# Technical Appendix 8.3: Peat Landslide Hazard Risk Assessment

# Technical Appendix 8.3: Peat Landslide and Hazard Risk Assessment

## 1.1 Introduction

1.1.1 The objectives of the PLHRA are to:

- undertake a desk-based review of published information including geological, hydrogeological and topographical information, to inform the baseline for the PLHRA;
- undertake site visits to identify evidence of, and potential for, active, incipient or relict peat instability, including identification of the location of features as required;
- reporting on evidence of any active, incipient or relict peat instability, and the potential risk of future instability, describing the likely causes and contributory factors;
- identify potential controls to be imposed during the construction phase to minimise the risk of any peat instability at the site; and
- provide recommendations for further work or specific construction methodologies to suit the ground conditions to mitigate against any increased risk of potential peat instability.

1.1.2 The scope of the PLHRA is as follows:

- characterise the peatland geomorphology to determine whether there have been prior occurrences of instability, and whether contributory factors that might lead to instability in future are present across the Site;
- determine the likelihood of a future peat landslide under natural conditions and in association with construction activities associated with the Proposed Development;
- identify potential receptors that might be affected by peat landslides, should they occur, and quantify the associated risks; and
- provide appropriate mitigation and control measures to reduce the risks to acceptable levels such that the Proposed Development is constructed safely with minimal risks to the environment.
- The contents of this PLHRA have been prepared in accordance with the Scottish Government's Best Practice Guidance[1], noting that the guidance 'should not be taken as prescriptive or used as a substitute for the developer's [consultant's] preferred methodology'.

## 1.2 Methodology

1.2.1 A desk study and field surveys were implemented to gather baseline conditions of the site and allow a PLHRA to be completed. The desk study included an overview of the following elements to inform the baseline design:

- Bedrock and superficial geology from BGS Mapping[2];
- Peatland and peat characteristic information from The Scottish Natural Heritage (NatureScot) carbon rich soils, deep peat and priority habitat[3]
- Habitat survey information from Chapter 6: Ecology (EIAR Volume 2);
- Hydrogeological and Hydrology information from Chapter 8: Hydrology, Hydrogeology and Geology (EIAR Volume 2); and
- Topographical information taken from published Digital Terrain Model (DTM) LIDAR data
- Media articles, historic maps and local landowner accounts of historic land movements; and
- Meteorological rainfall data[4].

1.2.2 The results of the desk study are discussed section 1.3 of this report.

**Field Survey**

1.2.3 Two rounds of peat survey were undertaken across the Site, based on the Proposed Development design. The surveys were designed based on best practice guidance for surveying developments on peatland[1] .

1.2.4 The first survey was undertaken during August 2023 by Fluid Environmental Consulting. The survey comprised probing on a 100 m grid within the areas of likely peatland; and a 200 m grid in areas likely to be absent of peat soils. Where peat was encountered within the 200 m grid intervals then probe spacings were reduced to 100 m to delineate the areas of peat.

1.2.5 The second survey was undertaken by Ramboll UK (RUK) in April 2024. The survey comprised probing at refined locations to target proposed turbine locations, access tracks and potential borrow pit locations. Survey details as follows:

- Turbine locations: Peat probing was carried out at 10 m intervals along cardinal points for a total of 60 m from the centre of each turbine location; and
- Access tracks: 50 m intervals along the track and at points every 10 m perpendicular to the centreline on either side of the proposed track.

1.2.6 Peat cores were taken using a Russian auger, with a sample volume of 0.5 l, and a number of field tests and observations were undertaken to identify:

- Depth of acrotelm;
- Degree of humification (using Hodgson, 1974[5]), to establish amorphous, intermediate, fibrous and content; and
- Degree of humification using the Von Post, (Hobbs, 1986[6]) classification.

1.2.7 Samples were subsequently submitted to a soils testing laboratory to analyse each sample for Bulk Density, Loss on Ignition (Organic Content), Moisture Content, and pH. Results of the testing are required for peat stability analysis detailed within this report.

**Limitations and Assumptions**

1.2.8 Surveying has been undertaken based on the Proposed Development design and associated infrastructure locations available at the time of the survey. Should the infrastructure design change outside the incorporated limits of deviation, then further surveying and subsequent amendments to the PLHRA reporting may have to be undertaken. The data collected to inform this PLHRA is considered sufficient to support a robust assessment of the peat landslide hazards and risks.

## 1.3 Desk Study & Site Information

1.3.1 The Site location and setting are described in Chapter 2: Development Description (EIAR Volume 2).

[1] Scottish Government (2017). Peat Landslide Hazard and Risk Assessments, Best Practice Guide for Proposed Electricity.

[2] British Geological Society BGS Geo Index mapping [Accessed 11/05/2024) Available: https://mapapps2.bgs.ac.uk/geoindex/home.htm

[3] NatureScot Spatial Data Hub, URL: https://opendata.nature.scot/maps/171df29c8c5b45a9b93438a3bc5700c6

4 Met Office Weather Data Drumalbin: https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcvk7n86b

[5] Hodgson, J.M (1974) Soil Survey Field Handbook.

[6] Hobbs N.B. (1986). Mire morphology and the properties and behaviour of some British and Foreign peats. Quarterly Journal of Engineering Geology, 19, pp7-80.

## Topography

1.3.2 The Site topography is generally undulating, moderately shallow rising ground from the southeast to the northwest across the Site at elevations of between 200 m to 350 m Above Ordnance Datum (AOD) at the summit of Outer Law Hill. Black Hill is located within the south of the Site with steep rising ground to its summit at 385 mAOD. Topography and elevation are shown on **Figure 8.3.1**.

1.3.3 Slope angles at the Site, as shown on **Figure 8.3.2**, are summarised below:

- Turbine T1 and T2 generally shallow (<5°);
- Turbine T3 generally moderate (5.1 to 10º);
- Turbine T4 to T8 generally shallow (<5°);
- Turbine T9 to T11 moderate (5.1 to 10º);
- Turbine T12 to T14 generally shallow (<5°);
- Turbine T15 and T16 moderate (5.1 to 10º);
- Turbine T17 to T21 generally shallow (<5°); and
- Turbine T22 moderate (5.1 to 10º).

1.3.4 The solar array areas to the east of the Site are generally located on shallow slopes (<5º) with the exception of the array located on the northern slopes of Craighead Hill. Here slope angles are moderately steep (10.1 to 15°). Borrow pit search area BP5 is located on moderately steep (10.1 to 15°) to locally very steep (>20°) ground associated with the northern slopes of Black Hill. All Access tracks, with the exception of T15 to T16 (moderate 5.1 to 10º), BP5 access (moderate 10.1 to 15º) and T16 turning head (moderate 5.1 to 10º), are located on shallow slopes (<5º).

## Geology

1.3.5 The 1:50,000 scale geological mapping available from the British Geological Survey (BGS)[2]. shows the northern and western extent of the Site are underlain by Devonian-aged sedimentary bedrock of the Auchtitench Sandstone Formation. The formation is made up of medium and coarse grained sandstones and conglomerates. The central and southern extents of the site are underlain by bedrock of the Marchburn and Kirkcolm formations, wacke turbidite sequence rocks comprising sandstones and siltstones. Bedrock geology is shown on **Figure 8.3.3a**.

1.3.6 BGS mapping[2] shows the superficial geology of the south of the Site predominantly comprises Quaternary aged, Devensian, Till – Diamicton. An area of peat is shown to be present within the southwest of the site. Mapping shows the northern extents of the Site are absent of superficial deposits. Superficial Geology is shown on **Figure 8.3.3b**.

1.3.7 BGS mapping[2]. shows two fault lines, running approximately parallel in a southwest to northeast direction across the central region of the Site. The faults represent boundaries between the sedimentary and turbidite sequence rock formations discussed in section 1.3.5 above.

## Hydrogeology and Hydrology

1.3.8 The BGS 1:625,000 scale hydrogeology mapping[7] defines the sedimentary rocks of the Auchtitench formation as a moderate productive aquifer. These deposits underlay the majority of the turbine and access track infrastructure locations within the Site. The Wacke formation rock formations underlying the remainder of the Site are classed as impermeable rock. Any groundwater flow within the wacke formation bedrock will be limited to the weathered zone or secondary fractures.

1.3.9 The average annual rainfall for the nearest weather station (Met Office weather station at Drumalbin) is 930.2 mm, based on the most recent dataset (1991 to 2020)

## Surface Water Features

1.3.10 A number of watercourses run through the Site. Mill Burn is present at the northeastern boundary of the Site and Black Burn is present at the southern Site boundary The solar array areas of the Site drain in a generally easterly direction towards the Duneaton Water and River Clyde, to the north and east.

