MORGAN AND MORECAMBE OFFSHORE WIND FARMS: TRANSMISSION ASSETS

Outline Hydrogeological Risk Assessment of Lytham St Annes Dunes SSSI

Deadline: Deadline ~~5~~6
PINS Reference: EN020028

Document Number:
MRCNS-J3303-RPS-19115
MOR001-FLO-CON-CAG-RPT-0088

Document Reference: S_D3_6/~~F02~~F03

22 ~~September~~October 2025

~~F02~~F03

Document status

Version	Purpose of document	Approved by	Date	Approved by	Date
F01	Submission at Deadline 3	HK	July 2025	PM	July 2025
F02	Submission at Deadline 5	GL	September 2025	PM	September 2025
F03	Submission at Deadline 6	GL	October 2025	PM	October 2025

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Prepared by:	Prepared for:
RPS	**Morgan Offshore Wind Limited** **Morecambe Offshore Windfarm Ltd**

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Glossary

Term	Meaning
Cable percussion drilling	Drilling technique used through superficial deposits and very weak rocks.
Cone penetration testing	Method used to determine the geotechnical engineering properties of soils and delineating soil stratigraphy.
D_{10} particle size	The point on the distribution curve below which 10% of the particles fall.
Dewatering	The removal of water from a location.
Direct Pipe drilling method	A cable installation technique which involves the use of a mini (or micro) tunnel boring machine and a hydraulic (or other) thruster rig to directly install a steel pipe between two points. Simultaneous excavation of the borehole and installation of the pipeline at the same time. A pipe is simultaneously installed along with the borehole excavation, eliminating the need for borehole wall support
Drawdown	A change in groundwater level due to an applied stress, caused by events such as pumping from a well.
Dynamic sampling	Drilling technique used for the construction of relatively shallow boreholes within superficial deposits.
Permeability (hydraulic conductivity)	A measure of the ability of a material (such as rocks) to transmit fluids.
Principal aquifer	A geological unit that yields significant groundwater that support regionally or nationally important supplies and support rivers, lakes and wetlands at a strategic scale.
Rortary core drilling	Drilling technique used to obtain core samples of rock.
Secondary A aquifer	A geological unit that provides modest groundwater that can support local water supplies and may form an important source of water to rivers.
Secondary B aquifer	A geological unit that is dominated by low permeability layers that may store and yield limited amounts of groundwater.
Secondary undifferentiated aquifer	Where it is not possible to apply either a Secondary A or B definition because of the variable characteristics of the rock type, but generally have only a minor resource value.
Zone of Influence	A region where the water level decreases due to well discharge.

Acronyms

Acronym	Meaning
BGS	British Geological Survey
BHS	Biological Heritage Site
PSD	Particle Size Distribution
LNR	Local Nature Reserve
MHWS	Mean High Water Springs

Acronym	Meaning
SSSI	Site of Special Scientific Interest
TJB	Transition Joint Bay

Units

Unit	Description
%	Percentage
m	Metre
D_{10}	Particle size value at which 10% of the sample’s particles are smaller
m/s	Metres per second
mAOD	Metres above Ordnance Datum
~~mgl~~mbGL	Metres below ground level
K	Hydraulic conductivity
s	Drawdown
n	Effective porosity
t	Elapsed time

1 Introduction

1.1 Overview

1.1.1.1 This document forms the Outline Hydrogeological Risk Assessment (oHyRA) prepared for the Morgan and Morecambe Offshore Wind Farms: Transmission Assets (referred to hereafter as 'the Transmission Assets').

1.1.1.2 The oHyRA has been prepared in response to Relevant Representations (RRs) from Natural England (RR-1601; PDA-021), the Environment Agency (RR-0677; PDA-010) and The Wildlife Trust for Lancashire, Manchester and North Merseyside (RR-2180; PDA-007) regarding the potential impact that the Transmission Assets landfall (shown in Work Nos. 6A/B, 8A/B, 9A/B and 10/A/B on **Figure 1-1**~~**Figure 1-1**~~) could have on the Lytham St Annes Dunes Site of Special Scientific Interest (SSSI), Lytham St Annes Local Nature Reserve (LNR) and St Annes Old Links Golf Course & Blackpool South Rail Line Biological Heritage Site (BHS) (see **Figure 1-2**~~**Figure 1-2**~~).

1.1.1.3 This oHyRA has been updated for Deadline 5 to include the following:

- Response to comments raised by the Environment Agency in their submission at Deadline 4 (REP4-132)
- The findings of the National Vegetation Classification (NVC) surveys of the Lytham St Annes Dunes SSSI and the St Annes Old Links Golf Club course
- The findings of a site visit to the St Annes Old Links Golf Club course

1.1.1.4 This oHyRA has been updated for Deadline 6 to include the following:

- Response comments raised by the Environment Agency in their submission at Deadline 5 (REP5-169)and comments on the Outline Hydrogeological Risk Assessment received from the Environment Agency on the 14 October 2025.
- Clarification of where commitments listed in Table 1.1 are described within the oHYRA and updates to wording of commitments in accordance with the Commitments Register (F1.5.3/F07).

1.2 Implementation

1.2.1.1 The oHyRA forms an appendix to the Outline Code of Construction Practice (CoCP) (document reference J1). Following the granting of consent for the Transmission Assets, detailed HyRA(s) will be prepared as part of the detailed Code of Construction Practice(s) on behalf of Morgan OWL and/or Morecambe OWL, prior to commencement of the relevant stage of works and will follow the principles established in this oHyRA. The detailed HyRA(s) will require approval by the relevant planning authority following consultation with relevant stakeholders.

1.2.1.2 This is an outline document based on the design set out in Volume 1, Chapter 3: Project Description of the Environmental Statement (document reference F1.3) and includes measures that have been identified as part of the EIA process.

1.2.1.3 The Applicants have committed to implementation of detailed HyRA(s) via commitment CoT128 (see Volume 1, Annex 5.3: Commitments Register (REP2-010)), which is secured through Requirement 8 of the draft Development Consent Order (DCO) (document reference C1) Schedules 2A for Morgan OWL & 2B for Morecambe OWL. The requirement wording for Project A (Morgan) is set out below (Project B's (Morecambe) requirement mirrors that of Project A's for this requirement and is, therefore, not repeated):

8.—(1) No stage of the Project A onshore works or Project A intertidal works may commence until for that stage a code of construction practice has been submitted to and approved by the relevant planning authority following consultation as appropriate with –

(a) Lancashire County Council;

(b) Natural England;

(c) the Environment Agency;

(d) in relation to the Project A intertidal works or, if applicable to the Project A offshore works, the MMO; and

(e) in relation to the Project A Blackpool Airport works, BAOL to the extent specified in the outline code of construction practice.

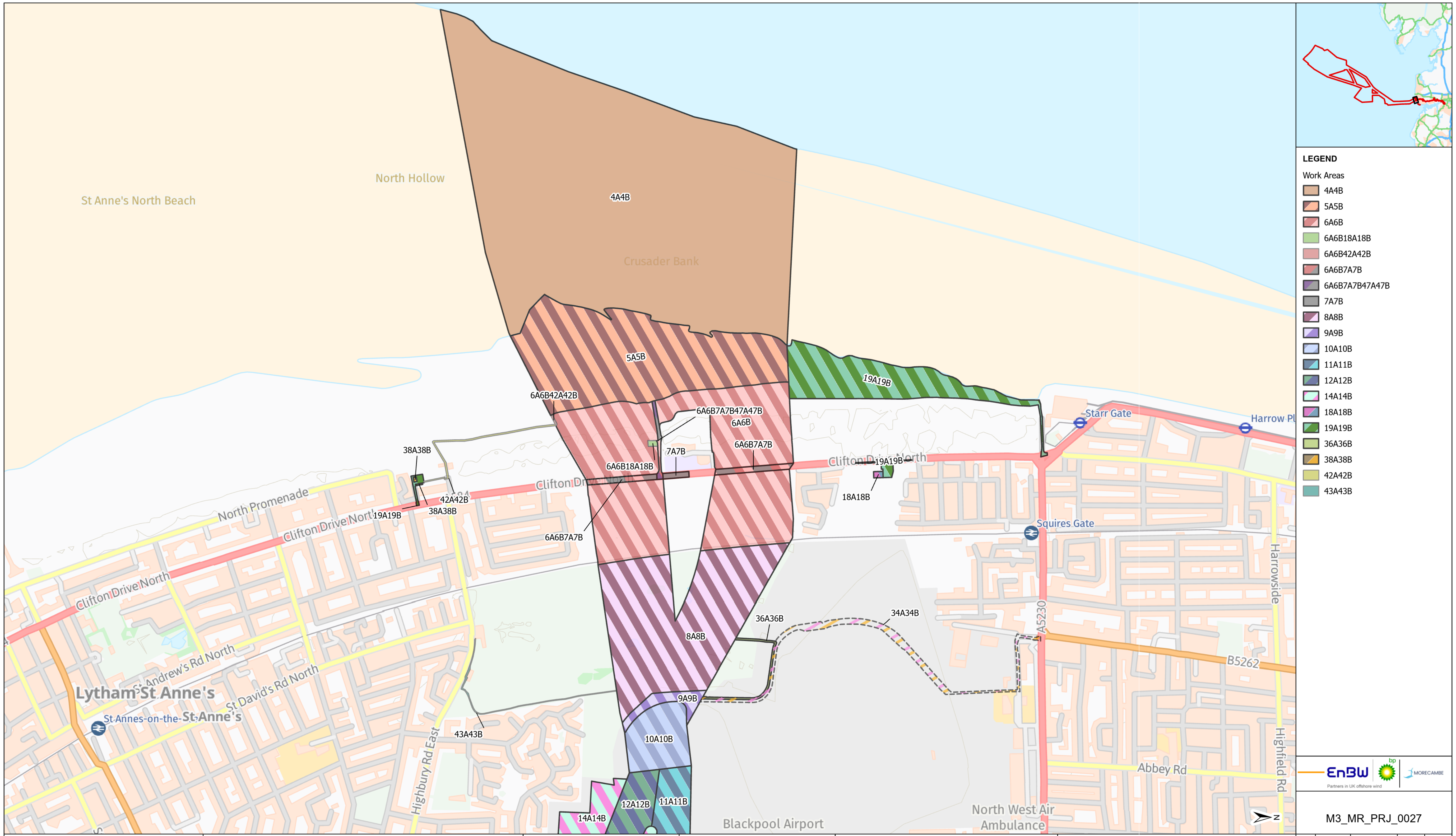
(2) Each code of construction practice must accord with the outline code of construction practice and include, as appropriate to the relevant stage-…

(o) hydrogeological risk assessment for trenchless installation beneath Lytham St Annes SSSI (in accordance with the outline hydrogeological risk assessment).

(3) The code of construction practice approved in relation to the relevant stage of the Project A onshore works must be followed in relation to that stage of the Project A onshore works and Project A intertidal works.

1.2.1.4 The Transmission Assets may adopt a staged approach to the approval of DCO requirements. This will enable requirements to be approved in part or in whole, prior to the commencement of the relevant stage of works in accordance with whether staged approach is to be taken to the delivery of the each of the offshore wind farms.

1.2.1.5 For onshore and intertidal works (landward of Mean Low Water Springs), this approach will be governed by the inclusion of Requirement 3 within the draft DCO, which requires notification to be submitted to the relevant planning authority/authorities detailing whether Project A or Project B relevant works will be constructed in a single stage; or in two or more stages to be approved prior to the commencement of the authorised development.



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MORGAN AND MORECAMBE
OFFSHORE WINDFARMS:
TRANSMISSION ASSETS

LANDFALL CONSTRUCTION OUTLINE

0 50 100 Meters

Geodetic Information:
Datum: OSGB 1936
Projection: British National Grid
Scale@379mmx231mm: 1:12,500

Data Sources: BP, Ordnance Survey, JNCC

Service Layer Credits: GB Cartographic Local Names: Contains OS data © Crown Copyright and database right 2023
Contains data from OS Zoomstack

VER	DATE	DETAILS	BY	CHECK
01	04/08/25	Initial Issue	HAH	JS

Figure 1-1: Onshore Order Limits and Work No. at Landfall [1]

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[1] The proposed works are set out in Schedule 1 (Authorised Project) of the draft DCO, and shown in Sheet 3 of the Works Plans - Onshore and Intertidal (AS-016)

1.3 Objective and methodology

1.3.1 Objective

1.3.1.1 The objective of the oHyRA is to determine the potential risk that construction activities associated with the installation of the offshore export cables beneath the Lytham St Annes Dunes SSSI, Lytham St Annes LNR and St Annes Old Links Golf Course & Blackpool South Rail Line Biological Heritage Site (BHS) may pose to the sand dune features of these sites.

1.3.1.2 Stakeholders have raised comments during the DCO Examination (see paragraph 1.1.1.2) relating to the potential presence of a shallow water table and the impact on the SSSI, LNR, BHS and St Anne's Old Links Golf Club course (hereafter referred to as ‘the Golf Course’) from the following activities:

- dewatering activities within the Blackpool Airport site and the exit pits at the beach during construction excavations potentially in hydraulic continuity with the SSSI/LNR/BHS and the Golf Course;
- construction activities relating to the trenchless installation; and
- the permanent location of the cables beneath the SSSI/LNR/BHS and the Golf Course.

1.3.1.3 The oHyRA considers the potential groundwater pathway or pathways that may exist between the landfall and the key groundwater dependant features of the SSSI, LNR,BHS and the Golf Course. It considers the risks that the construction and operational activities may have on those pathways should they be identified, and the potential consequences on those features.

1.3.1.4 The oHyRA comprises the initial stage of the risk assessment process. It sets out the hydrogeological and ecological assumptions and preliminary hydrogeological conceptual model that will inform the scope of the detailed HyRA(s) and the detailed crossing design of the offshore export cables beneath Lytham St Annes Dunes SSSI/LNR and the Golf Course & Blackpool South Rail Line BHS.

1.3.2 Methodology

1.3.2.1 The oHyRA has involved the following specific tasks:

- evaluation of existing Ground Investigation (GI) data undertaken to date by the Transmission Assets (see Section 3.0.1495270400~~3.515.-1937971168~~);
- development of a preliminary Hydrogeological Conceptual Model (HCM) for the local area (see Section 2.5);
- assessment of risk to water dependent features in the SSSI/LNR/BHS and the Golf Course abstractions based on potential linkages identified in the HCM utilising empirically derived estimates of zones of influence of required dewatering associated

with construction of the Transition Joint Bays (TJBs) (see Section 3.4.1) and the exit pits on the beach (see Section 3.4.2);

- identification of measures required to manage or mitigate those risks given their magnitude (see Section 3.5).

1.3.2.2 The key aspects of the SSSI/LNR/BHS hydrogeological regime that must be considered as part of the assessment include:

- the geological units/aquifers that underlie the SSSI/LNR/BHS; and
- the interaction between groundwater and the dune slacks.

1.3.2.3 Consideration of the level of certainty to each aspect of the hydrogeology is key, given the limited amount of site-specific data available.

1.3.2.4 The following construction activities are considered:

- construction of Transition Joint Bays (TJB) at Blackpool Airport for trenchless installation;
- establishment of exit pits on the beach; and
- trenchless installation of cables crossing beneath the SSSI/LNR/BHS.

1.3.2.5 The trenchless installation technique will drill underground from the landfall compound (located in or around Blackpool Airport) under the SSSI/LNR/BHS and exit on the North Beach at Lytham St. Annes 100 m from the sand dunes.

1.3.3 Sources of information

1.3.3.1 The following information sources have been utilised for this oHyRA:

- Environmental data disclosure report:
  - Groundsure Insight Report: Morgan, Report Ref. GSIP-2023-13424- 13080 (1-16). 10 March 2023
- Historical ground investigation data including borehole logs:
  - Fugro, Intertidal Survey - Morgan, Ground investigation Report (GIR) Factual Account, F216874-Morgan 02, 20 December 2023 (Fugro, 2023)
  - Central Alliance - Morgan St Annes Ground Investigation, 2372506-FAC-01,May 24 (Central Alliance, 2024)
- Literature values of hydrogeological properties
- Historical ecological survey reports:
  - Fylde Sand Dunes Management Plan (Skelcher, 2008)
- British Geological Survey (BGS) mapping data (1:50,000 Series Sheet 74 Solid and Drift Geology, 1989)
- The Fylde, Lancashire: Summary of the Quaternary Geology. British Geological Survey Open Report OR/16/013, 2016
- British Geological Survey GeoIndex (onshore)

- Lytham St Annes Dunes SSSI citation
- Outline cable engineering design parameters (set out in Volume 1, Chapter 3: Project Description (REP2-008)).

1.3.4 Limitations

1.3.4.1 This outline assessment is based on existing ground investigation data with no direct data pertaining to the ground conditions of the SSSI/LNR/BHS, including the groundwater regime and its likely seasonal variability.

1.3.4.2 The potential Zone of Influence distance is estimated using empirically derived relationships utilising hydraulic conductivity and dewatering drawdown requirements. These calculations are not used for strictly predictive purposes of likely impacts but to provide reasonable worst case screening criteria to inform relative potential of impacts given the site's hydrogeological setting and expected characteristics.

1.4 Report Structure

1.4.1.1 The structure of this oHyRA is as follows:

- Section 2: Site Setting – Description of key aspects of the site setting including most notably the SSSI designated features and the geology and hydrogeological characteristics that are required to develop the Conceptual Hydrogeological Model for the HyRA.
- Section 3: oHyRA – Describes the approach to be used for the oHyRA and activities under consideration to determine the potential impact on the SSSI/LNR/BHS given the pathway/hydraulic links identified in the Conceptual Hydrogeological Model.
- Section 4: Risk Management and Reduction Measures – Presents the recommended risk management measures, commensurate with the level of risk identified through the risk assessment.
- Section 5: Next Steps.
- Section 6: Conclusion

1.4.1.2 The detailed HyRA for the Lytham St. Annes Dunes SSSI will follow the structure of the oHyRA.

1.4.1.3 HyRAs will also be prepared where the onshore export cable corridor or 400kV grid connection cable corridor crosses sites of particular sensitivity (e.g. the River Ribble) (as specified in CoT41 of the Commitments Register (F1.5.3)). These HyRAs will follow the structure of the oHyRA for the Lytham St. Annes Dunes SSSI.

1.5 Commitments

1.5.1.1 Through the EIA process, the Applicants have identified commitments which seek to eliminate or reduce impacts or adopt best practice guidance as part of the Transmission Assets and these are recorded within Volume 1, Annex 5.3: Commitments Register of the ES (document reference F1.5.3). Where relevant, commitments have been detailed within subsequent sections of this oHyRA. All commitments associated with onshore and intertidal construction are provided in full within Table 1.1. These will be included within and developed further as part of the detailed HyRA.

Table 1.1: Measures (commitments) adopted as part of the Transmission Assets relevant to the outline hydrogeological risk assessment

Commitment (CoT) number	Measure adopted	How the measure will be secured (article references may be subject to change during DCO Examination)	Where is the commitment reference within the document?
CoT41	Where the onshore export cable corridor or 400 kV grid connection cable corridor crosses sites of particular sensitivity (e.g. embanked Environment Agency surface watercourses, Sites of Special Scientific Interest or groundwater inner Source Protection Zones) hydrogeological risk assessment(s) will be undertaken to inform a site-specific crossing method statement(s) where required. These will be agreed with the relevant stakeholders prior to construction.	DCO Schedules 2A & 2B, Requirement 8 (Code of Construction Practice)	Section 1.4
CoT44	The Project Description (Volume 1, Chapter 3 of the Environmental Statement) sets out that the installation of the offshore export cables under Lytham St Annes SSSI and the St Annes Old Links Golf Course will be undertaken by direct pipe trenchless installation technique. The exit pits associated with the direct pipe installation will be at least 100 m seaward of the western boundary of the Lytham St Annes Dunes SSSI.	DCO Schedules 2A & 2B, Requirement 8 (Code of Construction Practice)	Section 3.1, 3.4 and 3.5
CoT128	An Outline Hydrogeological Risk Assessment will be prepared in relation to the crossing of Lytham St Annes SSSI and St Annes Old Links Golf Course to mitigate potential impacts to the hydrologically dependant surface water features of the sand dune system and St Annes Old Links Golf Course abstraction borehole (ref: GWA_01). This will form part of the Outline Code of Construction Practice. At detailed design stage, Hydrogeological Risk Assessment(s) (will be developed in accordance with the Outline Hydrogeological Risk Assessment. The hydrogeological risk assessment(s) will be informed by additional ground investigation information. The scope of the	DCO Schedules 2A & 2B, Requirement 8 (Code of Construction Practice)	Section 1.2 and 5

Commitment (CoT) number	Measure adopted	How the measure will be secured (article references may be subject to change during DCO Examination)	Where is the commitment reference within the document?
	ground investigation and groundwater monitoring will be agreed with the Environment Agency and Natural England These assessment(s) will be used to inform the detailed site-specific crossing design for the installation of the offshore export cables beneath Lytham St Annes SSSI and St Annes Old Links Golf Course.		

