

Appendix 10.3: PLHRA



Mullaghclogher Wind Farm

Renewable Energy Systems Ltd

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1.0 Executive Summary

SLR Consulting Ltd (SLR) was commissioned by Renewable Energy Systems Ltd (RES) to undertake a Peat Landslide Hazard and Risk Assessment (PLHRA) at the proposed Mullaghclogher Wind Farm (The Proposed Development). The purpose of this report is to consider the extent of peat and potential peat slide hazard at the Proposed Development and consider the potential impact to the development, such that areas of deep peat and areas at high risk of a peat slide can be avoided during the design phase.

Since September 2022, SLR has completed a desk-based review and several phases of peat probing fieldworks to assess the ground conditions in relation to peat and peat instability. The results of the which are presented within this report.

Peat probing fieldworks have indicated that 31% of peat probe locations encountered >0.5m of peat. 49% of probe locations identified peat between 0.5 to 1.5m, and the remaining 20% of probe locations encountered peat depths >1.5m. Peat coring undertaken at selected locations has indicated the peat within the Proposed Development is predominantly fibrous to pseudo fibrous. There are some localised deposits of shallow peat that generally comprise clayey layers, whilst areas of thicker peat are predominantly fibrous layers.

The PLHRA method has been developed by SLR and described within this report. The results indicate that 19% of probe locations are at either a medium or high risk of peat instability. The overall conclusion regarding peat stability is that there are 33 areas of medium risk of peat instability across the Proposed Development. For the medium risk areas, a hazard impact assessment was completed which concluded that, subject to micro-siting and the employment of appropriate mitigation measures, all the areas can be considered as an insignificant risk.



2.0 Introduction

2.1 General

SLR Consulting Ltd (SLR) was commissioned by Renewable Energy Systems Ltd (RES) to undertake a Peat Landslide Hazard and Risk Assessment (PLHRA) at the proposed Mullaghclogher Wind Farm (The Proposed Development). The Proposed Development would comprise up to 11 wind turbines, with associated infrastructure including access tracks, crane hardstandings, turning heads, substation, battery storage compound, peat storage areas and temporary enabling works construction compound.

The purpose of this report is to consider the extent of peat and potential peat slide hazard at the Proposed Development and consider the potential impact to the development, such that areas of deep peat and areas at high risk of a peat slide can be avoided during the design phase. The recommendations of this report have been considered during evolution of the design of the Proposed Development as described in **Chapter 3: Design evolution and alternatives**.

The work has been undertaken by a team of Geotechnical Engineers and Geologists, with over 16 years' experience in undertaking peat assessments and specialising in the assessment of soils, geology and water for renewable power projects throughout the UK.

The methods adopted for the assessment follow the best practice guidance¹ issued by the Scottish Government for investigation, assessment and reporting for windfarms in peat areas. Where relevant, reference is also made to guidance published by the Scottish Environment Protection Agency (SEPA) and windfarm construction good practice guidance.

2.2 Background

The importance of assessing the stability of peat deposits in relation to wind farm developments came to the fore as a result of peat failures during the construction of Derrybrien² Wind Farm in Ireland in 2003. Although no fatalities were associated with these failures, there was a significant environmental impact. Wind farms tend to be constructed in high moorland areas which are associated with significant peat deposits (typically blanket bogs). There is a potential for peat instability to occur, particularly where deposits are in excess of 1m thick. Peat instability is influenced by many factors, including, but not limited to, peat thickness, hill slope gradient, underlying geology and subsurface hydrology. Other recent local natural events include a failure in the Glenelly Valley, Co. Tyrone in 2017 (BBC, 2018)³.

SLR have previously undertaken a preliminary PLHRA⁴ based on an initial design and this report provides an updated PLHRA based on the design fix as detailed below.

2.3 Scope and Objectives of Report

The purpose of a report is to identify those parts of the Proposed Development that are naturally susceptible to a higher risk of instability so that they can be avoided or accommodated. It should be noted that all peat slopes have a risk of instability and the vast majority of peat slope failures occur naturally.

The peat stability assessment is primarily concerned with the influence of the peat on the development of the wind farm. The main objective is to assess the potential peat stability at

¹ Peat Landslide Hazard and Risk Assessments (Scottish Government, April 2017)

² Lindsay, R.A. and Bragg, O., (2004), 'Windfarm and Blanket Peat, The Bog Slide of 16th October 2003 at Derrybrien, Co. Galway, Ireland'. University of East London

³ BBC (2018) Glenelly Valley landslides were 'one-in-3,000 year event'. <https://www.bbc.co.uk/news/uk-northern-ireland-43166964> accessed 19/07/2018

⁴ SLR Consulting, Stage 1 Peat Landslide Hazard Risk Assessment (PLHRA), November 2022



the Proposed Development, identify areas of potential concern and identify mitigation measures to ensure the maintenance of peat stability before, during and after construction. All aspects of construction should be based on ensuring minimum disruption to the peat areas. The objectives have been achieved by completion of the following:

- a desk based review of available reports which include geological, hydrological and topographical information;
- phase 1 peat depth survey undertaken by SLR in September 2022;
- stage 1 Peat Landslide Hazard and Risk Assessment (PLHRA)⁴;
- phase 2 peat depth surveys, undertaken by SLR in June 2023;
- geomorphological mapping of the Proposed Development to identify the prevailing conditions influencing the potential for, or any evidence of, active, incipient or relict peat instability, including identification of the location and photographic record, as appropriate;
- reporting on evidence of any active, incipient or relict peat instability, and the potential risk of future instability, describing the likely causes and contributory factors;
- identification of potential controls to be imposed on the Contractors for the works to minimise the risk of peat instability occurring at the Proposed Development; and
- provide recommendations for further work or specific construction methodologies to suit the ground conditions at the Proposed Development to mitigate any unacceptable risk of potential peat instability.

Construction of the development would only increase the risk of peat slope instability if good geotechnical construction practice is ignored and it is a requirement of all renewable energy developments to follow a very carefully worded and designed Construction and Environmental Management Plan (CEMP) which uses many of the recommendations of the PLHRA.

Without the guidance contained in a Construction Method Statement or CEMP, the following factors would increase the risk of instability:

- construction of access tracks;
- excavation and stockpiling for foundations;
- construction of hardstanding area; and
- blocking of natural drainage, inappropriate new drainage or drainage discharge.

It is important to note that peat instability and the impacts of any instability are not constrained by artificial site or ownership boundaries but by topographic and geomorphologic boundaries. It is therefore important to ensure that the breadth of scope of any assessment adequately covers the areal extent of possible impact.

The risk assessment is based on ground models developed using a Geographical Information System (GIS) specifically for this Proposed Development. A numerical analysis was undertaken in which coefficients were allocated for each of the factors influencing peat stability and their impact on possible receptors.

The conceptual layout of the wind turbines and access routes, the findings from the peat probing, sampling and analysis were used by the design team to optimise the wind turbine layout to avoid or mitigate areas of unacceptable peat slide risk. The layout presented in the drawings represents the final iteration of the wind turbine layout.

This system outlined above was developed in accordance with the guidelines on PLHRA by the Scottish Government¹ for the investigation, assessment, and reporting for wind farms in peat areas. The analysis and interpretation are based upon the results obtained from this



process as well as previous experience and the results of case studies elsewhere. Where deviations from this guidance have occurred, this is highlighted and explained in the text.

2.4 Site Description

The Proposed Development is an area of approximately 630 Hectares (Ha), located approximately 4km North East of Plumbridge, Northern Ireland, centred on National Grid Reference (NGR) of NV 659 582. The Proposed Development is detailed on Figure 1.

The Proposed Development is mostly located on the slopes of Mullaghcarbatagh and Mullaghclogher hills slopes which trend northwards. The highest elevation is on the slopes of Mullaghclogher Hill at 572mAOD with the lowest point approximately 3km to the northwest sitting at 180mAOD.

The Proposed Development is accessed from the north via the B48 and Carrickayne Road. It is located on predominantly upland moorland with some plots of cultivated farmland to the north. The surrounding land-use is largely agricultural farmland and uncultivated moorland.

A number of farmsteads are located in the vicinity, but no occupied residential properties are located within the Proposed Development.

Photograph 1. Field photograph of overview of the eastern side of the Proposed Development. Grid Reference 653164, 896294.



3.0 Desk Based Review

3.1 Topography

The Proposed Development is located on the northern side of two peaks, Mullaghcarbatagh (517mAOD) and Mullaghclogher (572mAOD). The topography of the Proposed Development slopes steeply upwards from north to south. The lowest point (~210mAOD) and low-lying areas are located in the north of the Proposed Development. The southern areas of the Proposed Development are characterised by steep slopes with the highest point (~486mAOD) at Turbine 6.

3.2 Geology

3.2.1 Artificial Geology

The published GSNI GeoIndex⁵ mapping data indicates that made ground deposits are not present within the Proposed Development.

3.2.2 Superficial Geology

Based on the available online GSNI GeoIndex mapping data, the Proposed Development area is largely underlain by superficial deposits of Glacial Till (Devensian) described as comprising mainly Diamicton clays, silts and sands. Alluvium deposited by meltwater streams are noted along water channels across of the Proposed Development, comprised of clay, silt, sand and gravels or organic material. Localised areas of Morainic and Glaciofluvial Ice Contact deposits comprising silt, sand, gravel and boulders are noted in the northeast of the Proposed Development. No superficial deposits are recorded around the crest of both hills to the south of the Proposed Development.

Overlying the glacial deposits are extensive Blanket Peat deposits are recorded across the majority of the Proposed Development area. Peat is an accumulation of wet, very slightly decomposed vegetation with abundant tree roots and rootlets, and it is typically characterised by waterlogged, nutrient poor and acidic conditions.

Figure 3 within this report details the superficial geology BGS mapping overlaid across the Proposed Development.

3.2.3 Bedrock Geology

The available online GSNI GeoIndex mapping data indicate that the bedrock geology underlying the Proposed Development is variable with the stratigraphy featuring two main units: Glenga Amphibolite Member and Dart Formation.

The Glenga Amphibolite Member (Neoproterozoic) is comprised of basalt (lava-pillowed) and volcanoclastic breccia (pillowed), and is located throughout, but pre-dominantly in the north, west and centre of the Proposed Development.

The Dart Formation (Neoproterozoic) is present throughout the Proposed Development, comprised of metamorphic psammite and minor metalimestone units. This formation is most common in the centre, east and south of the Proposed Development. There is also a minor semipelite unit present in the northwest.

The bedrock geology of the Proposed Development is detailed on Figure 4.

⁵ GSNI GeoIndex, https://mapapps2.bgs.ac.uk/gsni_geoindex/home.html, last accessed August 2023.



3.2.4 Structural Geology

The Proposed Development is structurally complex with a number of folds and thrust faults trending north east south west. There are a number of sills underlying the north and northwest of the Proposed Development comprised of metagabbro (Neoproterozoic), trending NE-SW.

3.3 Historical Boreholes

There are no boreholes located within the vicinity of the Proposed Development.

3.4 Mining and Quarrying

Following review of publicly available records, there is no evidence of historic mining across the Proposed Development.

3.5 Designations

NIEA Natural Environment Map Viewer⁶ shows that the Proposed Development is listed as a priority habitat for peatland.

3.6 Hydrogeology

The Proposed Development is underlain by impervious rock generally without groundwater except at shallow depth or in fractures. A review of aquifer characteristics confirms that water is likely to be present in the peat and that groundwater may be present within sand and gravel horizons within the Glacial Till (if present) and within fractures or fault zones within the bedrock deposits. A potential superficial aquifer is recorded on GSNi GeoIndex to the north of the Proposed Development.

3.7 Hydrology

There are multiple surface water features on the Proposed Development. The Burn dennett River flows southeast to northwest along the eastern perimeter of the Proposed Development and is given an overall classification of 'Good'. Two minor tributaries, the Stroanback Burn (centre of Proposed Development) and an 'unnamed' watercourse (east of Proposed Development) flow north towards the Burndennett River.

3.8 Geomorphology

The Proposed Development is generally characterised by steep slopes to the south and east with flatter lower-lying areas to the north and west. Thick areas of peat are noted within the lower-lying areas. Figure 5 details the relevant geomorphology features identified across the Proposed Development.

3.8.1 Aerial Photography Interpretation and Site Observations

Aerial photographs were used in conjunction with 5m DTM data for the Proposed Development to identify the major geomorphological features such as the breaks of slope and landslips. These were inspected where identified during site visits when more detailed assessment was undertaken.

Aerial photography using google earth was reviewed dating back to 1985 with images from 2002, 2005, 2009, 2010, 2011, 2012 and 2015 to 2023 also used. Interpretation of available aerial photographs was undertaken to assess and identify evidence of historic peat instability.

⁶ NIEA Natural Environment Map Viewer, <https://www.daera-ni.gov.uk/services/natural-environment-map-viewer>, last accessed August 2023.



The photographs were examined using various techniques to highlight features of interest, such as:

- Possible extension and/or compression features.
- Areas of historic failure scars and debris.
- Evidence of peat creep.
- Areas with apparently poor drainage.
- Areas with concentrations of surface drainage networks.
- Steeply incised stream cuttings within peat deposits.
- Areas with peat drift recorded on steep slopes.

The main features are detailed below.

3.8.2 Peat Erosional Features

Peat hags are rare throughout the Proposed Development and are absent in the flatter areas of deeper peat. There are small areas of haggings (up to 2.5 m in height) on sloping ground within the centre of the Proposed Development south of T5 and T7.

3.8.3 Peat Working

Peat working (stripping) has been noted by walkovers and review of aerial photography largely in the western part of the Proposed Development south of T2 and also noted at the site entrance.

3.8.4 Drainage Channels

Drainage across the Proposed Development is characterised by a network of streams, rivers with extensive artificial drainage typically present in the eastern area of the Proposed Development likely associated with former land-use. No evidence of peat instability was noted relating to drainage features.