## Groundwater Dependent Terrestrial Ecosystems (GWDTE)

1.3.11 The following information should be read in Conjunction with **EIAR Volume 4, TA 8.5 GWDTE**.

1.3.12 A number of High and Moderate GWDTE areas have been identified through ecological assessment of the Site. However, site-specific hydrogeological and hydrological assessment shows that the majority of these areas are not dependent on groundwater supplies.

1.3.13 Direct habitat loss of areas identified as potentially groundwater dependent are limited to small areas which are assessed to be of moderate groundwater dependency, based on Site-specific hydrological and hydrogeological assessment.

1.3.14 Maintaining drainage pathways across the Site and controlling pollution control from construction activities within these areas is considered sufficient to mitigate GWDTE habitat loss.

## Private Water Supplies

1.3.15 The following information should be read in Conjunction with **EIAR Volume 4, TA 8.6 Private Water Supplies**.

1.3.16 Two PWS abstraction sources are recorded within 5 km of the Site, these are:

- Nether Abington PWS is located approximately 350 m south of the Site and 1.3 km south of the nearest area of proposed development; and
- Duneaton House PWS is located approximately 270 m to the east of the Site at its nearest point and 350 m east of the nearest area of proposed development.

## Land use

1.3.17 The Site predominantly comprises open moorland, improved and semi-improved grassland, an area of forestry, and is intersected by the M74 motorway and B7078 and B740 local roads. The Site has been subject to extensive sand and gravel quarrying, with quarrying activity currently being concluded at Thirstone Quarry, located to the north of the B7078 and M74 in the central and northern parts of the Site, and previous quarrying activity identified by Ordnance Survey mapping in the northern and western parts of the Site. In addition, there are a number of utility and telecommunications links that cross the Site, including two high pressure gas pipelines, Scottish Water pipelines and fixed telecommunications links.

## Geomorphology

1.3.18 Digital aerial photography and Digital Terrain Model (DTM) LIDAR data was used to interpret and map geomorphological features within the developable areas of the Site. This interpretation and the resulting geomorphological map, as shown in Figure 8.3.4 were subsequently verified during site walkover surveys undertaken by an experienced peatland geomorphologist and hydrologist in April 2024.

1.3.19 The geomorphological features recorded are shown on **Figure 8.3.4**. The presence, characteristics and distribution of peatland geomorphological features have been defined to understand the hydrological function of the peatland, with reference to the balance of erosion and peat accumulation (or condition), and the sensitivity of peatland to potential land-use changes.

[7] British Geological Survey, 1:625,000 scale digital hydrogeological data. [Accessed 11/05/2024] Available: http://www.bgs.ac.uk/products/hydrogeology/maps.html

1.3.20 No significant evidence of peat instability features was identified during the surveys, with very few haggs, groughs, or other peat erosion noted. Several localised areas of peat flushes were recorded across the Site which displayed basal erosion of peat due to surface water run-off. No major instability features, evidence of incipient instability or past landslides were noted. The lack of visible evidence of instability features during the site walkovers is consistent with the findings of the desk study. The desk study review found there were no published articles, evidence from historical mapping or land owner accounts of land slips within the Site.

## 1.4 Field Survey

1.4.1 Results from the peat surveys are detailed within **TA 8.1 Peat Survey Results Report (EIAR Volume 4)**.

### Peat Depth and Character

1.4.2 Most of the Site has either no peat present or has a shallow depth of peat present (peat was absent at approximately 71% of locations and 27% were <0.5 m in depth). These areas of shallow peat can be considered as organo-mineral soils. These are further summarised as follows:

- 1720 no. samples (71.2%) located on land with no peat/ absent;
- 647 no. samples (26.8%) located on land with less than or equal to 0.5 m depth of peat
- 16 no. samples (0.7%) fell on land with between 0.51 m and 1.0 m depth of peat
- 3 no. samples (0.1%) located on land with between 1.51 m to 2.0 m depth of peat
- 10 no. samples (0.4%) located on land with between 2.1 m to 2.5 m depth of peat
- 9 no. samples (0.4%) located on land with between 2.51 m to 3 m depth of peat and;
- 10 no. samples (0.4%) located on land with >3.1m

1.4.3 The maximum depth of peat recorded at the Site during the Stage 1 survey was 4.4 m, located in the western area of the Site, south of the B7078, and in the central part of the Site, immediately south of the M74. The maximum depth of peat taken from samples dispersed across the Site during the Stage 2 peat probe survey was 2.3 m. The mean peat depth recorded was 0.1 m. The peat depth results are shown on **Figure 8.3.5** of this report

1.4.4 Overall, the peat sampled across the Site was relatively shallow. Peat was found to be generally dry and in a state of moderate decomposition.

1.4.5 The majority of the Site has either no peat present or has a shallow depth of peat present (approximately 27% of peat probes were <0.5 m in depth). These areas of shallow peat can be considered as organo-mineral soils or peaty soils as described in ECUBPG[1] and therefore not considered in this assessment for the following reasons:

- Peaty soils in isolation do not pose a significant threat to watercourse and habitat environments.
- In isolation, their soil properties differ to that of peat, and due to their limited depth, a potential slide would be minor and limited in volume.

1.4.6 However, peaty soils are considered within areas of adjacent peat instability as their presence may contribute to the peat slide likelihood.

## 1.5 Peat Instability

### Types of Peat Instability

1.5.1 Peat instability can be defined as either 'minor instability' or 'major instability' and observed by both field observations and through desk top review of aerial/satellite imagery of the Site:

- Minor instability can be defined as localised and small scale features that are not generally precursors to major failure and including gully sidewall collapses, pipe ceiling collapses, minor slumping along diffuse drainage pathways (e.g. along flushes). Indicators of minor instability include presence of tension cracks, compression ridges, or bulges; and
- Major instability can be defined by peat landslides.

1.5.2 For the purposes of this assessment, landslide classification is simplified and split into three main types:

- multiple peat slides with displaced slabs and exposed substrate;
- bog burst with peat retained within the failed area; and
- multiple peat soil slides with displacement of thin soils exposing substrate.

1.5.3 The term 'peat slide' is used to refer to large-scale landslides and occur 'top-down' from the point of initiation on a slope in thinner peats (between 0.5 and 1.5 m) and on moderate slope angles (typically 5-15°).

1.5.4 The term 'bog burst' is used to refer to very large-scale failures where peat is typically deeper (greater than 1.0 m and up to 10 m) and more amorphous than sites experiencing peat slides, with shallower slope angles (typically 2-5°).

1.5.5 'Peaty soil slide' is used to refer to small-scale slab-like slides in organic soils generally <0.5 m thick.

### Factors Contributing to Peat Instability

1.5.6 Peat landslides are caused by a combination of preconditioning factors and triggering factors. The combined factors are discussed in greater detail in the Landslide Susceptibility Approach Section of this report. Triggering factors have an immediate or rapid effect on the stability of a peat accumulation whereas preconditioning factors can influence peat stability over a much longer period. Only some of these factors can be addressed by site characterisation.

1.5.7 Preconditioning factors may influence peat stability over long periods of time (years to hundreds of years), and include:

- impeded drainage caused by a peat layer overlying an impervious clay or mineral base (hydrological discontinuity);
- a convex slope or a slope with a break of slope at its head (concentration of subsurface flow);
- proximity to local drainage, either from flushes, pipes or streams (supply of water);
- connectivity between surface drainage and the peat/impervious interface (mechanism for generation of excess pore pressures);
- artificially cut transverse drainage ditches, or grips (elevating pore water pressures in the basal peat mineral matrix between cuts, and causing fragmentation of the peat mass);
- increase in mass of the peat slope through peat formation, increases in water content or afforestation;
- reduction in shear strength of peat or substrate from changes in physical structure caused by progressive creep and vertical fracturing (tension cracking or desiccation cracking), chemical or physical weathering or clay dispersal in the substrate;

- loss of surface vegetation and associated tensile strength (e.g. by burning or pollution induced vegetation change);
- increase in buoyancy of the peat slope through formation of sub-surface pools or water-filled pipe networks or wetting up of desiccated areas; and
- afforestation of peat areas, reducing water held in the peat body, and increasing potential for formation of desiccation cracks which are exploited by rainfall on forest harvesting.

