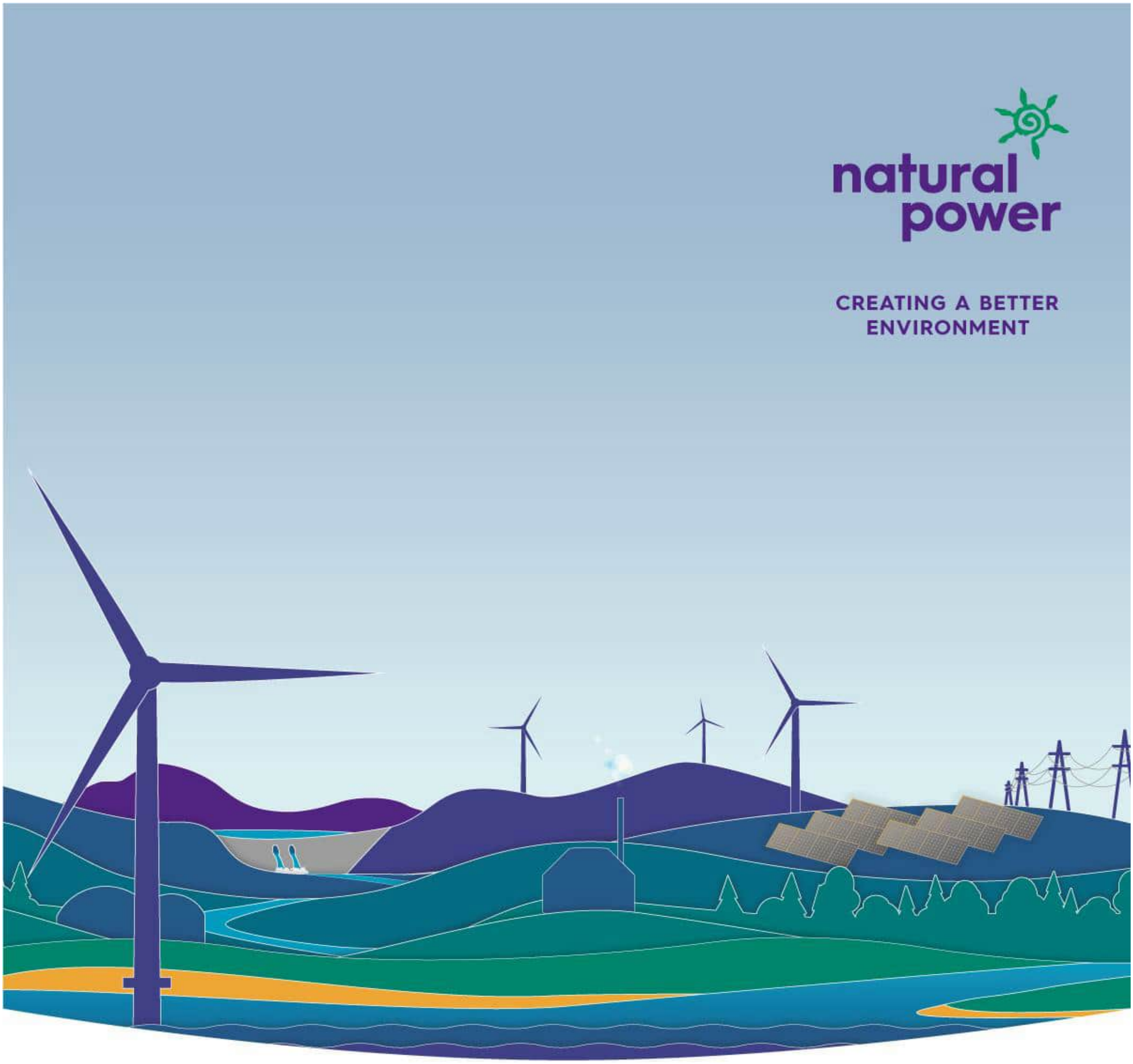
Technical Appendix 10.3:

Peat Slide Risk Assessment



Carnbuck Wind Farm

Peat Slide Risk Assessment

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Renewable Energy Systems

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1. Introduction

This report details the Peat Stability Assessment undertaken at the proposed Carnbuck Wind Farm. The proposed wind farm development comprises x12 wind turbine generators, ancillary infrastructure, and new access tracks. The indicative wind farm layout and relevant mapping is appended to this report:

- Figure A.1 Interpolated Peat Depth
- Figure A.2 Slope Angle Map
- Figure A.3 Geomorphological Features
- Figure A.4 Environmental Impact Zonation
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1.1. Reporting Team

Report Author: - Sam Fisher is a geotechnical engineer at Natural Power and engineering geologist by training (MSc Engineering Geology) with over 4 years of relevant geotechnical experience. Sam has completed multiple peat slide risk assessments for wind energy projects across the UK. Carrying out on site assessments, terrain analysis and risk assessment reporting.

Report Checker: – Gavin Germaine is a Principal Geotechnical Engineer at Natural Power and engineering geologist by training (MSc Engineering Geology) with greater than 12 years of relevant geotechnical experience. Gavin is a chartered Geologist (CGeol) and a Fellow of the Geological Society of London. Over the last decade has completed multiple peat slide risk assessments for wind energy projects across the UK and Ireland. Gavin has further provided expert technical advice as part of planning enquiries and being part of an international team examining new geotechnical investigation techniques for in-situ testing and sampling of peat.

1.2. Detailed Description of Development

The development will comprise of up to 12 wind turbine generators. Wind farm infrastructure will also be required in the form of external wind turbine transformer housings, crane hardstand areas, substation, underground electricity cables between the turbines, associated access tracks, water crossings and drainage attenuation measures as necessary. A full description of the ‘Proposed Development’ is provided in ES Volume 2 Chapter 1: Introduction and Description of Development. Figure 1.1 depicts the site layout. Figure 1.2 depicts the regional setting.

Source: RES, OpenStreet Map

Figure 1.1: Site Layout

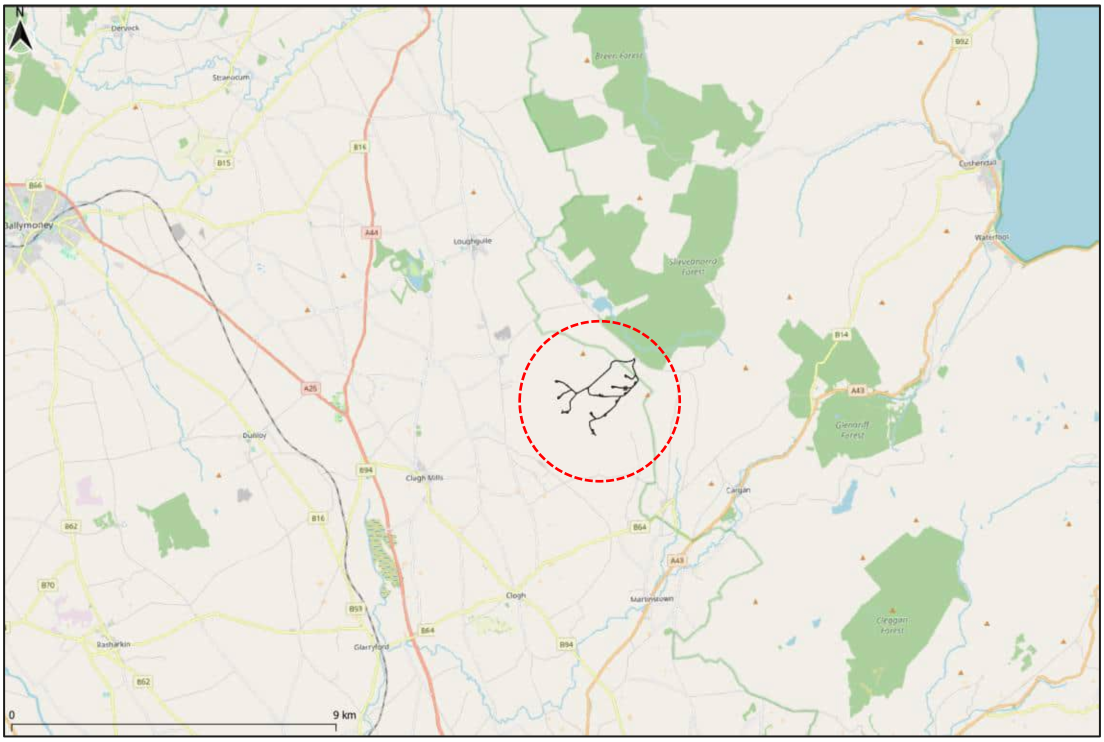


Figure 1.2: Regional Setting

1.2.1. Design Evolution

The proposed wind farm layout has been optimised during the environmental impact assessment. Previous layout iterations have been assessed with respect to peat slide risk prior to arriving at the final proposed layout. This has provided opportunity for peat slide risk and impacts on peatland to be minimised as far as practicable by the layout design process.

Peatland surveys were undertaken on an initial wind farm layout. Detailed peat depth survey data for the initial layout is included on Figure A1, Appendix A. Inclusion of this data is intended to highlight the evolution of the layout design. From the initial assessment it was possible to optimise infrastructure and track alignments to occupy shallower peat and low or negligible peat slide risk zones. This process has allowed nine out of the twelve turbine positions to be positioned onto shallow (<1.0m) or areas absent of peat. The proposed access track alignments have been optimised to occupy shallow peat areas or otherwise the staged assessment has identified where potential floating access track construction may be appropriate within the development.

1.2.2. Peat Management

All construction peat storage locations will be designated following detailed geotechnical investigation carried out post consent. An outline Peat Management Plan (report reference: 1277447) has been provided in this appendix which indicates potential peat storage locations for further investigation. Peat storage systems including location, geometry, monitoring and maintenance will be included in the detailed civil and geotechnical design for the project. The results of the peat stability assessment shall be incorporated at this later phase of investigation with storage only on negligible / low risk terrain.

1.3. Peat Slide Hazard – Risk Assessment Method

Natural Power Consultants carried out the peat stability assessment following the principles of the Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments (Scottish Government 2017) hereafter referred to as PLHRAG, (2017). Updated as a second edition in April 2017, this guide provides best practice methods which should be applied to identify, mitigate and manage peat slide hazard and associated risks in respect of consent application for electricity generation projects in the UK.

Assessment of potential instability at the proposed development was carried out according to the following work programme:

- Desk Study and review of existing site information carried out in February 2019, including desk-based mapping and site modelling.
- Web searches, local new and discussions with adjacent operational wind farm operative.
- Site reconnaissance survey (February 2019). This comprised a walkover survey of the site and identification of potential geo-hazards.
- Desk based aerial image review of open-source available Google Earth and Bing Aerial Images (February 2019).
- Review of historical mapping and historical aerial imagery.
- Development-wide peat probing survey comprising: An initial site wide peat probe survey within the preliminary site boundary on a grid resolution of 100m (February 2019), Phase 1 survey.
- Detailed peat probing survey covering designed infrastructure at higher resolution (January 2020), Phase 2 survey.
- Assessment of peat undrained shear strength through in-situ hand shear vane testing across representative turbine locations within the design envelope (January 2020), Phase 2 survey.
- Development-wide mapping and assessment of salient features such as active, incipient or relic instability within the peat deposits, geomorphological features, peat depth and composition (January 2020), Phase 2 survey.

- Peat coring at each wind turbine location and targeted wider across the site. Peat coring including Von Post humification classifications with depth to inform the Peat Management Plan. Core samples were examined by hand, and samples were submitted to the laboratory for testing for Carbon content of dry peat (% by weight) and Dry soil bulk density (g/cm^3) for input into the Carbon Balance Assessment.
- Quantitative slope stability assessment based on in-situ shear strength data.
- Assessment of the potential risk of peat failure across the turbine envelope.
- Comparison of the potential risk of peat failure with the site hydrological model including proximity to watercourses and sensitivity of those features.
- Recommendations for detailed design/construction control with specific examination the need for measures to mitigate potential peat failure as part of any future wind farm development.
- March 2022 – Minor updates to proposed layout design and undertaking of additional detailed peat probing and site reconnaissance.

1.4. Processes Contributing to Peat Instability

To provide a framework for the assessment this report highlights peatland processes which influence peat failure. Discussion of the destabilising factors which can contribute to peat failure are discussed below:

Groundwater Infiltration

There are two main processes which control groundwater infiltration: These are periods of drying, resulting in cracking of exposed peat surfaces and slope creep resulting in additional tension cracks.

Surface Loading

Any mechanism which increases the load on peat can increase the likelihood of failure. This can include continued peat growth, increased water content and surcharge loading. For example; construction works, stockpiling and forestry operations. Unloading can cause failures. for instance, the cutting of peat causing removal of a toe slope support to the upslope material. Cyclical loading over a short frequency (e.g., repeat heavy vehicle movements) may also contribute to peat failure through strain softening of the peat.

Vegetation

Factors which alter the surface vegetation are important particularly if the vegetation provides strength to the peat deposit through a dense fibrous root network. Loss of vegetation can therefore have a negative impact, making the peat susceptible to weathering and increased rates of infiltration.

Weathering

Weathering can weaken in-situ peat materials and destabilise a slope system. This may be in the form of weathering of exposed peat or the underlying mineral soils which could reduce shear strength at the basal contact with the peat. Internal vertical cracking and slope creep may slowly break down peat structure over long periods of time. This can develop into peat ‘hagging’, which is a strong indication that natural long-term weathering processes are active. Peat hags expose the peat to increased weathering rates and may provide preferential surface water flow pathways.

Base of Peat Soil/Rock Interface

Peat slides can occur at the interface with the underlying soil substrate such as soft clays. The presence of peat over time can lead to softening of underlying clays. The underlying material may also provide a layer with very little frictional resistance for which the peat to slide on. These are often referred to as ‘impermeable iron-pans’ or for example where peat is resting on a planar bedrock interface.

Precipitation

A dominant trigger for peat failures are intense rainfall events. Documented failures are associated with extreme rainfall events; reference is made to the Llyn Ogwen peat failure documented by Nichol et al., (2007). The Derrybrien Wind Farm final report on landslide of October 2003 AGEC, (2004) provides further evidence. An example is also highlighted in the characteristics of the Shetland Isles (UK) Peat Slides of 19 September 2003, Dykes & Warburton, (2008). The aforementioned ‘A5’ Llyn Ogwen Peat Slide of 2005 is a useful example of a rainfall induced slide. Peat deposits were approximately 1m thick with undrained shear strength of 10-15kPa.

The likely failure mechanism following a period of heavy rainfall is linked to the infiltration of surface water into the ground. There is a resulting build-up of pore water pressures and therefore reduced effective shear strength. This may be focussed within the peat deposit or at the interface between the peat and underlying mineral soil. Secondary effects may include swelling of the peat deposit and increased loading due to surface water ponding. Snow and subsequent melt can have a similar effect and is a potential factor across upland terrain.

Slope Morphology

Several case studies on peat failures note the presence of a convex break in slope (Dykes & Warburton 2008). There are three main effects of such terrain slope morphology:

- Firstly, the concentration of tensile stress at the apex of a convex slope (predisposes the slope for failure initiation at that point. In a convex slope the material lower down supports the material above which is held in compression. A concave slope has the opposite characteristics as material below the ‘roll-over’ maintains the apex in tension. The roll over is particularly vulnerable to additional destabilising forces in addition to propagation of tension cracks.
- Secondly, it can be postulated that at the point of maximum slope convexity, because of the favourable down-slope drainage conditions (below the roll over), a body of relatively well-drained and relatively strong peat material develops. This body of peat acts as a barrier providing containment for growth of peat upslope. This relatively well drained body of peat can subsequently fail due to a build-up of lateral pressure on the upslope face. In this scenario the slope is not supported from below so eventually the lateral pressures exceed the forces resisting sliding. The apex or point of convexity is also a likely initiation point for slope failure due to the slope tension being concentrated at this point.
- Thirdly, a failure mechanism, analogous to a piping failure underneath a dam, is postulated where springs are present in locations immediately down-slope of the relatively well drained peat body. Under these circumstances high pore pressure gradients within the peat can lead to hydraulic failure and undermining of the relatively well drained peat body resulting in a breach and loss of lateral support to peat upslope.

The assessment seeks to identify any significant slope features where these are coincident with proposed development infrastructure.

Peat Depth & Slope Angle

The PHLRAG, (2017) guidance provides the following information on peat slides with respect to peat depth and slope angle:

‘Peat slide – slab like shallow translational failure, with a shear failure mechanism operating within a discrete shear plane at the peat substrate interface, below this interface, or more rarely within the peat body. The peat surface may break up into large rafts and smaller blocks which are transported down slope mainly by sliding. Rapid re-moulding during transport may lead to the generation of organic slurry in which blocks of peat are transported.’

Peat slides correspond in appearance and mechanism to translational landslides and tend to occur in shallow peat (up to 2.0m) on slopes between (5° – 15°). A great majority of recorded peat landslides in Scotland, England & Wales are of the peat slide type. MacCulloch, (2006) highlights that a slope angle of 20° appears to be the limiting gradient for the formation of deep peat. Therefore, the risk assessment has assigned slope angles >20° to be an unlikely contributory factor to failure. Slope angle indicators and corresponding probability factors have been similarly adapted from MacCulloch, (2006).

For the purpose of this report 'deep peat' is defined as any peat deeper than 1.0m as defined in PHLRAG, (2017).

Boylan et al, (2008) indicates that most peat failures occur on slope angles between 4° and 8°. It is postulated that this may correspond to the slope angles that allow a significant amount of peat to develop that over time becomes potentially unstable. The same author also stipulates that several failures have been recorded on high slope angles (>20°) but, based on the authors inspection of such failures, peat cover is generally thin, and the failure tends to involve underlying mineral soils, as opposed to peat deposits.

Peat depth and slope angle indicators for probability of peat failure have been similarly adapted from MacCulloch, (2006). Maps showing the interpolated peat depth and slope angle across the proposed wind farm development site are appended to this report (Figures A.1 & A.2).

To prepare the "Interpolated Peat Depths" a spatial interpolation method termed 'Ordinary Kriging' was applied. Ordinary Kriging, as opposed to other types of Kriging, assumes spatial autocorrelation but does not assume any overriding trends or directional drift. This is therefore considered a good option for contours of peat depth. The output cell size was set at 10m, the search radius fixed at 100m with a spherical semi-variogram model used. The Kriging algorithm considers multiple data points close together, giving greater weight to the points most proximal.

A Slope Angle Map, comprised from the Digital Terrain Model derived from Ordnance Survey 'OS Terrain 5', carrying a grid resolution of 5m. The risk assessment considers slope angle across two areas. Firstly, the slope angle is used to screen the site for instability within the slope analysis numerical calculation. This is adjoined to assessment of the slope angle category in terms of a contributory factor to failure. This combined approach ensures a robust assessment of the risk and increases the sensitivity of the assessment to characterise risk more accurately across an expansive area.