3.8.5 Forestry

No forestry is noted within the footprint of the Proposed Development. A localised area of forestry is present to the north of the central area of the Proposed Development.

3.8.6 Bedrock

The OS maps show outcrops on-site in areas of higher elevations in areas south of Glengarrow. This is also confirmed by the site visit where bedrock was recorded.

3.8.7 Extension/Compression Features

It was not possible to identify evidence of any significant historic peat failures or slides at the Proposed Development from the aerial photographs and this was confirmed during site visits with no evidence of any extension or compression features identified in the peat during site visits. As noted in Section 2.2 a historic landslide occurred within the Glenelly Valley during 2017³. However, no evidence of the landslide event was noted across the Proposed Development during site walkovers or review of aerial photography.



4.0 Site Work

4.1 Peat Depth Survey

Peat depth surveys have been undertaken across two phases by SLR. The surveys carried out followed best practice guidance for developments on peatland^{7,8}.

Phase 1 peat probing resulted in probing on a 100 m grid to allow for initial assessment of the Proposed Development which was used in preliminary site layout designs. Phase 2 probing saw detailed probing undertaken across the proposed layout, focussing on access tracks, turbine locations and other infrastructure.

Peat is generally defined as an organic soil in excess of 0.5 m, if the soil is less than 0.5 m, then it is considered peaty soil.

Where surveys were undertaken by SLR, the thickness of the peat was assessed using a graduated peat probe, approximately 6 mm diameter and capable of probing depths of up to 10 m. This was pushed vertically into the peat to refusal and the depth recorded, together with a unique location number and the co-ordinates from a handheld Global Positioning System instrument (GPS). The accuracy of the GPS was quoted as ± 2 m, which was considered sufficiently accurate for this survey. All data was uploaded into a GIS database for incorporation into various drawings and analysis assessments.

4.2 Peat Depth

The results from all probing exercises listed above in Section 3.1 are detailed in the following sections and the peat depths identified on-site are shown in Figure 6 and Figure 7. All probing data is provided in Annex A.

The peat was found to vary across the Proposed Development in terms of thickness and coverage. The slopes on-site are detailed in Figure 8. When viewed in conjunction with Figure 6 and Figure 7, it is evident that the peat is generally limited to flatter lying topographic areas. There were localised areas of peat, defined by topography and undulating bedrock. Thick peat was generally encountered in the north across the flatter, lower gradient areas of the Proposed Development.

A total of 2,232 peat probes were undertaken across all survey phases, with the results summarised in Table A below.

Table A: Peat Probing Results

Peat Thickness (m)	No. of Probes	Percentage (of total probes undertaken on-site)
0 (no peat)	361	16.2
0.01 – 0.49 (peaty soil)	327	14.7
0.50 – 0.99	627	28.1
1.00 – 1.49	473	21.2
1.50 – 1.99	269	12.1
2.00 – 2.49	115	5.2

⁷ Scottish Renewables & SEPA (2012) 'Developments on Peatland Guidance on the Assessment of Peat Volumes, Reuse of Excavated Peat and the Minimisation of Waste'.

⁸ Scottish Natural Heritage (SNH), SEPA, Scottish Government & James Hutton Institute. (2014)' Peat Survey Guidance; Developments on Peatland: Site Surveys'.



Peat Thickness (m)	No. of Probes	Percentage (of total probes undertaken on-site)
2.50 – 2.99	39	1.7
3.00 – 3.49	17	0.8
3.50 – 3.99	2	0.1
> 4.0	2	0.1

The above results indicate that 31% of peat probe locations encountered >0.5m of peat. 49% of probe locations identified peat between 0.5 to 1.5m, and the remaining 20% of probe locations encountered peat depths >1.5m.

4.3 Peat Condition

Peat is described using the von Post¹² classification. Peat samples were collected by SLR in June 2023, using a peat auger and used to inform interpretations of the peat condition and underlying substrate.

Based on interpretations from probing and peat core samples, the peat within the Proposed Development is predominantly fibrous to pseudo fibrous. There are some localised deposits of shallow peat that generally comprise clayey layers, whilst areas of thicker peat are predominantly fibrous layers.

Based on field descriptions at augering points, most of the peat would be classified as between H2 and H4 in the von Post classification, showing insignificant to moderate decomposition. Peat Core logs and photographs are presented within Annex B.

4.4 Substrate

Where possible an assessment of the substrate was made. The assessment was based on a review of the aerial and geological mapping as well as evidence from site walkovers and peat coring. It is recommended that during detailed design the substrate should be verified by ground investigation data. The substrate falls into either of the two following categories:

- granular (sand and/or gravel/weathered rock), of glacial origin and occasionally interbedded with silty sands;
- rock, no rock samples were recovered from the probe locations; and
- No clay horizons were encountered and evidence from site walkovers did not encounter cohesive clay materials on-site.



5.0 Peat Instability

This section reviews the nature of peat and how current and past activities can influence stability. The factors which are likely to influence the potential for peat instability are:

- Significant peat depths over impermeable bedrock or minimal soil.
- The presence of slope gradients greater than 4° (approximately) and general topography.
- Natural drainage paths.
- Evidence of past failures, including soil creep.
- Drainage features at the base of slopes which could lead to undercutting.
- Forestry plantations and artificial drainage and recent climate patterns.

It should be noted that peat instability is not a recent phenomenon and there is documentary evidence of peat landslides dating back over 500 years⁹. Many landslides that involve peat have no human interference that could be considered as a trigger, and this should be borne in mind when considering the susceptibility of a site to potential instability.

5.1 Background Information Regarding Peat

Peat is found in extensive areas in the upland and lowland regions of the UK and is defined as the partly decomposed plant remains that have accumulated in-situ, rather than being deposited by sedimentation. When peat forming plants die, they do not decay completely as their remains become waterlogged due to regular rainfall. The effect of water logging is to exclude air and hence limit the degree of decomposition. Consequently, instead of decaying to carbon dioxide and water, the partially decomposed material is incorporated into the underlying material and the peat 'grows' in-situ.

Peat is characterised by low density, high moisture content, high compressibility and low shear strength, all of which are related to the degree of decomposition and hence residual plant fabric and structure. To some extent, it is this structure that affects the retention or expulsion of water in the system and differentiates one peat from another.

Lindsay¹⁰ defined two main types of peat bog, raised bog and blanket bog, which are prevalent on the West coast of Europe along the Atlantic seaboard. In Britain, the dominant peatland is blanket bog which occurs on the gentle slopes of upland plateaux, ridges and benches and is predominantly supplied with water and nutrients in the form of precipitation. Blanket peat is usually considered to be hydrologically disconnected from the underlying mineral layer.

There are two distinct layers within a peat bog, the upper acrotelm and the lower catotelm. The acrotelm is the fibrous surface to the peat bog¹¹, typically less than 0.5m thick, which exists between the growing bog surface and the lowest position of the water table in dry summers. Below this are various stages of decomposition of the vegetation as it slowly becomes assimilated into the body of the peat.

For geotechnical purposes the degree of decomposition (humification) can be estimated in the field by applying the 'squeezing test' proposed by von Post and Grunland¹² (1926). The humification value ranges from H1 (no decomposition) to H10 (highly decomposed). The

9 Smith, L.T., (Ed) (1910), 'The literary of John Leland in or about the years 1535-1543.' Vol.5, Part IX. London: AF Bell and Sons.

10 Lindsay, R.A., (1995), 'Bogs: The ecology, classification and conservation of Ombrotrophic Mires.' Scottish Natural Heritage, Perth.

11 Ingram, H.A.P., (1978), 'Soil layers in mires: function and terminology'. *Journal of Soil Science*, 29, 224-227.

12 Von Post, L. and Grunland, E., (1926), 'Sodra Sveriges torvillganger 1' *Sverges Geol. Unders. Avh.*, C335, 1-127.



extended system set out by Hobbs¹³ provides a means of correlating the types of peat with their physical, chemical and structural properties.

The relative position of the water table within the peat controls the balance between accumulation and decomposition and therefore its stability, hence artificial adjustment of the water table by drainage requires careful consideration.

5.1.1 Peat Shear Strength

In geotechnical terms, the shear strength of a soil is the physical characteristic that provides stability and coherence to a body of soil. For mineral soils such as clays or sands, such strength is variously given by an inter-particle friction value and cohesion. Depending on whether the mineral soil is predominantly cohesive (clay) or non-cohesive (sand) governs which of the components of strength control the behaviour of the soil.

For peat soils, where the major constituent is organic and there is likely to be little or no mineral component, the geotechnical definition of shear strength does not strictly apply. At present there is no real alternative method for defining the shear strength of peat, therefore the geotechnical definition is generally adopted, in the knowledge that it should be used with great caution.

As noted previously, the acrotelm or near surface peat comprises a tangle of fresh and slightly rotted roots and vegetable fibres. These roots and fibres impart a significant tensile shear strength capacity to the material which provides it with a significant load carrying capacity. The acrotelm is, in effect, a fibre reinforced soil.

In the more decomposed catotelm, the tensile shear strength is reduced as the roots and fibres become more rotted. However, the loss in strength due to decomposition is off set to a limited degree, by a gain in strength due to the overburden pressure. In geotechnical engineering there is an established relationship for recently deposited soils, between the shear strength of a sample and the thickness of overburden above it.

Consequently, it is almost impossible to predict a shear strength profile in peat and attempts to measure the shear strength using normal geotechnical methods can be misleading. Typical values of shear strength from hand shear vanes would be in the range 10-60 kilopascal (kPa) although values over 100 kPa have been recorded in peat elsewhere. The higher strengths are almost certainly the influence of roots or other non-decomposed material. It is believed that the strength of peat should be quoted as a cohesion value as there are few, if any, discrete particles to give the material a significant frictional resistance. It should be noted, however, that any quotation of shear strength for peat should be treated with extreme caution.

5.1.2 Peat Stability-Factors to be Considered

There is considerable observational information relating to debris and peat flows although the actual mechanisms involved in peat instability are not fully understood. The main influences on slope stability are geological, geotechnical, geomorphic, hydrological, topographic, climatic, agricultural and human influences such as drainage and construction activity. Peat is affected to a degree by changes in any of the above list and it is vital to appreciate that changes to the existing equilibrium would affect the level of slope stability during construction and operation of the Development.

Some of the contributory factors to peat instability are summarised as follows:

¹³ Hobbs, N.B., (1986), 'Mire morphology and the properties and behaviour of some British and foreign peats.' Quarterly Journal of Engineering Geology, London, 19, 7-80.



- The geographical limits which could be affected by potential instability are not confined to the artificial boundaries imposed by land ownership; landslip occurring above a site could affect the site and property down slope or downstream of the site for several kilometres.
- Agriculture and grazing have a substantial effect on peat areas, and this can be compounded in areas that have been managed to improve grazing. Grazing compacts the peat surface reducing the rainwater infiltration and the additional nutrients change the ecological balance of the original peat bog. Agricultural management can include surface drainage and periodic burning, both of which can leave the surface of the peat bare for a period of time resulting in temporary desiccation of the surface. Subsequent wetting of the peat and resumption of peat accumulation results in the former desiccated and possibly ash covered surface being incorporated into the body of the peat which introduces a weak discontinuity in the profile; this in turn becomes another unknown factor in the stability assessment.
- Forestry has a substantial effect on slope stability particularly in the early stages as the creation of a forest involves disruption of the natural equilibrium and drainage of the slopes and the installation of artificial drains by deep ploughing. The construction of access tracks further disrupts the drainage and concentrates groundwater flow into narrow, fast flowing erosive streams. The work by Winter *et al*¹⁴ noted that forest tracks can act to retard or concentrate the down slope flow of water and thus aid its penetration into the slope below. Such a mechanism has been observed at a number of recent landslips that have affected the road network in Scotland.
- Natural drainage – some of the precipitation falling onto a natural upland peat bog would be absorbed into the low permeability catotelm peat. However, most of the water would run-off as sheet flow through upper, high permeability acrotelm. Thus, the water is transmitted to the lower slopes in a reasonably controlled manner through a range of interconnections that operate at different scales and speed. Failure to understand this and to disrupt the transmission process for the groundwater could result in instability.
- Artificial drainage - where agricultural drainage has been used to improve the quality of the grazing or to promote forestry it reduces the overall volume of water entering the bog and transfers this water to the edges more rapidly. This can result in ditches and streams becoming enlarged, causing increased erosion and a greater silt burden in the stream water.

5.2 Peat Mass Stability

The principal surface indicator of peat slide potential is cracking of the peat land surface, and it is the identification of crack patterns in the field and the attendant causes of the cracking that is fundamental to a peat stability assessment.

Sites that have exhibited natural instability in the past are likely to be more susceptible to future instability during and following construction of a renewable energy development, therefore it is important to identify such instability as part of the Peat Stability Assessment.

5.2.1 Types of Failure

The result of instability in peat is the down-slope mass movement of the material; there are a number of definitions of peat instability which are used to characterise the type of failure including:

¹⁴ Winter, M.R., Macgregor, F. and Shackman, L. (2005a), 'Scottish tracks networks landslide study' Trunk tracks: network management division, published report series. The Scottish Government.



- Bog bursts or bog flows – the emergence of a fluid form of well humified, amorphous peat from the surface of a bog, followed by the settling of the residual peat, in-situ ¹⁵.
- Peat slides – the failure of the peat at or below the peat/ substratum interface leading to translational sliding of detached blocks of surface vegetation together with the whole underlying peat stratum¹⁵.
- Bog slide – an intermediate form of instability where failure occurs on a surface within the peat mass with rafts of surface vegetation being carried by the movement of a mass of liquid peat.

5.2.2 Bog Bursts

Accounts of bog bursts are generally associated with very wet climates or areas which have received storm rainfall events. Bog bursts can be associated with particularly wet peat landscapes; therefore, it is possible to identify broad regions of a higher susceptibility to these failures. The constraints used to identify the areas of higher susceptibility to bog burst failure are given below:

- Peat thickness greater than 2m.
- Shallow gradients, generally within the range of 2 to 5°, peat thicker than 1.5m is generally not observed on slopes steeper than 10°, also moisture content is generally reduced on steeper slopes due to drainage).
- Ground which is annually waterlogged to within the upper 1m below ground level (the groundwater level may rise above this but rarely falls below).
- Greater humification of the lower catotelm within the waterlogged ground; and lower surface tensile strength of the fibrous peat and vegetation.