1.5.8 Triggering factors are typically of short duration (minutes to hours) and any individual trigger event can be considered as a result of cumulative events:

- intense rainfall or snowmelt causing high pore pressures along pre-existing or potential rupture surfaces (e.g. between the peat and substrate);
- rapid ground accelerations (e.g. from earthquakes or blasting); unloading of the peat mass by fluvial incision or by artificial excavations (e.g. cutting);
- focusing of drainage in a susceptible part of a slope by alterations to natural drainage patterns (e.g.by pipe blocking or drainage diversion); and
- loading by plant, spoil or infrastructure.

1.5.9 External environmental triggers such as rainfall and snowmelt cannot be mitigated, though they can be managed (e.g. by limiting construction activities during periods of intense rain).

1.5.10 Unloading of the peat mass by excavation, loading of the peat by plant and focusing of drainage can be managed and mitigated by careful design, site specific stability analyses, informed working practices and monitoring.

## Approaches to Assessing Peat Instability

1.5.11 This report considers a qualitative contributory factor-based approach and conventional stability analysis (through limit equilibrium or Factor of Safety (FoS) analysis).

1.5.12 The advantage of the former is that many observed relationships between reported peat landslides and ground conditions can be considered together where a FoS is limited to consideration of a limited number of geotechnical parameters. The disadvantage is that the outputs of such an approach are better at illustrating relative variability in landslide susceptibility across a site rather than absolute likelihood.

1.5.13 The advantage of the FoS approach is that clear thresholds between stability and instability can be defined and modelled numerically. However, in reality, there is considerable uncertainty in input parameters and it is a generally held view that the geomechanical basis for stability analysis in peat is limited given the nature of peat as organic material, rather than mineral soil.

1.5.14 To reflect these limitations, both approaches are adopted and outputs from each approach integrated in the assessment of landslide likelihood.

## Assessment of Peat Landslide Likelihood

*Introduction*

1.5.15 This section provides details on the landslide susceptibility and limit equilibrium approaches to the assessment of peat landslide likelihood used in this report. The assessment of likelihood is a key step in the calculation of risk, where risk is expressed as follows:

*Risk = Probability of a Peat Landslide x Adverse Consequences*

1.5.16 The probability of a peat landslide is expressed in this Technical Appendix as peat landslide likelihood and is considered below.

*Limit Equilibrium Approach*

1.5.17 Stability analysis has been undertaken using the infinite slope model to determine the FoS for a series of 25 m x 25 m cells within the developable area. The limit equilibrium approach1 has been applied within areas where the peat thickness is over 0.5 m. The limit equilibrium approach is the most frequently cited approach for the quantitative assessment of the stability of peat slopes. The approach assumes that failure occurs by shallow translational land sliding, which is the mechanism usually interpreted for peat slides. Due to the relative length of the slope and depth to the failure surface, end effects are considered negligible and the safety of the slope against sliding may be determined from analysis of a 'slice' of the material within the slope.

1.5.18 The stability of a peat slope is assessed by calculating a Factor of Safety, F, which is the ratio of the sum of resisting forces (shear strength) and the sum of driving forces (shear stress):

$$\frac{c' + (\gamma - h\gamma_w)\, z \cos^2 \beta \tan \phi'}{\gamma z \sin \beta \cos \beta}$$

*In this formula:*

- c is the effective cohesion (kPa);
- γ is the bulk unit weight of saturated peat (kN/m$^3$);
- $\gamma w$ is the unit weight of water (kN/m$^3$);
- z is the vertical peat depth (m),
- h is the height of the water table as a proportion of the peat depth;
- β is the angle of the substrate interface (°); and
- φ' is the angle of internal friction of the peat (°).

1.5.19 This form of the infinite slope equation uses effective stress parameters, and assumes that there are no excess pore pressures, i.e. that the soil is in its natural, unloaded condition.

1.5.20 The choice of water table height reflects the full saturation of the soils that would be expected under the most likely trigger conditions, i.e. heavy rain.

1.5.21 Where the driving forces exceed the shear strength (i.e. where the bottom half of the equation is larger than the top), F is <1, indicating instability. A FoS between 1 and 1.4 is normally taken in engineering terms to indicate marginal stability (providing an allowance for variability in soil strength, depth to failure). Slopes with a FoS greater than 1.4 are generally considered to be stable.

1.5.22 There are numerous uncertainties involved in applying geotechnical approaches to peat, not least because of its high water content, compressibility and organic composition . Peat comprises organic matter in various states of decomposition with both pore water and water within plant constituents, and the frictional particle-to-particle contacts that are modelled in standard geotechnical approaches are different in peats. There is also a tensile strength component to peat which is assumed to be dominant in the acrotelm, declining with increasing decomposition and depth. As a result, analysis utilising geotechnical approaches is often primarily of value in showing relative stability across a site given credible and representative input parameters rather than in providing an absolute estimate of stability. With this in mind, representative data inputs have been derived from published literature and used for drained analysis only.

*Data Inputs*

1.5.23 Stability analysis was undertaken using GIS software and a 25 m x 25 m grid was superimposed on areas of peat only, with key input parameters derived for each grid cell. A 25 m x 25 m cell size was chosen because it is sufficiently small to define a minimum credible landslide size and avoid 'smoothing' of important topographic irregularities. Given the cell size of the input DTM, which provides a key input parameter, any smaller cell size would be unlikely to provide significant benefits.

1.5.24 Table 8.3.1 shows the input parameters and assumptions for the stability analyses undertaken. The shear strength parameters c′ and φ′ are usually derived in the laboratory using undisturbed samples of peat collected in the field and therefore site-specific values are often not available ahead of detailed site investigation for a development. Therefore, for this assessment, a literature search has been undertaken to identify a range of credible but conservative values for c′ and φ′ quoted in fibrous and humified peats. FoS analysis was undertaken with conservative φ′ of 20 ° and values of 2 kPa and 5 kPa for c′.

**Table 8.3.1: Geotechnical Parameters for Drained Infinite Slope Analysis**

| Parameter | Values | Rationale | Source |
|---|---|---|---|
| Effective Cohesion (c′) | 2, 5 | Credible conservative cohesion values for humified peat based on literature review | 5.5 - 6.1 - peat type not stated (Long, 2005)[8]<br>3, 4 - peat type not stated (Long, 2005)[8]<br>5 - basal peat (Warburton et al., 2003)[9]<br>8.74 - fibrous peat (Carling, 1986)[10]<br>4 - peat type not stated (Dykes and Kirk, 2001)[11]<br>7 – 12 - H8 peat (Huat et al, 2014)[12] |
| Bulk Unit Weight (γ) | 10.5 | Mid-range value for humified catotelmic peat taken from Laboratory testing | 10.1 – catotelm peat (Mills, 2002)[13]<br>10.1 – Irish bog peat (Boylan et al, 2008)[14] |
| Effective Angle of Internal Friction (φ′) | 22 | Credible conservative friction angle for humified peat based on literature review | 40 – 65 - fibrous (Huat et al, 2014)[12]<br>50 – 60 - amorphous (Huat et al, 2014)[12]<br>36.6 - 43.5 - peat type not stated (Long, 2005)[8]<br>31 – 55 - Irish bog peat (Hebib, 2001)[15]<br>34 – 48 - fibrous sedge pear (Farrell & Hebib, 1998)[16]<br>32 – 58 - peat type not stated (Long, 2005)[8]<br>23 - basal peat (Warburton et al, 2003)[9]<br>21 - fibrous peat (Carling, 1986)[10] |
| Slope Angle from Horizontal (β) | Various | Mean slope angle per 25 m x 25 m grid cell | 5 m DTM of site |
| Peat Depth (z) | Various | Mean peat depth per 25 m x 25 m grid cell | Interpolated peat depth model of site |
| Height of Water Table as a Proportion of Peat Depth (h) | 1 | Assumes peat mass is fully saturated (normal conditions during intense rainfall events or snowmelt, which are the most likely natural hydrological conditions at failure) | Assumed |

*Results*

1.5.25 **Figure 8.3.6** shows the results for drained analysis of the peat areas at the site for the more conservative of the two parameter sets above (φ′ of 22° and c′ of 2 kPa). The results indicate that even with conservative parameters, Factors of Safety demonstrate stability across most of the site (FoS >1.4). This is consistent with the lack of observation of instability features during the site walkover and on review of aerial imagery.

1.5.26 One area of Marginally Unstable (1.0 – 1.4) ground is shown >50m south (Downslope) of the access track leading to Turbine 13. Two further areas of Marginally Unstable ground are shown at distances >200m from proposed infrastructure locations.

