Cables, Offshore Substation Platform (if required), and Landfall. The Array Area combined with the OCAS is defined as the Offshore Project Boundary. The water depths across the Array Area range from 37 m-67 m with the southwest corner of the Array Area reaching 72 m. The proposed WTGs and fixed foundations will be located within a Turbine Area of approximately 140 km^2, within the Array Area.

1.2 PURPOSE OF THIS APPENDIX

1.2.1.1 This annex aims to assess whether the Borehole logs obtained as part of the geotechnical survey (Borehole locations shown on **Plate 1-1**) have the potential to provide information on how coastal, sea levels and palaeolandscapes changed during the prehistoric period and what this might suggest about human activity.

Plate 1-1 Site Location Map with Borehole Locations



1.2.1.2 This annex describes the following:

- Assess the geotechnical logs to identify deposits of geoarchaeological potential, assigning high, medium and low-priority status;
- Interpret the depositional environments represented;
- Cross-reference with other data (if available) to aid in determining the extents of any identified deposits;
- Identify any deposits suitable for palaeoenvironmental assessment;
- Determine the importance of the deposits, with regard to their archaeological and palaeoenvironmental potential;
- Report the results as part of the ongoing environmental assessment for the proposed scheme;

- Make recommendations for the next stage of investigation with reference to key research questions and regional/national period-specific and maritime research agendas.

1.2.1.3 This desk-based review is the first stage (Stage 1) of assessment and aims to establish the likely presence of deposits of geoarchaeological potential and broadly characterise sediment sequences and evaluate their potential. Research questions for maritime archaeology can broadly be divided into the 2 related categories of the environment (changing coasts, sea level and landscape) and people (maritime settlement, exploitation, seafaring and networks) (Ransley *et al*., 2013). The review forms the basis for deciding whether further investigation (Stage 2) is required. The results of the Stage 1 assessment and recommendations for further work are reported in section 5.

2 GEOLOGY, TOPOGRAPHY AND GEOARCHAEOLOGY BACKGROUND

2.1 INTRODUCTION

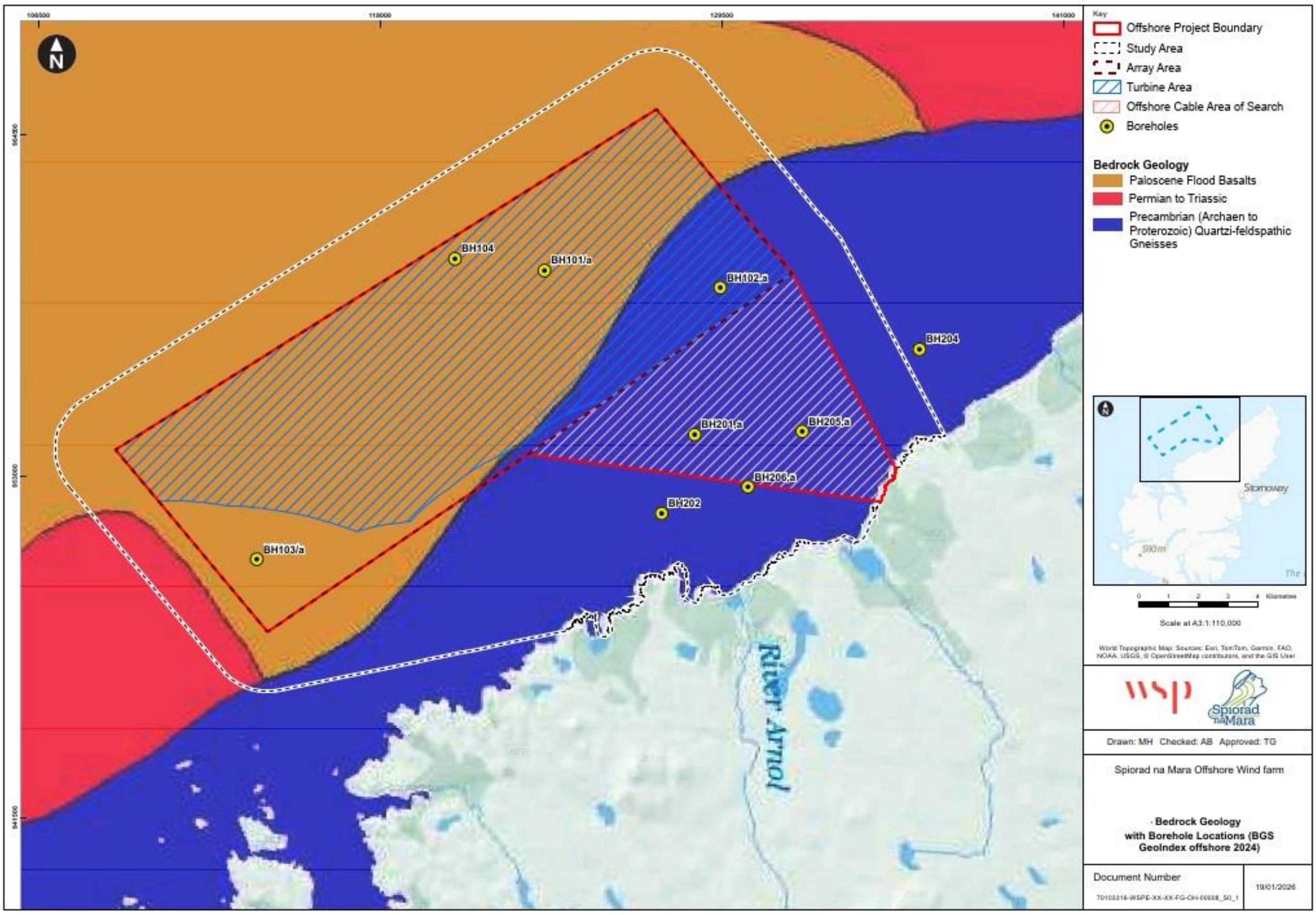
2.1.1.1 This section provides a summary of the landscape evolution and archaeological time periods relevant to the Offshore Project. It forms the background and context to the geoarchaeological review and supports the interpretation of depositional processes, archaeological potential and heritage significance. A baseline of terrestrial archaeological data has not been collated for the onshore and at this stage.