~~1.4.1.3~~

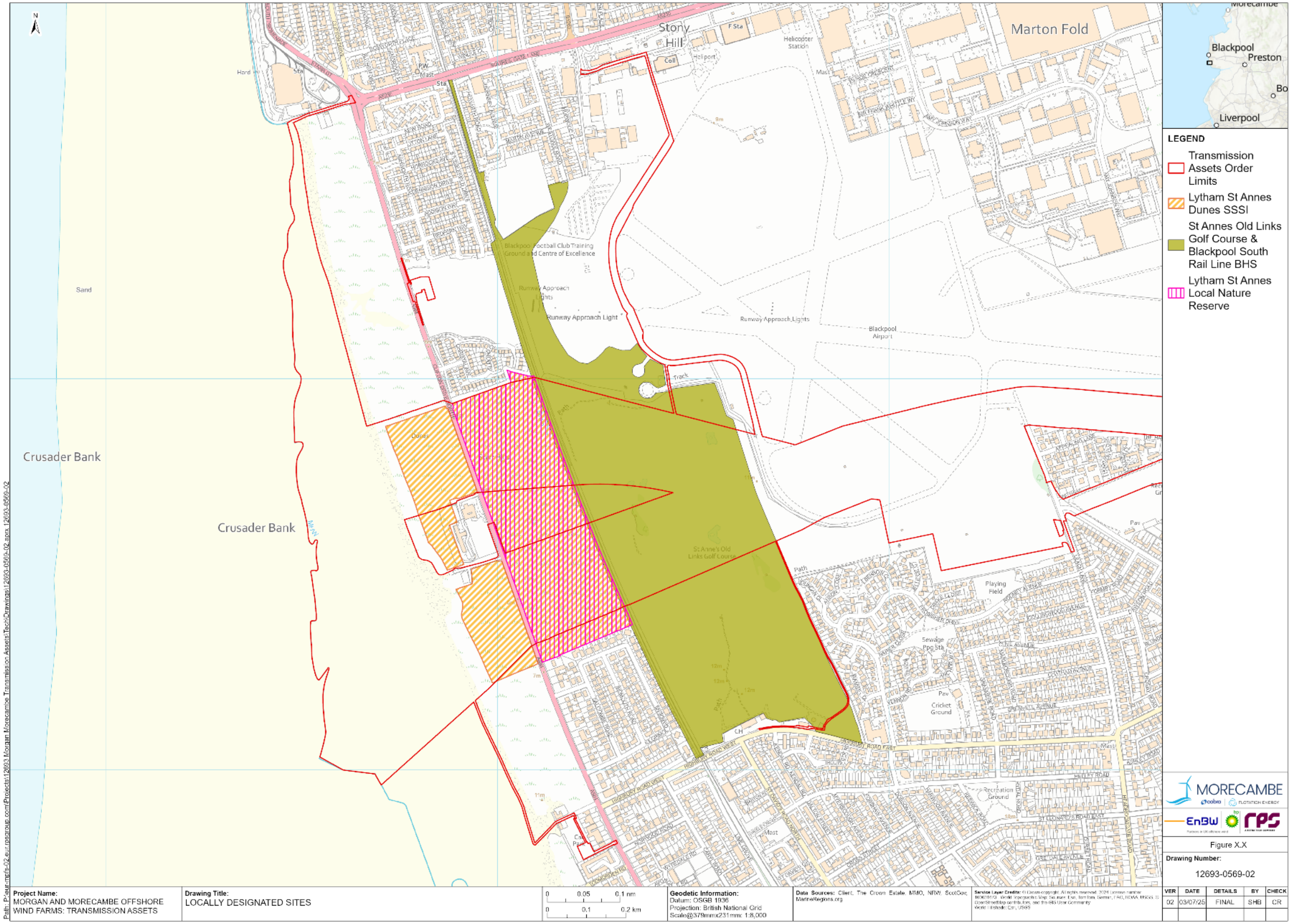

Figure 1-2: National statutory and local designated sites at Lytham St Annes

2 Site Setting

2.1 Introduction

2.1.1.1 This section provides an overview of the local ecological, geological and hydrogeological setting. For the purposes of this report, the term, 'study area', refers to the Transmission Assets Order Limits in which the offshore export cables are routed from the exit pits on the beach (100 m from the western boundary of the Lytham St Annes Dunes SSSI) through the direct pipe ducts beneath the Lytham St Annes Dunes SSSI, Lytham St Annes LNR and the St Annes Old Links Golf Course & Blackpool South Rail Line BHS to entry pits at Blackpool Airport as shown in **Figure 1-2**~~**Figure 1-2**~~.

2.2 Ecology

2.2.1 Lytham St Annes Dunes SSSI/LNR

2.2.1.1 The coastal dunes at the landfall site occur on either side of Clifton Drive North; the dunes to the west between the beach and the road are designated as the Lytham St Annes Dunes SSSI and the dunes on the eastern side (between the road and the rail line) are designated as the Lytham St Annes Dunes LNR. Further east, the remnant dunes occurring within the Golf Course are designated as the St Annes Old Links Golf Course & Blackpool South Rail Line BHS.

2.2.1.2 The Lytham St Annes Dunes SSSI citation states that the dunes support a wide range of species, particularly associated with dune slacks, which vary according to the depth of water and degree of moisture retention of overlying strata in relation to the water table.

2.2.1.3 Curelli et al (2013) provide a description of dune slack formation and interdependence on hydrogeological conditions:

"*Dune slacks form when bare sand is disconnected from seawater influence by the establishment of a new dune front, or inland, where wind erosion scours bare sand down to the water table or to the capillary wetted layer. Thus their formation and subsequent plant and soil development are intimately connected to the dune groundwater hydrological regimes. Large water table fluctuations are a feature of most slacks, and control slack vegetation development. Variation of water levels occurs both within the year, typically around 70 cm with a rapid rise in autumn and a gradual decrease from spring to summer and between years, depending on precipitation and evapotranspiration balances*."

2.2.1.4 The baseline environment at the Lytham St Annes Dunes SSSI and Lytham St Annes LNR may be considered non-static due to the natural state of dune succession and ecological colonisation and the changes in land management practice.

2.2.1.5 An extract from the National Vegetation Classification (NVC) survey for the SSSI/LNR is shown in **Figure 2-1**~~**Figure 2-1**~~ (after 2016 Map drawn by Graeme Skelcher Ecological Consultant, November 2016, based on survey work carried out in summer 2016).

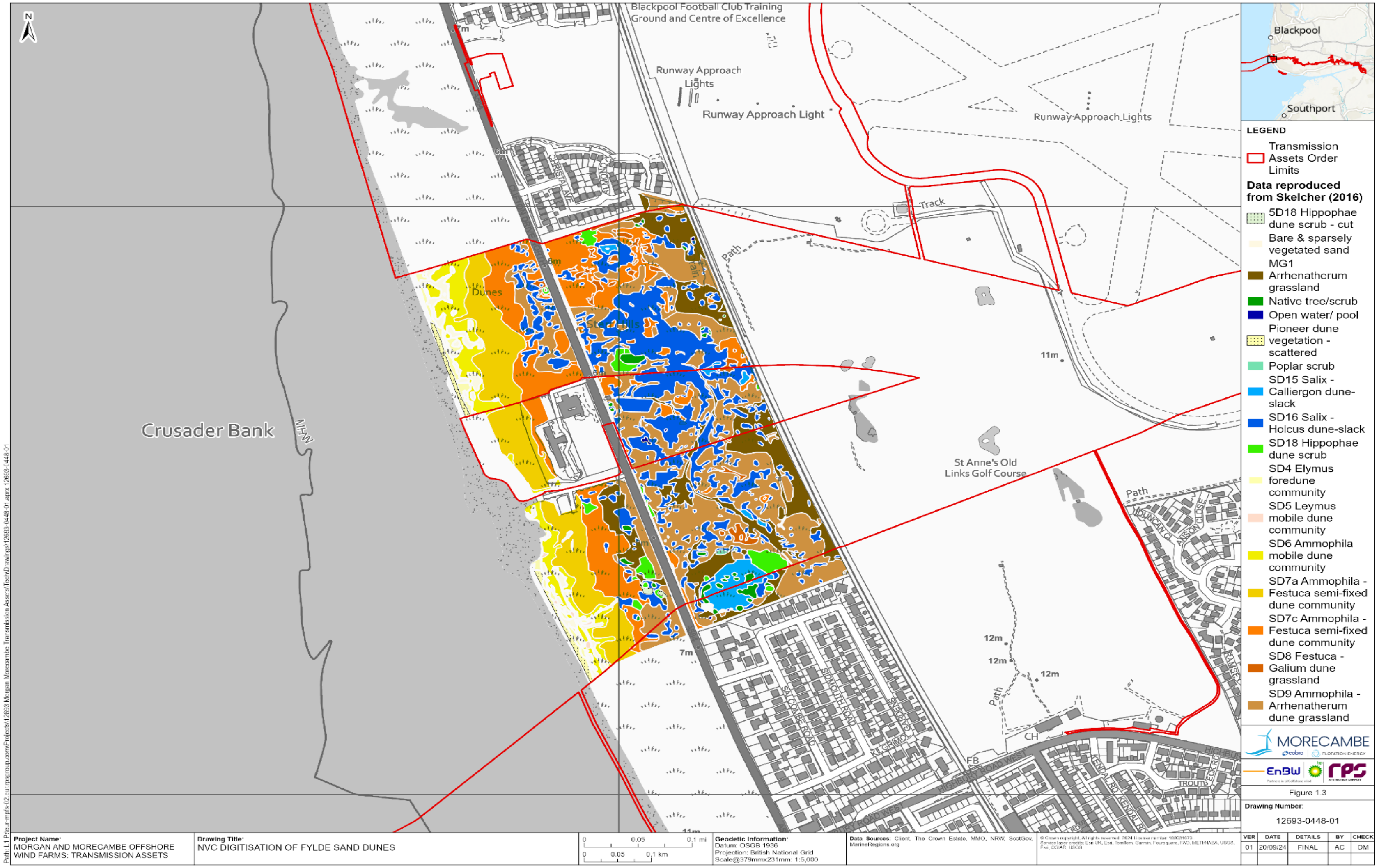

Figure 2-1: Location of dune slack and swamp vegetation communities at Lytham St Annes Dunes SSSI/LNR (2016)

2.2.1.6 The Fylde Sand Dunes Management Plan (Skelcher, 2008) describes the following relating to dune slacks within Lytham St Annes - being the part of the Lytham St Annes Dunes SSSI to the east of Clifton Drive North and indicate that the permanently wet dune slack ecosystems are more prevalent in this eastern portion of the SSSI:

> "*Separated from the coastal dunes of Starr Hills by the hard barrier of Clifton Drive North, the Lytham St Annes Local Nature Reserve nevertheless supports an impressive range of dune wildlife and habitats. This is the only area on the coast where substantial wet dune slacks can be found, and the associated helleborines, orchids and other dune-slack species are generally much more numerous here than elsewhere in the Fylde Dunes*."

2.2.1.7 The existing two groundwater abstractions associated with the Golf Course (see Section 2.4.3.6~~2.4.3.5~~) is not considered to be impacting the hydrogeology of the SSSI/LNR to an extent where effects on groundwater dependent terrestrial ecosystems are visible. Following a site visit to the Golf Course it was established that these boreholes have been replaced with a new shallower, horizontal groundwater abstraction system and the boreholes decommissioned.~~ .~~ The nearest SSSI unit to the Golf Course (unit 3) was assessed by Natural England in 2024 as being in 'unfavourable - recovering' condition, which was attributed to the positive management strategies implemented by the Fylde Sand Dunes Project in recent years.

2.2.1.8 Ground truthing of the NVC surveys at the Lytham St Annes Dunes SSSI/LNR were undertaken in August 2024. These surveys sought to reconcile the data from the Skelcher (2016) report with direct observation in the field, with a focus on the hydrologically sensitive dune slack communities present (see **Figure 2-2**~~**Figure 2-2**~~) .

2.2.1.9 A Geomorphological Study (JBA consulting, 2016) provides the following information with regard to the dune slack species:

> "*The series of exceptionally large and extensive dune slacks on either side of Clifton Drive North support a wide range of species, which vary according to the depth of water and degree of moisture retention in relation to the water table.*
>
> *The largest slack in the south-west corner of the site is permanently wet. Its central zone of standing water is dominated by water horsetail Equisetum fluviatile and water crowfoot Ranunculus aquatilis with fringing marsh pennywort, marsh bedstraw Galium palustre, water mint Mentha aquatica, water forget-me-not Myosotis scorpioides, lesser spearwort R. flammula and branched bur-reed Sparganium erectum. A large clump of the rare hybrid rush J. balticus inflexus is a notable feature as is common cottongrass Eriophorum angustifolium*."

2.2.2 St Annes Old Links Golf Course and Blackpool Rail Line BHS

2.2.2.1 The St Annes Old Links Golf Course and Blackpool South Rail Line BHS citation states that the following habitats are present:

> "A *mosaic of relict dune grassland, dune heath and sand dune within the wider golf course. The site is a fragment of the much larger Fylde dune system prior to the 19th and 20th century resort development. The site supports several plant species of local interest. The site is designated for its coastal sand dune, yellow bartsia and chaffweed Anagallis minima (both classed as endangered in Lancashire). It is also designated for Grass-of-Parnassus Parnassia palustris (classed as vulnerable in Lancashire) and trailing St. John's-wort Hypericum humifusum (classed as sensitive in Lancashire) with a significant county population of both species within the site."*

2.2.2.2 The golf course has been present since 1886, and therefore it is reasonable to conclude that it has been subject to significant anthropogenic modification over the past c. 140 years. The Phase 1 Habitat survey undertaken by RPS in 2023 did not identify any dune slack wetland habitats, and the habitats were found to be dominated by the short-mown grassland fairways and greens, with areas of rough semi-improved grassland to the fairway margins. The survey identified a small area of dry dune heath grassland in the north-west corner of the BHS, which is indicative of its previous, less modified history when it was part of the mobile dune system on this stretch of the coastline. Given that the golf course does not support any groundwater dependent terrestrial ecosystems, it is reasonable to assume that the habitats are less sensitive to the effects of hydrological changes than the SSSI/LNR and are shown in **Figure 2-2**~~**Figure 2-2**~~.

Figure 2-2: NVC and Phase 1 habitat survey results

2.2.3 2025 NVC Survey

2.2.3.1 An updated NVC survey was undertaken of Lytham St Annes Dunes SSSI in July 2025 (See Appendix D of Volume 3, Annex 3.3: Phase 1 habitat, national vegetation classification and hedgerow survey technical report (F3.3.3/F03)). A baseline NVC survey and habitat mapping was also undertaken of the St Anne's Old Links Golf Course BHS in September 2025 (See Appendix E of Volume 3, Annex 3.3: Phase 1 habitat, national vegetation classification and hedgerow survey technical report (F3.3.3/F03)).

Lytham St Annes Dunes SSSI/ LNR

2.2.3.2 The Fylde Sand Dunes Project undertook an NVC survey and habitat mapping of the SSSI/ LNR in 2016, which was subsequently ground truthed by an NVC survey undertaken by the Applicants in 2024. The results of the 2016 survey are presented in Section 1.3.1 of Volume 3 Annex 3.3: Phase 1 habitat, national vegetation classification and hedgerow survey technical report (APP-077), and the results of the 2024 ground truthing survey are presented in Section 1.3.2 of the same report.

2.2.3.3 The results of the updated NVC survey undertaken by the Applicants in July 2025 indicated a total of four topogenous wetland types including three communities of wet dune and one swamp, all of which correspond with the habitat types recorded in previous surveys. The wet dune habitats SD16, SD16/SD17 and SD17 (presented in **Figure 2-3**~~**Figure 2-3**~~) are likely to exhibit high groundwater dependency and are evaluated to represent 'groundwater dependent terrestrial ecosystems' (GWDTE) while the area of identified swamp habitat (S28) is likely to exhibit low groundwater dependency.

2.2.3.4 A total of 27 important plant taxa were identified during the survey including a rare Juncus hybrid (*Juncus x lancastriensis*), dune helleborine (*Epipactus dunensis*), bog pondweed (*Potamogeton polygonifolius*) and unbranched bur-reed (*Sparganium emersum*). Of the habitat affiliations identified, many important flora were particularly affiliated with dune slack, with little overlap between those found in fixed dune grassland verses those found within slack vegetation. In total 15 of the 27 important taxa were affiliated with dune slack, while 15 were affiliated with foredune, semi-fixed and fixed dune vegetation.

2.2.3.5 Overall, the 2025 surveys indicated a similar suite of dune habitats to those recorded in previous surveys of the dunes, with more dune slack habitat in the eastern part of the SSSI associated with the LNR area on the eastern side of Clifton Drive North.

2.2.3.6 The results of the 2025 NVC survey of Lytham St Annes Dunes SSSI/LNR are shown on **Figure 2-3**~~**Figure 2-3**~~ and reported in Appendix D of Volume 3, Annex 3.3 (F3.3.3/F03).

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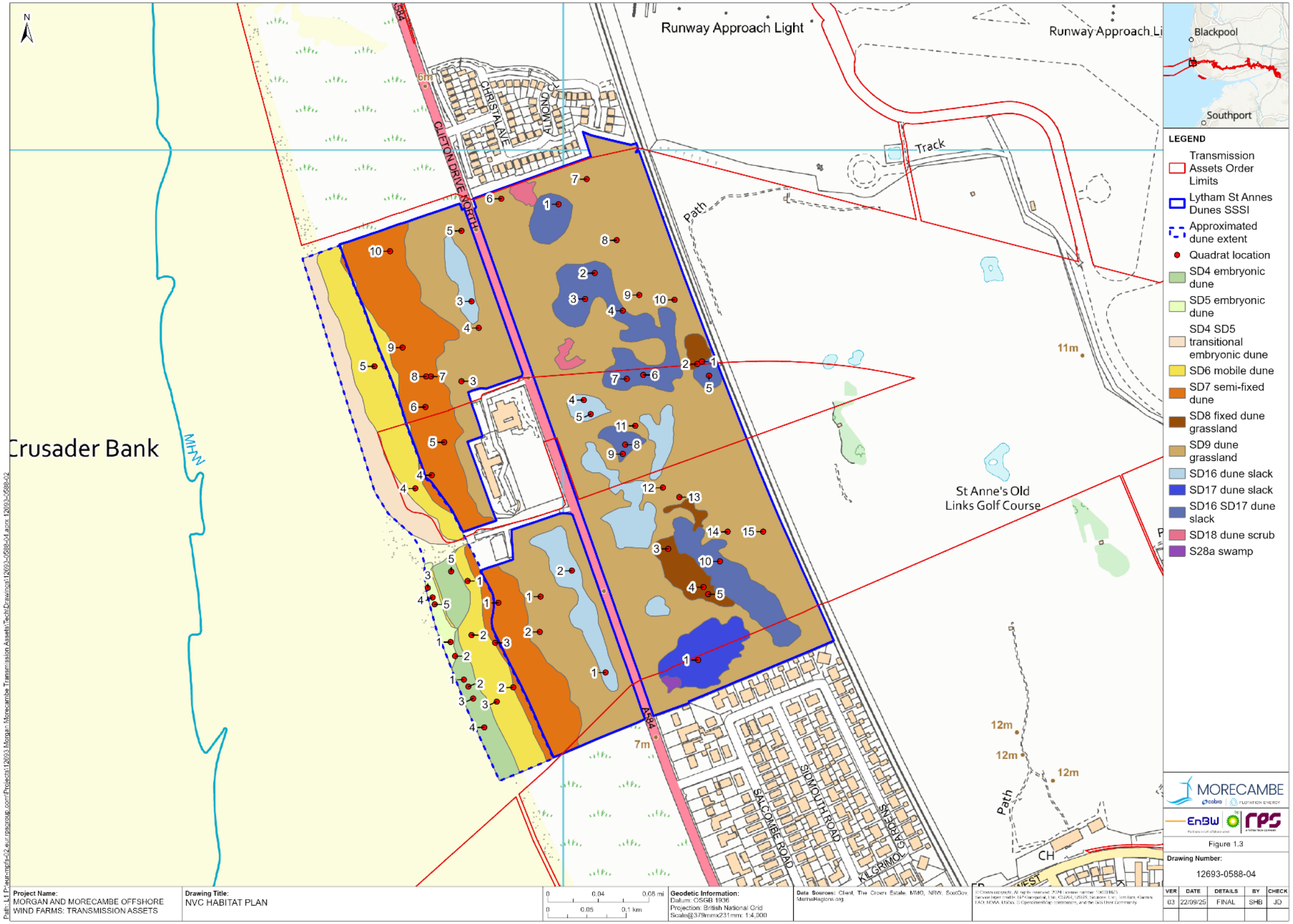

Figure 2-3: Location of dune slack and swamp vegetation communities at Lytham St Annes Dunes SSSI/LNR (2025)

St Annes Old Links Golf Course BHS

2.2.3.7 The 2025 surveys confirmed the findings of the Phase 1 habitat survey undertaken by the Applicants that the BHS is dominated by grassland habitat. The predominant habitat type recorded was dry, acidophilous dune grassland and scrub most often comprising degraded and somewhat enriched forms of SD12 *Carex – Festuca – Agrostis* dune grassland with W23 *Ulex europaeus – Rubus fruticosus* scrub, with one small fragment of remaining dune heath (NVC H11 *Calluna vulgaris – Carex arenaria* heath). Smaller areas of dry SD9 *Ammophila-Arrhenatherum* dune grassland, MG1 *Arrhenatherum* grassland and W24 *Rubus-Holcus* scrub also existed alongside these more calicfugeous habitats. In addition to these semi-natural vegetation types, the remainder of the course comprised a series of heavily managed fairways, tees and greens that were found to be best affiliated with the NVC community MG7 *Lolium* ley.