## Landslide Susceptibility Approach

1.5.27 The landslide susceptibility approach is based on the layering of contributory factors to produce unique ‘slope facets’ that define areas of similar susceptibility to failure. The number and size of slope facets will vary from one part of the site to another according to the complexity of ground conditions. As with the limit equilibrium approach, facets were only defined in areas of true peat.

1.5.28 Eight contributory factors are considered in the analysis:

- slope angle (S);
- peat depth (P);
- substrate geology (G);
- peat geomorphology (M);
- drainage (D);
- forestry (F);
- slope convexity (C); and
- land use (L).

1.5.29 For each factor, a series of numerical scores between 0 and 3 are assigned to factor ‘classes’, the significance of which is tabulated for each factor. The higher a score, the greater the contribution of that factor to instability for any particular slope facet. Scores of 0 imply neutral / negligible influence on instability.

1.5.30 Factor scores are summed for each slope facet to produce a peat landslide likelihood score (SPL), the theoretical maximum being 24 (8 factors, each with a maximum score of 3):

$$SPL = SS + SP + SG + SM + SD + SF + SC + SL$$

1.5.31 In practice, a maximum score is unlikely, as the chance of all contributory factors having their highest scores in one location is very small.

1.5.32 Figures to show the spatial distribution of each factor across the site are shown in **Figures 8.3.7a-h** of this report.

*Slope Angle*

1.5.33 Table 8.3.2 shows the slope ranges, their significance and related scores for the slope angle contributory factor. Slope angles were derived from the 5 m DTM and scores assigned based on reported slope angles associated with peat landslides rather than a simplistic assumption that ‘the steeper a slope, the more likely it is to fail’.

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[8] Long M (2005) Review of peat strength, peat characterisation and constitutive modelling of peat with reference to landslides.

[9] Warburton et al (2003) Anatomy of a Pennine peat slide, Northern England. Earth Surface Processes and Landforms.

[10] Carling (1986) Peat slides in Teesdale and Weardale, Northern Pennines, July 1983: description and failure mechanisms.

[11] Dykes and Kirk (2001) Initiation of a multiple peat slide on Cuilcagh Mountain, Northern Ireland.

[12] Huat et al (2014) Geotechnics of organic soils and peat.

[13] Mills (2002) Peat slides: Morphology, Mechanisms and Recovery

[14] Boylan N, et al (2008) Peat slope failure in Ireland

[15] Hebib (2001) Experimental investigation of the stabilisation of Irish peat

[16] Farrell and Hebib (1998) The determination of the geotechnical parameters of organic soils

| Table 8.3.2: Slope Classes, Significance and Scores | | |
|---|---|---|
| **Slope Range (°)** | **Significance** | **Score** |
| >20.0 | Failure typically occurs as peaty debris slides due to low thickness of peat | 1 |
| 15.1-20.0 | Failure typically occurs as peaty debris slides due to low thickness of peat | 2 |
| 10.1-15.0 | Failure typically occurs as peat slides, bog slides or peaty debris slides, a key slope range for reported population of peat failures | 3 |
| 5.1-10.0 | Failure typically occurs as peat slides, bog slides or peaty-debris slides, a key slope range for reported population of peat failures | 3 |
| 2.1-5.0 | Failure typically occurs as bog bursts, bog flows or peat flows; peat slides and peaty debris slides rare due to low slope angles | 2 |
| ≤2.0 | Failure is very rarely associated with flat ground, neutral influence on stability | 0 |

1.5.34 **Figure 8.3.7a** shows the distribution of slope angle scores across the site. The results show the slope angles across most of the site are shallow (<2°) but with some localised steeper gradients around hill and watercourse formations.

*Peat Depth (P)*

1.5.35 Table 8.3.3 shows the peat depths, their significance and related scores for the peat depth contributory factor. Peat depths were derived from the peat depth model shown on **Figure 8.3.7b** and reflect the peat depth ranges most frequently associated with peat slides (Evans and Warburton, 2007)[17].

| Table 8.3.3: Peat Depth Classes, Significance and Scores | | |
|---|---|---|
| **Depth Range (m)** | **Significance** | **Score** |
| >1.5 | Sufficient thickness for any type of peat failure | 2 |
| 1.0-1.5 | Sufficient thickness for peat slide or bog slide | 3 |
| 0.5-1.0 | Sufficient thickness for peat or bog slide and peaty-debris slide but not for bog burst | 3 |
| <0.5 | Organic soil rather than peat, failures would be peaty-debris slides | 1 |
| No Organic Soil | No organic soil and therefore failures cannot be interpreted as peat slides, neutral influence on stability | 0 |

1.5.36 **Figure 8.3.7b** shows the distribution of peat depth scores across the site. The results indicate that the site is predominantly covered by peat thicknesses <0.5 m. Areas near the forestry to the southeast of the Site show localised areas of peat accumulation of generally <1.5 m but in places up to 3.0 m. An area to the southeast of Turbine 13 also shows depth of <1.5m of peat but locally up to 2.0m.

*Substrate Geology*

1.5.37 Table 8.3.4 shows substrate type, significance and related scores for the peat depth contributory factor. The shear surface or failure zone of peat failures typically overlies an impervious clay or mineral (bedrock) base giving rise to impeded drainage. This, in part, is responsible for the presence of peat, but also precludes free drainage of water from the base of the peat mass, particularly under extreme conditions (such as after heavy rainfall, or snowmelt).

1.5.38 Peat failures are frequently cited in association with glacial till deposits in which an iron pan is observed in the upper few centimetres. They have also been observed over glacial till without an obvious iron pan, or over impermeable bedrock. They are rarely cited over permeable bedrock, probably due to the reduced likelihood of peat formation.

[17] Evans, M & Warburton, J 2007, Geomorphology of Upland Peat: Erosion, Form and Landscape Change.P104-135

| Table 8.3.4: Substrate Geology Classes, Significance and Scores | | |
|---|---|---|
| **Substrate Geology** | **Significance** | **Score** |
| Glacial Till With Iron Pan | Failures often associated with underlying till; particularly where impermeable iron pan provides polished shear surface | 3 |
| Glacial Till | Failures often associated with underlying till | 2 |
| Impermeable Bedrock | Failures sometimes associated with bedrock, particularly if smooth top surface | 1 |
| Permeable Bedrock | Failures rarely associated with permeable bedrock (peat is often thin or absent), neutral influence on stability | 0 |

1.5.39 **Figure 8.3.7c** shows the distribution of substrate geology scores across the site. The results indicate that the site is underlain mostly by permeable bedrock to the North western extents of the Site and impermeable bedrock to the southern area of the Site. There are two areas of localised Glacial Till noted in areas of peat >0.5 m depth located outside of the Proposed development infrastructure development. The results are consistent with the solid geology observed during the survey within exposures and watercourses, and indicated on BGS geology mapping[2].

*Peat Geomorphology*

1.5.40 Table 8.3.5 shows the geomorphological features identified across the site, their significance and related scores.

| Table 8.3.5: Peat Geomorphology Classes, Significance and Scores | | |
|---|---|---|
| **Geomorphology** | **Significance** | **Score** |
| Adjacent/upslope (<50 m) to existing instability (peat slide, peaty-debris slide, bank failure) | Failures often associated with underlying till; particularly where impermeable iron pan provides polished shear surface | 3 |
| Incipient instability (tension crack, compression ridge, bulging, quaking bog) | Failures are likely to occur where incipient failure morphology is observed | 3 |
| Undrained intact planar peat | Failures are most frequently recorded in intact peat, planar peat | 2 |
| Diffuse natural drainage / pool / flush | Failures are often associated with areas of diffuse subsurface drainage (such as flushes) | 2 |
| Pipe / Collapsed Pipe | Failures are often associated with areas of soil piping | 2 |
| Existing Peat Slide | Failures typically stabilise and do not reactivate after the initial event | 1 |
| Gullied / Dissected / Hagged / Eroded Peat / Bare Peat / Bare Ground | Failures are rarely recorded in peat fragmentated by erosion | 1 |

1.5.41 **Figure 8.3.7d** shows the distribution of geomorphology scores across the site. The results indicate that Turbine T19 is located within 100 m of recorded peat flush. There are no significant geomorphological features associated with historic peat slide failure.

