East Anglia ONE North and East Anglia TWO Offshore Windfarms

Landfall Hydrogeological Risk Assessment

Applicants: East Anglia ONE North Limited and East Anglia TWO Limited
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Applicable to East Anglia ONE North and East Anglia TWO

Revision Summary				
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Table of Contents

Glossary of Acronyms

BGS	British Geological Survey
CSM	Conceptual Site Model
DCO	Development Consent Order
ES	Environmental Statement
HDD	Horizontal Directional Drilling
HGV	Heavy Goods Vehicle
ODN	Ordnance Datum Newlyn
SPA	Special Protection Area
SPZ	Source Protection Zone
SSSI	Site of Special Scientific Interest

Glossary of Terminology

Applicants	East Anglia ONE North / East Anglia TWO
East Anglia ONE North	The proposed project consisting of up to 67 wind turbines, up to four offshore electrical platforms, up to one construction, operation and maintenance platform, inter-array cables, platform link cables, up to one operational meteorological mast, up to two offshore export cables, fibre optic cables, landfall infrastructure, onshore cables and ducts, onshore substation, and National Grid infrastructure.
East Anglia TWO	The proposed project consisting of up to 75 wind turbines, up to four offshore electrical platforms, up to one construction, operation and maintenance platform, inter-array cables, platform link cables, up to one operational meteorological mast, up to two offshore export cables, fibre optic cables, landfall infrastructure, onshore cables and ducts, onshore substation, and National Grid infrastructure.
Horizontal Directional Drilling	A method of cable installation where the cable is drilled beneath a feature without the need for trenching.
Landfall	The area (from Mean Low Water Springs) where the offshore export cables would make contact with land and connect to the onshore cables.
Principal Aquifers	These are layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as major aquifer.
Secondary A Aquifers	Permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers;

1 Introduction

1. This clarification note has been prepared by East Anglia TWO Limited and East Anglia ONE North Limited (the Applicants) in relation to the East Anglia TWO and East Anglia ONE North Development Consent Order (DCO) applications (the Applications).

2. During the Examinations for the East Anglia TWO and East Anglia ONE North Offshore Windfarm projects (the Projects) there have been Written Representations from different Interested Parties regarding construction and operation of the proposed landfall and its potential to impact upon groundwater and associated water supplies. This report have been prepared to provide a detailed consideration of this potential for impacts.

3. This document is applicable to both the East Anglia ONE North and East Anglia TWO DCO applications, and therefore is endorsed with the yellow and blue icon used to identify materially identical documentation in accordance with the Examining Authority's procedural decisions on document management of 23rd December 2019 (PD-004). Whilst this document has been submitted to both Examinations, if it is read for one project submission there is no need to read it for the other project submission.

1.1 Purpose

4. This report addresses Written Representations made to the Examinations in relation to the proposed landfall for the Projects, including submissions by, but not limited to Tessa Wojtczak (REP1-377), Richard Reeves (REP4-167) and Wardens Trust (REP5-122).

5. In particular, consideration is given to horizontal directional drilling (HDD) and its potential impact on the underlying aquifer, local hydrogeology and private water supplies to five properties at and around Ness House north of the likely location of the bores (see ***Figure 1*** in ***Appendix 1***).

6. This report is structured as follows:

- ***Section 2*** summarises the aims and objectives of the hydrogeological risk assessment and the data sources used;
- ***Section 3*** sets out the proposed works at the landfall;
- ***Section 4*** presents the environmental setting at the landfall and in the surrounding area;
- ***Section 5*** presents a Conceptual Site Model (CMS) and the results of the hydrogeological risk assessment; and

- ***Section 6*** summarises the hydrogeological risk assessment.

2 Aims and Objectives

7. This risk assessment will establish the hydrogeological conditions at the landfall through a review of relevant information relating to environmental site setting to characterise and address the following:

- The current groundwater quality in and around the landfall;
- The risk to groundwater associated with the proposed HHD activities; and
- Proposals for a groundwater monitoring regime to assess the potential impacts of the proposed HHD activities.