Drainage

Natural and artificial drainage measures designed to reduce the water content in the peat have often been identified as a contributory factor of peat failure. Preferential drainage paths may allow the migration of water to a failure plane therefore triggering failure when groundwater pressures become elevated over time. Within a peat mass, peat pipes can enable flow into a failure plane and facilitate internal erosion of slopes. It is also noted that in some instances, agricultural works can lead to the disturbance of existing drainage networks and cause failures. Forestry preparations and harvesting may also impact upon man-made drainage networks.

Recurrent Failures

The clustering of relict failures and any indication of previous instability are often important, indicating that site conditions exist that are conducive to peat failure. Relict peat slides may be dormant over long periods and be re-activated by any number of the contributory factors discussed here.

Pre-existing Weak Layers

Several peat failure reports identify the possibility of relative weaker layers within the peat mass (AGEC, 2004). In most cases, these weak layers are at the base of the peat deposit where there is usually the highest degree of peat humification and lowest relative peat strength. Alternatively, where failure is triggered by the ingress of water into the peat, there is a tendency for water to build-up at the base of the peat causing a reduction in effective stress at the base of the peat which can contribute to eventual failure. During construction existing peat drains are likely to be altered and care will need to be taken to avoid increased ingress of water.

Anthropogenic Effects

Man-made impacts on peat environments can include a range of affects associated with wind farm construction. Activities such as drainage, tracks across peat, peat cutting, and slope loading are all examples. Rapid ground acceleration is one such example where shear stress may be increased by trafficking or mechanical vibrations.

1.5. Peat Failure Definitions

Peat failure in this assessment refers to the mass movement of a body of peat that would have a significant adverse impact on the surrounding environment. This definition excludes localised movement of peat, for example movement that may occur below an access track, creep movement or erosion events and failures in underlying mineral soils.

The potential for peat failure at this site is examined with respect to the activities envisaged during construction and operation of the proposed Carnbuck Wind Farm. There are several classification systems for the mass movement of peat that were drawn together by PLHRAG, (2017) and by AGEC at Derrybrien in Ireland.

Hutchinson (1988) defines the two dominant failure mechanisms namely peat flows and peat slides:

- **Peat Flows & Bog Bursts**: are debris flows involving large quantities of water and peat debris. These flow down slope using pre-existing channels and are usually associated with raised bog conditions. Bog Bursts occur at slope ranges of 2°-5° while peat flows are not constrained by slope angle.
- **Peat Slides**: comprise intact masses of peat moving bodily down slope over comparatively short distances. A slide which intersects an existing surface water channel may evolve into a debris flow and therefore travel further down-slope. Slides are historically more common within blanket bog settings.

Due to the open topographic relief across the proposed wind farm development, peat slides are considered the dominant mode of potential peat failure. Where impacting a watercourse these would potential evolve into a peat flow. Bog bursts are rare across the UK but have the potential to occur locally. Consideration should be given to the potential for peat slides as a result of the slope geometry over discrete parts of the development area. Peat depths are generally shallow <1.0m across the proposed wind farm development and when possible infrastructure has been positioned away from the deepest zones of peat. A historical peat slide feature has been identified out-with the proposed infrastructure, indicating isolated conditions exist which may give rise to natural instability in the peat slopes.

1.6. Geotechnical Principles

The main geotechnical parameters that influence peat stability are: -

- Shear strength of peat.
- Peat depth.
- Pore water pressure (PWP).
- Loading conditions.

The stability of any slope is defined by the relationship between resisting and destabilising forces. In the case of a simple infinite slope model with a translational failure mode, sliding is resisted by the shear strength of the basal failure plane and the element of self-weight acting normal to the failure plane. The stability assessments within this study considers an undrained 'total stress' scenario when the internal angle of friction (φ') = zero.

An undrained peat deposit may be destabilised by; mass acting down the slope, angle of the basal failure plane and any additional loading events. The ratio between these forces is the Factor of Safety (FoS). When the FoS is equal to unity (1) the slope is in a state of 'limiting equilibrium' and is sensitive to small changes in the contributory factors leading to peat failure.

The infinite slope model as defined in Skempton et al. (1957) has been adapted to determine the FoS of a slope. A modified approach has been used; assuming a minimum FoS (Typically 1.3 after, BS6031: 2009).

A factor of safety map (Figure A.8) has been produced using a site wide GIS assessment. This mapping has utilised the terrain slope data, peat depth data and assigning the mean undrained shear strength measured for the peat on site. This map provides a useful screening tool to examine areas which may be at higher risk of peat failure.

Infinite Slope Analysis

The purpose of the analysis is to identify the baseline FoS at each proposed turbine base. A Factor of Safety (FoS) of 1.3; based on BS6031:2009: Code of practice for Earthworks (BSI, 2009) has been used.

The infinite slope analysis is based on modelling a translational slide, which represents the prevalent mechanism for peat failures. This analysis adopts total stress (undrained) conditions in the peat. This state applies to short-term conditions that occur during construction and for a time following construction until construction induced pore water pressures (PWP) dissipate. (PWP requires time to dissipate as the hydraulic conductivity can be low in peat deposits). The following assumptions were used in the analysis of peat deposits across the proposed wind farm development:

- The groundwater is resting at ground level.
- Minimum acceptable factor of safety required is 1.3.
- Failure plane assumed at the basal contact of the peat layer.
- Slope angle on base of sliding assumed to be parallel to ground surface and that the depth of the failure plane is small with respect to the length of the slope.
- Thus, the slope is considered as being of infinite length with any end effect ignored.
- In the surcharged case a 20kPa stress is modelled, this is approximately equivalent to a 2m high peat stockpile or 1.5m high subsoil stockpile.

The analysis method for a planar translational peat slide along an infinite slope was for calculated using the following equation in total stress terms highlighted by MacCulloch, (2006) and originally reported by Barnes, (2000):

$$\mathbf{F = Cu / (\gamma * z * \sin\beta * \cos\beta)}$$

Where:

F = Factor of Safety (FoS).

Cu = Undrained shear strength of the peat (kPa).

γ = Bulk unit weight of saturated peat (kN/m^3).

z = Peat depth in the direction of normal stress.

β = Slope angle to the horizontal and hence assumed angle of sliding plane (degrees).

Undrained shear strength values (Cu) are used throughout this assessment. Effective strength values are not applicable for the case of rapid loading of the peat during short term construction phase of works hence the formula cited above, has been adopted throughout.

1.6.1. Assumptions

The slope angle of the ground surface does not necessarily represent the true slope angle at the base of the peat. In the absence of more detailed intrusive site investigation data, the surface slope angle gives an indication of the likely slip surface angle at the base of the peat. It should be highlighted that a key controlling factor on potential instability may be the internal structure of the peat and not the underlying interface with the superficial deposits.

The occurrence of a severe rainstorm event controlled by meteorological factors is only in-directly evaluated by this assessment. Natural Power considers blanket peat on upland sites would be more susceptible to intense rainstorm events due to the larger catchment potential across the peat surface. The wide range of contributory factors included in this assessment are indirectly linked to rainfall and precipitation.

The thinning and cracking of peat can allow ready ingress of surface water into the base of the peat mass. Deeper deposits of peat may therefore be less likely to be affected by cracking. The preliminary analysis assumes that the groundwater rests at ground level. This is conservative and considered a worst-case scenario for the proposed wind farm development.

For the numerical analysis; the assumption was made that the ground surface is loaded by a nominal vertical 20kPa surcharge. Vehicle trafficking, construction of access roads and stockpiling of peat/soil during excavations all cause an increase in applied stress which can, without engineering control, increase the risk of peat slide. Surface loading in particular has been shown to have resulted in a number of construction stage related peat failures. The effects of cyclic loading are also not covered by the scope of the slope stability model. It is further highlighted that loading rates can be important in managing peat deformation under construction conditions.

1.7. Assessment Methodology

A semi-quantitative risk assessment has been used to determine the risk of peat failure and hence impact on the proposed wind farm development and surrounding environment. The methodology is well defined in PLHRAG, (2017) and has been further augmented with methods set out by Clayton (2001). It is important to highlight the assessment draws upon experiential and subjectively assigned parameters.

This assessment has analysed terrain conditions across the proposed wind farm development and utilised this information to clarify the preliminary peat slide risk map, (Figure A.7) appended to this report.

In support of the peat slide risk mapping, the environmental impact zonation (Figure A.4) has assessed the potential for a peat failure to detrimentally impact surface water courses. The Environmental Impact Zones (EIZ) based on proximity buffer zones applied to the main sensitive watercourse within the proposed development. The main water course has been determined to be a primary sensitive receptor to a peat failure event. Figure A.4 depicts the environmental impact zonation used as part of the risk assessment. Table 1.1 and Table 1.2 denote the impact scales (adverse consequence) to the *environment and to the development.*

Table 1.1: ***Environmental Impact Scales***

Criteria / Exposure	Environmental Impact (Ei)	Impact Scale
Infrastructure <50m of watercourse	**High**	**4**
Infrastructure within 50-100m of watercourse	**Medium**	**3**
Infrastructure 100-150m of watercourse	**Low**	**2**
Infrastructure >150m from watercourse	**Negligible**	**1**

Source: MacCulloch (2006)

Table 1.2: Development Impact Scales

% of damage to (or loss of) receptor	Impact Level (Adverse Consequence)	Impact Scale
> 100% of asset	Extremely High	5
10% - 100%	Very High	4
4% – 10%	Medium	3
1% - 4%	Low	2
< 1% of asset	Very Low	1

Source: PLHRAG (2017)

The proximity values are developed from a literature review and designed such that this parameter does not skew the assessment or override other key contributing factors. Where this linear approach leads to an overstating of the risk, the assessor has applied corrective factors to ensure results are not unrealistic.

Risk Assessment Ranking across the turbine locations is presented in Table 4.1. The assessment uses the following contributory factors to peat failure, identified from desk study and the detailed peat survey:

- Slope angle evaluated during field reconnaissance and OS digital elevation model (Figure A.2);
- Peat depth determined during a multi-phased probing survey (Figure A.1);
- FoS evaluated from infinite slope analysis;
- Limited evidence of groundwater flow;
- Surface water flow from maps and site walkover observations;
- Evidence of previous slope instability within the site wide geomorphological setting;
- Land management, qualitative based on previous site use.

Probability values for each contributory factor are summarised on Table 1.3 along with a brief discussion of the influencing factors.

Table 1.3: Contributary Factors and Probability Values

Contributing Factors	Comment	Criteria	Probability	Scale
Peat Depth (A)	Peat slides tend to occur in shallow peat (up to 2.0m) on A great majority of recorded peat landslides in Scotland, England & Wales are of the peat slide type.	0 – 0.5m	Negligible	1
		>3.0m	Unlikely	2
		0.5 – 1.0m	Likely	3
		2.0 – 3.0m	Probable	4
		1.0 – 2.0m	Almost certain	5
Slope Angle (B)	It has been acknowledged that peat slide tends to occur in shallow peat (up to 2.0m) on slopes between 5° and 15°. Slopes above 20° tend to be devoid of peat or only host a thin veneer deposit.	0 – 3°	Negligible	1
		>20°	Unlikely	2
		4 – 9°	Likely	3
		16 – 20°	Probable	4
		10 – 15°	Almost certain	5
FoS* (C)	Values are from Infinite slope model using Cu derived from hand shear vane in-situ testing. Slope angle and peat depth also input to this factor.	≥ 1.3	Negligible	1
		1.29-1.20	Unlikely	2
		1.10-1.19	Likely	3
		1.00-1.09	Probable	4
		<1.0	Almost certain	5
Cracking (D)	Visual assessment undertaken in the field during detailed probing survey and covers the same extends of this survey. Field workers examined for evidence of any major crack networks which may allow surface water to penetrate the peat mass. Reticulate cracking was not investigated as this normally requires intrusive ground investigation to remove the surface fibrous layer. This may be a more important consideration for forested areas or previously forested areas of a development site.	None	Negligible	1
		Few	Unlikely	2
		Frequent	Likely	3
		Many	Probable	4
		Continuous	Almost certain	5
Groundwater (E)	Challenging to evaluate without very detailed mapping and/or intrusive data. Look for entry / exit points. Evidence of surface hollows, collapse features at surface reflecting evidence of sub-surface peat pipe network, audible indicators including the sound of sub-surface running ground water surrounding proposed infrastructure locations	None	Negligible	1
		Few	Unlikely	2
		Frequent	Likely	3
		Many	Probable	4
		Continuous	Almost certain	5
Surface Hydrology (F)	Ranging from wet flushes to running burns to hags. Must be evaluated in conjunction with the season and weather preceding the site visit. Artificial drains (grips) have also been identified across the site. Their presence is generally linked to historical peat cutting sites which are factored into the risk assessment.	None	Negligible	1
		Few	Unlikely	2
		Frequent	Likely	3
		Many	Probable	4
		Continuous	Almost certain	5
Previous Instability (G)	Visual survey, scale and age are important as small to medium relict failures may be easy to detect but very large ones may require remote imaging. Recent failures should be obvious due to the scar left.	None	Negligible	1
		Few	Unlikely	2
		Frequent	Likely	3
		Many	Probable	4
		Continuous	Almost certain	5
Land Management (H)	Anthropogenic influences: forestry operations and removal of vegetation can be associated with de-stabilising peat deposits. This can occur as a result to surface disturbance and remoulding of peat through excavation, vehicle movements and loading. Changes in land use activities may also be associated with changes in drainage conditions. Criteria based on evidence of disturbance of peat deposit, i.e. broken surface, scarring or disrupted hydrology. For Carnbuck Wind Farm the assessment identifies peat cutting operations, where this has impacted the ground, a land management scale of '2' has been chosen. This assessment should be updated following the site investigation.	None	Negligible	1
		Few	Unlikely	2
		Frequent	Likely	3
		Many	Probable	4
		Continuous	Almost certain	5

Source: Natural Power

Table 1.4 below provides an illustration of how the qualitative description of likelihood relates to the numerical probability of a peat landslide occurring.

Table 1.4: Peat Landslide Probability Ranges

Scale	Likelihood	Probability of Occurrence
5	Almost certain	>1 in 3
4	Probable	1 in 10 – 1 in 3
3	Likely	1 in 10^2 – 1 in 10
2	Unlikely	1 in 10^7 – 1 in 10^2
1	Negligible	< 1 in 10^7

Source: PLHRAG (2017)

The aforementioned factor of safety has been introduced for two reasons: to rapidly assess the stability condition of the terrain across the proposed infrastructure elements and; allow a holistic ground model, through the use of the basal shear strength values to indicate propensity for failure along the basal peat interface. It is acknowledged that inclusion of FoS captures the slope angle and peat depth parameters a second time in the assessment. Natural Power considers this approach to provide a robust and conservative approach where the FoS factor has an ability to resolve multiple factors and their contribution to risk where otherwise standalone, each factor may have a lower contributing effect on the assessment.

The FoS analyses the ratio of ground resistance to disturbing forces and its use was introduced to the assessment following review of the guidance produced by MacCulloch, (2006). Where ground resistance is equal to disturbing forces, the FoS is at unity (equal to 1.0) and the ground should be considered to be at a point of limiting equilibrium and failing. A FoS greater than 1.0 would indicate a stable slope, and a FoS less than 1.0 would indicate an unstable slope.

Adoption of a narrow range in FoS values as indicated in Table 1.3 is derived from a ground engineering perspective. British Standard BS 6031, (2009), provides guidance on the design of both temporary and permanent earthworks. A design FoS of 1.3-1.4 is cited. The peat stability assessment has taken the upper bound value of 1.3 and a lower bound value of 1.0 to frame the FoS assessment as a contributory factor to failure. This range is considered to be in line with engineering best practice. Expanding this range beyond 1.3 would have a limited effect on highlighting any unstable slope conditions.

Additionally, the FoS approach used in the assessment ignores any passive resistance which would likely be present at the toe of a slope system. MacCulloch, (2006) to this effect states that: the FoS is a conservative estimate which considering the non-linear geotechnical behaviours of peat adds a degree of confidence to this aspect of the assessment.

Furthermore, the in-situ hand shear vane testing covered the deepest representative deposit of peat at each test location where peat depth was sufficient to carry out these tests, due to shallow peat depths spanning the site this was only possible at four turbine locations.

A qualitative Risk Ranking is assessed from the combined probability of occurrence for the main contributory factors which are greater than (1), multiplied by the highest impact scale. Table 1.5 identifies the hazard ranking based on concepts of PLHRAG, (2017).

Risk = Probability x Adverse Consequence

Risk Ranking = ((Sum A:H) if (A:H>1)) x (Ei)

Table 1.5: Risk Ranking and Suggested Actions

Risk Ranking Zone	Control Measures
17 - >25	**High:** Avoid project development at these locations.
11 - 16	**Medium:** Project should not proceed unless risk can be avoided or mitigated at these locations, without significant environmental impact, in order to reduce risk ranking to low or negligible.
5 - 10	**Low:** Project may proceed pending further investigation to refine risk assessment and mitigate hazard through relocation or re-design at these locations.
1 - 4	**Negligible**: Project should proceed with monitoring and mitigation of peat landslide hazards at these locations as appropriate.

Source: PLHRAG (2017)

Table 1.6 below further breaks down the Risk Ranking score into a risk matrix adapted from Clayton, (2001):

Table 1.6: Risk Rating

Highest Probability for Contributory Factor to Peat Failure						
Environmental Impact Scale	**Score**	**1**	**2**	**3**	**4**	**5**
	5	**5**	**10**	**15**	**20**	**25**
	4	**4**	**8**	**12**	**16**	**20**
	3	**3**	**6**	**9**	**12**	**15**
	2	**2**	**4**	**6**	**8**	**10**
	1	**1**	**2**	**3**	**4**	**5**

Source: Clayton (2001)

Using the equation and scoring present in the above tables, a Peat Slide Risk Map (Figure A.7) is created using raster calculations in QGIS. Each individual contributary layer is scored using Table 1.3, with scores of 1 being reset to 0 as they present a negligible risk and are not required to feed into the model. The layers are then ingested into the model using the Risk Rank Equation above. All information contributing to the peat slide risk map is pre-mitigation.

The map is then checked against manually calculated risk scores in Table 4.1.

2. Site Information

Location and Topography

The wind farm project is located on upland terrain dominated in the north by the existing Gruig Windfarm and to the south by Skerry Hill (511m AOD). Access onto the development is via a gate at the current entrance to the existing Gruig Windfarm at Irish Grid Reference [313248, 421711]. There are specific requirements for windfarm safety inductions before proceeding onto development.