*Drainage (D)*

1.5.42 Table 8.3.6 shows artificial drainage feature classes, their significance and related scores. Transverse / oblique drainage lines may reduce peat stability by creating lines of weakness in the peat slope and encouraging the formation of peat pipes. Review of published literature indicates that a number of peat failures have been identified which have failed over moorland grips . The influence of changes in hydrology become more pronounced the more transverse the orientation of the drainage lines are relative to the overall slope.

| Table 8.3.6: Drainage Feature Classes, Significance and Scores | |
|---|---|
| **Significance** | **Score** |
| Failures are sometimes reported in association with artificial drains oblique/transverse to slope | 3 |
| Failures are rarely associated with artificial drains parallel to slope | 1 |
| Neutral influence on stability | 0 |

1.5.43 **Figure 8.3.7e** shows the distribution of drainage feature scores across the site. Artificial drainage was observed within commercial forestry to the south and across moorland areas to the north of the Site (e.g. open moorland habitat areas characterised by underlying peat). Both of these areas were found to be parallel to the slope.

*Forestry (F)*

1.5.44 Table 8.3.1 shows forestry classes, their significance and related scores.

| Table 8.3.7: Forestry Classes, Significance and Scores | | |
|---|---|---|
| **Forestry Class** | **Significance** | **Score** |
| Afforested area (with mature trees), ridge and furrows oblique to slope | Peat underlying forestry stands with rows aligned oblique to slope has inter ridge cracks which are conducive to slope instability | 2 |
| Afforested area (with mature trees), ridge and furrows aligned to slope | Peat underlying forestry stands with rows aligned with slope is conducive to slope instability, but less so than where rows are aligned oblique to slope | 1 |
| Deforested area (few or no trees), ridge and furrows oblique to slope | Peat underlying deforested stands has a higher water table and more neutral buoyancy, but retains inter ridge cracks (lines of weakness) conducive to instability; alignment of cracks oblique to slope is most conducive to instability | 3 |
| Deforested area (few or no trees), ridge and furrows aligned to slope | Peat underlying deforested stands has a higher water table and more neutral buoyancy, but retains inter ridge cracks (lines of weakness), however, orientation of these cracks is less critical when aligned to slope | 2 |
| Not Afforested | Neutral influence on stability | 0 |

1.5.45 **Figure 8.3.7f** shows the distribution of forestry feature scores located in the southwest of the Site. Commercial forestry plantation within this area was shown to be aligned to the slope.

*Slope Convexity (C)*

1.5.46 Table 8.3.8 shows profile convexity classes, significance and related scores. Convex and concave slopes (i.e. positions in a slope profile where slope gradient changes by a few degrees) can be associated with the initiation point of peat landslides. Convexities are often associated with thinning of peat; such that thicker peat upslope applies stresses to thinner 'retaining' peat downslope. Conversely, buckling and tearing of peat may trigger failure at concavities.

| Table 8.3.8: Convexity Feature Classes, Significance and Scores | | |
|---|---|---|
| **Convexity Feature** | **Significance** | **Score** |
| Convex Slope | Peat failures are often reported on or above convex slopes | 3 |
| Concave Slope | Peat failures are occasionally reported in association with concave slopes | 1 |
| Rectilinear Slope | Rectilinear slopes show no particular predisposition to failure, neutral influence on stability | 0 |

1.5.47 **Figure 8.3.7g** shows the distribution of convexity feature scores across the site. Slopes are shown to be predominantly rectilinear in nature across the Site.

*Land use (L)*

1.5.48 Table 8.3.9 shows land use classes, significance and related scores. A variety of land uses have been associated with peat failures which form the scoring and potential for failure.

| Table 8.3.9: Land Use Feature Classes, Significance and Scores | | |
|---|---|---|
| **Land Use** | **Significance** | **Score** |
| Cutting / Turbary | Peat failures are often associated with peat cuttings/turbary | 3 |
| Adjacent Quarrying | Failures are occasionally reported adjacent to quarries (usually as bog bursts, bog flows or peat flows) | 2 |
| Burning | Failures are rarely associated with burning though this activity may create pathways for water to the base of peat | 1 |
| Other Land Use | Failures are rarely associated with other forms of land use | 0 |

1.5.49 **Figure 8.3.7h** shows the distribution of land use feature scores across the Site. One area of historic peat cutting was noted alongside the proposed access track between Turbines T4 to T6. There are two disused quarry locations shown, one to the north of Turbine 5 and one between Turbines T11 and T12. Existing Quarry operations are located on the sites of Turbine T7 and Site Compound CC2, Battery Site and Substation area. All Quarrying activities will be completed and areas restored prior to the construction of the proposed development infrastructure.

LIKELIHOOD SCORES

1.5.50 The eight contributory factor layers shown on **Figure 8.3.8** were combined in GIS software to produce likelihood scores for a peat landslide. These likelihood scores were then converted into descriptive 'likelihood classes' from 'Very Low' to 'Very High' with a corresponding numerical range of 1 to 5, and are described in Table 10.3.10 below.

| Table 8.3.10: Likelihood Classes Derived from the Landslide Susceptibility Methodology | | | |
|---|---|---|---|
| **Summed Contributory Factor Scores** | **Typical Site Conditions Associated with Score** | **Qualitative Likelihood** | **Peat Landslide Likelihood Score** |
| ≤6 | Unmodified peat with no more than low weightings for peat depth, slope angle, underlying geology and peat morphology | Very Low | 1 |
| 7-11 | Unmodified or modified peat with no more than moderate or some high scores for peat depth, slope angle, underlying geology and peat morphology | Low | 2 |
| 12-16 | Unmodified or modified peat with high scores for peat depth and slope angle and / or high scores for at least three other contributory factors | Moderate | 3 |
| 17-21 | Modified peat with high scores for peat depth and slope angle and several other contributory factors | High | 4 |
| >21 | Modified peat with high scores for most contributory factors (unusual except in areas with evidence of incipient instability) | Very High | 5 |

1.5.51 Table 8.3.10 describes the basis for the likelihood classes. Professional judgement was made that for a facet to have a moderate or higher likelihood of a peat landslide, a likelihood score would be required equivalent to both the worst case peat depth and slope angle scores (3 in each case, i.e. 3 x 2 classes) alongside three intermediate scores (of 2, i.e. 2 x 3 classes) for other contributory factors. This means that any likelihood score of 12 or greater would be equivalent to at least a moderate likelihood of a peat landslide. Given that the maximum score attainable is 24, this seems reasonable.

## 1.6 Peat Slide Risk Assessment and Mitigation

1.6.1 Table 8.3.11 below defines the stability risk assessment based on the peat slide likelihood and the required mitigation actions for each Risk Level.

**Table 8.3.11: Risk Assessment**

| Peat Slide Likelihood | Potential Stability Risk (Pre-Mitigation) | Mitigation Action |
|---|---|---|
| Very Low | Very Low | No peat present>0.5 m and therefore no mitigation action required |
| Low | Unlikely/Low | Development of a site-specific construction and management plan for peat areas |
| Moderate | Likely/Medium | As for Low condition plus may require mitigation to improve site conditions. |
| High | Probable High | Unacceptable level of risk, the area should be avoided. If unavoidable, detailed investigation and quantitative assessment required to determine stability with long term monitoring. |
| Very high | Almost Certain/Very high | Unacceptable level of risk, the area should be avoided |

1.6.2 Table 8.3.12 below shows the risk level (Likelihood) and required mitigation measures proposed for the towers and proposed access tracks of the Proposed Development.

**Table 8.3.12: Risk Level(Likelihood) and Mitigation**

**Wind Farm Infrastructure**

| Turbine/ Infrastructure | Peat Depth m (Max) | Slope Angle Deg (Mean) | Risk Level | Comment/Mitigation |
|---|---|---|---|---|
| Turbine 1 | 0.12 | 3.51 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Turbine 2 | 0.29 | 2.59 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Turbine 3 | 0.22 | 6.68 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Turbine 4 | 0.10 | 5.76 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Turbine 5 | 0.00 | 4.49 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Turbine 6 | 0.21 | 4.29 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Turbine 7 | 0.00 | 2.79 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Turbine 8 | 0.31 | 1.62 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Turbine 9 | 0.20 | 5.34 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Turbine 10 | 0.08 | 4.12 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Turbine 11 | 0.08 | 5.53 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Turbine 12 | 0.36 | 2.23 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Turbine 13 | 0.13 | 3.39 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Turbine 14 | 0.51 | 1.75 | Low | Peat >0.5 m recorded, Slope < 2 degrees. Low Likelihood. (Refer Section 1.8) |