2.1.1.2 Timeframes and the associated deposits mapped by the British Geological Society (BGS) are divided into hard or bedrock geology relating to pre-Quaternary timeframes and the superficial geology (Quaternary) associated with archaeological periods.

2.2 BEDROCK GEOLOGY

2.2.1.1 The Outer Hebrides/*Na h-Eileanan Sia* represent the exposed parts of a major submarine platform formed of resistant Precambrian (Archaean to Proterozoic) quartzo-feldspathic Lewisian gneiss (Campbell *et al.*, 2020; BGS 2024; **Plate 2-1**). The bedrock platform is extensive and <50 m below present-day sea level. Further offshore within the Outer Hebrides Platform the Array Area is flanked by the Flannan Trough, this is composed of Permian to Triassic sedimentary rock, primarily the New Red Sandstone Group and Mudstones (Fyfe *et al.*, 2021) and Palaeocene flood basalts (Fettes *et al.*, 1992). The majority of the Array Area is founded on these Palaeocene flood basalts, with the OCAS being dominated by the Precambrian gneisses inshore (**Plate 2-1**).

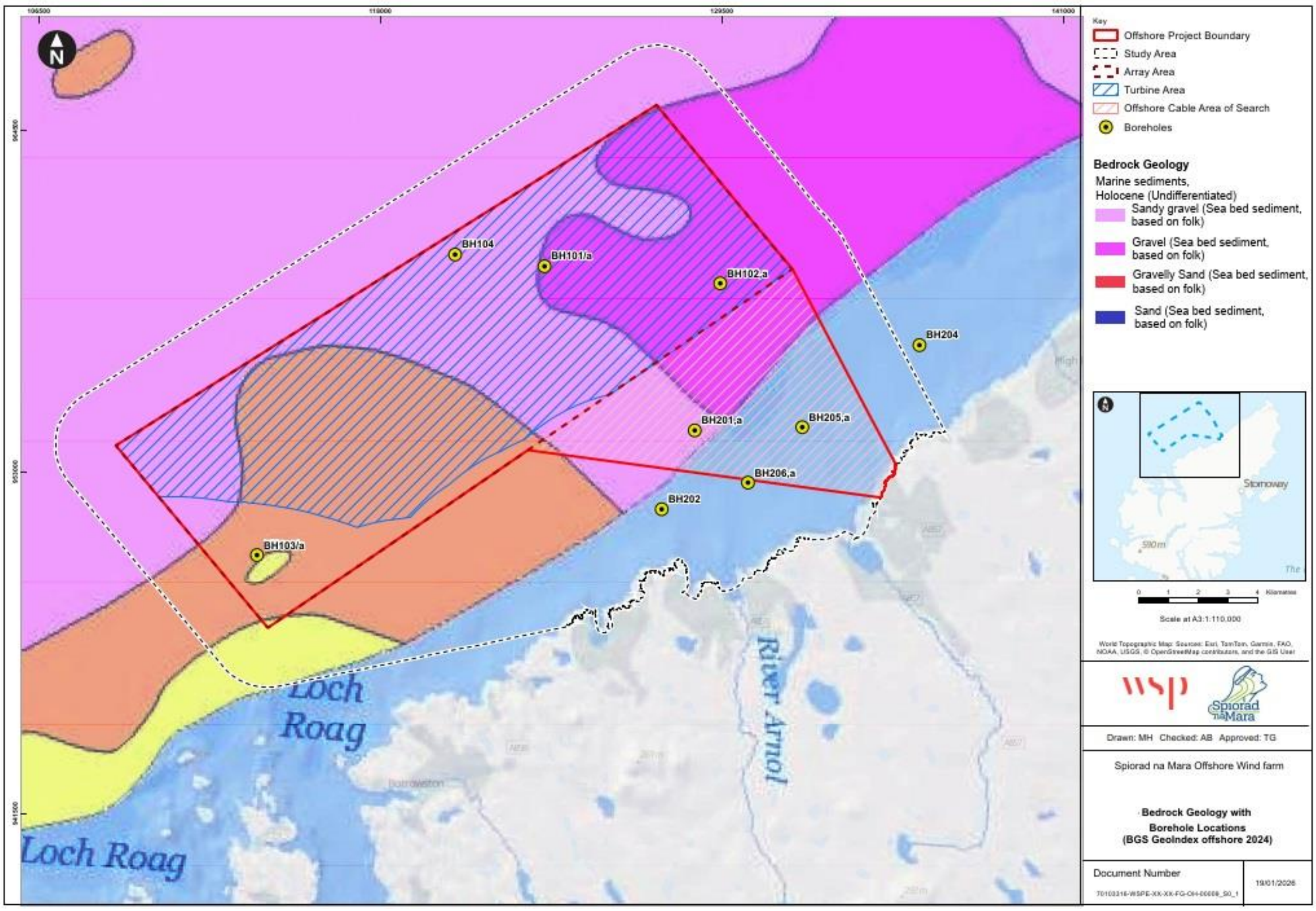
Plate 2-1 Bedrock Geology with Borehole Locations (BGS GeoIndex offshore 2024)



2.3 SUPERFICIAL GEOLOGY AND SEABED SEDIMENT

2.3.1.1 The BGS describes the superficial geology on the continental shelf offshore of Lewis as "undifferentiated Quaternary deposits" (BGS, 2024; **Plate 2-2**). The superficial geology was deposited during the last 2.6 million years (Mya) of the Earth's history, the Quaternary. The Quaternary is the period in which humans evolved and is characterised by a series of alternating cold-warm oscillations (glacial-interglacial cycles). These climatic phases are categorised into 'Marine Isotope Stages' (MIS), derived from palaeoclimate proxies (microfossils such as foraminifera) from deep-sea cores (see **Table 3-1**). Even-numbered MIS stages denote cold (glacial) periods and odd numbers represent warm (interglacial) stages. The Quaternary is subdivided into the Pleistocene (c. 2.6 million to approximately 12 thousand years ago before present (Ka BP)), and the Holocene (12 Ka BP to the present, MIS1) (**Table 3-1**) which covers the Mesolithic to present day.