2.1 Sources of Information

8. The following documents and data sources have been consulted in the preparation of this review:

- British Geological Survey (BGS) online Geology of Britain Viewer https://www.bgs.ac.uk/map-viewers/geology-of-britain-viewer/;
- BGS The Physical Properties of major aquifers in England and Wales; Environment Agency, 1997;
- Sizewell C Environmental Statement (ES), Volume 2 Main Development Site, Chapter 19 Groundwater and Surface Water, Appendix 19B Conceptual Site Model, EDF Energy, 2020;
- Magic Maps web site: https://magic.defra.gov.uk/magicmap.aspx; and
- ***HDD Verification Clarification Note*** (document reference ExA.AS-13.D6.V1) prepared by Riggall & Associates Ltd on behalf of the Applicants and submitted at Deadline 6.

9. Written Representations made to the Examinations were also considered when determining the environmental setting presented in ***Section 4***. These include submissions made by Tessa Wojtczak (REP1-377), Richard Reeves (REP4-167) and Wardens Trust (REP5-122).

3 Proposed Works

10. The landfall HDD bores are likely to be located north of Thorpeness (approximately 750m south of the Wardens Trust site) with planned lengths of up to 2000m.

11. The outline methodology for the HDD bores consists of pilot hole drilling followed by a forward reaming as far as is practical or efficient, then conventional pull reaming for the remainder of the bore.

12. The pilot hole will be steered and surveyed using a wireline guidance tool located behind the drilling bit. The HDD will be at approximately 11m below the base of the cliffs along the coast, and as such there is no risk that the HDD will inadvertently drill out through or near the cliffs.

13. The reaming will be undertaken in steps of increasing bore diameter. There are two methods of reaming, forward reaming, where the hole is enlarged form the HDD rig out towards sea, and conventional (pull) reaming where the pilot hole exits to the sea bed and a reamer is connected and pulled from exit towards entry. The use of forward reaming has benefits in allowing the drilling fluid to flow to the entry point where it can be recycled. Conventional (pull) reaming results in drilling fluid flowing to the exit point and therefore the sea.

14. During HDD activities, the drilling fluid engineer on the site will carefully monitor the fluid usage in the recycling system and will quickly identify if fluid is being lost to the ground. If fluid loss is identified there are a number of measures that can be taken to seal the bore, including:

    - Modifying the drilling fluid properties to increase the effectiveness of the bentonite clay filter cake that lines the wall of the borehole;
    - Addition of stop-loss materials to bridge and seal larger voids in the soil; and
    - Modifying the mud weight (drilling fluid density) to either balance or counter the groundwater pressure depending on the ground conditions.

15. For the majority of the length of the HDD, it is considered that drilling fluid losses would be confined to a limited area around the drill. The HDD is expected to be within the Coralline Crag beneath the cliffs, and the strength of the Coralline Crag is expected to prevent any drilling fluid breakout at this point (***Figure 1*** in ***Appendix 1***). Use of environmentally friendly drilling fluids and drilling with a minimum practical flow rate of the drilling fluid are the main mitigation methods.

16. The risk of spillages of drilling fluids or machinery fluids and oils from the HDD site is mitigated by the use of bunded containers, plant nappies for refuelling and beneath standing machinery, and standard site setup with bunding and silt fencing around the site perimeter.

4 Environmental Setting

4.1 Geology

17. ***Table 4.1*** presents a summary of the stratigraphy for the regional study area. The Chalk at the base of the section is lithologically transitional between northern and southern Chalk and shares characteristic of common hardgrounds and lack of tubular flints (Environment Agency, 1997).

18. The younger deposits which overlie the Chalk have a marked effect on the hydrogeology of the region. Palaeogene deposits, including the Lambeth Group and the London Clay, overlie the Chalk south east of the line which runs from Hertford to Ipswich and then northwards from Saxmundham to the north-east Norfolk coast. The Lambeth Group is sandy and may contribute to the water resources of the Chalk. The London Clay has low permeability and confines the Chalk aquifer.

