Tween Bridge Solar Farm

A Nationally Significant Infrastructure Project in the Energy Sector

Preliminary Environmental Information Report

Technical Appendix 9.1

Phase 1 Ground Conditions Desk Study Volume 1 – Main Report & Appendices A to G.

October 2023

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Understanding Ground Conditions

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Proposed Solar Energy Scheme
Land at Tween Bridge
Thorne, South Yorkshire

PHASE 1 GROUND CONDITIONS DESK STUDY

REPORT NO. 22072 Vers. 2, July 2023

GEOLOGICAL • GEOTECHNICAL • ENVIRONMENTAL • ENGINEERING

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Phase 1 Ground Conditions Desk Study
Land at Tween Bridge
Thorne, South Yorkshire

Client: RWE Renewables UK Limited

Intégrale Report No. 22072, Version 2, July 2023

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CONFIDENTIALITY STATEMENT

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1.0 INTRODUCTION

1.1 General

RWE Renewables UK Limited are considering construction, operation, maintenance and decommissioning of a ground mounted solar photovoltaic electricity generating scheme with a total design capacity of 818.9 MWp, with associated development, on land between Thorne, South Yorkshire and Crowle, North Lincolnshire. Their planning consultants are Pegasus Planning Group.

Integrale Limited are commissioned to undertake an Initial Phase 1 Desk Study, concentrated on ground conditions, geotechnical and contamination aspects. The aim of the current report is to provide baseline data on which to develop the Ground Conditions aspects of an Environmental Impact Assessment (EIA).

This report therefore describes the geological setting, soils, groundwater, and preliminary historical and environmental data. An initial site visit has allowed outline assessment of the topography, drainage and access to inform the desk studies. The range of ground and groundwater conditions are anticipated and used to establish an initial conceptual model of potential pollutant linkages. Implications for the development are considered, recommendations for further desk study, assessment and investigation made, and preliminary comments made on contaminated land and geotechnical risk aspects.

This Version of the desk study is an updated document, based on the Initial Desk Study that accompanied the EIA Scoping report. It includes the revised Order Limits and layout, additional environmental and historical data and updated conceptual model, and takes into account preliminary comments from statutory consultees and regulators.

1.2 Data Sources

The principal data sources used to inform this report comprise Open Government Licence data and Groundsure Enviro & GeoInsight reports, including:

Multi-Agency Geographic Information for the Countryside (MAGIC) interactive map available under Open Government Licence (OGL) on-line https://magic.defra.gov.uk
Accessed November 2022-June 2023.

British Geological Survey (BGS) GeoIndex Onshore for mapping and exploratory records (available under OGL on-line) https://mapapps2.bgs.ac.uk/geoindex/home.html
Accessed November 2022-June 2023

LandIS Soilscapes map for soils mapping and data (available on-line https://www.landis.org.uk/soilscapes
Accessed November 2022

Coal Authority Interactive map for mining information (available on-line
https://mapapps2.bgs.ac.uk/coalauthority/home.html Accessed November 2022

South Yorkshire & North Lincolnshire Mineral Resources reports and plans (available on-line, accessed November 2022
https://www2.bgs.ac.uk/mineralsuk/download/england/southYorkshire.pdf
https://www2.bgs.ac.uk/mineralsuk/download/england/lincolnshireMap.pdf
Local Plan documentation on Mineral Resources for North Lincolnshire and City of Doncaster Council, accessed June 2023.

National Library of Scotland for historical maps available on-line https://maps.nls.uk
Accessed November 2022

LIDAR data files (available on-line under OGL)
https://environment.data.gov.uk/DefraDataDownload/?Mode=survey Accessed November 2022

2.0 THE SITE

2.1 Location and General Description

As shown in Appendix A, the Order Limits area is located to the east of Thorne and west of Crowle, bounded to the north by the Humberhead Peatlands National Nature Reserve, and to the south by Hatfield Moors and the Isle of Axholme. It has an approximate central Ordnance Survey Grid Reference of SE 73000 11000.

The Order Limits area includes a series of land parcels and link corridors shown bounded in red in the appendices. For ease of reference, the wider study area setting of these land parcels is illustrated beyond by a rectangular zone approximately 10kms east-west by 10 kms north-south (between grid kilometre co-ordinates Easting 68000 to 78000 and grid Northing 8000 to 16000).

The site straddles land within Doncaster Council and North Lincolnshire local authorities, with the boundary line as marked on various drawings in the appendices. For ease of review, where aspects specific to each Authority area are discussed in the text below, these are highlighted yellow for Doncaster and green for North Lincolnshire.

An initial reconnaissance visit was completed by Integrale Limited in early November 2022, and typical photographs are included in Appendix B, along with on-line Google Earth imagery. The main features and pertinent aspects within the Order Limits and immediately adjacent land forming the wider study area can be summarised as:

Current Use	Predominantly large-scale agricultural fields with isolated farmsteads.
Site Area	Approximately 1300 Hectares (13 km^2).
Maximum Dimensions	Very irregular but approximately 7km N-S by 9km E-W.
Ground Slopes & Topography	Lowland basin of former east flowing River Don and north flowing River Idle. Low-lying between typically 1-4mOD, with overall very low to negligible natural gradients. Lowest lying areas in southwest, northwest, centrally and to northeast at 0-2mOD. Mid Elevations in south and northwest at 2-4mOD Higher land occurs beyond the study area to the east (Crowle), southeast (Isle of Axholme), west (Thorne), and southwest (Hatfield) at >4 to 6mOD.
Major Features & Infrastructure	Bounded to north by Humberhead Peatlands National Nature Reserve (Thorne Waste or Moors). Tween Bridge Wind Farm centrally in north with large-scale overhead pylons. Rail line, closely aligned with: Stainforth & Keadby Canal running east-west centrally. A18 road (High Levels Bank) east-west centrally. M180 motorway east-west in southern boundary area.
Surfacings & Condition Vegetation & Trees	Agricultural soils predominate, with occasional hedgerows and woodland.

Water Courses	Mapping shows numerous drainage ditches forming a rectilinear grid of linked water channels across complete study area. Larger water courses include (from north to south): Stainforth & Keadby Canal (Sheffield and South Yorkshire Navigation) with North and South Soak Drains parallel on either side. Boating Dyke Drain centrally, flowing into Old Dun/Don Drain, North Engine Drain and Wood Carr Drain. River Torne forming extreme southeast boundary of study area.

2.2 Areas & Land Parcels

For the purposes of the current report only, various Areas within the Order Limits have been defined based on their location and mapped geology. These are referred to throughout the text as follows (highlighted yellow for Doncaster and green for North Lincolnshire) and as shown on the plan drawing in Appendix B:

Area 1. Old River Don (North Lincolnshire)

Northeast – to West of Crowle
Low lying at 1-3mAOD

Area 2. North Engine Drain to River Torne (North Lincolnshire)

Southeast – between A18 and M180 roads
Mid elevations at typically 2-4mAOD

Area 3. Plains Lane (North Lincolnshire)

Central South – between A18 and M180 roads
Low lying at 2-3mAOD

Area 4. Bletchers Drain (North Lincolnshire)

Central
Low lying at 2-3mAOD

Area 5. Elder Gates, High Levels (Doncaster)

Central South
Low lying at 2-3mAOD

Area 6. Hatfield Chase (Doncaster)

Southwest
Very low lying at 0-2mAOD

Area 7. Ferne Carrs (Doncaster)

Southwest
Mid elevations at 2-3mAOD

Area 8. Clay Bank (Doncaster)

Central west
Very low lying at 1-2mAOD

Area 9 Tween Bridge Wind Farm East (Doncaster)

Central north
Mid elevations at 2-4mAOD

Area 10. Tween Bridge Moors & Wind Farm West (Doncaster)

Northwest
Low lying at 1-3mAOD

Where link corridors for services are considered, these are referred to by adjacent land parcels, eg Area 1 Old River Don to Area 9 Tween Bridge Wind Farm.

2.3 Published Geology

2.3.1 British Geological Survey (BGS) Mapping

This area of the southern part of the Vale of York and the Humberhead Levels, is low-lying, low relief ground underlain by thick stratified sequences of complex late Quaternary Period superficial deposits (Drift). It is defined by BGS as a Lowland Basin Domain.

It comprises the former courses of the Rivers Don and Idle, the initial channels of which were incised during low Quaternary sea levels, then infilled from the late Devensian, when glacial blockage of the Humber Gap occurred. This caused deposition of thick ponded (lake) deposits, sands and gravels, and infill sediments mapped historically as the '25 Foot Vale of York Drift'. Around 10,000 years ago at the end of the Devensian cold period, aeolian (wind-blown) sands were deposited, followed by further river channel incision.

Those channels were then infilled during the Flandrian by Alluvium, which overlaps marginal Peat deposits. During historical times artificial river diversions (particularly of the meandering multi-channel Rivers Don, Idle and Torne) and redeposition of Alluvium as 'Warp' material have taken place.

Whilst the larger Lowland Basin Domain is typically dominated by glaciofluvial sand and gravel and glaciolacustrine clay and silt at depth, the current study area at surface is masked by wide spreads of the younger Flandrian Alluvium and marginal Peat. BGS geological maps indicate the following strata beneath and adjacent to the study area, as shown in Appendix C:

Map / Scale	Sheet 79 Goole and Sheet 88 Doncaster at 1:63,360 scale (Solid & Drift Sheets).	
BGS On-Line Viewer	BGS GeoIndex Maps Portal Accessed September – November 2022	
BGS Maps Portal	Geological Survey of Great Britain National Grid Series 1:10,560 & 1:10,000 scale maps (SE 60, 61, 70, 71) accessed June 2023.	
BGS Memoir	Geology of the Country around Goole, Doncaster and the Isle of Axholme, Memoir for One Inch Sheets 79 & 88 (England & Wales) British Geological Survey, 1994.	
Artificial Ground	None mapped in study area or immediately beyond (see also below however). Warp soils (historically artificially created Alluvium) are mapped in the east and just beyond the northwest boundary.	
Superficial Deposits (Quaternary sequence)	**Flandrian**	Warp (Historically artificially induced Alluvium) Alluvium (Fluvial Clay & Floodplain Sands and Gravels) Peat (Lowland raised bog)
	Devensian	Blown Sand (Aeolian) Sutton Sand Formation River Terrace Deposits (Sands & Gravels) Breighton Sand Formation (formerly Sand of 25 Foot Drift of Vale of York*)

	Hemingbrough Glaciolacustrine Formation (Clays & Silts – formerly Silt and Clay of the 25 Foot Drift of Vale of York) Glacial Sand & Gravel (Fluvioglacial Sand & Gravel) (Concealed sand and gravel deposits of Gaunt 1976/2020) (Older River Sand & Gravel Beneath 25 Foot Drift)

Solid Geology	Triassic age Mercia Mudstone Group – Mudstones- beneath eastern Areas 1 & 2 (East of Easting 75000) Triassic age Chester Formation Sandstone - Gravelly Sandstone – beneath Areas 3-8 Inclusive (West of Easting 75000 and South of Northing 12000) Permo-Triassic age Sherwood Sandstone Group – Sandstone - beneath Areas 9-11 (West of Easting 75000 and North of Northing 12000)
Geological Features	Two geological faults inferred across Areas 1 & 2

* (The term 25 Foot Drift referred to the elevation restriction of this deposit, being largely confined to areas below 8mAOD).

The BGS Memoir for the district was compiled by G D Gaunt, along with other contributors. Much of the Quaternary section was based on data collected in preparation of his 1976 doctoral thesis on "The Quaternary Geology of the southern part of the Vale of York". This was published in 2020 by the Thorne & Hatfield Moors Conservation Forum, with the aim of making his primary data available, to aid interpretation of the Quaternary sequence. Much of the information below is based on both the Memoir and his thesis.

2.3.2 Flandrian Deposits and Thicknesses

Alluvium is a river deposited clay, silt, sand and gravel, sorted or semi-sorted in a water course or on a floodplain. It is generally soft to firm, compressible silty clay, but with silt, sand, peat and basal gravel. A somewhat firmer, desiccated surface zone or 'crust' may be present locally. The numerous rivers converging on the Humber Estuary have deposited wide spreads of Alluvium in the study area over the Holocene / Flandrian Quaternary period. This is typically less than 1-5m thick across the former floodplains of the Rivers Don and Idle, but where it infills those incised channels cut during the previous Devensian glacial period, can be in excess of 15m within the study area. The lower deposits are coarser basal gravels, becoming increasingly finer sands, overlain by silts, becoming clayey near surface.

2.3.3 Devensian Superficial Deposits and Thicknesses

Those Devensian age Superficial Deposits given above are described in the BGS rock lexicon as follows:

Sutton Sand Formation:
Fine-grained silty sand.
Upper Boundary: present land surface.
Lower Boundary: unconformable on older superficial deposits, mainly Devensian glacial lake deposits and glacial till or underlying bedrock.
Thickness: to about 7m.

Breighton Sand Formation: Dominantly yellow to pale brown and reddish yellow slightly clayey sand to silty sand with a variably developed very dusky red to black compressible peat to clayey sandy peat base. Typically composed of moderately well-sorted medium quartz grains with minor bands of finer, coarser or poorly sorted material, including finely comminuted flint and lithic clasts. Thin beds of clayey sandy peat and poorly developed fine to medium-grained slightly gravelly clayey sand are noted towards the base of the formation.

Upper Boundary: Typically exposed at surface beneath a thin (0.2 to 0.5m thick) sandy soil or locally overlain by alluvial and aeolian deposits.
Lower Boundary: Sharp to gradational (over several tens of cms) transition to underlying clay, silt or sand of the Hemingbrough Glaciolacustrine Formation, or directly to bedrock
Thickness: Average 1 to 2m, but can exceed 6m.

Hemingbrough Formation:
Unfossiliferous laminated clays, silts and sands with rare dropstones (typically fine-grained pale coloured sandstone, grey limestone and dark mudstone).
Upper Boundary: either the present land surface or overlain by later superficial deposits, commonly represented by sand deposits of the Breighton Sand Formation.
Lower Boundary: unconformable, resting directly on bedrock or underlain by basal glaciofluvial deposits.
Thickness: to 30m.

Inferred contours on the base of the Devensian deposits in the study area indicate the Flandrian infilled valleys, whilst typically 1-5m deep, extend in mid channel down to 15m+ below OD, and potentially locally 20-30m below OD. The more recent meandering channels of the Rivers Don and Idle have cut through this Flandrian Alluvium, also depositing deep channels of organic material, with slightly raised levees of silty clay built up during flood episodes. This sequence is critical to an assessment of shallow depth ground conditions across the southern parts of the study area, as discussed further below.

2.3.4 Historical Warp / Floodwarp

The BGS Memoir confirms that Warp is artificial improved soil created by historical 'floodwarping', or occasionally 'cartwarping', undertaken between the 1700's to mid 20th Century. It used the suspended silt and clay in rivers and reversal of flow during high tides. An area is embanked and a warping drain cut from it to the nearest river. Sluice gates at the river end of the drain are opened at high tide, allowing sediment-rich water to flood in and deposit silt. The water is let back slowly into the river at low tide.

Each flooding creates c. 2mm of deposit, and up to 300mm could be left in a single year. The thickest known floodwarp is 1.5m. The soil deposited is light, silty and well-drained. It is recognisable by laminations below plough level, pre-existing soil beneath, traces of old embankments, differences in field levels or documentary evidence.

Cartwarping is manual spreading of silt or clay carried on carts on rails. Small areas are shown in the Memoir (Figure 46) within Area 1 at approximately SE 755 135, but are likely indistinguishable from floodwarping.

2.3.5 Mapped Surface Strata by Area

The published geological strata mapped at surface for each Area are as follows:

Area 1. Old River Don (North Lincolnshire)

Flandrian Alluvium in south and centre. Northwest of Moorbottom Drain is Warp (artificially induced Alluvium created by Floodwarping and Cartwarping*)
Marginal Peat to northwest south of Moorbottom Drain

Area 2. North Engine Drain to River Torne (North Lincolnshire)

Sutton Sand Formation.
Marginal Peat on northern, western and southern peripheries.
Small pocket of Alluvium and peat in central north

Area 3. Plains Lane (North Lincolnshire)

Flandrian Alluvium.
Peat in southeast
Sutton Sand Formation alongside M180

Area 4. Bletchers Drain (North Lincolnshire)

Flandrian Alluvium in south and centre Sutton Sand Formation in northern third Peat on north boundary with South Soak Drain and Canal

Area 5. Elder Gates, High Levels (Doncaster)

Flandrian Alluvium

Area 6. Hatfield Chase (Doncaster)

Flandrian Alluvium

Area 7. Ferne Carrs (Doncaster)

7a) River Terrace Deposits in west Breighton Sand Formation with channels of Peat in south Glaciofluvial Sand and Gravel in north Sutton Sand and Flandrian Alluvium in east
7b) Flandrian Alluvium north of Low Levels Bank Sutton Sand Formation south of Low Levels Bank Peat in channel within southeast alongside Crow Trees Moor Drain

Area 8. Clay Bank (Doncaster)

Hemingbrough Glaciolacustrine Formation in west with pockets Sutton Sand Formation Flandrian Alluvium in east

Area 9 Tween Bridge Wind Farm East (Doncaster)

Warp east of centre Peat on west periphery

Area 10. Tween Bridge Moors & Wind Farm West (Doncaster)

Hemingbrough Glaciolacustrine Formation Peat in southwest and east Sutton Sand Formation to south

The BGS on-line GeoIndex includes scan copies of boreholes sunk previously throughout the site area and these have been used to compile the anticipated ground conditions given in Section 3.

2.4 Soils Information

Data available on the LandIS Soilscapes Viewer from the Cranfield Soil and AgriFood Institute indicates:

Area 1. Old River Don (North Lincolnshire)

Typically Soilscape 20: loamy and clayey floodplain soils with naturally high groundwater, draining to the groundwater and rivers. (The northwestern and northern parts overlap with Natural England mapped peat) **Northwest of Moorbottom Drain Soilscape 21:** loamy and clayey soils of coastal flats with naturally high groundwater. Drains to local groundwater so risk of pollution including marginal ditches. (Superficial Floodwarp alluvial soils)

Area 2. North Engine Drain to River Torne (North Lincolnshire)

Typically Soilscape 15: naturally wet, very acid sandy and loamy soils, draining to the shallow groundwater table. Subject to wind erosion when dry and to rapid leaching. Winter working leads to damaged soil structure and compaction. **Northern and northwestern area plus west to North Idle Drain Soilscape 23:** loamy and sandy soils with naturally high groundwater and a peaty surface. (Overlaps with Natural England mapped peat).

Area 3. Plains Lane (North Lincolnshire)

Typically Soilscape 18: slowly permeable, seasonally wet, slightly acid but base rich, loamy and clayey soils. Impeded drainage to streams network. Risk of poached fields and damage to soil structure so timeliness of fieldwork important due to wet conditions.

Extreme southeast includes small areas of Soilscape 15 and 23, and Natural England mapped peat.

Area 4. Bletchers Drain (North Lincolnshire)

Southern half Soilscape 18: slowly permeable, seasonally wet, slightly acid but base rich, loamy and clayey soils. Impeded drainage to streams network. Risk of poached fields and damage to soil structure so timeliness of fieldwork important due to wet conditions.

Northern half Soilscape 21: loamy and clayey soils of coastal flats with naturally high groundwater. Drains to local groundwater so risk of pollution including marginal ditches.

Area 5. Elder Gates, High Levels (Doncaster)

Soilscape 18: slowly permeable, seasonally wet, slightly acid but base rich, loamy and clayey soils. Impeded drainage to streams network. Risk of poached fields and damage to soil structure so timeliness of fieldwork important due to wet conditions.

Area 6. Hatfield Chase (Doncaster)

Typically Soilscape 18: slowly permeable, seasonally wet, slightly acid but base rich, loamy and clayey soils. Impeded drainage to streams network. Risk of poached fields and damage to soil structure so timeliness of fieldwork important due to wet conditions.

Northern area of western half Soilscape 21: loamy and clayey soils of coastal flats with naturally high groundwater. Drains to local groundwater so risk of pollution including marginal ditches.

Area 7. Ferne Carrs (Doncaster)

Typically Soilscape 15: naturally wet, very acid sandy and loamy soils, draining to the shallow groundwater table. Subject to wind erosion when dry and to rapid leaching. Winter working leads to damaged soil structure and compaction. (Narrow channels of peat mapped by Natural England in western area)

Peripheral northern area adjacent motorway: Soilscape 18: slowly permeable, seasonally wet, slightly acid but base rich, loamy and clayey soils. Impeded drainage to streams network. Risk of poached fields and damage to soil structure, so timeliness of fieldwork important due to wet conditions.

Area 8. Clay Bank (Doncaster)

Typically Soilscape 21: loamy and clayey soils of coastal flats with naturally high groundwater. Drains to local groundwater so risk of pollution including marginal ditches.

Western third Soilscape 18: slowly permeable, seasonally wet, slightly acid but base rich, loamy and clayey soils. Impeded drainage to streams network. Risk of poached fields and damage to soil structure so timeliness of fieldwork important due to wet conditions.

Area 9 Tween Bridge Wind Farm East (Doncaster)

Soilscape 20: loamy and clayey floodplain soils with naturally high groundwater, draining to the groundwater and rivers. (Western periphery overlaps with Natural England mapped peat).

Area 10. Tween Bridge Moors & Wind Farm West (Doncaster)

Typically Soilscape 18: slowly permeable, seasonally wet, slightly acid but base rich, loamy and clayey

soils. Impeded drainage to streams network. Risk of poached fields and damage to soil structure so timeliness of fieldwork important due to wet conditions.

Southern area Soilscape 21: loamy and clayey soils of coastal flats with naturally high groundwater. Drains to local groundwater so risk of pollution including marginal ditches. (Includes southwestern and southeastern areas with Natural England mapped peat).

It can therefore be seen that the majority of soils are loamy and clayey, which either help maintain a naturally high groundwater table, and drain into ditches and streams, or they are only slowly permeable and seasonally wet with more impeded drainage to the ditches and streams. Several areas are mapped separately by Natural England as peat, but none of the land parcels being considered include Soilscapes classed as bog peat soils.

These soils can be prone to damage to soil structure or consolidation when worked, particularly during wet periods; this is highlighted for Soilscape 18, where timeliness of fieldwork is noted as important. Where drainage is into surrounding ditches, there is a risk of pollution to these water courses.

2.5 Past Mining, Quarrying and Peat Deposit Workings

2.5.1 Coal

The Coal Authority (CA) interactive map has been consulted, which indicates the majority of the study area is within the Coal Reporting Area (the known extent of coal mining activity used to determine whether a coal mining report is required for property transactions and the conveyance process). The boundary crosses the southeast, such that Area 2 lies outside it.

None of the area within the Order Limits and for a zone beyond lies within the Development High Risk Area, However, there were two former shafts at Thorne Colliery, approximately 875m to the northwest. The Development High Risk Area is the part of the coal mining reporting area which contains one or more recorded coal mining related features which have the potential for instability or a degree of risk to the surface from the legacy of coal mining operations.

Thorne Colliery was open between 1925 and 1958 but operational issues including shaft water, caused the pit to be non-productive for much of its lifespan. Production ended in 1958 due to geological problems. There were two shafts, referred to by BGS as 470415-001 and -002, and shown in Appendix E. Such mine entries pose a risk due to their potential Zone of Influence, albeit both shafts appear to be capped. The Zone of Influence of these shafts can be calculated using a departure value of 10m to account for inaccuracy of recording position, the depth to rockhead and the entry radius. This calculates at <40m. Since the actual distance to the boundary of Area 10 of the Order Limits is c. 875m, this is not considered significant.