Plate 2-2 Bedrock Geology with Borehole Locations (BGS GeoIndex offshore 2024) Superficial Sediments



2.3.1.2 The Isle of Lewis/*Eilean Leòdhais* experienced significant change due to the advance and retreat of the British–Irish Ice Sheet (BIIS) during the Devensian glacial complex (MIS4-2; ~35-11.7 Ka BP). Recent work suggests a highly dynamic ice mass responding to abrupt temperature oscillations (on a sub-millennial scale) (Dansgaard-Oeschger cycles) (Labeyrie *et al*., 2007) over the last 45 Ka BP (Bradwell *et al.,* 2021). During the extreme cold periods of the Devensian glacial complex (stadials), the BIIS on Lewis/*Eilean Leòdhais* extended across the terrestrial and marine environment. Late Devensian age shelly deposits in the north of the island indicate that an ice margin crossed northern Lewis/*Eilean Leòdhais*, leaving part of the island ice-free while evidence of the offshore ice sheet comes from moraines (material left behind by a moving glacier) mapped on the mid-shelf (Bradwell *et al.,* 2019). There is no evidence for the accumulation of ice-sheet centres on the continental shelf to the north or west of Lewis/*Eilean Leòdhais* (Bradwell *et al.,* 2021) despite the extensive bedrock platform.

2.3.1.3 The legacy of glaciation can be seen today in the Lewisian landscape, which is characterised by rocky, ice-scoured hills and low-relief knock-and-lochan topography made up of ice-moulded hillocks and intervening lochans (small lakes). Sediments overlying bedrock were deposited by glacial and pro-glacial systems comprising either structureless glacial diamicton, or strongly layered glaciomarine sediments (Bradwell and Stoker, 2015). Cliffs of superficial sediment comprise Pleistocene raised beach and till deposits (MacTaggart, 1998) and reworking this material is widespread, often resulting in the winnowing of finer components, leaving behind gravels. The finer material, such as muddy sands from outwash deposits, accumulated in glacially excavated hollows or around the southern edges of open coastline extents (Royal Haskoning, 2011).

2.3.1.4 During the Holocene, peat accumulated, and much of northern Lewis/*Eilean Leòdhais* is covered in thick peat that obscures bedrock outcrops and Pleistocene glaciogenic deposits. Offshore of Lewis/*Eilean Leòdhais*, sediment sources were progressively augmented by eroded calcareous shelly sands of the machair (Gaelic for a low-lying, grass-dominated coastal plain composed of calcareous sand), rather than wave action driving glacial sediment onshore (as in the Uists) (Ballantyne and Gordon 2021; Burrows *et al.,* 2014).

Table 2-1 Late Quaternary Chronology and UK Archaeological Periods

	Marine Isotope Stage (MIS)	Approximate date (thousands of years ago)	Epoch	Stage name				British archaeological period	Climate	
Late Quaternary	1	0.5	Holocene		Late		Historic	post medieval	warm	Interglacial
		1						Medieval		
		2						Roman		
		3					Prehistoric	Iron Age		
		4			Mid			Bronze Age		
		6						Neolithic		
		12			Early			Mesolithic		
	2	13	Late Pleistocene	Devensian	Late	Devensian 'Lateglacial'	Loch Lomond stadial	Upper Palaeolithic	cold	Glacial (last cold stage)
		14					Windemere interstadial		warmer	
		20					Dimlington stadial (late glacial maximum)		cold	
	3	58			Middle		Upton Warren interstadial	Middle Palaeolithic	warmer	
	4	75			Early				cold	
	5a	79					Brimpton interstadial		warmer	
	5b	96							cold	
	5c	103					Chelford interstadial		warmer	
	5d	115							cold	
	5e	125		Ipswichian					warm	Interglacial
	6	190	Late Middle Pleistocene	Wolstonian Complex					cold	glacial
	7	220		Aveley interglacial					warm	interglacial
	8	315		Wolstonian Complex					cold	glacial
	9	325		Purfleet interglacial				Lower Palaeolithic	warm	interglacial
	10	390							cold	glacial
	11	400		Hoxnian					warm	interglacial
	12	475		Anglian					cold	glacial

2.4 SEA LEVEL, ICE MASS AND COASTAL CHANGE

2.4.1.1 Coastal environments are dynamic, and during the Quaternary sea-level varied significantly with remarkable effect on both the terrestrial landscape and marine zone of the UK's shores. Shorelines dramatically shifted as global sea levels rose and fell and sediment was eroded and transported largely by waves, ice and wind. The current coastline is characterised by Lewisian gneiss bedrock bordered by till cliffs (see paragraph 2.3.1.3) and stabilised dune systems known as machair, the evolution of which is complex and characterised by recycling and degradation of pre-existing sediment (Dawson *et al*., 2011).

2.4.1.2 During warm interglacial stages, conditions were relatively calm. Deposition in low energy conditions is typical and sea-levels were high. During these periods, organic-rich and fine-grained sediment (silts and clays) were deposited in sheltered coastal locations, estuaries and across floodplains forming marsh environments. With the onset of glacial stages, the climate cooled and ice gradually built up in the Polar regions, lowering global sea-levels and exposing previously submerged land around coasts. Areas that are now offshore would have been dry land, exposed to the elements and available for human exploitation. Sand was deposited on beaches and gravels in higher-energy coastal zones (by aeolian and littoral processes). Sediment reworked by wave action is typical in shallow and near-shore marine environments, while in more stable and protected coastal locations and deeper marine environments fine-grained sediments accumulated.