The humified mass can be considered as analogous to a heavy liquid and the stability of this mass is maintained by the strength of the surface or acrotelm peat. Should the surface become weakened through erosion or desiccation or the construction of a surface drainage ditch for agricultural or forestry reasons or through turbary (peat cutting), failure is made more likely.

5.2.3 Peat Slides

Peat slides tend to be translational failures with a defined shear surface at or close to the interface with the substrate.

The factors generally considered to influence susceptibility to peat slide failures are listed below:

- Peat depth up to 3m;
- Slope gradients between 4.5° and 32°
- Natural or artificial drainage cut into the surrounding peat landscape
- Greater humification of the lower catotelm within the waterlogged ground
- Lower surface tensile strength of the fibrous peat and vegetation

It is noted that some of the factors causing instability are common to both bog bursts and peat slides.

The peat – substrate interface is the primary zone of failure and is enhanced by elevated water content at this boundary and softening or weathering of the lower mineral surface. For this

¹⁵ Dykes, A.P and Kirk, K.J., (2001), 'Initiation of a multiple peat slide on Cuilcagh Mountain, Northern Ireland.' *Earth Surface Processes and Landforms*, 26, 395-408.



reason, any investigation or probing should try to distinguish the nature of the lower mineral substrate.

5.2.4 Bog Slides

A bog slide is a variation on a peat slide where part of the peat mass is subject to movement, usually on an internal layer of material, which may be more prone to movement, such as an interface between the acrotelm and catotelm layer.

5.2.5 Natural Instability

The stability of a peat mass is maintained by a complex interrelationship of many factors. Key factors include sloping rock head and proximity to a water body. Rainfall often acts as the trigger after the slope has already been conditioned to fail by natural processes.

It should also be remembered that peat bogs are growing environments and that there would come a time, on sloping ground, where the forces causing instability, the weight of the bog, can no longer be resisted by the internal strength of the peat and its interface with the underlying mineral surface. At this point, failure would occur.

The weight of the peat bog or any soils mantling steep hill slopes would be increased during periods of very heavy rain and it is common to see landslips occurring following extreme rain events. This may be a concern for future developments where one of the predicted effects of global warming will be a greater frequency of extreme weather, intense storms being one element.



6.0 Hazard and Risk Assessments

6.1 Introduction

The Scottish Government Guidance¹ provides an overview of the principles of hazard and risk with respect to peat landslides. The guidance is noted as illustrative only and the developers can present their own methodology providing, it is clearly explained and incorporates consideration of the likelihood of instability and the consequences should it occur. The following sections detail the proposed methodology used within this peat landslide hazard risk assessment.

A 'Hazard Ranking' system has been applied based on the analysis of risk of peat slide as outlined in the Scottish Government Guidance¹. This is applied on the principle:

$$\text{Hazard Ranking} = \text{Hazard} \times \text{Exposure}$$

This philosophy can be applied to the assessment carried out so far in the following approach:

$$\text{Hazard Ranking} = \text{Risk Rating} \times \text{Impact Rating}$$

6.2 Methodology

The determination of Risk Rating and Impact Rating values is based on a number of variables which impact the likelihood of a peat slide and the relative importance of these variables specific to the site.

Similarly, the consequences or Exposure to receptors is dependent on variables including the particular scale of a peat slide, the distance it will travel, and the sensitivity of the receptor.

In the absence of a predefined system, the approach to determining and categorising Risk Rating and Impact Rating is determined on a site-by-site basis. The particular system adopted for the PLHRA is outlined in the following sections.

6.3 Slope Stability

The stability of peat is a complex subject and there are numerous inter-relationships that affect the stability.

A quantitative assessment requires a numerical input and such an analysis cannot account for the unquantifiable input required for a comprehensive peat stability assessment. For this reason, a purely quantitative assessment should only be considered as a guide and a qualitative assessment of stability should be used to inform the final recommendations.

The characteristics of the peat failure phenomena have been incorporated in a stability risk assessment to evaluate the risk of instability occurring within the peat areas. The main factors controlling the stability of the peat mass are the surface gradients, the depth and condition of the peat at each location and the type of substrate.

The natural moisture content and undrained shear strength of the peat are important; however, it is generally accepted that where present, the peat would be saturated and have a very low strength. It is believed to be unrealistic to rely on specific values of shear strength to maintain stability when back analysis of failed slopes indicates that there is often a significant discrepancy between measured strength in peat and stability. Shear strength has been assumed to be constant and worst case, throughout this assessment. It has also been assumed, as a worst case, that the groundwater level is coincident with the ground surface.



It is apparent that the stability of peat is complex and the numerous inter-relationships that affect the stability are not fully understood. The problem with a quantitative assessment is that it requires a numerical input and the analysis cannot account for the unquantifiable input required for a comprehensive peat stability assessment. For this reason, a purely quantitative assessment should only be considered as a guide and that a qualitative assessment of stability should be used to provide the final recommendations.

6.4 Risk Rating

The potential for a peat slide to occur during the construction of the Proposed Development depends on several factors, the importance of which can vary from site to site. The factors requiring considerations include:

- slope gradient;
- peat thickness;
- substrate type or condition; and
- historic instability.

Of these, peat depth and slope gradient are considered to be principal factors. Without a sufficient peat depth and a prevailing slope, peat slide hazard would be negligible.

The rating system outlined below differs slightly from that proposed in the Scottish Government Guidance¹ as the system adopted here incorporates three inputs compared to two in the guidance, with the potential impact of substrate added in this section.

The probability of a peat landslide 'Risk Rating' (score) was derived by multiplying the coefficients for the four key factors (with historic instability as 1) together to produce a risk rating which is a measure of the likelihood of peat instability, and this enables potential areas of concern to be highlighted. For the assessment, the following rating system was applied as shown in Table B with the individual factors used to derive the probability of instability detailed in the following sections within Tables C – E.

Table B: Probability of Peat Landslide

Risk Coefficient	Rating	Potential Stability Risk (Pre-Mitigation)	Action
<5		Negligible	No mitigation action required.
5 - 15		Low	As for negligible condition plus development of a site-specific construction and management plan for peat areas.
16 - 30		Medium	As for Low condition plus may require mitigation to improve site conditions.
31-50		High	Unacceptable level of risk, the area should be avoided. If unavoidable, detailed investigation and quantitative assessment required to determine stability and sensitivity to minor changes in strength and groundwater regime combined with long term monitoring.
>51		Very High	Unacceptable level of risk, the area should be avoided.

6.4.1 Peat Depth

Table C shows the peat depth ranges and their related peat depth coefficients. Peat depths were derived from the peat depth model shown on Figure 6 and Figure 7.



Where the probing recorded peat less than 0.5m thick, this has been considered to be an organic soil rather than peat and are outside the scope of this assessment.

In addition to peat thickness, the presence of existing landslip debris or indicators of meta-stable conditions such as tension cracks or slumping in the peat suggest the material is likely to become even less stable should the existing ground conditions change. Where evidence of historical slips, collapses, creep or flows is seen, a separate coefficient has been applied.

Table C: Coefficients for Peat Depth

Peat Depth Range	Peat Depth Coefficients
(<0.5 m)	1
(0.5 – 1.5 m)	2
(>1.5 m)	3*
-	8

*Note that thicker peat generally occurs in areas of shallow gradients and records indicate that thick peat does not generally occur on steeper gradients.

6.4.2 Slope Gradients

Table D gives the coefficients applied to the categorised slope angles. The slope gradients were assessed by reference to the mapping and particularly the DTM which was used to generate a slope map (Figure 8), from which the gradient at each probe location could be determined and input into the risk rating spread sheet (Annex A). The gradient quoted at each location was based on the average gradient over a 5m grid.

Coefficients for slope gradient have been assigned to ensure the potential for both peat slides (gradients of 4-15°) and bog slides (gradients of 2-10°) are addressed. By simple inspection it is clear that steeper slopes pose a greater risk of instability than shallow gradients. Therefore, a graduated gradient scale from 0° to >12° (the practical maximum gradient on which peat is commonly observed) has been applied.

Table D: Coefficients for Slope Gradients

Slope Angle (°)	Slope Angle Coefficients
Slope <2°	1
2° ≤ Slope <4°	2
4° ≤ Slope <8°	4
8° ≤ Slope <12°	6
>12° Slope	8

6.4.3 Substrate

Table E shows the substrate type and their related substate coefficient. As noted above, most failures in thin peat layers occur at the interface with the underlying substrate; the nature of the substrate has an influence on the probable level of stability.

Table E: Coefficients for Substrate

Substrate Conditions	Substrate Coefficients
Granular	1



Substrate Conditions	Substrate Coefficients
Rock	2
Cohesive	2
Not proven	3
Slip material (Existing materials)	5

Probing across the Proposed Development indicated primarily granular and bedrock substrates using the refusal method. This was confirmed by visual inspection of exposures and peat coring at selected locations across the proposed infrastructure.

6.4.4 Results

The table of results, included in Annex A, shows that 2,232 probe locations were identified within the extent of the Digital Terrain Model, peat (>0.5 m) was present at 1,544 locations. The stability risk rating identified the following:

- Negligible risk at 272 (12%) probe locations;
- Low risk at 1,176 (53%) locations;
- Medium risk at 400 (18%) locations;
- High risk at 23 (1%) locations; and
- No peat was recorded at 361 locations (16%), hence no risk.

Figure 9 presents the interpreted risk of peat instability based on the multiplication of the risk coefficients discussed above in Table C to Table E.

6.5 Impact Rating

An assessment of the receptors 'Impact Rating' of the medium and high risk locations has been undertaken. It should be noted that the impact assessment is primarily concerned with impacts that affect the environment, ecology, public or infrastructure associated with the development, both on-site and potentially off-site. This assessment does not consider the detailed ecological impact of construction induced peat instability; however, the majority of the sensitive on-site receptors are the watercourses and thus the inferred ecological and environmental issues are addressed. The proposed mitigation measures in Section 6.0 would limit the potential for any slope failures into water courses and drainage features hence limit such impacts. The effect a slope failure may have on the construction site and infrastructure can be easily identified. However, the effect of an instability event on features impacted by an event not associated with the Proposed Development is harder to predict. In order to address this effect, it is not considered appropriate to assess the effect at every potential receptor location close to the Proposed Development; but rather to assess the effect a particular infrastructure feature (UGC, track, trident pole/steel poles) would have on the structures or features surrounding it. By adopting such an approach, the assessment of infrastructure features where a risk ranking of 'negligible' or 'low' (assessed in the stability risk assessments described above) is discounted from further assessment.

The impact rating coefficient (score) is derived by multiplying the receptor ranking coefficient (score) by the distance coefficient (score) and the elevation coefficient (score) for each impact receptor associated with a particular infrastructure feature. The ranking process by attributing the different weighting systems to each factor is detailed in the following sub-sections.



6.5.1 Receptor Ranking

Receptors are generally nearby structures or features that may be affected by peat movements caused during or following construction. Generally, only receptors immediately down gradient of the infrastructure feature could be affected by peat instability therefore the first phase of feature ranking requires topographic ridges and valleys to be identified across the Proposed Development and surrounding area. From this, receptors at risk from particular infrastructure features can be identified. However, should instability occur on a steep slope, there is the risk of the back scarp of the instability migrating up-slope, there-by affecting areas previously considered not to be at risk.

The main receptors located within the Proposed Development and surrounding area which could potentially be affected in the event of a peat slide; were primarily watercourses and associated tributaries, existing tracks, paths and the proposed infrastructure.

Following identification of receptors at risk, these are ranked according to their size and sensitivity. Table F presents the coefficients placed on particular receptor types.

Table F: Coefficients for Receptor Ranking

Nature of Feature	Feature Coefficient
Non-critical infrastructure (minor/private roads, tracks)	1
Watercourses and critical infrastructure (pipelines, motorways, dwellings and business properties etc.)	3
Sub-Community (settlement 1-10 residents)	6
Community (settlement of >10 residents)	8

6.5.2 Receptor Proximity

The proximity of an impact receptor is also critical in assessing the likely level of disruption it may suffer following an instability event. Based on this, two further coefficients – distance from infrastructure feature and relative elevation differences between the infrastructure feature and impact receptor - are applied in deriving an impact ranking. Table G and Table H present the coefficients derived for distance and elevation of impact receptors.

Table G: Coefficient for Receptor Proximity

Distance from Coefficient Feature	Distance Coefficient
> 1 km	1
100 m – <1 km	2
10 – <100 m	3
0 – <10 m	4

Table H: Coefficient for Impact Feature Elevation

Relative Elevation of Feature	Elevation Coefficient
0 – <10 m	1
10 – <50 m	2
50 – <100 m	3



Relative Elevation of Feature	Elevation Coefficient
> 100 m	4

Based on distance to impact receptors, in this instance we have identified watercourses (which are the most sensitive receptor near the Proposed Development). The other receptors have been discounted, either they are not present or distance to receptor mitigates risk. Watercourses are the principal receptor as they are at risk of not only direct impact from a peat slide but potentially the water course creates a pathway to impact other receptors indirectly, either ecological or potential water users downstream. Based on Table J the watercourses would have an impact receptor coefficient (score) of 3 and then considering the distance to the receptor and the relative elevation differences on-site of receptors, a potential impact can be derived.

6.6 Hazard Ranking

In order to achieve a meaningful and manageable result from the hazard ranking, the results of the risk rating and impact rating have been normalised to a standard numerical scale (below).