The shafts and colliery site were redeveloped as the Thorne solar farm in 2015; Google Earth imagery indicates the former shafts apparently concrete capped and surrounded by solar arrays.

BGS records of the shaft bores indicates rockhead at 20 and 27m depth and base of the Trias/top of Carboniferous at c. 280m depth.

The Coal Authority were contacted and advised that, whilst the site falls within the coalfield, it is located outside the Development High Risk Area; meaning that there are no recorded coal mining legacy hazards at shallow depth that could pose a risk to public safety and / or land instability at the surface.

Accordingly, the Coal Authority confirmed (their consultation response 8th February 2023) that there is no requirement to consider coal mining legacy as part of the Environmental Impact Assessment, or to consult with them further on this project.

2.5.2 Peat Deposits & Workings

2.5.2.1 Occurrence & Thickness

Thick peat deposits occur to the south on Hatfield Moor and to the north on Thorne Moors, which were exploited for centuries by block cutting, and more recently by surface milling. Peat working has also taken place at Crowle Moor on and adjacent to Area 1. The extent of 'peat' mapped by BGS and Natural England are shown in Appendix D.

The deposits are the remains of lowland raised bog, or raised mire fenland, extending beyond the designated conservation moorland, and beneath parts of the study area, as shown in Appendix D. The deposits lie both within and beneath the Alluvium, in areas flanking the deep incised river courses, in particular due to poor drainage and waterlogging in the late Flandrian period. Gaunt postulated that the peat formation was not simply due to high rainfall (as this area has a relatively lower rainfall for northern England) but also the low elevation, relative sea levels, and resulting high groundwater table. He considered that ground saturation in the lowest areas, initiated growth of peat (ie a fenland environment) which then isolated the surface from base rock or subsoil nutrients. As this developed into raised bog above the water table, it became more dependent on rainfall.

The BGS Memoir reports that Thorne Moor was formerly more extensive before peat cutting in the west and southwest, and floodwarping northeast, east and south. Original estimated thicknesses of 6m on Thorne Moor have been significantly reduced by workings to around 3m, and some areas are flooded. BGS state that peat cropping out between Crowle and Sandtoft has not been proven to more than 0.7m depth, despite a significant lateral extent. (Although peat deposits east of Medge Hall at Lover's Ground are reported ranging from 0.6-1.6m thick, see Sections 2.5.3 and 3.1). Locally thick Alluvium on Hatfield Chase, is peaty at depth, however BGS state there is little evidence of true concealed peat. This may apply to parts of Areas 1, 2, 9 and 10 where peat is mapped by BGS or Natural England (Appendix D).

Gaunt (2020) also reported that *"…According to historical accounts, peat formerly extended across Tween Bridge Moors and South or Sand Moors, but has been complete worked off". On Nun Moors* (Area 10*) sandy peat up to 0.5m thick is sporadic….variably sandy and peaty clay over a metre thick in parts skirts the north edge of Hatfield Chase and the old course of the south branch of the River Don west of Crowle* .." (parts of Areas 1 and 2).

Irregular peat outcrops between Thorne Moors and Hatfield Chase, are reported to thin out against the underlying Hemingbrough silts and clays or Blown Sutton Sand, or pass under floodwarp or natural Alluvium of the old River Don. There has been compression of the original peat thickness where floodwarp deposits overlie it.

The range of near surface (ie at less than 1-3m depth) peat thickness therefore anticipated within the Order Limits area is from 0.5-1.5m, but more typically less than 0.6m to 1m. Sandy peat or peaty clays and silts above and below the true peat are likely included in the reported thicknesses and mapped areas.

2.5.2.2 Peat Classification

Natural England's 2010 survey of "England's Peatlands: carbon storage and greenhouse gases" indicates this area includes peaty soils of more than 400mm thick. Maps included in this document and in the International Union on the Conservation of Nature UK "Peatland Strategy 2018-40" (2018) indicate the area defined as **'wasted peat'**. This distinction is where drainage and cultivation has degraded the peat, the soil is no longer waterlogged and it has wasted away by shrinkage, decomposition, wind erosion and cropping. Wasted peat is now dominated by the underlying mineral material.

2.5.2.3 Impacts of Agriculture and Development on Shallow Peat Soils

Agriculture, workings and development can impact peatland soils, by creating changes in water levels and flow, dissecting peat masses, removing vegetation, or excavation and removal of peat. The lowland raised bog type of peat within the Order Limits area has been degraded to a 'wasted peat' state by drainage and

agriculture over the centuries, such that it does not constitute a peatland habitat, and the dominant land use is arable production. The Humberhead Peatlands National Nature Reserve of Thorne Moor beyond to the north has been restored to variable degrees.

The organic matter content remaining in the shallow soils within mapped 'peat' areas is likely to be variable and minimal due to ploughing, cropping and drainage. This is reflected in the LandIS soil descriptions reported in Section 2.4 above, where no peat bog soils are defined, with the most organic soils described being those in Area 2 (North Engine Drain to River Torne) which are simply 'loamy and sandy soils with naturally high groundwater and a peaty surface'.

2.5.2.4 Peat Stability Risk

In spite of the above, the need for a peat stability assessment during detailed design stage requires consideration. The risk factors for stability (with regard to upland blanket bog peats) are quoted in Natural England NECR032 (2010) as:

- Peat overlying impervious or very low permeability clay or mineral, giving a hydrological discontinuity at the peat base;
- Connectivity between surface drainage and the peat/ impervious interface;
- Proximity to local drainage (seepage, groundwater flow, flushes, pipes or streams);
- Convex slopes or breaks in slope.

Instability is more likely if there is:

- Very deep peat >3m
- Low shear strength <6kN/m^2
- High Von Post Number >7 (highly, very or completely decomposed peat)
- Slopes of >6°
- Nearby water features.

However elsewhere in the literature, instability by peat sliding is often quoted as likely in shallow (<2m) peat on 5-15° slopes, or bog bursts as likely in deeper peat (>1.5m) on 2-10° slopes. Where near surface, fibrous, and low humified peat occurs, it is more permeable and this drainage capacity increases stability.

The risks of peat instability in lowland raised bog are much reduced, but require consideration to identify critical areas where specific construction could have localised impact such as trench failure. As an initial assessment the key risk factors have been considered for the Tween Bridge site:

Risk Criteria	Area 1 Old River Don	Area 2 North Engine Drain & west	Area 3 Plains Lane	Area 4 Bletchers Drain	Area 6 Hatfield Chase	Area 9 Tween Wind Farm	Area 10 Tween Bridge Mooors
Peat thickness >1.5m intersected by infrastructure	Old River Drain previous boreholes found deep organic soils & peat in former river channel(s) only	Unlikely that peat >1.5m	Peaty soils likely in former river channels. Remainder likely degraded or masked by Alluvium.	Former river channel crosses so peaty soils possible locally	Former river channels cross so peaty soils possible locally	Boreholes show peat 1-1.6m thick	Unknown to date on Nun Moors and southeast area
Existing shallow peat degradation	Highly degraded or degraded due to historical / ongoing agriculture						
Degree of pre-development drainage	High density effective drainage dissecting shallow peat						
Low shear strength, highly decomposed peat	Fibrous or woody		Peat overlain by clayey organic soils			Pseudo fibrous, clayey & sandy peat. Shear strength <4kN/m^2	
Slopes greater than 2-4°	Lidar slope assessment shows typically 2-4°, except on levees where 2-6°. Drainage ditch and stream /river course banks locally steeper						
Proximity to water /drainage courses	All areas include drainage or stream/river courses typically peripheral to field / plot boundaries. No significant evidence of slippage failure in typical shallow existing drainage network						
Site Sensitivity to Peat Instability	**Very Low or Low for majority of site as risk factors limited due to degradation, drainage and low slopes, and limited intersection by proposed development. Possible medium sensitivity locally where deeper intersection by specific construction in deeper peat.**						

Peat stability will therefore require consideration during detailed design at any specific locations where intrusive investigation proves a sufficient peat thickness would be intersected by the proposed construction (e.g. new accesses, structures).

2.5.3 Geoarchaeological Report Medge Hall / Lover's Ground

A 2015 'Geoarchaeological Report' by Headland Archaeology comprised soils augering and reassessment of earlier geophysical survey in this area, including three locations (for then proposed wind turbines Nos. 4, 5 and 6). The aim was to assess peat deposit thickness and the sub-surface topography of basement sands. This data has been used in Section 3.1 below to anticipate the strata, and extracts are included in Appendix J, Volume 3.

2.5.4 Historical Mapping Evidence for Non-Coal Mining & Quarrying

Historical maps are discussed in more detail below. There is localised evidence for small scale near surface workings where sand or sand and gravel deposits occur at the surface. The following details on aggregate workings, ponds and peat workings have been taken from the Groundsure data reports included in

Appendix H, Volume 2. (References to the canal excavation and Thorne Colliery have been omitted from this section).

Location	Surface Workings Type	Comment
Area 1: 33m NW	Water body (former River Don)	1908 map
Area 1:160-65mS	Brickworks disused	1885 – 1951 maps
Area 1: Off Site to N	Peat Workings	Historical
Area 2: On site boundary E of Belton Grange	Ponds	1886 & 1973 maps
Area 1: 340mSE & Area 2 – 500m NE	Crowle Brickworks – clay and shale workings	1947 onwards now ceased
Area 3: 375m S	Brier Farm Sand Pit	Ceased
Area 3: 96-108m SW	Unspecified Workings linear shape	1904 to 1951 maps
Area 6: Northern Boundary	Unspecified Levels	1907 & 1930
Area 6: 46m NW	Cuttings	1982
Area 6: 103m NW	Pond	1904-48 maps
Area 7a: Tudworth Hill	Sand Pit / Workings	1966 -68 maps
Area 7b: near Severals Cottage	Pond	1907 - 1951
Area 7b: Off Site Hatfield Moor	Hatfield Moors Peat Workings	Historical mineral planning area & workings
Area 8: at Double Bridges SW boundary	Pond	1904-55 maps
Area 9: South of Limberlost	(Warping) Pond	1891-1908
Area 9: near Limberlost	(Warping?) Ponds	1891 & 1948
Areas 9 & 10: Off Site to N	Peat Moss Litter Workings	Historical now ceased
Area 10: on NE boundary near Pumping Station	Pond	1908-55

2.5.5 Minerals Resources

The Humberside and South Yorkshire Minerals Resources maps and reports dated 2006 were obtained from the BGS website. Annotated extracts are included in Appendix E and indicate the following within the study area:

- Thorne Moors Peat areas active workings and nature conservation zones;
- A roughly triangular area at Tudworth Field Road (Area 7a) in glaciofluvial deposits was likely worked for sand and gravel, but mapped as inactive. (This shows on Lidar imagery as lower lying than surroundings);
- The Crowle Brickworks (now lakes north of the Canal and Area 2) was worked in clay and shale and is inactive.

Minerals Safeguarding Zones are designed to protect finite resources and prevent their sterilization by non-minerals development. Development which is exempt from the mineral safeguarding policy includes temporary planning permissions, which by definition includes renewable schemes with time limited permission and an integral decommissioning phase.

The North Lincolnshire Council Local Plan (2020-2038) which is currently submitted for Examination includes details of the Council strategy for Minerals Planning, and specifically their Minerals Safeguarding Areas. An extract of their Policy Map is included in Appendix E, annotated to show the Preferred Options Safeguarding Areas for Sand & Gravel (Superficial Deposits) including a 250m buffer, and for Brick Clay. This indicates that a small section of Area 1, most of Area 3, approximately half of Area 4 and almost all of Area 2, fall within the Sand & Gravel Safeguarding Zone. None of the existing consented extraction sites, areas of search, nor proposed sites allocations lie within the Order Limits however.

The Doncaster Council Local Plan (2015-2035) Adopted Policy Map, an annotated extract of which is included in Appendix E, indicates a section of the extreme southwestern area falls within the Sand & Gravel Safeguarding Zone, including the 250m buffer. Again, none of the Order Limits area falls within the existing consented extraction sites, areas of search, nor proposed sites allocations. The Council's 2012 Stage 2 Evaluation Assessing Minerals Areas of Search considered land at Hatfield Woodhouse (Area 52) (including Tudworth Green Farm and part of Area 7A south of the M180) but commented *'it is not proposed to bring forward this area as an area of search. Reasons borehole data and proximity to housing and Hatfield Moor SAC'*. Similarly, land at Brierholme Carr (Area 55) bordering the site at Sandtoft Road Drain was *'not proposed to bring forward this area as an area of search. Reason: the area appears to have reached the limit of extraction'*.

It is concluded that whilst areas within the Order Limits are included in Minerals Safeguarding Zones for sand and gravel, these do not include any current operational extraction sites, and no sites have been identified by the local authorities as consented, proposed, or of interest for future searches within the period of the adopted Local Plans.

2.5.6 Hydrocarbons

2.5.6.1 Hatfield Moors Gasfield

The Hatfield Moors gas fields are located c. 1.5-2 kms south of the southern Site boundary, being the only important hydrocarbons discovery in the area to date. Permo-Triassic rocks of the district have very limited source potential. Westphalian and late Namurian rocks contain large quantities of organic matter; they are thus gas-prone and can yield only very small amounts of oil. Almost everywhere in the district the organic maturity in these rocks is well below the level of peak gas generation.

Hatfield Moors Gas Field was accidentally discovered by gas ignition whilst drilling an oil exploration well in 1981 at *(Hatfield Moors No. 1 Oil Borehole SE 7035 0668 approximately 1.5kms south of Ferne Carrs, Area 7A)*. Hatfield West Field *(Hatfield West Oil Borehole SE6766 0604, approximately 4kms southwest of Moor Lane Area 7b)* was subsequently proven within the same reservoir rock of the Westphalian B Oaks Rock sandstone. Following gas production, a gas storage project using this depleted reservoir was commissioned by Scottish Power in 2000. Gas is imported from the Transco network at Beltoft (6kms southeast of Crowle) via pipeline to a compression site at Lindholme, then piped to Hatfield for injection into the reservoir.

Belton Oil Borehole *(drilled 1945 at SE 7771 0846 c. 0.8km southeast of Area 2*) proved Superficial Deposits to around 8.5m over the Mercia Mudstone, with Coal Measures at c. 1.3kms depth. Crowle No. 1 Oil Borehole *(Drilled 1966 at SE 7734 1193 c. 1.4kms north of Area 2 and 1.2kms east of Area 1)* proved 2.4m of Superficial Deposits over the Mercia Mudstone, with Coal Measures again at c. 1.3km depth.

The Hatfield gas field is operated under Oil & Gas Authority Licence (BNG) PL 162 by Scottish Power Energy Management Limited.

A further Coal Bed Methane site is marked on the North Lincolnshire Local Plan Policies mapping just north of North Engine Drain at c. *SE 7700 1070 c. 300m north of Area 2*, although no further details of this are currently known.

2.5.6.2 Petroleum Exploration & Development

The following Petroleum Exploration and Development Licence (PEDL) Areas cover parts of the Order Limits, and details can be viewed at:

https://nstauthority.maps.arcgis.com/apps/webappviewer/index.html?id=29c31fa4b00248418e545d222e57ddaa

PEDL 281:

This extends across the northwestern section of Area 7a at Ferne Carrs / Tudworth and the western section of Area 6 at Hatfield Chase. The licensees from 2016 are Alkane Energy UK Ltd and Infinis Energy. The licence is extant, with a Term 3 end date of 2046.

PL 161:
This extends across the southwestern section of Area 7A at Ferne Carrs. The licensees are Egdon Resources, Infinis Energy and Scottish Power UK plc. The license start date was 1971 and the Term 1 end date 1977, while the licence is still extant. The licence field is known as Askern Coal Mine Vent, Hatfield.

Further liaison with the North Sea Transition Authority is to be undertaken on these aspects.

2.6 Outline History

2.6.1 Drainage and River Diversions

This low-lying district has been subject to ongoing artificial changes to the natural drainage pattern for centuries, if not longer, as widely reported in the literature. It is crossed by numerous drainage ditches forming a rectilinear grid of linked water channels. Larger water courses include (from north to south) the Stainforth & Keadby Canal (Sheffield and South Yorkshire Navigation) with the North and South Soak Drains parallel on either side; the Boating Dyke Drain centrally, flowing into the Old Dun/Don Drain, North Engine Drain and Wood Carr Drain; the River Torne forming the extreme southeast boundary of Area 2 and the study area.

Gaunt (2020) states that *".. in view of this vast drainage hinterland…. These rivers have to be contained within artificially elevated embankments to preclude flooding. Much of the drainage of the lowland itself is facilitated by artificial dikes, some of these going back to early medieval times; some appear to be of pre-Norman age and may be of Roman origin".*

The process of warping to produce better drained and elevated light soils for agriculture has been described in Section 2.3.3 above.

Major diversions of large rivers, cutting of additional drainage ditches and dykes, and minor improvements to drainage of individual fields to control flooding and run-off have been a pre-requisite for historical and current agriculture. These may date from the Roman period onwards, but the most substantial programme was undertaken in 1625-7 by Vermuyden. This included stopping up that part of the River Idle which previously flowed north to meet the River Don just south of Area 3. The River Don previously had (at least) two channels flowing east across Hatfield Chase and west of Crowle, but was stopped up at Thorne and channelled north instead. The New River Torne artificial channel now forms the southeast boundary.

Evidence of the former courses survives as topographic features identified in Lidar imagery, as discussed in Section 2.7, and in the deep channels proven in some boreholes (e.g. see Section 3.1, Areas 1, 2 and 6).

2.6.2 Historical Mapping

Historical maps provided in the Groundsure data report in Appendix H Volume 2 have been studied. Historical map features pertinent to geological, geotechnical and contaminated land aspects are shown as a summary plan in Appendix F (complemented by a further plan of environmental data features). Those features highlighted in bold below as the most pertinent to ground conditions aspects are shown on that summary plan.

It should be noted that the Groundsure data includes additional land areas subsequently removed from the draft Order Limits, and therefore the red line boundaries on the data maps does not concur with those shown in Appendix A.

The historical maps indicate:

Area 1. Old River Don (North Lincolnshire Council)

Floodplain with peaty soils in northwest and north. Floodwarp area northwest of Moorbottom Drain. The channel of the former River Don crosses mid south to northeast. A few additional ditches, and field boundaries from current day. Main drainage (Crook o' Moor Drain, Moor Middle Drain, & Moor Bottom

Drain (alongside Moor Bottom Road/track) and ditches flow southwest to northeast, with rectilinear subsidiary drains. In southwestern area Lovers Ground farm centrally. Central northwest area termed 'The Warpings'. Thousand Acre Second Drain and Tramway beyond to west in 1906 may reflect Warping, or peat working operations. **Old River Don channel crosses southeastern area** as relatively narrow drainage ditch.

Railway forms extreme southwestern boundary from earliest maps. Overhead cables and pylons cross southern part from 1968.

Peat Works at Medge Hall off-site adjacent southwest of Area 1 and **crossing Area 9 link corridor** from 1900's, disused by 1968. Peat Works c. 250m northeast at Moor Middle Drain (on Peatlands Way) labelled from 1967, although small buildings there from earliest maps. Smaller scale peat working likely across area, but no specific mapping evidence.

Gas Works on western outskirts of Crowle approximately 500m east, from 1850's to early 20th Century (removed by mid century). Brickworks (clay pits) 300m southeast at Godnow Bridge marked as 'old' 1904.

Area 2. North Engine Drain to River Torne (North Lincolnshire Council)

West of Hirst Priory (became golf course between 2003-2010). Large square field pattern with north-south and east-west drainage ditches. **Small pond west of Belton Grange in 1850's removed by 1900**. Small scale shallow peat working possible in past, but no specific mapping evidence.

An on-line Unexploded Ordnance risk search has identified a WWII Decoy Site at SE 76000 10000. No evidence of this on current satellite imagery, or historical maps, but see comments below under Lidar. A **bomb store area** for the WWII Sandtoft airfield extended north to Woodcarr Small Drain, lying within the southwestern extension of Area 2. RAF aerial photographs of 1946 & 1948 and maps of 1967-68 indicate layout of small mounds (likely ordnance storage bunkers) and huts centred on 475550 409150. This area is shown as taxi routes only on the 1973-1986 maps. Further details are given in Section 2.6.3 and the separate heritage assessments.

Western boundary Cataline drainage course, linked further south into Hatfield Waste Drain. M180 built between 1971-78 along southern boundary.

Area 2 – Area 3 Link Corridor & Arrays (North Lincolnshire Council)

As Area 2, and notably during WWII part of Sandtoft airfield infrastructure**. Includes airfield Bomb Store area**. RAF aerial photographs of 1946 & 1948 and maps of 1967-68 indicate layout of small mounds / huts and by 1973-1986 maps shown as taxi routes only,

Area 3. Plains Lane (North Lincolnshire Council)

Crossed by **meandering former course of River Don** (likely a peaty clay-filled channel)
Extreme southeast includes small areas of mapped peat.

Plains Cottages (or farm) in southwest, removed by 1931.
Goodcop Cottage to its south in 1963-1969 appears later demolished.

The Poultry Farm constructed by 2010 off-site adjacent southern boundary and M180 (built 1971-78).
Sewage Works c. 300m south by 1948. Small sand pit mapped c. 400m south in 1880's.

Area 4. Bletchers Drain (North Lincolnshire Council)

Small rectangular fields pattern. Additional field boundary shown centrally on 1904 mapping. Length of cutting slope or mounding parallel to Bletchers Drain on southwest boundary on 1893 and 1948 maps. **Former course of River Don** crosses centrally.

Area 5. Elder Gates, High Levels (Doncaster Council)

Small rectangular fields pattern. **Length of the meandering course of former River Don** close to

southern boundary. Central drainage ditch and pump on earlier maps removed by 1962. Elder Gates Farm and Crow Tree Hall off site beyond south and west boundaries. School and Chapel off-site beyond northwest boundary on High Levels Bank.

Area 6. Hatfield Chase, High Levels (Doncaster Council)

Rectangular field pattern, crossed by **meandering course of former River Don** (likely a peaty clay filled channel). Old buildings on 1850's map alongside river course later removed. Old Tudworth Fields Road forms south west boundary with higher land of Tudworth Hill.

M180 constructed 1970's forms much of southern boundary. Low Hassocks Drain and Kitchens Drain (& High Levels Bank) form northern boundary in parts, while the area is divided east-west by Askerns Drain.

By 2010 a large pond had been created in the extreme eastern area. Dale Mount house and farm and Drain House Farm form embayments within central section. The Severals house & farm in southeastern area.

Area 7. Ferne Carrs, Low Levels (Doncaster Council)

Tudworth Hill forms northwestern section.
Former Sand pits south of motorway at Tudworth Field Road likely to have worked sands and gravels. Not shown on historical maps until 1962, with one area marked as disused by then, and remainder disused by 1974. Not mapped by 1978 (**presumed infilled**).

M180 and slip roads beyond to west were constructed by 1974 map, with large pond west of Tudworth Road by 1986. Tudworth Green Farm buildings complex c. 400m beyond the western boundary.