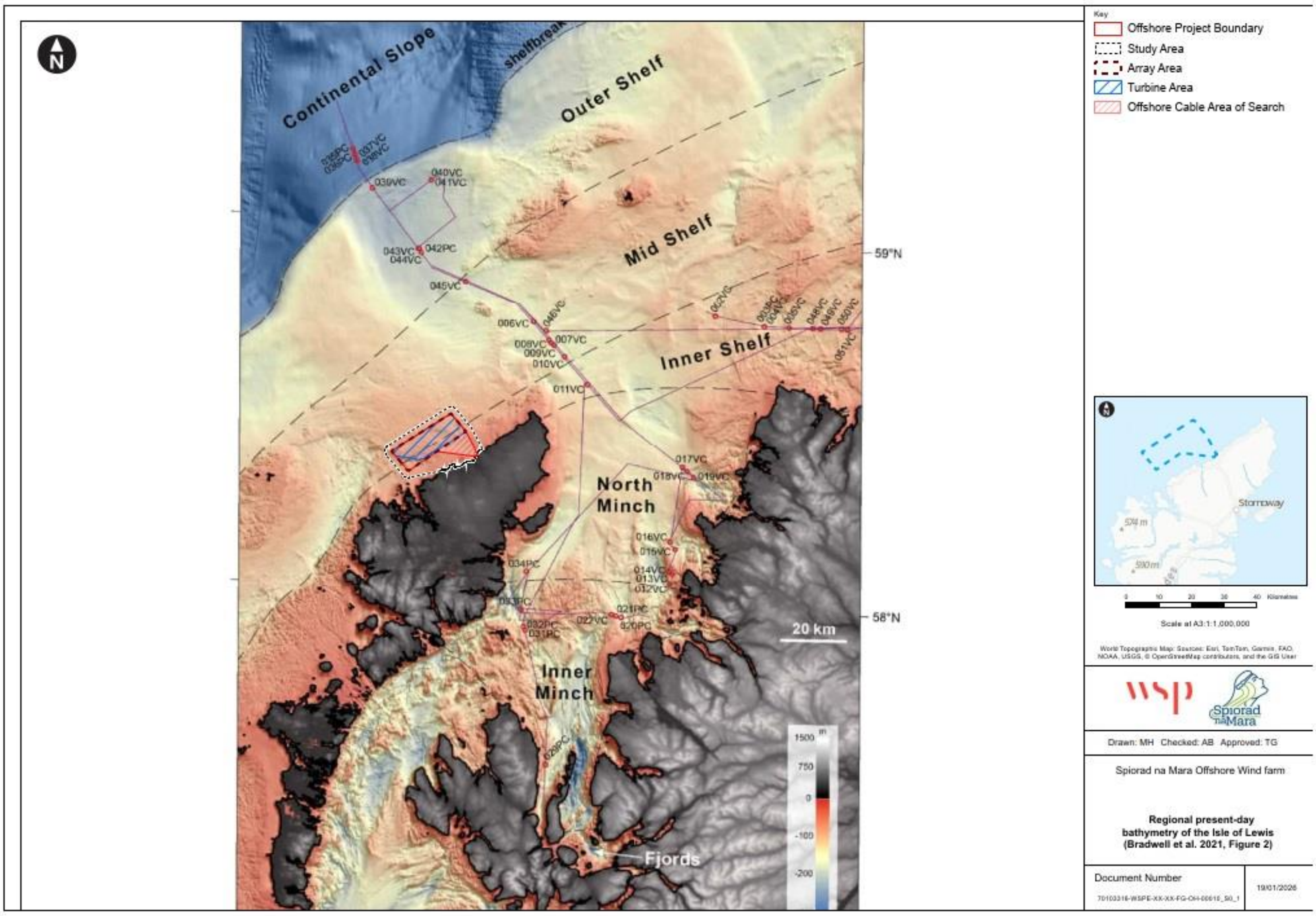
2.4.1.3 This mode of sea-level change related to variations in global ice and ocean water volume is described as Eustatic. Isostatic sea-level change refers to variations due to vertical movements in the Earth's crust in response to the release of the weight of the ice mass during deglaciation for example, creating a 'bobbing-up' effect. No single location on Earth can therefore be considered stable and a record of 'absolute' sea-level change (Shennan, 2007), and sea level is referred to in relative terms. In regions such as those covered by the major ice sheets, relative sea-level (RSL) fell by over 100 m because of isostatic rebound (Horton, 2007). In contrast, observations of the regions at the periphery such as the Isle of Lewis/*Eilean Leòdhais* and beyond the ice sheets can be complex due to the interplay of many factors (such as postglacial isostatic recovery, marginal forebulge collapse and hydro-isostatic loading). Due in part to the hinge effect of the fault found along the Minch/*Mhaoil*, the Outer Hebrides/*Na h-Eileanan Sia* was lowering into the sea while the rest of Scotland/*Alba* was steadily rising, accounting for up to a 5 m increase in local RSL in the last 5 Ka BP (Burgess, 2008).

2.4.1.4 The Devensian ice mass was concentrated in the western Highlands, with thinner ice cover at the periphery of the Outer Hebrides/*Na h-Eileanan Sia*. It is of note that, during the Late Devensian stadials, an independent Isle of Lewis/*Eilean Leòdhais* ice cap formed that also experienced margin oscillations and erosion associated with climate change. Northwest Lewis was the first substantial area to deglaciate. This took place in several stages at a time of reduced sea-level (c. 26 Ka BP), enhanced by ice streams (corridors of fast-flowing ice) bringing about rapid loss of fronting ice shelves (~19-17 Ka BP) and intensive erosion on the east of the island (Bradwell *et al.,* 2008). Final glacier retreat occurred by ~16-15 Ka BP, with at least one ice readvance (during the Late glacial stadial/Dimlington stadial), and glaciers fed outwash sediment to coastal deltas.

2.4.1.5 Even though the ice was shorter-lived on Lewis/*Eilean Leòdhais* during MIS4 and MIS2 than in the Inner Hebrides (Smith *et al*., 2017) and an extensive bedrock platform was available for occupation (see paragraph 2.2.1.1), the cold climate (<-5°C) may not have been favourable to humans (Ballantyne, 2019).