Table I: Rating Normalisation

Risk Rating		Impact Rating	
Current Scale	Normalised Scale	Current Scale	Normalised Scale
Negligible <5	1	Very Low <10	1
Low 5 - <15	2	Low 11 - 20	2
Medium 15 - 30	3	High 21 - 30	3
High 31 - 50	4	Very High 31-50	4
Very High >51	5	Extremely High >51	5

The method of assessing risk rating and impact rating by SLR Consulting incorporates additional critical elements such as the substrate interface and coefficients for the receptor position, distance and elevation and as such is considered to be more rigorous than the assessment scheme proposed by the Scottish Government¹. The Hazard Ranking scale does equate to the Scottish Government¹ scale, with rankings divided over four zones.

A simple multiplication of these coefficients would result in potentially large and unwieldy risk and impact rating numbers. SLR has therefore opted to normalise these values to bring them in line with the values used in the Scottish Government Guidance¹, as illustrated in Table J.

Table J: Hazard Ranking

Hazard Ranking	Hazard Ranking Zone	Action
1-4	Insignificant	No mitigation action required although slide management and monitoring shall be employed. Slide management shall include the development of a site specific construction plan for peat areas.
5 - 10	Significant	As for Insignificant condition plus further investigation to refine the assessment combined with detailed quantitative risk assessment to determine appropriate mitigation through relocation or re-design.



Hazard Ranking	Hazard Ranking Zone	Action
11 - 16	Substantial	Consideration of avoiding project development in these areas should be made unless hazard mitigation can be put in place without significant environmental effect.
17-25	Serious	Unacceptable level of hazard; development within the area should be avoided.

The stability risk assessment has demonstrated that the majority of the Proposed Development lies within an area of negligible to low risk (81% of probe locations) with regards to stability based on Figure 9.

19% of probe locations identified a medium or high risk of peat instability across the Proposed Development. Following review, the majority of these locations are not considered to have an impact above very low or low on the development infrastructure, due to locality, either well away from influencing infrastructure, in a down gradient position or have no impact on the local watercourses (receptors). Therefore 33 medium risk sites have been identified and are discussed in the following section.

The stability risk assessment results presented in Table K shows the calculated hazard ranking associated with every location where there is a stability risk of medium or above, at or close to infrastructure. The particular mitigation measures to reduce the risk of instability occurring are dependent upon location and the type of proposed structure. Proposed mitigation measures and actions already undertaken to reduce the risk of peat instability occurring are also identified in Table K, together with the associated, revised hazard ranking. A more detailed discussion of the possible mitigation measures is presented in Section 6.0.



7.0 Risk Mitigation

7.1 Overview

A number of mitigation measure can be implemented to further reduce the risk levels identified across the Proposed Development site. These range from infrastructure specific measures to general good practice that should be applied across the site to increase awareness of peat instability and enable early identification of potential displacement and opportunities for mitigation.

Risks may be mitigated by:

- Undertaking site specific stability analysis using detailed geotechnical data, final design loads for infrastructure and detailed ground models in areas of specific concern.
- Precautionary construction measures – including use of monitoring, good practice and a geotechnical risk register relevant to all locations.

Mitigation measures are provided below specific to each area of “Medium” risk. These mitigation measures will also help further reduce “Low” and “Negligible” risks to potential receptors. Sections 7.3 to 7.4 provide information on good practice pre-construction, during construction and post-construction (i.e. during operation).

7.2 Proposed Mitigation

As noted in Figure 9, where the risk assessment has identified a negligible or low risk of peat instability, no specific mitigation measures are necessary. However, in order to ensure best practise is employed, there would be a need for careful monitoring and the construction management must include careful design of both the permanent and temporary works appropriate for peat soils; these are discussed further in Section 7.3 to 7.4.

The areas of the infrastructure that were rated as medium or high risk, or above, were subjected to a hazard assessment; a number of areas were discounted as they do not fall within influencing distance of any of the key proposed site infrastructure. The procedure adopted was to review the peat slide risk data and identify those areas with a medium risk or greater, that were in close proximity or influencing distance of any of the proposed infrastructure or watercourses. Those risk areas where there is no development would not affect the natural stability of the peat.

Table O lists the 33 locations that have been identified to have either a “Medium” or “High” risk of peat instability on the Proposed Development infrastructure. A variety of mitigation measures are recommended to reduce the risk of peat instability. Analysis of each location has shown that all can be mitigated to a Hazard Ranking of “Insignificant”.



Table K: Stability Hazard Ranking Assessment

Location	Key Receptor	Risk Rating	Impact Rating	Hazard Ranking	Mitigation	Revised Hazard Ranking
1	Unnamed Watercourse	Medium	Low	Significant	Turbine 11 and hardstanding. Good construction practices to mitigate against peat landslide to the northwest. Excavation of peat prior to construction would reduce risk.	Insignificant
2	Burn Dennet River	Medium	Low	Significant	Access track from T11 to T10. Good construction practices to mitigate against peat landslide to the north. Excavation of peat prior to construction would reduce risk.	Insignificant
3	Burn Dennet River	Medium	Low	Significant	Access track from T11 to T10. Good construction practices to mitigate against peat landslide to the north. Excavation of peat prior to construction would reduce risk.	Insignificant
4	Unnamed Watercourse	Medium	Low	Significant	Access track junction leading to T10. Good construction practices to mitigate against peat landslide to the northwest. Excavation of peat prior to construction would reduce risk.	Insignificant
5	Burn Dennet River	Medium	Low	Significant	Turbine 5 and hardstanding. Good construction practices to mitigate against peat landslide to the north. Excavation of peat prior to construction would reduce risk.	Insignificant
6	Unnamed Watercourse	Medium	Very Low	Insignificant	Access track junction leading to T10. Good construction practices to mitigate against peat landslide to the northwest. No additional measures required.	Insignificant
7	Unnamed Watercourse	Medium	Low	Significant	Access track junction leading to T10. Good construction practices to mitigate against peat landslide to the northeast. Excavation of peat prior to construction would reduce risk.	Insignificant
8	Unnamed Watercourse	Medium	Low	Significant	T09 and hardstanding. Good construction practices to mitigate against peat landslide to the northeast. Excavation of peat prior to construction would reduce risk.	Insignificant
9	Unnamed Watercourse	Medium	Low	Significant	Access track junction leading to T09. Good construction practices to mitigate against peat landslide to the northeast. Excavation of peat prior to construction would reduce risk.	Insignificant



Location	Key Receptor	Risk Rating	Impact Rating	Hazard Ranking	Mitigation	Revised Hazard Ranking
10	Unnamed Watercourse	Medium	Low	Significant	Access track junction leading to T09. Good construction practices to mitigate against peat landslide to the northeast. Excavation of peat prior to construction would reduce risk.	Insignificant
11	Unnamed Watercourse	Medium	Low	Significant	Access track junction leading to T09. Good construction practices to mitigate against peat landslide to the east. Excavation of peat prior to construction would reduce risk.	Insignificant
12	Unnamed Watercourse	Medium	Low	Significant	Access track junction leading to T10. Good construction practices to mitigate against peat landslide to the east. Excavation of peat prior to construction would reduce risk.	Insignificant
13	Unnamed Watercourse	Medium	Low	Significant	Turbine 08 and hardstanding. Good construction practices to mitigate against peat landslide to the east. Excavation of peat prior to construction would reduce risk. Micro-siting and benching slope could further reduce risk.	Insignificant
14	Unnamed Watercourse	Medium	Low	Significant	Access track to T08 and Peat Storage Area. Good construction practices to mitigate against peat landslide to the east. Excavation of peat prior to construction would reduce risk. Micro-siting and benching slope could further reduce risk.	Insignificant
15	Unnamed Watercourse	Medium	Low	Significant	Access track junction leading to T05/T07. Good construction practices to mitigate against peat landslide to the east. Excavation of peat prior to construction would reduce risk. Micro-siting and benching slope could further reduce risk.	Insignificant
16	Unnamed Watercourse	Medium	Very Low	Insignificant	Access track junction leading to T05. Good construction practices to mitigate against peat landslide to the east. No additional measures required.	Insignificant
17	Unnamed Watercourse	Medium	Low	Significant	Turbine 07 hardstanding. Good construction practices to mitigate against peat landslide to the east. Excavation of peat prior to construction would reduce risk. Micro-siting and benching slope could further reduce risk.	Insignificant
18	Unnamed Watercourse	Medium	Low	Significant	Turbine 07 and hardstanding. Good construction practices to mitigate against peat landslide to the east. Excavation of peat prior to construction would reduce risk. Micro-siting and benching slope could further reduce risk.	Insignificant



Location	Key Receptor	Risk Rating	Impact Rating	Hazard Ranking	Mitigation	Revised Hazard Ranking
19	Sub-Community	Medium	High	Significant	Turbine 05 and hardstanding. Good construction practices to mitigate against peat landslide to the northwest. Excavation of peat prior to construction would reduce risk.	Insignificant
20	Sub-Community	Medium	High	Significant	Turbine 05 hardstanding. Good construction practices to mitigate against peat landslide to the northwest. Excavation of peat prior to construction would reduce risk.	Insignificant
21	Sub-Community	Medium	High	Significant	Access track leading to T04 and T06. Good construction practices to mitigate against peat landslide to the northwest. Excavation of peat prior to construction would reduce risk.	Insignificant
22	Sub-Community	Medium	High	Significant	Turbine 06 and hardstanding. Good construction practices to mitigate against peat landslide to the northwest. Excavation of peat prior to construction would reduce risk.	Insignificant
23	Stroanback Burn	Medium	Low	Significant	Turbine 04 and hardstanding. Good construction practices to mitigate against peat landslide to the northwest. Excavation of peat prior to construction would reduce risk.	Insignificant
24	Sub-Community	Medium	Very High	Substantial	Access track west of T07. Good construction practices to mitigate against peat landslide to the north. Excavation of peat prior to construction would reduce risk. Micro-siting and benching slope could further reduce risk.	Insignificant
25	Sub-Community	Medium	Very High	Substantial	Turbine 07 and hardstanding. Good construction practices to mitigate against peat landslide to the northwest. Excavation of peat prior to construction would reduce risk.	Insignificant
26	Sub-Community	Medium	Very High	Substantial	Access track leading to T07 and T08. Good construction practices to mitigate against peat landslide to the northwest. Excavation of peat prior to construction would reduce risk.	Insignificant
27	Stroanback Burn	Medium	Low	Significant	Access track leading to T07. Good construction practices to mitigate against peat landslide to the northwest. Excavation of peat prior to construction would reduce risk.	Insignificant



Location	Key Receptor	Risk Rating	Impact Rating	Hazard Ranking	Mitigation	Revised Hazard Ranking
28	Stroanback Burn	Medium	Low	Significant	Turbine T03 hardstanding. Good construction practices to mitigate against peat landslide to the northwest. Excavation of peat prior to construction would reduce risk.	Insignificant
29	Stroanback Burn	Medium	Low	Significant	Turbine T02 hardstanding. Good construction practices to mitigate against peat landslide to the northeast. Excavation of peat prior to construction would reduce risk.	Insignificant
30	Stroanback Burn	Medium	Low	Significant	Turbine T02 hardstanding. Good construction practices to mitigate against peat landslide to the northeast. Excavation of peat prior to construction would reduce risk. Micro-siting and benching slope could further reduce risk.	Insignificant
31	Stroanback Burn	Medium	Low	Significant	Access track leading to Turbine T02. Good construction practices to mitigate against peat landslide to the northeast. Excavation of peat prior to construction would reduce risk. Micro-siting and benching slope could further reduce risk.	Insignificant
32	Stroanback Burn	Medium	Very Low	Insignificant	Access track leading to T2. Good construction practices to mitigate against peat landslide to the north. No additional measures required.	Insignificant
33	Stroanback Burn	Medium	High	Significant	Enabling works compound. Good construction practices to mitigate against peat landslide to the northeast. Excavation of peat prior to construction would reduce risk. Micro-siting and benching slope could further reduce risk.	Insignificant



7.3 Good Practice During Construction

The paragraphs below detail good practice that is recommended during construction. These measures are considered 'embedded mitigation' for the purposes of the assessment, and have been assumed to be in place for the purposes of the assessment presented in the EIA Report:

For excavated groundworks:

- Use of appropriate supporting structures around peat excavations to prevent collapse and the development of tension cracks.
- Avoid cutting trenches or aligning excavations across slopes (which may act as incipient head scarps for peat failures) unless appropriate mitigation has been put in place.
- Implement methods of working that minimise the cutting of the toes of slopes, e.g. working up-to downslope during excavation works.
- Monitor the ground upslope of excavation works for creep, heave, displacement, tension cracks, subsidence or changes in surface water content.
- Monitor cut faces for changes in water discharge, particularly at the peat-substrate contact.
- Minimise the effects of construction on natural drainage by ensures natural drainage pathways are maintained or diverted such that there is no significant alteration of the hydrological regime of the site; drainage plans should avoid creating drainage/infiltration areas or settlement ponds towards the tops of slopes (where they may act to both load the slope and elevate pore pressures).

For cut tracks:

- Maintain drainage pathways through tracks to avoid ponding of water upslope.
- Monitor the top line of excavated peat deposits for deformation post-excavation.
- Monitor the effectiveness of cross-track drainage to ensure it water remains free-flowing and that no blockages have occurred.

For floating tracks:

- Prior to the construction, setting out the centre-line of the proposed track should include a walk over performed by the site manager or general foreman, along with the suitably qualified Geotechnical Engineer, and appropriate Clerk of Works. This should be carried out to check that the ground conditions/drainage paths are as expected, and "fine-tuning/micrositing" of the alignment if required.
- Weather policy should be agreed and implemented during works, e.g. identifying 'stop' rules (i.e. weather dependent criteria) for cessation of track construction or trafficking (e.g. allowing tracks to thaw following periods of hard frost).
- Allow peat to undergo primary consolidation by adopting rates of road construction appropriate to weather conditions.

For storage of peat:

- Ensure stored peat is not located in areas identified with 'Medium' or higher peat landslide likelihoods.
- Undertake site specific stability analysis for all areas of peat storage to ensure the likelihood of destabilisation of underlying peat is minimised. Analysis should consider the slope angle of the storage location, the thickness of peat being stored and being loaded and use representative parameters for both the stored and underlying peat.