The development primarily occupies a west facing hillside. Slopes aspects are across all directions from the summit of Skerry Hill. There are southern facing slopes down to a stream from the existing windfarm. The development rises from approximately 230m AOD elevation in the south to a height of 511m AOD at top of Skerry Hill in the west portion of the development. There are occasional deep channels cutting across the slopes, and these are formed by small upland streams. On the upper slopes of Skerry Hill there is evidence of historical peat cutting.

A stream cuts across the development between Skerry Hill and the existing windfarm, on the northern side of this stream there is generally short grass with drier ground, south of this stream the ground is more saturated with heather vegetation.

Site photos taken during the peat probing surveys are included within Appendix B to provide an overview of the general ground conditions and topography encountered.

Source: Natural Power, Google Earth Professional – x2 Vertical Exaggeration

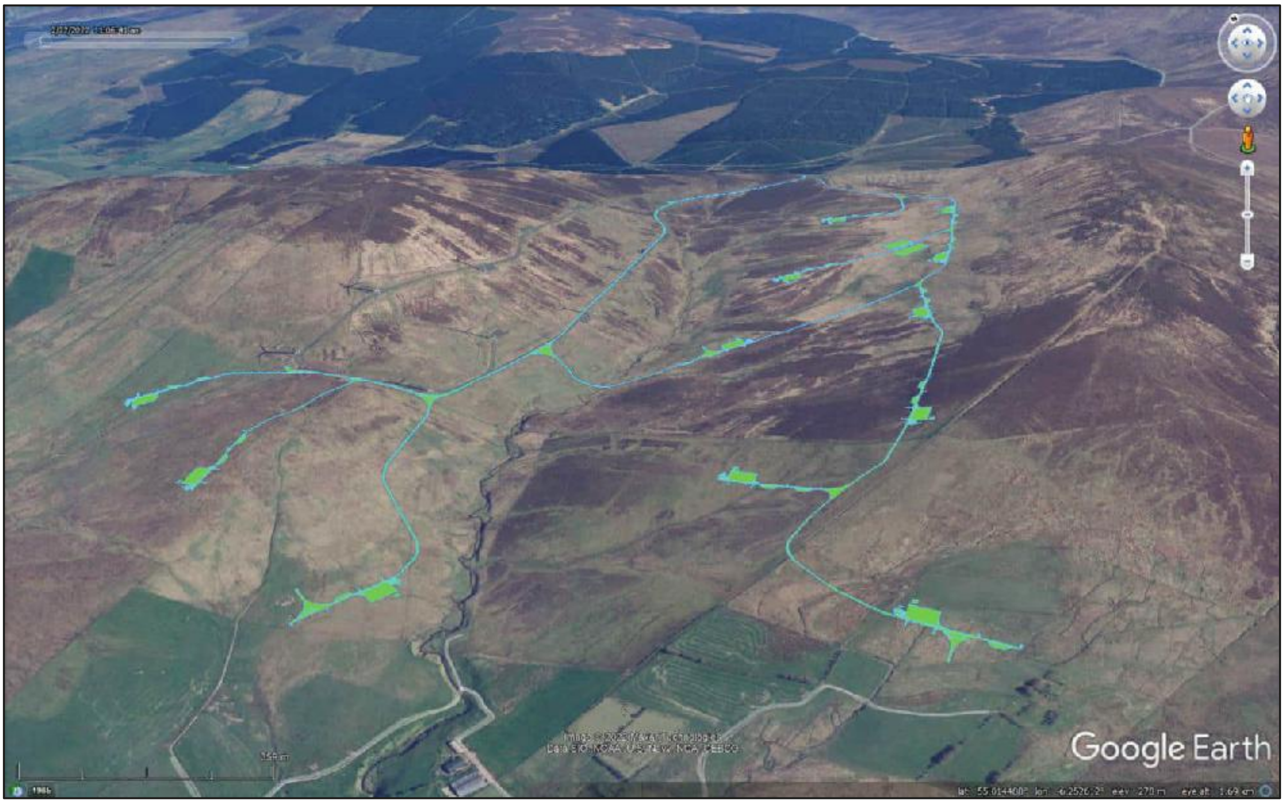


Figure 2.1: Aerial view northeast across the proposed development

2.1. Desk Study and Site Reconnaissance

Desk Study

A desk study was completed as part of the peat stability risk assessment incorporating the hydrology, geology and hydrogeology. All relevant background data, including geomorphology, peat depths and water course information has been reviewed. This review of available literature, maps, and data was undertaken together with a general review of peat failures across the British Isles. The primary data sources with respect to the proposed wind farm development include:

- Historical Ordnance Survey Map review
- British Geological Survey (BGS) geology map data and historical borehole records.
- Geological Survey Northern Ireland (GSNI)
- Aerial photographic records assessed on Google Earth Professional.
- Northern Ireland Rivers Agency Flood Map.

The following series of images provide an overview of the terrain and the existing wind farm development over the last decade for the proposed development. These images identify a moderate scale peat slide on the slopes of Skerry Hill that was also identified on the site walkover, the slide is known to have occurred between 2002 and 2010

Source: Google Earth Professional

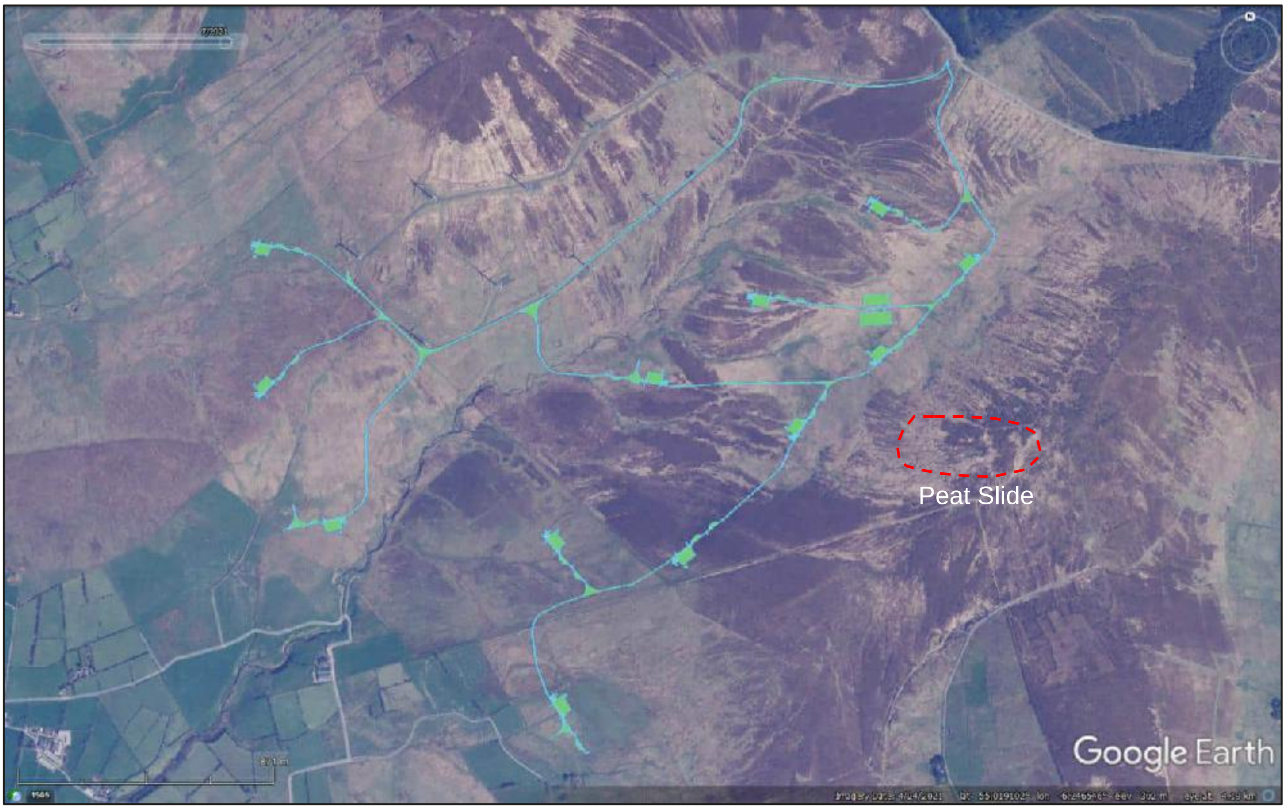


Figure 2.2: **Aerial Photograph 2021**

Figure 2.3: **Aerial Photograph 2005**

An existing peat slide identified is ~360m upslope from the proposed access track at turbine T08. The feature measures approximately 3,000m^2 in area. The instability occurred in an area of peat hags where a failure plane is likely to have developed along the base of the peat. The trigger is postulated to have been long term erosion and infiltration of water to the base of the peat mass. The morphology of the slide has been controlled be the pre-existing peat hag geometry and the slide appearing to have taken the form of an initial slide evolving into a debris flow. Debris has been entrained and run-out for approximately 250m down-slope. The debris fan (now obscured by vegetation) has been measured from aerial photography to measure approximately 4,500m^2 in area.

Due to this specific peat slide morphology, it is possible that future areas of instability may develop on this slope of a similar scale. The recorded run-out distance and proximity of the proposed infrastructure should mean that T08, T10 & T12 are at a low risk of impact from future events. Visual and or topographic control monitoring of the slope on a regular basis however should be considered as the development moves forward to predict any future instability.

Source: ESRI Satellite

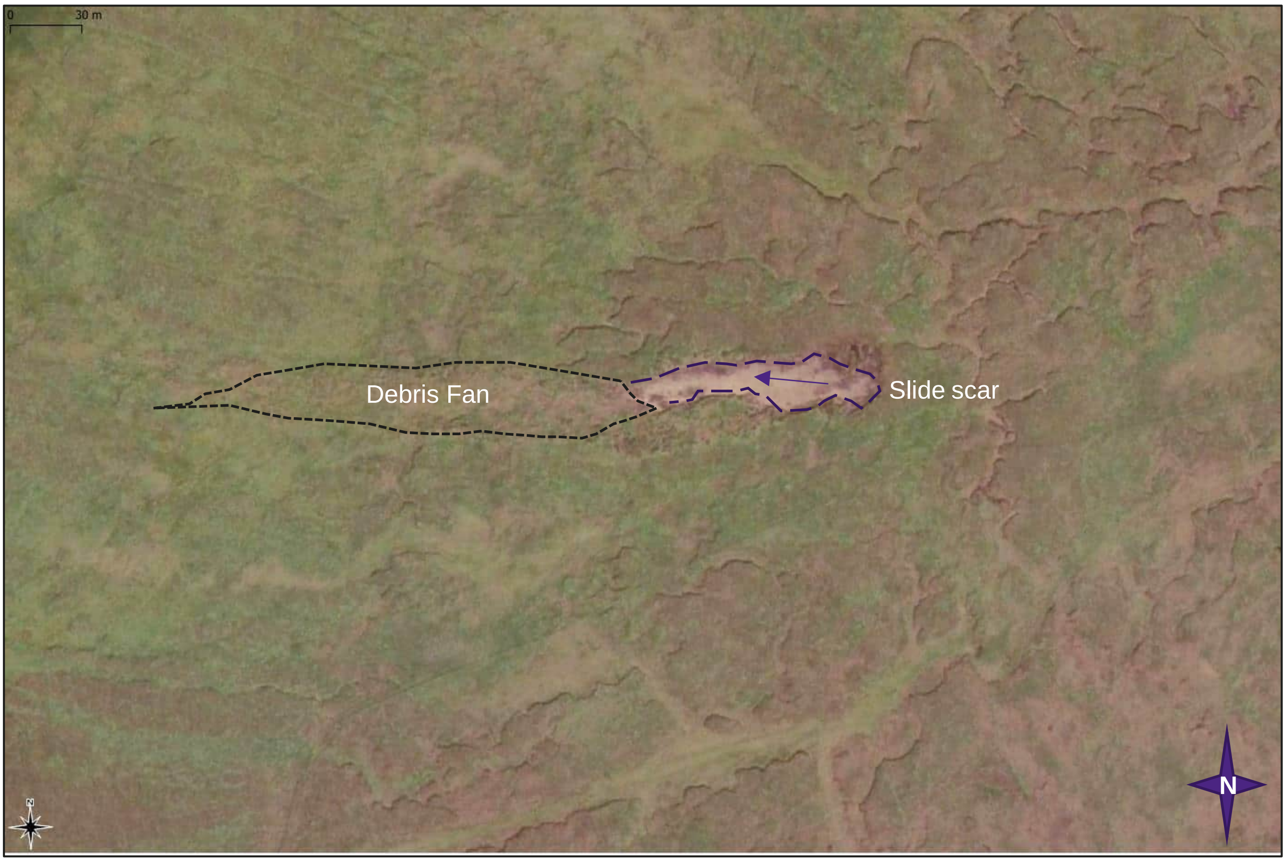


Figure 2.4: Natural Peat Slide Morphology

The review of contemporary aerial photograph images for the past two decades indicates that a moderate scale peat slide occurred on the sloped of Skerry Hill pre-2010. No windfarm infrastructure is positioned within the vicinity of this peat movement. The run-out distance of the peat slide was such that it has not reached the areas of proposed infrastructure. This natural slope instability on the side of Skerry Hill has also been highlighted within Figure A.1, this is not thought likely to change due to the Proposed Development. Extensive networks of peat drainage ditches and extensive peat cutting can be seen all the way back to the earliest available photography in 2002.

Site Reconnaissance

The site reconnaissance included a visual assessment of the superficial ground conditions across the site supplemented with peat probing and hand shear vane testing. Field investigation was carried out in accordance with PHLRAG, (2017). Disturbed samples were also acquired for visual inspection using a Russian peat corer. Samples were classified using the Von Post scale as outlined in Hobbs, (1986). The testing, sampling and probing methodology is summarised as follows:

- Peat probing at 100 m intervals across the full preliminary site boundary (phase 1 survey)
- Peat probing at a minimum of 50 m intervals; three probe locations aligned perpendicular to the track alignment, one at the centre of the track with two further probes spaced 10 m from the centre on either side of the track;
- Peat probing at all turbine bases across a 50x50 m area at 20 m probe spacing;
- Peat probing at crane hard standings and the construction compound and substation extension area at 20 m spacing across the indicative footprint of the infrastructure element;
- Peat coring at each wind turbine location. Peat coring including Von Post humification classifications with depth to inform the Peat Management Plan. Core samples were examined by hand, and samples were submitted to the laboratory for testing for Carbon content of dry peat (% by weight) and soil bulk density (g/cm^3) for input into the Carbon Balance Assessment.
- Hand shear vane testing at wind turbine locations and along access track alignment to establish the approximate range of undrained shear strength values and variability with depth or humification. (Appendix B.1)

Phase 2 detailed peat probing was not undertaken across areas where peat cover was absent and identified to be shallower than 0.50m. The area around Turbine 5, the shallow peat was not suitable for the application of peat probing. Peat probing surveys have been undertaken at open / accessible turbine base infrastructure generally with a 20m spacing.

Figure A.1 appended to this report, indicates interpolated peat depth across site, a total of 1,640 peat probe data points were acquired.

The phase one study found the average peat depth across the site to be 1.0m however this is statistically skewed by localised areas of deeper peat over 3.0m in depth. During the phase 1 survey 62% of the probes across the development were less than 1.0m. The conditions applicable to peat slide are observed to be rare due to shallow peat depths on steeper slopes, and deep peat being found in small localities with relatively shallow gradients.

The deepest areas of peat were recorded in the central areas of the development at the base of Skerry Hill and within saturated areas of heather and bog on the northern slopes of Skerry Hill. The deepest peat encountered on the development was 4.70m although not coincident with any infrastructure footprint.

The interpolated peat depth map (Figure A.1) is appended to this report. The site walkover identified key surface features across the development and determine the wider geomorphological features across the site. The desktop aerial photographic assessment has been used along with field observations to derive the geomorphological map, also appended to this report (Figure A.3).

2.2. Principal Geological Units

Superficial Deposits

Peat is identified across the site as shown in the superficial geology map, (Figure A.6) appended to this report. It is also noted that the GSNI Geoindex 1:10,000 Superficial map identifies Cenozoic Glacial Till, this was not encountered during the field surveys but likely underlies the peat deposits.

Peat forms a relatively shallow blanket deposit of peat across higher plateau areas of the development. The blanket peat has formed deeper deposits in discrete areas across the site often in topographic depressions and near water courses. Due to the high topographic relief across the site; the main control on peat depth is inferred to be the proximity to watercourses.

Smith (2006) describes peat as a form of organic soil and is typically almost entirely comprised of lightly to fully decomposed vegetation. Peat can exist in one of three forms:

- Fibrous – Non plastic with a firm structure and only slightly altered by decomposition;
- Pseudo-fibrous – Peat in this form still has a fibrous appearance but is much softer and more plastic than fibrous peat. The change is due to more prolonged sub-mergence in airless water than to decomposition;
- Amorphous – With this type of peat decomposition has destroyed the original fibrous vegetation structure so that it has virtually become organic clay.

The peat encountered across the development is typically soft to firm dark brown, pseudo-fibrous, plastic, PEAT with little amorphous material due to the low depths encountered. Von Post classes are predominantly H4 - H5. Two photos of typical peat cores taken across the site are presented in Figure 2.5 and Figure 2.6.

Source: Natural Power

Figure 2.5: Peat Core at Turbine T10

Source: Natural Power

Figure 2.6: Peat Core at Turbine T12

15No. peat core samples were submitted to the laboratory for Carbon content (% by weight) and dry soil bulk density testing. The average site wide total carbon content was **31%** and the average dry bulk density was **0.27 Mg/m^3.**

Glacial Till: The thickness of the glacial till deposits is unknown and likely to be variable, although the presence of rock outcrops across the site suggest there are not significant depths of till.

Till is described as unsorted and unstratified drift, generally unconsolidated, deposited directly by and underneath a glacier without subsequent reworking by water from the glacier. It consists of a combination of clays, sand, gravel and boulders varying wildly in size and shape.

Solid Geology

The 1:10,000 scale GSNI Geoindex Interactive Viewer shows the bedrock geology across the site to be predominantly the Lower basalt formation. Typically, extrusive mafic lavas or tuffs, formed approximately 23 to 66 million years ago. The bedrock geology is shown in Figure A.5 at the end of this report.

The BGS Engineering geology viewer describes this rock as:

‘Very strong medium, irregular or columnar jointer generally dark-coloured, fine grained basaltic rock.’

The BGS also indicates that these rock units may weather to ‘very weak clay rich rock and is often associated with interbedded tuffs. It is generally classified as good for foundations when fresh or slightly weathered but can contain areas of highly weathered rock or even palaeosols which will need to be accounted for. Highly weathered rock may be excavated, although other areas may need blasting for fresher material, depending on orientation of discontinuities. The rock can be used as engineering fill, providing care is taken in selection and abstraction, some basalts can be prone to exfoliation after long periods of weathering.