Sandtoft Road and Drain form southern boundary in western zone, and transect eastern area. Housing of Bearswood Grove c. 600m beyond southwest boundary after 1948. **Pumping Station and garage** approximately 700m west of southwest corner by 1981.

Ancient Drain & Old Moor Dike (later Crow Trees Moor Drain West and East) form boundary of southeastern area at Brier Hills. Water Engines on 1853 map alongside Low Levels Drain in northeastern area. **Peat Moss Litter Works** by 1891, later called Hatfield Peat Works, 120m south at edge of Hatfield Moors.

Area 8. Clay Bank (Doncaster Council)

Drained by parallel north-south ditches into Stainforth and Keadby Canal (Sheffield and South Yorkshire Navigation) which forms northern boundary from Moor's Bridge west to Maud's Bridge.

Double Bridges farm (including large moat shaped ponds) adjacent western side, Buildings Farm adjacent central south, and **Claybank Farm** centrally within site boundary (now demolished).

Meander channel of **former River Don** likely impinged within extreme eastern area. Boating Dyke (called Meer Drain on 1853 map) crosses Link Corridor from Area 5 to 8.

Canal bounded by High Bridge Road, North Soak and South Soak Drains, with Brierholme Carr Drain (known as Old Godnow Drain after 1968) further south crossing the area.

Area 9 Tween Bridge Wind Farm East (Doncaster Council)

Whittaker's Plantations in 1890's had **large rectangular embanked pond** from 1891 to 1907, perhaps concerned with warping. This area altered by 1948 (by warping?) and creation of Thorne Waste Drain and Waste Road. **Limberlost Farm** constructed by 1968 and largely demolished by 2009-13. Wind Farm constructed by 2014.

Area 10. Tween Bridge Moors & Wind Farm West

No evidence of specific peat workings on mapping, although western area mapped as peat. However from earliest maps, field pattern is very narrow, linear fields and bounding drainage ditches curving southwest to

northeast or roughly east-west, and suggestive of peat workings. Southern area called South or Sand Moors, and Nun Moors. Tween Bridge Moors forms northern area. Poultry Houses and farm beyond northwestern boundary from 1960's. Dairy Farm outside area boundary, Causeway Bank Cottage in 1950's had become **Causeway Farm** by 1968. Moor Owners Road and parallel Boating Dyke cross centrally, becomes Thorne and Crowle Road in eastern area. Top Boating Dyke crosses northwest to southeast, at odds with overall fields, tracks and drains pattern. Elmhirst Plantation (woodland) and Cottage in northern area replaced by current **Pumping Station**. Wind Farm constructed by 2014.
Off-Site: Complex series of embanked drainage ditches off-site, north of Thorne Waste Drain and Road by 1892, associated with warping. Durham's Warping Drain c. 400m north of northern boundary dug from northwest to southeast by 1907, and removed/infilled by 1930. Substantial embanked area (potentially a warping pond) just northeast of boundary in 1892, apparently out of use by 1906. Single Coal Shaft and building first shown on 1904-07 map, around 800-900m north of Order Limits. Substantial area of Thorne Colliery (1925-56) mapped on 1930's and 1950's sheets, with extensive spoil mounds southeast to Thorne Moors fed by tramlines. Spoil heaps closest to Order Limits were c. 100m remote by 1962. Moorends housing also built by 1930 between 200-300m to west. By 1960's area surrounded by colliery, spoil heaps, allotments, housing and recreation /cricket ground, all at least 200m remote from northern boundary. By 1985 large electricity sub-station(s) off-site with overhead cables and pylons at 500-600m remote from northern boundary.

2.6.3 World War II airfields and UXO Risk

Two World War II airfields were located outside the study area. RAF Lindholme (Hatfield Woodhouse) was located c. 4m miles south of Thorne, east of the A614, with Bomber Command, training, and radar functions. It was later used as a gliding club and by 1985 became HM Prison Lindholme.

RAF Sandtoft was a satellite airfield to Lindholme and closed in 1945. It is now in commercial use for vehicle storage and a flying club, with Trolleybus Museum also on the site. The majority of the RAF station site was on the area south of the later M180, however a bomb store area extended as far as the southern boundary of Area 2 at Woodcarr Small Drain, with an area potentially considered to be the ordnance / bomb storage bunkers centred on 475550 409150 (as seen on Lidar discussed below in Section 2.7).

According to the on-line Zetica unexploded ordnance (UXO) risk map the complete study area is Low Risk for UXO. A World War II decoy site was located in Area 2 (see Section 2.6.2 above).

Anecdotal evidence of several air crashes during WWII, associated with these airfields and operations, includes a Lancaster bomber. The location of the Lancaster crash is unclear, with at least two recorded possible locations in the area immediately to the west of Crowle given in Heritage Environment Records. Anecdotally the wreckage sank in the peat. Further details are provided in the separate heritage assessment for this site.

It will therefore be appropriate to obtain a detailed UXO risk report for assessment of both Area 1 and 2 prior to construction works, and adopt any recommendations for both intrusive investigations and during construction.

2.7 Lidar Imagery

Study of Digital Terrain Modelling (DTM) and LIDAR data has been undertaken to confirm the overall topography and occurrence of former river courses.

The elevation and exaggerated hillshade imagery included in Appendix G has been manipulated to indicate the extent of former drainage courses, including the Rivers Don and Idle across the southern area. **The main southerly course of the River Don formerly crossed Area 1 Old River Don, Area 3 Plains Lane, and Area 6 Hatfield Chase. Its earlier courses can be seen crossing the east side of Area 8 Clay Bank, and Area 4 Bletchers Drain.**

This imagery also shows the extent of Flood Warp and potentially earlier peat working in the northeast at Tween Bridge Wind Farm and Medge Hall, where small ridge patterning is evident. The blander imagery across the sand and peat deposits at Area 2 Old Engine Drain to River Torne suggests potentially better drainage and deeper agricultural working of these soils. The former airfield infrastructure and potentially the bomb store mounds are evident in the southwestern extension of Area 2 near Woodcarr Small Drain.

The slope model also included in Appendix G indicates typical slopes of less than 2˚ predominate, with the network of subsidiary and main field boundary drainage ditches or banks standing out against this relatively bland background. The slightly raised broader levees either side of former channels are less apparent on this slope model, showing gentle (ploughed?) slopes of 4-5˚.

2.8 Hydrogeology & Groundwater Vulnerability

Data within the Groundsure report included in Appendix H Volume 2 along with BGS hydrogeological and groundwater data available on-line has been used to provide the following summary:

The western and central area is underlain by Sherwood Sandstone bedrock at depth, which has a regional geological dip eastwards. This forms a Principal Aquifer of good quality water supply, which becomes more saline eastwards from Crowle Moors and Medge Hall, as it is confined beneath increasingly thick overlying Mercia Mudstone bedrock. Contouring on the estimated potentiometric (pressure) surface within the Sherwood Sandstone indicates 0mOD crossing the Order Limits area centrally.

Within the superficial drift deposits, the Alluvium, Warp and Sands and Gravels form a Secondary A Aquifer. Small supplies are reportedly obtained where the Alluvium is in hydraulic continuity with a river. Where sand and gravel are in hydraulic continuity with a river, yields can be induced.

Those areas of Thorne Moors, the Brier Hills area of Low Levels in Area 7b, and Area 2 (all where peaty soils occur) and the large area of Hemingbrough Formation across Tween Bridge Moors (where the silts and clays are largely impermeable laminated lacustrine deposits) are Unproductive as an aquifer.

For the majority of the site, the Secondary Superficial Aquifers have Medium Groundwater Vulnerability to pollution, whereas the peat within Area 2, and Tween Bridge Moors Area 10 south to Area 8 Clay Bank, and parts of Area 1 are of Low groundwater vulnerability. Areas of High Vulnerability in the secondary Superficial Aquifer are located over the Sands in Area 2, the sands in Areas 6 (Hatfield Chase) 7a (Tudworth) and 7b (across Low levels). A detailed breakdown of the complexity of vulnerability is given in the Groundsure data report in Appendix H Volume 2, and discussed in Section 2.9 below.

From the above data, the geological information given above and topographic maps, the following can be anticipated:

Aquifer Type	Secondary A in permeable horizons of Warp and Alluvium superficial deposits. Unproductive Strata formed by peat and Hemingbrough Formation silt/clays Bedrock Principal Aquifer in Sherwood Sandstone at depth
Hierarchy of Surface Water Courses and Flow Direction	Main Rivers, large engineered or maintained drainage or natural courses eg North Engine Drain, Cataline Drain, Boating Dyke. Several metres deep and wide, may maintain groundwater level immediately adjacent at c. 2m below Ground Level (GL) and 1-2m below in winter, unless flood conditions.

	Intermediate engineered and maintained drains eg North and South Soak Drains, Boating Dyke. Between 2-4m wide and deep, may maintain groundwater level immediately adjacent at c. 2m summer and 1-1.5m below GL in winter, unless flood conditions. Minor Ditches variably maintained between fields, typically rectilinear pattern. Between 2-3m wide and deep and variably high or low level in spring-autumn. Probably near bank full in winter, unless flood conditions. Act as run-off catchment and only locally effective in lowering groundwater table immediately alongside.
Surface or Shallow Soils Permeability	Slowly to moderately permeable where intergranular flow possible, or relatively impermeable and seasonally wet within peaty or clayey soils, ie soils at or close to field capacity in worst winter periods.
Anticipated Groundwater Table Depth	Within 1-10m distance of drainage ditches, groundwater may be maintained at 1-2m below GL much of year and 0.5-1m below GL in winter. More remote than 8-10m probably between 0.5-2m below GL most of year in most areas. In some areas groundwater will stand at less than 0.5m below GL in winter, or at field capacity ie at ground surface in worst periods.
Anticipated Groundwater Flow Direction	Rectilinear drainage pattern controls, and little or no flow locally, but overall flow west to east across study area.
Hydraulic Continuity of Groundwater and Water Courses	Likely throughout site.

The overall groundwater level and flow pattern will be controlled by local factors such as backfilled old drainage channels, former river courses, historical features such as meers and artificial lakes. The zone of capillarity will also be dependent on soil types.

2.9 Environmental Information

The following pertinent information on activities within 250m of the site has been extracted from the Groundsure report included in Appendix H Volume 2. It should be noted that the Groundsure data includes additional land areas subsequently removed from the draft Order Limits, and therefore the red line boundaries on the data maps does not concur with those shown in Appendix A.

Significant features, landfill sites, and On Site, Major or recent (<10 years) pollution incidents are indicated in Bold type, and are shown on a summary drawing in Appendix F (to complement that for historical mapping features). For the purposes of risk assessment, those conventional farming practices that have been designated as waste exemptions, such as storage of dredging sludge or spreading of plant matter or waste from dredging, composting or mulching etc. have been omitted, but non-agricultural exemptions are included below.

2.9.1 Area 1. Old River Don (North Lincolnshire)

Pollution, Licensing and Hydrogeology

	Number	**Distance & Details**
Surface Water Abstractions	8	7 On Site – Crook o' Moor Drain, Old River Drain, all for direct spray irrigation. Off-Site – 1 No. Old River Drain, spray irrigation.
Groundwater Abstractions	0	
Groundwater Vulnerability		**High** in Secondary Superficial Aquifer –

		majority of area **Medium** in Secondary Bedrock Aquifer – southwestern periphery peat zone Low in Secondary Bedrock Aquifer – central peat zone
Source Protection Zones	1	Zone 3 Total Catchment On Site – western section of Link Corridor to Area 9 only. Remainder not in SPZ
Floodplain Area / Flood Warning Status	High Risk	Potential for groundwater and surface water flooding
Contaminated Land Register Entry/ Enforcement / Prohibition	0	
Pollution Incidents	2	Off Site 2005: 19m SW Significant impact to water from storm sewage. **2015: 90m SW Significant impact to water from Oil & Fuel**
Pollution Control / Licensing	0	
Fuel Station Entry	0	
Registered Radioactive Substances	0	
Discharge Consent	1	Off Site - (1961) effluent discharge Medge Hall, 196mSW
Known Landfills / Waste Management / Transfer Sites within 250m	0	
Waste Exemptions	1	On Site: storage of waste in secure containers, Medge Hall

Recent & Historical Industrial Use

Recent Potentially Contaminative Activities on Site	No additional activities other than overhead power supply pylons. Single Water pumping station at Crook o' Moor Road near Link Corridor
Recent Potentially Contaminative Business Activities within 250m	No additional significant activities other than pylons, wind turbine, moorings, and telecommunications mast given in Groundsure data.
Historical Potentially Contaminative Activities on Site	Peat workings tramways, sidings, disused works etc 1890-1968 associated with Medge Hall peat works.
Historical Potentially Contaminative Business Activities within 250m	Railway sidings and station 20-40mSW to 1955, sewage works 140m E to 1973, disused brickworks 160mS to 1951.

Geological Information

Hazard Type	**Hazard Rating/Features** (worst case)
Natural and Mining Cavities	None
Potential for Ground Dissolution	Negligible
Potential for Landslides	Very Low
Potential for Shrinking/Swelling Clay	Very Low
Potential for Compressible Deposits	**High**
Potential for Collapsible Deposits	Negligible
Potential for Running Sands	Low

Background Soils Chemistry

The Groundsure report includes BGS estimated background soil chemistry for 5 metals within shallow soils. Interpretation suggests that at these levels, such metals would be unlikely to exceed generic assessment criteria for commercial use. Current National Planning Policy guidance does not consider naturally occurring metals as evidence of contamination.

Groundsure Radon Risk Information
The Groundsure report indicates that the specific site does not lie in a Radon Affected Area and no protection measures are required for new buildings and dwellings.

2.9.2 Area 2. North Engine Drain to River Torne (North Lincolnshire)

Pollution, Licensing & Hydrogeology

	Number	Distance & Details
Surface Water Abstractions	30	12 On Site – All from Surface Water Drains for spray irrigation. Off-Site – 18 All from Surface Water Drains, for spray irrigation.
Groundwater Abstractions	0	
Groundwater Vulnerability		**High** in Secondary Superficial Aquifer – majority of southern and central zone **Medium** in Secondary Superficial Aquifer – northeastern area peat / Alluvium zone Low in Secondary Superficial Aquifer – northern peripheral peat zone & western area
Source Protection Zones	1	Zone 3 Total Catchment On Site across western area and Link Corridor to Area 3. Remainder not in SPZ.
Floodplain Area / Flood Warning Status	High Risk	Potential for groundwater and surface water flooding
Contaminated Land Register Entry/ Enforcement / Prohibition	0	
Pollution Incidents	4	**On Site: 2003 Minor Land impact from Oil & Fuel on trackway forming southern boundary of link corridor in west of Area 2.** Off Site: 2003: 20m NW Significant impact to land household waste. 2002: 22m SE Minor impact to water Unknown to River Torne **2021: 224m SW Significant impact to water from paint & varnish Hatfield Waste Drain**
Pollution Control / Licensing	0	
Fuel Station Entry	0	
Registered Radioactive Substances	0	
Discharge Consent	0	
Known Landfills / Waste Management / Transfer Sites within 250m	0	

Recent & Historical Industrial Use

Recent Potentially Contaminative Activities on Site	No additional activities other than wind turbine west of Belton Grange
Recent Potentially Contaminative Business Activities within 250m	No additional significant activities other than telecommunications mast given in Groundsure data.
Historical Potentially Contaminative Activities on Site	**Historically bomb stores of WWII airfield at Sandtoft extended across Area 2 and Link Corridor to Area 3** **(See above)**

Historical Potentially Contaminative Business Activities within 250m	Airfield as above, still in partial use (See above)

Geological Information

Hazard Type	**Hazard Rating/Features** (worst case)
Natural and Mining Cavities	None
Potential for Ground Dissolution	Negligible
Potential for Landslides	Very Low
Potential for Shrinking/Swelling Clay	Very Low
Potential for Compressible Deposits	**High**
Potential for Collapsible Deposits	Very Low
Potential for Running Sands	Low

Background Soils Chemistry

The Groundsure report includes BGS estimated background soil chemistry for 5 metals within shallow soils. Interpretation suggests that at these levels, such metals would be unlikely to exceed generic assessment criteria for commercial use. Current National Planning Policy guidance does not consider naturally occurring metals as evidence of contamination.

Groundsure Radon Risk Information

The Groundsure report indicates that the specific site does not lie in a Radon Affected Area and no protection measures are required for new buildings and dwellings.

2.9.3 Area 3 Plains Lane and Area 4 Bletchers Drain (North Lincolnshire)

Pollution, Licensing and Hydrogeology

	Number	**Distance & Details**
Surface Water Abstractions	17	6 On Site – All from Surface Water Drains for spray irrigation. Off-Site – 11 All from Surface Water Drains, for spray irrigation.
Groundwater Abstractions	0	
Groundwater Vulnerability		High – none **Medium** in Secondary Superficial Aquifer – majority of area Low in Principal Bedrock aquifer – southeast area of Area 3 Plains Lane and extreme north Area 4 Bletchers Drain (both overlain by Unproductive Superficial Aquifer)
Source Protection Zones	2	Zone 3 Total Catchment On Site
Floodplain Area / Flood Warning Status	High Risk	Potential for groundwater and surface water flooding
Contaminated Land Register Entry/ Enforcement / Prohibition	0	
Pollution Incidents	0	
Pollution Control / Licensing	1	Off Site - Hatfield Farm Poultry Unit 75mS, Intensive Farming, including pollution inventory substances and waste transfers
Fuel Station Entry	0	
Registered Radioactive Substances	0	
Discharge Consent	2	Off Site - Bank House Farm 158mW Site Discharge to underground strata
Known Landfills / Waste Management /	0	

Transfer Sites within 250m		
Waste Exemptions	1	On Site: Goodcop Farm. Storage of non-agricultural Sludge

Recent & Historical Industrial Use

Recent Potentially Contaminative Activities on Site	No additional activities other than telecommunications mast near M180 at Poultry Farm (= off-site)
Recent Potentially Contaminative Business Activities within 250m	Water pumping station on Boating Dyke Arms/ammunition at Plains House Farm 26m SW Distribution/Haulage at High Levels Bank 29mN Poultry Farm 70mS Slurry bed 89mW Telecommunications mast 100mSE.
Historical Potentially Contaminative Activities on Site	None
Historical Potentially Contaminative Business Activities within 250m	Off Site - Unspecified ground workings 1904-1951, south of M180, linear feature alongside Anchor Drain, likely drainage works.

Geological Information

Hazard Type	**Hazard Rating/Features** (worst case)
Natural and Mining Cavities	None
Potential for Ground Dissolution	Negligible
Potential for Landslides	Very Low
Potential for Shrinking/Swelling Clay	Very Low
Potential for Compressible Deposits	**High**
Potential for Collapsible Deposits	Negligible
Potential for Running Sands	Low

Background Soils Chemistry

The Groundsure report includes BGS estimated background soil chemistry for 5 metals within shallow soils. Interpretation suggests that at these levels, such metals would be unlikely to exceed generic assessment criteria for commercial use. Current National Planning Policy guidance does not consider naturally occurring metals as evidence of contamination.

Groundsure Radon Risk Information

The Groundsure report indicates that the specific site does not lie in a Radon Affected Area and no protection measures are required for new buildings and dwellings.

2.9.4 Area 5 Elder Gates, Area 6 Hatfield Chase, Area 7 Ferne Carrs (Doncaster)

Pollution, Licensing and Hydrogeology

	Number	**Distance & Details**
Surface Water Abstractions	3	Off-Site – 3 All from Surface Water Drains, for spray irrigation.
Groundwater Abstractions	3	**Off Site – Hatfield Woodhouse 700m W, Yorkshire Water Services Ltd, Pumping Station adjacent Sandtoft Road & A18 junction.** Crow Trees Farm Borehole 113mE, farming and domestic use. Grove Farm Borehole 184mNE, farming and domestic use.

		(Historical abstractions at Hatfield Peat Works and Lindholme Hall)
Groundwater Vulnerability		**High** in Secondary Superficial Aquifer – Central zone of Area 6 and southern zone of Area 7A **Medium** in Secondary Superficial Aquifer – majority of Areas 5, 6, 7. **Medium & Low** in Principal Bedrock Aquifer- along drainage channels in southwest of Area 7A Low in Principal Bedrock Aquifer – southeast Area 7B
Source Protection Zones	3	**On Site: Zone 3 Total Catchment** **Off Site : Zone 2 Outer Catchment 250m west of boundary of Area 7A** **Zone 1 Inner Catchment 600m west of boundary of Area 7A.** **All relate to Pumping Station Sandtoft Road Groundwater Abstraction.**
Floodplain Area / Flood Warning Status	Medium & High Risk	Potential for groundwater and surface water flooding
Pollution Incidents	4	Off Site: 2001 Minor impact on land due to food waste, 12m S Brier Hills. 2002 – 57m S Brier Hills Atmospheric. **2002 – Major Water and Significant Land Impact >600m W due to Petrol (Garage on A18, Tudworth Road)**
Pollution Control / Licensing	1	Off Site – Brier Hills Recycling 76m S incineration.
Fuel Station Entry	1	Off Site – Former Green Tree Garage, Tudworth Road (see above)
Registered Radioactive Substances	0	
Discharge Consent	5	Off Site -Bearswood Road Sewage Treatment Works, 2m W, Treated Sewage to tributary of West Moor Drain. Drain House Cottage 5m N, treated effluent to underground strata. Bank House Farm 248mE, site drainage to underground strata
Known Landfills / Waste Management / Transfer Sites within 250m	2 Landfills 10 licensed waste site entries	**Off Site - Historical landfill Tudworth Hall Farm 47m NW at SE69100 11000, licensed for Inert Waste 1996 to date; also Physical Treatment & Recovery. (Google Earth imagery also suggests groundworks, filling or restoration up to NW & W boundary of Order Limits).** **2 Licensed waste site entries at Tudworth Hall Farm also** **Tudworth Landfill & Recycling Centre, 300mW at SE68707 10510, licensed for Non Biodegradable Wastes, & Physical Treatment from 1993 to 2017.** **6 Licensed waste site entries at Tudworth Landfill & Recycling also**

		Waste Transfer Station & Composting Facility, Brier Hills Farm, 26mS, from 2006. 2 Licensed waste site entries at Brier Hills Farm also. This site is adjacent the southern boundary of the Order Limits, and as noted above is a safeguarded waste management site on the Doncaster Local Plan policy map.
Waste Exemptions	4	Off Site: Brier Hills Farm: screening, sorting, blending, burning waste and recovery of scrap metal

Recent & Historical Industrial Use

Recent Potentially Contaminative Activities on Site	None
Recent Potentially Contaminative Business Activities within 250m	Off Site: 20 No. Other than telecommunications mast, recycling/landfill given above, Pumping station given above, there are Insulation products 117mW, vehicle sales & parts 184mW, variety of other activities >175m remote.
Historical Potentially Contaminative Activities on Site	**8 No. – Sand Pits & Ground Workings 1905-1974 mainly relate to Tudworth Hill workings (see 2.6.2 above).**
Historical Potentially Contaminative Business Activities within 250m	Off Site – 3 No. at Pumping Station, Garage & Tudworth Hill Cutting (sand/gravel working)? Hatfield Peat Works 100m south of Area 7b from 1890's onwards.