2.4.1.6 At the beginning of the Holocene (Mesolithic c. 12-6 Ka BP), sea-level reconstructions for the Outer Hebrides/*Na h-Eileanan Sia* suggest RSL was 20-30 m below present (Saville and Wickham-Jones, 2012). The onset of the Holocene (~11.7 Ka BP) was marked by rapid warming and melting of glacier ice (Ballantyne and Gordon, 2021), along with associated RSL rise. Sea-level records from nearby Harris/*Na Hearadh* (Jordan *et al*., 2010), a similar location on the periphery of the ice mass, can be correlated with Lewis. Extreme flooding between 8.3 and 7.9 Ka BP could represent the Storegga Slide tsunami when the sea-level reached a height of around 0 m OD (Jordan *et al*., 2010), although the origin of the event is unclear (Smith *et al*., 2017). By the Neolithic period (c. 6-5 Ka BP), RSL had subsided to between 0.0 m and -2 m OD but began to rise again to between approximately -1.5m to 0.5 m OD by 5.5-4.8 Ka BP (Jordan *et al*., 2010) and continued through the Bronze Age (-2.3 m to 0.25 m OD; 2.9-3.3 Ka BP) before reaching present levels. Over the last 2,000 years RSL has been fairly stable or falling (to approximately 0.0 m to -1 m) and since the end of the last glaciation has not been above its present level (**Plate 2-3**) (Smith *et al*., 2017).

Plate 2-3 Regional present-day bathymetry of the Isle of Lewis (Bradwell *et al*. 2021, Figure 2)



2.5 GEOARCHAEOLOGICAL POTENTIAL

2.5.1.1 Coastal zones, like rivers, are resource-rich and are known foci for prehistoric human activity. The growing body of underwater finds worldwide demonstrates the potential for survival of prehistoric material offshore often sealed beneath marine sediments in anaerobic conditions (Bailey *et al*., 2020).

2.5.1.2 In Lewis/*Eilean Leòdhais*, exposures of potentially habitable shelf were at their greatest when sea levels were low and shelves ice-free, i.e. just before and after glacial maxima, and sites and finds may have been buried beneath seabed sediment, during the Palaeolithic. Palaeolithic geoarchaeology (780-12 Ka BP; often focussing on the well-studied Devensian) is rare but significant for understanding the early human occupation of Britain. Evidence is often contained within the sedimentary record and can comprise tools and faunal remains (including the remains of early humans) or environmental proxy evidence for human presence. Archaeology typically comprises artefactual finds (stone or bone tools), lithic scatters, and occasionally cave and rock-shelter sites. Finds and sites are sporadic in remote Scotland/*Alba* due to the climate (see paragraph 2.4.1.5) and Palaeolithic sites are not mapped offshore in Lewis/*Eilean Leòdhais*

(SPLASHCOS, 2024). In addition, the Mesolithic tsunami event would have devastated human populations (see paragraph 2.4.1.6) and removed any evidence of Palaeolithic and Mesolithic human activity to a height of 0 m OD.

2.5.1.3 The Mesolithic (12-6 Ka BP) and Neolithic (6-3.5 Ka BP) onshore in the Highlands and Islands comprises megaliths (for example the Calanais Standing Stones), middens, lithic scatters, heaths and in rare circumstances, temporary camps. Examples of archaeology submerged within lochs such as Neolithic crannogs are also recorded (Garrow *et al*., 2017). In the offshore environment, land above approximately -1.5- 0.5 m OD would have remained exposed in the Neolithic and Bronze Age.

2.5.1.4 Regarding sediments of geoarchaeological potential, thick Holocene peat is mapped onshore across northern Lewis/*Eilean Leòdhais* (see paragraph 2.3.1.3), and peat found in the ice-free east could date to a former interstadial (Sutherland and Walker, 1984; Bradwell *et al*., 2021), demonstrating the potential for peat in the near-shore environment. Organic-rich deposits such as peat can preserve pollen, seeds and plant fragments important for understanding past environmental change and chronology (including radiocarbon dating to 50 Ka BP). There has been little evidence of former exposures and dateable organic material offshore of Scotland/*Alba* (Smith *et al*., 2017) other than near-shore e.g. Symbister, Shetland/*Sealtainn* (Hoppe, 1965). This stands in contrast to England where Holocene tidal and alluvial deposits are good preserving environments for archaeological and palaeoenvironmental remains. Within fine-grained minerogenic sediments (typically silts and clays) ecofacts such as diatoms, molluscs and ostracods can be preserved and may have evidential value for reconstructing local and regional environmental and landscape change if well preserved.

3 GEOARCHAEOLOGICAL REVIEW FRAMEWORK

3.1 INTRODUCTION

3.1.1.1 A 5-stage approach sets out the levels of investigation appropriate to the results obtained, accompanied by formal reporting of the results at the level achieved. The stages are summarised below (**Table 3-1**) and broadly follow The Crown Estate (2021) guidance on Archaeological Written Schemes of Investigation for Offshore Wind Farm Projects and Offshore Geotechnical Investigations and Historic Environment Analysis: Guidance for the Renewable Energy Sector (Gribble and Leather, 2011). This annex comprises the Stage 1 log review.