In addition to the Lower Basalt Formation the 1:10,000 scale GSNI Geoindex Interactive Viewer indicated Skerry Hill in the southeast of the site is underlain by the Upper Basalt Formation, with the Interbasaltic Formation between. Several Micro-Gabbro Dykes intersect the site with an approximately north-south orientation. The presence of these was not identified during the field survey.

2.3. Hydrogeology

The plateau basalts underlying the main development are classified by the BGS as a moderately productive aquifer, with yields ranging from 0.5 to 20 L/s with typical rates around 5 to 10 L/s. ground water movement is confined to fractures within the rock, rather than intergranular flow.

The sedimentary rocks under the plateau basalts are classified as highly productive aquifers, which is a regionally important aquifer up to 150m thick. Due to the karstic characteristics of the limestones, the flow is confined to relatively large, fractured pathways allowing yields at springs of up to 32 L/s, yields in boreholes are typically less, around 5 L/s.

Care should be taken when drilling not to puncture this boundary unless absolutely necessary. The bedrock geology shows basalt units underly all infrastructure across the site. The depth of these units is unknown therefore preliminary investigation for limestones, for example geophysical survey may be considered ahead of the intrusive works. Drilling operations should be equipped with materials, tooling, and experienced operators for the potential of artesian water.

2.4. Hydrology, Flooding and Draining

The position of watercourses and their proximity to proposed wind farm infrastructure is a prominent criterion within this peat slide risk assessment. From this standpoint; Figure A.3 appended to this assessment clearly identifies the main surface watercourses across the wind farm development area. The watercourses and how they pertain to peat slide risk is set out clearly in the assessment methodology. Surface water courses are a primary receptor when considering peat slide events and as such the position and proximity from proposed infrastructure is central to this assessment.

There are instances where the proposed turbine location is within 100m of a proposed watercourse however where these watercourses are minor and no off-site run-off is possible, the environmental hazard rating has been reviewed. This has been covered on an individual turbine and infrastructure basis within Table 4.1.

There are other small surface water courses and ephemeral watercourses identified on the site that will require consideration during the construction phase. Of note is the man-made drainage network established to drain the peat bogs, presumably for grazing and peat cutting, these have also been identified on the geomorphological map Figure A.3, however additional unmapped smaller drains will also be present.

2.5. Peat Depth Analysis

Peat Probe Data

In total 1,640 peat probes were acquired across the preliminary site boundary. As can be seen in Figure 2.7 the majority of the peat probes taken were less than 1.0m in depth with 57% of the total probes undertaken being between 0-1.0m in depth. A peat depth interpolation map was generated from the peat data and is appended to this report (Figure A.1).

Source: Natural Power

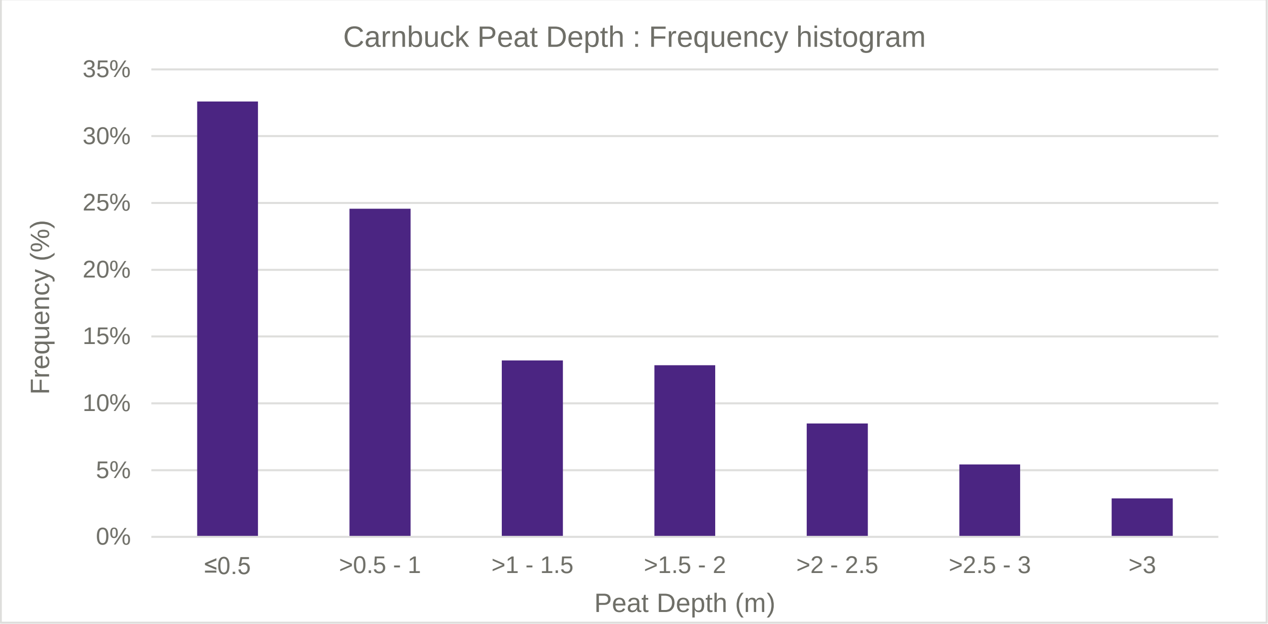


Figure 2.7: **Peat Depth Frequency Phase 1 Surveys**

Peat Depth at Turbine Bases

Table 2.1 summarises peat depths recorded across the proposed wind turbine location, construction compound and substation.

Table 2.1: **Overview of Peat Depths at Turbines and Construction compound**

Depth Range	0 – 1.0m	1.0 – 2.0m	2.0 – 3.0m	> 3.0m
Location	**Peat Depth (m)**	**Peat Depth (m) 50m radius**	**Slope Geometry (Degrees)**	**Comments**
T01	0.30	0.28	6.0	Located on exposed upland
T02	0.40	0.40	6.0	Located on exposed upland
T03	0.50	0.70	5.0	Located on exposed upland
T04	0.40	0.60	5.5	Located on exposed upland
T05	0.20	0.30	9.0	Located on exposed upland
T06	0.80	1.00	6.0	Located on exposed upland
T07	0.40	0.60	5.0	Located on exposed upland
T08	1.10	1.10	6.0	Located on exposed upland
T09	1.60	1.60	6.0	Located on exposed upland

Depth Range	0 – 1.0m	1.0 – 2.0m	2.0 – 3.0m	> 3.0m
Location	**Peat Depth (m)**	**Peat Depth (m) 50m radius**	**Slope Geometry (Degrees)**	**Comments**
T10	0.90	0.70	7.0	Located on exposed upland
T11	1.60	1.70	5.0	Located on exposed upland
T12	0.70	1.0	6.0	Located on exposed upland
Control Building and Energy Storage	1.60	1.60	5.0	Located on exposed upland

Source: Natural Power

Peat Depth along Access Tracks

The peat depth beneath proposed access tracks have a measured site wide average of 1.0 m for new access tracks. Table 2.2 summarises the mean peat depth along discrete sections of the proposed wind farm access tracks. Peat slide risk will be elevated in areas where the access track directly cross the main watercourse.

Table 2.2: Overview of Peat Depths at Proposed Access Tracks

Depth Range	0 – 1.0m	1.0 – 2.0m	2.0 – 3.0m	> 3.0m
Location	**Mean Peat Depth (m)**	**Comments**		
Track 1 T01 track	0.50	Located on short grass field adjacent to the existing Gruig windfarm.		
Track 2 T02 track	0.35	Located on exposed upland moorland.		
Track 3 T03 track	0.40	Located on exposed upland moorland.		
Track 4 T07 track	0.95	Located on exposed upland moorland.		
Track 5 T04 Spur	0.70	Located on exposed upland moorland.		
Track 6 T06 to T05	0.35	Located on exposed upland moorland.		
Track 7 T08 to T06	1.50	Located on exposed upland moorland.		
Track 8 T10 to T08	0.70	Located on exposed upland moorland.		
Track 9 T9 Spur	1.80	Located on exposed upland moorland.		
Track 10 T11 Spur	2.00	Located on exposed upland moorland.		
Track 11 T12 to T10	1.20	Located on exposed upland moorland.		
Track 12 T12 Track	1.50	Located on exposed upland moorland.		

Source: Natural Power

Estimation of Peat Shear Strength

During Phase 2 surveys a 25mm 'Geonor' hand shear vane was used to record the undrained shear strength of the in-situ peat deposits. The hand shear vanes were only undertaken in areas where the peat was deeper than 0.50m and within 50m radius of the proposed turbine location.

The method of determining un-drained shear strength was carried out by inserting a steel vane vertically into the peat deposit. At increasing depth increments a torque head is rotated at the surface which turns the shear vane within the peat deposit. The maximum shearing resistance is recorded on the torque dial. The apparatus is calibrated to the peak un-drained shear strength of the peat. Once the peak un-drained shear strength was determined the shearing resistance of the free turning shear vane was recorded and is representative of the re-moulded un-drained shear strength.

The shear vane has a small surface area compared to the larger scale soil structures within the peat. This scale factor is highlighted as the main limitation of this in-situ test method. The scale effect can lead to an underestimation of peat strength. The hand shear vane therefore provides a preliminary value of peak and re-moulded un-drained shear strength. The peak un-drained shear strength (Cu) ranges from **15kPa** to **47kPa** with a mean value of **26kPa**. The minimum un-drained shear strength (Cu) across the proposed infrastructure location was **11kPa** recorded at wind turbine T11.

Figure 2.8 depicts the peak un-drained shear strength data with depth:

Source: Natural Power

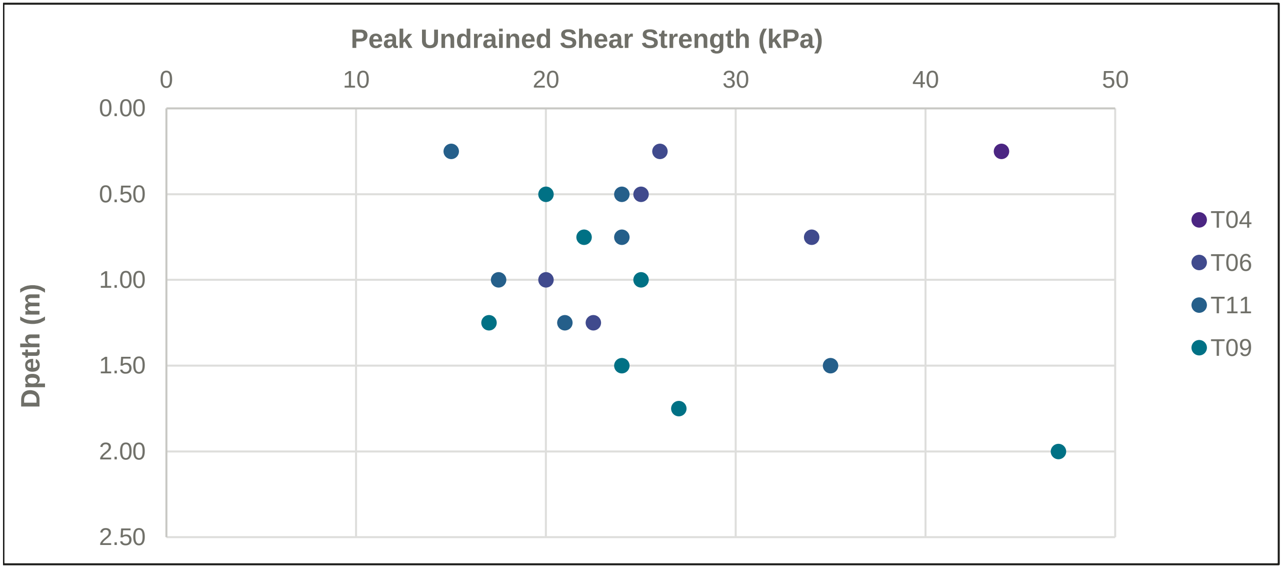


Figure 2.8: Undrained Shear Strength of Peat Soils

Humification of Peat

The material characteristic of the peat and specifically the degree of humification has been recorded at locations where peat was deep enough to obtain a core sample. The peat has been characterised according to the von Post Classification (Von Post & Granland, 1926) Table 2.3 sets out the classification and Table 2.4 presents the classifications at each turbine location where a peat coring was undertaken. Peat coring was not undertaken at T01, T02, T03, T05, T07 and T08 due to shallow depths of peat encountered. Otherwise, peat deposits within 50m of the turbine centre have been sampled.

Table 2.3: Von Post Classification

Degree of Humification	Peat Description
H1	Completely unconverted and mud-free peat which when pressed in the hand only gives off clear water. Plant remains are easily identified.
H2	Practically unconverted and mud free peat which when pressed in the hand gives off almost clear colourless water. Plant remains are still easily identifiable.
H3	Very slightly decomposed or very slightly muddy peat which when pressed in the hand gives off marked muddy water, but no peat substance passes through the fingers. The pressed residue is thickish. Plant remains have lost some of their identifiable features.
H4	Slightly decomposed or slightly muddy peat which when presses in the hand gives off marked muddy water. The pressed residue is thick. Plant remains have lost more of their identifiable features.
H5	Moderately decomposed or muddy peat. Growth structure evident but slightly obliterated. Some amorphous peat substance passes through the fingers when pressed but, mostly muddy water. The pressed residue is very thick.
H6	Moderately decomposed or very muddy peat with indistinct growth structure. When pressed approximately 1/3 of the peat substance passes through the fingers. The remainder extremely thick but with more obvious growth structure than in the case of unpressed peat
H7	Fairly well decomposed or markedly muddy peat but the growth structure can just be seen. When pressed about half the peat substance passes through the fingers. If water is also released this is dark and peaty.
H8	Well decomposed or very muddy peat with very indistinct growth structure. When pressed about 2/3 of the peat substance passes through the fingers and at times a thick liquid. The remainder consists mainly of more resistant fibres and roots.
H9	Practically completely decomposed or mud-like peat in which almost no growth structure is evident. Almost all the peat substance passes through the fingers as a uniform paste when pressed.
H10	Completely decomposed or mud peat where no growth structure can be seen. The entire peat substance passes through the fingers when pressed.

Source: Von Post and Granland (1926)

Table 2.4: Von Post Classification at Turbine Locations

WTG	Von Post Degree of Humification	Description
T04	**H7 / B2**	Firm dark brown plastic pseudo-fibrous PEAT, no water released on squeezing.
T06	**H5 / B3**	Soft to firm brown plastic pseudo-fibrous PEAT, dark brown water released on squeezing.
T09	**H4 / B3**	Soft to firm brown plastic pseudo-fibrous PEAT, brown water released on squeezing.
T10	**H8 / B2**	Firm dark brown plastic amorphous PEAT, no water released on squeezing.
T11	**H4 / B1**	Firm brown plastic pseudo-fibrous PEAT, no water released on squeezing (dry).
T12	**H5 / B2**	Soft dark brown slightly sandy plastic pseudo-fibrous PEAT. Layers of sand and gravel.

Source: Natural Power

3. Stability Analysis of Peat Slopes

3.1. Introduction

Assessing the desk study information, updated site layout and survey data; a preliminary infinite slope stability analysis and peat slide risk assessment has been undertaken. Slope stability was assessed at each turbine location using slope angle measurements, peat depth, and the recorded undrained shear strength. This assessment is semiquantitative drawing on both qualitative assumptions and numerical parameters.

For each proposed turbine location, the recorded peak undrained shear strength values have been input into the infinite slope model in order to calculate the potential factor of safety against peat slide.

3.2. Undrained Slope Analysis

The current baseline peat condition is assumed to be in a state of equilibrium at the infrastructure locations. Surcharge loading has been considered to demonstrate the effect of construction works proposed as part of the Development. Figure A.3 depicts geomorphological features mapped across the site and is based on site reconnaissance visits and aerial imagery. The historical peat slide described suggests that there is natural instability on the slopes of Skerry Hill however this is not currently affecting the proposed infrastructure.

As previously discussed, it should be acknowledged that the in-situ measurement of undrained shear strength of peat is preliminary and shall be taken with caution, due to scale effects of shear vane testing.

The factor of safety (FoS) against sliding has been calculated at the centre of proposed turbine locations. Table 3.1 below summarises the results.

Table 3.1: Infinite Slope Analysis Wind Turbines

Location	Average Peak Shear Strength (kPa)	Unit Weight, y (kN/m^3)	Depth, z (m)	Slope Geometry (β°)	**FoS = Cu/ yz** sin **β** cos **β**	**FoS = Cu/ ((yz)+20)** sin **β** cos **β**
					No applied load	**Surcharge 20kPa**
T01	15*	10	0.30	6	**48.1**	**6.3**
T02	15*	10	0.40	6	**36.1**	**6.0**
T03	15*	10	0.50	5	**34.6**	**6.9**
T04	44	10	0.40	5.5	**105.8**	**17.6**
T05	15*	10	0.20	9	**48.5**	**4.4**
T06	20	10	0.80	6	**24.0**	**6.9**
T07	15*	10	0.40	5	**43.2**	**7.2**
T08	15*	10	1.10	6	**13.1**	**4.7**
T09	17	10	1.60	6	**10.2**	**4.5**
T10	15*	10	0.90	7	**13.8**	**4.3**
T11	15	10	1.60	5	**10.8**	**4.8**
T12	15*	10	0.70	6	**20.6**	**5.3**

** Shallow Depths of peat at T01, T02. T03, T05, T07, T08, T10 and T12 meant a reliable shear vane field test was not possible, therefore conservative shear strength values taken from guidance literature used in Table 1.3 and other conservative shear vane results from site, have been used to infer an estimated shear strength at these locations (15kPa).*

Source: Natural Power

The factor of safety across the site has been mapped on Figure A.8. This is a lumped factor of safety and is calculated to inform the semi quantitative risk assessment. Detailed numerical slope stability analysis adopting national design codes should be applied following intrusive geotechnical investigations and to inform the detailed design of the infrastructure.

3.3. Discussion of Stability Analysis

The preliminary stability analysis indicates no potential for translational peat slide at proposed turbine locations under current equilibrium or modelled surcharge loading conditions.

In the absence of more detailed sub-surface data, the surface slope angle has been used as a reference to the likely slope surface angle at the base of the peat in the analysis. Advanced in-situ test methods should be considered as part of a detailed site investigation phase usually carried out post-consent. This may adopt large size shear vane apparatus which allows a greater volume of peat to be tested. This may offer more representative results of mass behaviour and reduce the smaller scale fabric effects within the peat.

Un-disturbed sampling with thin-walled samplers will allow for laboratory testing to be undertaken. However, issues of sample preservation and disturbance are important factors to address. Such methods are generally suited to deep peat deposits (i.e.>2m) and require plant mobilisation. The potential of disturbing sensitive peat deposits during pre-construction survey access should be considered during future phases of work.

