Scottish & Southern Electricity Networks

TRANSMISSION

Dunoon to Loch Long 132 kV OHL Rebuild

Environmental Impact Assessment

Volume 4 | Technical Appendices

Appendix 10.1 – Peat Landslide Hazard and Risk Assessment

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LIST OF ABBREVIATIONS

BS	British Standards
DTM	Digital Terrestrial Model
EIA	Environmental Impact Assessment
EU	European Union
FoS	Factor of Safety
GIS	Geographical Information System
GI	Ground Investigation
AOD	Above Ordnance Datum
OS	Ordnance Survey
OHL	Overhead Line
PLHRA	Peat Landslide Hazard Risk Assessment
PSA	Peat Stability Area
SEPA	Scottish Environment Protection Agency
s37	Section 37
SNH	Scottish Natural Heritage (now NatureScot)
SSEN	Scottish and Southern Electricity Networks Transmission
UXO	Unexploded Ordnance

1. INTRODUCTION

1.1.1 This report forms an appendix to **Chapter 10: Hydrology, Hydrogeology, Geology and Soils** of the Environmental Impact (EIA) Report and should be read with reference to this chapter and associated figures.

1.1.2 Scottish and Southern Electricity Networks (SSEN) have established a requirement to replace the overhead line (OHL) between the existing Dunoon Substation and the Loch Long crossing to ensure security of supply. The Applicant is seeking consent under section 37 (s37) of the Electricity Act 1989[1] to replace the OHL between the existing Dunoon Substation and Tower 15, to the west of the Loch Long crossing (hereafter referred to as the Proposed Development). This will comprise of:

- the erection and operation of a replacement twin circuit 132 kV OHL, supported by steel lattice towers, between the existing Dunoon Substation and existing Tower 15, to the west of the Loch Long crossing; and
- the erection and operation of temporary single circuit wood pole 132 kV OHL diversions, to facilitate safe erection of the replacement OHL, close to, or on the existing OHL alignment.

1.1.3 The Proposed Development is approximately 18.0 kilometres (km) long, within the Argyll and Bute Council area and the Loch Lomond and The Trossachs National Park and is described fully in **Chapter 3: Description of the Proposed Development** of the EIA.

1.1.4 The Proposed Development footprint is a mixture of conifer woodland plantations, acid grassland and shrub heathland, the current land use is rough grazing and forestry. Peat is recorded in isolated pockets across the Site, notable in open areas coincident with lower slopes. The Study Area is defined as the peat depth grid, which was cropped to limit data to that within 250 m of the proposed OHL alignment, access track (new), access track to be upgraded (very poor condition) and the borrow pits. Access issues were encountered along the Proposed Retained Access Track at the northern extent, therefore the Study Area has not been extended outside of this track (see **Figure 10.1.5 Peat**). Specific mitigation measures have been proposed along the northern alignment in order to minimise the risk of peat landslides.

1.1.5 There are a number of existing forestry tracks, approximately 41.48 km, within the Site due to current land use, which have been utilised where possible to minimise environmental effect of the Proposed Development, and require different levels of repair or upgrade. Approximately 10.77 km permanent new access track will be required to be installed. Approximately 8.53 km of temporary access tracks will be installed which may range from stone construction to roadway panels (see **Chapter 3 Description of the Proposed Development** for further detail). All temporary tracks will be removed and reinstated on completion of construction.

1.1.6 An Unexploded Ordnance (UXO) assessment was commissioned to Zetica in April 2022. The report identified the northern extent of the Site (north of Glenfinart) as Moderate risk. As a result, peat probing at the northern extent was limited to 1.00 m depth due to UXO risk and the associated precautionary methodology, which was advised by the UXO Engineer escorting the peat survey team.

1.1.7 The Scottish Government developed guidance[2] to provide best practice information on methods for identifying, mitigating and managing peat landslide hazards and their associated risks. This guidance has been used for this assessment. Section 37 applications under the Electricity Act 1989[1], should also be assessed for peat landslide risk where infrastructure is proposed in peatland areas.