2.2.3.8 Whilst topogeneous wetland vegetation was observed, this was typically extremely limited in extent and confined to a small number of artificial ponds within the Golf Course. SD15 and SD16 dune slack vegetation with *Salix repens* was recorded across the outskirts of pool margins covering several square metres only, while swamp vegetation comprising planted *Typha* and *Caltha* typically dominated the expanse of pools. A review of aerial imagery indicates that Ponds 1 and 4 within the golf course were substantially modified approximately 20 years ago..

2.2.3.9 The baseline NVC survey and mapping of the St Annes Old Links Golf Course BHS therefore confirmed previous assumptions within the assessment that the habitats within the golf course have been heavily influenced by substantial anthropogenic modifications (including groundwater abstraction) over the past 125 years since the golf course was established on the dunes in 1901. There are some very small areas of marginal pond vegetation (equating to c. 25 square metres in total across the four ponds within the golf course) with affinity to the dune slack community SD15, although the extent to which these small habitat fragments are groundwater dependent given the level of modifications to the surrounding land is unclear, and they are therefore considered to be a 'likely GWDTE'.

The results of the 2025 NVC survey of St Annes Old Links Golf Course within the proposed Order Limits are shown on **Figure 2-4** and reported in Appendix E of Volume 3, Annex 3.3 (F3.3.3/F03).

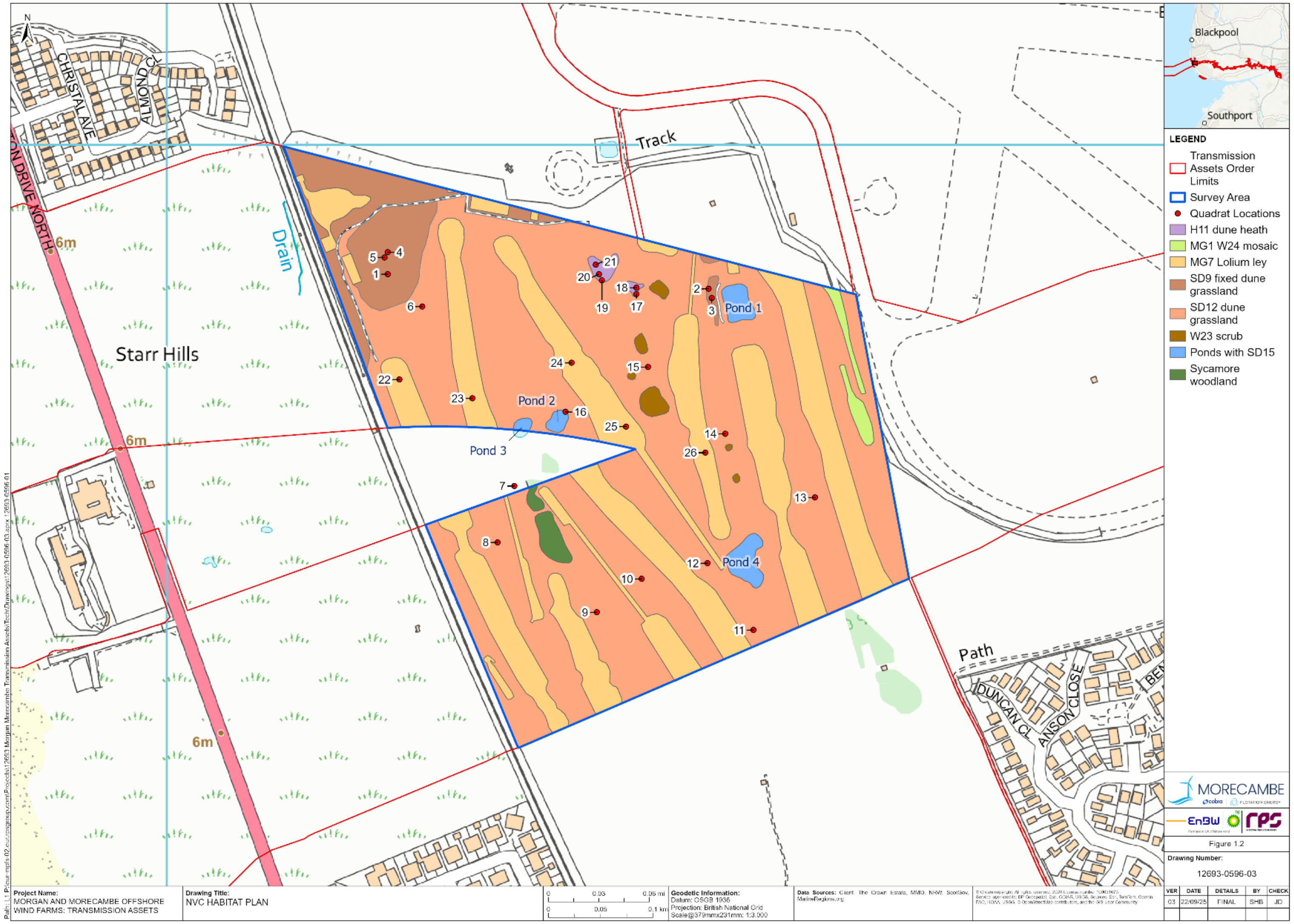

Figure 2-4 Location of dune slack and swamp vegetation communities within the proposed Order Limits at St Annes Old Links Golf Course (2025)

2.3 Geology

2.3.1 Introduction

2.3.1.1 Geological conditions have been delineated based on BGS mapping (1:50,000 Solid and Drift Sheet 74) data shown in **Figure 2-5**~~**Figure 2-5**~~ and **Figure 2-6**~~**Figure 2-6**~~. From the boreholes conducted, LHBH01 and MORGAN_A2_CP01B provided cross sections of strata under the Lytham St Annes Dunes SSSI, with total depths of 39.0 metres (m) and 20.45 m respectively. The location of these boreholes is shown on **Figure 2-7**~~**Figure 2-7**~~. Borehole LHBH01 is located to the east, and borehole MORGAN_A2_CP01B is located to the west, of the study area respectively. Borehole logs are presented in Appendix A.

2.3.1.2 The local stratigraphy is summarised as a conceptual cross section in **Figure 2-9**~~**Figure 2-9**~~. The line of the cross section and topography between the two local boreholes is shown on **Figure 2-8**~~**Figure 2-8**~~. The two boreholes have identified the same lithological layers with the exception of peat and associated clays, which are only observed in borehole LHBH01 to the east of the study area as a layer within the sands.

2.3.2 Made Ground

2.3.2.1 A thin horizon of Made Ground (0.2 m thickness) is observed in borehole LHBH01, representative of the drilling location within the maintenance yard of the Golf Course site.

2.3.3 Superficial deposits

Blown sand deposits

2.3.3.1 Surface superficial deposits in this area are dominated by sand strata. These unconsolidated, granular, deposits form naturally unstable dunes at the coast. Such dunes are formed by blown sands being mobile in character. These dunes become progressively stabilised by vegetation inland until they ultimately thin out upon peat, alluvium or glacial till (Wray et al., 1948).

2.3.3.2 Based on exploratory hole locations, sands were encountered to depths of 14.0 m (LHBH01) and 14.5 m (MORGAN_A2_CP01B). These comprised medium dense (sometimes loose, dense and very dense) fine to coarse sand with variable gravel and cobble content of mixed lithologies.

2.3.3.3 Regional studies of the sands have identified a stratigraphic distinct sand contained between an upper and lower till, as described further below. It is unclear from the two borehole logs whether this so called 'middle sand' has been identified, as till does not appear to be observed above any such sand horizon, however till is observed directly below the sands in both boreholes.

2.3.3.4 For the purposes of interpretation, it is assumed that the upper till has been eroded within the study area with the blown sands resting directly on the middle sands in the west with a peat and clay layer separating them in the east as described next. This is shown on the cross section presented in **Figure 2-9**~~**Figure 2-9**~~. There are no significant lithological differences between the sand layers encountered in the two boreholes.

Peat and clay

2.3.3.5 A single layer of peat (thickness 1.7 m) overlying very soft silty clay (thickness 2.8 m) is identified in borehole LHBH01 to the east of the study area at a depth of between 3.5 m and 8.0 m. No corresponding peat/clay layer was observed in borehole MORGAN_A2_CP01B. The peat was described as comprising two layers - amorphous peat (thickness 0.60 m) overlying pseudo fibrous peat (thickness 1.1 m). The thinning of peat horizons toward the west and the current shoreline is observed regionally (BGS, 2016).

Tidal flat deposits

2.3.3.6 British Geological Survey (BGS) mapping shows a significant extent of comparatively thick tidal flat deposits where they outcrop along the coast and extend inland becoming concealed beneath blown sand deposits.

2.3.3.7 The tidal flat deposits are typically dominated by muds and sand of a marine or estuarine origin. These deposits are commonly overlain by thinner layers of saltmarsh deposits or tidal river/creek deposits.

2.3.3.8 Tidal flat deposits are present to the west of the study area associated with the marine tidal zones and have not been encountered beneath the study area.

Glacial clays

2.3.3.9 These unconsolidated strata predominately comprise cohesive clays with some interspersed sands and gravels horizons. The geological cross section provided on BGS Sheet 74 for Southport (BGS, 1989) and BGS Sheet 75 for Preston (BGS, 2012) shows that the glacial till can be thick, typically being 20 m to 30 m in the Lytham St. Annes area.

2.3.3.10 Regionally, the glacial clays in the local area have been divided into a cohesive 'upper till' and 'lower till'. These till horizons are separated by the granular 'middle sand' horizon. As previously described, it is summarised that the upper till is absent within the study area.

2.3.3.11 Borehole LHBH01 recorded glacial clays from a depth of 14.4 m to 32.7 m. Borehole MORGAN_A2_CP01B did not prove the full depth extent of these strata. Within these two boreholes, these strata are described as brown clay with increasing gravel and cobble content with depth, with the gravel and cobbles being of mudstone and siltstone.

2.3.4 Bedrock

2.3.4.1 The bedrock comprises red mudstones (Singleton Mudstone Member) of the Sidmouth Mudstone Formation of the Mercia Mudstone Group (see Figure 2-6~~Figure 2-6~~).

2.3.4.2 Within borehole LHBH01, which encountered bedrock, the strata are described as weak and very weak reddish brown and greenish grey mudstone including a weathered uppermost horizon (1.9 m thickness) of very stiff reddish brown clay.

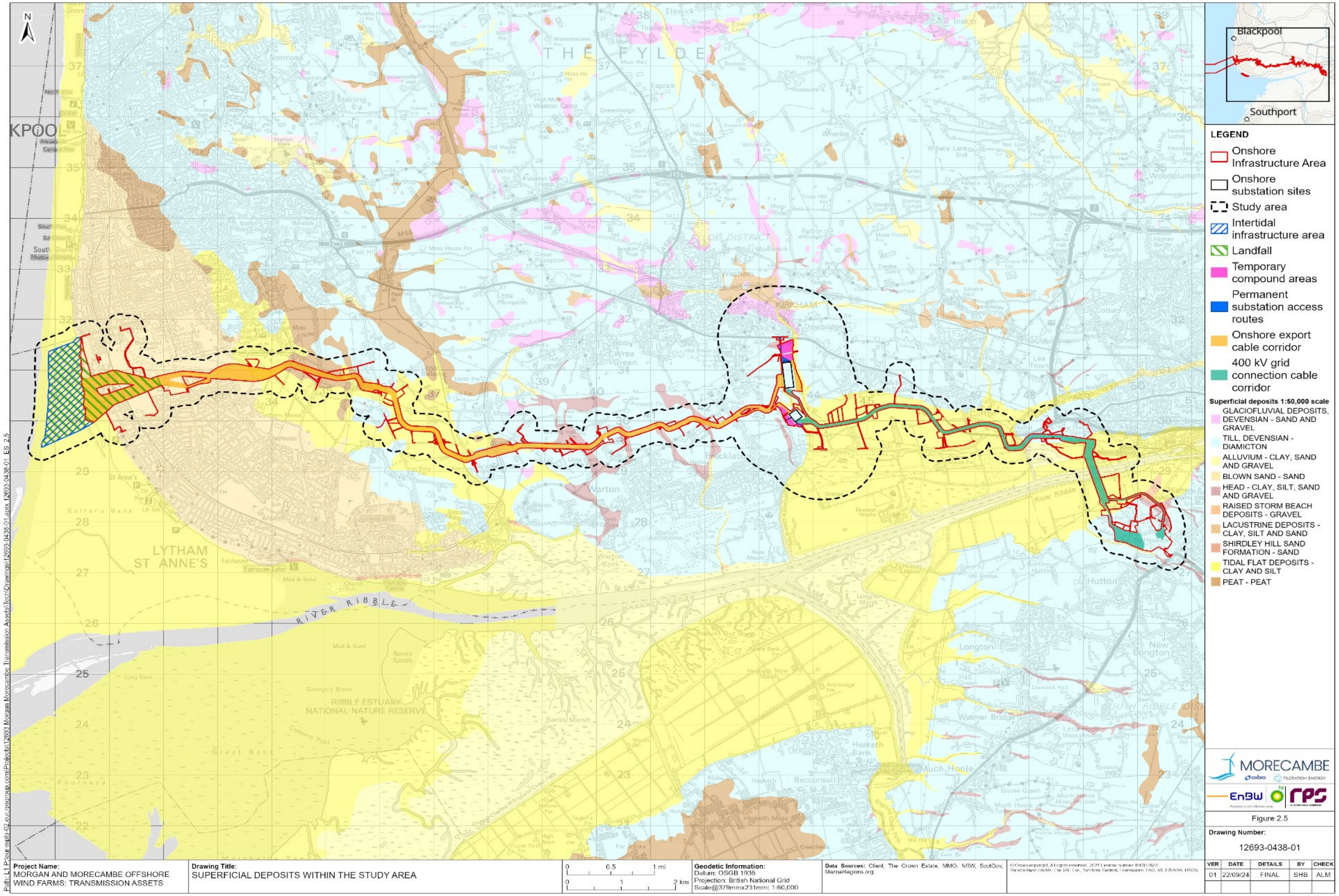

Figure 2-5: Superficial deposits within the region

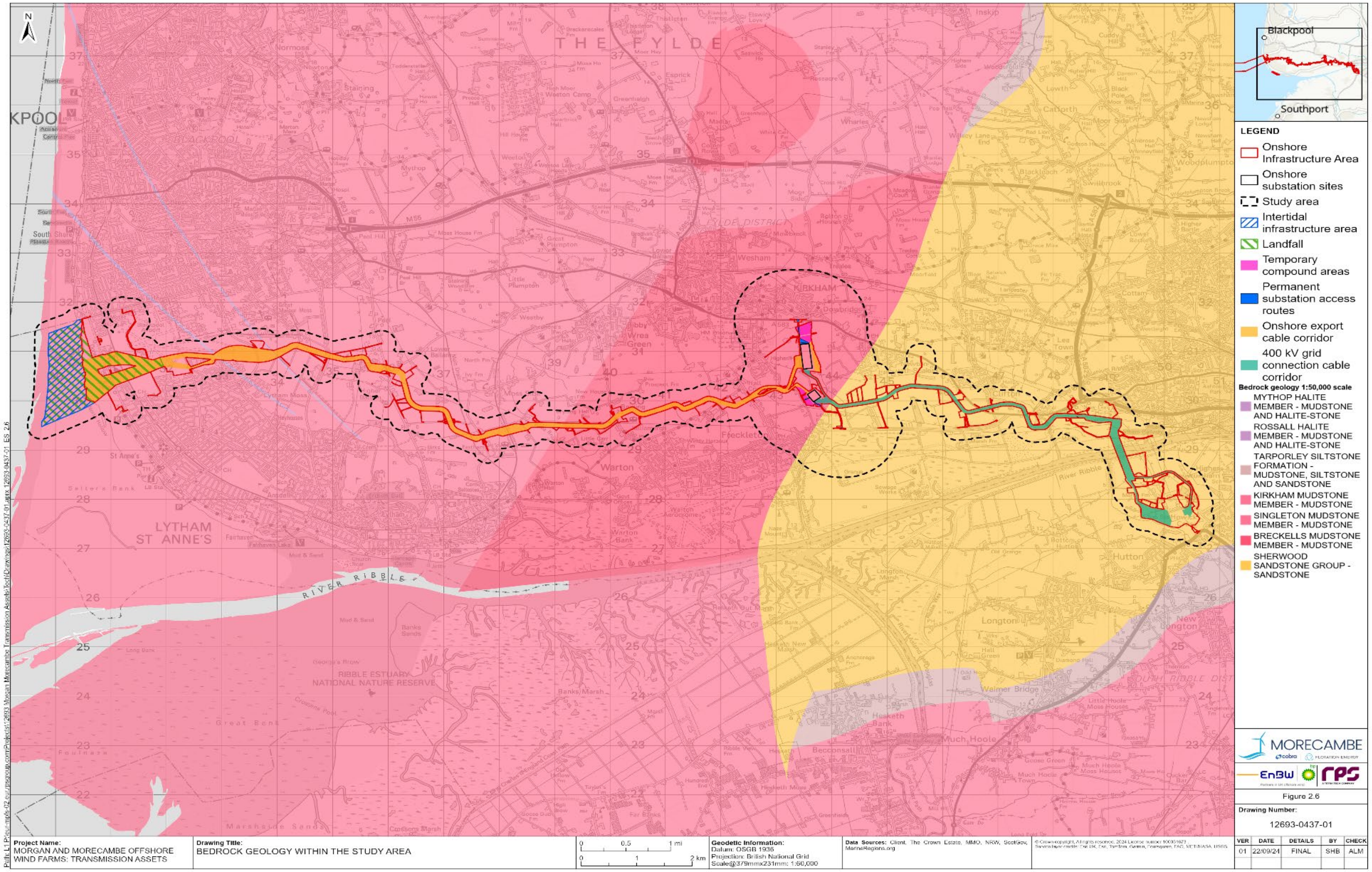

Figure 2-6: Bedrock geology within the region

2.4 Hydrogeology

2.4.1 Introduction

2.4.1.1 This section describes the strata anticipated to be the most significant hydrogeological conceptual model of the study area. These are the blown sands and middle sand, peat with associated clay and bedrock.

Blown sands

2.4.1.2 The blown sand deposits are designated as a Secondary A aquifer. These are unconsolidated granular surface deposits commonly underlain by sand and gravel deposits that may be attributed to the middle sand of the glacial till. Together, these deposits form a locally important groundwater resource from which modest abstractions are made, typically for spray irrigation. Groundwater discharge from these shallow deposits is likely to contribute to flow in surface watercourses and other groundwater dependent features, i.e. dune slacks within the SSSI/LNR and ponds within the Golf Course.

Peat and clay

2.4.1.3 Peat and associate clay bands within the blown sands may be associated with perched shallow water tables where present, or depending on the hydrogeological properties of the peat, comprise relatively saturated strata. Based on the borehole evidence it is not understood to what extent peat and clay layers persist within the blown sands, although they weren't observed within borehole MORGAN_A2_CP01B to the west of the study area.

2.4.1.4 The clay-rich glacial till is classified as a Secondary (undifferentiated) aquifer unit. The presence of groundwater in this clay-rich, low permeability material is likely restricted to localised granular lenses or layers. These granular deposits do not typically form significant groundwater bodies and the glacial till is not considered to be of significant resource value in the study area.

2.4.1.5 The tidal flat deposits and peat are designated as unproductive strata and are not important from a groundwater perspective.

Bedrock

2.4.1.6 The red mudstones of the Mercia Mudstone Group are designated as a Secondary B aquifer and are of little groundwater resource value given that:

- groundwater is uncommon within these mudstone units; and
- the bedrock concealed beneath a thick sequence of low permeability glacial till.

2.4.2 Particle Size Distribution tests

2.4.2.1 Samples of sands were collected during the site investigations for particle size distribution analysis. This provides useful hydrogeological information to assist in the estimation of hydraulic conductivity of the strata using literature empirical relationships. Table 2.1~~Table 2-1~~ and Table 2.2~~Table 2-2~~ present results for samples obtained within the sand deposits.

Table 2~~-~~.1: Particle Size Distribution – borehole LHBH01

Borehole and Sample Depth (m)	Strata	Clay/Silt (%)	Sand (%)	Gravel (%)	Cobbles (%)
LHBH01 2.00 – 2.45	Blown sands	1	99 Fine – 45 Medium – 54 Coarse - 0	0	1
LHBH01 11.00 – 11.50	Blown sands	10	89 Fine – 41 Medium – 47 Coarse - 1	1 Fine – 1 Medium – 0 Coarse - 0	0
LHBH01 13.00 – 13.50	Blown sands	10	88 Fine – 51 Medium – 35 Coarse - 2	2 Fine – 2 Medium – 0 Coarse - 0	0

Table 2~~-~~.2: Particle Size Distribution – boreholes A2_CP01 / A2_CP01B

Borehole and Sample Depth (m)	Strata	Clay/Silt (%)	Sand (%)	Gravel (%)	Cobbles (%)
A2_CP01 8.00 – 8.20	Blown sands	2.9	54.9	42.2	0.0
A2_CP01B 1.20 – 1.65	Blown sands	0.4	99.3	0.3	0.0
A2_CP01B 2.50 – 2.80	Blown sands	0.2	99.8	0	0.0
A2_CP01B 4.50 – 4.80	Blown sands	0.3	58.8	28.4	12.5
A2_CP01B 6.00 – 6.45	Blown sands	9.3	56.9	33.8	0.0
A2_CP01B 9.00 – 9.45	Sand and gravel	1.0	54.0	45.0	0.0

Borehole and Sample Depth (m)	Strata	Clay/Silt (%)	Sand (%)	Gravel (%)	Cobbles (%)
A2_CP01B 11.00 – 11.30	Blown sands	0.9	95.3	3.8	0.0
A2_CP01B 13.00 – 13.30	Blown sands	0.9	86.6	12.5	0.0

2.4.3 Groundwater observations

2.4.3.1 No groundwater observations were made during or following the drilling of borehole MORGAN_A2_CP01B to the west of the study area.