- Avoid storage of peat in areas of peat >1.5m in depth.
- Minimise haul distances for peat, storing as near to excavation as possible.
- Monitor effects of wetting / re-wetting stored peat on surrounding peat areas, and prevent water build up on the upslope side of peat mounds. Mitigate any run-off.

In addition to these control measures, the following good practice should be followed:

- A geotechnical risk register (GRR) should be prepared for the site following intrusive investigations post-consent and location specific stability analyses – the risk register should be considered a live document and updated with site experience as infrastructure is constructed.
- All construction activities and operational decisions that involve disturbance to peat deposits should be overseen by an appropriately qualified geotechnical engineer with experience of construction on peat sites.
- Awareness of peat instability and pre-failure indicators should be incorporated in site induction and training to enable all site personnel to recognise ground disturbances and features indicative of incipient instability.
- Monitoring checklists should be prepared with respect to peat instability addressing all construction activities proposed for site.

7.4 Good Practice During Operation

Following cessation of construction activities, the following activities will be built into any monitoring of groundworks undertaken for the development:

- Ponding on the upslope side of infrastructure sites and on the upslope side of access tracks.
- Subsidence and lateral displacement of tracks.
- Blockage or underperformance of the installed site drainage system.
- Slippage or creep of stored peat deposits.
- Development of tension cracks, compression features, bulging or quaking bog anywhere in a 50 m corridor surrounding the site of any construction activities or site works.

This monitoring should be undertaken on a quarterly basis in the first year after construction, biannually in the second year after construction and annually thereafter; in the event that unanticipated ground conditions arise during construction, the frequency of these intervals should be reviewed, revised and justified accordingly.



8.0 Conclusion

The report has highlighted the complicated inter-relationship between all the aspects that have an effect on the stability of peat. Consequently, the discussion has also addressed areas of construction and drainage in order to avoid a stability problem rather than attempt to put it right after the event. The Proposed Development has been assessed for potential hazards associated with peat instability; the assessment has been based on:

- a walk-over survey by an experienced geologist;
- a thorough inspection of the digital terrain map;
- review of historical and geological maps and publications and aerial photography; and
- a detailed geotechnical probing exercise at 2,232 locations in areas of identified peaty soil/peat to determine the thickness thereof.

Peat probing fieldworks have indicated that 31% of peat probe locations encountered >0.5m of peat. 49% of probe locations identified peat between 0.5 to 1.5m, and the remaining 20% of probe locations encountered peat depths >1.5m. Peat coring undertaken at selected locations has indicated the peat within the Proposed Development is predominantly fibrous to pseudo fibrous. There are some localised deposits of shallow peat that generally comprise clayey layers, whilst areas of thicker peat are predominantly fibrous layers.

The PLHRA method has been developed by SLR and described within this report. The results indicate that 19% of probe locations are at either a medium or high risk of peat instability. The overall conclusion regarding peat stability is that there are 33 areas of medium risk of peat instability across the Proposed Development. For the medium risk areas, a hazard impact assessment was completed which concluded that, subject to micro-siting and the employment of appropriate mitigation measures, all the areas can be considered as an insignificant risk.

This Technical Appendix should be considered as the first stage in the development of a fundamental understanding of the various inter-relationships that govern and control the peat lands at the proposed development.

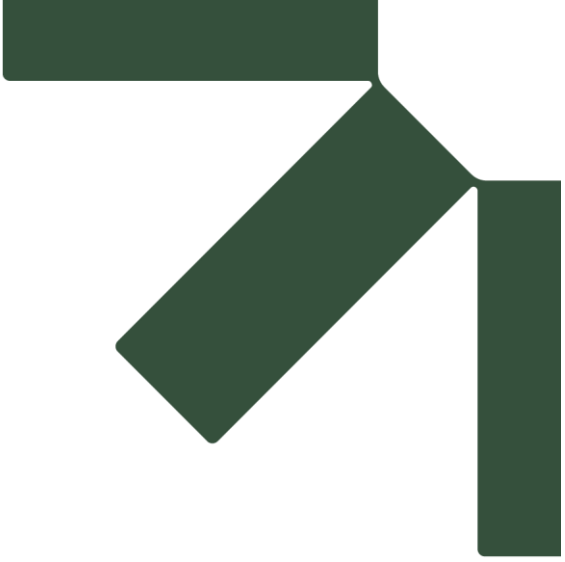
The commissioned assessment has purposefully kept the extent of physical intrusion into the sensitive peat areas to an absolute minimum. The results are considered appropriate for the planning application.

More detailed ground investigations will be required to facilitate the geotechnical design of the various foundations and access track, particularly the vertical and horizontal alignment and the design of the river/stream crossings. These will be incorporated into the Construction Method Statement which will be submitted to the Planning Authority for approval as part of the condition compliance prior to any site works commencing.

It is not the purpose of this report to provide a detailed scope for the investigation; however, it is believed that the strength and stiffness parameters are needed for turbine design and regular probes along access tracks to determine bearing capacity for either excavated or floated track design.