1.1.8 WSP was commissioned in 2022 to undertake a Peat Landslide Hazard Risk Assessment (PLHRA), for the Proposed Development, in conjunction with the soil and water elements of the EIA. The qualifications and experience of the team is stated in **Section 1.10 Technical Authors and Experience** of this report.

[1] UK Government (1989). *Electricity Act 1989*. Available at: https://www.legislation.gov.uk/ukpga/1989/29/contents

[2] Scottish Government (2017b). *Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments* (Second Edition). Available at: http://www.gov.scot/Publications/2017/04/8868

1.1.9 This document presents WSP's method for PLHRA, also referred to as peat stability assessment, the analyses performed and results obtained.

1.2 Aims

1.2.1 The broad aims of this assessment were to:

- provide a good level of understanding of site baseline (pre-development) peat stability conditions;
- aid the development design in order to reduce development activities that could cause an increased likelihood of peat instability, by careful consideration of infrastructure location and also construction techniques employed;
- identify the receptors that would be subject to adverse consequences, should a peatslide occur; and
- report peat stability risk assessment outcomes of the design following the principles of the Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments[2].

1.2.2 The assessment is based upon professional judgement and experience of assessing similar developments in similar environments. The following terms are used across this report.

- Proposed Development footprint – the footprint of the Proposed Development including towers, access tracks, borrow pits and temporary working areas.
- Site – comprises the Proposed Development footprint including towers, existing tracks (upgrades required – very poor condition), proposed retained access track, proposed access temporary and borrow pit search areas. The existing tracks (upgrades required – good, fair and poor conditions) have not been included as part of the scope of works for this assessment due to the minimal works required. The proposed retained access track at the northern extent is excluded from this assessment due to the lack of peat depth data, specific mitigation measures have been proposed to minimise the risk.

1.3 Methods

1.3.1 The methods adopted by WSP for the PLHRA of the Proposed Development have involved the following stages:

- desk study review of peat stability literature and available site data;
- aerial photography review;
- site reconnaissance including peat depth survey to characterise the prevailing ground conditions and identify existing or potential peat instability;
- Ground Investigation (GI) at specific locations of concern to provide additional data;
- initial stability analysis to identify likelihood, using a purposefully cautious factor of safety (FoS) method;
- identification of receptors;
- initial risk assessment undertaken to identify locations of concern ('Moderate' or 'High' initial risk level);
- revised risk assessment based on additional site information and visits to locations of concern, presented as datasheets detailing local characteristics and appropriate mitigation for specific locations of concern; and
- summarising key findings, including appropriate recommendations for further investigations at later stages of the development, subject to planning consent.

1.3.2 The PLHRA applied a phased approach, with findings at each phase feeding into the iterative design process and associated EIA. This included gathering further site information as the design progressed and revising stability calculations using the best information available.

1.3.3 Further detail on each of these stages is provided in the following sections, with Geographical Information System (GIS) software employed to manage and identify relationships between the various spatial datasets.

1.3.4 Figures have been provided that demonstrate the data available and analysis undertaken within this assessment, as Figures 10.1.1 to 10.1.14.

2. DESK STUDY

2.1 Literature Review of Peat Stability

2.1.1 Peat is a soft to very soft, highly compressible and highly porous organic material which can consist of up to 90% water by volume. Scottish Government guidance[3] defines peat as a soil with a surface organic layer greater than 0.50 metres (m) depth, which has an organic matter content of more than 60%. Unmodified peat typically has two layers:

- Acrotelm (surface layer) - often around 0.30 m thick (but can vary widely in depth depending on local conditions), highly permeable and receptive to rainfall. It generally has a high proportion of fibrous material and often forms a crust under dry conditions; and
- Catotelm (base layer) – in deeper peat deposits, this layer lies beneath the acrotelm and forms a stable colloidal substance which is generally impermeable. As a result, the catotelm usually remains saturated with little groundwater flow. A sub-division in catotelmic peat may occur, but is not always present, with fibrous catotelmic peat above amorphous catotelmic peat. Amorphous catotelmic peat is characterised as highly decomposed plant matter, with low structural integrity and may act as a liquid in terms of physical or geotechnical qualities, with associated challenges in terms of excavation, handling and storage.