Table 3-1 Stage 1-5 Framework

Stage	Method	Description
1	Geoarchaeological Review of Core Logs	A desk-based archaeological assessment of any ground investigation (trial pits and boreholes). It aims to establish the likely presence of and broadly characterise deposits of archaeological interest as a basis for deciding whether Stage 2 archaeological recording is required. The Stage 1 report will state the scale of Stage 2 work proposed. This is based on professional judgement of the potential and heritage significance of any findings in consultation with stakeholders.
2	Geoarchaeological Recording	Archaeological recording of selected retained or new core samples will be undertaken. This will entail splitting the cores longitudinally and cleaning and recording half of each core. The Stage 2 report will state the results of the archaeological recording and will indicate whether any Stage 3 work is warranted.
3	Sampling and Assessment	Depending upon the results of Stage 2, sub-sampling and palaeoenvironmental assessment (pollen, diatoms and foraminifera) may be required. Subsamples will be taken if required. Assessment will comprise laboratory analysis of the samples to a level sufficient to enable the value of the palaeoenvironmental material surviving within the cores to be identified. Subsamples will also be taken and/or retained at this stage in case scientific dating is required during Stage 4. Some scientific dating (e.g. radiocarbon or Optically Stimulated Luminescence (OSL)) may be undertaken at this stage if appropriate material is present to provide chronological context. The Stage 3 report will set out the results of each laboratory assessment together with an outline of the archaeological implications of the combined results and will indicate whether any Stage 4 work is warranted.

Stage	Method	Description
4	Analysis and Dating	Full palaeoenvironmental analysis of ecofacts assessed during Stage 3. Typically, Stage 4 will be supported by scientific dating (e.g. radiocarbon or OSL) of suitable subsamples. Stage 4 will result in an account of the successive environments within the coring area, a model of environmental change over time, and an outline of the archaeological implications of the analysis.
5	Final Report	If required, Stage 5 will comprise the production of a final report of the results of the previous phases of work for publication in an appropriate journal. This report will be compiled after the final phase of archaeological work, whichever phase that is.

3.2 SOURCES

3.2.1.1 The data sources used for this Stage 1 geoarchaeological review are provided in **Table 3-2**.

Table 3-2 Data sources used for the Stage 1 geoarchaeology review

Stage	Method	Description
Project geotechnical survey	Geotechnical Log data and report, Scoping Report	Geotechnical Survey was conducted for the Project between July and September 2023 by Aratellus on behalf of the Applicant.
British Geological Survey (BGS)	GeoIndex Offshore Drift and solid geology, digital map; online historical geological and geotechnical borehole and trial pit data	Data used to understand the characteristics of the bedrock, soils and substrate of the area of the site, which can provide an indication of suitability for early settlement, and potential depth of remains. These datasets include information on lithostratigraphic units and structural geology of bedrock, seabed sediments, hard substrate distribution, as well as summaries of bedrock lithologies and Quaternary deposits. These datasets offer valuable insights into the offshore geology of the UK, supporting geological studies, resource exploration, and coastal management efforts.
BRITICE Glacial Map v2.0	Map and GIS database	Map and GIS database of glacial landforms and features of the last British-Irish Ice Sheet.
Literature Review	Web-published reports and articles	Information on geomorphological evolution and Quaternary history of Scotland/*Alba*.

3.3 METHODOLOGY

3.3.1 GEOTECHNICAL DRILLING/CORING AND SAMPLING

3.3.1.1 A Sonic Wireline Offshore Remote Drill (SWORD), equipped with sonic coring and push/piston sampling tools, was utilised to extract cores. A total of 8 geotechnical cores were obtained and logged using a combination of sonic and push core sampling from within the Array Area and OCAS (Bluefield, 2023) (see **Plate 1-1**). Cores were taken at 8 locations, with repeat attempts at 3 of those locations where original attempts were aborted (Bluefield, 2023). A total of 25.9 metres of soil/rock sample was recovered from 32 sonic coring runs (for details refer to Geophysical Factual Data Report; Bluefield, 2023).

3.3.2 REVIEW OF GEOTECHNICAL INVESTIGATION

3.3.2.1 The 8 geotechnical logs were reviewed by a qualified geoarchaeologist at Stage 1. Logs did not include information on height (m OD). The following sedimentary information was included:

- Depth;
- Texture;
- Composition;
- Colour;
- Inclusions;
- Structure (massive or bedded);
- Contacts or boundaries between deposits

3.3.2.2 An interpretation of depositional environments, formation processes, and geoarchaeological potential was made based on the Geotechnical Investigation (GI). Of greatest geoarchaeological potential are sediments from former terrestrial environments and features or inclusions of possible archaeological and palaeoenvironmental interest. These may include the following:

- Peat layers and deposits containing organic material such as wood fragments, roots, dark staining, and charcoals;
- Clay or silt deposits, especially those containing laminations that may represent lake or tidal environment (such as lacustrine varves or tidal rhythmites);
- Inorganic fossils (such as molluscs);
- Any indication of human activity including artefacts such as flint or pottery (although finding these within core samples is rare);
- Any other indications of terrestrial depositional environment (such as sand banks or soil horizons).

4 GEOARCHAEOLOGICAL REVIEW OF GEOTECHNICAL INVESTIGATION

4.1 INTRODUCTION

4.1.1.1 This Stage 1 review of Geotechnical borehole logs used the geology, topography, sea-level change history, and past ice mass locations to develop an understanding of the palaeolandscape and sediment sequences on this part of the inner shelf and coastal zone. A basic geoarchaeological classification (GC) was then established, outlining likely depositional processes and geoarchaeological potential (**Table 4-1**).

4.1.1.2 The potential for archaeological and palaeoenvironmental remains and their preservation within submerged seabed sediment is largely governed by:

- How habitable the environment was - the deposition of archaeological material within these layers due to human activity (such as temporary camps and lithic scatters);
- The extent of sediment reworking - subsequent alteration by natural agents (mainly coastal processes);
- The accumulation and preservation of sediments and the degree of organic content, both pre- and post-Devensian, within which archaeological and environmental material could survive.