Wind Turbines: FoS values for the turbine locations, when allowing for a 20kPa surcharge load have been derived. The lowest FoS was calculated was **4.3** for proposed turbine **T10**. The FoS values allowing for a 20kPa surcharge load are high. It should be reiterated that the natural slope condition has been calculated to be stable and was observed to be so around the wind turbine locations during the field survey.

The FoS accounts for a 20 kPa surcharge representing scenarios at infrastructure such as: temporary storage areas where peat can be excavated out and temporary stockpiled. The Peat Management Plan (PMP) accounts mitigation measures for peat stockpiling. Slope stability assessments shall be carried out further during design phase for site tracks, hardstands and other relevant structures ensuring the proposed design results safe, stable and environmentally compliant. It is Natural Power’s view that, if during design phase structures are proposed (i.e., floating tracks) additional numerical stability assessment shall be carried out.

Access tracks: The average peat depths across the new access tracks is 1.00m. The majority of proposed access track is within low-risk areas. It is likely much the access track will be constructed of the floating construction type. Areas of track with an elevated risk of peat slide instability have been highlighted within Table 2.2 and can be seen on Figure A.7 this is primarily attributed to being near or crossing a watercourse.

4. Peat Slide Risk Assessment

4.1. Risk Assessment of Peat Failure

The potential environmental impact (adverse consequence) of a peat slide triggered by proposed wind farm infrastructure is obtained from assessing the proximity to the main watercourse on site, see Figure A.4 appended to this report. The peat stability assessment also includes consideration for the potential impact (adverse consequence) to the proposed development infrastructure (scored 1 – 5) from peat slide (See Table 1.5). Assessment of the proposed layout with respect to peat failure risk zones was considered. If for example infrastructure was down-slope of a potential failure site, the development impact scale is increased. This is based on a subjective assessment of a resultant peat slide inundating infrastructure and rendering damage. The time and cost for the project would be increased due to the requirement for remediation.

Probability values were assessed for combined contributory factors recorded across the turbine locations and added together values >1 (See Table 4.1). The highest impact rating (either development infrastructure or environmental) is then combined with the cumulative effects of the contributory factors. This is to convey the overall risk rank.

Risk rankings for the proposed turbine positions are presented in Table 4.2. The risk ranking map is appended to this report (Figure A.7), Figure A.7 presents the peat slide risk assessment prior to any mitigation methods. The risk map provides a representation of the risk zonation across the site and includes all infrastructure elements. The map is based on a development wide GIS analysis and should not be viewed in isolation without the narrative of this report. Figure A.8 should also be viewed in conjunction with the risk mapping.

An indicative residual risk rating is also provided assuming implementation of appropriate mitigation measures. Further detail of the risk assessment is highlighted within the preliminary geotechnical risk register presented in Table 4.3.

Table 4.1: **Hazard Ranking Proposed Turbine Location**

	Adverse Consequence				
WTG ID	Development Infrastructure	Environmental	Contributary Factors (Probability/Exposure)		Risk Ranking
T01	1	1	Peat Depth (Mean = 0.30m)	1	**Risk = 1 x 3 = 3 (Negligible – Not Peat)**
			Slope Angle (6°)	3	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	

T01 Location – Google Aerial Imagery – 1:5000 Scale

Location Specific Mitigation:

Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should remain negligible given the absence of peat at this location.

Minor ephemeral streams can be seen around the turbine base however these are not believed to have any potential for off-site movement of peat, hence have not been considered when evaluating the environmental hazard.

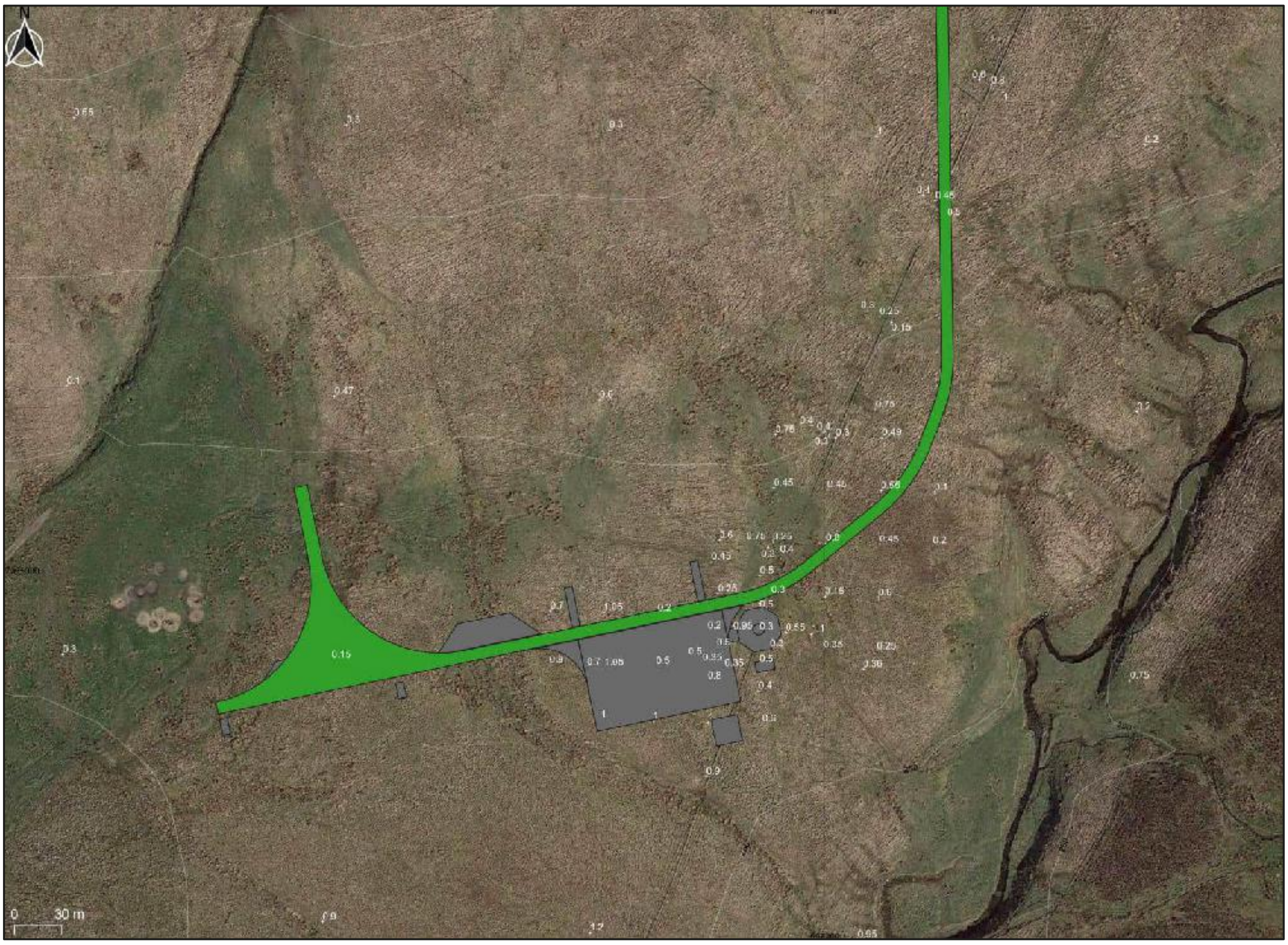
	Adverse Consequence				
WTG ID	Development Infrastructure	Environmental	Contributory Factors (Probability/Exposure)		Risk Ranking
T02	1	1	Peat Depth (Mean = 0.40m)	1	**Risk = 1 x 3 = 3 (Negligible – Not Peat)**
			Slope Angle (<6°)	3	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	

T02 Location – Google Aerial Imagery – 1:5000 Scale

Location Specific Mitigation:

Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should remain negligible given the absence of peat at this location.

WTG ID	Adverse Consequence		Contributory Factors (Probability/Exposure)		Risk Ranking
	Development Infrastructure	Environmental			
T03	1	3	Peat Depth (Mean = 0.50m)	1	**Risk = 3 x 3 = 9 (Low)**
			Slope Angle (5°)	3	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	



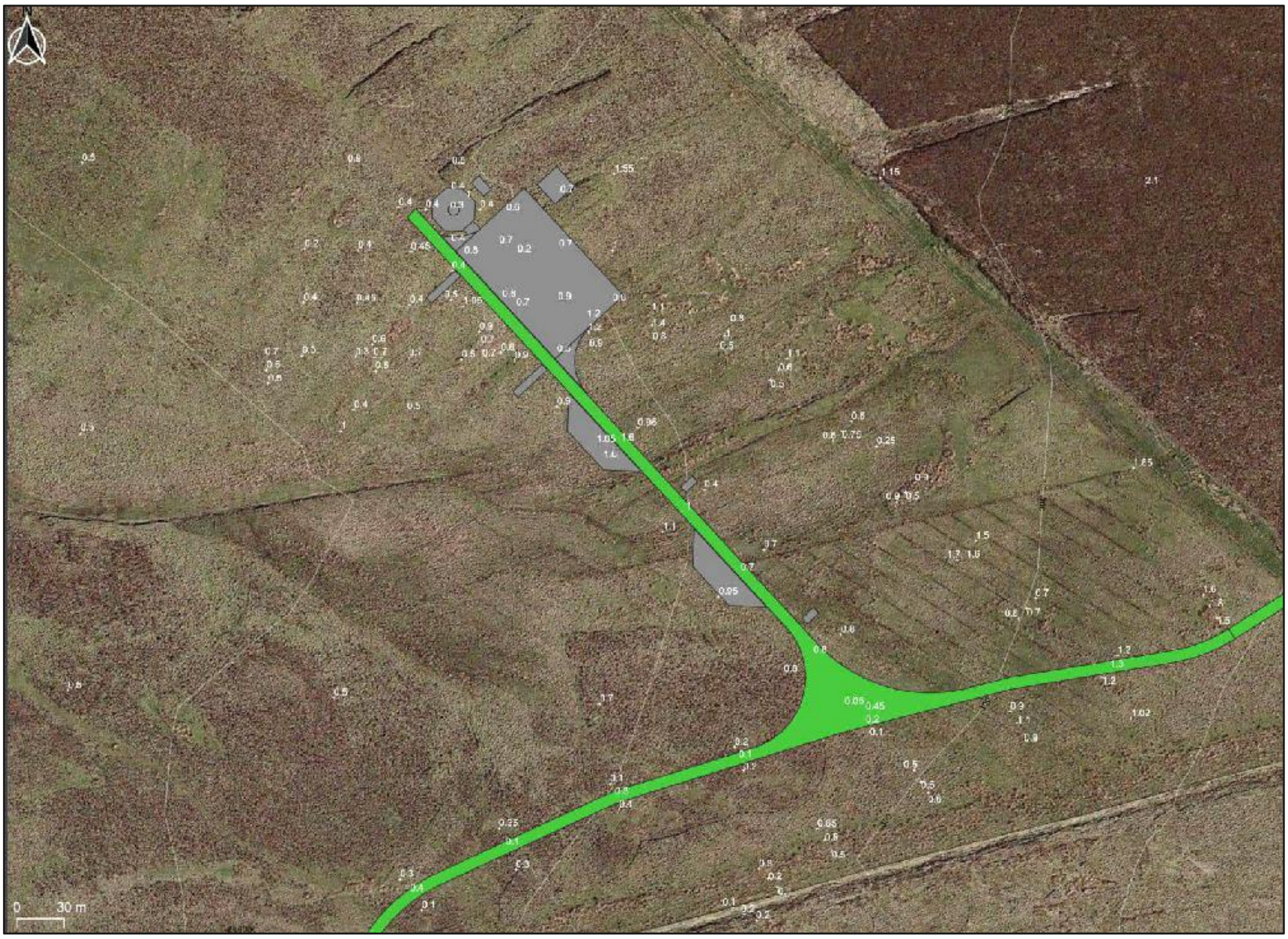
T03 Location – Google Aerial Imagery – 1:5000 Scale

Elevated Environmental factor due to the close proximity to main on-site water course.

Location Specific Mitigation:

Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should remain negligible given the absence of continuous deep peat at this location.

WTG ID	Adverse Consequence		Contributary Factors (Probability/Exposure)		Risk Ranking
	Development Infrastructure	Environmental			
T04	1	1	Peat Depth (Mean = 0.40m)	1	**Risk = 1 x (3+2) = 5 (Low)**
			Slope Angle (5.5°)	3	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	2	



T04 Location – Google Aerial Imagery – 1:5000 Scale

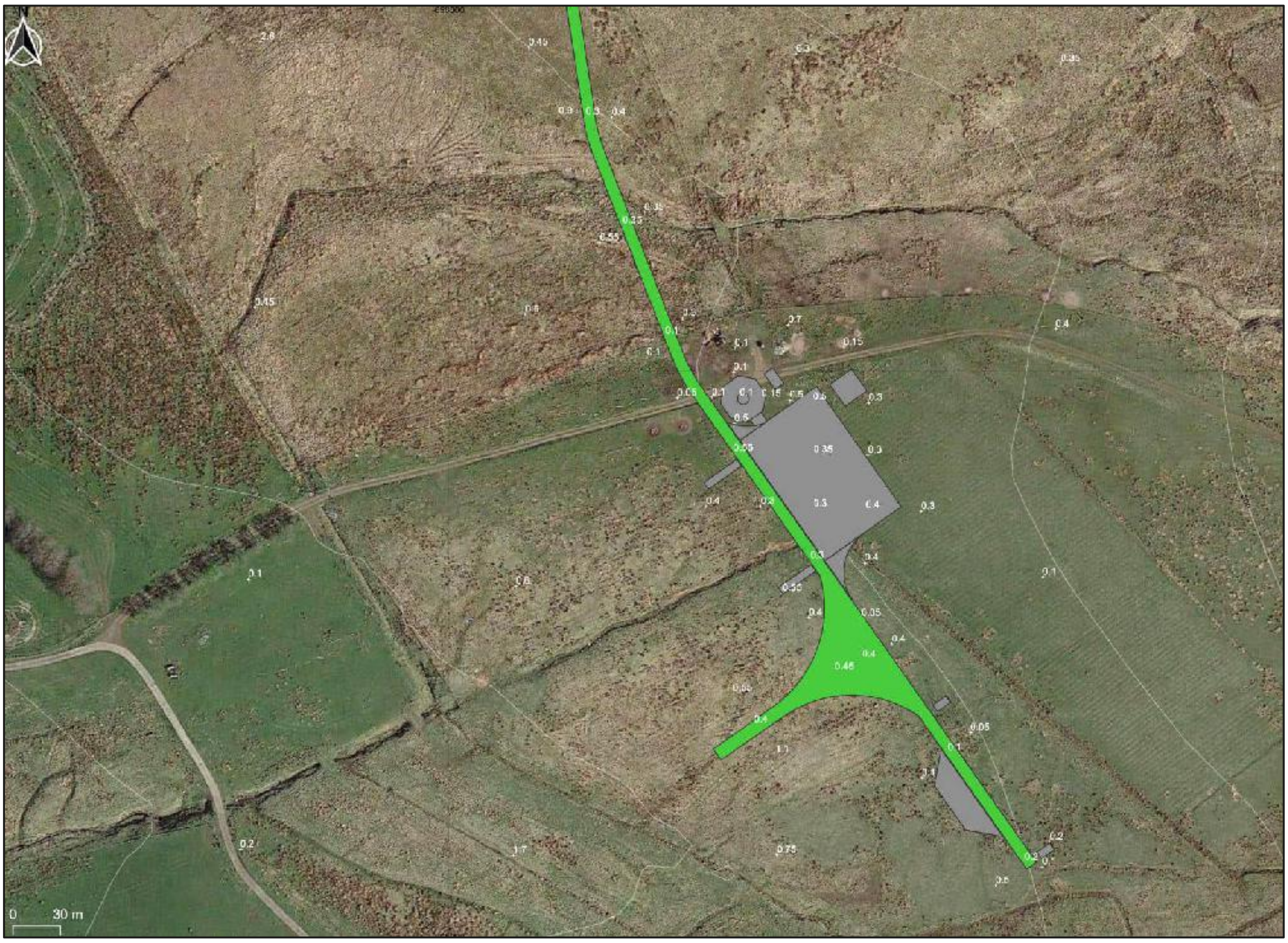
Adjacent watercourse is minor and sufficiently proximal from the main watercourse on site. This combined with the shallow peat depth which has resulted in low risk.

Location Specific Mitigation:

Drainage ditches are indicated to be present beneath the proposed development. A higher confidence in the geometry of the basal peat interface and understanding of the geotechnical properties of the underlying superficial deposits will allow for more confidence in the risk ranking.

Drainage measures should be implemented to re-route any up-slope water supplies and ensure outflows from the infrastructure is not concentrated onto the downslope peat deposits.

WTG ID	Adverse Consequence		Contributory Factors (Probability/Exposure)		Risk Ranking
	Development Infrastructure	Environmental			
T05	1	1	Peat Depth (Mean = 0.20m)	1	**Risk = 1 x (3) = 3 (Negligible – Not on Peat)**
			Slope Angle (9°)	3	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	



T05 Location – Google Aerial Imagery – 1:5000 Scale

Location Specific Mitigation:

Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. The risk should remain negligible given the absence of peat at this location.

WTG ID	Adverse Consequence		Contributory Factors (Probability/Exposure)		Risk Ranking
	Development Infrastructure	Environmental			
T06	1	1	Peat Depth (Mean = 0.80m)	3	**Risk = 1 x (3+3) = 6 (Low)**
			Slope Angle (6°)	3	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	

T06 Location – Google Aerial Imagery – 1:2,500 Scale

Location Specific Mitigation:

Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. A higher confidence in the geometry of the basal peat interface and understanding of the geotechnical properties of the underlying superficial deposits will allow for increased confidence in the risk ranking.

The slope angle and peat depth are contributary factors at this site. No temporary storage of peat on the slopes around the turbine base.

	Adverse Consequence				
WTG ID	Development Infrastructure	Environmental	Contributary Factors (Probability/Exposure)		Risk Ranking
T07	1	2	Peat Depth (Mean = 0.40m)	1	**Risk = 2 x (1) = 2 (Negligible)**
			Slope Angle (3°)	1	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	

T07 Location – Google Aerial Imagery – 1:5000 Scale

Location Specific Mitigation:

Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. A higher confidence in the geometry of the basal peat interface and understanding of the geotechnical properties of the underlying superficial deposits will allow for more confidence in the risk ranking.

No temporary storage of any peat on the steeper slopes around the turbine base. Drainage measures should not direct or concentrate down slope flow into the peat deposits.

WTG ID	Adverse Consequence		Contributory Factors (Probability/Exposure)		Risk Ranking
	Development Infrastructure	Environmental			
T08	1	1	Peat Depth (Mean = 1.10m)	5	Risk = 1 x (5+3+2) = 10 (Low)
			Slope Angle (6°)	3	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	2	

T08 Location – Google Aerial Imagery – 1:5000 Scale

Adjacent watercourse is minor and proximal from main on-site watercourse. Location is down slope from existing slope instability. Location has not been affected by debris flow which has run-out up slope. Periodic visual and topographical monitoring should be considered at this location to detect and predict any further up-slope movements.