19. The Pliocene and Pleistocene Crag deposits rest on Chalk or on London Clay. The oldest of these deposits, the Coralline Crag, is a calcarine and is preserved only locally near Aldeburgh. The overlaying Crag group is a marine sand with some clay and gravels. It is anticipated that the base of the Crag Group deposits (including the Coralline Crag) is an unconformable contact with the underlying London Clay Formation.

20. In East Anglia, drift deposits are variable, including pebbly sand, gravels, silts, and clays. A chalky till, known as Lowestoft Till covers much of the area. The unweathered till is gravelly and grey, sandy, silty clay and has low permeability and where weathered, the till is rust brown and is generally more permeable.

Table 4.1 Summary of Stratigraphy – Regional Study Area

Unit	Sub-Unit	Age		Comments
Superficial Deposits				
Marine Deposits	Tidal Flats	Quaternary	Holocene	Present close to coast
	Sand and Gravel			
Peat	-			Low lying marshy areas
Alluvium	-			Present in river valley
Head	-			Present in river valley
Lowestoft Formation	Lowestoft Till		Anglian	Locally absent

Unit	Sub-Unit	Age		Comments
	Lowestoft Sand and Gravel			Locally present
Bedrock				
Crag Group	Red Crag Formation	Quaternary	Pliocene - Pleistocene	Present in entire regional study area
Thames Group	London Clay Formation	Tertiary (Paleogene)	Palaeocene – Eocene	Only present in the east of the regional study area
	Harwich Formation			
Lambeth Group	Woolwich and Reading Beds Formation			
Thanet Group	Thanet Sand Formation			
Lista Formation	Ormesby Clay Membe			
Chalk Group	White Chalk	Cretaceous	-	Present in entire regional study area

21. The basal Chalk bedrock dips gently to the south-east, as do the Palaeogene strata which overlie it. In the east of the area, the Pliocene and Pleistocene Crag deposits dip eastward (Environment Agency, 1997).

22. Existing BGS boreholes surrounding the landfall (see ***Figure 1*** in ***Appendix 1***) indicate that the London Clay is at approximately -50m Ordnance Datum Newlyn (ODN). However, this differs to the base of Crag contour map shown on the 1:50,000 series published map, which shows the base of the Crag at -20 to -30m ODN.

23. Pre-construction ground investigations will confirm the true depth to the London Clay, however, unless it is significantly shallower than expected, the HDD will not be drilling within the London Clay.

4.2 Hydrogeology

24. According to ground investigation information undertaken in support of the Sizewell C DCO application (EDF Energy, 2020), groundwater is encountered within the following strata:

- Made Ground;
- Lowestoft Sand and Gravel and any associated private water supplies (including the Ness House well);
- Crag Formation; and
- Chalk.

25. The Crag and the Chalk are designated by the Environment Agency as 'Principal Aquifers', which can provide a high level of water storage and support water supply and base river flows on a strategic scale. However, In the study area, the Chalk groundwater below the London Clay is highly saline and potable supplies are taken only from the Crag.

26. The Chalk is a dual porosity aquifer with both matrix pores and fractures, both of which contribute to the overall hydraulic conductivity of the aquifer. The matrix hydraulic conductivity is low and the overall hydraulic conductivity of the aquifer is generally controlled by the larger pores and fractures. The transmissivity of the Upper Chalk in east Suffolk is generally lower than the catchment to the west due to the confinement by low hydraulic conductivity sediments and possible occurrence of marl dominated horizons (Environment Agency, 1997). The published hydrogeological map for the area (Environment Agency, 1997) indicates that groundwater flow within the Chalk aquifer is eastwards towards the coast.

27. The Crag is generally unconfined, and where the Crag Group overlies Chalk directly, the two may be in hydraulic continuity. Groundwater flow in the Crag is intergranular and the flow is locally controlled by alternating layers of clays, silt and sand and their contrasting hydraulic conductivity values. It is anticipated that the levels and chemistry of water abstractions in the vicinity of the landfall will be tidally influenced. This has been confirmed by groundwater monitoring undertaken for the Sizewell C DCO application (EDF Energy, 2020). This indicates a degree of connectivity between the groundwater regime and the North Sea. Groundwater within the Crag is observed to flow eastwards.