Geological Information

Hazard Type	**Hazard Rating/Features** (worst case)
Natural and Mining Cavities	None
Potential for Ground Dissolution	Negligible
Potential for Landslides	Very Low
Potential for Shrinking/Swelling Clay	Low
Potential for Compressible Deposits	**High**
Potential for Collapsible Deposits	Very Low
Potential for Running Sands	Low

Background Soils Chemistry

The Groundsure report includes BGS estimated background soil chemistry for 5 metals within shallow soils. Interpretation suggests that at these levels, such metals would be unlikely to exceed generic assessment criteria for commercial use. Current National Planning Policy guidance does not consider naturally occurring metals as evidence of contamination.

Groundsure Radon Risk Information

The Groundsure report indicates that the specific site does not lie in a Radon Affected Area and no protection measures are required for new buildings and dwellings.

2.9.5 Area 8. Clay Bank, Area 9 Tween Bridge Wind Farm East, Area 10 Tween Bridge Moors & Wind Farm West (Doncaster)

Pollution, Licensing and Hydrogeology

	Number	Distance & Details
Surface Water Abstractions	5	On Site: 2 from Crook o Moor & North Soak Drains for spray irrigation. Off Site: 3 from surface water Drains for spray irrigation.
Groundwater Abstractions	4	Off Site: 2 at Thorne Colliery remote NW & Process Water; 164mW Chesterfield Poultry process water; 235mS Grove Farm borehole for farming and domestic use.
Groundwater Vulnerability		**High** in Secondary Superficial Aquifer – Area 8, South zone of Area 10, and all Area 9. **Medium** in Secondary Superficial Aquifer – limited northern zone Area 8a, and southwest zone of Area 10. **Low** in Principal Bedrock Aquifer – Majority of Area 10 and 11, and western zone of Area 8.
Source Protection Zones	2	Zone 3 Total Catchment
Floodplain Area / Flood Warning Status	High Risk	Potential for groundwater and surface water flooding
Contaminated Land Register Entry/ Enforcement / Prohibition	0	
Pollution Incidents	7	**Off Site: 2013 – 12m W Significant unknown impact to water (SW of Maud's Bridge)** 16mNW in 2001 Minor water impact from Organic Chemical, and 2003 minor impact to land from diesel 180mW 2001 & 2008 Minor water impact from organic chemical, and biodegradable material / waste, and significant impact to water from blood/offal (Chesterfield Poultry)?
Pollution Control / Licensing	1	Off Site: 8m W Causeway Farm, Historical Notification of Installations Handling Hazardous Substances. Hazardous Substance Storage: ammonium nitrate based fertilizers. 248mW Chesterfield Poultry Slaughterhouse
Fuel Station Entry	0	(1 Obsolete)
Registered Radioactive Substances	0	
Active Discharge Consent	2	Off Site: 206mW Electrotec historical non Active – Cr, Cu, Pb, Zn. 10m W Moors Swing Bridge House - treated sewage effluent to underground strata
Known Landfills / Waste Management / Transfer Sites within 250m	0	(The Environment Agency note an historical landfill at SE69200 14100 however this Brickworks landfill at King Edward Road, Thorne is c. 350m NW of the site boundary. A further historical inert landfill at Long Meadows Farm, Moor Edges Road SE 70300 12800 is 345m W

		and was licensed between 1984-1993).
Waste Exemptions	1	On Site: Storage of non-agricultural sludge East of Thorne Waste Drain at SE 7251 1363

Recent & Historical Industrial Use

Recent Potentially Contaminative Activities on Site	39 – All relate to wind turbines or energy infrastructure, plus pumping station at NE of Tween Bridges, adjacent Thorne Moor.
Recent Potentially Contaminative Business Activities within 250m	16 – most relate to masts, pylons, wind turbines, and substation infrastructure, plus poultry houses 20m NW, and pumping station 180mNW. 6 No. electricity substations to N & W in industrial /commercial area adjacent
Historical Potentially Contaminative Activities on Site	39 No. – All relate to Thorne Colliery remote to north, being tramways, sidings, refuse heap and are not within the Order Limits. **One tank (1961 map) at Limberlost Farm.**
Historical Potentially Contaminative Business Activities within 250m	30+ mostly related to Thorne Colliery remote to north of site. 30+ Tanks – mostly relate to industrial & commercial area to N & W at Moorends. 12 No. electricity substations to N & W in industrial /commercial area adjacent

Geological Information

Hazard Type	**Hazard Rating/Features** (worst case)
Natural and Mining Cavities	None
Potential for Ground Dissolution	Negligible
Potential for Landslides	Low
Potential for Shrinking/Swelling Clay	Low
Potential for Compressible Deposits	**High**
Potential for Collapsible Deposits	Very Low
Potential for Running Sands	Low

Background Soils Chemistry

The Groundsure report includes BGS estimated background soil chemistry for 5 metals within shallow soils. Interpretation suggests that at these levels, such metals would be unlikely to exceed generic assessment criteria for commercial use. Current National Planning Policy guidance does not consider naturally occurring metals as evidence of contamination.

Groundsure Radon Risk Information

The Groundsure report indicates that the specific site does not lie in a Radon Affected Area and no protection measures are required for new buildings and dwellings.

3.0 ANTICIPATED GROUND & GROUNDWATER CONDITIONS

3.1 Anticipated Strata

As described above, numerous previous investigation records are available on the BGS GeoIndex under the Open Government Licence. The BGS modelled thickness of the buried valleys in the study area is typically 10-20m, with a deeper area of 20-30m thickness within Areas 8, 9 10 and potentially 4, as shown on a plan included in Appendix C.

For the area of the existing Tween Bridge Wind Farm (Areas 9 and 10 of this report) the findings of the 2009 factual ground investigation report provided in Appendix I Volume 3 have been used to anticipate the typical sequence of strata.

As stated in Section 2, the late GD Gaunt's 1976 doctoral thesis on "The Quaternary Geology of the southern part of the Vale of York" was published in 2020 by the Thorne & Hatfield Moors Conservation Forum, with the aim of making his primary data available, to aid interpretation of the Quaternary sequence. Many of his original fieldwork and mapping sites were within the current study area, and the data is invaluable for interpreting the published investigation records and achieving an overall understanding of the stratigraphy. Details given in this seminal publication are therefore described or referenced below, largely as direct quotations in italics. The terminology of Gaunt (2020) for 'Concealed sand or sand and gravel' deposits beneath the 25 Foot Drift has been adopted.

For the northeastern area of Medge Hall and Lover's Ground, to the west of Crowle, the auger and geophysical survey included in a Geoarchaeological Report by Headland Archaeology (2015) has been used to interpret the shallow ground conditions (see also Section 2.5.3). Extracts are included in Appendix J in Volume 3

Finally, recent LIDAR imagery has been used to confirm the occurrence, elevations and topography of various features, in particular former drainage courses.

The combined findings are summarised below, with tentative interpretations of the anticipated strata given in Capitals.

Area 1. Old River Don

Near Surface:
Flandrian Alluvium
Marginal Peat to its northwest
Warp Soils northwest of Moor Bottom Drain

Based on sparse boreholes information immediately south of Area 1 and the Canal, and the 1:10560 scale BGS maps, the typical ground conditions could be:

Depth (m)	Description
GL to 0.3/1.0	TOPSOIL / SUBSOIL (peaty, loamy and clayey)
0.3/1.0 to 1.0/2.5	Very soft grey and brown organic alluvial Clay/Silt
0.3/1.0 to 1.5/9.5	Very soft or soft clayey Peat
1.5/9.5 to 5.0/12.0	Soft organic alluvial Clay/Silt or firm clayey sandy Silt (FLANDRIAN ALLUVIUM & PEAT)
5.0/12.0 to 10.0/12.0	Loose becoming medium dense laminated clayey sandy Silt or firm Silt/Clay, gravelly in parts SPT N = 7/8 at top (HEMINGBROUGH FORMATION?)

Below 10/12.0+	Medium dense or dense red brown clayey SAND to very weak SANDSTONE/MUDSTONE (TRIASSIC MERCIA MUDSTONE GROUP)

Groundwater was typically struck and stood at between 1.5-3.5m depth.

However auger and geophysical information from the Headland Archaeology Geoarchaeological Report, 2015, included in Appendix J in Volume 3, suggested the following may be more typical of the majority of Area 1 at Lover's Ground:

Location 4 North of Boundary Drain Approx. OS Grid 475000 413100	
GL to 0.2/0.4	Topsoil
0.2/0.4 to 0.8/1.6	Grey brown laminated sandy silt or silty clay
0.8/1.6 to 1.8/2.6	Dark brown Peat or fibrous peat
Below 1.8/2.6	Clay or silty clay rich sand

Location 5 North of Moor Bottom Drain Approx. OS Grid 475100 412900	
GL to 0.2/0.4	Topsoil
0.2/0.4 to 0.2/0.9	Localised only - grainy organic Peat in apparent peat filled channels
0.2/0.9 to 1.0+/1.8+	Grey or brown sand

Location 6 South of Moor Bottom Drain Approx. OS Grid 475450 412700	
GL to 0.2/0.4	Clay rich Topsoil
0.2/0.4 to 0.2/0.5	Silty clays
0.2/0.5 to 0.4/0.8	Localised only - Dark brown Peat
Below 0.4/0.8	Grey or brown sand

Compound Location Adjacent Old River Drain Approx. OS Grid 476000 412250	
GL to 0.2/0.4	Sandy clayey Topsoil
0.2/0.4 to 2.0/2.5+	Mid grey clay with wood fragments (impenetrable tree fragments in parts)
Below 2.0+/4.0	Dark brown Peat

The report here confirmed a 'substantial palaeochannel of the Old River Don' at the southeast field corner close to Old River Drain.

The former River Don course (prior to 1630AD) crossing the central area was not surveyed, but can be seen on Lidar imagery and from historical mapping boundary evidence. Further north the channel reportedly extends to more than 15m below OD, filled with peaty clay, silt and sand. Annotation on the geological map shows clay to 1.2m, underlain by Clay with Peat to 1.5m+ on the channel course in the centre of Area 1.

Overall the thickness of peat proven in most cases was less than 1.2m, and ranged between 0.6-1.6m. This correlates with the single annotation on the geological sheet centrally in Area 1 giving 1.15m of peat overlying sands.

Location 6 is on a low topographic rise composed of sands and gravels consistent with a channel bar or levee capped by sand. There was generally no more than a 1m undulation in the level of the sub-peat floodplain topography, at or around 0mOD, with Location 6 a former area of higher ground within the floodplain.

The northwestern fields are overlaid by Warp soils, typically laminated silts and clays, and very likely to overlie Peat deposits, which still outcrop in parts. Gaunt (2020) reports that *"…variably sandy and peaty clay over a metre thick in parts skirts the north edge of Hatfield Chase and the old course of the south branch of the River Don west of Crowle"*. He describes warp soils here as pale brown silty clay up to 0.8m thick, resting on natural alluvial grey clay and peat. Map annotation indicates warp clay to c. 0.6m depth. The Floodwarp was deposited between approximately 1850-1880 from an extension of Swinefleet Warping Drain.

This Warp clay/silt is described in the Headland Geoarchaeological Report as 'highly compact', such that recovery of the soils by hand augering was hindered. It was also considered that the placement of warp had compressed the underlying peat.

Gaunt (2020) in discussing the lower sand division of the Hemingbrough Formation (25 Foot Drift) concealed in this area, records a single borehole *"…on the southern side of Crowle Moors (SE7553 1371* [Land Parcel 166]*) penetrated 6.7m of pale brown silty sand"* (presumably beneath the 25 Foot Drift).

Area 2. North Engine Drain to River Torne

Near Surface:
Sutton Sand Formation.
Marginal Peat on northern, western and southern peripheries and western extension to North Idle Drain.
Small pocket of Alluvium and peat in central north

Typical ground conditions based on the existing boreholes and geological mapping are likely to be:

Depth (m)	Description
GL to 0.3/0.6	TOPSOIL / SUBSOIL (loamy and sandy with peat)
(0.3/0.6 to 1.0/1.5+	Very soft or soft clayey Peat anticipated in peripheries (based on mapping and Gaunt (2020)
0.3/0.6 to 1.5/5.0+	Medium dense yellow, brown or red brown slightly clayey or silty fine to medium SAND, soft and wet silty sand to sandy clay in parts (BLOWN SAND/SUTTON SAND FORMATION)
1.5/5.0+ to 7.0/11.0	Soft to firm laminated red or red brown very silty slightly sandy CLAY, becoming firm to stiff with fine sand or sandy silt bands in parts (HEMINGBROUGH FORMATION)
Below 7.0/11.0+	Medium dense or dense red brown clayey SAND to very weak SANDSTONE/MUDSTONE (TRIASSIC MERCIA MUDSTONE GROUP)

Groundwater was typically struck and stood at between 1.5-3.5m depth.

Gaunt (2020) reports that *"…variably sandy and peaty clay over a metre thick in parts skirts the north edge of Hatfield Chase and the old course of the south branch of the River Don west of Crowle"*. The 1:10560 map is annotated as " pale brown sand on low hills and peaty sand in hollows" across Area 2.

To the east, the sand cover thins, since a single map annotation alongside the River Torne shows sand only 1.2m thick, overlying Mercia Mudstone, which outcrops from beneath the sand cover within 100m east of the Area 2 boundary.

Area 3. Plains Lane

Near Surface:
Flandrian Alluvium
Peat in southeast
Sutton Sand Formation alongside M180

Typical soils based on the (sparse) existing boreholes are likely to be:

Depth (m)	Description
GL to 0.4/0.5	TOPSOIL / SUBSOIL (loamy and clayey with peat)
0.4/0.5 to 2.0/5.0	Soft grey brown peaty Clay or loose red brown Sand (FLANDRIAN ALLUVIUM)
2.0/5.0 to 2.0/7.0	Very soft or soft clayey Peat and Peat (FLANDRIAN ALLUVIUM & PEAT)
2.0/7.0 to 3.5/7.0+	Soft organic /peaty alluvial Clay/Silt (SPT N = 8) (FLANDRIAN ALLUVIUM & PEAT)
3.5/7.0 to 6.0/7.0+	Medium dense laminated clayey Sand or firm Silt/Clay, gravelly in parts (HEMINGBROUGH FORMATION)

Groundwater was typically struck and stood at between 1.5-3.5m depth.

Directly west of Area 3, through its central zone, and further north and east there is evidence of peat beds between 3 to 6m thick, underlying near surface peaty clays and sands. Whilst the surface expression of the former Don course is clear on Lidar, the extent of such buried peats is not shown by the mapping, where these are masked by relatively thin Alluvium.

Gaunt (2020) discussing sand, or sand and gravel concealed beneath the Hemingbrough Formation (25 Foot Drift) states that 2.7-3.3m of such concealed sand and gravel is present in the Plains Farm – Dirtness Bridge Farm area.

Area 4. Bletchers Drain

Near Surface:
Flandrian Alluvium in south and centre
Sutton Sand Formation in northern third
Peat on north boundary with South Soak Drain and Canal

Typical soils based on the (very sparse) existing boreholes are likely to be:

Depth (m)	Description
GL to 0.3/0.8	TOPSOIL / SUBSOIL (loamy and clayey)
0.3/0.8 to 0.5/4.0	Medium dense grey brown silty Sand (thin in south, thickening northwards) SPT N = 13-15 (BLOWN SAND/SUTTON SAND FORMATION)
0.5 to 3.5	Soft to firm brown laminated silty Clay with silt lenses (HEMINGBROUGH FORMATION)
3.5 to 6.5	Medium dense brown Sand and Gravel (CONCEALED SAND AND GRAVEL)
Below 6.5	Sandstone (TRIASSIC CHESTER FORMATION)

Groundwater was typically struck and stood at between 1.5-3m depth.

The former River Don meandering east across Hatfield Chase had several courses or secondary channels. Drainage in this area is now concentrated along the Boating Dike Drain, forming the southern boundary of Area 4, although the absence of raised levee slopes along this relatively straight channel suggests it is modern and artificial. At least three former courses are identifiable on the Lidar imagery by levee ridges: firstly running north past Grove House and east to Sandhill Farm, before turning south to rejoin the main course at Jacques Bridge. This ridge is likely silty clay or silt and crosses Area 4 in a northeasterly direction; secondly a less obvious channel flowed even further north of this, marked by a very low broad levee; thirdly a broader levee between the Black Bull road junction and Red House Farm could be the edge of a wider channel.

Whilst the surface alluvial deposits are likely to be clayey, those associated with the old River Don channels are variably peaty, and silty on the old levee slopes.

Gaunt (2020) reports thick Sutton Sand beneath Alluvial deposits elsewhere on Hatfield Chase, being 3.4m thick to 5.2m depth south of Grove House, and at Red House being 4.6m thick under a veneer of alluvial clay, overlying Hemingbrough Formation.

He interprets the sands and gravels under the 25 Foot Drift (Hemingbrough Formation) as follows: "…*Most boreholes which penetrate below the clay of the 25 Foot Drift prove sand, with or without gravel, under the clay… a clear distinction can be made within these concealed deposits between pebble-free sand, generally fine grained and silty, and underlying sand and gravel. The pebble free sand is identified as the lower sand division of the 25 Foot Drift; the underlying sand and gravel include several different deposits….all these concealed deposits are considered together for convenience of description".* He suggests perhaps up to 6.4m of concealed sand and gravel is found in the Red House Farm area.

Area 5. Elder Gates, High Levels

Near Surface: Flandrian Alluvium

Typical soils based on the existing boreholes are likely to be:

Depth (m)	Description
GL to 0.3/0.6	TOPSOIL / SUBSOIL (loamy and clayey)
0.3/0.6 to 1.0/2.5 (Southeast only?)	Soft dark brown clayey PEAT
0.5/2.5 to 1.8/3.7	Soft brown silty Clay or medium dense grey brown silty Sand with organic traces SPT N = 17/22) (FLANDRIAN ALLUVIUM & PEAT)
1.8/3.7 to 6.0/12.0	Soft to firm or firm dark brown silty or silty Clay with silt laminations and fine sand lenses SPT N = 4-6 to 6m, 8 at 7m, 12 below 8.5m (HEMINGBROUGH FORMATION)
6.0/12.0 to 15+	Sand & fine Gravel (CONCEALED SAND & GRAVEL)
Below 15+	Red Sandstone (TRIASSIC CHESTER FORMATION)

Groundwater was typically struck and stood at between 1.3-3m depth.

The former River Don Channel, traceable on Lidar imagery, was penetrated by a borehole at Elder House Farm (SE70 NW25) proving clay and clayey peat over silty clay with sand and organic debris to at least 10.7m below OD.

Area 6. Hatfield Chase

Near Surface: Flandrian Alluvium

Typical soils based on the existing boreholes are likely to be:

Depth (m)	Description
GL to 0.3/0.6	TOPSOIL / SUBSOIL (loamy and clayey)
0.3/0.6 to 1.3/3.0	Medium dense brown silty Sand or Firm silty sandy Clay, occasionally peaty SPT N = 8-30 (FLANDRIAN ALLUVIUM) *Possible thin Blown Sand centrally (Gaunt)*
1.3/3.0 to 3.0/4.2	Soft or firm brown silty Clay with silt laminations and fine sand lenses SPT N = 5-20 (typically c. 10) (HEMINGBROUGH FORMATION)
2.8/4.2 to 5.0/7.0+	Loose becoming medium dense and dense Sand with some fine to coarse Gravel, clayey pockets and cobbles in parts SPT N = 10-30 (CONCEALED SAND & GRAVEL)
Below 7.0+	Red Sandstone (TRIASSIC CHESTER FORMATION)

Groundwater was typically struck and stood at between 1.0-2.5m depth.

The former River Don channel ran north of Tudworth Hall Farm, south of Levels Farm, between Dale Mount and Drain House, then east to Crow Tree and Elder Gates Farm. This is again traceable on Lidar imagery. Gaunt (2020) confirms this channel as deeply incised and filled with soft peaty silty and clay with wood fragments. The typical sequence of deposits given above are therefore cut across a substantial length of Area 6 by such deep and soft organic soils. For example at Crow Tree (SE70NW3) clay and silt to 11m overlay sand and gravel to 15m, with the rock head notably deeper than other boreholes. Borehole SE71SW11 on the west side of Land Parcel 157 (south of Drains House and near Askerns Drain) also appears to have intercepted the former course of the River Don. It proved Peat to 6.4m depth, underlain by sand and sand/gravel to 13.7m depth before reaching weathered Sandstone.

It is clear that the wide mapped extents of Alluvium somewhat mask the narrow, deep incised channels cut by the rivers.

Gaunt (2020) indicates several low ridges of sand rising to the surface, below 0.9m of alluvial clay in the western area and near Drain House. He reports the concealed sand and gravel is c. 3m thick at Crow Tree, in line with the above.

Area 7. Ferne Carrs

7a) Near Surface:
River Terrace Deposits in west
Breighton Sand Formation with channels of Peat in south
Glaciofluvial Sand and Gravel in north
Sutton Sand and Flandrian Alluvium

Soils in the eastern area adjacent the M180 are indicated in a single relevant borehole as:

Depth (m)	Description
GL to 0.5	TOPSOIL / SUBSOIL (sandy and loamy with a little gravel)
0.5 to 2.3	Loose or medium dense grey brown slightly silty fine and medium SAND SPT N = 10 (BLOWN /SUTTON SAND FORMATION? / BREIGHTON SAND?)
2.3 to 4.6	Soft or firm laminated brown very silty Clay to clayey Silt with some sand horizons, becoming gravelly below 4.3m (HEMINGBROUGH FORMATION)
4.6 to 7.5	Dense to very dense Sand with some gravel SPT N = 40 (CONCEALED SAND & GRAVEL)
Below 7.5+	Red Sandstone (TRIASSIC CHESTER FORMATION)

Groundwater stood at c. 1m depth.

No relevant boreholes are available for the central and western zone, where mapped ground conditions should comprise GlacioFluvial Gravels, River Terrace Deposits and Blown Sand, cut by narrow peaty channels. However, Gaunt (2020) states that: *"…The older sand and gravel between Hatfield Woodhouse and Tudworth Hall…are not exposed…. Trial excavations in 1964 into the floor of the quarry (SE693 100) at the southern end of the ridge… which runs in a SSE direction from Tudworth Hall showed that beneath the younger (Pennine) glacial sand and gravel, here 5.2m thick, is a medium gravel consisting of pebbles of Carboniferous sandstone with a few pebbles of Bunter quartzite type".* This suggests more than 5m of sand and gravel was originally present, although it is not clear if this was subsequently worked out, or the quarry later landfilled.

Gaunt described the Tudworth ridge as: *"… A low but distinct ridge runs from Tudworth Hall (SE 6896 1097) to the SSE for a distance of 1.4km, reaching up to approximately 8mOD. The surface consists of pale brown sand with sporadic to locally abundant pebbles of Carboniferous sandstone and Permian limestone".* He also comments on up to a metre of pale brown Blown Sand (Sutton Sand) rests on top of this older sand and gravel.

7b) Near Surface:
Flandrian Alluvium north of Low Levels Bank
Sutton Sand Formation south of Low Levels Bank
Peat in extreme south alongside Crow Trees Moor Drain

Typical soils based on relevant boreholes in Sutton Sand south of Low Levels Bank are likely to be:

Depth (m)	Description
GL to 0.3	TOPSOIL / SUBSOIL (sandy and loamy)
0.3 to 1.8/3.7	Loose becoming medium dense grey brown slightly silty fine SAND SPT N = 14-20 (BLOWN /SUTTON SAND FORMATION)

1.8/3.7 to 5.3/6.0+	Soft or firm laminated brown very silty Clay with silt partings (HEMINGBROUGH FORMATION?)
Or in extreme SW)	
1.8 to 5.0	Gravel over
To 9.0	Sand
	(BREIGHTON SAND?)
Below 9.0+	Red Sandstone (TRIASSIC CHESTER FORMATION)

Groundwater stood at c. 1m depth.