**Table 8.3.12: Risk Level(Likelihood) and Mitigation**

**Wind Farm Infrastructure**

| Turbine/ Infrastructure | Peat Depth m (Max) | Slope Angle Deg (Mean) | Risk Level | Comment/Mitigation |
|---|---|---|---|---|
| Turbine 15 | 0.18 | 8.16 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Turbine 16 | 0.08 | 9.93 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Turbine 17 | 0.37 | 1.21 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Turbine 18 | 0.30 | 0.90 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Turbine 19 | 0.05 | 1.61 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Turbine 20 | 0.24 | 1.91 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Turbine 21 | 0.27 | 0.93 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Turbine 22 | 0.00 | 8.24 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Access Track T1/T2 to T5 | 0.90 | 3.92 | Low | Peat >0.5 m recorded, Slope < 5 degrees. Low Likelihood. (Refer Section 1.8) |
| Access Track T3 to T7 | 0.40 | 5.06 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Access Track T4 to T6 | 0.33 | 3.69 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Access Track to T6 from M74 | 0.58 | 5.34 | Low | Peat >0.5 m recorded, Slope 5 degrees. Low Likelihood. (Refer Section 1.8) |
| Access Track T7 to compound | 0.32 | 3.91 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Access Track T8 to T9 | 0.35 | 3.78 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Access Track T10 to T11/T12 | 0.60 | 3.55 | Low | Peat >0.5 m recorded, Slope < 5 degrees. Low Likelihood. (Refer Section 1.8) |
| Access Track T12 to T13 | 1.34 | 3.82 | Low | Peat >0.5 m recorded south of track, Slope < 5 degrees. Low Likelihood. (Refer Section 1.8) |
| Access Track T13 to T14 | 0.00 | 2.07 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Access Track T14 to T15 | 1.00 | 4.41 | Low | Peat >0.5 m recorded, Slope < 5 degrees. Low Likelihood. (Refer Section 1.8) |
| Access Track T15 to T16 | 0.23 | 8.19 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Access Track T16 Turning Head | 0.11 | 7.89 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Access Track T17 to T18 | 0.32 | 2.03 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Access Track T17 Turning Head | 0.35 | 1.03 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Access Track T19 | 0.16 | 2.29 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Access Track T20 to T22 | 0.43 | 4.58 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Access Track T14 to T21 | 0.41 | 4.22 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Access Track Turning Head T18 | 0.30 | 1.14 | Very Low | No peat recorded>0.5 m depth. No mitigation required |

| Table 8.3.12: Risk Level(Likelihood) and Mitigation | | | | |
|---|---|---|---|---|
| **Wind Farm Infrastructure** | | | | |
| **Turbine/ Infrastructure** | **Peat Depth m (Max)** | **Slope Angle Deg (Mean)** | **Risk Level** | **Comment/Mitigation** |
| Construction Compound CC1 | 0.40 | 4.66 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Construction Compound CC2 | 0.29 | 2.26 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Battery Storage area | 1.12 | 1.80 | Low | Peat >0.5 m recorded, Slope < 2 degrees. Low Likelihood. (Refer Section 1.8) |
| Substation | 0.14 | 3.04 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| | | | | |
| **Solar Infrastructure** | | | | |
| Inverter Inv 1 | 0.44 | 2.38 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Inverter Inv 2 | 0.00 | 6.90 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Inverter Inv 3 | 0.10 | 12.54 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Inverter Inv 4 | 0.05 | 4.62 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Inverter Inv 5 | 0.24 | 2.40 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Inverter Inv 6 | 0.28 | 0.89 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Inverter Inv 7 | 0.12 | 2.62 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Inverter Inv 8 | 0.09 | 3.20 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Inverter Inv 9 | 0.09 | 2.62 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Inverter Inv 10 | 0.29 | 3.82 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Inverter Inv 11 | 0.21 | 8.35 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Inverter Inv 12 | 0.28 | 17.40 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Construction Compound CC3 | 0.16 | 1.91 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Construction Compound CC4 | 0.00 | 2.71 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Access Track West of CC4 | 0.11 | 8.31 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Access Track Western Solar Track | 0.73 | 3.12 | Low | Peat >0.5 m recorded, Slope < 4 degrees. Low Likelihood. (Refer Section 1.8) |
| Access Track CC3 | 0.34 | 4.05 | Very Low | No peat recorded>0.5 m depth. No mitigation required |
| Access Track CC4 | 0.00 | 3.59 | Very Low | No peat recorded>0.5 m depth. No mitigation required |

1.6.3 From Table 8.3.12, all of the proposed wind farm and solar area infrastructure locations are classified as Very Low or Low likelihood of peat slide. The combined factor assessment scoring for peat slide likelihood is shown on **Figure 8.3.8.**

*Results*

1.6.4 The results of the Peat Slide Likelihood are shown on **Figure 8.3.6** and Figure **8.3.8** for the FoS and Combined Factor Assessment respectively. The results indicate that both assessments agree that all of of the proposed construction infrastructure location across the Site are considered to be of 'Low' or 'Very Low' likelihood of a peat landslide.

1.6.5 In order for there to be a 'High' or 'Medium' risk associated with Proposed Develoment, combined peat landslide likelihood must be 'Moderate' or higher at an infrastructure location, as defined by Scottish Government Guidance[1]

1.6.6 Where combined peat landslide likelihoods are assessed as 'Low' or 'Very Low', post-consent site investigations and application of good practice construction mitigation methods should be employed prior to and during construction as detailed in Section 1.8 below.

## 1.7 Consequence Evaluation

1.7.1 Based on the assessment of consequence of risk methodology, as defined by the Scottish Government Best Practice Guidance[1], six receptors have been identified at the site, and are assessed for consequence in Table 8.3.13 below:

- Highway infrastructure
- watercourses including Drinking Water Protection Areas (DWPA) and Private Water Supplies (PWS);
- non-riverine habitats;
- Groundwater Dependent Terrestrial Ecosystems (GWDTE) habitats;
- residential properties; and
- proposed development infrastructure.

| Table 8.3.13: Assessment of Consequence and Risk | | | | |
|---|---|---|---|---|
| **Receptor** | **Consequence** | **Score** | **Justification for Score** | **Consequence Scale** |
| B7078 and M74 Highways infrastructure. | Medium term loss of access for transport link. Significant cost to restore highway infrastructure and public access. | 3 | Disruption to local and wider national highways routes. Although highways are bounded via cut off ditches and elevated verge, significant peat slide could temporarily disrupt traffic/access. | High |
| Watercourses including DWPA and PWS | Increased turbidity and acidification, fish kill, blockage of drainage, effects on private water supplies | 3 | Water Quality, Flood risk and Private water supplies have been assessed within Hydrology Reporting within EIA Technical Appendices 8.4 & 8.5. | High |
| Non-riverine Habitats | Medium term loss of vegetation cover, disruption of peat hydrology, carbon release | 3 | Effects on peatland habitats, though the effects of peat landslides are generally short in duration | High |
| GWDTE habitats | Medium term loss of downslope water pathway and pooling upslope, loss of habitat | 3 | Effects on GWDTE habitats, though the effects of peat landslides are generally short in duration | High |
| Residential properties and public buildings | Medium term loss of residency for local occupants. Significant cost to restore property and temporary accommodation. Possible injury, loss of life to occupants | 5 | Loss of life, though unlikely, is a severe consequence; financial implications of damage and repair to residents property are less significant | Extremely high |

| **Table 8.3.13: Assessment of Consequence and Risk** | | | | |
|---|---|---|---|---|
| **Receptor** | **Consequence** | **Score** | **Justification for Score** | **Consequence Scale** |
| Proposed Development Infrastructure | Damage to infrastructure, possible injury, loss of life | 5 | Loss of life, though unlikely, is a severe consequence; financial implications of damage and repair to infrastructure are less significant | Extremely high |

1.7.2 Although there are no areas of moderate likelihood of peat slide identified directly at infrastructure locations, Receptors have been included in Table 8.3.14 below to confirm the evaluation for the level of risk associated with the proposed development.

| **Table 8.3.14 Risk levels derived from Likelihood vs Consequence** | | | | | | |
|---|---|---|---|---|---|---|
| **Receptor** | **Qualitative Likelihood worst case (See Table 8.3.12)** | **Consequence Scale/ Score (See Table 8.3.13)** | **Risk Level** | **Minimum Distance to Receptor** | **Level of Mitigation Required** | **Risk Level (Post Mitigation)** |
| B7078 and M74 Highways infrastructure. | Low (2) | High (3) | Low | 200m Battery Site | General Good Practice Section 1.8 | Low |
| Watercourses including DWPA and PWS | Low (2) | High (3) | Low | >50m (Various) | General Good Practice Section 1.8* | Low |
| Non-riverine Habitats | Low (2) | High (3) | Low | 50 m (Various) | General Good Practice Section 1.8 | Low |
| GWDTE habitats | Low (2) | High (3) | Low | 10m Western Solar Access Track and Inverter 1 | General Good Practice Section 1.8 | Low |
| Residential properties and public buildings | Low (2) | Extremely High (5) | Low | >1km Netherton Farm Access Track T14 to 15 | General Good Practice Section 1.8 | Low |
| Proposed Development Infrastructure | Low (2) | Extremely High (5) | Low | 10m Western Solar Access Track | General Good Practice Section 1.8 | Low |

1.7.3 The risk levels identified above for each potential receptor are based on the worst case likelihood and closest proximity to the receptor. The risk level for these areas is considered to be Low, based on:

- proximity of potential for unstable ground from infrastructure location;
- level and slope angle both up and down slope; and
- run out distances to potential receptors (Refer to **Figure 8.3.9**).