28. The sand and gravel component of the Lowestoft Formation is designated as a 'Secondary A Aquifer'. The properties of 'Secondary A Aquifer' are more variable and as such they may be of local rather than regional importance as a source of

water supply. Secondary A Aquifers often constitute important sources of flow to rivers and associated wetlands.

29. The Lowestoft Sand and Gravel overlies the Crag and in many borehole logs it has not been possible to differentiate between these aquifers due to their similar lithological composition (EDF Energy, 2020). Due to their lithological similarities it is considered that they will be similar to those specified for the Crag.

30. It is understood that the Ness House well is located in a locked building within the bounds of the property over 400m north of the likely location of the HDD bores. The well supplies five properties at and around Ness House, including Wardens Trust. Data made available on the supply (REP5-122) indicates that the water level in the well is at 11.7m, with the depth of the well itself being 13.1m. This confirms that the abstraction aquifer is likely to be Lowestoft Sand and Gravel. The water supply is regularly tested by East Suffolk Council for iron and manganese.

4.3 Hydrology

31. The landfall is not located within a catchment of any permanent surface water features and could only be affected by surface runoff. The site lies in a predominantly agricultural area of the coastal fringe which drains eastwards into the sea rather than south or westwards into the Hundred River catchment.

32. The landfall lies within Flood Zone 1 (annual probability of less than 0.1%), as defined by the Environment Agency online flood map for Planning (Environment Agency undated) and is determined to be at low risk from all sources of flooding.

4.4 Sensitive Land Uses

33. The landfall is located within 2km of the following statutory protected sites:

- Leiston-Aldeburgh Site of Special Scientific Interest (SSSI);
- Sandlings SPA;
- Sizewell Marshes SSSI;
- Sandlings and Chelmsford Nitrate Vulnerable Zone G78.

34. Details on the key features of each protected site are shown in ***Table 4.2***.

Table 4.2 Key Features of Designated Sites within 2km of the Landfall

Designated Sites	Key Features
Leiston to Aldeburgh SSSI	Acid grassland, heath, scrub, woodland, fen, open water and vegetated shingle.

Designated Sites	Key Features
Sandlings SPA	Breeding populations of nightjar and woodlark. Acid grassland, heath, scrub, woodland (including commercial forest), fen, open water and vegetated shingle.
Sizewell Marshes SSSI	Lowland unimproved wet meadow.

35. The landfall lies more than 2km from a Source Protection Zone (SPZ 1 and 2). This SPZ is located to the east of Leiston. However, given the direction of flow, zones 2 and 3 extend towards the west rather than the east.

36. Wardens Trust is a charitable organisation that was set up in 1991 to offer recreational and outdoor facilities for children and adults with disabilities. The Trust is located within a large hall with a large kitchen, bunk bed accommodation and fully equipped toilet, shower and washing facilities with wheelchair access. There is also a separate holiday flat with disabled access and an outside camping area. The Trust offers a range of services for local disabled groups form adventure camping for young people to bath and music days and a lunch club for people living with dementia and their carers. As noted in ***Section 2***, the landfall HDD bores are likely to be located approximately 750m south of the Wardens Trust site.

5 Conceptual Site Model

37. The CSM summary presented here describes the potential source, potential contaminant migration pathways and potentially exposed receptors associated with the proposed HDD. A schematic cross section illustrating the CSM is presented in ***Figure 1*** in ***Appendix 1***. The key components of the conceptual model are discussed in more detail below.

38. Existing contamination sources can include neighbouring land uses and historical activities within the onshore development area and in its surroundings. From the desk-based information and the findings of a site walkover (July 2018, see ***Appendix 20.4 Geomorphological Baseline*** of the ES (APP-498)), potential sources of contamination have been identified within the onshore development area and include:

- Agricultural land, which can be associated with some contaminative activities including use/storage of pesticides and herbicides and burial of wastes; and
- A number of historical sand and gravel pits (including Thorpe Sand Pit) present in various locations within the onshore development area have been infilled and may contain unknown and potentially contaminated fill material.