Gaunt (2020) reports a double ridge of crescentic dunes of yellow brown Blown Sand stretching across Low Levels. An intervening peat filled channel divides the ridge. That is assumed to refer to the channel in the extreme south of Area 7b. A single borehole beyond the southern boundary at Hatfield Peat Works (SE70NW2) showed:

GL to 0.3m	Sandy Topsoil / cover
0.3 to 0.9m	Peat
0.9 to 13+	Breighton Sand

Water stood at 0.5m depth.

The northern peripheral areas are mapped as Flandrian Alluvium and a single borehole beyond the eastern boundary (SE70NW31) indicated:

GL to 1.7m	Stiff grey brown mottled silty CLAY with organic matter
1.7 to 4.7m	Soft grey brown organic or peaty CLAY

Water was struck at 3.5m.

Area 8. Clay Bank

Near Surface:
Sutton Sand Formation across northern periphery
Hemingbrough Glaciolacustrine Formation in west & centre
Flandrian Alluvium in east

Typical soils based on four relevant boreholes are likely to be:

Depth (m)	Description
GL to 0.3/0.9	TOPSOIL / SUBSOIL (sandy and loamy)
0.3/0.9 to 1.0/2.6	Soft to firm or firm brown and grey mottled and peaty sandy Clay SPT N = 11 (ALLUVIUM)
1.0/2.6 to 2.4/3.3	Loose grey silty Sand SPT N = 5-6 (BLOWN /SUTTON SAND FORMATION)
2.3/3.3 to 6.5/7.6+	Soft or firm laminated brown Clay with silt partings and loose sand horizons (HEMINGBROUGH FORMATION)
6.5/7.6+ to 10.6+/16.0	Mixed grey silty Clay and Sand with some gravel becoming Medium dense silty Sand Sand SPT N = 5 & 23 (HEMINGBROUGH/CONCEALED SAND AND GRAVEL?)

Below 10/16+	Red Marl and Sandstone (TRIASSIC CHESTER FORMATION)

Groundwater stood at 2.0-3.5m depth.

In the eastern area of Flandrian Alluvium the single nearby borehole suggests alluvial soils to 13m, underlain by Hemingbrough Formation mixed silty Clay and Sand to 18m, over the marl and sandstone bedrock.

Area 9 Tween Bridge Wind Farm EAST

Near Surface: Warp east and centre Peat on west periphery

Typical soils based on the (very sparse) existing BGS boreholes in the extreme southern area are likely to be:

Depth (m)	Description
GL to 1.0/1.25	TOPSOIL /Made Ground /WARP? soils (loamy and clayey)
1.0/1.25 to 3.4	Soft to firm organic very silty sandy odorous Clay (Reworked PEAT/ALLUVIUM)
3.4 to 4.5/5.2	Very soft or firm brown silty sandy Clay with organic fragments (FLANDRIAN ALLUVIUM/ HEMINGBROUGH FORMATION)
4.5/5.2 to 6.8	Loose rapidly medium dense brown Sand SPT N= 21/24 (HEMINGBROUGH / CONCEALED SAND?)
6.8 to 9.6/10.0+	Dense red brown slightly silty Sand with occasional gravel SPT N = 38-43 (CONCEALED SAND & GRAVEL / WEATHERED BEDROCK?)

Groundwater was typically struck and stood at between 2.0-4.0m depth.

It is currently unclear why such a thickness of superficial Topsoil/soil deposits is present, since these boreholes are on the edge of that mapped as Warp soils, but also so close to the Canal that some placement of canal excavation spoil may have occurred.

Gaunt (2020) records the large area of Warp soils forming Area 9 as *"…being former peat workings on the former southern edge of Thorne Moors, flood warped directly from the southern end of Swinefleet Warping Drain at various times between 1900-1918, possibly later in parts, producing up to a metre of pale brown silt"*. The 1:10560 scale map is annotated as " pale brown silt and silty clay Flood Warp".

The concealed Hemingbrough Formation and underlying sands and gravels appear to occur at shallower depth on the northern periphery, as the geological map is annotated to show gravels exposed in ditches at Limberlost Farm.

The 2009 investigation for the Tween Bridge Wind Farm given in Appendix I in Volume 3 included 3 cable percussion boreholes with rotary follow-on in this area (Appendix I). Integrale have used the findings of these, together with Window Samples and Cone Penetration Tests to interpret the typical ground conditions as follows:

Depth (m)	Description
GL to 0.0/0.35	TOPSOIL
0.0/0.35 to 1.0/1.1	Soft or soft to firm grey brown silty sandy CLAY or clayey silty SAND (WARP?)
(0.0 to 0.5/0.7 WS 5 & 6 only	(Possible Made Ground associated with track – soft/firm brown sandy gravelly Clay, with ash, brick, concrete)
(0.2/1.0 to 1.0/2.6 Wind Turbines 16, 17, 18 and 21)	Soft or very soft plastic clayey pseudo fibrous PEAT with occasional sandy clay pockets SPT 'N' <4 (In Situ PEAT or REWORKED PEAT & WARP)
1.0/2.6 to 2.8/3.4 Beneath Peat only)	Very soft or soft brown sandy CLAY or Loose grey fine to medium SAND SPT 'N' 4-8 (FLANDRIAN ALLUVIUM/HEMINGBROUGH FORMATION)
1.0/3.4 to 2.0/8.2	Soft to firm thinly laminated brown sandy CLAY with sand laminae SPT 'N' 8-12 (HEMINGBROUGH FORMATION) [CPT 22 shows firm CLAY and very loose silty sand interbeds]
2.0/8.2 to 6.7/12.0	Medium dense, occasionally loose, grey brown silty SAND. Firm sandy slightly gravelly CLAY in parts SPT 'N' 10-15 (HEMINGBROUGH FORMATION / CONCEALED SAND?)
6.7/12.0 to 11.2/16.5	Dense rapidly very dense yellow, brown or grey fine to medium SAND becoming slightly gravelly SPT N = 35-50 (WEATHERED BEDROCK)
11.2/16.5 to 15/24+	Weak to medium strong red brown or grey SANDSTONE, with occasional extremely weak to very weak red brown MUDSTONE bands (SHERWOOD SANDSTONE GROUP)

Groundwater was struck at variable depths of 7-8m, rising to stand at 5-6.5m in the short term, or closer to the Top Boating Dyke struck at 2.2m rising to 1.2m in the short term.

In situ Plate Load Tests at 400mm depth, with a 300mm plate size and incremental loads of 15-75kN/m^2 gave CBR% results over for the eastern area of Wind Turbines 18-22 of typically 2-2.2%. The soils were described as sandy clay mixed with peat and may reflect Warp mixtures or peat working disturbance. This typically fell to 1% or less in the central area at Wind Turbines 12 and 13 in dark brown clayey soils, possible the edge of the Warp area, or softer Alluvium.

Area 10. Tween Bridge Moors

Near Surface: Hemingbrough Glaciolacustrine Formation Peat in southwest and east Sutton Sand Formation to south

No relevant BGS boreholes were identified within this area.

Gaunt (2020) refers to the area east and southeast of Thorne as 1.8m of clay, (within the Hemingbrough Formation) becoming increasingly sandy further east (at Sand Moors). A ditch south of Thorne Colliery tip is cut into grey brown clay to 0.5m, passing into clayey sand at 0.9m. Again, near Causeway Farm grey brown clay to 0.6m overlies sand and sandy clay with thin sand beds.

He refers to the overlying (Breighton Sand) of the 25 Foot Drift occurring in one location close to Leonards Drain on the northern boundary as a low ridge of silty and clayey sand.

The 2009 investigation for the Wind Farm included 4 cable percussion with rotary follow on boreholes. Integrale's summary interpretation of these, along with data from Cone Penetration Tests, is given below:

Depth (m)	Description
GL to 0.3/0.5	Topsoil
0.3/0.5 to 1.4/2.1	Soft occasionally firm orange brown and grey sandy CLAY or occasionally loose clayey silty SAND SPT 'N' ≤ 4 (HEMINGBROUGH GLACIOLACUSTRINE FORMATION) [CPT 4 shows firm SILT, stiff CLAY and Medium dense SAND in layers of c. 600mm thickness]
1.4/2.1 to 3.8/8.8	Soft to firm or firm thinly laminated brown sandy CLAY or SILT SPT 'N' 8-12 (HEMINGBROUGH GLACIOLACUSTRINE FORMATION) [CPT 2, 3, 4 show firm to stiff CLAY with very loose to loose silty sand interbeds]
3.8/8.8 to 10.0/11.0	Medium dense red brown silty fine to medium SAND SPT'N' 10-20 (FLUVIOGLACIAL SAND & GRAVEL OR HEMINGBROUGH FORMATION)
10.0/11.0 to 11.0/14.5	Becoming dense
11.0/14.5 to	Weak, occasionally very weak red brown medium to coarse grained SANDSTONE, becoming weak to medium strong. With occasional very weak to weak thinly laminated MUDSTONE (SHERWOOD SANDSTONE GROUP)

At Borehole 22 (Wind Turbine 14) a thickness of (loose?) brown slightly clayey slightly gravelly SAND to 1.5m depth may be a thin deposit of wind-blow Sutton Sand. This was underlain by soft to firm, occasionally soft thinly laminated brown sandy clay with thin sand laminae.

Groundwater was struck in the western area at 7-9m depth, rising in the short term to 6-7m. In the eastern area close to the Top Boating Dyke groundwater was struck at 3.8-4m, rising to stand at 1.2-1.3m in the short term.

Plate Load Tests at 400mm depth gave typical CBR% of 2.5% in this western area in sandy clay or sandy silt soils. This dropped to typically 1-1.5% in sandy clays in the central and southern parts near Wind Turbines 14 and 15. The highest results were on the northern road near the former colliery with 3.3 and 3.8% measured in sandy silts and clays.

For the extreme northwestern area crossed by Leonard's Drain, Warp soils are not mapped within the Order Limits area. However the geological map is annotated as "Pale brown silty clay Floodwarp" nearer the former colliery, and "grey brown slightly sandy clay" in the southern area close to Leonard's Drain.

3.2 Anticipated Groundwater

It is anticipated that the majority of soils are either poor or slow draining and seasonally wet. Better drainage is likely in areas of either Warp soils, Blown Sutton Sand or some of the less clayey Hemingbrough Formation.

Initial judgement based on the early autumn site visit suggests that within 1-10m of drainage ditches, groundwater may be maintained at 1-2m below GL much of year and 0.5-1m below GL in winter. More remote from drainage, the groundwater could be between 0.5-2m below GL for most of year in most areas. In some very low lying or poorly drained areas, groundwater may stand at less than 0.5m below GL in winter, or at field capacity ie at ground surface in worst periods.

3.3 Anticipated Ground Gas Regime

The only areas identified where there is potential for abnormal ground gas development are:

Area 7A: the recorded sand and gravel workings at Tudworth Hill, if these are infilled with organic and degradable materials;

Area 6: the extreme western section adjacent Tudworth Hall Farm landfill, if infilled with organic or degradable materials.

Elsewhere the more organic or peaty soils can potentially generate slightly raised carbon dioxide as a natural occurrence. At shallow depth this is unlikely to be significant due to oxidation and dispersal to atmosphere. However deep Alluvium and buried peat can give higher ground gas concentrations, as discussed in Card G, Wilson S, Mortimer S. 2012, 'A Pragmatic Approach to Ground Gas Risk Assessment' CL:AIRE Research Bulletin RB17. Methane and carbon dioxide often occurs in monitoring wells from historically generated gas trapped in soil pore spaces with low diffusion potential. Methane accumulates at increasing depth in peat columns, but this does not indicate high rates of production. There is no, or very little, current gas generation and the carbon dioxide has dissolved out, which causes a higher percentage of methane to be recorded.

Card et al. concluded that sites on Alluvial soils or buried peat (well decomposed and woody) do not generate sufficient hazardous gas flows to exceed Characteristic Situation 2 as defined in BS 8485: 2007. Therefore if gas monitoring is not undertaken, it is generally considered acceptable to simply install Characteristic Situation 2 protection for structures and confined spaces on sites where alluvial or peaty soils are present.

4.0 INITIAL CONCEPTUAL EXPOSURE MODEL

This section draws together desk study information, outlines an initial conceptual exposure model, and provides a qualitative assessment of potential contamination via a Source-Pathway-Receptor framework for the proposed redevelopment, in line with the Environment Agency 'Land Contamination Risk Management: Stage 1 Risk Assessment Guidance (2021). This is presented by written and tabular description below:

4.1 Proposed Development

The scheme is likely to include the following key works, the indicative locations of some of which are shown on draft RWE Plant Layout Drawing E01 Rev 2, 27-06-2023 in Appendix A:

- Arrays of ground mounted solar panels
- Underground cabling
- Substation building(s) and Compound(s)
- A Battery Energy Storage System site within the existing Tween Bridge Wind Farm (Area 10)
- Fencing and Security Measures
- Access Tracks and Construction of new accesses onto the highway
- New lengths of access road within the individual plots of arrays
- Temporary construction and decommissioning compound(s).

The arrays will be laid out in parallel rows running east to west across the field enclosures. The mounting structure and solar panels will be static. The distance between the arrays would respond to topography and typically 11.6m. The array height above ground level will be from 1-3.6m

The insulated electrical cabling from each array will be concealed through shallow trenches linking the solar panels to the inverters and substations. The cable trenches are likely to typically be between 0.5m to 1.5m depth and up to 1m wide. The cable trench may also carry earthing and communications cables and be backfilled with aggregate and excavated materials to original ground level.

The inverters and associated switch gear to convert DC energy into AC energy, will be located across the solar arrays area, assumed typically on a permeable gravel bed.

Underground cables will connect the various land parcels via trenches. Crossing points at the canal, major infrastructure (road or rail) will require directional drilling. It is yet to be determined if all the onsite cables can be laid underground or if some sections will need to be above ground.

4.2 Potential Current Sources of Contamination

The initial desk study findings have been used to identify the likely remnant contaminant sources and distribution. The potential likely current and historical on- and off-site sources and the contaminants associated with these, derived using CLR8 Potential Contaminants for the Assessment of Land, and through experience of industrial land uses, are detailed below. Where further assessment or analyses of potential contaminant sources is deemed necessary this is noted below.

Potential Current Contaminants Associated with On-Site Sources			
Source	**Metals, semi-metals, non-metals, inorganic chemicals and others**	**Organic chemicals**	**Ground Gases & Vapours**
Localised small sand/gravel/clay/ peat pits, if backfilled (none identified to date)	Range of remnant metals possible, dependent on nature of backfill. Unlikely significant given size and age	Unlikely significant given age of likely backfilling	Unlikely significant given age of likely backfilling and size of localised features
	Further assessment not required at this stage		
Tudworth Sand/Gravel Workings (Not considered backfilled as no landfilling records, and topographic information shows lower ground than surroundings).	Range of remnant metals possible, dependent on nature of backfill	Range of contaminants possible dependent on nature of backfill	Dependent on backfill
	Further clarification assessment required by detailed walkover		
Recent Agricultural Use & Maintenance	Likely occurrences of common agricultural contaminant sources given prolonged, mechanised working, fertilizing and crop spraying. No significant existing farmyard structures or infrastructure are understood included in proposed arrays areas, or to be demolished, other than where existing access tracks to be upgraded. Diffuse agricultural chemicals may be present throughout the agricultural fields, but at very low concentrations given surface exposure, rainfall and periodic temporary application. One historical tank at Limberlost Farm 1961, but location unknown and likely insignificant given age. Sources of oil or fuel leaks and spillages due to use of mechanical agricultural equipment are plausible, but will have been extremely localised and can be dealt with by adoption of standard best practice at construction stage, in the context of limited exposure. A watching brief for unforeseen, obvious gross soils contamination and protocols for dealing with this should be incorporated within management plans.		
Former Airfield infrastructure and bomb store area	Majority of area unlikely significant given age and restoration for agriculture many decades ago.		
	Further clarification assessment in conjunction with other disciplines, UXO Reports and check analyses prudent		
Pollution Incident 2003: Minor Land impact due to Oil & Fuel, Area 2 / Link Corridor	Limited data as minor impact only. Assumed from Groundsure data to be on the existing farm trackway, and within the reported former WWII airfield bomb store area. Incident occurred more than 20 years ago and did not result in a water impact, so source is assumed either remediated at the time, or substantially degraded.		
	Further assessment or check analyses prudent in view of proposed use of track for cabling/infrastructure and access		
Pollution Incident 2003: Significant Land impact due to Household Waste Area 2	EA data shows this at SE75843 10066 on trackway/bridge south of road and north of Hatfield Waste Drain (Cataline) water course. Likely fly-tipping of household waste? This apparently did not result in water impact. Given more than 20 years ago, a residual source assumed unlikely.		
	Further assessment or check analyses prudent only if trackway to be used for site access (not shown currently).		

Electricity Substations, overhead cables/pylons, turbine infrastructure at Tween Bridge Wind Farm	Unlikely significant contaminant sources associated with existing infrastructure given age and ongoing maintenance/use

In addition, whilst not a chemical contaminant source, the risk of poached, damaged or over compacted soils due to intensive trafficking during adverse weather conditions, could result in enhanced silt mobilization. This has been described in Section 2.4, particularly for Soilscape 18 during wet conditions. This soil type occurs in Areas 2-8 and 10. This aspect therefore needs taken forward as a potential impact source.

<table>
<tr><th colspan="4">Potential Relevant Contaminants Associated with Off-Site Sources</th></tr>
<tr><th>Source</th><th>Metals, semi-metals, non-metals, inorganic chemicals and others</th><th>Organic chemicals</th><th>Ground Gases & Vapours</th></tr>
<tr><td rowspan="2">Tudworth Hall Farm Landfill at 47mNW (but may extend adjacent to site boundary</td><td>Range of contaminants possible, mobility will control likelihood of migration.</td><td>Range of contaminants possible, mobility will control likelihood of migration.</td><td>Distance, topography and ground conditions will control likelihood of migration if ground gas present</td></tr>
<tr><td colspan="3">Requires further assessment by detailed on-site walkover and data assessment</td></tr>
<tr><td rowspan="2">Tudworth Landfill & recycling at 300m W</td><td>Range of contaminants possible, although unlikely sufficiently mobile given distances to impact site</td><td>Range of contaminants possible, although unlikely sufficiently mobile given distances to impact site</td><td>Unlikely given distance, topography and ground conditions</td></tr>
<tr><td colspan="3">Further assessment not required given distance</td></tr>
<tr><td rowspan="2">Waste Transfer & Composting Station at Brier Hills Farm at 27m S (but may extend adjacent to site boundary)</td><td>Range of contaminants possible, on site boundary although likely surface particulates only</td><td>Range of contaminants possible, on site boundary dependent on processes and features</td><td>Unlikely given no landfilling reported</td></tr>
<tr><td colspan="3">Requires further assessment by detailed on-site walkover and data assessment</td></tr>
<tr><td rowspan="2">Former Green Tree Garage Petrol Pollution Incident 2002 Contaminated Land Determination 2007 at >600m distant to W.</td><td colspan="3">No direct linkage via surface water courses, or very shallow superficial geology, so migration of residual free product within Order Limits very unlikely. Groundwater plume extending beneath Order Limits possible, however unlikely significant given distance, pollutant type and time since incident.</td></tr>
<tr><td colspan="3">Requires further data search with Environment Agency to confirm any existing details of investigation and risk assessments relating to incident.</td></tr>
</table>

Former Peat Works at Medge Hall and Hatfield Moor	Unlikely residual source migration within Order Limits
Canal, railway and roads infrastructure at site boundaries	Unlikely residual source migration within Order Limits
Off-Site Major or Recent Pollution Incidents	Water: 2013, 12mSW Maud's Bridge, Significant impact, Unknown type. 2015, 90mSW North Soak Drain (or Canal) Significant impact, Oil & Fuel 2002, 600m W, Garage on A18 Tudworth Road, Major impact, Petrol 2021, 224mSW, Hatfield Waste Drain, Significant impact, Paint & Varnish Land: 2002, 600m W, Garage on A18 Tudworth Road, Significant Land impact, Petrol
	These recorded pollution incidents are assumed suitably remediated under regulatory enforcement to ensure no ongoing pollution legacy in water courses. With regard to the Major petrol incident in 2002, whilst a residual groundwater plume extending beneath the Order Limits is possible, it is considered unlikely significant given the pollutant type and time since incident, in the context of the proposed arrays construction at more than 600m distance. **Requires further data search with Environment Agency to confirm any existing details of investigation and risk assessments relating to incident.**

4.3 Potential Receptors

A future solar scheme end use and continuing neighbouring agricultural land uses have been used to develop an understanding of the likely sensitive human receptors. In view of the very limited ground intrusion needed to install the panels, the shallow depth of any service runs, access track/roadways, and areas for substations and battery storage, it is envisaged that potential receptors to contamination (if present within the soils on-site, or via migration from adjacent sites) are limited to:

- **Construction Workers** during installation or maintenance, and eventual decommissioning. The most critical receptor would therefore be an adult groundworker or adult maintenance staff.
- **Future construction staff** during any below ground repairs or upgrading, and during decommissioning.

There are no identified residential receptors within 250m of the proposed substation and BESS areas. Specific residential properties occur within this distance of the Order Limits and the solar array zones but in view of the limited ground intrusion for array and fencing installation are not regarded as a viable receptor in this contect.

Information gathered during the site research has been used to develop an understanding of the likely sensitive Controlled Waters receptors. These are considered to be:

- **Drainage ditches and water courses throughout site**
- **Groundwater within the Secondary Superficial Aquifer**

Given the anticipated depth to the Principal Aquifer in the bedrock, and the type of construction proposed, those very limited areas of bedrock aquifer classed as medium or high vulnerability to pollution have been considered. Groundsure data indicates this is limited to Area 7A, in the southwest, where drainage

channels cross Ferne Carrs. Here the cover of Unproductive Superficial Deposits is anticipated at 3-10m. This area is proposed for solar arrays only, with a single length of new access road. Given the absence of proposed deeper construction, the groundwater of the Principal bedrock aquifer has been discounted as a relevant receptor.

The proposed new solar scheme infrastructure will also create receptors, considered to be:

- **Solar array cabling throughout the site**
- **Substations and Inverter Stations at specific locations**
- **Battery Energy Storage System compound within existing Tween Bridge Wind Farm.**
- **Building materials, ie buried concrete and services.**

The fencing and security systems surrounding the solar areas are taken as minor construction only and not considered as distinct receptors.

4.4 Potential Current and Future Pathways

Where there is suitable topography and continuity of similar superficial deposits beneath both the site and adjacent areas this could create a potential pathway for cross-migration of any ground gases, leachate or mobile contaminants. The presence of drainage water courses indicates a potential pathway for leachate or other mobile contaminants within the site area to locally impact on water receptors.