2.4.3.2 During drilling in November 2023, a groundwater strike was recorded within the blown sands in borehole LHBH01 at 1.0 m bgl rising to 0.73 m bgl after 20 minutes. Further groundwater strike was not recorded, however it is acknowledged that water added from 1.2 m bgl to 16 m bgl to assist boring might have obscured groundwater strikes. This borehole is installed with a groundwater monitoring well placed at a depth of between 21.0 m and 30.0 m, within the glacial till. It is therefore not expected to provide useful information on the shallow groundwater conditions of the site.

2.4.3.3 Groundwater elevations were observed weekly in this borehole on four occasions between 30/11/2023 and 21/12/2023. Surprisingly, given the monitoring well depth, this showed groundwater levels at 0.53 m below ground level (9.40 mAOD) on the first round rising to ground level (9.93 mAOD) by the final two rounds. This either suggests a sub artesian piezometric pressure within the low permeability glacial till or, more likely, that the borehole has become flooded by surface water potentially due to a poorly surface sealed installation and given the high rainfall experienced during this period.

2.4.3.4 Consequently, the groundwater elevation data recorded from borehole LHBH01 following installation have not been relied upon for the purposes of developing the site's Hydrogeological Conceptual Model.

~~2.4.3.4~~2.4.3.5 Table 2.4~~Table 2-4~~ presents the groundwater monitoring results from borehole LHBH01.

Table 2~~-~~.3: Groundwater monitoring – borehole LHBH01

Date	Borehole Level (mAOD)	Water Depth (m bgl)	Water Level (mAOD)
30/11/2023	9.93	0.53	9.40
07/12/2023	9.93	0.21	9.72
14/12/2023	9.93	0.00	9.93

Date	Borehole Level (mAOD)	Water Depth (m bgl)	Water Level (mAOD)
21/12/2023	9.93	0.00	9.93

~~2.4.3.5~~2.4.3.6 The BGS GeoIndex lists groundwater observations obtained during a drawdown and recovery pump test conducted in February 1999 on a borehole located within the Golf Course (BGS ID SD33SW154) assumed to be the licensed abstraction (see Section 2.4.4 below). No borehole log is available for review making groundwater level data comparisons difficult. However, the rest level recorded for three days prior to the conduction of the test was recorded as 0.99 m bgl. This is consistent with the water strike observation recorded during the drilling of borehole LHBH01. The drawdown data is presented in Appendix B.

2.4.4 Groundwater abstractions

2.4.4.1 A licensed groundwater abstraction (GWA_01) is located within the Golf Course in close proximity to the SSSI/LNR. Details of this abstraction are provided in **Table 2.4~~Table 2-4~~**. Given the provided NGR is only accurate to 500 m, this approximate location is shown in **Figure 2-7~~Figure 2-7~~**. Following discussions with the Environment Agency, it is understood this abstraction point is representative of a number of abstraction points within the golf course grounds. Following a site visit to the Golf Course on 10 September 2025 it was learnt that a new horizontal groundwater abstraction system has been recently commissioned within the southeastern corner of the site, to replace the two existing borehole. The horizontal borehole, understood to be installed in the manner of a shallow groundwater drain, has a length of approximately 350 metres.

Table 2~~-~~.4: Licenced groundwater abstraction GWA_01 (BGS ID SD33SW154)

Location	Licence No.	Purpose of abstraction	Abstraction volume (m^3)
St Annes Old Links Golf Course NGR 331500, 430500	2671353002	Spray irrigation	Annual volume 11,365 Maximum daily volume: 454.60

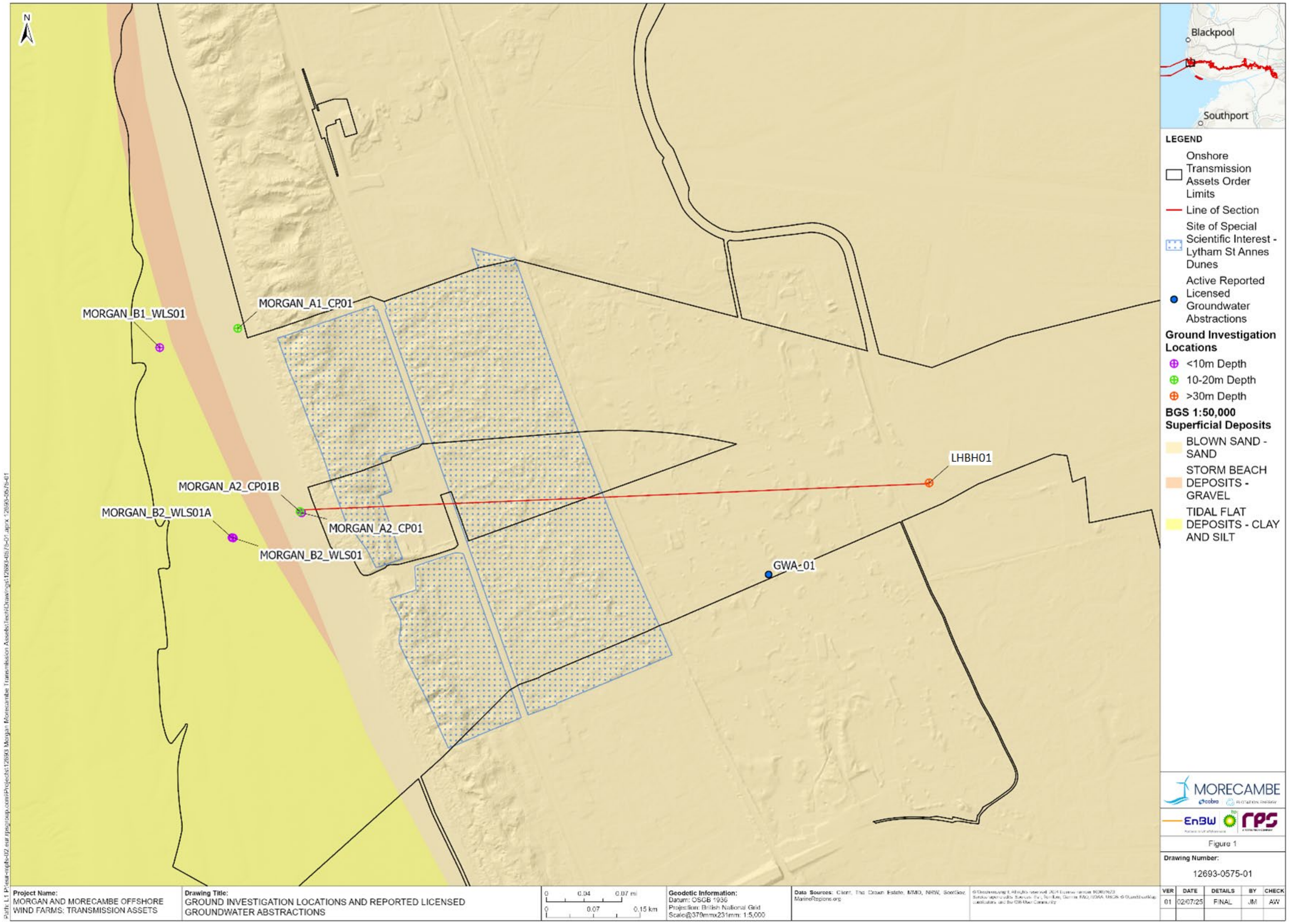

Figure 2-7: Ground investigation locations

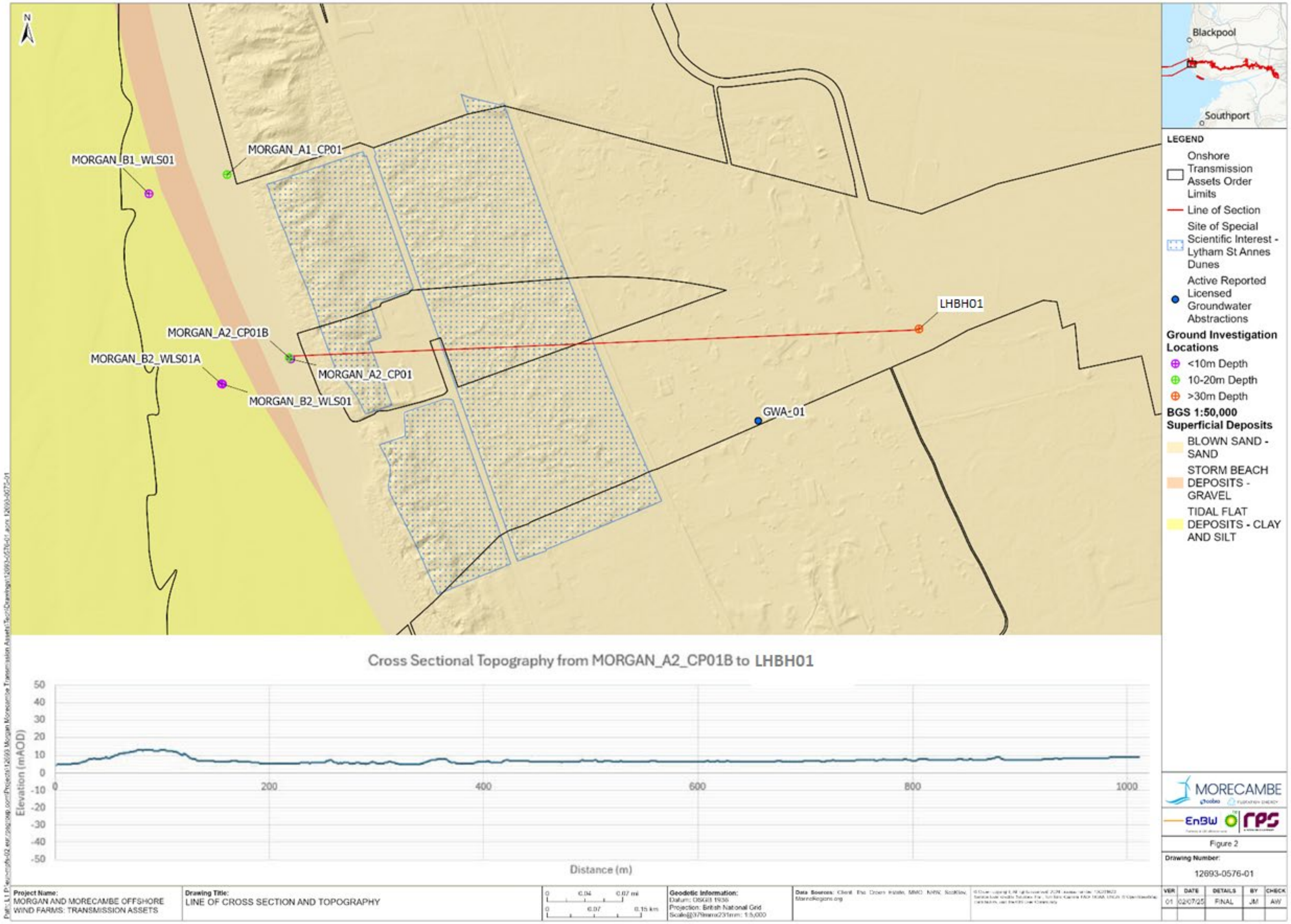

Figure 2-8: Line of cross section and topography

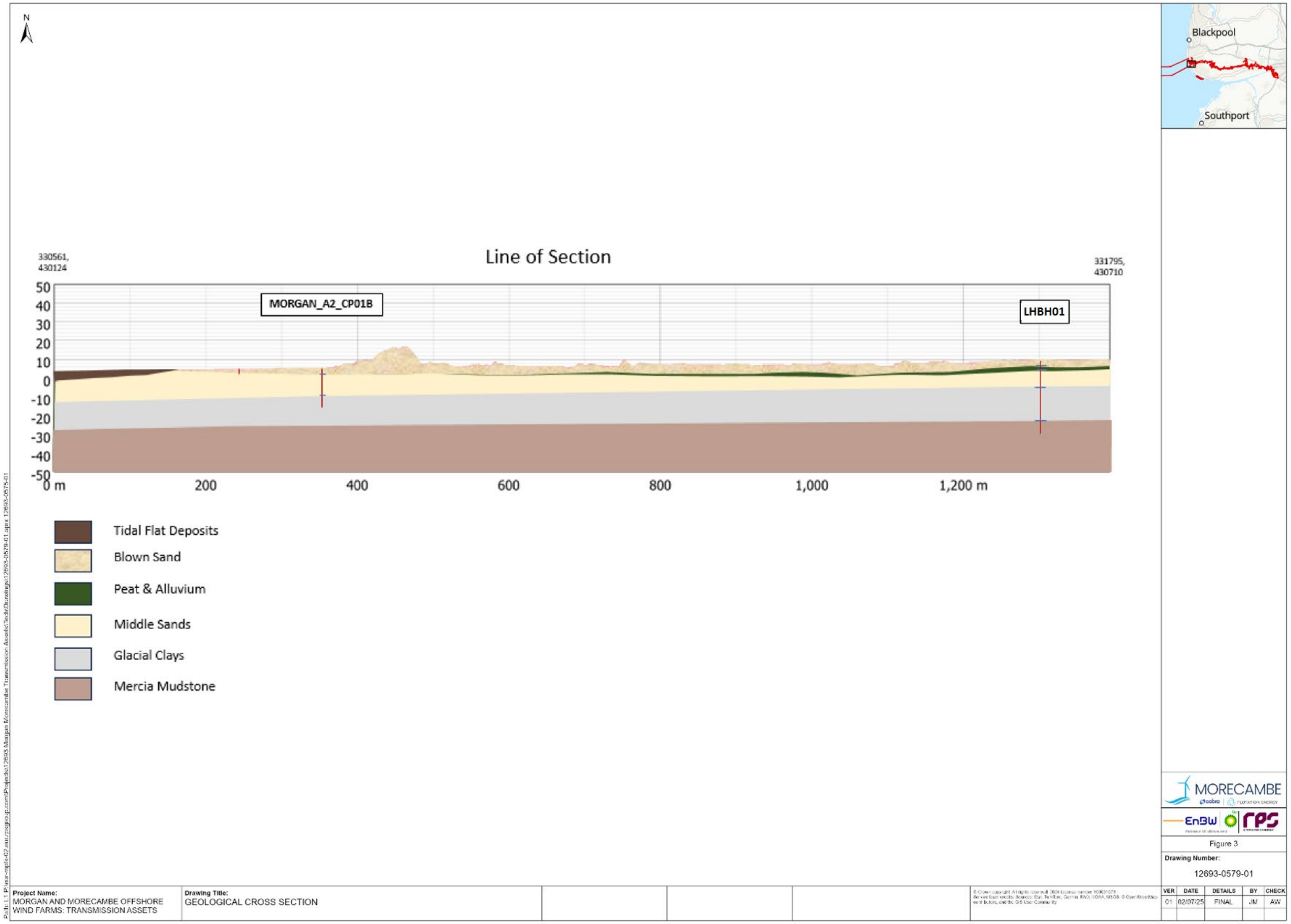

Figure 2-9: Conceptual geological cross section

2.5 Preliminary Hydrogeological Conceptual Model

2.5.1.1 Based on the available data set out in Section 2 of the report, a number of characteristic hydrogeological features of the current local site setting can be identified as follows.

- A relatively simple and well constrained geological sequence is present beneath the SSSI/LNR/BHS site with a likely permeable layer of surficial blown (aeolian) sands resting upon relatively impermeable, cohesive deposits comprising clays over mudstone bedrock. The blown sands strata are conceptually in direct contact with the underlying middle sand other than where separated by peat and associated clay strata. The sands are expected to be capable of supporting a permanent, shallow and laterally persistent groundwater body.
- A shallow (<1 m depth) water table is suggested to be present observed as a water strike during drilling of the borehole LHBH01 and rest observations at the licensed abstraction borehole GWA-01, both situated within the Golf Course site to the east of the SSSI/LNR within the BHS..
- Any laterally continuous water table is expected to be in hydraulic continuity with the sea and fluctuate on the diurnal tidal cycle. A laterally discontinuous water table would be present as perched lenses of groundwater where local hydrogeological conditions support them, i.e., where relatively impermeable strata may be present near the surface, i.e., lenses of peat, which have been identified in the easternmost borehole.
- The surficial blown sands form a dynamic dune system that includes localised depressions (slacks) capable of retaining water under the right conditions of rainfall and surface water run-off and ponding (hydrology) as well as the supporting presence and persistence of a shallow water table and the permeability of shallow soils (hydrogeology), The interrelationship between rainfall and groundwater is not known, i.e., what groundwater recharge is typical following rainfall events or on a seasonal basis, and how the elevation of any water table or tables responds.
- The Golf Course to the east of the SSSI/LNR is licensed by the Environment Agency to abstract groundwater from an unknown number of abstraction points totalling 11,365 m^3 annually with a maximum daily abstraction rate of: 454.60 m^3 (c. 5.26 l/s). The actual abstraction rates and volumes for each abstraction point are not presently known. It is not known to what if any degree the current SSSI/LNR/BHS habitat and supported biodiversity is affected by these abstractions, or whether these abstractions are constrained by the prevailing hydrogeological conditions, i.e., groundwater resources are limited or ephemeral (seasonal).
- The presence, sensitivity and temporary or permanent impact on any water table or tables as a consequence of the project is considered to be the primary risk as this impact has the potential to

adversely affect the current local hydro-ecological ‘steady state’ that supports both the current SSSI/LNR/BHS biodiversity as well as the Golf Course abstractions. Shallower water tables are considered to have a relatively higher sensitivity than deeper ones owing to their increased potential to support dune slack habitats.

3 Outline Hydrogeological Risk Assessment

3.1 Proposed construction activities to be assessed

3.1.1.1 The oHyRA considers the potential risks the temporary construction and permanent location of the offshore export cable may have on the sand dune features of the SSSI/LNR/BHS and abstractions at the Golf Course taking into account the preliminary conceptual hydrogeological understanding of the system.

3.1.1.2 The construction activities to be undertaken at landfall and their respective Maximum Design Scenario are defined in Table 3.13 of Volume 1, Chapter 3: Project description, and are summarised below and form the basis of this assessment:

- Transition Joint Bay (TJB) 10A/10B working area:
    - TJB with six entry pits with area of 450 m^2 to a depth of 6.0 m per entry pit and total working surface area of 2,700 m^2 and permanent infrastructure area of 1,600 m^2.
    - Dry excavations are required for TJB construction, so any groundwater ingress into the excavations will be pumped out and discharge to the local surface water drainage system, i.e. surface water drains or sewers where present or surface watercourses subject to environmental consents or permits
    - TJB located within Blackpool Airport at Work Nos. 10A/10B
- Beach cable exit pits 4A/4B and/or 5A/5B working areas
    - Up to six exit pits, to accommodate up to 4 cable circuits for Morgan OWL and up to 2 cable circuits for Morecambe OWL. Note that there will never be six exit pits located at the beach at the same time, as only one Applicant will carry out construction works at any given time
    - the maximum working area of each exit pit, with or without cofferdams, is up to 875 m^2 per cable circuit. Each working area will be at least 100 m seaward of the Lytham St Annes sand dunes SSSI (CoT44).
    - A temporary cofferdam, approximately 15m by 5m (maximum 75 m^2 may be installed inside the exit pit working area to create a dry and stable working area and prevent the ingress of seawater as the trenchless drilling reaches the exit pit.

- Trenchless drilling techniques to install the offshore export cable beneath from the TJBs / entry pits at Blackpool Airport to the Exit Pits on Lytham St Annes Beach:
    - Six trenchless installation entry pits at the TJBs with a maximum depth of 6.0 m and surface area of 450 m^2 per entry pit and total working surface area of 2,700 m^2.
    - Installation of ducting for 6 cable circuits comprising 18 cables.
    - Drilling at a diameter of 1.4 m
    - Typical permanent cable corridor width: 70 m
    - Minimum drill depth of 10 m
    - Maximum drill depth of 30 m

3.2 Potential risks to be assessed

3.2.1.1 The assessment has considered the potential risk to baseline physical and chemical groundwater conditions in the study area that is posed by the proposed temporary construction activities and presence of the cables. The potential impacts that have been considered with respect each of the activities listed above, are as follows:

- Construction of the TJBs and exit pits:
    - Short-term reduction of groundwater levels due to temporary dewatering of TJB excavation.
    - Impact on groundwater quality through accidental release / emissions of polluting materials or historical contamination.
    - Impact on groundwater quality via surface water runoff from within the construction area, i.e. unmanaged surface drainage
- Installation of the offshore export cables via trenchless techniques:
    - Short term reduction in groundwater levels during drilling.
    - Long term reduction in groundwater levels due to presence of the export cables.
    - Impact on groundwater quality through accidental release / emissions of polluting materials.
    - Impact on groundwater temperature through heat dissipation from the cable.