1.7.4 Based on the combined Qualitative likelihood vs Consequence and the findings within the FoS assessment previously outlined, it is considered that the combined risk level of peat landslide in association with the construction of the Proposed Development is assessed as being Low risk. This assessment of Risk level is based on Low likelihood vs High or Very High consequence as outlined in Table 5.3 of ECU best practice guidance[1], as shown below:

*Table 5.3 Indicative risk levels*

| Peat landslide probability or likelihood | Adverse consequence: Extremely High | High | Moderate | Low | Very Low |
|---|---|---|---|---|---|
| Almost certain | High | High | Moderate | Moderate | Low |
| Probable | High | Moderate | Moderate | Low | Negligible |
| Likely | Moderate | Moderate | Low | Low | Negligible |
| Unlikely | Low | Low | Low | Negligible | Negligible |
| Negligible | Low | Negligible | Negligible | Negligible | Negligible |

*Image 1, Table 5.3: Extract from Scottish Government (2017). Peat Landslide Hazard and Risk Assessments, Best Practice Guide for Proposed Electricity Generation Developments;*

## 1.8 Mitigation Measures and Recommendations

1.8.1 Although no moderate risk areas have been identified, micrositing infrastructure away from areas of peat >0.5m in depth, where practicable, is considered best practice.

1.8.2 General good practice should be applied across the Site to engender awareness of peat instability and enable early identification of potential displacements and opportunities for mitigation.

### General Mitigation Measures

1.8.3 A comprehensive intrusive geotechnical assessment should be undertaken post-consent based on the combined ground investigation, previously undertaken, to support the engineering design of Turbine foundations, tracks and ancillary infrastructure for the Proposed Development.

1.8.4 Appropriate field and laboratory testing would also be undertaken as part of the comprehensive ground investigation to confirm the peat stability baseline across the Site to cover the areas affected by the tracks and ancillary infrastructure, and further design mitigation used as appropriate to reduce the likelihood of peat instability (where required).

1.8.5 A geotechnical risk register would be prepared detailing any ground risks identified during the ground investigation and providing mitigation measures as appropriate. The risk register should be considered a live document and updated throughout the phases of the Proposed Development. The monitoring requirements discussed in the following paragraphs would be undertaken by the Applicant's contractor.

1.8.6 During construction of the Proposed Development the following mitigation would be undertaken for excavations:

- a geotechnical risk register would be prepared for the Proposed Development following intrusive investigations post consent and location specific stability analyses;
- site inspections and audits would be undertaken at scheduled intervals to identify any unusual or unexpected changes to ground conditions (which may be associated with construction or which may occur independently of construction);
- all construction activities and operational decisions that involve disturbance to peat deposits would be overseen by an appropriately qualified geotechnical engineer with experience of construction on peat sites;
- awareness of peat instability and pre-failure indicators would be incorporated in site induction, tool box talks, and training to enable all site personnel to recognise ground disturbances and features indicative of incipient instability;
- monitoring checklists would be prepared with respect to peat instability addressing all construction activities forming the Proposed Development;
- use of appropriate supporting structures around peat excavations, where required, (e.g. for towers, crane pads and compounds) to prevent collapse and the development of tension cracks;
- avoid cutting trenches or aligning excavations across slopes (which may act as incipient back scars for peat failures) unless appropriate mitigation has been put in place;
- implement methods of working that minimise the cutting of the toes of slope, e.g. working up-to-downslope during excavation works;
- monitor the ground upslope of excavation works for creep, heave, displacement, tension cracks, subsidence or changes in surface water content;
- monitor cut faces for changes in water discharge, particularly at the peat-substrate contact; and
- minimise the effects of construction on natural drainage by ensuring natural drainage pathways are maintained or diverted such that there is no significant alteration of the hydrological regime of the site; drainage plans should avoid creating drainage/infiltration areas or settlement ponds towards the tops of slopes (where they may act to both load the slope and elevate pore pressures).

1.8.7 During construction of the Proposed Development the following mitigation would be undertaken for excavated tracks:

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

1.8.8 During construction of the Proposed Development the following mitigation would be undertaken for floating tracks:

- Allow peat to undergo primary consolidation by adopting rates of road construction appropriate to weather conditions.
- Monitor the effects of secondary compression over the life of the development, where required, while the tracks are utilised (can be up to 35 years) to ensure running surfaces remain elevated above the ground surface and does not cause ponding.
- Identify 'stop' rules, i.e. weather dependent criteria for cessation of track construction based on local meteorological data.
- Run vehicles at 50% load capacity until the tracks have entered the second compression phase.
- Prior to construction, setting out the centreline of the proposed track to identify any ground instability concerns or particularly wet zones.

1.8.9 During construction of the Proposed Development the following mitigation would be undertaken for temporary storage of peat and restoration activities:

- where practicable, ensure temporary stores of peat are located on non-peat soils to minimise potential for instability of the underlying soils;
- avoid storing peat on slope gradients >3° and preferably store on ground with neutral slopes and natural downslope barriers to peat movement;
- monitor effects of wetting / re-wetting stored peat on surrounding peat areas, and prevent water build up on the upslope side of peat mounds; and
- maximise the interval between material deliveries over newly constructed tracks that are still observed to be within the primary consolidation phase.

1.8.10 During the operational phase of the Proposed Development monitoring of key infrastructure locations would continue through site walkovers and inspections by the Applicant's maintenance contractor to look for signs of unexpected ground disturbance, including:

- ponding on the upslope side of infrastructure sites and on the upslope side of access tracks;
- subsidence and lateral displacement of tracks;
- changes in the character of natural or artificial peat drainage within a 50 m buffer strip of tracks and infrastructure (e.g. development of quaking bog, waterlogging of previously dry drains);
- blockage or underperformance of the installed site drainage system;
- slippage or creep of stored peat deposits (including in restored peat cuttings); and
- development of tension cracks, compression features, bulging or quaking bog anywhere in a 50 m corridor surrounding the site of any construction activities or site works.

1.8.11 Monitoring would be undertaken during construction and as part of the commissioning phase the need for on-going monitoring would be reviewed and any ongoing monitoring requirements identified.