To develop an understanding of the potential risks posed by contaminants to human receptors, the pathways through which contaminants may impact sensitive receptors need to be identified. The proposed infrastructure will not include any permanently occupied structures and continued agricultural use ie grazing beneath solar arrays will be available. Potential exposure routes for assessing risks to human health for a future solar array use can be limited to:

- **Direct human dermal exposure** if contaminated soil exposed during groundworks
- **Inhalation of dust or particulates** if contaminated soil exposed during groundworks
- **Migration of abnormal ground gases** via permeable soils beneath proposed enclosed spaces eg substations, batteries, control room buildings etc.
- **Unexploded Ordnance contact** in Area 2 former airfield/bombstore.

It is considered that the potential pathways with respect to Controlled Waters will be limited to:

- **Creation of new pathways for lateral migration** of contaminated groundwater or leachate to surface water drainage ditches or courses during construction;
- **Surface run-off** to water courses if uncontrolled drainage allowed. Additional potential for silt laden run-off if intensive machinery trafficking occurs during unfavourable weather.

Potential pathways with respect to solar scheme infrastructure are considered limited to:

- **Migration of abnormal ground gases** beneath proposed enclosed spaces, eg substations, batteries, control room buildings etc.
- **Direct contact of construction material** if contaminated soil or water present.

4.5 Initial Conceptual Site Model with Respect to Human Health

In line with Environment Agency Land Contamination Risk Management (LCRM, 2021) guidance, the plausible contaminant linkages have been assessed. Where no linkage is possible, then no risk is determined. The initial conceptual site model therefore indicates the following potential Source-Pathway-Receptor linkages:

SOURCE		PATHWAY		RECEPTOR
Former Tudworth Sand/Gravel Workings if contaminated soils present	→	Dermal exposure Inhalation (if contamination exposed during groundworks)	→	On-site construction worker.
Former Airfield / bomb store Unexploded Ordnance or contaminated soils	→	UXO risk Dermal exposure Inhalation (if contamination exposed during groundworks)	→	On-site construction worker.
Brier Hills Waste Management Site on southern boundary Area 7B if airborne surface particulates spread beyond	→	Dermal exposure Inhalation of particulates (if surface disturbed significantly during construction)	→	On-site construction worker

The construction of foundations for the solar arrays typically comprises driving a short pre-formed steel pin into the ground, without production of spoil, or installation of a small diameter 'foot-pad' to support the steel legs. In view of the very limited groundworks required during installation or decommissioning, and the associated minimal interaction with existing soils, it is considered that the actual risk to groundworkers, should contaminated soils be present within the topsoil and subsoil, is very low or negligible for the majority of the site.

There are inverter stations proposed within 250m of the former Tudworth sand/gravel workings, although these will not include enclosed or confined spaces, so no abnormal ground gas linkage can be postulated.

The current proposed layout of substations and the battery energy storage compound does not coincide with any of the identified on-site potential contaminant sources. Therefore a contaminant linkage is not postulated for these features for human health. The petrol pollution from Green Tree Garage some 600m remote is not considered likely to form any linkage for human health of construction workers within the Order Limits.

Further clarification of topography, features and likely ground conditions at the former sand workings in the southwest at Area 7A, the immediate boundary of Area 7B with Brier Hills Farm waste management site, and in the former airfield section of Area 2, will therefore be appropriate.

The risks to construction and future maintenance workers will be considered within the standard health and safety approach as part of the construction, operation and decommissioning management plans.

4.6 Initial Conceptual Site Model with Respect to Controlled Waters

The initial conceptual site model therefore indicates the following potential Source-Pathway-Receptor linkages:

SOURCE		PATHWAY		RECEPTOR
Former Tudworth Sand/Gravel Workings if contaminated soils within construction depth	→	Creation of new pathways for leaching or migration of liquid contaminants through the unsaturated zone by means of new man-made or natural pathways. Inverter stations only.	→	Surface Water Courses & Groundwater
Former Airfield / bomb store contaminated soils	→	Creation of new pathways for leaching or migration of liquid contaminants through the unsaturated zone by means of new man-made or natural pathways. Run-off from disturbed soils. Inverter stations only.	→	Surface Water Courses & Groundwater
Pollution Incident 2003 Oil/Fuel impact Area 2 trackway	→	Creation of new pathways for leaching or migration of liquid contaminants through the unsaturated zone by means of new man-made or natural pathways. Run-off from disturbed soils.	→	Surface Water Courses & Groundwater
Clay/Silt laden Run-off (loamy and clayey soils areas in particular)	→	Mobilisation due to intense machinery trafficking during wet weather	→	Surface Water Courses

The very limited groundworks required to install the solar arrays are considered to have negligible potential to cause or increase leaching, should any contaminated soils be present within the shallow depth of penetration. The current proposed layout of substations and the battery energy storage compound does not coincide with any of the identified potential contaminant sources.

There are inverter stations proposed within potential influence of the former sand /gravel workings and airfield bomb store area, and so these have been identified above as potential linkages, thus meriting further consideration, albeit the very small area of this unenclosed plant.

Run-off during construction works will need to be controlled and managed, as is standard practice, including development of a Construction Environmental Management Plan. The scheme design will include buffer or access zones alongside drainage ditches and stream courses, further limiting the potential for close working to result in potential for run-off. However careful consideration to working practices to avoid intensive traffic movements in critical areas and routes during unfavourable weather conditions, which could result in poaching, over-compaction or rutting of soils and mobilisation of fines laden run-off. The use of cover systems or track matting for main haul routes should be incorporated within construction planning and the experience of most effective methods for construction works on the Tween Wind Farm taken account of.

During future use, run-off is unlikely throughout the array areas due to the predominant topsoil and turf cover, but requires consideration within the design. Where hardstandings or other removal of topsoil and turf cover is proposed, the measures to deal with infiltration and drainage need designed to prevent future run-off.

4.7 Initial Conceptual Site Model with Respect to New Construction and Infrastructure

The initial conceptual site model therefore indicates the following potential Source-Pathway-Receptor linkages:

SOURCE		PATHWAY		RECEPTOR
Former Tudworth Sand/Gravel Workings if contaminated soils within construction depth	→	Migration of abnormal ground gases	→	Array cables or pipework Inverter stations
	→	Contact with soils	→	In-ground concrete
Tudworth Hall Farm Landfill if gas migration has occurred beyond boundaries	→	Migration of abnormal ground gases	→	Array cables or pipework
Former Airfield / bomb store contaminated soils	→	Contact with soils	→	Array cables or pipework In-ground concrete
Pollution Incident 2003 Oil/Fuel impact Area 2 trackway	→	Contact with soils	→	Array cables or pipework In-ground concrete
Brier Hills Waste Management Site on southern boundary Area 7B if airborne surface particulates spread beyond	→	Contact with airborne surface particulates	→	Array cables or pipework In-ground concrete
Highly peaty Alluvium or Peat at shallow depth where Battery Energy Storage, Substations or Inverters located	→	Migration of combustible gases	→	BESS compound Substations Inverter Stations (and by connection therefore human receptors)

The shallow depth ground gas regime at the site boundaries adjacent Tudworth Hall Farm landfill and potentially at the former Tudworth sand/gravel workings area requires consideration. The potential ignition sources within the solar plant could introduce a new pathway for reaction or combustion, albeit the array cabling is at shallow depth and typically beneath permeable surfaces. Appropriate design and protection measures could be required for critical plant, structures and buried services within influencing distance, to prevent gas ingress or accidental ignition.

The design of all infrastructure needs to take account of the potential for peaty soils at shallow depth above the water table, which could potentially form a combustion source, albeit unlikely given the ambient moisture contents of such soils.

4.8 Initial Conceptual Site Model with Respect to Directional Drilling

At the time of writing the location of Horizontal Directional Drilling at crossing points is unknown. However this is likely to be required in the area where the canal and railway are to be crossed near Maud's Bridge, and where the M180 motorway is to be crossed between Areas 6 and 7 at Hatfield Chase.

5.0 CONTAMINATED LAND CONSIDERATIONS

5.1 General

The desk study has indicated that the majority of the study area has a prolonged history of agricultural usage. There is no specific evidence of significant large-scale aggregate workings or landfilling within the boundaries proven to date, with the exception of the extreme southwestern Tudworth area. There has been prolonged historical peat excavation within the north and northwest in particular. Major historical river diversions and drainage schemes, and continuing maintenance of drainage courses to the present day, have created levees of alluvial material and organic deposits alongside water courses.

5.2 Qualitative Risk Assessment

The proposed solar scheme will involve construction activity predominantly within the uppermost 500-1500mm of ground level. The likelihood of solar array construction creating an adverse, or worsening impact on the contaminant exposure model given above, is therefore considered negligible for most of the site, given design environmental controls during construction and operation.

There is a negligible risk of a new Controlled Waters pollutant linkage being created due to the very shallow depth of construction activity, and the non-polluting nature of the development. However construction practices will need environmental management procedures in place given the proximity to many drainage courses and water bodies.

It is not currently anticipated that the majority of shallow depth soils include significant remnant contamination, however where specific features occur that have been identified as potential contaminant linkages, as given in Section 4 above, this aspect should be confirmed. The majority of proposed construction involves minimal ground intrusion, and the pathways for contaminant exposure during construction can be further controlled with standard health and safety practice and a construction environmental management system in place. Where deeper construction is proposed, eg piled foundations at BESS or substations, those areas should also be investigated to confirm ground conditions, in combination with geotechnical investigation.

The overall ground gas regime beneath the site is likely to be normal or near normal. The proposed construction of solar arrays will not have any overall adverse impact on that gas regime. Where very organic Alluvium or buried peat may be present at or near ground surface, this requires further consideration where structures, confined spaces or sensitive plant are proposed.

5.3 Conclusions

In view of the overall low level of risk and type of scheme proposals, it is considered that the site area is suitable for the intended end use. The Phase 1 desk study findings can be used to design specific targeted confirmatory investigation for contaminated land purposes at detailed design stage. This can be combined most effectively with geotechnical intrusive investigation for detailed construction and foundation design.

- Confirmatory intrusive contamination investigation is recommended following consent. This should be targeted at the specific features identified from historical maps or environmental searches, as described in Section 2, and where potential contaminant linkages have been identified in the conceptual exposure model in Section 4. These include further assessment of the extent and nature of any backfilling within the former Tudworth aggregate workings on site, and around the boundary area with Brier Hills Farm activities and Tudworth Hall Farm landfill. This will confirm the occurrence and variation in shallow depth soils conditions (typically between ground level to 1m depth, and with deeper investigation at limited locations). The most technically appropriate method of investigation would be with shallow open-drive sampling boreholes.

- If these boreholes confirm the absence of significant extraction or landfilling, it seems unlikely to be necessary to undertake further investigation for this aspect across the remainder of the site. However where other geotechnical or drainage investigations are to be undertaken to provide data for design and construction, the opportunity to inspect and sample at those locations could be

taken, to confirm deeper ground conditions and obtain additional soils samples for confirmatory analyses.

- Near surface gas monitoring should confirm the typical shallow soils gas regime for any significant peat areas proposed for substations and battery energy storage compounds. This can be achieved by gas measurements within the borehole standpipes, which should have a variety of response zone depths. A sufficient programme of gas and groundwater monitoring would be 2-3 visits initially during low or rapidly falling atmospheric pressure periods. That should identify if further monitoring is required to conclude on the prevalent gas regime.

Following intrusive investigations the conceptual model and risk assessment can be updated to identify the need for any further assessment, or additional design measures.

6.0 GEOTECHNICAL CONSIDERATIONS

6.1 Solar Array Foundations

The majority of this site will be populated with ground mounted solar arrays. On many sites their lightweight construction ensures that axial compression loads are of little concern on moderate or high strength soils. Although their foundations do not need to be designed to withstand compression and bending loads, in most cases wind loading is a critical design feature, as it produces uplift forces on the long linear arrays. When arrays fail, it is generally because those uplift wind loadings dislodge them from the ground. Wind loading is directionally random, but system performance generally remains operational even with small lateral movements. The primary design concern is that tension in the foundation should counteract the wind loading uplift.

For sustainability consideration, cast in situ 'in-ground' foundations are likely to be unsuitable, as will conventional cast in-ground piers or piles, which produce drilling spoil for storage and disposal and whose construction is slow.

The easiest foundations to place are **ballast foundations,** adequate size blocks of concrete which will prevent not only differential settlement on poor soils but counteract upward wind loadings. Their disadvantages are manoeuvrability and production costs.

The common foundations adopted for ground mounted solar arrays in soils of adequate strength are simple **steel 'pin' piles**, often only taken to shallow depth. Installation is with lightweight plant, with little ground disturbance and minor clean up. However, these can have limited side friction to resist wind uplift forces. They are easy to install, and extract on decommissioning.

An increasingly popular foundation for solar arrays are **steel helical or screw piles,** consisting of a base steel pipe shaft with one or more helical plates welded to the bottom end. They can be manufactured in a wide range of sizes and lengths, adjusted to suit variable ground conditions. They can be installed in a few minutes, produce no spoil with little ground disturbance and no clean up. Installation is with conventional construction equipment such as mini-excavator or backhoe, fitted with a hydraulic torque head. The helix produces uplift resistance as combined side resistance along the pipe, and end bearing from the helical plate. They will be easy to unscrew and recover on decommissioning.

A review of available literature concludes that any form of pile foundation is likely to between 1-3m length and unlikely to be longer for these lightweight arrays. However there is a significant difference in cost between 1-2m pin piles and similar length screw piles. Local ground conditions will determine which is the most technically efficient and the embedded pile length may need to change along a single array if the ground conditions are similarly variable.

At this site the shallow depth soils are frequently soft, clayey and silty, although the reported surface soils textures suggest they could be more silty and fine sandy. The presence of a discontinuous, variable depth (perhaps 0.5-1.5m) **'desiccated crust'** will enhance the foundation characteristics. Its occurrence will need to be understood if the preferred foundation type is to not only be technically suitable, but also economically attractive. Locally the shallow depth soils will be predominantly sandy and (as seen at the existing solar farm on Thorne Colliery) concrete ballast foundations the most suitable option. This site is sufficiently large to consider a variety of foundation types to suit the soil conditions in differing areas.

It is likely that in areas of complex alluvial soils, such as where old river channels have been abandoned, backfilled and new channels excavated, the ground conditions will change along the anticipated 30-40m length of a solar array. This could necessitate different lengths of piles to overcome potential variations in differential movement.

6.2 Foundations for Substations and Larger Structures

It seems unlikely that conventional shallow footings will be suitable where alluvial soils are soft and thick. Piles seem the most likely option. Floor slab design will be critical, as these also may need to be piled for moderate or heavy loadings.

6.3 Site Preparation and Groundworks for Access, Compounds and Cable Routes

Sustainable solar schemes need to be designed to minimise site preparation works normally required on general construction sites. The use of piled foundations for solar arrays minimises disturbance, and attendant plant can be tracked on temporary matting where appropriate.

New access with a predictable design life will be designed on conventional principles, although the use of geogrid should be optimised to minimise pavement thicknesses, and hence import of materials. Design CBR values will frequently be low, in the order of 1-3% over soft clays and silts. The water table will be high during winter months, so cable trenching should be scheduled for drier periods.

The risk of surface soils damage or mobilisation of run-off has been noted in Sections 2.4 and 4.6 above.

6.4 Directional Drilling

The scheme proposals are likely to necessitate cable ducting beneath the canal and road / rail infrastructure, although specific locations are currently undefined. Major issues are not anticipated, but site specific boreholes information will be required, guided by the requirements of specialist installers.

6.5 Targetted Ground Investigations

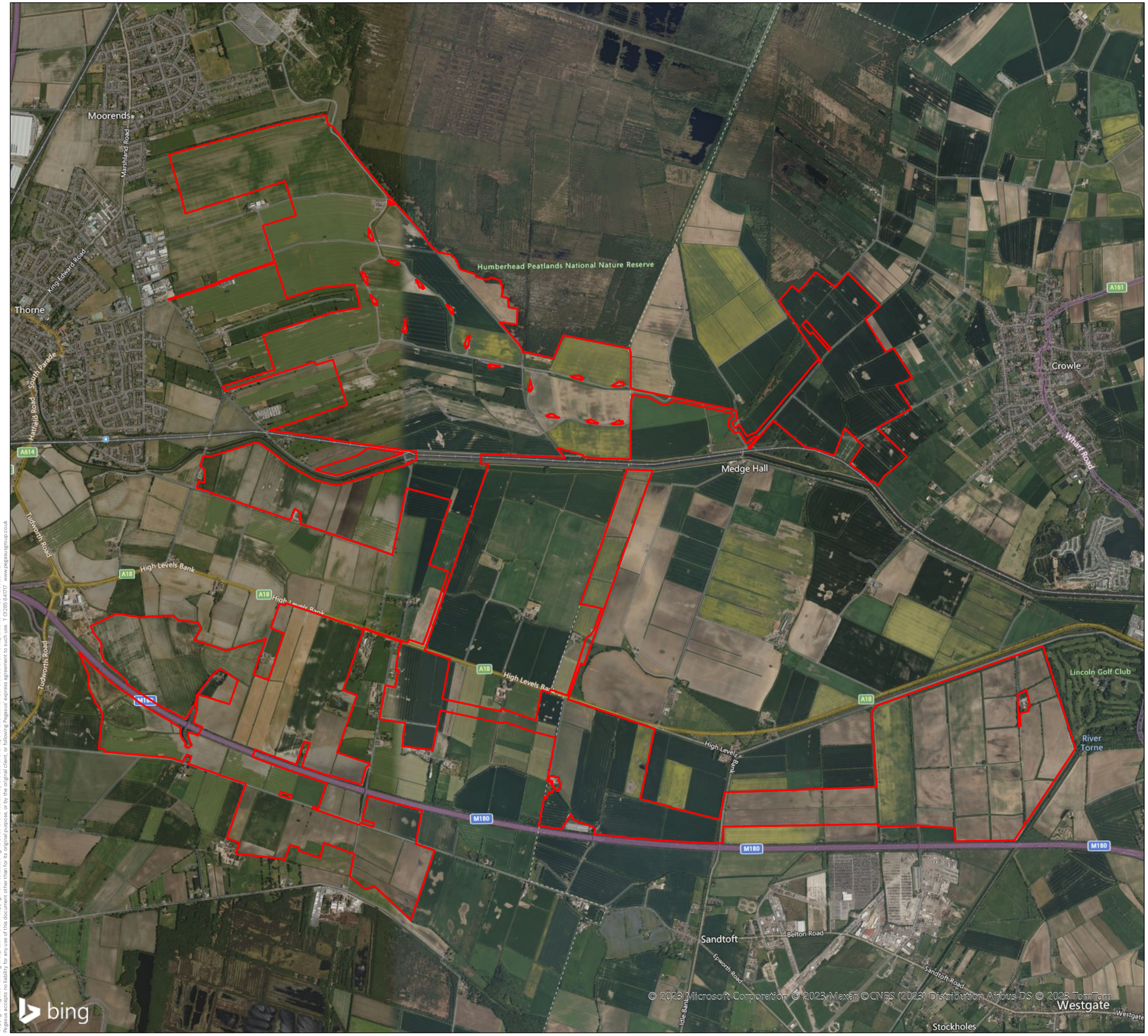
Adequate ground investigation is required to determine the range of foundations options for arrays, substations and other structures including in the battery storage area, access routes and crossings once these locations are frozen. The investigation should include:

- Developing a ground model in areas of anticipated variable ground conditions, particularly alluvial soils with river channel complexity. This may be by probing along traverses at select locations to capture the ground conditions highlighted by this desk study.
- A few control boreholes to enable the above probing exercise to be correctly interpreted.
- Additional boreholes at directional drilling locations.
- Perhaps simple foundation trials to optimise the shallow foundations for solar arrays. The foundations cost for this element alone will be more important than for smaller sites on more predictable, better quality soils.

Intégrale

Appendix A

Order Limits Location & Proposed Solar Areas



KEY

DRAFT ORDER LIMITS (REV P – 13/06/23)

REVISIONS:
A – 21/09/22 – ADDED EASEMENTS
B – 29/09/22 – ADDED EASEMENTS & PARCELS
C – 11/10/22 – REMOVED PARCEL
D – 21/10/22 – ADDED PARCELS
E – 25/10/22 – ADDED AND REMOVED PARCELS
F – 29/11/22 – REMOVED PARCEL
G – 19/12/22 – ADDED ACCESS TRACK & AMMENDED BOUNDARY
H – 05/04/23 – ADDED AND REMOVED PARCELS
I – 12/04/23 – REMOVED PARCELS
J – 13/04/23 – REMOVED PARCEL & ADDED ACCESS
K – 19/04/23 – ADDED ACCESS TRACK
L – 04//05/23 – REMOVED PARCEL
M – 23/05/23 – ADDED AND REMOVED PARCELS
N – 25/05/23 – REDUCED CABLE EASEMENT
O – 08/06/23 – MULTIPLE EDITS
P – 13/06/23 – REMOVED PARCELS

SITE BOUNDARY PLAN

TWEEN BRIDGE SOLAR

CLIENT
RWE

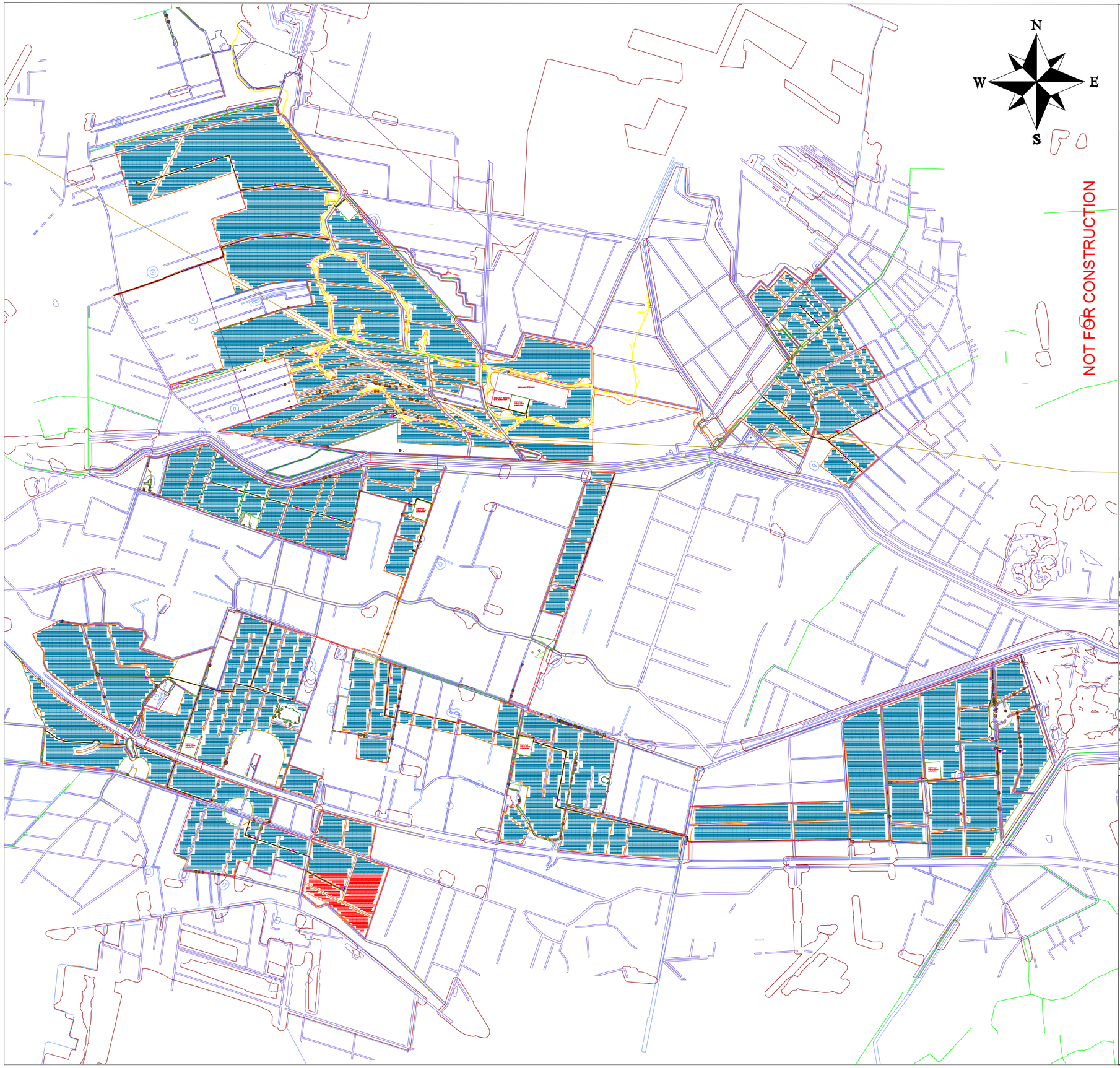
DATE	DRAWN	APPROVED	SCALE
13/06/2023	RL	HS	1:32,000@A3

SHEET	REVISION	DRAWING NUMBER
-	P	P21-3484_06

N

0 1 km

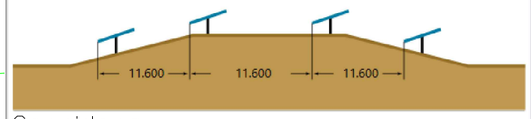
PEGASUS GROUP



NOT FOR CONSTRUCTION

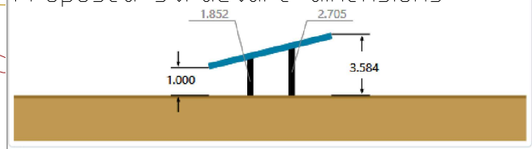
PV TWEEN BRIDGE	
MAIN EQUIPMENT	
PV Module type	N-type Half-cut Bifacial, 570 Wp
Substructure type	Fix Tilt, South 34º tilt
Inverter type	Central, 4200 kVA
OVERVIEW	
Nº PV Modules per String	27
Azimuth (º)	0 (S)
Pitch (m)	11.60
Total Nº Strings	53,210
Total Nº PV Modules	1,436,662
Total Installed DC Capacity (MWp)	818.90

Inter-row separation



Corridors

Proposed structure dimensions



NOTES:
1. A slope limit of 8.5º (15%) is considered along the structure length, using the topographic data provided.
2. All constraints (e.g. avian ecology, drains, water-courses, ditches, hedgerows, ponds, ecology, wind turbine generator buffers) have been considered in design.
3. Structures marked in red indicate no topographic data available.
4. Fence is assumed to be installed along the site boundary. Also, 3m is offset from the site boundary to allow for perimeter circulation during operational phase.
5. Existing roads are yet to be determined whether they will fall inside or outside the fence. Irrespective of its location, these roads will be used for circulation of different parts of the PV site, with the corresponding gates required at each fence-road boundary.
6. Proposed internal roads have been added to facilitate access to the inverter stations.
7. Existing 7kV lines have been assumed that they will be moved or placed underground in order to install more DC capacity.