3.3 General approach for risk assessment

3.3.1.1 The risk assessment provides a largely qualitative assessment of impacts to groundwater levels and, by association, flow, based on the outline conceptual hydrogeological model developed for the site. The qualitative assessment has been augmented by the results of the ground investigation completed to date.

3.3.1.2 The risk assessment considers the likelihood of a pathway existing that could provide a hydraulic connection between the study area and construction activities in the cable route corridor. The likelihood a connection exists are as follows:

- No Pathway;
- Unlikely;
- Possible; and
- Highly Likely.

3.3.1.3 The risk assessment then considers the likely severity that each impact may have on groundwater levels, flow and quality within the study area. Severity is determined semi quantitatively based on the nature of the impacts that can be expected in the immediate vicinity of the construction activity being considered. Based on those localised impacts to groundwater the effect to the identified receptors is evaluated through consideration of the characteristics of the hydrogeological pathway.

3.3.1.4 The incorporated mitigation measures implemented to control risk are included in the assessment and include the management plans that are produced and any additional measures that are identified through the risk assessment process.

3.3.1.5 The risk matrix provided in **Table** 3.1~~**Table** 3-1~~ is then used to determine the overall risk classification for each of the activity evaluated.

Table 3~~-~~.1: Matrix for determining risk ranking classifications

		Severity of consequences if pathway exists				
		Extreme	**Severe**	**Moderate**	**Mild**	**Negligible**
Probability that the hydrogeological pathway exists	**Highly likely**	Extreme Risk	Extreme Risk	Very high risk	High risk	Moderate risk
	Likely	Extreme Risk	Very high risk	High risk	Moderate risk	Low risk
	Possible	Very high risk	High risk	Moderate risk	Low risk	Very low risk
	Unlikely	High risk	Moderate risk	Low risk	Very low risk	Very low risk
	No pathway	Moderate risk	Low risk	Very low risk	Very low risk	No risk

3.3.1.6 The risk matrix, pathway criteria and consequence criteria presented above have been developed specifically for this oHyRA to reflect the receptor being considered. The matrix approach is based on the methodology set out in Volume 1 Chapter 5: Environmental Impact Assessment Methodology (APP-034) and guidance set out in Design Manual for Roads and Bridges (DMRB) LA104 (Highways England et al., 2020).

3.4 Risk assessment

3.4.1.1 This section provides and assessment of the potential risks defined in section 3.2 for the perceived potential impacts associated with the construction of the TJBs and the installation of the offshore export cables via trenchless techniques.

3.4.1 Construction of the TJBs

Short term reduction in groundwater levels due to temporary dewatering of TJB excavation

3.4.1.1 The construction of the TJBs will require dry excavations. Dewatering of the assumed shallow, unconfined aquifer at the study area could result in:

- groundwater levels being locally reduced by up to 6 m due to the proposed depth of the TJB excavation; and
- change in local groundwater flow directions, which could become oriented towards the dewatering activities.

3.4.1.2 In order to assess the impact of the proposed dewatering the calculation of an approximate zone of influence is made using ground investigation data in Section 2 of this report. This indicative calculation does not consider other abstractions within the area, most notably the golf course abstractions (GWA_01).

3.4.1.3 It is acknowledged that the current hydrogeological baseline locally will be influenced by the current and historical groundwater abstractions at the golf course.

3.4.1.4 The zone of influence within the superficial unconfined aquifer likely to be generated by the proposed dewatering can be estimated using Sichardt's formula:

$$R = 3000\ s\ \sqrt{K}$$

R = radius of influence (m)

K = saturated hydraulic conductivity (m/s)

s = drawdown in the borehole

3.4.1.5 Hazen's method has been used to estimate permeability for soil samples using PSD data for samples of blown sands detailed in **Table 2.1**~~Table 2-1~~and **Table 2.2**~~Table 2-2~~.

Hazen's method (CIRIA, 2016) relates to permeability k (in m/s) to the D_{10} particle size (in mm):

$$k = 0.01 \times (D_{10})^2$$

3.4.1.6 The data indicates permeability values for the blown sands ranging from 3.97×10^{-5} m/s to 4.00×10^{-4} m/s. The geometric mean of the permeability values for the blown sands is 1.01×10^{-4} m/s.

3.4.1.7 Using the geometric mean permeability value of 1.01×10^{-4} m/s and a drawdown value of 1 m a radius of influence of 30 m is calculated.

3.4.1.8 The drawdown in the dewatering boreholes is currently unknown however a value of 6 m is the maximum TJB excavation depth requiring dewatering. Based on this and using the above formula a radius of influence of 180 m is calculated.

3.4.1.9 Using a 'factor of safety' of 2, a 360 m zone of influence is well within the total distance from the TJB to the SSSI (measured at approximately 600 m).

3.4.1.10 The estimated Zone of Influence for dewatering at the TJB is shown on ~~Error! Reference source not found..~~**Figure 3-1**.

3.4.1.11 An alternative method proposed by Aravin and Numerov (1953) for unconfined aquifers using a time dependant relationship:

$$R = \sqrt{(1.9K\ s\ t / n)}$$

t = elapsed time

n = effective porosity

3.4.1.12 Using a specific yield value (as an equivalent to effective porosity) of 0.38 for a dune sand (Domenico and Schwartz) a radius of influence of 180 m (as calculated above) is reached for a dewatering duration of 124 days (c. 4 months). This gives some indication of the potential equivalence of duration as well as magnitude of dewatering impact. This will be used to further screen dewatering activities once the expected duration of these construction activities is quantified during detailed design.

3.4.1.13 In reality, a steady state (static) drawdown will be reached where the propagation of a cone of depression will cease due to aquifer recharge. This effect has not been taken into account in these formulae, which means the calculated magnitudes of radius size and duration are pessimistic.

3.4.1.14 Although based on a single observation, the stabilised water strike recorded during drilling of borehole LHBH01 at a depth of 0.73 m bgl suggests a shallow water table is present within the blown sands. It is uncertain whether this water table is continuous beneath the SSSI or present as a discontinuous perched water resting above lower permeability strata.

3.4.1.15 This shallow water table observation is located approximately 300 m from the golf course abstraction, based on the grid reference provided for the location by the Environment Agency. Given the licensed abstraction from the golf course borehole of up to 454.6 m^3 per day, this is suggestive, if far from conclusive, that there is low magnitude of impact on water levels at a smaller distance to the SSSI as the location of the TJB will be located subject to temporary dewatering.

3.4.1.16 It is possible given the proximity of the airport that historical contaminants associated with historical contaminative activities, e.g. from fuel storage, firefighting training, etc. may reside in groundwater beneath the site. Such contaminated groundwater could be drawn into excavations undergoing dewatering. Such contaminated groundwater would require assessment to determine any suitability for disposal or reinjection to ground.

3.4.1.17 Additionally, the migration of such contaminated groundwater as a consequence of dewatering may lead to unacceptable impacts on the existing groundwater abstractions at the Golf Course.

Impact on groundwater quality through accidental release / emissions of polluting materials and historical contamination

3.4.1.18 This short-term temporary risk would be minimised through implementation of standard practices and management during construction. Direct pipe drilling techniques limit the use of drilling fluid and maintain separation of the drill string from the ground as the steel ducting is placed during advancement, which acts as a pipe to bring drilling materials and fluids to the safely to the surface.

3.4.1.19 It is possible given the proximity of the airport that historical contaminants associated with historical contaminative activities, e.g. from fuel storage, firefighting training, etc. may reside in groundwater beneath the site. Such contaminated groundwater could be drawn into excavations undergoing dewatering. Such contaminated groundwater would require assessment to determine any suitability for disposal or reinjection to ground.

3.4.1.20 Additionally, the migration of such contaminated groundwater as a consequence of dewatering may lead to unacceptable impacts on the existing groundwater abstractions at the Golf Course.

Impact on groundwater quality via surface water runoff from within the construction area.

3.4.1.21 Similarly, the uncontrolled loss of surface runoff from the construction areas into excavations could introduce silt laden waters, that potentially contain low concentrations of metals and or hydrocarbons associated with construction vehicles, into the shallow soils and groundwater. This short-term temporary effect would be minimised through implementation of standard practice effective surface water management during construction.

3.4.2 Construction of the Beach Working Areas

3.4.2.1 Trenchless technique exit pits will be located at least 100 m seaward of the western boundary of the Lytham St Annes Dunes SSSI, as secured in Schedule 2A & 2B, Requirement 8 of the Draft DCO (CoT44) as shown on ~~**Error! Reference source not found.**2.~~ Figure 3-2. Six pits are proposed each measuring 15m x 5m in size to be constructed using coffer dams to limit water ingress.

Short term reduction in groundwater levels due to temporary dewatering of exit pit excavations

3.4.2.2 The exit pits are anticipated to be 3 metres deep and only 5 metres in width. Saline water is expected in the saturated coastal sand and gravel deposits where the direct pipe will exit at or around Mean High Water

Springs (MHWS). Freshwater may be encountered if a lens forms above the saline water where the dunes extend above MHWS.

3.4.2.3 Utilising the previous formula for estimating dewatering zones of influence gives a radius of 90 metres, i.e. using the geometric mean permeability value of 1.01 x 10^{-4} m/s and a drawdown value of 3 m a radius of influence of 90 m is calculated. The location of the pits down hydraulic gradient from, and at a lower topographic elevation than, the study area will reduce water table impacts beneath the SSSI from temporary dewatering.

3.4.2.4 Accordingly, the Zone of Influence of dewatering associated with the seaward exit pits is expected to be minimal and the proposed 100 metre separation distance is appropriate to mitigate such effects impacting on the SSSI. This assessment will be refined following further site hydrogeological data gathering following completion of detailed design.

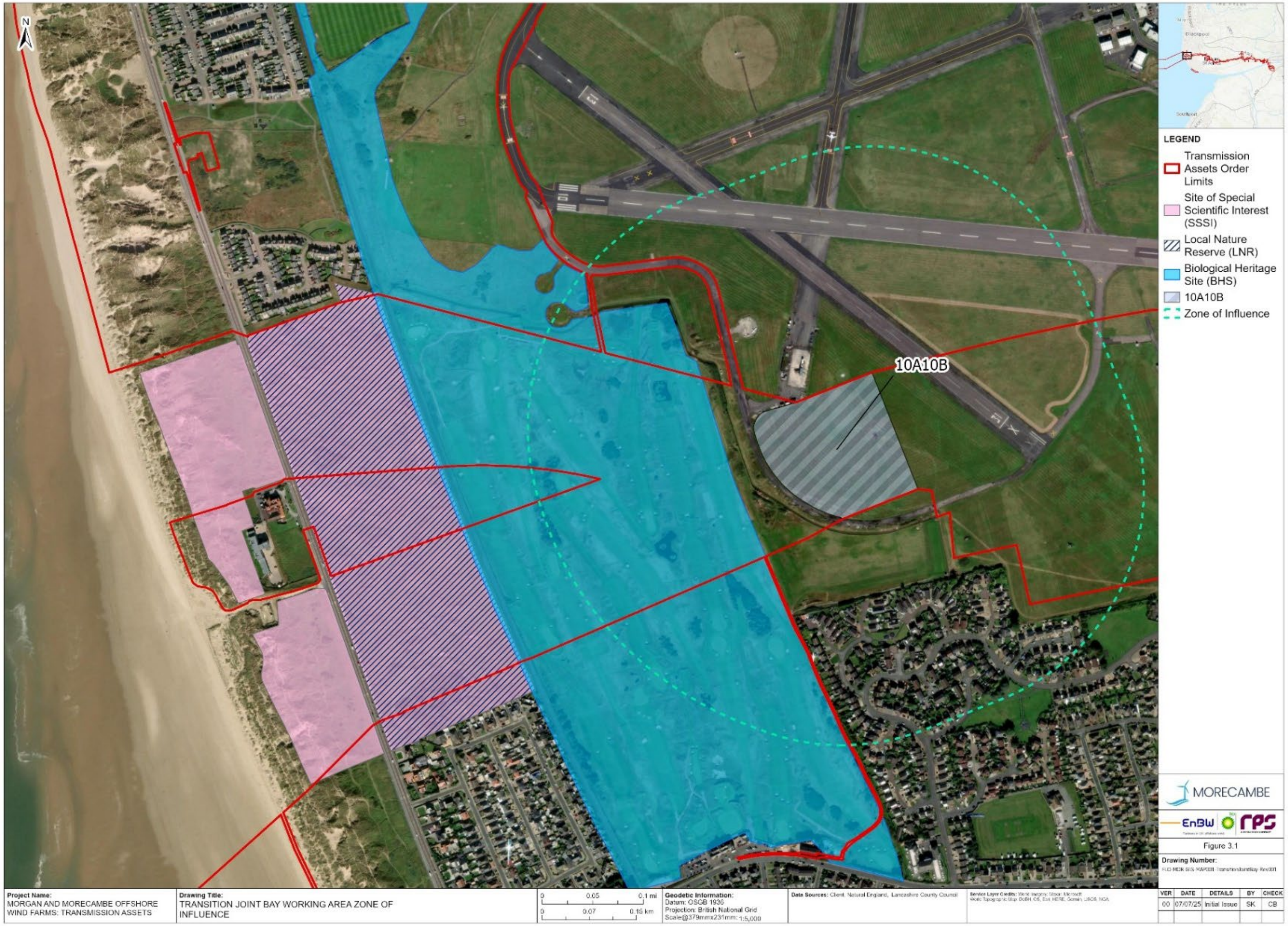

Figure 3-1 TJB working area Zone of Influence

General

-Up to a maximum of 6 exit pits (up to 4 Morgan OWL and up to 2 Morecambe OWL cable circuits) will be located on the beach.

-Exact position of exit pit work area subject to detailed design.

-Each exit pit working area will be in place for up to two weeks within a max 66 months (36 Morgan OWL and 30 Morecambe OWL).

-Not all exit pit working areas will be in place at the same time.

-Only one of the two Applicants will undertake construction activities on the beach at any given time.

Public Access

-No public access inside the exit pit working area when in use.

-When there are trenchless installation activities under the surface of the beach, a managed public access crossing may be implemented between the exit pit working areas and the SSSI.

-Public access to all other areas of the beach will remain unrestricted.

VER	DATE	DETAILS	BY	CHECK
01	20/05/25	Initial Issue	HAH	AG
02	21/08/25	Added Compound 1	HAH	JS

Figure 3-2: Indicative Beach Working Areas for Trenchless Installation Exit Pit and Coffer Dam Works

Impact on groundwater quality through accidental release / emissions of polluting materials and historical contamination

3.4.2.5 The accidental release of polluting substances to ground within the cable route corridor (most notably hydrocarbons used for fuel for construction equipment) could affect local groundwater quality, particularly if lost directly to excavations. Only a small proportion of any product lost to ground could have the potential to enter the dissolved phase and be transported through unsaturated zones to saturated strata at the water table in the underlying aquifer.

3.4.2.6 Most of the product that could be lost to ground will be retained within shallow soils. The volume of hydrocarbons and other polluting substances potentially lost to groundwater will be minimised through the implementation of agreed management plans that control where the highest risk activities are undertaken (i.e., refuelling and storage) and define the necessary emergency response to any such release.

3.4.2.7 Historical contamination is not anticipated to be encountered at the beach so unlikely to represent a significant risk for the exit pit excavation works.

Impact on groundwater quality via surface water runoff from within the construction area.

3.4.2.8 Similarly, the uncontrolled loss of surface runoff from the construction areas into excavations could introduce silt laden waters, that potentially contain low concentrations of metals and or hydrocarbons associated with construction vehicles, into the shallow soils and groundwater. This short-term temporary effect would be minimised through implementation of standard practice effective surface water management during construction.

3.4.3 Assessment of trenchless drilling techniques

Short term reduction in groundwater levels during drilling

3.4.3.1 No groundwater dewatering is required for the installation of the offshore export cables utilising the trenchless installation techniques. These works are therefore considered unlikely to present a risk the neighbouring golf course abstractions.

3.4.3.2 However there is a potential risk to localised shallow perched water tables. These are considered below as they are also considered to be a potential long term risk of the export cable placement.

Long term reduction in groundwater levels due to presence of cable ducting

3.4.3.3 Cable ducting installed during construction will be permanently installed. The emplacement of permanent sub water table cable ducts does have the potential to affect shallow water table(s) should significant, saturated, and hydraulically connected perched water tables be intercepted, which could lead to the localised loss of such features. In the absence of evidence of the presence of a significant, shallow and laterally continuous water table beneath the SSSI/LNR/BHS, such potential risks remain.

3.4.3.4 Such potential risks and effects are anticipated to diminish with depth beneath the study area. A minimum drill depth of 10 metres as detailed in section 3.2 would place the cable duct towards the base of the blown sands strata, anticipated to be approximately 14 metres in thickness. A burial depth of 30 metres would place the cable ducts toward the base of the underlying glacial clays.

3.4.3.5 As described in section 2.4, these low permeability, peaty and clay-rich strata, whilst designated as a Secondary (undifferentiated) aquifer unit, contain groundwater restricted to localised granular lenses or layers. Placing the cable duct within these strata would not be expected to have a significant impact on shallow water tables within the permeable blown sands.

Impact on groundwater quality through accidental release / emissions of polluting materials or historical contamination

3.4.3.6 As is the case for the construction works associated with the TJB, this short-term temporary risk would be minimised through implementation of standard practices and management during construction. Direct pipe drilling techniques limit the use of drilling fluid and maintain separation of the drill string from the ground as the steel ducting is placed during advancement, which acts as a pipe to bring drilling materials and fluids to the safely to the surface.

Impact on groundwater temperature through operational cable heating

3.4.3.7 The effects of potential cable heating are presently unquantified due to the requirement for detail design input to cable spacing configuration, burial depths and temperature profiles.

3.4.3.8 The offshore export cables will be permanently installed in direct pipe ducts beneath the SSSI/LNR/BHS. The installation of offshore export cables has the potential to generate heat that dissipates naturally to the surrounding ground during power transmission.

3.4.3.9 The levels of heat loss and dissipation of heat through the soil can only be determined once further details of the cable voltage, soil structure (including its thermal properties) and the final engineering design are known. This will include consideration of the cable depth (in terms of the receptor that may be affected).

3.4.3.10 However, the offshore cables themselves will consist of copper or aluminium conductors wrapped with various materials for insulation, protection, and sealing. Once installed, the electrical cables must be suitably spaced out in order to minimise the mutual heating effect of one cable circuit on another, this enables the cables to effectively carry the large power volumes required without overheating and damaging the cable.

3.4.3.11 It is therefore likely that any heat dissipation will be localised and confined to the areas immediately surrounding the offshore cables. On this basis, it is unlikely that there will be any significant impact on the quality or temperature of groundwater.

3.4.3.12 Thermal conductivity measurements have been undertaken on samples recovered from borehole BHLH01. These are presented in Appendix C Appendix C. For samples of sands below the design burial depth of 10 metres, thermal conductivity values range from 0.282-2.340 W/mK. These values compare well with data presented by Dalla Santa et al. (2019) for the thermal conductivity of dry medium sand of between 0.15 and 0.90 and wet medium sand of between 1.00 and 2.60 W/mK., and for wet silty sand of between 1.20 and 2.25 W/mK.

3.4.3.13 Given a minimum cable burial depth of 10m below ground level and likely position within the saturated zone of the sand deposits, horizontal groundwater flow within these permeable strata will also act to dissipate heating effects around the cables and further limit vertical migration of heat.

3.5 Risk assessment summary

3.5.1.1 Following the assessment of potential temporary and permanent risks, associated with the installation and long-term presence of the export cable on the identified receptors, risk rankings have been determined. These assessments are shown in **Table 3.2**~~**Table 3-2**~~ and **Table 3.3**~~**Table 3-3**~~ together with the embedded mitigation measures considered and the relative quantification of both the likelihood of effect and the potential severity of the consequence.