39. There are considered to be two key groundwater receptors linked to the landfall:

- Lowestoft Sand and Gravel and any associated private water supplies (including the Ness House well); and
- Crag aquifer.

40. The Chalk aquifer is not considered as a receptor in this assessment due to presence of isolating layer of London Clay and due to depth of the proposed activities.

41. No pollutant linkages have been identified for the Projects during their operational phase. As such, there is not considered to be a risk to groundwater during the operation of the landfall.

42. The HDD will initially pass through a short length of chalky pebbly Glacial Till that is likely to be silty sandy clay. The length drilled in the Till is expected to be approximately 30m to 50m. Glacial Tills are routinely drilled throughout the United Kingdom and drill holes are typically self-supporting in the clayey soils. In rare cases where there are concentrations of cobbles or boulders, the Till may need

to be cased, however cobbles and boulders in Till are rare in Suffolk and casing is not expected to be required.

43. From the 50m drilled length, up until 110m drilled length, the HDD is expected to be in the Crag Group deposits. The Crag in this section of the bore is expected to be medium dense fine-grained shelly, glauconitic and micaceous sands with flint gravel.

44. The main risk of instability within the Crag is the existence of loose layers; these could potentially result in localised collapse in the borehole after the HDD has exited to the seafloor, provided that the zones are located above mean sea-level. After the HDD has exited, drilling fluid levels in the HDD will equilibrate with mean sea level and any zones of loose ground will not be supported by drilling fluid. The ground in these sections will rely on the development of soil arching to support the crown of the bore. Granular sediments that are medium dense or denser typically form a stable bore in these conditions, but loose granular sediments may not.

45. The main risk in this section of bore is the loss of drilling fluid to the surrounding ground, potentially extending to the seafloor. This risk will be evaluated by hydrofracture modelling, where the calculated drilling fluid pressures for the profile can be compared to the pressure at which the ground is fractured during construction. This hydrofracture pressure is calculated by formulas that use soil strength parameters derived from laboratory testing of samples recovered from the ground.

46. The HDD drilling depth and profile will be optimised to defer the loss of fluid and breakout, but it is inevitable that at some point losses will occur, particularly as the HDD curves upwards to the exit.

47. Loss of some drilling fluid to the surrounding ground, and eventually to the seafloor occurs at all landfalls where HDD is used. The use of environmentally friendly drilling fluids and drilling with a minimum practical flow rate of the drilling fluid are the main mitigation methods.

48. The HDD is likely to be within the Coralline Crag from 110m until 1,300m of the drilling distance. The Crag is expected to provide ideal conditions for HDD.

49. Previous studies for the area note the presence of vertical joints within the Coralline Crag. Some of the fractures appear to have remained open. These will not pose a problem for bore stability, being vertically oriented, but there might be temporary fluid losses as the drilling bit passes through them. When the bit has passed, the drilling fluid in the fractures will gel to seal the fractures. If persistent losses occur there is a wide range of stop-loss materials that can be added to the drilling fluid to seal the fractures.

50. The permeability of the Crag appears to be from interstitial flow (flow through the pores or spaces between the sand grains), rather than from flow along fractures, and the bentonite drilling fluid alone should seal the bore.

51. Given that HDD activities are only temporary in duration and are unlikely to comprise significant volumes of water and drilling fluid, they are unlikely to affect the Lowestoft Sand and Gravel and Crag aquifer to a considerable degree. The Applicants propose to implement water quality and levels monitoring at the Ness House well during HDD activities to ensure no that the proposed mitigation is sufficient.

52. The risk ratings applied in the assessment are defined in ***Table 5.1***. The pollutant linkages are described in more detail in ***Table 5.2***.