LAYOUT LEGEND

- Boundary line (Fence)
- Public Right of Way
- Existing Road for Wind farm
- New Road
- Indicative BESS site
- Fixed Tilt Structure - 2Px27
- Trees/vegetation
- Ecological constraints
- Individual plots
- Indicative 132/33kV substation
- Central Inverter + MV Power Station

A SITE PLAN
Scale: 1:800

RWE

RWE RENEWABLES EUROPE

LOCATION: THORNE, ENGLAND
LATITUDE: 53.606894º
LONGITUDE: -0.899778º
ELEVATION: 2.0 m.a.s.l

TWEENBRIDGE 818.9 MWp PV PLANT LAYOUT

DATE	REV	DRAWN	REVISION
19-05-23	1	KDR	PRELIMINARY LAYOUT
27-06-23	2	KDR	Addition, modification and removal of plots. Updated constraints plan.

E01

Intégrale

Appendix B

Topography and Photographs

0 1 2 km

m O.D.

- <= -1.0
- -1.0 - 0.0
- 0.0 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- > 5.0

Key:

- Draft Order Limits Boundary
- Local Planning Authority Boundary

Appendix B
Topography
Tween Bridge
Solar Energy Scheme
Thorne
Doncaster

July 2023

Intégrale
Understanding Ground Conditions

Scale = 1:35,000 (approx.) @ A3

Former Thorne Colliery
Humberhead Peatlands National Nature Reserve
Area 10 Tween Bridge Moors
Thorne
Area 9 Tween Bridge Wind Farm
Area 1 Old River Don
Crowle
Railway
Area 8 Clay Bank
Area 6 Hatfield Chase
Area 4 Bletchers Drain
Canal
A18
Area 5 Elder Gates High Levels
Area 7A Ferne Carrs Low Levels
Area 2 North Engine Drain to River Torne
M180
Area 3 Plains Lane
Area 7B Ferne Carrs Low Levels
M18

70 71 72 73 74 75
15 14 13 12 11 10 09 08
66 67 68 69 70 71 72 73 74 75 76 77 78

Plate 1 – Area 3 Plains Lane from North Idle Drain East towards Area 2. Peat Deposits

Plate 2 – Area 3 North Idle Drain looking North from Plains Drain junction bridge. Peat Deposits

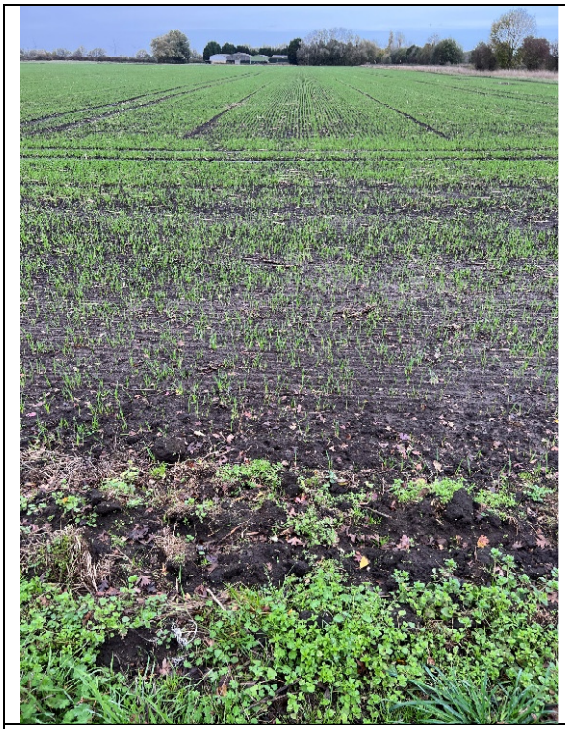


Plate 3 – Plains Lane Track North – Field surface soils. Alluvium.

Plate 4 –Looking Southwest from Plains Lane track (to right of photo). Alluvium and Peat Deposits

	
Plate 5 – Area 2 Cataline Ditch looking south from Northwest corner. Peat Deposits and Sutton Sand Formation (Blown Sand)	Plate 6 – Area 2 Looking southwest from access bridge (area of former WWII decoy site)

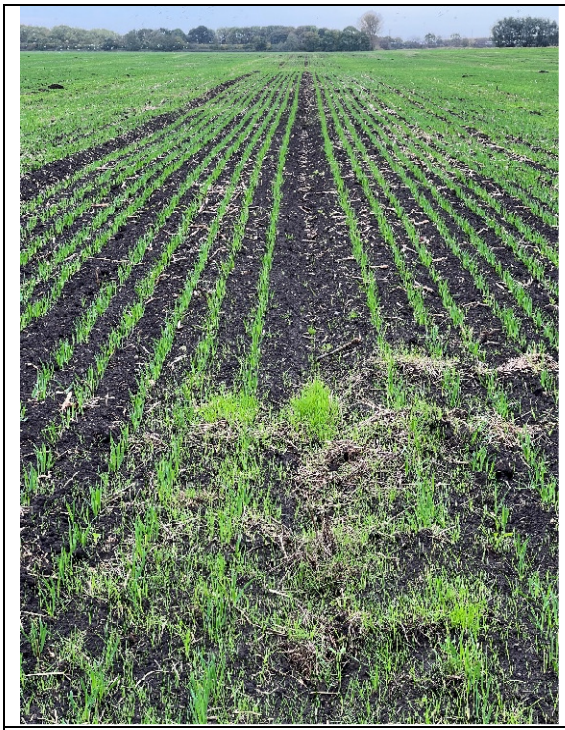



Plate 7– Area 2 Field surface soils. Peat Deposits	Plate 8 – Area 2 Field surface soils. Peat Deposits

	
Plate 9 – Area 2 looking Southwest across Woodcarr Drain by Belton Grange pumping station. Peat Deposits	Plate 10 – Area 7A looking northeast from Tudworth Green Farm to northwest extremity of Area 7A Tudworth Hill & M180. River Terrace Deposits
	
Plate 11 –Looking East from Tudworth Road to Tudworth Hill with M180 beyond	Plate 12 –Soils heaps and potential landfilling stockpiles to West of A18 At Tudworth Green
	
Plate 13 – Area 7A from Sandtoft Road looking Northeast to Tudworth Hill, with M180 beyond. Breighton Sand Formation.	Plate 14 –Looking North to former sand/gravel pit Area 7A, with Tudworth Hill beyond. Breighton Sand Formation.

Plate 15 – Area 7A soil surface, Sandtoft Road. Breighton Sand Formation

Plate 16 – Area 7B north to M180 from Askerns Drain. Alluvium.

Plate 17 – Area 6 from Crow Tree Bank bridge. Alluvium

Plate 18 - Area 6 from Crow Tree Bank bridge. Alluvium

Plate 19 – Area 6 ploughed Alluvial soil detail.

Plate 20 - Area 5 northwest corner looking southeast.

	
Plate 21 -Area 8 Link Corridor to southeast corner of Area 8 looking north from High Levels Bank. Alluvium.	Plate 22 -Area 4 Link Corridor from High Levels Bank looking north. Alluvium.
	
Plate 23 -Area 6 Fields looking south from High Levels Bank. Alluvium.	Plate 24 -Area 6 Fields looking south from High Levels Bank
	
Plate 25 -Area 8 looking north from Clay Bank Road.	Plate 26 -Area 8 north to wind farm. Hemingbrough Glaciolacustrine Formation.

	
Plate 27 -Area 8 looking north to canal and wind farm.	Plate 28 -Area 8 Drainage ditch between fields looking north. Alluvium.
	
Plate 29 -Area 8 ditch showing Alluvium south of Clay Bank Road	Plate 30 -Area 8 Mauds Bridge over Canal looking east
	
Plate 31 - Area 8 Mauds Bridge over Canal looking west	Plate 32 - Beyond Site northeastern boundary Thorne Solar Farm

	
Plate 33 – Beyond Site - Substation adjacent former Thorne colliery	Plate 34 - Beyond Site - looking southwest from pylon next to electricity substation. Warp soils.
	
Plate 35 – Beyond Site - Thorne Colliery revegetated spoil heaps	Plate 36 - Northwest beyond site, example of Warp soils

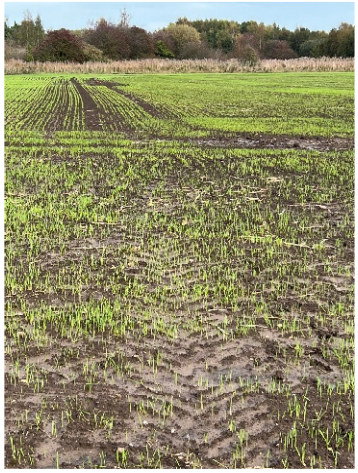



Plate 37 –Beyond Site & Area 10, looking east to woods. Clayey Warp soils	Plate 38 Area 10 East end of Leonards Drain looking southeast to woods. Substation in distance. Hemingbrough Glaciolacustrine Formation.

Plate 40 – Area 10 Ditch at field junction. Hemingbrough Glaciolacustrine Formation.

Plate 41 - Area 10 looking south to fertiliser storage silos

Plate 42 – Area 10 Top Boating Dyke looking north. Turbine WTG 01 to left. Hemingbrough Glaciolacustrine Formation

Plate 43 Area 10 Junction of Thorne Waste Drain and Boating Dyke looking north to woods. Hemingbrough Glaciolacustrine Formation clays & silts to left and Wasted Peat to right of ditch

	
Plate 44 - Area 9/10 Looking south along Thorne Waste Drain. Field to right on Hemingbrough Glaciolacustrine Formation clays & silts. Field to left on Wasted Peat	Plate 45 – Area 9/10 Track alongside Thorne Waste Drain to railway. Field to left on Wasted Peat
	
Plate 46 – Area 10 looking west along North Soak Drain. Field on right on Wasted Peat	Plate 47 – Area 10 – ploughed peaty soils

	
Plate 48 – Area 9/10 Thorne Waste Drain looking north. Peaty soils	Plate 49 – Area 9/1 Link Corridor. East beyond existing track & Turbine WTG 20 on Warp area
	
Plate 50 – Area 9/1 Link Corridor. West along existing track to Turbine WTG 20 on Warp area	Plate 51 – Area 10 Turbine WTG 06. Looking South southeast to Mauds Bridge

Plate 52 – Area 10 trafficing of surface by harvesting. Hemingbrough Glaciolacustrine Formation mapped, but suspect thin peaty soils overlie?

Plate 53 – Area 10. Blown Sand covering surface south of Turbine WTG 06.

Plate 54 - Area 10 ponded surface on peaty soil

Plate 55 - Area 10 ponded surface on peaty soil

Plate 56 – Area 10 Peaty soils at junction of Hemingbrough Glaciolacustrine Formation


Area 1 Marsh Lane
looking North
Google Earth
© 2022 Google
N
2.19 m


Area 1 Marsh Lane looking North
Google Earth
© 2022 Google
N
3.38 m

Intégrale

Appendix C

Geological Information

Appendix C

BGS GeoIndex Mapping & Contours on Base of Flandrian below OD

Tween Bridge
Solar Energy Scheme
Thorne
Doncaster

July 2023

Intégrale
Understanding Ground Conditions

Scale = 1:25,000 (approx.) @ A3

Key:

- Draft Order Limits Boundary
- Local Planning Authority Boundary
- 5 — Inferred Contours on Base of Flandrian below OD

GLACIOFLUVIAL DEPOSITS, DEVENSIAN - SAND AND GRAVEL
SUTTON SAND FORMATION - SAND
ALLUVIUM - CLAY, SILT, SAND AND GRAVEL
BREIGHTON SAND FORMATION - SAND
TIDAL FLAT DEPOSITS - CLAY AND SILT
PEAT - PEAT
WARP - CLAY AND SILT
HEMINGBROUGH GLACIOLACUSTRINE FORMATION - CLAY, SILTY

Crowle
M180

Adapted from Pegasus Group drawings: P21-3484_06 Rev.P. June 2023. Contains British Geological Survey materials © UKRI 2022. Contains OS data © Crown Copyright and database right 2020. Adapted from BGS Memoir for Sheets 79 and 88 (England &Wales) 1994, BGS GeoIndex Onshore.

Intégrale

Appendix D

Soils Information

Adapted from Pegasus Group drawings: P21-3484_06 Rev.P. June 2023. Contains British Geological Survey materials © UKRI 2022. Contains OS data © Crown Copyright and database right 2020. Adapted from BGS Memoir for Sheets 79 and 88 (England &Wales) 1994. Google Earth Images. British Geological Survey Maps.

Area 10
Tween Bridge Moors

Thorne

Area 9
Tween Bridge
Wind Farm

Crowle

Area 1
Old River Don

Area 8
Clay Bank

Area 6
Hatfield Chase

Area 4
Bletchers Drain

Area 5
Elder Gates
High Levels

Area 7A
Ferne Carrs
Low Levels

Area 3
Plains Lane

Area 2
North Engine Drain
to River Torne

Area 7B
Ferne Carrs
Low Levels

Key:

- Draft Order Limits Boundary
- Approximate areas of Peaty Soil (from British Geological Survey maps)
- Local Planning Authority Boundary

Scale = 1:35,000 (approx.) @ A3

Appendix D
Geological Sheets 79 & 88
Mapped Peat Deposits
Tween Bridge
Solar Energy Scheme
Thorne
Doncaster

July 2023

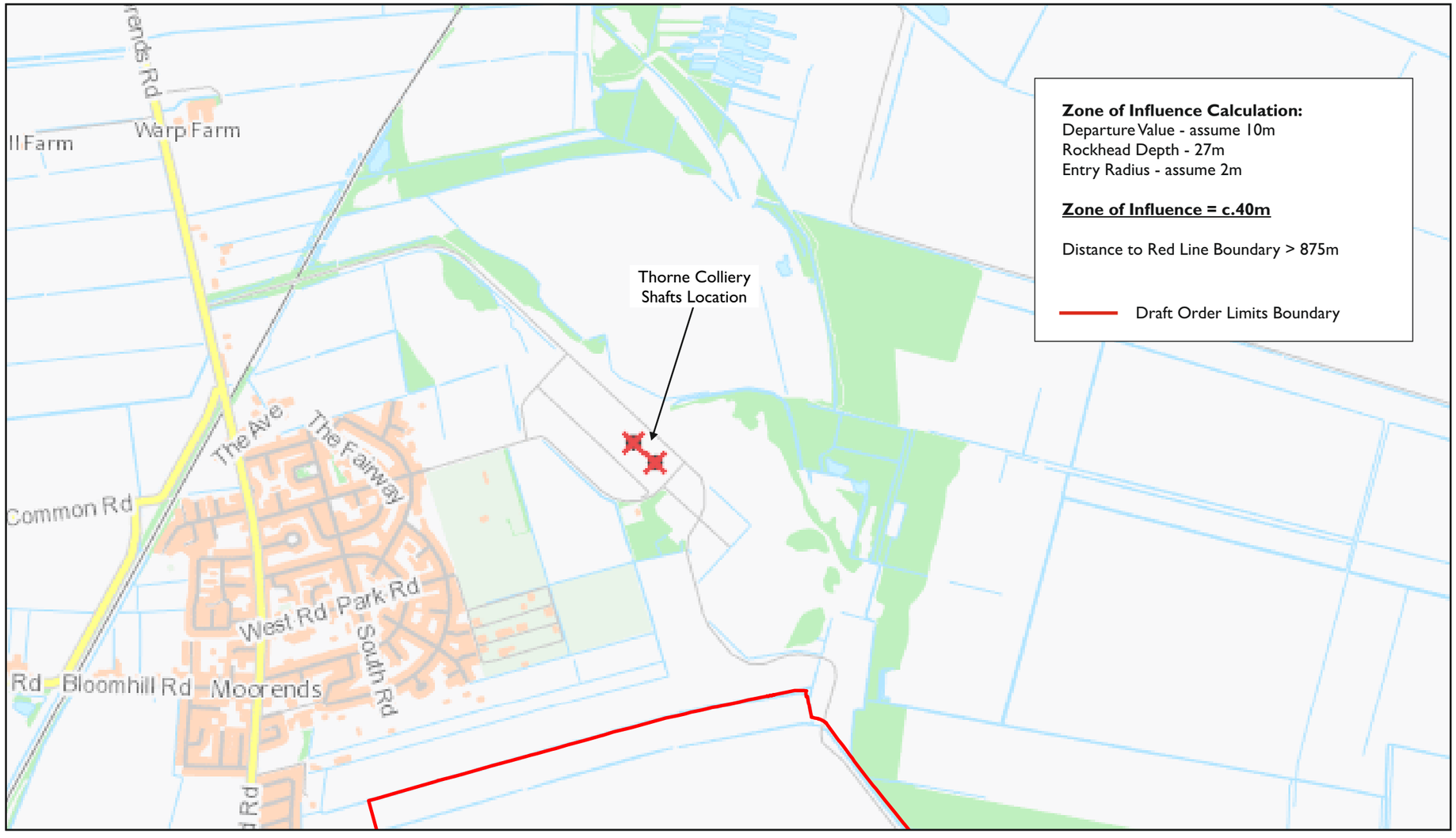
Intégrale
Understanding Ground Conditions

Intégrale

Appendix E

Mining, Quarrying & Minerals

Notts Coal Mining Reporting Area:
470415-001 and 470415-002 Shafts = Development High Risk Area
Rockhead depths 20.4m and 27.1m
Base of Trias/Top of Carboniferous Strata at 279m depth.



Scale = 1:15,000 (approx.) @ A3

Appendix E
Location of Development High Risk Area at Former Thorne Colliery
Tween Bridge
Solar Energy Scheme
Thorne
Doncaster

July 2023

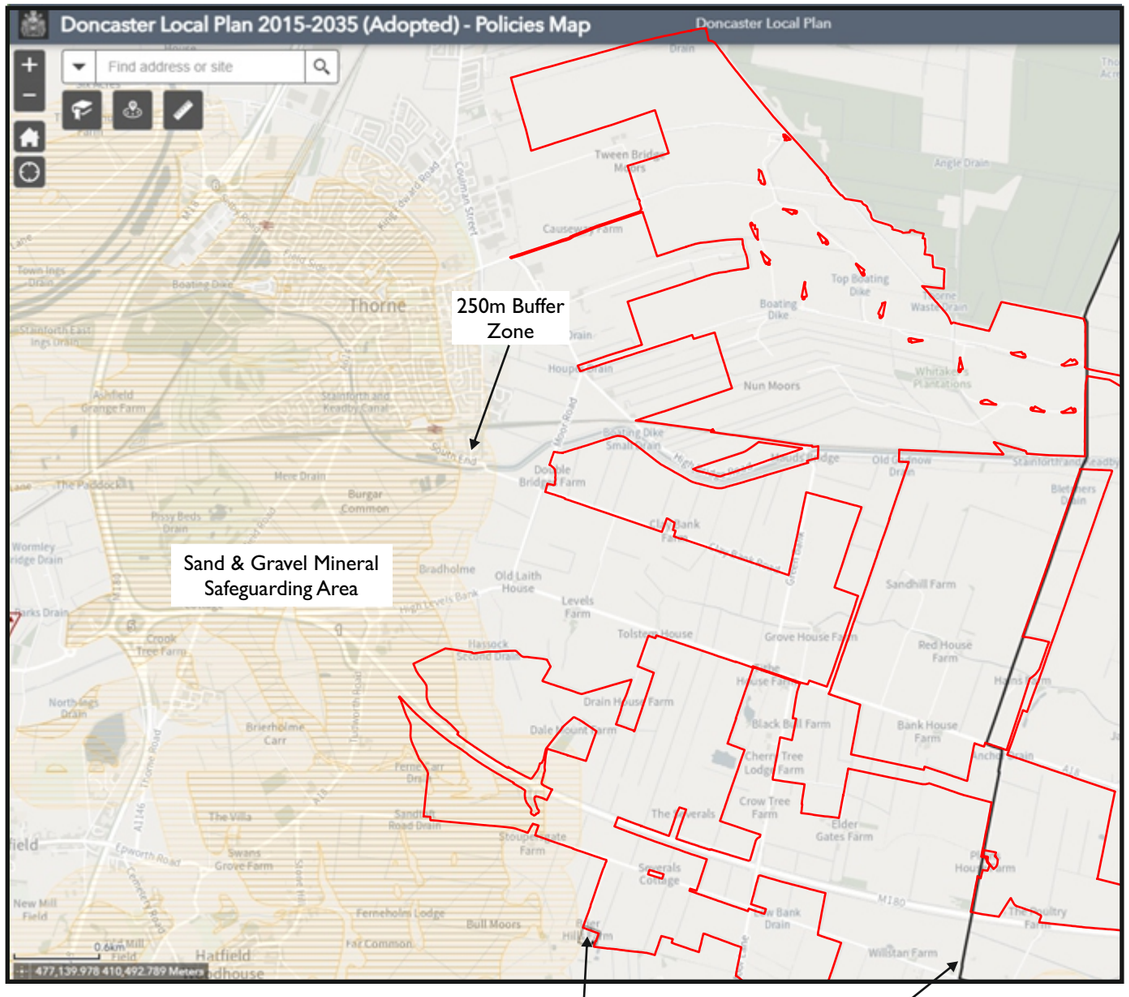
Intégrale
Understanding Ground Conditions

Notes:

1) Extract from:
https://maps.doncaster.gov.uk

2) Not to scale.