Table 3~~-~~.2: Outcome of risk assessment of the TJB working area and Beach working area

Activity	Receptor	Potential impacts to groundwater	Effect	Embedded mitigation	Likelihood	Severity	Initial Risk Ranking	Secondary Mitigation Options	Likelihood	Severity	Residual Risk Ranking
Construction of the TJBs	BHS	Short-term reduction of groundwater levels due to temporary dewatering of TJB excavation	Increased vulnerability of dune slacks hydrology due to reducing dependency on shallow water table	Locating TBJ excavation outside of BHS. Small area requiring dewatering Outline Code of Construction Practice (APP-193) Outline Surface and Groundwater Management Plan (APP-202)	Possible	Moderate (temporary affect and limited in aerial extent. High sensitivity of BHS).	Moderate Risk	Refinement of options will be developed as part of detailed HyRA. Possible options include: Potential for returning abstracted clean groundwater to ground as infiltration Possible use of shuttered sheet piling to limit groundwater ingress Undertaking works during periods of reduced sensitivity, i.e. when water tables (where present) are lowest	Unlikely	Moderate (temporary affect and limited in aerial extent. High sensitivity of BHS).	Low risk
	SSSI/LNR/BHS	Impact on groundwater quality through accidental release / emissions of polluting materials and surface water runoff from with the construction area.	Accidental release of polluting material into excavations and migration into saturated strata	Use of Direct Pipe trenchless technique (CoT44) with low disturbance and reduced use and risk from drilling fluids. Outline Code of Construction Practice (APP-193) Outline Pollution Prevention Plan (APP-197) Outline Surface and Groundwater Management Plan (APP-202) Outline Bentonite Breakout Plan (APP-206)	Unlikely	Negligible	Very Low Risk	Non required	-	-	-
	Golf Course groundwater abstractions	Short-term reduction of groundwater levels due to temporary dewatering of TJB excavation.	Reducing availability of groundwater and rates of abstraction from boreholes	Small area requiring dewatering Outline Code of Construction Practice (APP-193) Outline Surface and Groundwater Management Plan (APP-202)	Possible	Moderate (temporary affect and limited in aerial extent. Moderate sensitivity of abstractions)	Moderate Risk	Refinement of options will be developed as part of detailed HyRA following updated hydrogeological conceptual model. Possible options include: Returning abstracted clean groundwater to ground as infiltration Possible use of shuttered sheet piling to limit groundwater ingress Utilising alternative mains water supply	Possible	Mild (temporary affect and limited in aerial extent. Moderate sensitivity of abstractions)	Low Risk

Activity	Receptor	Potential impacts to groundwater	Effect	Embedded mitigation	Likelihood	Severity	Initial Risk Ranking	Secondary Mitigation Options	Likelihood	Severity	Residual Risk Ranking
		Impact on groundwater quality through accidental release / emissions of polluting materials surface water runoff from with the construction areas (TJB working areas)	Accidental release of polluting material into excavations and migration into saturated strata causing pollution from hazardous liquids including fuels hydrocarbons), hydraulic fluids and oils/grease associated with construction	Use of Direct Pipe trenchless technique (CoT 44) with low disturbance and reduced use and risk from drilling fluids. Outline Code of Construction Practice (APP-193)) Outline Pollution Prevention Plan (APP-197) Outline Surface and Groundwater Management Plan (APP-202) Outline Bentonite Breakout Plan (APP-206)	Unlikely	Negligible	Very Low Risk	None required.	-	-	-
		Impact on groundwater quality through mobilisation of historical contamination	Mobilisation of historically contaminated groundwater associated with the airport towards Golf Course abstractions.	Undertaking groundwater monitoring prior to and during dewatering from appropriately located and installed groundwater monitoring wells to identify and/or demonstrate no additional impacts on groundwater quality at the boundary to the Golf Course.	Possible	Moderate	Moderate Risk	Recovering contaminated groundwater for appropriate treatment and/or disposal as wastewater in line with the Outline Pollution Prevention Plan (APP-197)	Unlikely	Moderate	Low Risk
Beach working area (exit pit)	SSSI/LNR/BHS Golf Course groundwater abstraction	Short-term reduction of groundwater levels due to temporary dewatering of exit pit excavation.	Increased vulnerability of dune slacks hydrology due to reducing dependency on shallow water table Reducing availability of groundwater and rates of abstraction from boreholes	Small area requiring dewatering Use of cofferdam sheet piling to limit groundwater ingress Outline Code of Construction Practice (APP-193) Outline Surface and Groundwater Management Plan (APP-202)	Unlikely	Mild (temporary affect and limited in aerial extent. Moderate sensitivity of SSSI/LNR/BHS and abstraction)	Very Low Risk	None required.	-	-	-

Activity	Receptor	Potential impacts to groundwater	Effect	Embedded mitigation	Likelihood	Severity	Initial Risk Ranking	Secondary Mitigation Options	Likelihood	Severity	Residual Risk Ranking
		Impact on groundwater quality through accidental release / emissions of polluting materials surface water runoff from with the construction areas (exit pits working areas)	Accidental release of polluting material into excavations and migration into saturated strata causing pollution from hazardous liquids including fuels hydrocarbons), hydraulic fluids and oils/grease associated with construction	Use of Direct Pipe trenchless technique (CoT 44) with low disturbance and reduced use and risk from drilling fluids. Outline Code of Construction Practice (APP-193) Outline Pollution Prevention Plan (APP-197) Outline Surface and Groundwater Management Plan (APP-202) Outline Bentonite Breakout Plan (APP-206)	Unlikely	Negligible	Very Low Risk	None required.	-	-	-

Table 3~~-~~.3 Outcome of risk assessment of the installation of the export cable via trenchless techniques and the presence of the export cable during operation

Activity	Receptor	Potential impacts to groundwater	Effect	Embedded mitigation	Likelihood	Severity	Initial Risk Ranking	Secondary Mitigation Options	Likelihood	Severity	Residual Risk Ranking
Installation of the offshore export cables via trenchless techniques	SSSI/LNR/BHS	Short term reduction in groundwater levels during drilling	Lowering of water table(s) supporting dune slacks due to dewatering	Use of Direct Pipe trenchless technique (CoT44) with low disturbance and reduced use and risk from drilling fluids Outline Code of Construction Practice (Surface and Groundwater Management Plan (APP-202).	Unlikely due to no active dewatering required	Moderate (temporary affect and limited in aerial extent. High sensitivity of SSSI)	Low Risk	Refinement of options will be developed as part of detailed HyRA following updated hydrogeological conceptual model. This may include placement of offshore export cable within low permeability glacial clays to avoid water tables where present.	No pathway	Moderate (temporary affect and limited in aerial extent. High sensitivity of SSSI)	Very low risk
		Long term reduction in groundwater levels due to presence of cable ducting	Lowering of water table(s) in hydraulic continuity with dune slacks where support of perched, shallow water tables is reduced, e.g. due to perforation of low permeability strata within blown sands.	Placement of onshore export cable beneath SSSI/LNR/BHS. Direct Pipe techniques under SSSI (CoT44)	Possible	Severe (permanent affect but limited in aerial extent. High sensitivity of SSSI.)	High Risk	Refinement of options will be developed as part of detailed HyRA following updated hydrogeological conceptual model. This may include placement of offshore export cable within low permeability glacial clays to avoid water tables where present.	No pathway	Severe (permanent affect but limited in aerial extent. High sensitivity of SSSI.)	Low risk
		Impact on groundwater quality through accidental release / emissions of polluting materials during drilling	Accidental release of polluting material into excavations and migration into saturated strata causing pollution from hazardous liquids including fuels (hydrocarbons), hydraulic / drilling fluids and oils/grease associated with construction	Use of Direct Pipe trenchless (CoT44) technique with low disturbance and reduced use and risk from drilling fluids Outline Code of Construction Practice (APP-193) Outline Pollution Prevention Plan (APP-197) Outline Surface and Groundwater Management Plan (APP-202) Outline Bentonite Breakout Plan (APP-206)	Unlikely	Negligible	Very Low Risk	None required	-	-	-

Activity	Receptor	Potential impacts to groundwater	Effect	Embedded mitigation	Likelihood	Severity	Initial Risk Ranking	Secondary Mitigation Options	Likelihood	Severity	Residual Risk Ranking
		Impact on groundwater temperature through operational cable heating	Heating of shallow groundwater and dune slacks	Cables wrapped with various materials for insulation Cables cemented within steel ducting by bentonite. Cables will be suitably spaced out to minimise the mutual heating effect. ~~Low thermal conductivity of dry sand~~Cables placed in highly permeable saturated sands at least 10 mbGL. Groundwater advection will assist seaward dissipation of heat horizontally reducing potential for vertical heating.	Possible	Mild (ephemeral affect but limited in aerial extent. High sensitivity of SSSI.)	Low Risk	Placement of offshore export cable within low permeability glacial clays to avoid water tables where present.	Unlikely	Moderate (ephemeral affect but limited in aerial extent. High sensitivity of SSSI.)	Very low risk
	Golf Course groundwater abstractions	Short term reduction in groundwater levels during drilling	Lowering of water tables reducing rates of abstraction from boreholes	Outline Code of Construction Practice (APP-193) Outline Surface and Groundwater Management Plan (APP-202)	Unlikely	Mild (temporary affect and limited in aerial extent. Moderate sensitivity of abstractions)	Very Low Risk	None required	-	-	-
		Impact on groundwater quality through accidental release / emissions of polluting materials during drilling	Accidental release of polluting material into excavations and migration into saturated strata causing pollution from hazardous liquids including fuels (hydrocarbons), hydraulic / drilling fluids and oils/grease associated with construction	Use of Direct Pipe trenchless technique (CoT44) with low disturbance and reduced use and risk from drilling fluids Outline Code of Construction Practice (APP-193) Outline Pollution Prevention Plan (APP-197) Surface and Groundwater Management Plan (APP-202) Outline Bentonite Breakout Plan (APP-206)	Unlikely	Mild (temporary affect and limited in aerial extent. Moderate sensitivity of abstractions)	Very Low Risk	None required	-	-	-

Activity	Receptor	Potential impacts to groundwater	Effect	Embedded mitigation	Likelihood	Severity	Initial Risk Ranking	Secondary Mitigation Options	Likelihood	Severity	Residual Risk Ranking
		Long term reduction in groundwater levels due to presence of cable ducting	Lowering of water tables reducing rates of abstraction from boreholes	None.	No pathway (localised affects not affecting abstraction boreholes)	Negligible (permanent affect but highly limited in aerial extent. Moderate sensitivity of abstractions	No Risk	None required	-	-	-
		Impact on groundwater temperature through operational cable heating	Heating of shallow groundwater abstracted from boreholes	Cables wrapped with various materials for insulation Cables cemented within steel ducting by bentonite. Cables will be suitably spaced out to minimise the mutual heating effect. ~~Low thermal conductivity of dry sand~~Cables placed in highly permeable saturated sands. Groundwater advection will assist seaward dissipation of heat horizontally reducing potential for vertical heating.	Unlikely	Negligible (ephemeral affect but highly limited in aerial extent. Low sensitivity of abstractions due to small proportion of groundwater intake affected)	Very Low Risk	None required.	-	-	-

4 Risk Management Measures

4.1.1.1 The outline HyRA assessment has taken into account secondary mitigation options to identify risk reduction potential. The scope of secondary mitigation options will be finalised and agreed following detailed design. This section of the detailed HyRA will include refined options following an updated hydrogeological conceptual model.

5 Next Steps

5.1.1.1 The Applicants have made a commitment (CoT128 of Volume 1, Annex 5.3: Commitments Register of the ES (F 1.5.3/F03)) to undertake detailed hydrogeological risk assessment(s) in relation to the crossing of the Lytham St Annes Dunes SSSI~~.~~ and St Annes Old Links Golf Course. The hydrogeological risk assessment will be informed by additional ground investigation information(s~~), where necessary and practicable.~~). The scope of the ground investigation and groundwater monitoring will be agreed with the Environment Agency and Natural England. These assessment(s) will be used to inform the detailed site-specific crossing design(s) for the installation of the offshore export cables beneath Lytham St Annes Dunes SSSI and St Annes Old Links Golf Course. This is secured by Requirement 8 of Schedules 2A and 2B of the draft DCO (REP1-008).

5.1.1.2 Information has been requested from the St Annes Old Links Golf Club regarding the groundwater abstractions to inform the refinement of the hydrogeological conceptual model. This information will be added to the detailed HyRA(s) (subject to data sharing agreements]) and is likely to include abstraction borehole logs and associated water table elevation observations, historical and current abstraction regimes including timings - both diurnal and seasonal - and rates of abstraction, uses of water whether consumptive or non-consumptive and understanding of any on any physical or temporal limitations or constraints on abstraction.

5.1.1.3 ~~Depending on the required depth of burial of the export cables, further~~Additional ground information ~~may~~will be ~~required~~undertaken to establish site specific groundwater conditions below the Lytham St Annes SSSI/LNR/BHS site and St Annes Old Links Golf Course including monitoring to establish a suitable hydrogeological conditions baseline to include contamination testing. The scope of the ground investigation and groundwater monitoring will be agreed with the Environment Agency and Natural England. This could comprise suitably located boreholes drilled to the depth of the underlying Mercia Mudstone Formation bedrock strata with groundwater monitoring well installations at an appropriate depth and screen lengths to facilitate detection of a shallow water table and observations of variation in elevation as well as the recovery of groundwater samples for laboratory analysis.

6 Conclusions

6.1.1.1 The installation of the export cable using trenchless drilling techniques beneath the sand dunes at Lytham St Annes Dunes SSSI/LNR and St Annes Old Links Golf Course & Blackpool South Rail Line BHS, has the potential to affect groundwater in terms of its quality and water levels. This is due to both temporary effects associated with the construction within the TJB working areas and exit pit area on the beach, primarily involving dewatering of the excavations, the installation of the export cable using trenchless techniques and long term effects associated with the presence of the export cable ducts beneath the sensitive ecological sites, known to include dune slack features.

6.1.1.2 The site has a relatively simple hydrogeological conceptual model, supported by boreholes advanced to the west and east of the dune system. These proved the thickness of sands deposits making up the blown sand dunes and underlying sand strata to be 14 metres in thickness. These dune deposits are expected to support a licensed groundwater abstraction regime for the Golf Course to the east of the dunes and west of the proposed TJB working area. It is not currently known the location, depth, rate and timings of these abstractions. In addition to these abstractions, further evidence for a shallow water table within one metre of the surface was observed to the east of the dunes. It is not known whether this is laterally extensive further to the west. Beneath the sands are cohesive strata comprising glacial clay overlying mudstone bedrock. Neither of these strata are anticipated to contain hydrogeologically significant groundwater.

6.1.1.3 The principal temporary effects of dewatering identified are on the assumed laterally extensive shallow water table where temporary lowering is predicted. An assessment on the potential radius of influence of this activity estimated a distance of approximately 260 metres beyond which drawdown may be considered negligible. This places the ecological sites on the sand dunes outside of this distance suggesting a moderate risk of effects on the water table if the cable ducts were located at least 10 meters below ground level or a low risk following secondary mitigation options including shuttering of pits and re-infiltration of abstracted groundwater. A similar assessment for the exit pit dewatering concluded the proposed 100 metre distance from the SSSI would be sufficient to avoid significant impact.

6.1.1.4 The principal long term effects of dewatering identified is the lowering of water table(s) in hydraulic continuity with dune slacks where support of perched, shallow water tables is reduced, e.g. due to perforation of low permeability strata within blown sands. Given the current uncertainty on shallow, potentially perched groundwater conditions within the sand dune system, this effect is currently assessed as a high risk due the sensitivity of dune slack features to groundwater where the cable duct is placed within the blown sands deposits and a low risk where the cable duct is placed below the blown sands within the low permeability glacial clays.

6.1.1.5 The risk assessment of heating of groundwater where present requires further assessment following detailed design, but currently is assessed to represent a low risk to the dune system and a very low risk on the golf course abstractions given the cable duct's depth and the limited zone of effect expected.

6.1.1.6 Impact on groundwater quality through accidental release of polluting materials and surface water runoff from with the construction area and the trenchless drilling methodology is expected to have a very low risk given the management of these works to avoid pollution and effectively manage surface water runoff. These management measures are set out in the Outline Pollution Prevention Plan (J1.4) and include measures for the use and storage of potentially polluting materials (e.g. storage of fuels within bunds with appropriate capacity and impermeable bases) and the control of surface water runoff. There is a possibility that pre-existing groundwater contamination associated with the airport may enter excavations or licensed abstractions during dewatering of the TJB. Groundwater testing prior to dewatering works being undertaken will allow this risk to be assessed and potential mitigation measures to be introduced as required. These may be the need to recover contaminated groundwater for treatment and/or disposal as wastewater.

6.1.1.7 The risk assessments will be revised within an updated hydrogeological risk assessment to be undertaken following completion of detailed engineering design that will be agreed with the relevant consultees and stakeholders.

7 References

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Wray, D.A., Cope, F.W., Jones, R.C.B., Tonks, L.H. (1948) The geology of Southport and Formby with contributions by LH TONKS and RCB Jones): Explanation of sheets 74 and 83. DF074+83.

Appendix A Borehole Logs

Borehole MORGAN_A2_CP01B

Location ID corrected from previous ID CP+RC

CENTRAL ALLIANCE
GROUND ENGINEERING TECHNICAL SERVICES

Alliance House,
3A South Park Way
Wakefield 41 Business Park
Wakefield WF2 0XJ
+44(0)1924 229889
www.central-alliance.co.uk

Start Date:	23/10/2023	Checked:	DR
End Date	01/11/2023	Approved:	JP

Location ID

LHBH01

FINAL

Methodology & Plant

Depth (m)	Method	Plant Used
0.00 - 1.00	Inspection Pit	Hand Tools
1.00 - 21.70	Cable Percussion Boring	Dando 3000
21.70 - 39.00	Rotary Coring	Fraste ML

Log Type

Combined Borehole

Scale: 1:50

Sheet 1 of 4

Project No:	**2372506**
Name:	**Morgan St Annes GI**
Location:	**Lytham St Annes**
Client:	**EnBW**

Location Details

Easting:	**331757.01**	Northing:	**430646.37**
Elevation:	**9.93mAOD**	Final Depth:	**39.00m**
Logged By:	**RW**	Grid System:	**OSGB**
Orientation:	**N/A**	Inclination:	**90°**

Strata Description	Depth (m) (Stratum Thickness)	Reduced Level (mAOD)	Hole Ø (mm) Depth (m)	Casing Ø (mm) Depth (m)	Water Level (m)
MADE GROUND: Blackish brown slightly clayey slightly gravelly fine to medium SAND with frequent roots and rootlets. Gravel is angular fine to coarse brick.	(0.20) 0.20	9.73			
Medium dense light orangish brown fine to medium SAND with occasional roots.	(1.30) 1.50	8.43			0.73 1.00
Medium dense greyish brown slightly silty fine to medium SAND.	(2.00) 3.50	6.43			
Plastic blackish brown sandy silty amorphous PEAT. Sand is fine to coarse.	(0.60) 4.10	5.83			
Spongy black slightly sandy pseudo-fibrous PEAT. Sand is fine to coarse.	(1.10) 5.20	4.73			
Very soft grey silty CLAY.	(2.80) 8.00	1.93		200 6.00	
Loose becoming medium dense grey silty fine to medium SAND.					

Continued on Next Page

Coring, Samples & Testing

Depth (m)	Ref	Test Results
0.00	1 EW	
0.10	1 ES	PID 0.10m = 0.0ppm
0.10 - 0.20	2 B	
0.25	4 ES	PID 0.25m = 0.0ppm
0.25 - 0.35	3 B	
0.40 - 0.60	5 B	
1.00	6 ES	SPT(S) 1.00m, N=11 (1,1/1,2,3,5)
1.00 - 1.45	7 D	PID 1.00m = 0.0ppm
1.45 - 2.00	8 B	
2.00 - 2.45	9 D	SPT(S) 2.00m, N=17 (2,2/3,5,4,5)
2.45 - 3.00	10 B	
3.00 - 3.50	12 B	
3.10 - 3.55	11 D-NR	SPT(S) 3.10m, N=2 (1,0/1,0,1,0)
3.50 - 4.00	14 B	
4.00 - 4.45	13 D	SPT(S) 4.00m, N=4 (1,1/1,1,1,1)
4.50 - 5.00	15 B	
5.00 - 5.45	16 D	SPT(S) 5.00m, N=4 (1,1/1,1,1,1)
5.50 - 6.00	17 B	
5.75	20 D	
6.00 - 6.45	18 D	SPT(S) 6.00m, N=2 (1,0/0,1,0,1)
6.50 - 7.00	19 B	
7.50 - 7.95	21 D	SPT(S) 7.50m, N=10 (2,2/2,3,2,3)
8.00 - 8.50	22 B	
9.00 - 9.45	23 D	SPT(S) 9.00m, N=9 (1,1/2,2,3,2)
9.50 - 10.00	24 B	

Observations / Remarks

Misc.

Shift Information

Date	Time	Depth (m)	Casing (m)	Water (m)
23/10	07:00	0.00	-	-
23/10	15:00	5.00	4.60	3.30
24/10	07:30	4.60	4.60	0.70
24/10	16:15	17.00	16.50	12.00
25/10	07:15	17.00	16.50	8.80
25/10	17:00	21.70	21.00	-
26/10	08:00	21.70	21.00	-
26/10	17:00	31.50	29.20	5.50
27/10	08:00	31.50	29.20	5.37
27/10	15:00	33.00	29.20	5.64
30/10	08:00	33.00	29.20	11.50

Backfill

From (m)	To (m)	Material
0.00	21.00	Bentonite
21.00	30.00	Gravel
30.00	39.00	Bentonite

Installations

Instrument Type	Resp. Zone	Depth (m)	Diameter
Standpipe	21.00 - 30.00	30.00	50

Groundwater Strikes

Strike (m)	Rises To (m)	Time (min)	Remarks
1.00	0.73	20	

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GROUND ENGINEERING TECHNICAL SERVICES

Alliance House,
3A South Park Way
Wakefield 41 Business Park
Wakefield WF2 0XJ
+44(0)1924 229889
www.central-alliance.co.uk

Start Date:	23/10/2023	Checked:	DR
End Date	01/11/2023	Approved:	JP

Methodology & Plant

Depth (m)	Method	Plant Used
0.00 - 1.00	Inspection Pit	Hand Tools
1.00 - 21.70	Cable Percussion Boring	Dando 3000
21.70 - 39.00	Rotary Coring	Fraste ML

Location ID

LHBH01

FINAL

Log Type

Combined Borehole

Scale: 1:50

Sheet 2 of 4

Project No:	**2372506**
Name:	**Morgan St Annes GI**
Location:	**Lytham St Annes**
Client:	**EnBW**

Location Details

Easting:	**331757.01**	Northing:	**430646.37**
Elevation:	**9.93mAOD**	Final Depth:	**39.00m**
Logged By:	**RW**	Grid System:	**OSGB**
Orientation:	**N/A**	Inclination:	**90°**

Strata Description	Depth (m) (Stratum Thickness)	Reduced Level (mAOD)
From 11.00m, with angular 5mm shell fragments.	(4.20)	
Medium dense grey fine to medium SAND with occasional 5mm shell fragments.	12.20 (1.80)	-2.27
Blackish brown silty sandy subangular to subrounded fine to coarse mudstone and siltstone GRAVEL. Sand is fine to coarse.	14.00 (0.40)	-4.07
Soft brown slightly gravelly silty CLAY. Gravel is subangular fine mudstone and siltstone.	14.40 (3.10)	-4.47
Firm brown slightly gravelly CLAY. Gravel is subangular to subrounded fine to coarse mudstone.	17.50 (3.60)	-7.57

Continued on Next Page

Coring, Samples & Testing

Depth (m)	Ref	Test Results
10.50 - 10.95	25 D	SPT(S) 10.50m, N=5 (1,1/1,2,1,1)
11.00 - 11.50	26 B	
12.00 - 12.45	27 D	SPT(S) 12.00m, N=22 (6,12/10,5,4,3)
13.00 - 13.50	28 B	
13.50 - 13.95	29 D	SPT(S) 13.50m, N=10 (2,2/2,2,2,4)
14.00 - 14.50	30 B	
14.50 - 15.00	31 B	
14.80	32 D	
15.00 - 15.45	33 D	SPT(S) 15.00m, N=22 (3,3/4,5,6,7)
15.50 - 16.00	34 B	
16.50 - 16.95	35 D	
17.00 - 17.50	36 B	
18.00 - 18.45	37 D	SPT(S) 18.00m, N=21 (2,2/3,5,6,7)
18.50 - 19.00	38 B	
19.60 - 20.05	39 D	SPT(S) 19.60m, N=20 (2,3/4,5,5,6)
19.75	40 D	

Observations / Remarks

Misc.