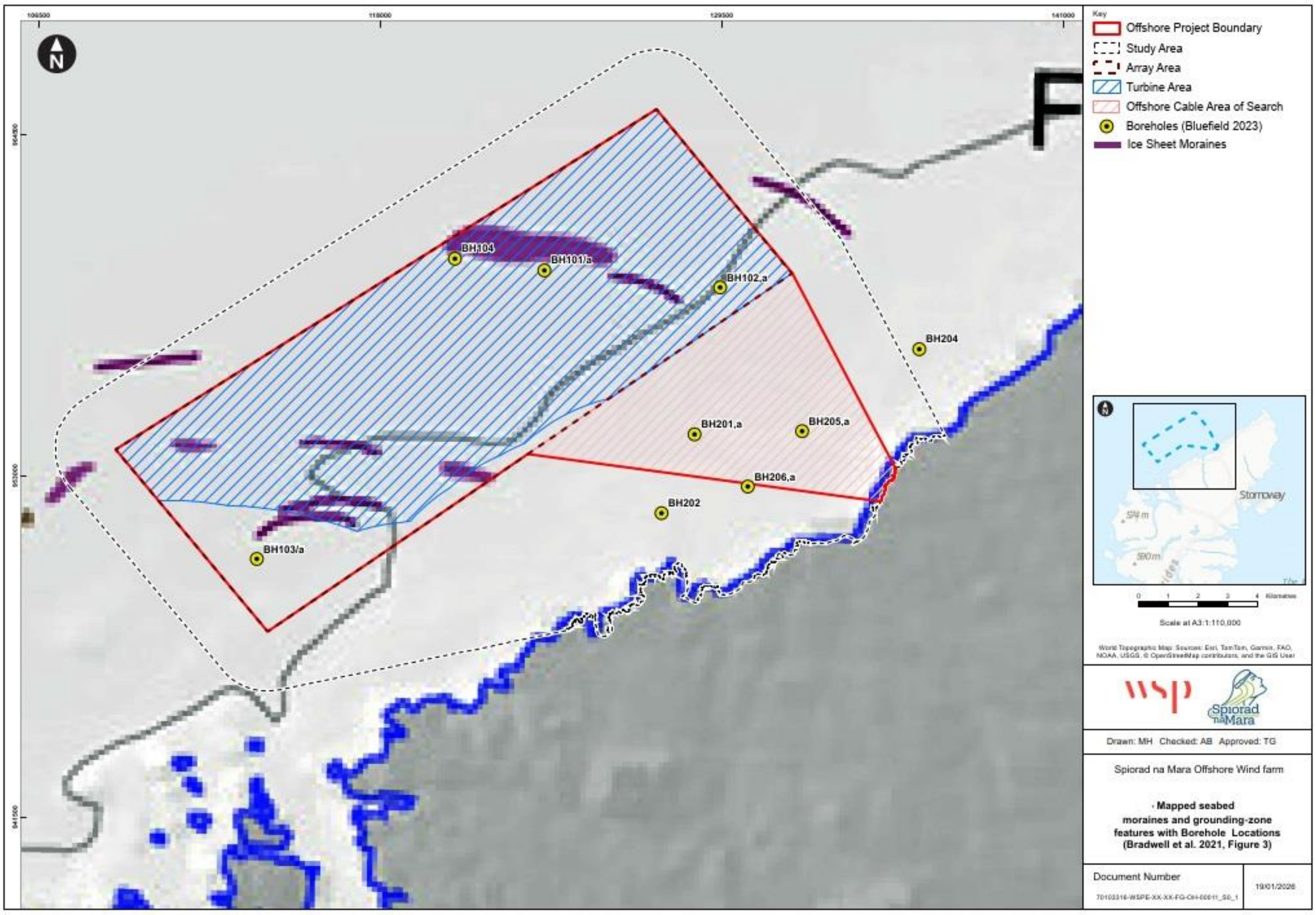
4.2 GEOARCHAEOLOGICAL CLASSIFICATION

4.2.1.1 Within the 8 GI locations, water depth is recorded as Mean Sea Level (MSL) and boreholes recorded as metres below seafloor (mbsf). Seabed characterisation utilising elevations would be useful to support interpretations at any future stage of work if required, giving an indication of seabed topography and a reference point for past RSL. Within the Array Area and OCAS, seabed sediment ranges from gravelly sand in the west to gravel in the east (BGS 2024; Northland Power Ltd, 2023) (**Plate 2-2**). Outcropping bedrock is present at the seabed from the southern edge of the Array Area to the coast, i.e. within the OCAS (BGS, 2024) (**Table 4-1**).

4.2.1.2 Boreholes BH101 - BH104 (**Plate 1-1**) are located offshore within the Array Area. In the Array Area, a sequence of alternating sand and gravel is recorded. Fine orange-brown sand with occasional shell fragments, variously clayey and silty (Geological Classification 1 (GC1), see **Table 4-1**) overlies a sedimentary unit of fine to coarse gravel (GC2). This gravel is made up of mixed lithologies and is sometimes shelly and seen in most of the boreholes located within the Array Area. A further dark grey fine to medium sand (GC3) is recorded beneath gravels, where present.

4.2.1.3 The GC1-GC3 sand and gravel sequence is likely to represent glaciogenic material deposited subaqueously offshore at the retreating edge of the Devensian ice mass (moraines). GC2 deposits are mainly represented in BH201-206. Moraines are mapped by Bradwell *et al.*, 2021 (**Plate 4-1**) and extend across the Inner, Mid, and Outer shelf. Moraines typically display a wide range of sediment grade, from cobbles to clay as reflected by GC1-GC3. The presence of clay laminations within sands or the GC2 gravel may demonstrate periodic changes in flow, ice movement or wasting. The sequence is best represented in BH104, which displays each unit (GC1-GC4). All deposits date to the Pleistocene and are therefore of low archaeological potential (see Section 2.3), and the minerogenic nature of the sediment is not conducive to the survival of environmental material. Shelly inclusions are fragmentary, reworked and are unlikely to provide information on contemporary environments or archaeology.

Plate 4-1 Mapped seabed moraines and grounding-zone features with Borehole Locations (Bradwell *et al.,* 2021, Figure 3)



4.2.1.4 The water depth in BH102 is c. 10-20 m shallower than other Array Area borehole locations (49 m, as opposed to between 61 and 68 m), similar to the nearest boreholes within the OCAS. This may suggest raised seabed topography, even taking into account tidal range (approx. 3 m; tides4fishing, 2024), or the presence of channels and grooves with accumulated sand and gravel (see Figure 6.1.2 of the Scoping Report, 2023).