3) ——— Draft Order Limits Boundary



Appendix E

Extract from Doncaster Local Plan 2015-2035 (Adopted) Policies Map showing Minerals Safeguarding Areas and Waste Plan Sites

Tween Bridge
Solar Energy Scheme
Thorne
Doncaster

July 2023

Intégrale
Understanding Ground Conditions

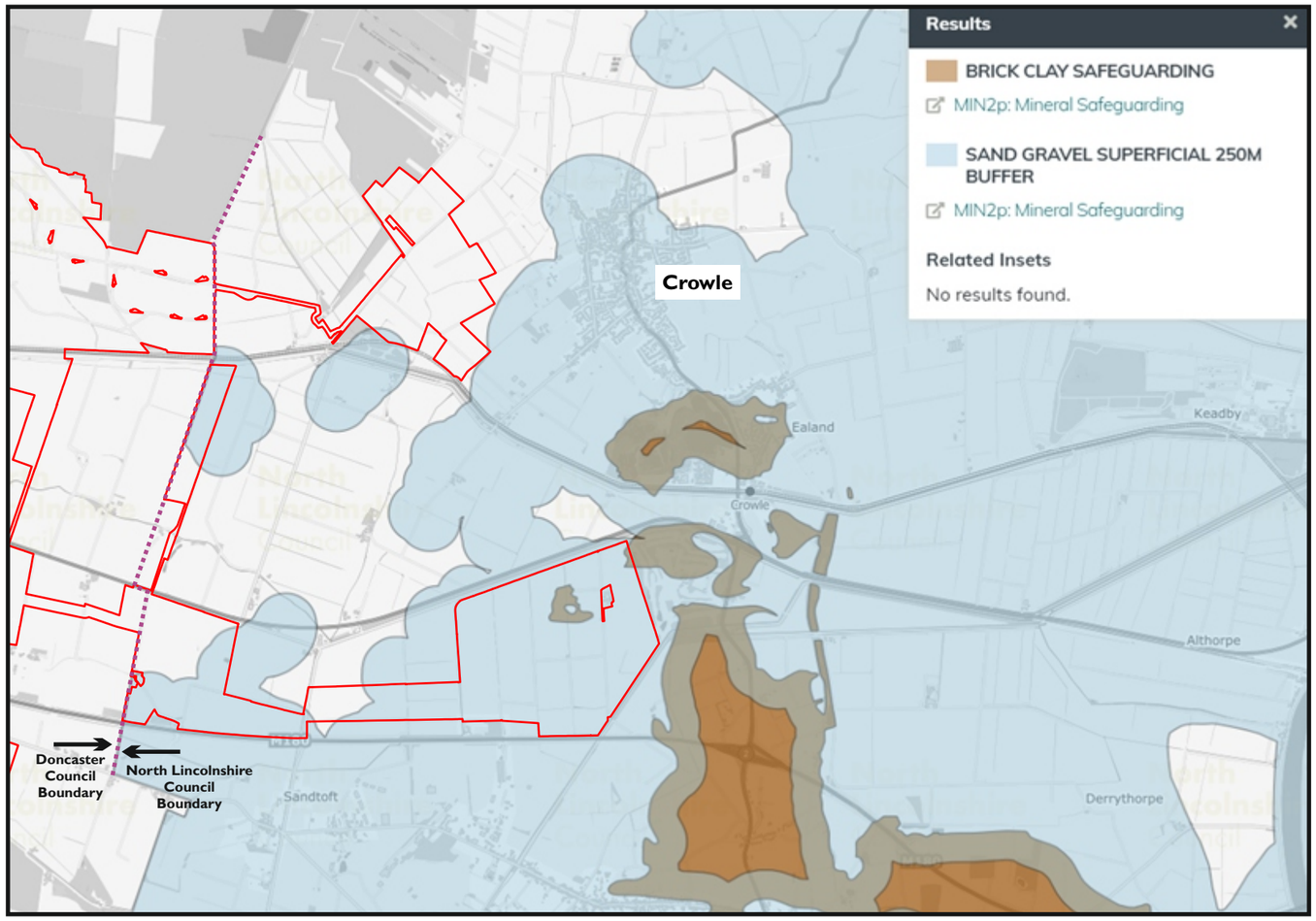
Notes:

1) Extract from:
https://localplan.northlincs.gov.uk/stages/3/policy-map

2) Not to scale.

3) ——— Draft Order Limits Boundary

4) * Stage 3 (2020) Preferred Option
(Regulation 18) Policy Map



Appendix E
Extract from North Lincolnshire Local Plan (2020-2038) Mineral Safeguarding Areas Policy Map*
Tween Bridge
Solar Energy Scheme
Thorne
Doncaster

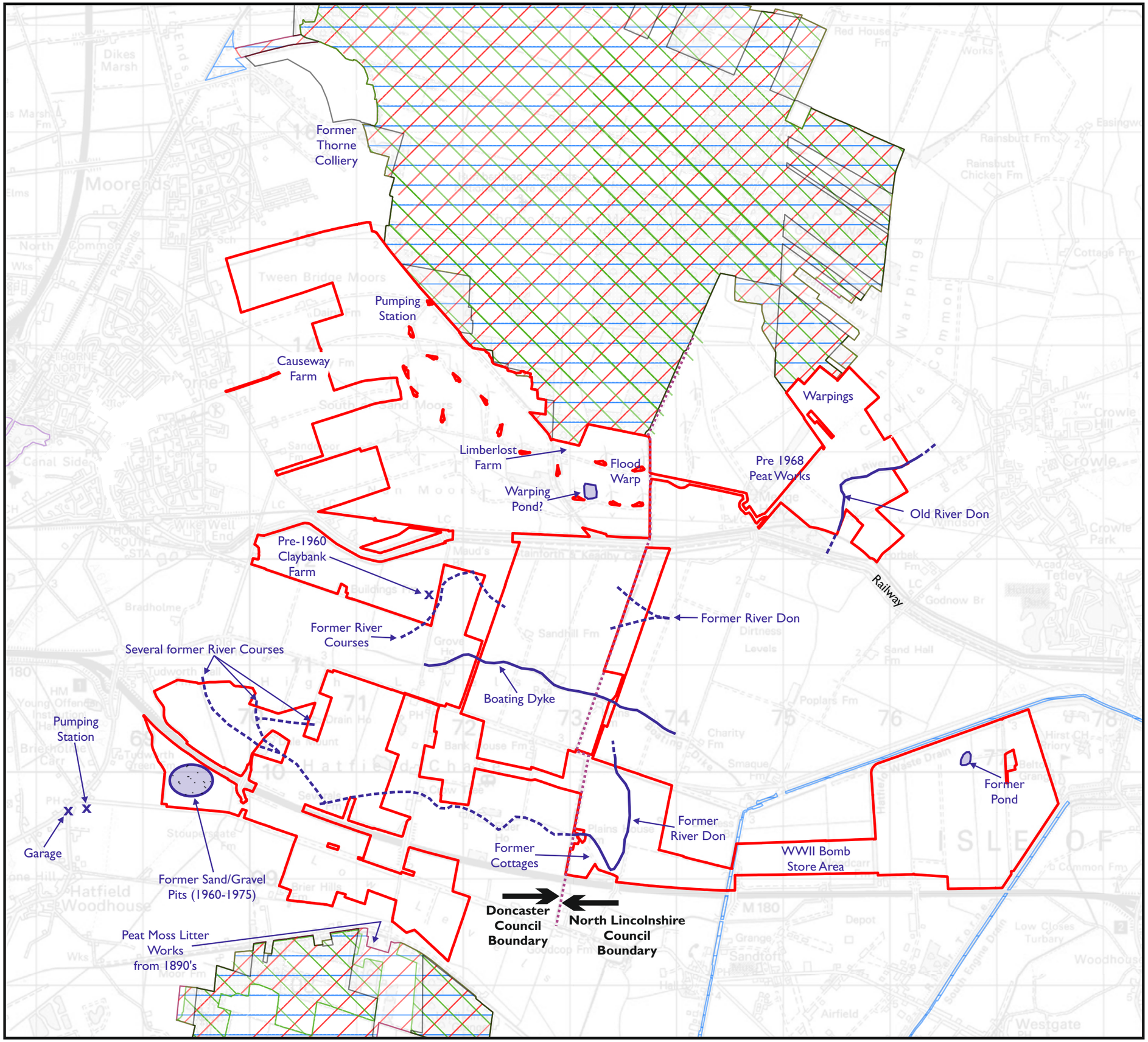
July 2023

Intégrale
Understanding Ground Conditions

Intégrale

Appendix F

Summary Plans of Historical & Environmental Features



KEY

- LOCAL NATURE RESERVES
- SPECIAL PROTECTION AREAS
- SPECIAL AREAS OF CONSERVATION
- SITES OF SPECIAL SCIENTIFIC INTEREST
- NATIONAL NATURE RESERVES

Draft Order Limits Boundary

Adapted from Pegasus Group drawing No. P21-3484_09, November 2022.

Scale = 1:35,000 (approx.) @ A3

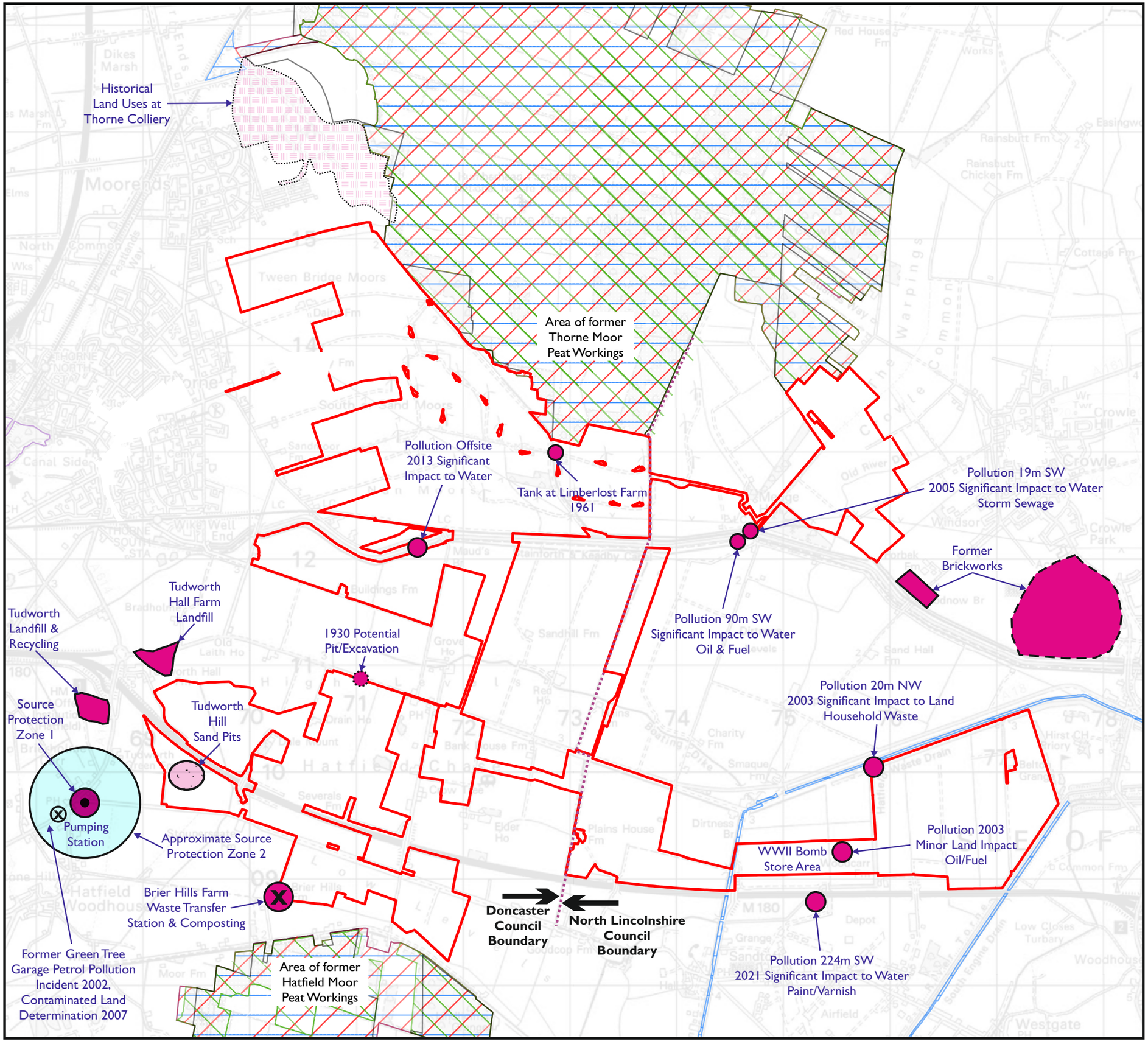
Appendix F

Summary Plan of Pertinent Historical Features from 1850 - Present Day Mapping

Tween Bridge
Solar Energy Scheme
Thorne
Doncaster

July 2023

Intégrale
Understanding Ground Conditions



KEY

- LOCAL NATURE RESERVES
- SPECIAL PROTECTION AREAS
- SPECIAL AREAS OF CONSERVATION
- SITES OF SPECIAL SCIENTIFIC INTEREST
- NATIONAL NATURE RESERVES

Draft Order Limits Boundary

Adapted from Pegasus Group drawing No. P21-3484_09, November 2022.

Scale = 1:35,000 (approx.) @ A3

Appendix F

Summary Plan of Significant Environmental Features, Landfills, Significant Pollution Incidents from Groundsure Data

Tween Bridge
Solar Energy Scheme
Thorne
Doncaster

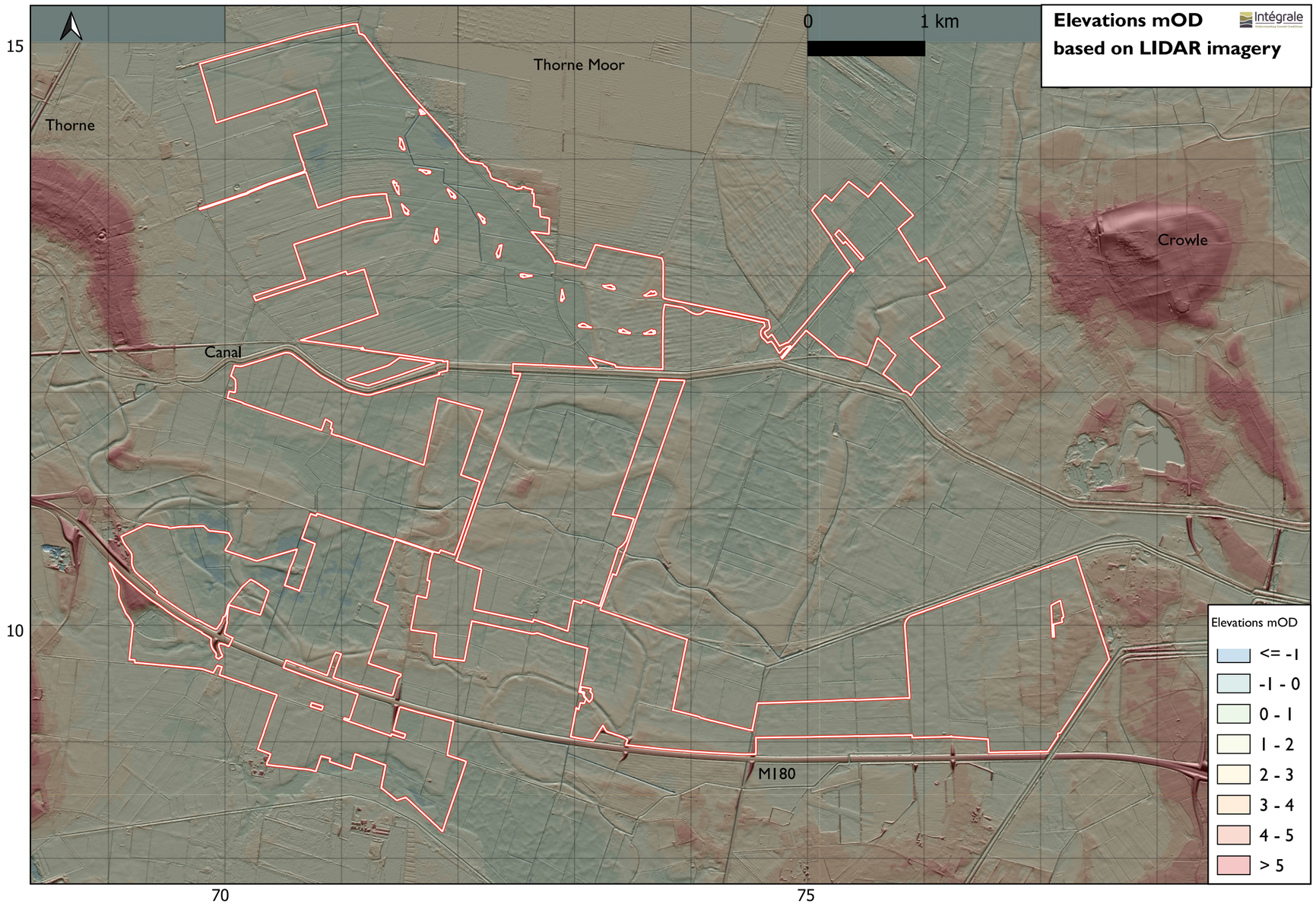
July 2023

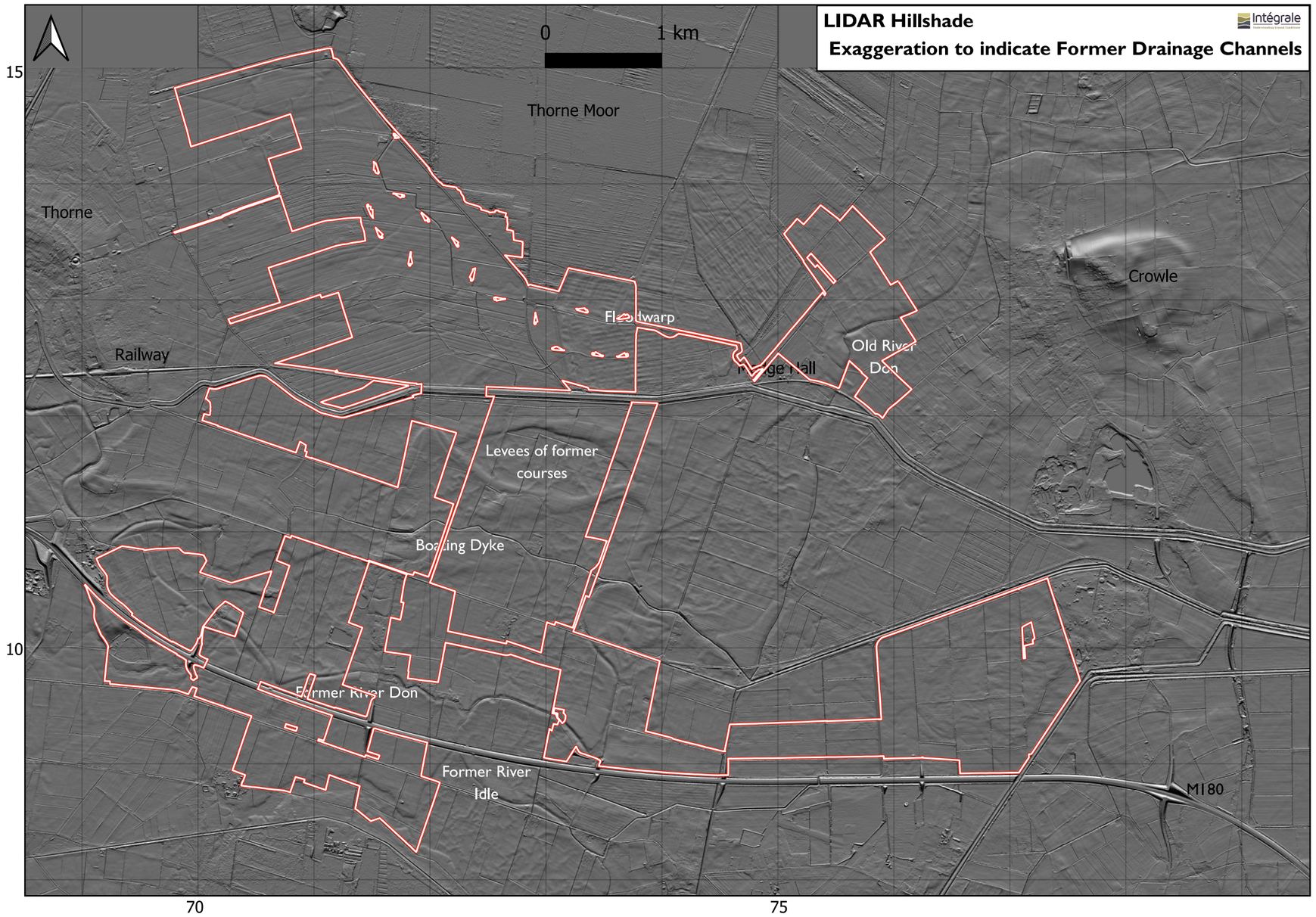
Intégrale
Understanding Ground Conditions

Intégrale

Appendix G

Annotated LIDAR Imagery


0
1 km
Elevations mOD
based on LIDAR imagery
Intégrale
Thorne Moor
Thorne
Crowle
Canal
M180
Elevations mOD
<= -1
-1 - 0
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
> 5
15
10
70
75
Draft Order Limits Boundary


LIDAR Hillshade
Exaggeration to indicate Former Drainage Channels
Intégrale
0
1 km
15
Thorne Moor
Thorne
Railway
Floodwarp
Old River Don
Crowle
Levees of former courses
Boxing Dyke
10
Former River Don
Former River Idle
M180
70
75
Draft Order Limits Boundary

Slope Angles

Intégrale

0 1 2 km

15

10

70

75

Slope Angle in Degrees

- 0
- 0-2
- 2-4
- 4-6
- 6-8
- 8-10
- 10-12
- 12-14
- 14-16
- 16-20

Draft Order Limits Boundary