-





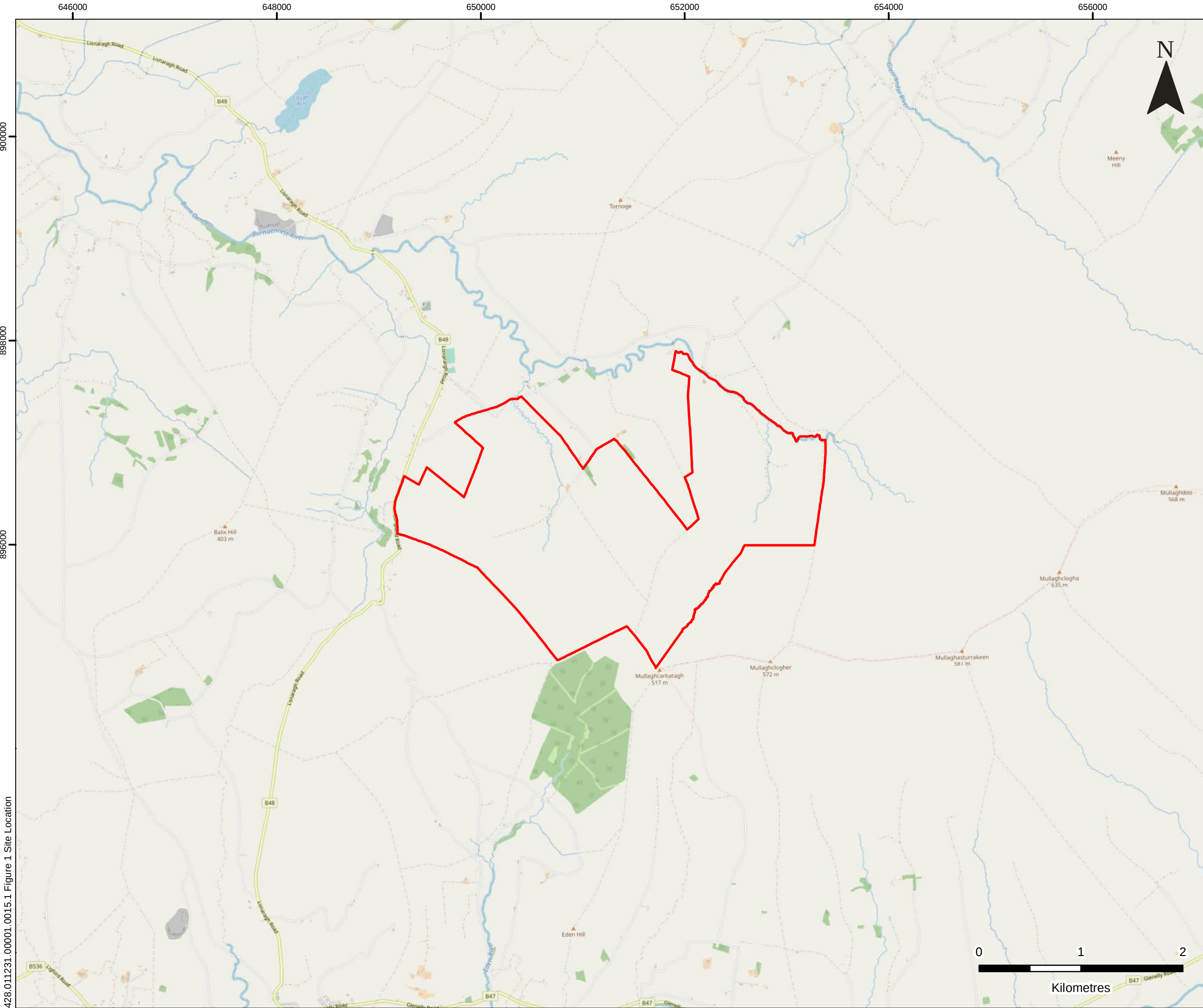
Figures

Mullaghclogher Wind Farm

Renewable Energy Systems Ltd

SLR Project No.: 428.011231.00001

9 April 2024



LEGEND

Site Boundary



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PLHRA MULLAGHCLOGHER

PLHRA

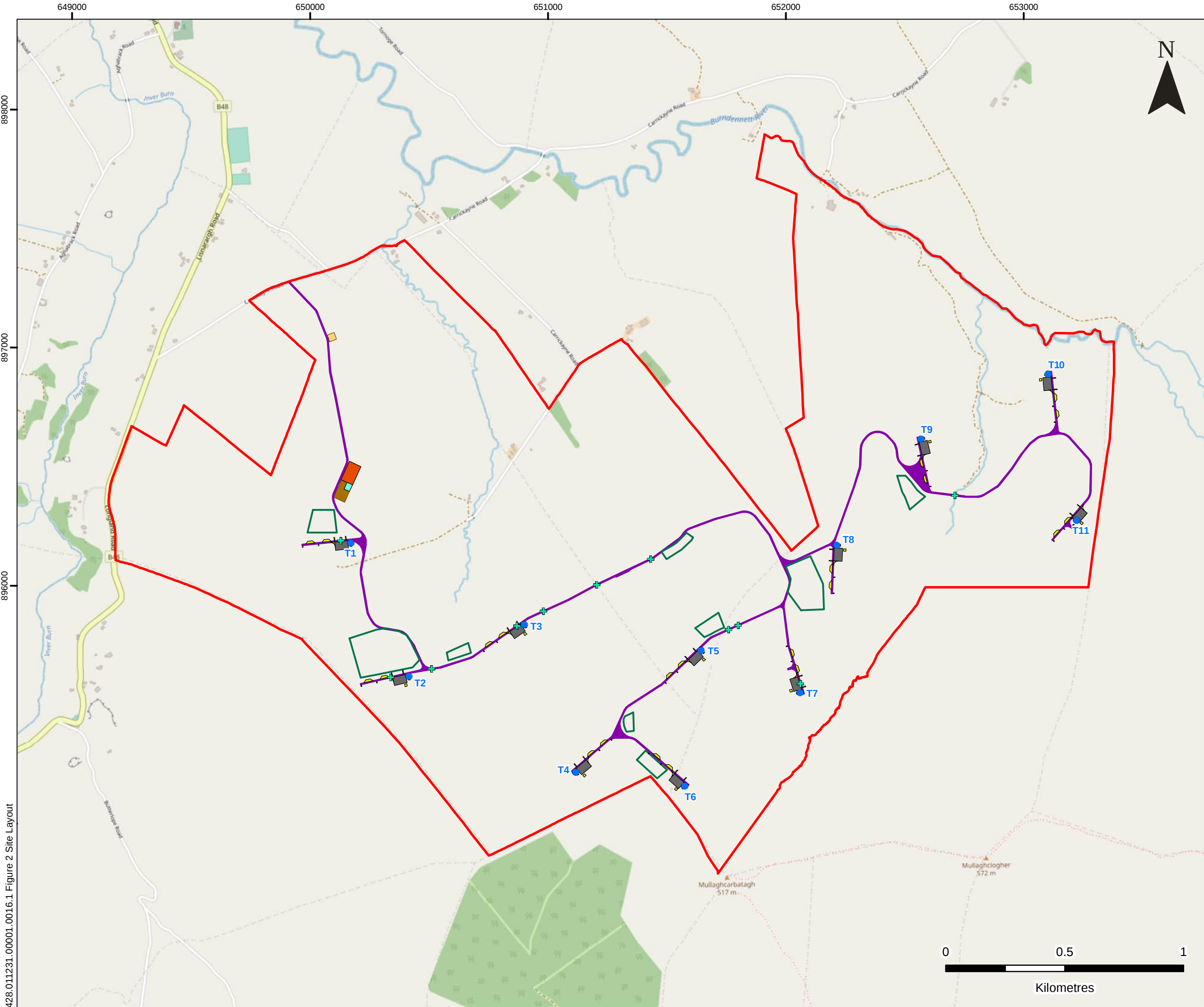
SITE LOCATION

FIGURE 1

Scale 1:35,000 @ A3

Date OCTOBER 2023

428.011231.00001.0015.1 Figure 1 Site Location



LEGEND

Site Boundary

Proposed Turbine Location

New Site Track

Permanent Hardstanding

Temporary Hardstanding

Substation Compound

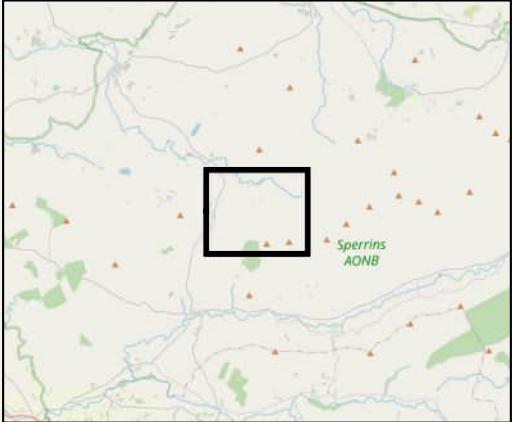
Temporary Construction Compound

Battery Storage Compound

Temporary Enabling Works Compound

Peat Storage Area

Water Crossing Location



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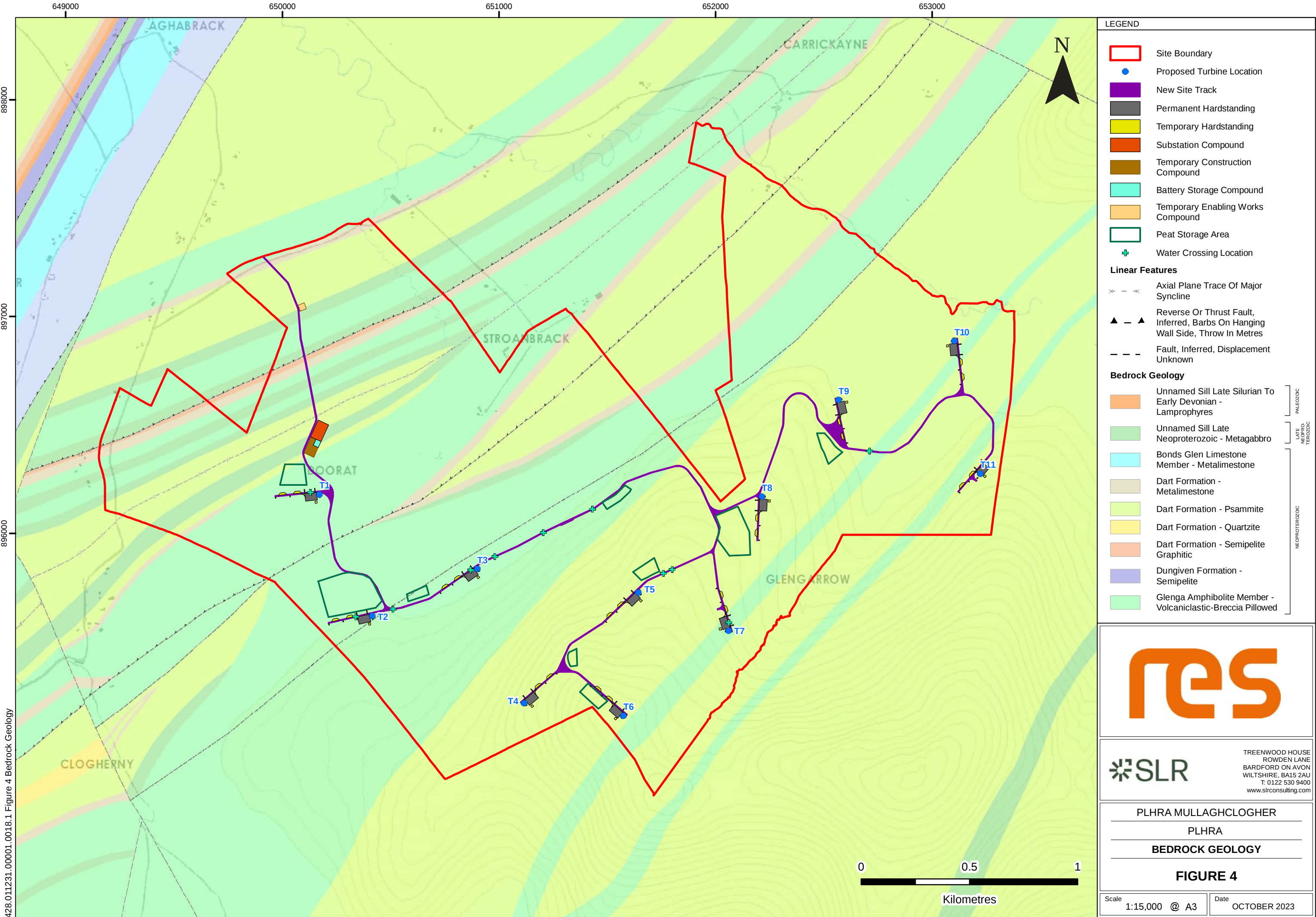
SITE LAYOUT

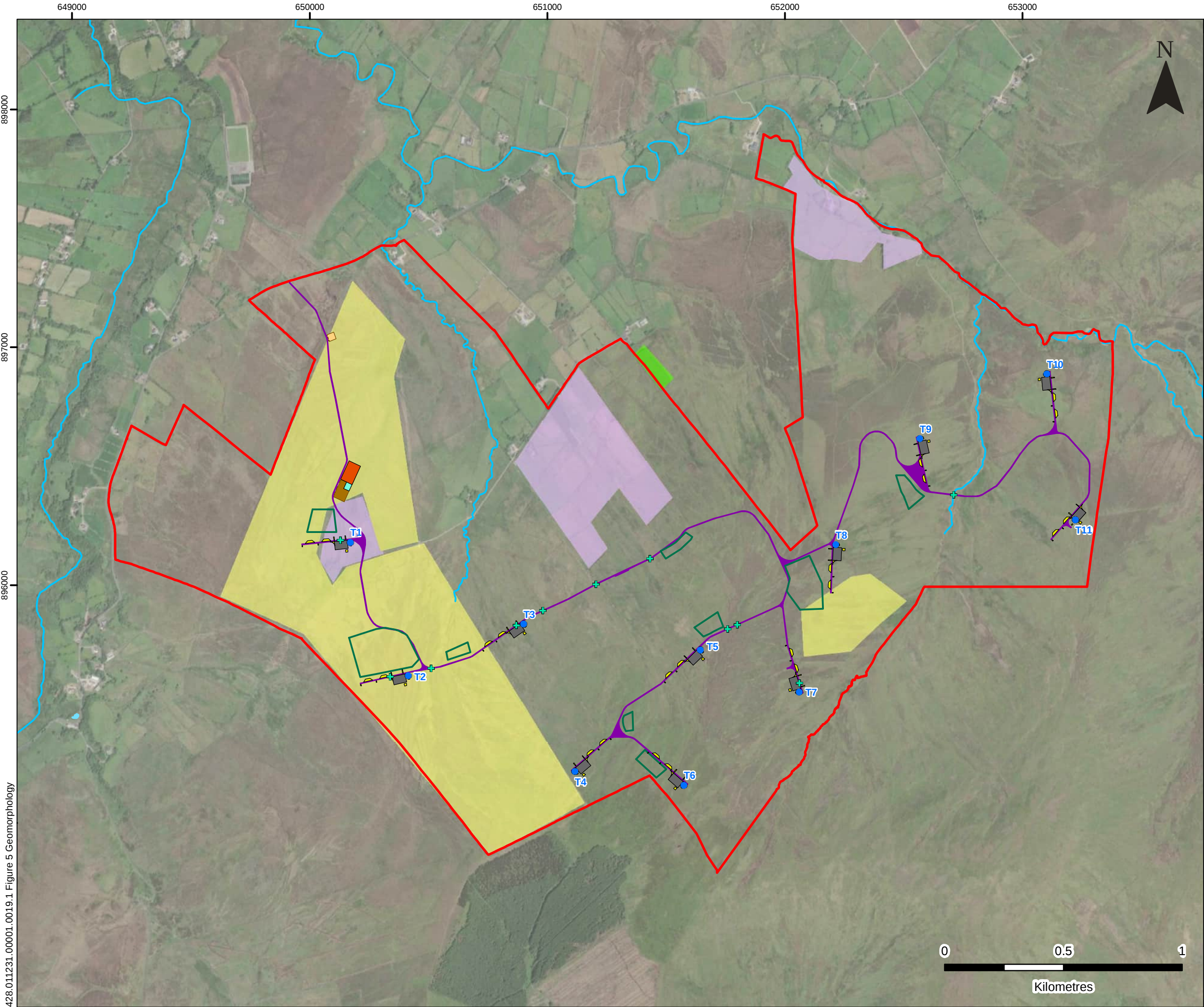
FIGURE 2

Scale1:15,000 @ A3

DateOCTOBER 2023

428.011231.00001.0016.1 Figure 2 Site Layout



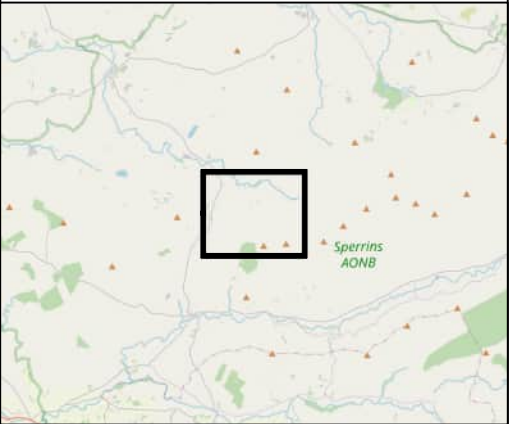


LEGEND

Site Boundary

Proposed Turbine Location

Geomorphology



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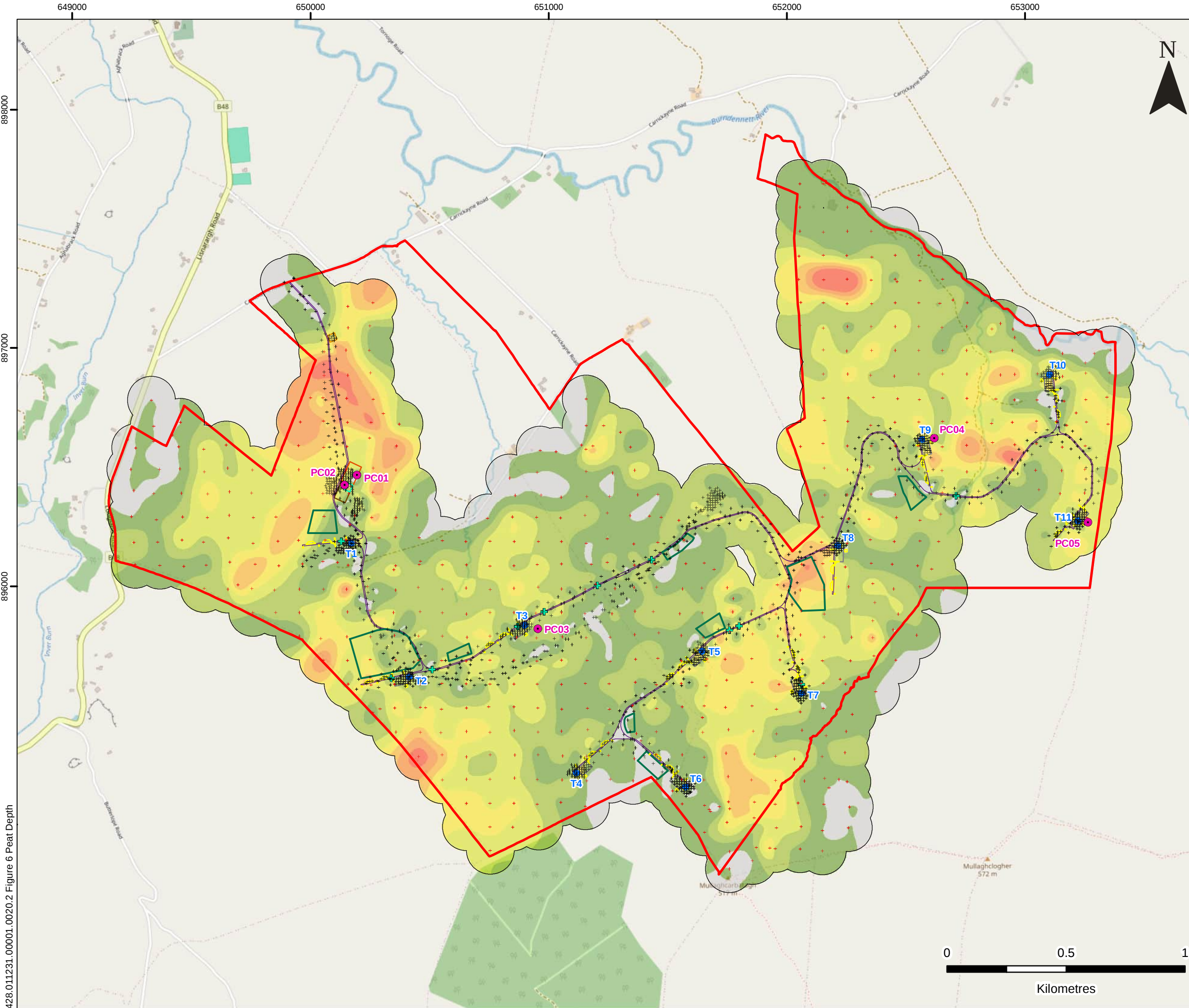
GEOMORPHOLOGY

FIGURE 5

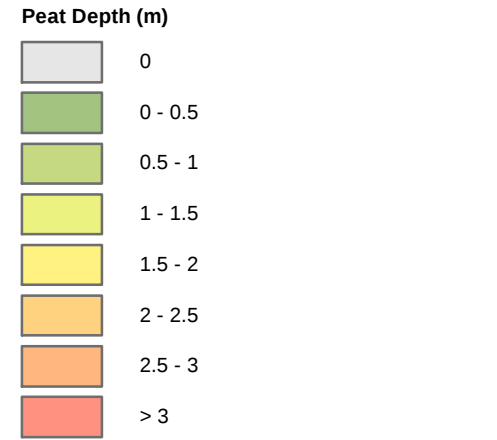
Scale 1:15,000 @ A3

Date OCTOBER 2023

428.011231.00001.0019.1 Figure 5 Geomorphology



- LEGEND
- Site Boundary
 - Proposed Turbine Location
 - New Site Track
 - Permanent Hardstanding
 - Temporary Hardstanding
 - Substation Compound
 - Temporary Construction Compound
 - Battery Storage Compound
 - Temporary Enabling Works Compound
 - Peat Storage Area
 - Water Crossing Location
 - Peat Core Location
 - Phase I Peat Probing Location
 - Phase II Peat Probing Location