Table 5.1 Risk Rating Terminology

Risk Rating	Description
High risk	• Contaminants very likely to represent an unacceptable risk to identified receptors. • Site probably not suitable for current / future use. • Enforcement action possible. • Urgent action required.
Medium risk	• Contaminants likely to represent an unacceptable risk to identified receptors. • Site probably not suitable for current / future use. • Action required in the medium term.
Low risk	• Contaminants may be present but unlikely to create unacceptable risk to identified receptors. • Site probably suitable for current/future use. • Action unlikely to be needed whilst site remains in current use.
Negligible risk	• If contamination sources are present they are considered to be minor in nature and extent. • Site suitable for current / future use. • No further action required.

Table 5.2 Hydrological Risk Assessment

Source	Pathway	Receptor	Unmitigated Risk Rating	Mitigation Proposed	Risk Rating Following Mitigation
Fuel or oil spills from machinery on site.	Excavation of trench for cable route and surface water run-off.	Groundwater in superficial aquifer (Lowestoft Sand and Gravel and Crag).	High	• No refuelling in or in close proximity to landfall site. • No storage of any potentially contaminative materials in or in close landfall site. • No welfare facilities in or in close proximity to landfall sites.	Negligible
Contaminated surface water.	Over-pumping in the area of the entry pits.	Groundwater in superficial aquifer (Lowestoft Sand and Gravel and Crag).	Medium	• No discharge to ground of any over-pumped water.	Negligible
Contaminated groundwater from superficial aquifer.	Creation of new pathways for contamination as results of HDD activities including drilling fluid breakouts.	Groundwater in superficial aquifer (Lowestoft Sand and Gravel and Crag).	Medium	• Usage of Environmentally friendly fluid. • Hydrofracture modelling is used to manage the risk of drilling fluid breakout or losses into the ground surrounding the HDD bore. • Drilling fluids are designed to seal permeable ground, the naturally occurring bentonite clay used as the base for the drilling fluid, lines the borehole wall, preventing fluid loss and groundwater ingress.	Negligible

Source	Pathway	Receptor	Unmitigated Risk Rating	Mitigation Proposed	Risk Rating Following Mitigation
				• If the ground investigations indicate that flow is through fractures in the ground, the mitigation will be to add stop-loss materials to the drilling fluid to seal the fractures. There are a wide range of environmentally friendly stop-loss additives available in the industry that can be deployed.	
HDD bore filled with seawater.	Planned boring into Crag.	Groundwater in superficial aquifer (Lowestoft Sand and Gravel and Crag).	Low	• The vertical deviation tolerance that will be adopted for design is selected to be conservative. • Pre-construction Ground Investigation will provide further detailed information on the ground conditions at the HDD alignment to confirm geology and soil properties and allow final HDD route alignment and route specification to be established.	Negligible
Loss of water from aquifer.	Geological conditions, planned and unplanned boring into Lowestoft Sand and Gravel and	Loss of yield for private users (licensed and unlicensed).	Low	• Use of drilling fluids which are designed to seal permeable ground. The naturally occurring bentonite clay used as the base for the drilling fluid, lines the	Negligible

Source	Pathway	Receptor	Unmitigated Risk Rating	Mitigation Proposed	Risk Rating Following Mitigation
	Crag aquifers, ingress of water into HDD bore.			borehole wall, preventing fluid loss and groundwater ingress. • Additional preconstruction Ground Investigation is planned to refine the design. It will provide more detailed information on the ground conditions at the HDD alignment including confirmation of geology and soil properties. • Provision of a temporary portable water supply tied into the well at Ness House during HDD activities at the landfall.	

6 Summary

53. No pollutant linkages have been identified for the Projects during their operational phase. As such, there is not considered to be a risk to groundwater during the operation of the proposed landfall site.