Location Specific Mitigation:

A higher confidence in the geometry of the basal peat interface and understanding of the geotechnical properties of the underlying superficial deposits will allow for more confidence in the risk ranking. Drainage measures should be implemented to re-route any up-slope water flow and ensure outflows from the infrastructure is not concentrated onto the downslope peat deposits. No temporary storage of peat at this location.

WTG ID	Adverse Consequence		Contributory Factors (Probability/Exposure)		Risk Ranking
	Development Infrastructure	Environmental			
T09	1	2	Peat Depth (Mean = 1.60m)	5	**Risk = 2 x (5) = 10 (Low)**
			Slope Angle (3°)	1	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	

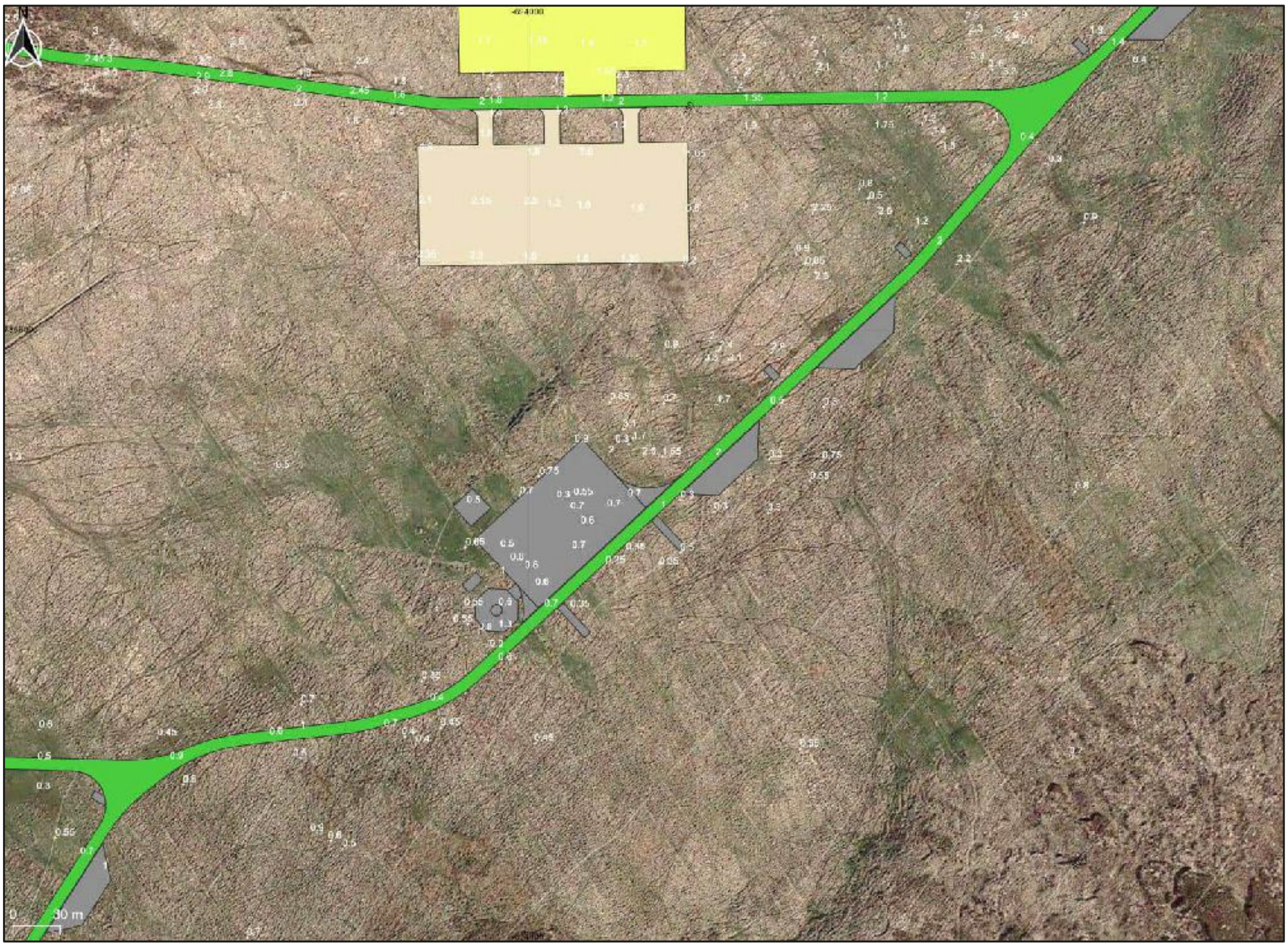
T09 Location – Google Aerial Imagery – 1:2,500 Scale

Elevated Environmental factor due to the proximity to main water course.

Location Specific Mitigation:

Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. A higher confidence in the geometry of the basal peat interface and understanding of the geotechnical properties of the underlying superficial deposits will allow for more confidence in the risk ranking. No temporary storage of peat at this location.

	Adverse Consequence				
WTG ID	**Development Infrastructure**	**Environmental**	**Contributary Factors (Probability/Exposure)**		**Risk Ranking**
T10	1	1	Peat Depth (Mean = 0.90m)	3	**Risk = 1 x (3+3+2) = 8 (Low)**
			Slope Angle (7°)	3	
			FoS (Min = Cu$_{min}$ > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	2	



T10 Location – Google Aerial Imagery – 1:2,500 Scale

Location Specific Mitigation:

Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. A higher confidence in the geometry of the basal peat interface and understanding of the geotechnical properties of the underlying superficial deposits will allow for more confidence in the risk ranking.

Periodic visual and topographical monitoring should be considered at this location to detect and predict any further up-slope movements.

WTG ID	Adverse Consequence		Contributory Factors (Probability/Exposure)		Risk Ranking
	Development Infrastructure	Environmental			
T11	1	1	Peat Depth (Mean = 1.60m)	5	**Risk = 1 x (5+3) = 8 (Low)**
			Slope Angle (5°)	3	
			FoS (Min = $\mathrm{Cu}_{\mathrm{min}}$ > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	

T11 Location – Google Aerial Imagery – 1:2,500 Scale

Elevated Environmental factor due to the proximity to a water course however the watercourse is minor and distant from main on-site watercourse.

Location Specific Mitigation:

Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. A higher confidence in the geometry of the basal peat interface and understanding of the geotechnical properties of the underlying superficial deposits will allow for more confidence in the risk ranking. No temporary storage of peat at this location.

	Adverse Consequence				
WTG ID	Development Infrastructure	Environmental	Contributary Factors (Probability/Exposure)		Risk Ranking
T12	1	1	Peat Depth (Mean = 0.70m)	3	**Risk = 1 x (3+3+2) = 8 (Low)**
			Slope Angle (6°)	3	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	2	
			Previous Instability	1	
			Land Management	2	

T12 – Google Aerial Imagery – 1:2,500 Scale

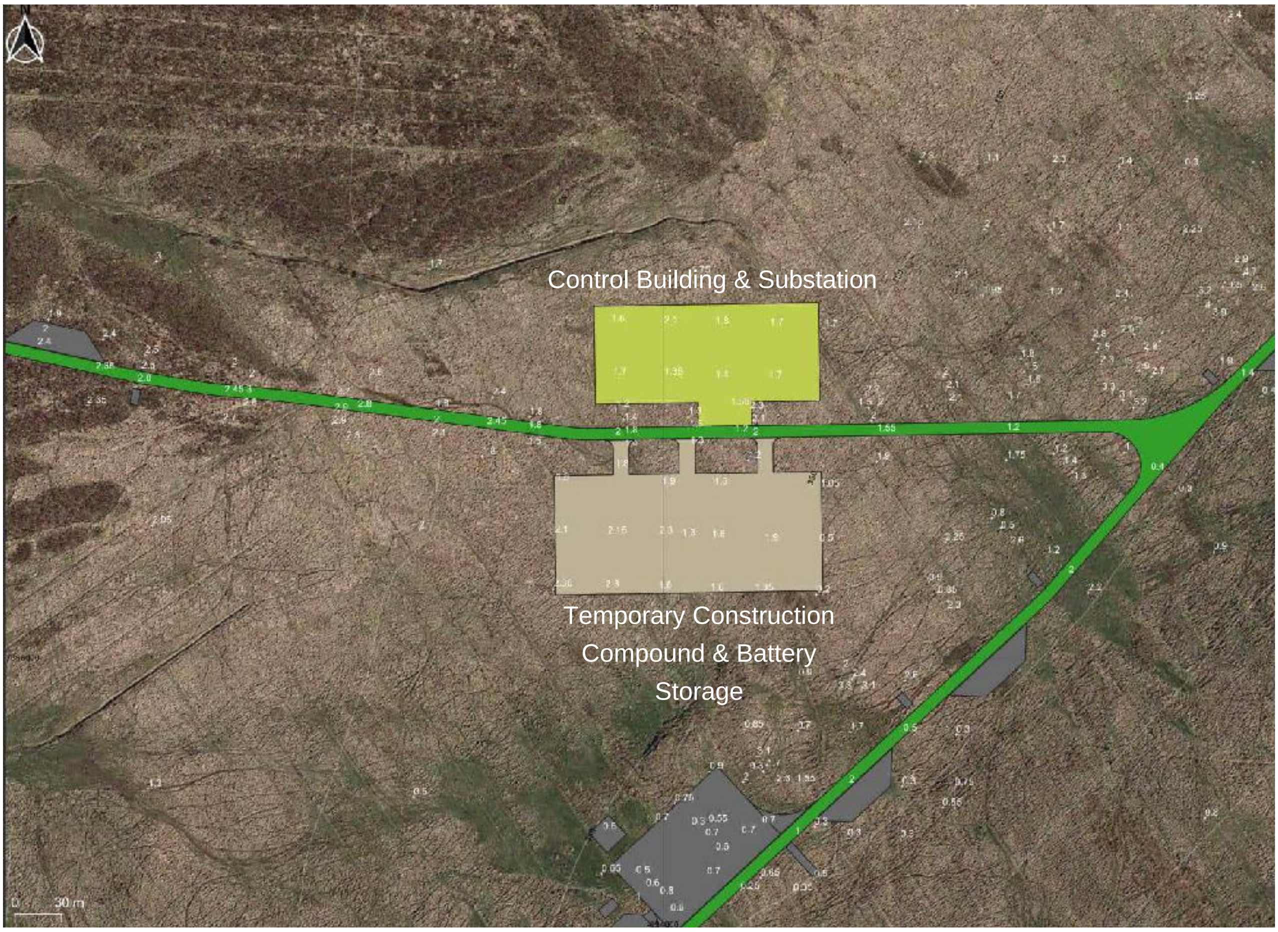
Location Specific Mitigation:

Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. A higher confidence in the geometry of the basal peat interface and understanding of the geotechnical properties of the underlying superficial deposits will allow for more confidence in the risk ranking.

Drainage measures should be implemented to re-route any up-slope water supplies and ensure outflows from the infrastructure is not concentrated onto the downslope peat deposits.

Periodic visual and topographical monitoring should be considered at this location to detect and predict any further up-slope movements.

WTG ID	Adverse Consequence		Contributary Factors (Probability/Exposure)		Risk Ranking
	Development Infrastructure	Environmental			
Control Building and Energy Storage	1	1	Peat Depth (Mean = 1.60m)	5	**Risk = 1 x (5+3+2) = 10 (Low)**
			Slope Angle (5°)	3	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	2	



Control Building and Energy Storage Location – Google Aerial Imagery – 1:5000 Scale

Location Specific Mitigation:

Following further intrusive site investigation post-consent, the risk ranking should be re-evaluated. A higher confidence in the geometry of the basal peat interface and understanding of the geotechnical properties of the underlying superficial deposits will allow for more confidence in the risk ranking.

No temporary storage of peat at this location.

Source: Natural Power

4.1.1. Turbine Bases

Table 4.2 below summarises the risk assessment outcome and hazard ranking assignments for each turbine location. The principal contributory factors and impact scales used to derive these assignments are also stated.

Table 4.2: Risk Assessment Outcome and Hazard Ranking Assignment

Turbine ID	Risk Ranking Baseline	Principal Contributory Factors in Risk Assessment	Risk Ranking with Targeted Mitigation
T01	**(3) Negligible**	Slope angle	**Negligible**
T02	**(3) Negligible**	Slope Angle	**Negligible**
T03	**(9) Low**	Environmental, Slope Angle	**Negligible**
T04	**(5) Low**	Slope Angle, Land Management	**Negligible**
T05	**(3) Negligible**	Slope Angle	**Negligible**
T06	**(8) Low**	Peat Depth, Slope Angle	**Negligible**
T07	**(2) Negligible**	Peat Depth, Slope Angle,	**Negligible**
T08	**(8) Low**	Peat Depth, Slope Angle, Land Management	**Low**
T09	**(8) Low**	Peat Depth, Slope Angle,	**Low**
T10	**(9) Low**	Peat Depth, Slope Angle, Land Management	**Low**
T11	**(8) Low**	Peat Depth, Slope Angle, Environmental	**Low**
T12	**(7) Low**	Slope Angle, Hydrology, Land Management	**Low**
Substation and Construction Compound	**(10) Low**	Peat Depth, Slope Angle, Land Management	**Negligible**

Source: Natural Power

The risk assessment reflects the probability of peat material entering the surface water course and being entrained to an offsite receptor without any mitigation. The wider geomorphological assessment and evidence from recorded peat depths at infrastructure locations would indicate that a large-scale translational mass movement of peat deposits is unlikely. Natural instability is present across Skerry Hill and should be monitored however. Areas close to watercourses would therefore be the focus of mitigation measures set out within the geotechnical risk register.

4.1.2. Access Tracks

In addition to the turbine bases the sections of track have also been reviewed across the site. The highest risk areas would be where track alignments cross the watercourses and the steep slopes around the watercourse. The areas of highest risk can be seen in Figure A.7, these sections are primarily the spur to T05, the spur to T04 and the long track between T06 and T08.

4.2. Preliminary Geotechnical Risk Register

A preliminary geotechnical Risk Register has been produced for each proposed turbine location (Table 4.3) The risk register is intended for use by the Applicant and future Principal Contractor appointed for the construction of the proposed infrastructure. A complete geotechnical risk register should be utilised throughout the construction phase and amended accordingly as new information is received. Key mitigation control measures are highlighted in bold for each infrastructure.

Table 4.3: Preliminary Geotechnical Risk Register

Hazard	Cause	Location	Consequence
Peat Landslide / Bog Burst / Peat Flow	High rainfall, and increased surface water infiltration leading to build up of pore water pressure	**Site Wide**	Instability of peat deposits and underlying superficial deposits around earthworks; Contamination of natural watercourses and damage to hydrological systems; Harm to personnel and damage to plant / equipment; Destruction of built infrastructure
Mitigation	Due consideration given to prevailing ground and weather condition when scheduling construction works. I.e. avoid opening new excavation during heavy precipitation and ensure sufficient drainage measures are in place to support construction activities. Ensure a contingency is in place to concentrate on more suitable construction activities during wet weather. The drainage design should be such that its construction is in sequence with providing necessary drainage to new areas of excavation and construction in advance of works. I.e. ensure cut-off ditches are in place prior to opening new excavation. The drainage design should as far as practicable preserve the natural hydrological regime and should not inundate areas with run-off which were previously not subjected to such affects. Monitoring weather forecast with site specific weather station; Monitoring (visual) regular site inspection to detect early indications of ground movement (tension cracks, groundwater issues).		
Peat Landslide / Bog Burst / Peat Flow	Concentrated loads placed at the top of slope system or on marginally stable peat deposits	**Site Wide** **T08** **T11**	Contamination of natural watercourses and damage to hydrological systems; Rapid ground movement and mobilisation of material down slope of construction operations; Harm to personnel, plant and equipment; Destruction of temporary or permanent construction works;
Mitigation	At these locations, robust and strict controls on the phasing and pace of construction must be in place. This would be most effectively managed through the CMS. Plant operatives should be briefed in detail regarding the side-casting and stockpiling of materials. Higher risk areas particularly at T06 and T08 should be demarked by high visibility ticker tape or similar as a warning not to stockpile any materials in the deeper peat areas. Ensure the peat depth contour mapping is available and has a high visibility during construction; A programme of frequent inspections should be implemented during excavation and access track construction works. This should be carried out by suitably experienced and qualified personnel. Where stockpiles are placed in suitable areas, these should be closely monitored through the use of high accuracy GPS level and visual survey.		
Peat Landslide / Bog Burst / Peat Flow	Increased subsurface groundwater flow and 'piping' failure beneath natural peat deposits, temporary and permanent earthworks	**Site Wide** **T10** **T08**	Localised instability associated with temporary and permanent earthworks; Triggering of mass movement of peat material down slope causing harm to personnel, plant and equipment;
Mitigation	Ensure geotechnical design prevents blockages of groundwater flow. This may be achieved through the use of free draining fills and ensuring temporary and permanent earthworks do not cause the build-up of groundwater pressures.		

Hazard	Cause	Location	Consequence
	A programme of geotechnical inspections should be implemented throughout construction phase. Ensuring focus extends beyond immediate areas of construction, both up-slope and down-slope to detect any unforeseen effects on stability		
Bearing Capacity Failure (Peat Surface)	Increased loading of low shear strength deep peat deposits	**Site Wide**	Localised instability and settlement associated with temporary and permanent earthworks; Triggering of mass movement of peat material down slope causing harm to personnel, plant and equipment; Contamination of natural watercourses and damage to hydrological systems from peat material mobilised down slope;
Mitigation	Due consideration given to the prevailing ground and weather conditions when scheduling site works Ensure detailed peat depth contour plan to be used in construction planning and design; Use of appropriate plant machinery (low ground pressure and long reach to avoid over loading peat deposits) A programme of geotechnical inspections will be implemented during excavation works Geotechnical monitoring post-construction		
Peat Failure	Mass movement of temporary storage mounds and bunds	**Site Wide** **Construction Compound** **T08** **T11**	Localised instability and settlement associated with temporary and permanent earthworks Triggering of mass movement of peat material down slope causing harm to personnel, plant and equipment;
Mitigation	Storage site selection and stockpile design by a suitably qualified and experienced geotechnical engineer; Routine maintenance and inspection of peat storage mounds		
Creep, long term settlement of structures	Tracks or hardstand founded on peat and or poor or variable foundation soils	**Site Wide**	Ongoing settlement and damage of infrastructure, e.g. damage to access track running surface.
Mitigation	Contingency of routine maintenance of infrastructure and drainage elements to ensure longer term issues do not cause a build-up of effects leading to higher level consequences e.g. larger scale instability		

Source: Natural Power

5. Summary of Construction Risks and Management

5.1. Construction Risks

The factors which influence natural and induced peat slope failures were discussed in detail during the introduction of this report. The following construction related factors are highlighted for consideration.