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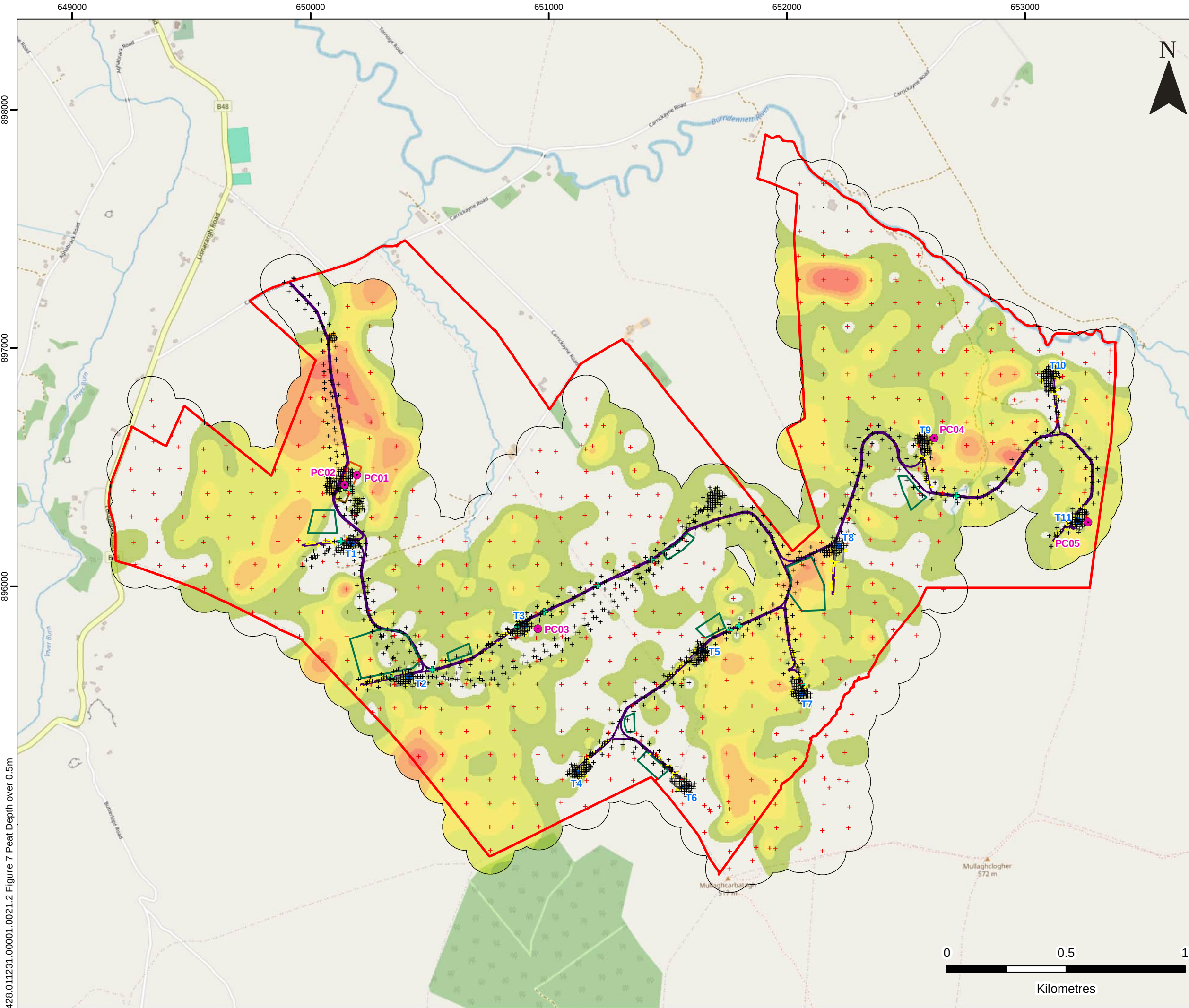
PEAT DEPTH

FIGURE 6

Scale 1:15,000 @ A3

Date DECEMBER 2023

428.011231.00001.0020.2 Figure 6 Peat Depth



LEGEND

- Site Boundary
- Proposed Turbine Location
- New Site Track
- Permanent Hardstanding
- Temporary Hardstanding
- Substation Compound
- Temporary Construction Compound
- Battery Storage Compound
- Temporary Enabling Works Compound
- Peat Storage Area
- Water Crossing Location
- Peat Core Location
- Phase I Peat Probing Location
- Phase II Peat Probing Location

Peat Depth (m)

0.5 - 1
1 - 1.5
1.5 - 2
2 - 2.5
2.5 - 3
> 3

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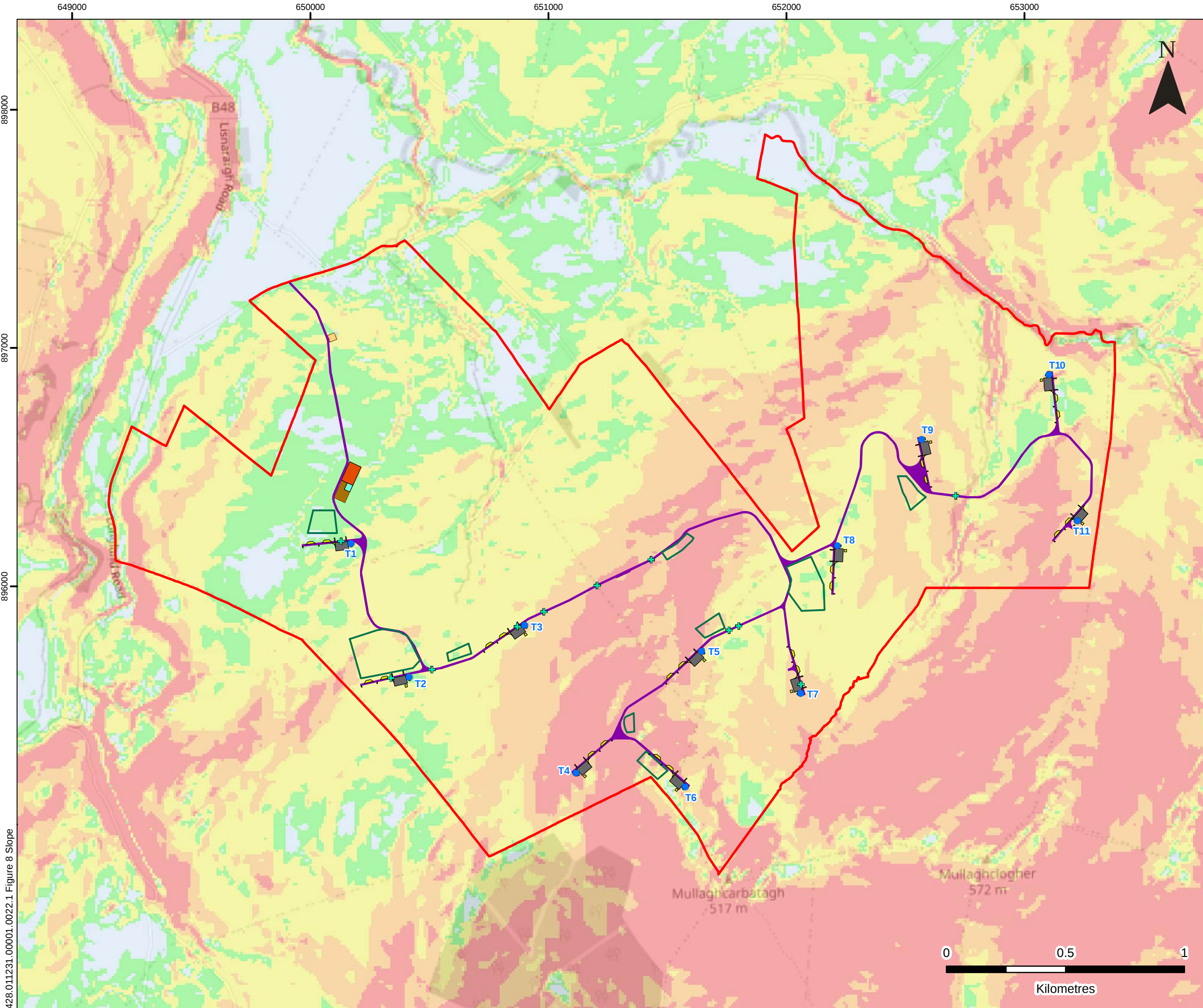
PLHRA

PEAT DEPTH > 0.5M

FIGURE 7

Scale 1:15,000 @ A3

Date DECEMBER 2023

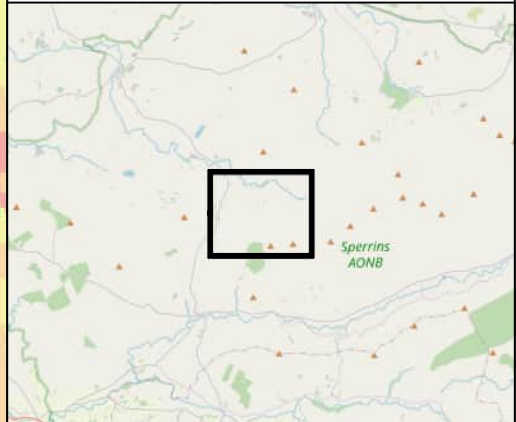


LEGEND

- Site Boundary
- Proposed Turbine Location
- New Site Track
- Permanent Hardstanding
- Temporary Hardstanding
- Substation Compound
- Temporary Construction Compound
- Battery Storage Compound
- Temporary Enabling Works Compound
- Peat Storage Area
- Water Crossing Location

Slope (Degrees OSNI 10m DTM)

- 0 - 2
- 2 - 4
- 4 - 8
- 8 - 12
- > 12



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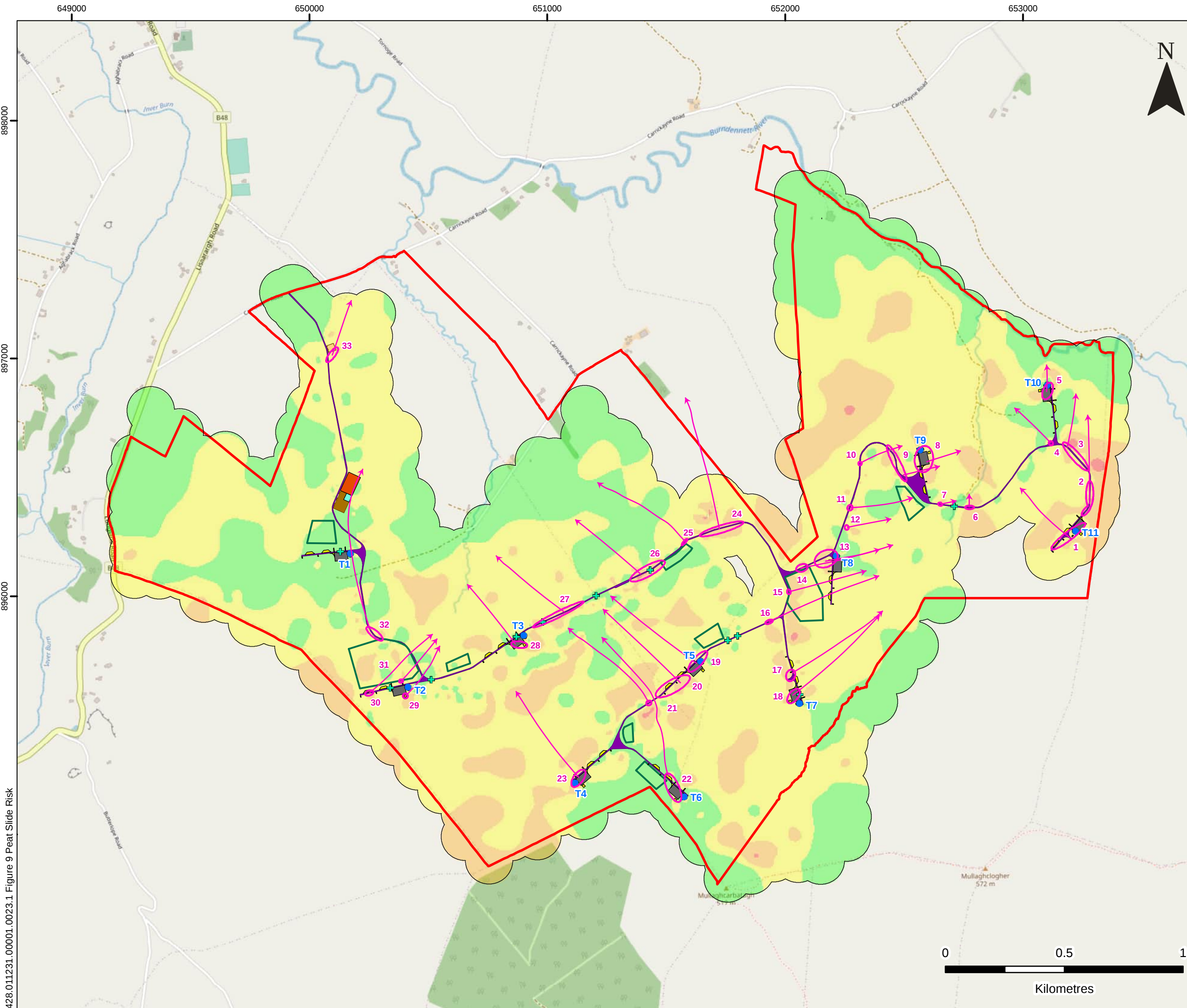
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SLOPE