Shift Information

Date	Time	Depth (m)	Casing (m)	Water (m)
23/10	07:00	0.00	-	-
23/10	15:00	5.00	4.60	3.30
24/10	07:30	4.60	4.60	0.70
24/10	16:15	17.00	16.50	12.00
25/10	07:15	17.00	16.50	8.80
25/10	17:00	21.70	21.00	-
26/10	08:00	21.70	21.00	-
26/10	17:00	31.50	29.20	5.50
27/10	08:00	31.50	29.20	5.37
27/10	15:00	33.00	29.20	5.64
30/10	08:00	33.00	29.20	11.50

Backfill

From (m)	To (m)	Material
0.00	21.00	Bentonite
21.00	30.00	Gravel
30.00	39.00	Bentonite

Installations

Instrument Type	Resp. Zone	Depth (m)	Diameter
Standpipe	21.00 - 30.00	30.00	50

Groundwater Strikes

Strike (m)	Rises To (m)	Time (min)	Remarks
1.00	0.73	20	

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GROUND ENGINEERING TECHNICAL SERVICES

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Wakefield WF2 0XJ
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www.central-alliance.co.uk

Start Date:	23/10/2023	Checked:	DR
End Date	01/11/2023	Approved:	JP

Methodology & Plant

Depth (m)	Method	Plant Used
0.00 - 1.00	Inspection Pit	Hand Tools
1.00 - 21.70	Cable Percussion Boring	Dando 3000
21.70 - 39.00	Rotary Coring	Fraste ML

Location ID

LHBH01

FINAL

Log Type

Combined Borehole

Scale: 1:50

Sheet 3 of 4

Project No:	**2372506**
Name:	**Morgan St Annes GI**
Location:	**Lytham St Annes**
Client:	**EnBW**

Location Details

Easting:	**331757.01**	Northing:	**430646.37**
Elevation:	**9.93mAOD**	Final Depth:	**39.00m**
Logged By:	**RW**	Grid System:	**OSGB**
Orientation:	**N/A**	Inclination:	**90°**

Strata Description	Depth (m) (Stratum Thickness)	Reduced Level (mAOD)
Firm brown slightly gravelly CLAY. Gravel is subangular to subrounded fine to coarse mudstone.		
Very stiff dark brown gravelly CLAY. Gravel is subangular to subrounded fine to coarse mudstone.	21.10 (0.60)	-11.17
Assumed zone of core loss. CLAY (Drillers description)	21.70 (0.40)	-11.77
Very stiff high strength dark brown very gravelly CLAY with high cobble content. Gravel is angular to subrounded medium to coarse mudstone and siltstone. Cobbles are angular to subangular.	22.10 (2.30)	-12.17
Assumed zone of core loss. CLAY (Drillers description)	24.40 (0.70)	-14.47
Very stiff high strength dark brown very gravelly CLAY with high cobble content. Gravel is angular to subrounded medium to coarse mudstone and siltstone. Cobbles are angular to subangular.	25.10 (5.30)	-15.17

Casing Ø (mm) Depth (m): 150 / 29.20

Coring, Samples & Testing

Core Run	TCR	SCR	RQD	If
				AZCL
21.70 23.00	66	0	0	NA
23.00 24.40	100	0	0	
24.40 25.90	53	0	0	AZCL
				NA
25.90 27.40	100	0	0	
27.40 28.90	100	0	0	
28.90 30.40	100	0	0	

Depth (m)	Ref	Test Results
20.10 - 20.60	41 B	
21.00 - 21.40	42 D	SPT(S) 21.00m, N=50 (5,6/9,12,12,17)
21.50 - 21.70	43 B	
21.70 - 22.15	44 D	SPT(S) 21.70m, N=38 (5,7/7,9,9,13)
22.00	45 D	HV 22.00m, (p)=90 kPa (r)=20 kPa HV 22.10m, (p)=90 kPa (r)=30 kPa
		HV 22.40m, (p)=150 kPa (r)= kPa
22.70	46 D	HV 22.70m, (p)=150 kPa (r)= kPa
23.30	47 D	
		HV 23.70m, (p)=150 kPa (r)= kPa
24.00	48 D	
24.80	49 D	
		HV 25.00m, (p)=150 kPa (r)= kPa
		HV 26.10m, (p)=150 kPa (r)= kPa
26.20	50 D	
26.60	51 D	
		HV 26.90m, (p)=150 kPa (r)= kPa
27.10	52 D	
27.80	53 D	
28.40	54 D	
29.10	55 D	
29.60	56 D	

Continued on Next Page

Observations / Remarks

Misc.

Shift Information

Date	Time	Depth (m)	Casing (m)	Water (m)
23/10	07:00	0.00	-	-
23/10	15:00	5.00	4.60	3.30
24/10	07:30	4.60	4.60	0.70
24/10	16:15	17.00	16.50	12.00
25/10	07:15	17.00	16.50	8.80
25/10	17:00	21.70	21.00	-
26/10	08:00	21.70	21.00	-
26/10	17:00	31.50	29.20	5.50
27/10	08:00	31.50	29.20	5.37
27/10	15:00	33.00	29.20	5.64
30/10	08:00	33.00	29.20	11.50

Backfill

From (m)	To (m)	Material
0.00	21.00	Bentonite
21.00	30.00	Gravel
30.00	39.00	Bentonite

Installations

Instrument Type	Resp. Zone	Depth (m)	Diameter
Standpipe	21.00 - 30.00	30.00	50

Groundwater Strikes

Strike (m)	Rises To (m)	Time (min)	Remarks
1.00	0.73	20	

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GROUND ENGINEERING TECHNICAL SERVICES

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Wakefield WF2 0XJ
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Start Date:	23/10/2023	Checked:	DR
End Date	01/11/2023	Approved:	JP

Methodology & Plant

Depth (m)	Method	Plant Used
0.00 - 1.00	Inspection Pit	Hand Tools
1.00 - 21.70	Cable Percussion Boring	Dando 3000
21.70 - 39.00	Rotary Coring	Fraste ML

Location ID

LHBH01

FINAL

Log Type

Combined Borehole

Scale: 1:50

Sheet 4 of 4

Project No:	**2372506**	Easting:	**331757.01**	Northing:	**430646.37**
Name:	**Morgan St Annes GI**	Elevation:	**9.93mAOD**	Final Depth:	**39.00m**
Location:	**Lytham St Annes**	Logged By:	**RW**	Grid System:	**OSGB**
Client:	**EnBW**	Orientation:	**N/A**	Inclination:	**90°**

Strata Description	Depth (m) (Stratum Thickness)	Reduced Level (mAOD)
Between 30.30m and 30.40m, Extremely weak MUDSTONE and SILTSTONE non intact core recovered as grey gravelly fine to medium SAND. Gravel is subangular fine to coarse mudstone and siltstone.	30.40	-20.47
Very stiff reddish brown CLAY.	(1.90) 32.30	-22.37
Grey fine sandy subangular to subrounded fine to coarse siltstone and quartz GRAVEL. Sand is fine to coarse. *Between 32.50m and 32.70m, weak greyish brown very firm high strength CLAY.*	(0.40) 32.70	-22.77
Weak MUDSTONE recovered as very stiff very high strength brown CLAY. [MERCIA MUDSTONE [IVb]]	(0.65) 33.35	-23.42
Weak MUDSTONE recovered as very stiff very high strength reddish brown CLAY with interbedded bands of light grey and white calcareous fine to medium SAND. [MERCIA MUDSTONE [IVa]]	(0.40) 33.75	-23.82
Weak MUDSTONE recovered as very stiff very high strength reddish brown CLAY interbedded with bands of light grey and white fine to medium calcareous SAND and fine to medium angular gravel of gypsum. [MERCIA MUDSTONE [IVa]]	(0.45) 34.20	-24.27
Very weak greenish grey MUDSTONE with closely spaced thin beds of medium weak fine grained gypsum. Discontinuities are medium to widely spaced horizontal to subhorizontal <10 degrees planar smooth tight partly open clean tight. [MERCIA MUDSTONE [II]]	(0.30) 34.50	-24.57
Assumed zone of core loss. Brown/Blue grey MUDSTONE (Drillers description).	(0.35) 34.85	-24.92
Very weak greenish grey MUDSTONE with very closely spaced thin beds of medium weak fine grained gypsum. Discontinuities are horizontal to subhorizontal <10 degrees medium to widely spaced planar smooth tight partly open clean tight. [MERCIA MUDSTONE [III]]	(1.15) 36.00	-26.07
Very weak reddish brown mottled greenish grey MUDSTONE with closely spaced thin beds of medium weak fine grained gypsum. Discontinuities are horizontal to subhorizontal <10 degrees medium to widely spaced planar smooth tight partly open clean tight. [MERCIA MUDSTONE [II]]	(3.00) 39.00	-29.07
EOH at 39.00m - Scheduled Depth		

Coring, Samples & Testing

Core Run	TCR	SCR	RQD	If
30.40 31.50	100	0	0	
31.50 33.00	100	0	0	NI NA
33.00 34.50	13	13	13	3
34.50 36.00	81	81	78	AZCL 2
36.00 37.50	100	97	97	2
37.50 39.00	100	100	15	

Depth (m)	Ref	Test Results
30.80	57 D	
31.30	58 D	
31.90	59 D	
32.60	60 D	
		HV 33.40m, (p)=150 kPa (r)= kPa
33.60	57 D	
34.30	58 D	
		HV 35.20m, (p)=150 kPa (r)= kPa
		HV 35.60m, (p)=150 kPa (r)= kPa
35.70	59 D	
38.90 - 39.00	60 D	

Observations / Remarks

Misc.

Shift Information

Date	Time	Depth (m)	Casing (m)	Water (m)
23/10	07:00	0.00	-	-
23/10	15:00	5.00	4.60	3.30
24/10	07:30	4.60	4.60	0.70
24/10	16:15	17.00	16.50	12.00
25/10	07:15	17.00	16.50	8.80
25/10	17:00	21.70	21.00	-
26/10	08:00	21.70	21.00	-
26/10	17:00	31.50	29.20	5.50
27/10	08:00	31.50	29.20	5.37
27/10	15:00	33.00	29.20	5.64
30/10	08:00	33.00	29.20	11.50

Backfill

From (m)	To (m)	Material
0.00	21.00	Bentonite
21.00	30.00	Gravel
30.00	39.00	Bentonite

Installations

Instrument Type	Resp. Zone	Depth (m)	Diameter
Standpipe	21.00 - 30.00	30.00	50

Groundwater Strikes

Strike (m)	Rises To (m)	Time (min)	Remarks
1.00	0.73	20	

Borehole LHBH01

Contract Name	Intertidal Survey - Morgan			Location ID **MORGAN_A2_CP 01B**
Client	Morgan Offshore Wind Farm Limited			
Fugro Reference	F216874			
Coordinates (m)	E330750.55 N430600.45	Ground Elevation (m Datum)	4.82	Sheet 1 of 1
Hole Type	Cable Percussion			Status: Final

Equipment

Depth From (m)	Depth To (m)	Hole Type	Date From	Date To	Equipment	Core Barrel	Core Bit	Drilling Crew	Logged By	Remarks
0.00	20.45	CP	01/08/2023	09/08/2023	Dando 4000			BS	SM	

Progress

Date (dd/mm/yyyy)	Time (hh:mm)	Hole Depth (m)	Casing Depth (m)	Water Depth (m)	Weather
01/08/2023	07:30	0.00			Sunny, drizzle, fine
01/08/2023	18:00	10.50	10.00	1.50	
02/08/2023	07:30	10.50	10.00	1.00	
02/08/2023	18:00	20.00	15.00	3.00	

Rotary Details

Depth From (m)	Depth To (m)	Flush Type	Flush Return (%)	Flush Colour	Run Time (hh:mm)

Core Details

Depth From (m)	Depth To (m)	Diameter (mm)

Hole and Casing

Depth To (m)	Hole Diameter (mm)	Depth To (m)	Casing Diameter (mm)
6.00	250	6.00	250
20.00	200	20.00	200

Chiselling / Slow Progress

Depth From (m)	Depth To (m)	Duration (hh:mm)	Tool / Remark

Water Strike

Strike At (m)	Rise To (m)	Time Elapsed (mins)	Casing Depth (m)	Depth Sealed (m)

Water Added

Depth From (m)	Depth To (m)
1.20	16.00

Water Strike Remarks

Groundwater strike not noted but water added to assist boring might have obscured groundwater strikes

General Remarks

1. Prior to boring, a Cable Avoidance Tool (CAT) survey was undertaken to check for services. Services were not located.
2. Driller added water to assist boring.
3. Borehole terminated at scheduled depth of 20.00m.

Installation

Type	Tip Depth / Distance (m)	Response Zone Top (m)	Response Zone Base (m)	Installation Date

Pipe

ID	Top Depth (m)	Base Depth (m)	Diameter (mm)	Type

Backfill

Depth From (m)	Depth To (m)	Backfill Material	Date
0.00	1.00	Arisings	09/08/2023
1.00	20.45	Bentonite	09/08/2023

Notes

- Abbreviations and results data defined in 'Exploratory Location Records Keysheets'

Checked By	KES	Elevation Datum	OD Newlyn	Grid Coordinate System	OSGB

Template: FGSL/HBSI/FGSL BH Summary.hbt/Config Fugro Rev5/26/06/2019/TS+AW

Print Date 20/12/2023

Contract Name	Intertidal Survey - Morgan			Location ID
Client	Morgan Offshore Wind Farm Limited			**MORGAN_A2_CP01B**
Fugro Reference	F216874			
Coordinates (m)	E330750.55 N430600.45	Ground Elevation (m Datum)	4.82	Sheet 1 of 3
Hole Type	Cable Percussion			Status: Final

Sampling and In Situ Testing

Depth (m)	Type	No.	Test Results
0.20 - 0.50	B	1	
0.20 - 0.50	ES	37	
0.80 - 1.20	B	2	
0.80 - 1.20	ES	38	
1.20 - 1.65	B	3	
1.20 - 1.65	D	4	
1.20 - 1.65	SPT		N = 27 (S)
1.70 - 2.00	B	5	
2.00 - 2.45	B	6	
2.00 - 2.45	D	7	
2.00 - 2.45	SPT		N = 30 (S)
2.50 - 2.80	B	8	
3.00 - 3.45	B	9	
3.00 - 3.45	D	10	
3.00 - 3.45	SPT		N = 33 (S)
3.50 - 3.80	B	11	
4.00 - 4.45	B	12	
4.00 - 4.45	SPT		N = 34 (S)
4.50 - 4.80	B	13	
5.00 - 5.45	B	14	
5.00 - 5.45	SPT		N = 6 (S)
5.50 - 5.80	B	15	
6.00 - 6.45	B	16	
6.00 - 6.45	D	17	
6.00 - 6.45	SPT		N = 9 (S)
6.50 - 6.80	B	18	
7.00 - 7.30	B	19	
7.50 - 7.95	B	20	
7.50 - 7.95	D	21	
7.50 - 7.80	SPT		50/150 mm (S)
8.00 - 8.30	B	22	
8.50 - 8.80	B	23	
9.00 - 9.45	B	24	
9.00 - 9.30	SPT		50/145 mm (C)
9.50 - 9.80	B	25	

Strata Details

Strata Descriptions	Depth (Thickness) (m)	Level (m Datum)
Light brown slightly silty SAND with frequent shell fragments (<1mm x 2mm). Sand is fine to coarse. 1.20m to 3.00m; medium dense.	(3.00) 3.00	1.82
Dense light brown very gravelly slightly silty SAND. Sand is fine to coarse. Gravel is subangular and subrounded fine to coarse of mixed lithologies including granite and basalt. 4.00m to 4.45m; 1 No. cobble (<65mm x 70mm x 160mm) of subangular granite. 4.45m to 4.80m; 1 No. cobble (<65mm x 80mm x 130mm) of subrounded basalt. 5.00m to 5.45m; loose.	(3.00) 6.00	-1.18
Loose becoming very dense light brown very gravelly silty SAND with rare shell fragments (<1mm x 1mm). Sand is fine to coarse. Gravel is angular to subrounded fine to coarse of mixed lithologies including granite, basalt and quartz. 7.50m to 7.80m; very dense.	(2.50) 8.50	-3.68
Very dense light brown slightly silty SAND and GRAVEL with rare shell fragments (<1mm x 1mm). Sand is fine to coarse. Gravel is angular to subrounded fine to coarse of mixed lithologies including basalt, quartz and sandstone.	(2.00)	

Continued next page

Groundwater: Water Strike | Backfill / Installation

Notes
- Abbreviations and results data defined on 'Notes on Exploratory Position Records'

Contract Name	Intertidal Survey - Morgan			Location ID
Client	Morgan Offshore Wind Farm Limited			**MORGAN_A2_CP01B**
Fugro Reference	F216874			
Coordinates (m)	E330750.55 N430600.45	Ground Elevation (m Datum)	4.82	Sheet 2 of 3
Hole Type	Cable Percussion			Status: Final

Sampling and In Situ Testing

Depth (m)	Type	No.	Test Results
10.50 - 10.80	B	26	
10.50 - 10.95	SPT		N = 34 (C)
11.00 - 11.30	B	27	
11.50 - 11.80	B	28	
12.00 - 12.45	B	29	
12.00 - 12.45	D	30	
12.00 - 12.45	SPT		N = 34 (S)
12.50 - 12.80	B	31	
13.00 - 13.30	B	32	
13.50 - 13.95	B	33	
13.50 - 13.95	D	34	
13.50 - 13.95	SPT		N = 15 (S)
14.00 - 14.30	B	35	
14.50 - 14.80	B	36	
15.00 - 15.40	B	40	
15.00 - 15.40	UT	41	
15.50 - 15.80	B	42	
16.00 - 16.30	B	43	
16.50 - 16.80	B	44	
16.50 - 16.80	D	45	
16.50 - 16.95	SPT		N = 47 (S)
17.00 - 17.30	B	46	
17.50 - 17.80	B	47	
18.00 - 18.30	B	48	
18.00 - 18.40	UT	53	
18.50 - 18.80	B	52	
19.00 - 19.30	B	49	
19.50 - 19.90	UT	50	
20.00 - 20.45	D	51	
20.00 - 20.45	SPT		N = 26 (S)

Strata Details

Depth (m)	Strata Descriptions	Depth (Thickness) (m)	Level (m Datum)	Legend	Groundwater Water Strike	Backfill / Installation
	Dense light brown slightly gravelly slightly silty SAND. Sand is fine to coarse. Gravel is subangular and subrounded fine to coarse of mixed lithologies including basalt and sandstone.	10.50	-5.68			
11						
12						
		(4.00)				
13	13.00m to 13.30m; gravelly.					
	13.50m to 13.95m; medium dense.					
14						
	Soft and firm brown slightly sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is angular to subrounded fine to coarse of mixed lithologies including granite and sandstone.	14.50	-9.68			
15						
16						
17						
		(5.95)				
18						
19	19.00m to 19.30m; 1 No. cobble (<30mm x 65mm x 80mm) of subrounded granite.					
	Continued next page					

Notes

- Abbreviations and results data defined on 'Notes on Exploratory Position Records'