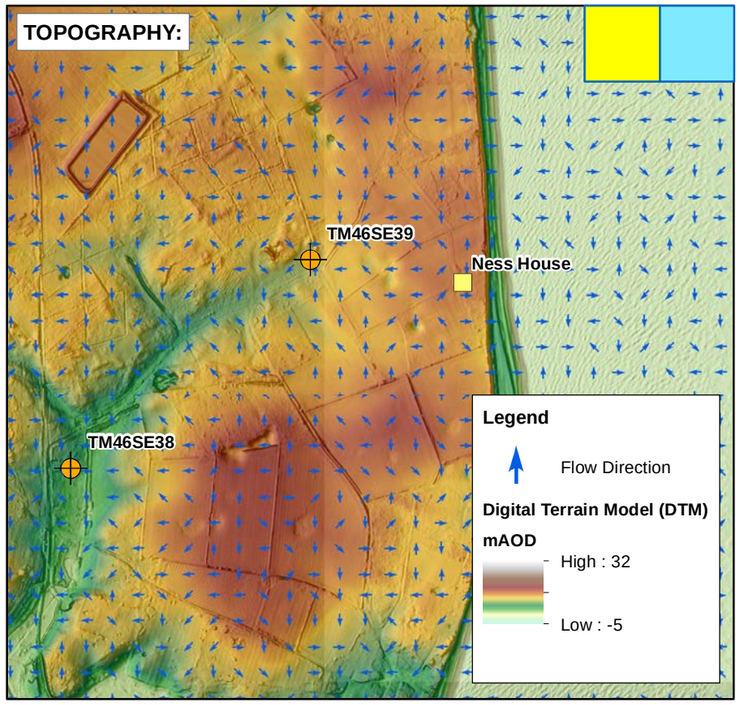
54. Ground investigations will be used to confirm the assumed levels of geological strata and inform the detailed design of the HDD to enable it to drill in the most favourable strata where possible and ensure the optimum selection of equipment for the works. In situ permeability testing and ground water monitoring undertaken prior to construction of the landfall will inform groundwater flows and characteristics for input into requirements for drilling fluid formulation including any stop-loss additive requirements.

55. Given that HDD activities are only temporary in duration and unlikely to comprise significant volumes of water and drilling fluid, there is unlikely to be a significant impact to the Lowestoft Sand and Gravel and Crag aquifers. The Applicants propose to implement a water quality and levels monitoring regime at the Ness House well, and a temporary portable water supply tied into the well will be provided for the duration of the HDD activities.

56. The risk assessment has determined that no degradation of water supplies is likely to result from the Projects' works.

Appendix 1 Figures

TOPOGRAPHY:



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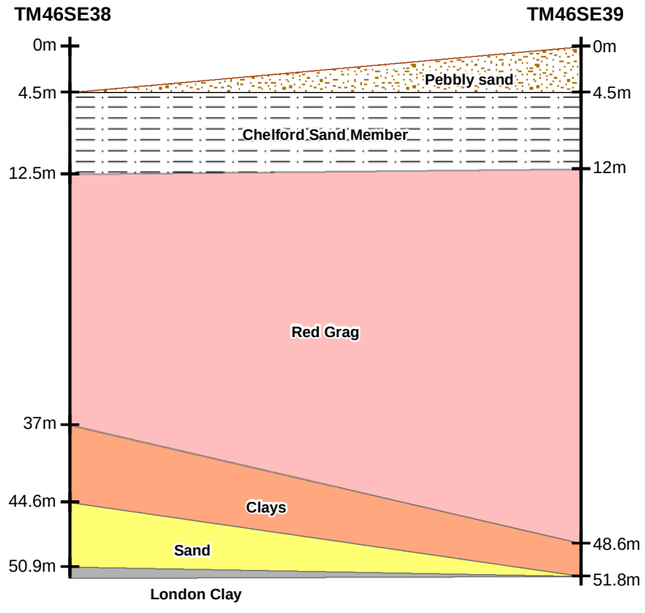

SCOTTISHPOWER RENEWABLES

Rev	Date	By	Comment
1	10/02/2021	AZ	First Issue.

Prepared: AZ
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1:8,000 Scale @ A3

0 230 460 Metres

East Anglia ONE North and East Anglia TWO

Conceptual Geological Profile

Drg No	EA1N-EA2-DEV-DRG-IBR-001272
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Date	10/02/21
Figure	1

Coordinate System: BNG
Datum: OSGB36

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