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Table 4-1 Data sources used for the Stage 1 geoarchaeology review

Geoarchaeological classification	Depth (m from top of core) - general	Description	Interpretation and date	Geoarchaeological potential (archaeological and ecofactual)	GI location where sediment represented
GC1	0.0-2.5	Fine orange-brown shelly sand occasionally laminated with sandy clay or gravelly silty clay with shell fragments	Glaciofluvial moraine sediment at the glacial margin.	Low	BH101, BH101a, BH103, BH103a (shell fragments observed), BH104
GC2	2.5-3.5	Medium to coarse gravel mixed lithologies	Glaciofluvial moraine sediment at the glacial margin.	Low	BH101, BH101a, BH102, BH102a, BH103, BH103a, BH104, BH201a, BH202, BH204, BH206
GC3	3.5-10.0	Dark brown silty clayey fine to medium sand or sandy clay	Glaciofluvial moraine sediment at the glacial margin.	Low	BH101, BH101a, BH103, BH103a, BH104, BH201a
GC4	0.25-1.4 and 10.5	Coarse angular cobbles	Basalt/Gneiss/Sandstone bedrock	Low	BH104, BH202, BH204, BH206a

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5 CONCLUSION AND RECOMMENDATIONS

5.1.1.1 The Stage 1 geoarchaeological review of geotechnical data used the reported geology, topography, and research on sea-level change and past ice mass locations to develop an understanding of the palaeolandscape and sediment sequences off the north-west coast of Lewis. The potential preservation of archaeological and palaeoenvironmental remains submerged within seabed sediment, is governed how sediment were deposited, the extent of sediment reworking, land use and the preservation potential of sediments.

5.1.1.2 At the end of the last glaciation, Lewis/*Eilean Leòdhais* deglaciated earlier than in other parts of the UK, being at the periphery of the BIIS ice sheet. Sea-level rise in the Mesolithic was rapid, and there is evidence of rapid flooding (around 8 Ka BP; possibly the Storegga Slide tsunami). The log review shows that boreholes further from the coast record sediment deposited by retreating glaciers. These sediments would have accumulated beneath the ice through glaciofluvial processes. The offshore borehole logs record entirely minerogenic deposits with no evidence of organic remains. The dynamic environment, remote location and cold temperatures would have likely made this location fairly inhospitable for human occupation in the Pleistocene and early Holocene. It is considered that the potential for prehistoric archaeological remains is low; however, it is recognised that early Neolithic RSL fell (to -2 m OD) following Mesolithic flooding and would have exposed land now offshore to human exploitation during a period of megalith and crannog construction on Lewis/*Eilean Leòdhais*.

5.1.1.3 While Stage 2 investigation is considered not to be warranted based on present results, any further geotechnical information both off- and onshore will contribute to understanding the landscape and archaeological potential, leading to a review of conclusions and recommendations.

6 GLOSSARY OF TERMS AND ABBREVIATIONS

6.1.1.1 A list of key terms and acronyms used in this annex are provided in **Table 6-1** and **Table 6-2**.

Table 6-1 Acronyms and abbreviations

Term	Definition
BGS	British Geological Survey
BIIS	British–Irish Ice Sheet
EIAR	Environmental Impact Assessment Report
GC	Geoarchaeological Classification
GI	Geotechnical Investigation
Ka BP	Thousand years ago before present
MHWS	Mean High Water Springs
MIS	Marine Isotope Stages
MSL	Mean Sea Level
OCAS	Offshore Cable Area of Search
OSL	Optically Stimulated Luminescence
OWF	Offshore Wind Farm
RSL	Relative Sea Level
SWORD	Sonic Wireline Offshore Remote Drill
WTG	Wind Turbine Generator

Table 6-2 Glossary

Term	Definition
the Applicant	Spiorad na Mara Limited (the Project owner).
Array Area	The offshore area within which the offshore wind turbine generators (WTGs), associated foundations, Offshore Cables, and Offshore Substation Platform (OSP) (if required), will be located. This area encompasses the Turbine Area that will contain all above water surface infrastructure (WTGs / OSP) and an additional area within which further below water infrastructure (foundations and cables) may also be located.
Environmental Impact Assessment Report (EIAR)	The Environmental Impact Assessment Report (EIAR) prepared to assess the likely significant effects of the Project on the environment.
Landfall	This consists of works from offshore Horizontal Directional Drill (HDD) exit pits (located below MLWS) to onshore at the Transition Joint Bays (TJB) (located above MHWS). The infrastructure and installation methods associated with the Landfall involves both onshore and offshore components.
Offshore Cable Area of Search (OCAS)	The area within which the offshore electrical and communication cables between the Array Area and Landfall up to Mean High Water Springs (MHWS) will be located.

Term	Definition
Offshore Landfall Area	The area seaward of Mean High Water Springs (MHWS) within the Offshore Cable Area of Search (OCAS) that includes works associated with the Horizontal Directional Drill (HDD) installation, including HDD exit pit(s) (located below MLWS) and offshore cable connection to the onshore (TJB) (located above MHWS).
Offshore Project	The components of the Spiorad na Mara offshore wind farm (the Project) located seaward of Mean High Water Springs (MHWS).
Offshore Project Boundary	The 'red line boundary' encompassing the Offshore Project.
Project	The Spiorad na Mara offshore wind farm development. This term describes the whole development, including all offshore and onshore components.
Project Boundary	The 'red line boundary' encompassing all offshore and onshore components of the Project.
Study Areas	Study Areas are determined for each technical discipline and are described within each technical chapter.
Turbine Area	A reduced area within the Array Area where above water surface infrastructure would be located i.e. wind turbine generators (WTG) and Offshore Substation Platform (OSP) (if required). This area has been developed and refined through stakeholder engagement and environmental assessment.
Wind Turbine Generator (WTG)	The wind turbines that generate electricity consisting of tubular towers and blades attached to a nacelle housing mechanical and electrical generating equipment.

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