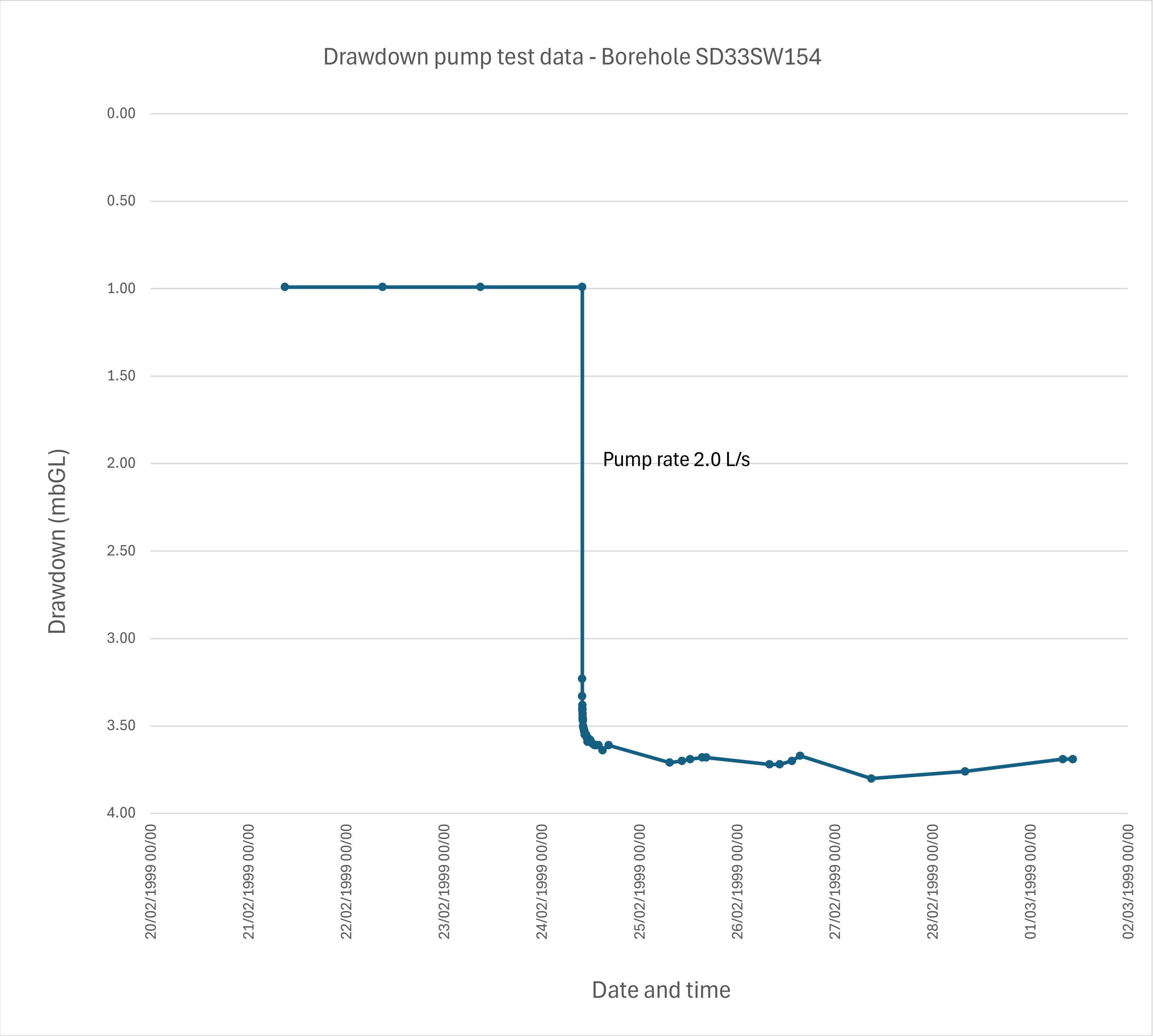
Contract Name	Intertidal Survey - Morgan			Location ID **MORGAN_A2_CP01B**
Client	Morgan Offshore Wind Farm Limited			
Fugro Reference	F216874			
Coordinates (m)	E330750.55 N430600.45	Ground Elevation (m Datum)	4.82	Sheet 3 of 3
Hole Type	Cable Percussion			Status: Final

Sampling and In Situ Testing				Strata Details					Groundwater	
Depth (m)	Type	No.	Test Results	Depth (m)	Strata Descriptions	Depth (Thickness) (m)	Level (m Datum)	Legend	Water Strike	Backfill / Installation
					End of Borehole at 20.45 m	20.45	-15.63			
				21						
				22						
				23						
				24						
				25						
				26						
				27						
				28						
				29						

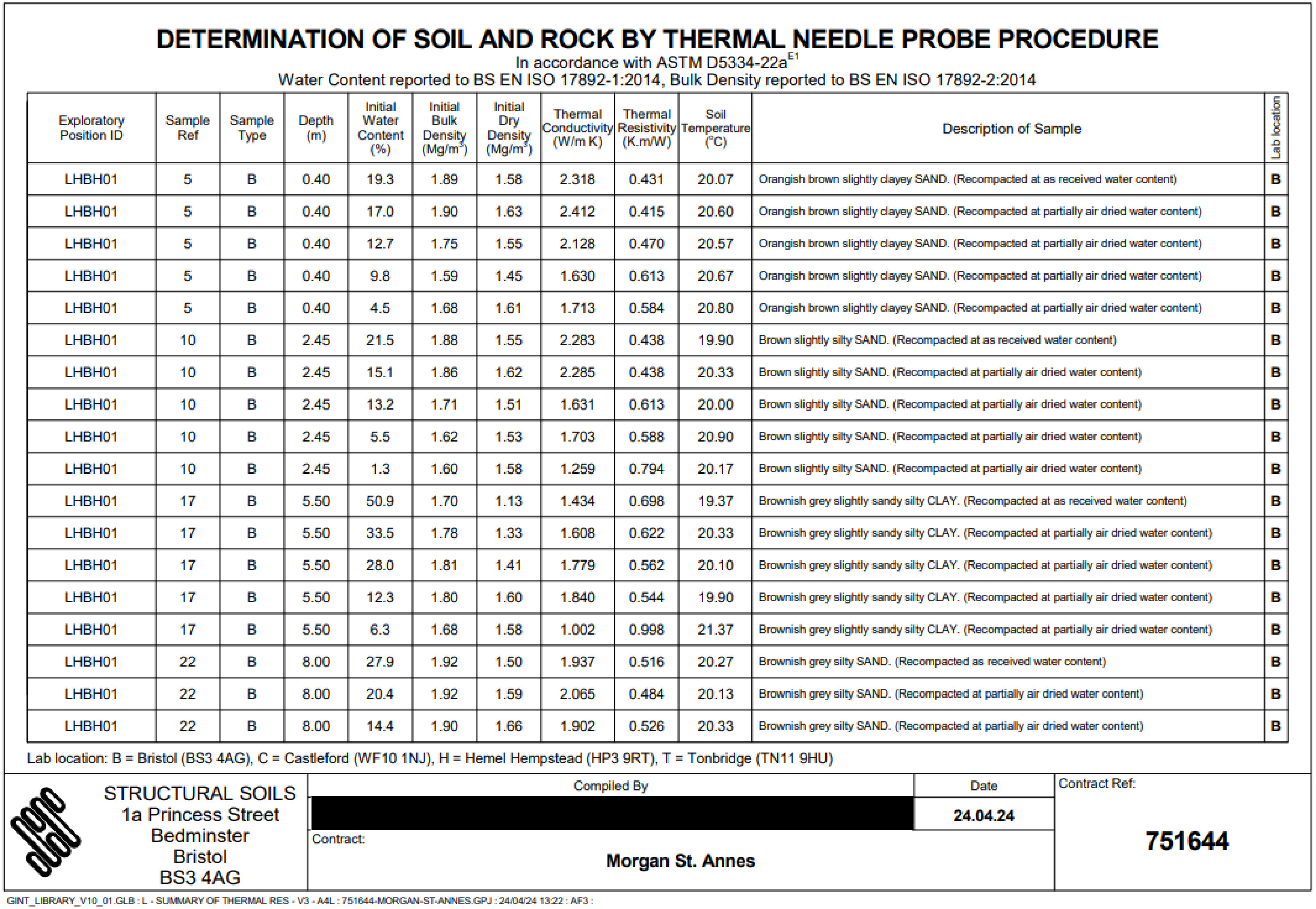
Notes

- Abbreviations and results data defined on 'Notes on Exploratory Position Records'

Appendix B Pump test drawdown graph – borehole BGS ID SD33SW154


Drawdown pump test data - Borehole SD33SW154
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
Drawdown (mbGL)
Pump rate 2.0 L/s
20/02/1999 00/00
21/02/1999 00/00
22/02/1999 00/00
23/02/1999 00/00
24/02/1999 00/00
25/02/1999 00/00
26/02/1999 00/00
27/02/1999 00/00
28/02/1999 00/00
01/03/1999 00/00
02/03/1999 00/00
Date and time

Appendix C Thermal Conductivity Data



DETERMINATION OF SOIL AND ROCK BY THERMAL NEEDLE PROBE PROCEDURE

In accordance with ASTM D5334-22a^{E1}

Water Content reported to BS EN ISO 17892-1:2014, Bulk Density reported to BS EN ISO 17892-2:2014

Exploratory Position ID	Sample Ref	Sample Type	Depth (m)	Initial Water Content (%)	Initial Bulk Density (Mg/m^3)	Initial Dry Density (Mg/m^3)	Thermal Conductivity (W/m K)	Thermal Resistivity (K.m/W)	Soil Temperature (°C)	Description of Sample	Lab location
LHBH01	5	B	0.40	19.3	1.89	1.58	2.318	0.431	20.07	Orangish brown slightly clayey SAND. (Recompacted at as received water content)	**B**
LHBH01	5	B	0.40	17.0	1.90	1.63	2.412	0.415	20.60	Orangish brown slightly clayey SAND. (Recompacted at partially air dried water content)	**B**
LHBH01	5	B	0.40	12.7	1.75	1.55	2.128	0.470	20.57	Orangish brown slightly clayey SAND. (Recompacted at partially air dried water content)	**B**
LHBH01	5	B	0.40	9.8	1.59	1.45	1.630	0.613	20.67	Orangish brown slightly clayey SAND. (Recompacted at partially air dried water content)	**B**
LHBH01	5	B	0.40	4.5	1.68	1.61	1.713	0.584	20.80	Orangish brown slightly clayey SAND. (Recompacted at partially air dried water content)	**B**
LHBH01	10	B	2.45	21.5	1.88	1.55	2.283	0.438	19.90	Brown slightly silty SAND. (Recompacted at as received water content)	**B**
LHBH01	10	B	2.45	15.1	1.86	1.62	2.285	0.438	20.33	Brown slightly silty SAND. (Recompacted at partially air dried water content)	**B**
LHBH01	10	B	2.45	13.2	1.71	1.51	1.631	0.613	20.00	Brown slightly silty SAND. (Recompacted at partially air dried water content)	**B**
LHBH01	10	B	2.45	5.5	1.62	1.53	1.703	0.588	20.90	Brown slightly silty SAND. (Recompacted at partially air dried water content)	**B**
LHBH01	10	B	2.45	1.3	1.60	1.58	1.259	0.794	20.17	Brown slightly silty SAND. (Recompacted at partially air dried water content)	**B**
LHBH01	17	B	5.50	50.9	1.70	1.13	1.434	0.698	19.37	Brownish grey slightly sandy silty CLAY. (Recompacted at as received water content)	**B**
LHBH01	17	B	5.50	33.5	1.78	1.33	1.608	0.622	20.33	Brownish grey slightly sandy silty CLAY. (Recompacted at partially air dried water content)	**B**
LHBH01	17	B	5.50	28.0	1.81	1.41	1.779	0.562	20.10	Brownish grey slightly sandy silty CLAY. (Recompacted at partially air dried water content)	**B**
LHBH01	17	B	5.50	12.3	1.80	1.60	1.840	0.544	19.90	Brownish grey slightly sandy silty CLAY. (Recompacted at partially air dried water content)	**B**
LHBH01	17	B	5.50	6.3	1.68	1.58	1.002	0.998	21.37	Brownish grey slightly sandy silty CLAY. (Recompacted at partially air dried water content)	**B**
LHBH01	22	B	8.00	27.9	1.92	1.50	1.937	0.516	20.27	Brownish grey silty SAND. (Recompacted as received water content)	**B**
LHBH01	22	B	8.00	20.4	1.92	1.59	2.065	0.484	20.13	Brownish grey silty SAND. (Recompacted at partially air dried water content)	**B**
LHBH01	22	B	8.00	14.4	1.90	1.66	1.902	0.526	20.33	Brownish grey silty SAND. (Recompacted at partially air dried water content)	**B**

Lab location: B = Bristol (BS3 4AG), C = Castleford (WF10 1NJ), H = Hemel Hempstead (HP3 9RT), T = Tonbridge (TN11 9HU)

STRUCTURAL SOILS
1a Princess Street
Bedminster
Bristol
BS3 4AG

Compiled By	Date	Contract Ref:
[redacted]	**24.04.24**	**751644**
Contract: **Morgan St. Annes**		

GINT_LIBRARY_V10_01.GLB : L - SUMMARY OF THERMAL RES - V3 - A4L : 751644-MORGAN-ST-ANNES.GPJ : 24/04/24 13:22 : AF3 :

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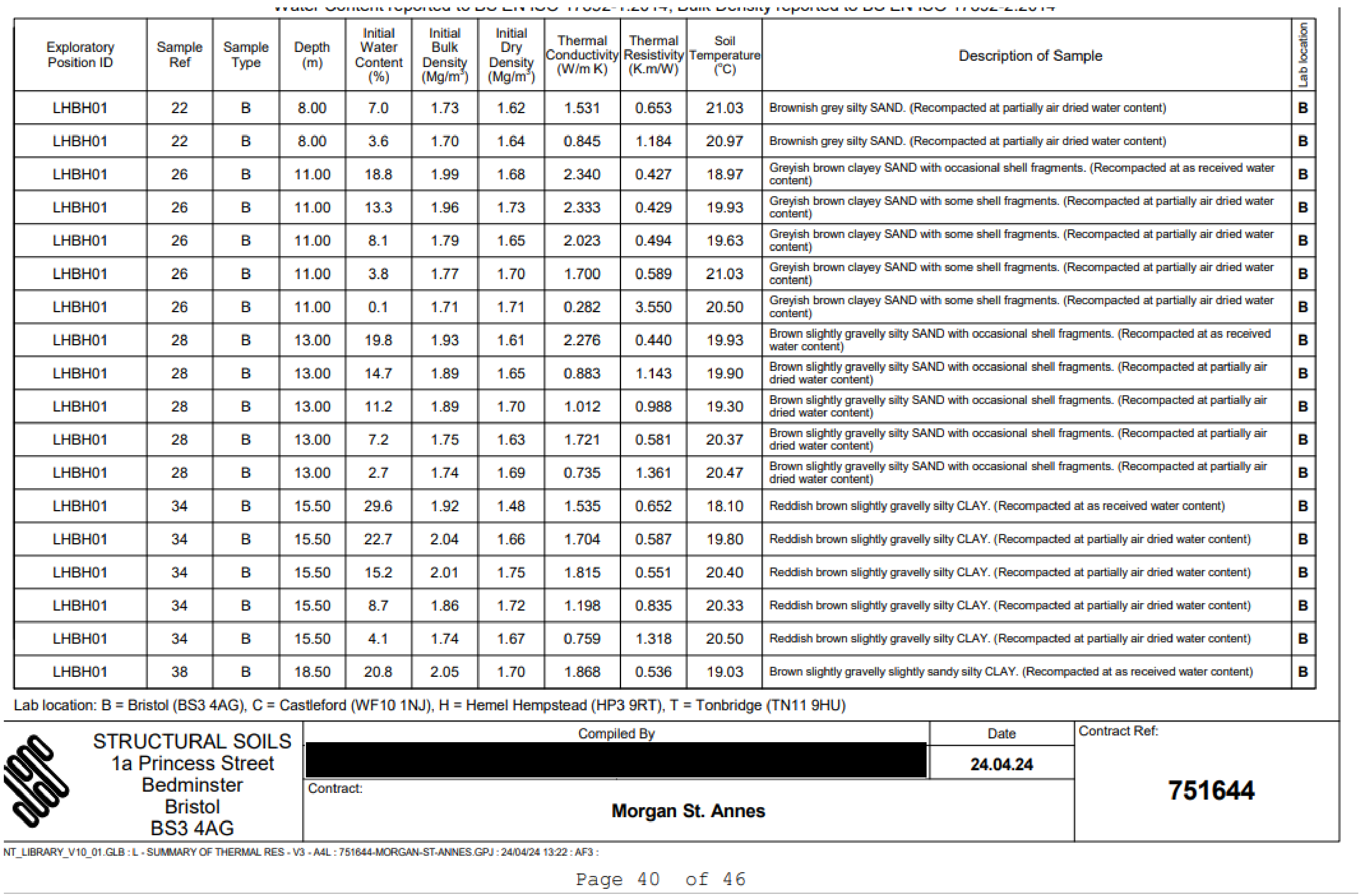
Thermal conductivity data for samples recovered from borehole LHBH01 (0.0-8.0 mbGL)



Water Content reported to BS EN ISO 17892-1:2014, Bulk Density reported to BS EN ISO 17892-2:2014

Exploratory Position ID	Sample Ref	Sample Type	Depth (m)	Initial Water Content (%)	Initial Bulk Density (Mg/m^3)	Initial Dry Density (Mg/m^3)	Thermal Conductivity (W/m K)	Thermal Resistivity (K.m/W)	Soil Temperature (°C)	Description of Sample	Lab location
LHBH01	22	B	8.00	7.0	1.73	1.62	1.531	0.653	21.03	Brownish grey silty SAND. (Recompacted at partially air dried water content)	B
LHBH01	22	B	8.00	3.6	1.70	1.64	0.845	1.184	20.97	Brownish grey silty SAND. (Recompacted at partially air dried water content)	B
LHBH01	26	B	11.00	18.8	1.99	1.68	2.340	0.427	18.97	Greyish brown clayey SAND with occasional shell fragments. (Recompacted at as received water content)	B
LHBH01	26	B	11.00	13.3	1.96	1.73	2.333	0.429	19.93	Greyish brown clayey SAND with some shell fragments. (Recompacted at partially air dried water content)	B
LHBH01	26	B	11.00	8.1	1.79	1.65	2.023	0.494	19.63	Greyish brown clayey SAND with some shell fragments. (Recompacted at partially air dried water content)	B
LHBH01	26	B	11.00	3.8	1.77	1.70	1.700	0.589	21.03	Greyish brown clayey SAND with some shell fragments. (Recompacted at partially air dried water content)	B
LHBH01	26	B	11.00	0.1	1.71	1.71	0.282	3.550	20.50	Greyish brown clayey SAND with some shell fragments. (Recompacted at partially air dried water content)	B
LHBH01	28	B	13.00	19.8	1.93	1.61	2.276	0.440	19.93	Brown slightly gravelly silty SAND with occasional shell fragments. (Recompacted at as received water content)	B
LHBH01	28	B	13.00	14.7	1.89	1.65	0.883	1.143	19.90	Brown slightly gravelly silty SAND with occasional shell fragments. (Recompacted at partially air dried water content)	B
LHBH01	28	B	13.00	11.2	1.89	1.70	1.012	0.988	19.30	Brown slightly gravelly silty SAND with occasional shell fragments. (Recompacted at partially air dried water content)	B
LHBH01	28	B	13.00	7.2	1.75	1.63	1.721	0.581	20.37	Brown slightly gravelly silty SAND with occasional shell fragments. (Recompacted at partially air dried water content)	B
LHBH01	28	B	13.00	2.7	1.74	1.69	0.735	1.361	20.47	Brown slightly gravelly silty SAND with occasional shell fragments. (Recompacted at partially air dried water content)	B
LHBH01	34	B	15.50	29.6	1.92	1.48	1.535	0.652	18.10	Reddish brown slightly gravelly silty CLAY. (Recompacted at as received water content)	B
LHBH01	34	B	15.50	22.7	2.04	1.66	1.704	0.587	19.80	Reddish brown slightly gravelly silty CLAY. (Recompacted at partially air dried water content)	B
LHBH01	34	B	15.50	15.2	2.01	1.75	1.815	0.551	20.40	Reddish brown slightly gravelly silty CLAY. (Recompacted at partially air dried water content)	B
LHBH01	34	B	15.50	8.7	1.86	1.72	1.198	0.835	20.33	Reddish brown slightly gravelly silty CLAY. (Recompacted at partially air dried water content)	B
LHBH01	34	B	15.50	4.1	1.74	1.67	0.759	1.318	20.50	Reddish brown slightly gravelly silty CLAY. (Recompacted at partially air dried water content)	B
LHBH01	38	B	18.50	20.8	2.05	1.70	1.868	0.536	19.03	Brown slightly gravelly slightly sandy silty CLAY. (Recompacted at as received water content)	B

Lab location: B = Bristol (BS3 4AG), C = Castleford (WF10 1NJ), H = Hemel Hempstead (HP3 9RT), T = Tonbridge (TN11 9HU)

STRUCTURAL SOILS
1a Princess Street
Bedminster
Bristol
BS3 4AG

Compiled By	Date	Contract Ref:
[redacted]	24.04.24	**751644**
Contract: **Morgan St. Annes**		

NT_LIBRARY_V10_01.GLB : L - SUMMARY OF THERMAL RES - V3 - A4L : 751644-MORGAN-ST-ANNES.GPJ : 24/04/24 13:22 : AF3 :

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Thermal conductivity data for samples recovered from borehole LHBH01 (8.0-18.5 mbGL)