FIGURE 8

Scale 1:15,000 @ A3 Date OCTOBER 2023

428.011231.00001.0022.1 Figure 8 Slope

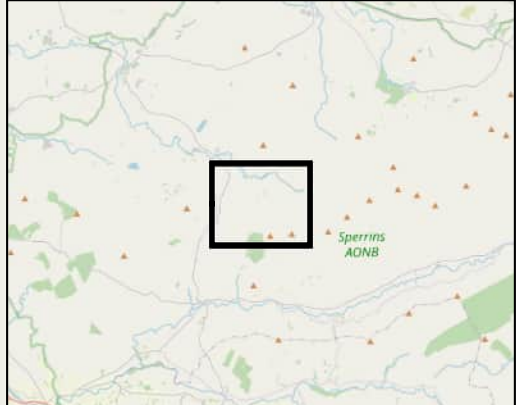


LEGEND

- Site Boundary
- Proposed Turbine Location
- New Site Track
- Permanent Hardstanding
- Temporary Hardstanding
- Substation Compound
- Temporary Construction Compound
- Battery Storage Compound
- Temporary Enabling Works Compound
- Peat Storage Area
- Water Crossing Location
- Identified Risk Location
- Identified Risk Location - Distance to Nearest Watercourse

Peat Slide Risk

- High
- Medium
- Low
- Negligible



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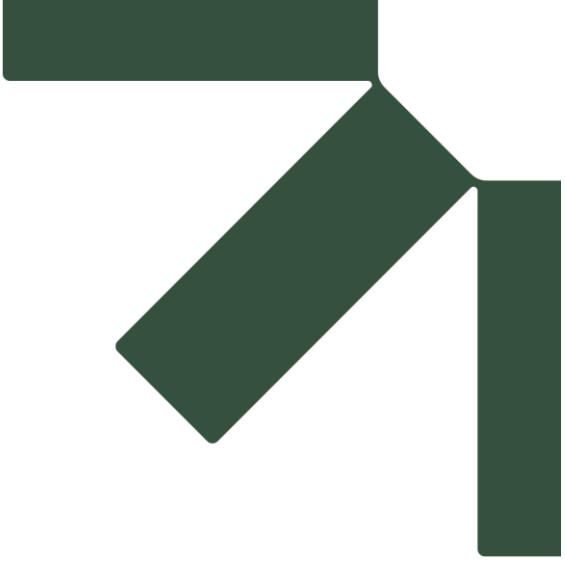
PEAT SLIDE RISK

FIGURE 9

Scale 1:15,000 @ A3

Date OCTOBER 2023

428.011231.00001.0023.1 Figure 9 Peat Slide Risk



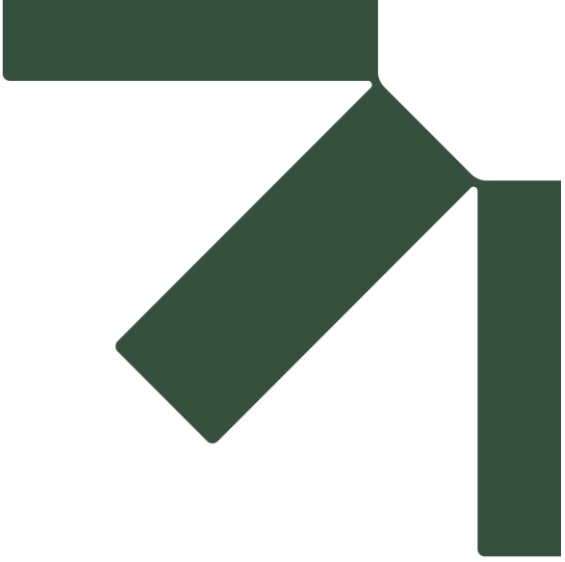
Annex A Peat Risk Data

Mullaghclogher Wind Farm

Renewable Energy Systems Ltd

SLR Project No.: 428.011231.00001

ID	SOURCE	X	Y	Depth	Surface	Substrate	Slope	Peat Coefficient	Peat Coefficient	Slope Coefficient	Substrate Coefficient	Risk Coefficient	Potential Instability
2186	Point	651654	894969	0.4	Peat	Granular	5.99	Peaty Soil	1	4	1	4	Negligible
2187	Point	651674	895065	0.0	Superficial	Granular	8.71	No Peat	0	6	1	0	None
2188	Point	651654	895081	0.2	Peat	Granular	11.10	Peaty Soil	1	6	1	6	Low
2189	Point	651560	895088	0.3	Peat	Granular	5.18	Peaty Soil	1	4	1	4	Negligible
2190	Point	651519	895142	0.0	Rock	Granular	2.65	No Peat	0	2	1	0	None
2191	Point	651558	895190	0.4	Peat	Granular	13.29	Peaty Soil	1	8	1	8	Low
2192	Point	651652	895188	0.4	Peat	Granular	8.13	Peaty Soil	1	6	1	6	Low
2193	Point	651653	895284	0.2	Peat	Granular	12.13	Peaty Soil	1	8	1	8	Low
2194	Point	651560	895293	0.3	Peat	Granular	13.93	Peaty Soil	1	8	1	8	Low
2195	Point	651452	895190	0.0	Superficial	Granular	6.12	No Peat	0	4	1	0	None
2196	Point	651452	895295	0.2	Peat	Granular	5.22	Peaty Soil	1	4	1	4	Negligible
2197	Point	651360	895277	0.0	Superficial	Granular	19.74	No Peat	0	8	1	0	None
2198	Point	651354	895185	0.0	Superficial	Granular	12.17	No Peat	0	8	1	0	None
2199	Point	651154	895078	0.0	Superficial	Granular	13.30	No Peat	0	8	1	0	None
2200	Point	651259	895191	0.0	Superficial	Granular	19.65	No Peat	0	8	1	0	None
2201	Point	651252	895291	0.3	Peat	Granular	17.86	Peaty Soil	1	8	1	8	Low
2202	Point	651160	895185	0.0	Superficial	Granular	7.45	No Peat	0	4	1	0	None
2203	Point	651159	895287	0.7	Peat	Granular	22.62	Thin Peat	2	8	1	16	Medium
2204	Point	651864	895296	1.0	Peat	Granular	9.31	Thin Peat	2	6	1	12	Low
2205	Point	651851	895188	2.2	Peat	Granular	5.64	Thick Peat	3	4	1	12	Low
2206	Point	651864	895096	1.8	Peat	Granular	1.80	Thick Peat	3	1	1	3	Negligible
2207	Point	651863	895030	1.7	Peat	Rock	2.63	Thick Peat	3	2	2	12	Low
2208	Point	651864	895000	0.7	Peat	Granular	4.43	Thin Peat	2	4	1	8	Low
2209	Point	651872	894905	0.7	Peat	Rock	18.53	Thin Peat	2	8	2	32	High
2210	Point	651855	894849	0.0	Rock	Granular	19.18	No Peat	0	8	1	0	None
2211	Point	651929	894903	2.0	Peat	Granular	12.69	Thick Peat	3	8	1	24	Medium
2212	Point	651952	894900	0.9	Peat	Granular	17.05	Thin Peat	2	8	1	16	Medium
2213	Point	652055	894898	0.4	Peat	Granular	9.03	Peaty Soil	1	6	1	6	Low
2214	Point	652149	894890	0.2	Peat	Granular	7.61	Peaty Soil	1	4	1	4	Negligible
2215	Point	652258	894987	0.0	Superficial	Granular	7.70	No Peat	0	4	1	0	None
2216	Point	652150	894976	0.0	Superficial	Granular	15.75	No Peat	0	8	1	0	None
2217	Point	652060	894992	1.0	Peat	Granular	12.15	Thin Peat	2	8	1	16	Medium
2218	Point	651956	894988	1.3	Peat	Granular	8.39	Thin Peat	2	6	1	12	Low
2219	Point	651951	895087	1.9	Peat	Granular	4.56	Thick Peat	3	4	1	12	Low
2220	Point	652047	895092	0.9	Peat	Granular	10.66	Thin Peat	2	6	1	12	Low
2221	Point	652156	895087	0.0	Superficial	Granular	18.50	No Peat	0	8	1	0	None
2222	Point	652262	895075	0.0	Rock	Granular	22.28	No Peat	0	8	1	0	None
2223	Point	652177	895155	0.0	Rock	Granular	16.02	No Peat	0	8	1	0	None
2224	Point	652218	895190	0.0	Rock	Granular	16.84	No Peat	0	8	1	0	None
2225	Point	652252	895180	0.0	Rock	Granular	22.65	No Peat	0	8	1	0	None
2226	Point	652159	895194	0.3	Peat	Granular	15.79	Peaty Soil	1	8	1	8	Low
2227	Point	652073	895183	0.2	Peat	Granular	23.27	Peaty Soil	1	8	1	8	Low
2228	Point	651953	895186	1.8	Peat	Granular	7.59	Thick Peat	3	4	1	12	Low
2229	Point	651953	895287	1.0	Peat	Granular	9.01	Thin Peat	2	6	1	12	Low
2230	Point	652031	895276	1.4	Peat	Granular	9.36	Thin Peat	2	6	1	12	Low
2231	Point	652148	895286	0.4	Peat	Granular	10.47	Peaty Soil	1	6	1	6	Low
2232	Point	652244	895302	0.9	Peat	Granular	12.95	Thin Peat	2	8	1	16	Medium



Annex B Peat Core Logs & Photographs

Mullaghclogher Wind Farm

Renewable Energy Systems Ltd

SLR Project No.: 428.011231.00001

		Peat Core Log						Hole No. PC01 Sheet 1 of 1	
Project: Mullaghclogher Wind Farm				Client: RES Ltd				Dates: 27-06-2023	
Project No: 428.011231.00001				Logger: CR		Approved By:		Coordinates: E: 64784.00 N: 559030.00	
Location:				Hole Type: PC		Level:		Vertical Scale: 1:11	
Water	Depth (m)	Sample Type	Depth	Recovery (%)	Depth (m) / Discontinuity Detail	Level (mAOD)	Legend	Stratum Description	
	0.00 - 0.50	C	0.00 - 0.50	Recovery = 100%	0.50	0.50		Brown fibrous PEAT, with abundant plant remains. (H2, B2).	1
	0.50 - 1.00								
	1.00 - 1.50	C	0.50 - 1.00	Recovery = 100%		1.50			
		C	1.00 - 1.50	Recovery = 100%				Peat Core Complete at 1.50m	
2									
Remarks: Peat core recovered using peat sampler.									

		Peat Core Log						Hole No. PC02 Sheet 1 of 1	
Project: Mullaghclogher Wind Farm				Client: RES Ltd				Dates: 27-06-2023	
Project No: 428.011231.00001				Logger: CR		Approved By:		Coordinates: E: 64729.00 N: 558992.00	
Location:				Hole Type: PC		Level:		Vertical Scale: 1:11	
Water	Depth (m)	Sample Type	Depth	Recovery (%)	Depth (m) / Discontinuity Detail	Level (mAOD)	Legend	Stratum Description	
	0.00 - 0.50	C	0.00 - 0.50	Recovery = 100%	0.75	0.75		Brown fibrous PEAT. (H2, B2).	1
	0.50 - 1.00								
	1.00 - 1.50	C	0.50 - 1.00	Recovery = 100%	1.25	1.25		Reddish brown fibrous PEAT. (H3, B2).	
		C	1.00 - 1.50	Recovery = 100%	1.50	1.50		Dark brown fibrous PEAT. (H4, B2).	
								Peat Core Complete at 1.50m	2
Remarks: Peat core recovered using peat sampler.									

		Peat Core Log						Hole No. PC03 Sheet 1 of 1	
Project: Mullaghclogher Wind Farm				Client: RES Ltd				Dates: 27-06-2023	
Project No: 428.011231.00001				Logger: CR		Approved By:		Coordinates: E: 65486.00 N: 558321.00	
Location:				Hole Type: PC		Level:		Vertical Scale: 1:11	
Water	Depth (m)	Sample Type	Depth	Recovery (%)	Depth (m) / Discontinuity Detail	Level (mAOD)	Legend	Stratum Description	
	0.00 - 0.50	C	0.00 - 0.50	Recovery = 100%	0.50			Brown fibrous PEAT, with abundant plant remains. (H2, B2).	
	0.50 - 1.00				0.75		Dark brown fibrous PEAT, with frequent plant remains. (H3, B2).		
		C	0.50 - 1.00	Recovery = 100%	1.00			Reddish brown fibrous PEAT. (H3, B2).	
							Peat Core Complete at 1.00m		
Remarks: Peat core recovered using peat sampler.									

		Peat Core Log						Hole No. PC04 Sheet 1 of 1	
Project: Mullaghclogher Wind Farm				Client: RES Ltd				Dates: 27-06-2023	
Project No: 428.011231.00001				Logger: CR		Approved By:		Coordinates: E: 67215.00 N: 558976.00	
Location:				Hole Type: PC		Level:		Vertical Scale: 1:11	
Water	Depth (m)	Sample Type	Depth	Recovery (%)	Depth (m) / Discontinuity Detail	Level (mAOD)	Legend	Stratum Description	
	0.00 - 0.50	C	0.00 - 0.50	Recovery = 100%	0.50	0.50		Brown fibrous PEAT, with frequent plant remains. (H2, B2).	1
	0.50 - 1.00							Brown fibrous PEAT. (H3, B2).	
	1.00 - 1.25	C	0.50 - 1.00	Recovery = 100%	1.00	1.00		Dark brown fibrous PEAT. (H3, B2).	
		C	1.00 - 1.25	Recovery = 50%				Peat Core Complete at 1.25m	
2									
Remarks: Peat core recovered using peat sampler.									



Hole No.

PC05

Sheet 1 of 1

[illegible]

Remarks:

Peat core recovered using peat sampler.



Peat Auger 1
0 – 0.5m



Peat Auger 1
0.5 – 1.0m



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Project : Mullaghclogher Wind Farm



Project No. :- 428.011231.00001

Date :- June 2023



Peat Auger 1
1.0 – 1.5m



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Peat Auger 2
0 – 0.5m



Peat Auger 2
0.5 – 1.0m



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Peat Auger 2
1.0 – 1.5m



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Peat Auger 3
0 – 0.5m



Peat Auger 3
0.5 – 1.0m



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Peat Auger 4
0 – 0.5m



Peat Auger 4
0.5 – 1.0m



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Peat Auger 4
1.0 – 1.25m

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Peat Auger 5
0 – 0.5m



Peat Auger 5
0.5 – 1.0m



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Peat Auger 4
1.0 – 1.1m

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