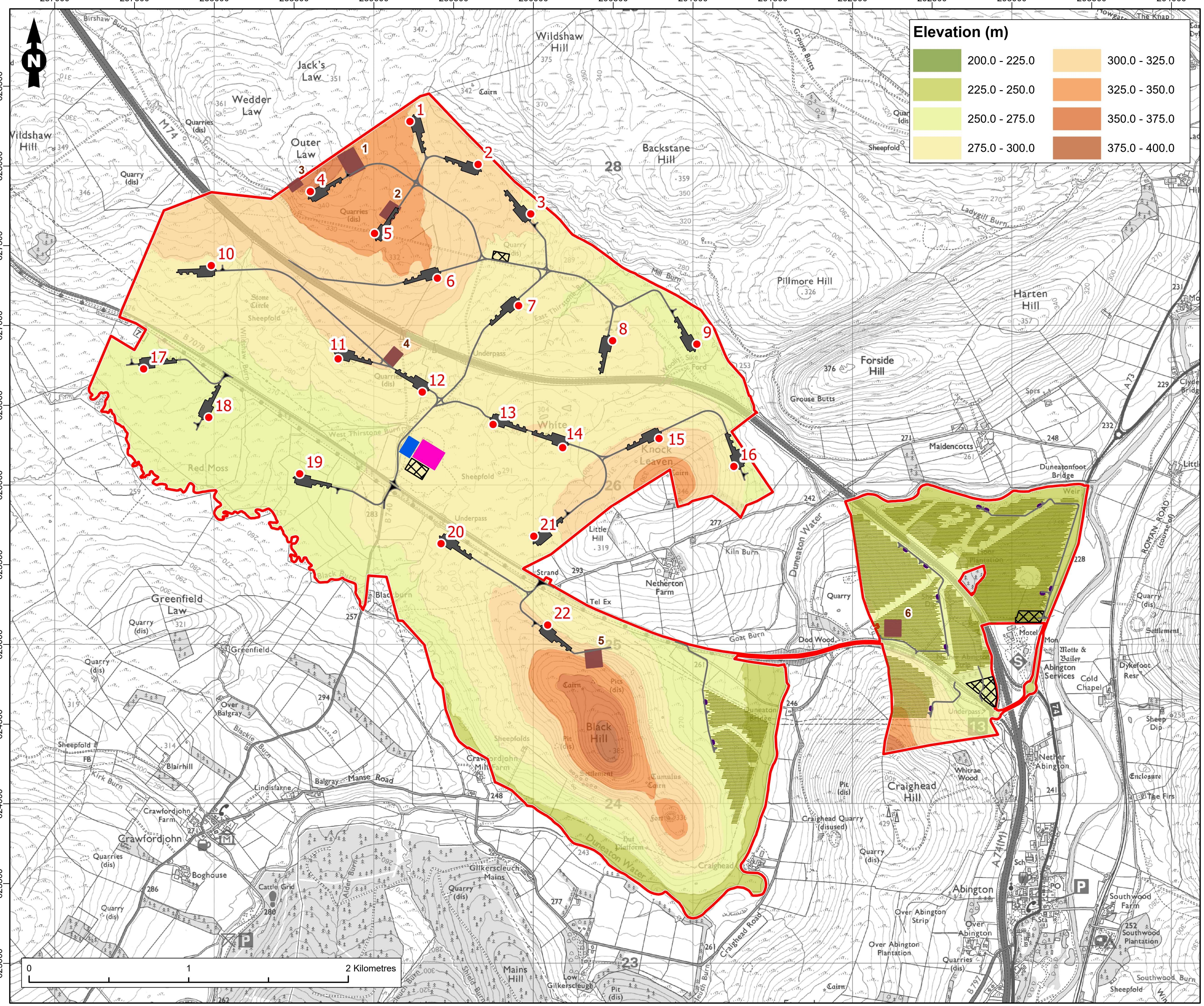
## 1.9 Conclusion

1.9.1 The Proposed Development site is considered to be Low or Very Low risk with regards to peat slide risk.

1.9.2 However, where areas of peat depth >0.5 m have been identified, micrositing of turbine and track infrastructure away from these areas, where practicable, is considered best practice.

1.9.3 Recommendations in the PWS assessment (**Technical Appendix 8.5, EIAR Volume 4**) are to be implemented to mitigate the potential impacts on DWPA and PWS catchment areas. It is considered that the general good practice mitigation measures included within Section 1.8 of this Technical Appendix will be sufficient to provide mitigation for low risk areas of the proposed development site.

1.9.4 Where new and temporary access tracks cannot be microsited away from areas of peat >0.5m in depth, with Low potential for instability, then the use of floating track construction may be used to avoid excavation of peat.




## Legend

- Site Boundary
- Turbines
- Solar PV Modules
- Inverter
- Substation
- Construction Compound
- Battery Site
- Borrow Pit Location
- Turbine Hardstanding Concrete
- Access Track, Junction & Turning Heads

| | |
|---|---|
| Figure Title | |
| Peat Landslide Hazard and Risk Assessment: Elevation | |
| Project Name | |
| M74 West Renewable Energy Park | |
| Project Number | Figure No. |
| 1620015684 | 8.3.1 |
| Date | Prepared By |
| August 2024 | BE |
| Scale | Issue |
| 1:22,500 @A3 | 1 |
| Client | |
| M74 West Ltd | |

RAMBOLL



Coordinate System: British National Grid. Projection: Transverse Mercator. Datum: OSGB 1936.
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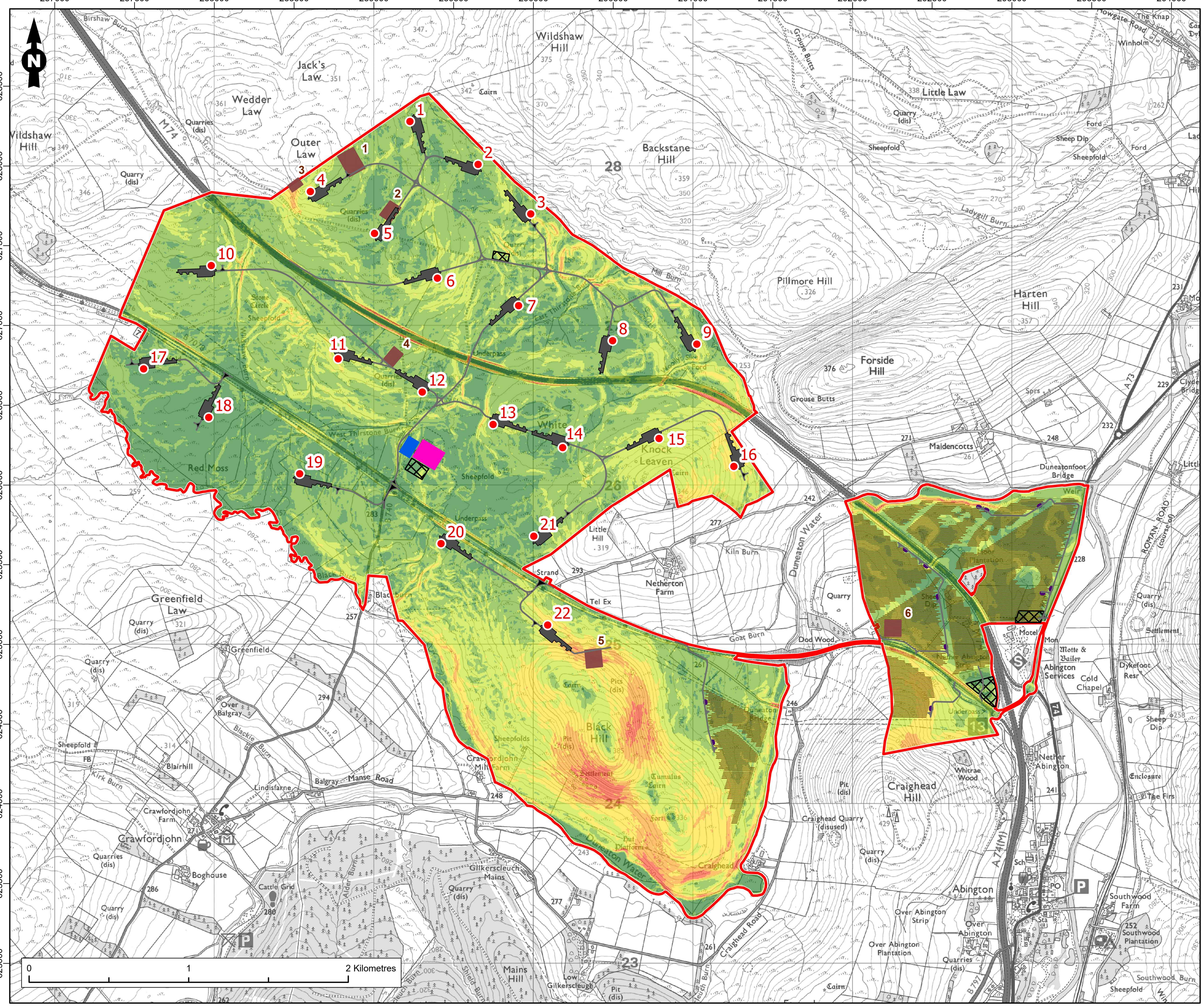


# Legend

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**Slope Angle (Degrees)**

- 0.1 - 2
- 2.1 - 5
- 5.1 - 10
- 10.1 - 15
- 15.1 - 20
- >20

| | |
|---|---|
| Figure Title | |
| Peat Landslide Hazard and Risk Assessment: Slope Angle | |
| Project Name | |
| M74 West Renewable Energy Park | |
| Project Number | Figure No. |
| 1620015684 | 8.3.2 |
| Date | Prepared By |
| August 2024 | BE |
| Scale | Issue |
| 1:22,500 @A3 | 1 |
| Client | |
| M74 West Ltd | |

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Coordinate System: British National Grid. Projection: Transverse Mercator. Datum: OSGB 1936.
1620015684-RAM-MA-IA-00046_Fig8.3.2SlopeAngle_04.pagx