- Movement can occur following over-loading of peat slopes, e.g. by placement of fill, stockpiling and end-tipping directly onto peat slopes;
- Suitability of drainage measures and the prevailing groundwater conditions are also key factors to consider during construction. Increasing pore water pressures within peat deposits decreases the stability of a slope;
- In extreme events, peat can act as a viscous fluid and travel over very shallow slopes. The re-working or excessive handling of peat can reduce the shear strength to residual levels and hence lead to 'liquid' peat behaviour;
- The rate of construction can have a major influence on the stability of peat land environments. Rapid loading and limited time for excess pore pressure dissipation can also decrease the stability state of peat slopes;
- Excavation across a side slope, a convex slope / break in slope can induce peat failure;

The consequence of peat failure at the development may result in several negative impacts; external public infrastructure has been excluded due to the remote nature of the proposed development. Therefore, the most significant but unlikely impact is death or injury to site personnel. More likely is disruption to the proposed infrastructure through infrastructure damage leading to time and cost impacts on the development. Impact through degradation of the hydrological and peat land environment has been considered. Impacts such as the contamination of water courses are considered as the Aghanagerrah River Bog running through the middle of the site is a priority local wildlife site.

5.2. General Risk Management Recommendations

The following recommendations, when incorporated into the design of the project will assist in the management of the risk from peat instability.

- The use of experienced and competent construction contractors;
- Detailed monitoring programme of geomorphology and hydrology across the critical areas as part of the construction management; this should be focussed across all infrastructure elements, as well as areas with high Environmental Impact.
- Refine the environmentally sensitive zones across the site and integrate these areas into the detailed Construction Method Statement (CMS);
- Apply conservative design parameters across the elevated hazard zones (i.e. where undrained shear strengths are low and there is shallow groundwater interaction);
- Produce a robust drainage design which preserves the natural hydrological regime across the development. The control of silt and suspended solids should be carefully planned to avoid detrimental environmental effects. All drainage discharges should be under consent from the relevant environmental agency control unit and performed in an environmentally compliant manner;
- A documented procedure should be in place and rapid reaction strategy in place prior to the commencement of construction on peatland. This strategy should be easily enacted should signs of peat movement be recorded across the development. This approach requires periodic and continued monitoring of the construction process by a suitably qualified geotechnical engineer;
- A detailed Construction Method Statement (CMS) should incorporate the conclusions of the peat stability report and continuously update the assessment and develop appropriate mitigations to respond to the peat slide risk;

- The Geotechnical Risk Register should be maintained as a 'live' document and updated and amended as required throughout the pre-construction and construction phase of development;

The proposed turbine layout design has been arrived at through an iterative design process. The design has included consideration across a wider set of environmental constraints. As part of this process specific consideration including steepness of terrain, peat depth and associated environmental sensitivities has been given. The proposed layout has emerged from design process during which technical requirements; environmental and visual considerations have been identified and addressed. During this process the Proposed Development has sought to avoid steep terrain and areas of deep peat where practicable. If significant layout changes are implemented it is recommended that the peat stability assessment is updated accordingly.

5.3. Conclusions

It should be noted that where peat probes indicate shallow depths 0.10m to 0.40m that the deposits are likely to be composed of a topsoil and subsoil.

The mean un-drained shear strength determined across the development is 29kPa.

The risk ratings are a combination of the likelihood and the effect of a peat landslide event. With increased proximity to watercourses the effect or exposure of such an event is vastly increased as watercourses act as a sensitive off-site receptor. This consequently increases the risk ranking for these locations but is not indicative of conditions conducive to peat instability on this site. Applied mitigations and appropriate control measures including best practice construction shall ensure the residual hazard rankings are insignificant across these areas. Only the main on-site watercourse has factored into this assessment with minor and ephemeral watercourses removed in order not to overstate the stability risks at the proposed infrastructure locations.

The derived risk rankings are based on the risk of peat failure occurring without appropriate mitigation and control measures during construction. It should be highlighted that through geotechnical risk management, strict construction management and implementation of relevant control measures shall reduce the risk of peat failure across the development to negligible / low levels.

The qualitative risk assessment should be reviewed prior to construction and further refined as part of future intrusive ground investigation. When more accurate data is available at the pre-construction stage the analysis should be reviewed and updated accordingly. The respective risk ratings should be central to development of the Construction Method Statement (CMS) in order to ensure that extra care is taken with respect to the contributory factors at the time of the construction process and that geotechnical risk is adequately managed.

5.4. Recommendations

The preliminary geotechnical risk register for peat at the development cites key control measures which are required to reduce the risk of peat slide to residual levels. These control measures apply to the infrastructure locations. However, there should be wider consideration of these measures across all areas of the proposed development which may be influenced by the proposed construction. This is critical where infrastructure may impact terrain and slope conditions beyond the proposed working areas.

- A detailed intrusive ground investigation should be carried out (post-consent) and as part of the pre-construction phase of development. This investigation should seek to further characterise the peat deposits with emphasis on, advanced in-situ shear strength testing and targeted undisturbed sampling and laboratory testing. All peat samples recovered should be classified in accordance with the Von Post system, (Hobbs, 1986) and current British and Eurocode standards for site investigation.
- Groundwater level information should be collated as part of any future ground investigation;
- The results of a detailed ground investigation should be assessed with respect to refining the peat stability assessment at all infrastructure locations. All pertinent control measures and mitigation measures should be

revised, and their implementation supervised following the results of the ground investigation and construction design phase of works;

- Continued assessment and monitoring throughout the construction phase of works and at suitable intervals post construction should be implemented to ensure the control measures are suitable and are providing adequate mitigation against peat slide;
- Micro-siting of distances up to 50m should be considered for proposed infrastructure in order that during detailed design shallower peat deposits can be targeted by the final civil engineering design.
- Future periodic visual and topographical monitoring should be considered for the slope system where past instability has been identified. In particular upslope from T08, T10 and T12.

5.5. Construction Method Statement

Construction practices shall be managed through the Construction Method Statement (CMS) and within the wider context of the Construction Environmental Management Plan (CEMP). The CMS should be prepared by the appointed principal contractor and reviewed by a suitably experienced geotechnical engineer who has read and understood this report. The following general recommendations are provided in line with the, Good practice during wind farm construction, (2019) guidance:

- Avoidance of peat arisings being placed as local concentrated loads on peat slopes without first establishing the stability condition of the ground and slope system. Stockpiling on areas of deep peat and in close proximity to steep slopes should be avoided.
- Avoidance of uncontrolled and concentrated surface water discharge onto peat slopes as this may act as contributory factor to failure. All water discharged from excavations during construction phase should be directed away from all areas identified as susceptible to peat failure and should managed by a suitably designed site drainage management plan.
- All excavations where required should be adequately supported to prevent collapse and the destabilising peat deposits adjacent to excavations.
- A system of daily reporting should be established during construction and utilised to monitor the geotechnical performance of slopes including peat, sub-soil and bedrock. This should be implemented and undertaken by a suitable experienced and qualified geotechnical engineer. Post construction this monitoring procedure should be curtailed to allow for annual or ad-hoc inspection as required.

5.5.1. ‘Floating’ track construction

The following salient advice has been provided. MacCulloch, (2006) advises that a ‘floating’ type road construction which leaves the peat deposits in situ may be advantageous with respect to preventing peat failure. This method of construction has a lower impact on the internal groundwater flow within the peat land. However, there are cases where groundwater flow within the peat can be detrimentally affected. The following control measures should be implemented as part of the design and construction of ‘floating’ access track:

- Prevent the rupture of vegetation surface of the peat by avoiding the use of large sharp rock fill;
- Prevent the overloading and subsequent shearing of the peat throughout construction and use of the ‘floating’ track;
- Monitoring of the long-term settlement of the ‘floating’ track is necessary to predict the effects of reducing permeability within the peat and hence increasing groundwater pressures beneath the track construction. Through ongoing monitoring additional drainage relief measures can be implemented when conditions for peat failure are predicted;
- Do not position ‘floating’ access track on or adjacent to convex side slopes.

An additional control on the construction and use of ‘floating’ track is through the strict management of construction traffic loading. This may involve the timing between heavy traffic to be staggered to prevent the effect of cyclic loading over short time periods reducing the shear strength of the peat. In order to assess the maximum loading rate or timing between heavy construction traffic it may be necessary to monitor the vertical deformation of the 'floating' track sections following loading and recording the time taken for recovery of vertical deformation. The use of simple settlement plates and survey pegs can be used to achieve this. The frequency of trafficking for heavy loads must then be timed to allow deformation of the 'floating' road to recover its deformation.

MacCulloch (2006) generally advises that in order to prevent injury or an environmental incident, it is important that there is a robust procedure in place should it become apparent that a peat failure is imminent.

5.5.2. Cut track construction

Across areas of the Development not mantled by deep blanket peat the construction of proposed access tracks should be considered by excavation and replacement method, MacCulloch, (2006). Excavated peat is carefully placed along bunds at either side of the access track. Imported aggregate would be used to form the subgrade and running surface of the track.

For 'Cut' track construction the risk of peat failure is therefore focussed on the peat deposits adjacent to the access track, and the placement of peat arisings. In these areas the following control measures are listed by MacCulloch, (2006):

- Careful excavation of peat deposits by appropriate machine excavator to limit localised peat failures which can occur on the edge of the track excavation. This is in order to prevent a minor failure triggering retrogressive peat failure affecting a larger area of peat adjacent to the track;
- Temporary drainage systems followed by establishment of a permanent drainage network. Silt traps and small retaining structures may be required especially in proximity to water crossings to prevent siltation and blockage of watercourses;
- Ongoing monitoring and on demand maintenance when silt traps require emptying and temporary drainage reinstated if blocking occurs. This will assist in maintaining hydrology baseline conditions;
- The permanent drainage system must direct surface water flow away from the 'cut' track to prevent peat failure within the track bunds;

5.5.3. Foundation Excavation and Crane Pads

Where excavation into deep areas of peat is unavoidable; the use of detailed geotechnical design to ensure stability of excavations shall be required. This detailed earthworks design requirements shall be re-assessed following detailed site investigation (post-consent).

Piling of turbine foundations can also be considered at the detailed design stage. This method of foundation construction can reduce the requirement for deep and large excavations within peat and hence reduce the associated risk of failure when excavating. Full consideration must however be given to the plant requirements and working area which may need to be formed on a 'floated' hard standing or working platform.

Rock fill displacement methods, which are sometimes employed for crane pads in deep peat, should be subject to thorough risk assessment, particularly in the vicinity of slope crests where the lateral loading may add to slope destabilising forces.

5.5.4. Drainage Measures

Environmentally compliant drainage designs for the proposed development will form a primary control and mitigation for maintaining surface hydrology and shallow groundwater flow across the proposed development.

Some of the key responses to minimising the effect on the hydrology of the proposed development are reiterated below:

- Check dams, silt traps, settlement ponds and buffer strips will be incorporated into the drainage system as necessary and will serve the dual purpose of attenuating peak flows, by slowing the flow of runoff through the drainage system, and allowing sediment to settle before water is discharged from the drainage system;
- The constructed drainage system shall not discharge directly to any natural watercourse, but will instead discharge to buffer strips. These buffers will act as filters and minimise sediment transport, attenuate flows prior to discharge and maximise infiltration back into the soils and peat. Erosion protection shall be installed at discharge points;
- To reduce the impact of the proposed development on the natural hydrological regime, the site design will aim to mimic the greenfield runoff response at source through the use of sustainable drainage practices;
- Ponds and basins that can store water at the ground surface, can be designed to control flow rates by storing floodwater and releasing it slowly once the risk of flooding has passed;
- All watercourse crossing structures will be designed and constructed using best practice techniques and will be of sufficient capacity to accommodate storm flows for a 1 in 100year storm event, with an allowance for increased flows that may occur as a result of climate change. By ensuring that structures have enough capacity the risk of upstream flooding and increased erosion and sedimentation will be reduced;

All drainage management plans including any proposed drainage blocking should be agreed with the relevant environment agency and the relevant statutory bodies prior to starting construction. Full details of proposed drainage are provided in the ES Volume 2 Chapter 10: Geology and water environment.

5.5.5. Earthworks

It has been identified that there is a likely requirement for the excavation of considerable volumes of peat and superficial deposits during construction of the wind farm. Initially the vegetated peat layer and any topsoil should be stripped and temporarily stockpiled away from areas of deep peat. The design of this stockpile must be agreed by a suitably qualified geotechnical engineer. When working in areas of deep peat (i.e. >1.5m) no peat or overburden should be stored on such deposits as this may lead to instability.

Further discussion on best practise peat handling and storage methods is outlined within the Peat Management Plan (document reference: 1277447).

For in-situ and undisturbed peat; site vehicle movements must be minimised across such areas, throughout construction and post construction. Observation and monitoring for settlement, deformation or signs of failure along access tracks and critical working areas must be implemented. This may be achieved with a network of settlement plates and survey markers which can be periodically re-surveyed, and any differential movements identified. It is recommended that all earthworks are designed in accordance with current standards. Suitable guidance for temporary workings in peat is outlined in Table 5.1 below, in line with Construction Health and Safety, Earthworks, (2005) Observations suggest ‘soft non-fibrous dry peat’ is predominant on site:

Table 5.1: Temporary Slope Geometry (1-14 days)

Peat Type	‘Dry’ Site	‘Wet’* Site
	Degrees from horizontal (min/max)	
Soft non-fibrous	10/20	5 / 10
Firm non-fibrous	15/25	10 / 15
Firm fibrous	35/40 (6)	20 / 25 (6)
Stiff fibrous	35/45 (6) (7)	25 / 35 (6) (7)

’Dry’ Site: minor or no seepage from excavation faces, with minor or no surface runoff.

**'Wet' Site: submerged or widespread seepage from excavated faces*

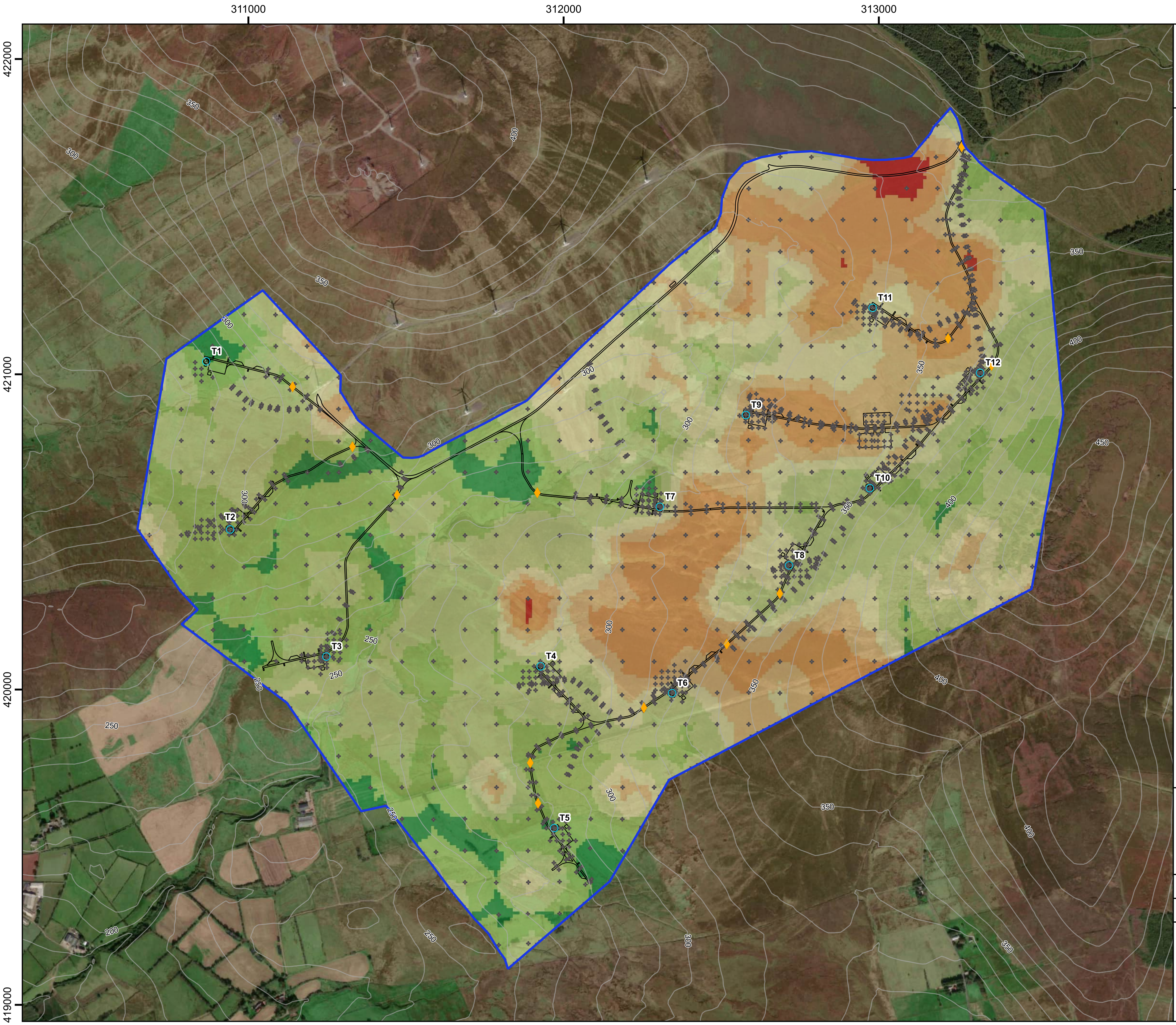
Source: Construction Health and Safety Earthworks, (2005)

References

- BS EN 1997-1:2004, EC7: Geotechnical Design, Part 1: General Rules.
- BS EN 1997-2:2007, EC7: Geotechnical Design, Part 2: Ground Investigation and Testing.
- British Geological Survey, Northern Ireland 1:50,000 Digital Data.
- British Geological Survey, Borehole Database.
- British Standards Institute (2009). BS6031:2009 Code of practice for Earthworks.
- Barnes, G.E., (2000), Soil Mechanics, Principles and Practice, 2nd Edition, Palgrave Macmillan.
- Northern Ireland Rivers Agency, Flood Map, Risk of Flooding from Rivers and Sea.
- Health Protection Agency, Radon Maps, Indicative Atlas of Radon.
- Scottish Executive (2017), Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments Second Edition. http://www.gov.scot/Publications/2017/04/8868.
- Hobbs, N. B. (1986). Mire morphology and the properties and behaviour of some British and foreign peats. Quarterly Journal of Engineering Geology, London, 1986, vol. 19, pp.7-80.
- SEPA Flood maps, http://map.sepa.org.uk/floodmap/map.htm.
- National Library of Scotland, http://maps.nls.uk/os/.
- Clayton, C.R.I. (2001). Managing Geotechnical Risk. Institution of Civil Engineers, London.
- Carling, P.A., (1986), Peat slides in Teesdale and Weardale, Northern Pennines, July 1983: description and failure mechanisms. Earth Surface Processes and Landforms, 1986 – Wiley.
- Farrell, E.R. & Hebib, S. 1998. The determination of the geotechnical parameters of organic soils. Proceedings of International Symposium on Problematic Soils, IS-TOHOKU 98, Sendai, Japan, 33–36.
- BRE 211, RADON, Guidance on protective measures for new buildings, BRE Press, 2007.
- Gas Networks.ie, Gas Networks Pipeline Map
- Von Post, L. & Granland, E., 1926 Peat Resources in Southern Sweden, Sverges geoligiska undersokning.
- Smith, I, Smith's Elements of Soil Mechanics, 8th Edition, ISBN: 978-1-4051-3370-8
- Hobbs, N. B. (1986). Mire morphology and the properties and behaviour of some British and foreign peats. Quarterly Journal of Engineering Geology, London, 1986, vol. 19, pp.7-80.
- Good Practice During Wind Farm Construction, A joint publication by: Scottish Renewables, Scottish Natural Heritage, Scottish Environmental Protection Agency, Forestry Commission Scotland, Historic Environment Scotland, Marine Scotland Science, AEECoW, 4th Edition, 2019.
- MacCulloch, F. (2006). Guidelines for the Risk Management of Peat Slips on the Construction of Low Volume/Low Cost Roads over Peat.
- Construction Health and Safety: Section 8B-1 – Earthworks, (2005), JR Illingworth Esq.
- Hanrahan, E.T., Dunne, J.M. & Sodha, V.G. 1967. Shearstrength of peat. Proceedings of the Geotechnical Conference, Oslo, 1, 193–198.
- Rowe, R., and Mylleville, B. L. J., (1996) A geogrid reinforced embarkment on peat over organic silt: a case history. Canadian Geotechnical Journal, 1996, 33(1): 106-122.
- Landva, A.O. 1980a. Geotechnical behaviour and testing of peat. PhD thesis, Laval University, Quebec.
- Rowe, R., MacLean, M.D., and Soderman, K.L., (1984), Analysis of a geotextile-reinforced embankment constructed on peat. Canadian Geotechnical Journal. 21, 563 -576 (1984).
- Hunger, O. & Evans, S.G. 1985. An example of a peat flow near Prince Rupert, Britis Columbia. Canadian Geotechnical Journal, 22, 246–249.
- Dykes, A.P. & Kirk, K.J. 2006. Slope instability and mass movements in peat deposits. In Martini, I.P., Martinez Cortizas, A. & Chesworth, W. (eds) Peatlands: Evolution and Records of Environmental and Climate Changes. Elsevier, Amsterdam, 377–406.
- Warburton, J., Higgit, D. & Mill, A.J. (2003), Anatomy of a Pennine peat slide, Northern England. Earth Surface Processes and Landforms, 28, 457–473.
- Skempton, A.W., DeLory, F.A., 1957. Stability of natural slopes in London clay. Proceedings 4th International Conference on Soil Mechanics and Foundation Engineering, vol. 2, pp. 378 – 381.

- Hutchinson, J.N., 1988, General Report: morpho9logical and geotechnical parameters of landslides in relation to geology and hydrogeology. In Bonnard, C. (Editor), Proceedings, Fifth International Symposium on Landslides, A.A.Balkema, Rotterdam, Vol.1, pp. 3-36.
- Applied Ground Engineering Consultants (2004). Derrybrien Wind Farm Final Report on Landslide of October 2003.
- Boylan, N,. Jennings, P., & Long, M., (2008) Peat slope failure in Ireland, Quarterly Journal of Engineering Geology and Hydrogeology 2008; V. 41; p. 93-108.
- Dykes, A.P. & Warburton J. (2008) Characteristics of the Shetland Isles (UK) peat slides of 19 September 2003. Landslides 2008 vol. 5 pp. 213-226.
- Nichol, D, Doherty, G.K & Scott, M.J (2007) A5 Llyn Ogwen peat slide, Capel Cruig, North Wales. Quarterly Journal of Geology and Hydrogeology Vol 40, pp 293-299.

A. Maps



Project:

Carnbuck Wind Farm, Co. Antrim, Northern Ireland

Title:

Figure A.1: Interpolated Peat Depth

Key

- ▭ Site Survey Boundary
- ○ Proposed turbine
- ✦ Peat probe
- ▭ Infrastructure footprint
- ◆ Water crossing

Peat depth (m BGL)*

- 🟩 ≤ 0.25
- 🟩 ≤ 0.5
- 🟩 ≤ 1
- 🟨 ≤ 1.5
- 🟧 ≤ 2
- 🟧 ≤ 3
- 🟥 ≤ 4

* Peat probe data interpolated using kriging method

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Scale @ A3: 1:12,000

Coordinate System: TM75 Irish Grid

0 125 250 375 500 m

N

Date: 15-04-22	Prepared by: IW	Checked by: SF

Ref: GB201993_M_005_D	Layout: 280322_12t_A

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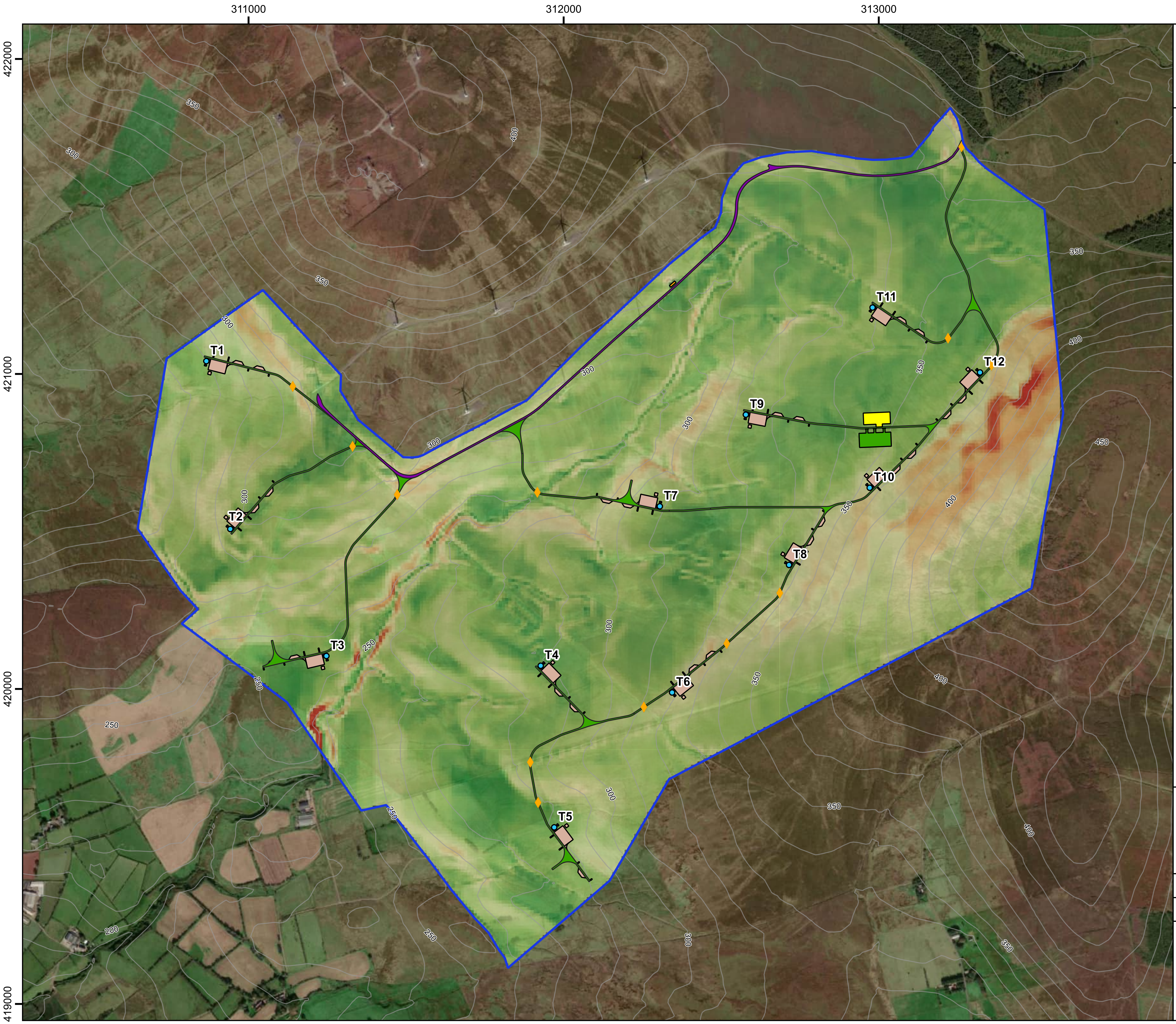

Project:

Carnbuck Wind Farm, Co. Antrim, Northern Ireland

Title:

Figure A.2: Slope Angle

Key

- ▭ Site Survey Boundary
- ● Proposed turbine
- — Upgraded existing track
- — Proposed track
- ▨ Proposed hardstanding
- 🟨 Proposed control building and substation compound
- 🟩 Proposed energy storage / construction compound
- 🟧 Existing Gruig Wind Farm substation
- ♦ Water crossing

Slope angle *

- 0°
- 5°
- 10°
- 15°
- ≥ 20°

* Slope angle calculated from OSNI 10m terrain data.

Scale @ A3: 1:12,000

Coordinate System: TM75 Irish Grid

0 125 250 375 500 m

N

Date: 18-04-22	Prepared by: IW	Checked by: GG

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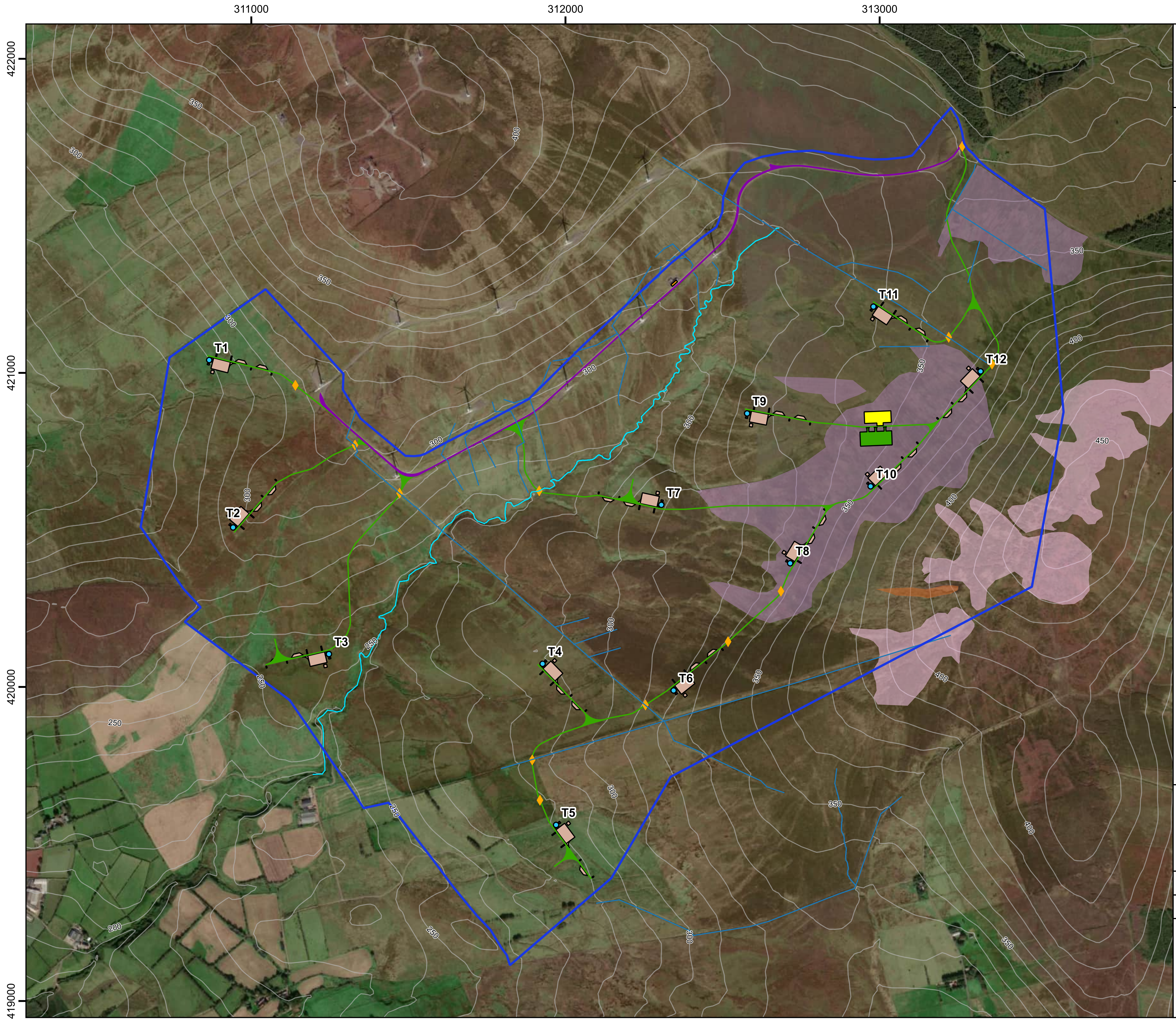

Project:

Carnbuck Wind Farm, Co. Antrim, Northern Ireland

Title:

Figure A.3: Geomorphological Features

Key

- ☐ Site Survey Boundary
- ● Proposed turbine
- — Upgraded existing track
- — Proposed track
- 🟫 Proposed hardstanding
- 🟨 Proposed control building and substation compound
- 🟩 Proposed energy storage / construction compound
- 🟧 Existing Gruig Wind Farm substation
- ◆ Water crossing

Geomorphological feature

- 🟪 Peat artificial drainage area
- ▨ Peat hag
- 🟫 Slide / escarpment
- — Drainage ditch
- — Watercourse

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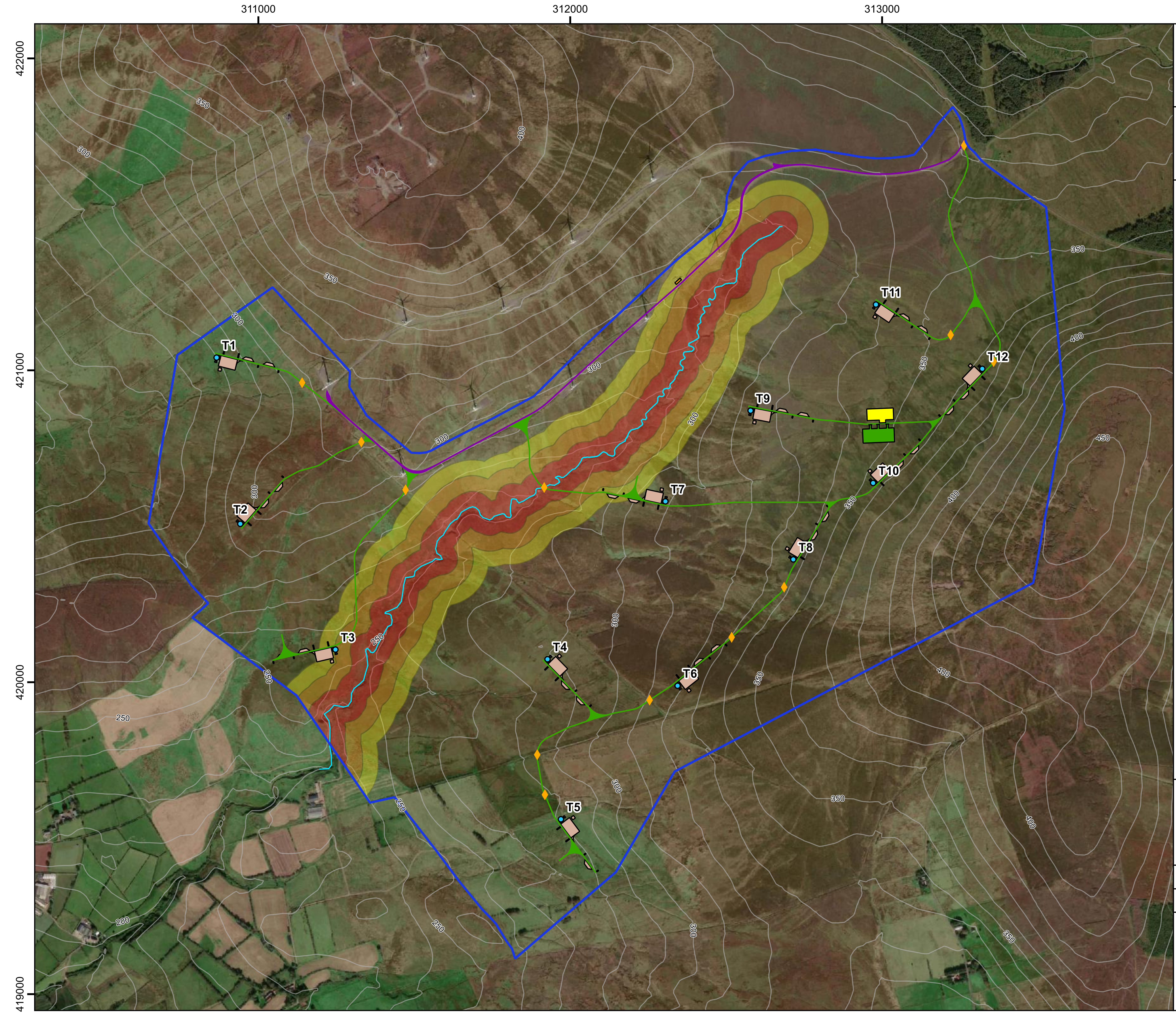

Project:

Carnbuck Wind Farm,
Co. Antrim, Northern Ireland

Title:

Figure A.4: Environmental Impact Zonation

Key

- ☐ Site Survey Boundary
- ● Proposed turbine
- — Upgraded existing track
- — Proposed track
- ■ Proposed hardstanding
- 🟨 Proposed control building and substation compound
- 🟩 Proposed energy storage / construction compound
- 🟧 Exisitng Gruig Wind Farm substation
- ◆ Water crossing
- — Watercourse

Environmental Impact Zonation (proximity to watercourse)

🟥	< 50 m:	High impact
■	50 - <100 m:	Medium impact
■	100 - <150 m:	Low impact

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Coordinate System: TM75 Irish Grid

0 125 250 375 500 m

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