2.1.2 Blanket peat tends to be formed in areas with high rainfall and low temperatures. In the Scottish context, blanket peat can be over 5.00 m in depth, especially in hollows or valleys, but is generally much shallower. Peaty podzols are characteristic of any topographic position where aerobic conditions prevail and water can percolate freely through the upper part of the profile. Podzols are formed in acid, coarse textured, well drained materials. Blanket peat is the most common form of peat in Scotland, podzols are widespread throughout Scotland.

2.1.3 Peat is thixotropic, meaning that its viscosity decreases under applied stress. This property may be considered less important where the peat has been modified through artificial drainage and is drier but can be an important factor when the peat body is saturated and is an important issue to consider in relation to potential peat stability failures.

2.1.4 Peat movements can be small-scale or large-scale. Small-scale movements include slope terracing, slumps, collapse of peat banks and collapses above peat pipe features. These small-scale events are relatively widespread in peatland environments and have limited consequences to receptors, although they do provide useful indicators of peatland morphology and processes which may influence large-scale peat instability.

2.1.5 A series of large scale (mass movement) peat events in autumn 2003, including at Derrybrien in the Republic of Ireland, and Dooncanton in Channerwick (South Shetland Mainland), Scotland, led to an increased recognition of the mass movement hazard, particularly in relation to development design and construction of windfarm projects on peatland. This led to Scottish Government guidance for energy developments being published in 2006 and updated in 2017 (Scottish Government, 2017b) to assess development risk of peat landslide. More recently, in November 2020 a mass movement of peat was recorded and widely reported at Meenbog Wind Farm, in County Donegal, Republic of Ireland.

2.1.6 Peat mass movement events have been classified by geomorphologists[4], within a Scottish context the primary processes of concern are peat landslides and peaty debris slides, with limited evidence of historic bog bursts and other phenomena. These features are defined below:

- Peat landslide – failure of a blanket bog slope, involving intact peat material shearing and sliding along at, or immediately above, the interface with underlying mineral soil, bedrock or boulder clay substrate[4]. The peat above the shear plane generally initially moves as an intact mass, then breaks

[3] Scottish Government (2017a). *Guidance on Developments on Peatland - Peatland Survey* (2017 Edition). Available at: https://www.gov.scot/publications/peatland-survey-guidance/

[4] Dykes, A.P. & Warburton, J. (2007). Mass movements in peat: A formal classification scheme. Geomorphology, Volume 86, 2007.

into smaller pieces and may then act as a liquid flow and follow drainage routes until material has been deposited[5]; and

- Peaty debris slides - shallow translational failure of a slope, often on very steep gradients, with the failure zone occurring wholly in mineral soil substrate below a shallow organic soil surface layer which may be less than 0.50 m depth. Surface peat is sheared and displaced due to failure of underlying material, rather than inherent peat instability[4].

2.1.7 In comparison with other peat mass movement phenomena described by Dykes & Warburton[4], peat landslides and peaty debris slides typically involve lower volumes of material, estimated as 500 - 50,000 m^3, with estimated velocities of 0.1 - 5.0 m/s for peat landslides and 0.1 - 10.0 m/s for peaty debris slides.

2.1.8 Peatland characteristics that may initially suggest a higher likelihood of peat mass movement, i.e. pre-disposition, include:

- increasing depth of peat;
- increasing slope angle;
- the presence of amorphous peat (well humified/decomposed); with less structural integrity and cohesion to remain on slope;
- convex slopes; instability may occur at or immediately downhill of the ‘break of slope’, often at the interface of deeper peat on a lower slope angle plateau or ridge; and
- waterlogged peat conditions; providing extra weight upon slope and lubricating transition zone/ basal surface between peat and underlying materials, such as clay, mineral soil or bedrock.

2.1.9 Specific conditions that are generally recognised as triggers for mass movement of peat include:

- Removal of slope support; reduces slope stability by natural or anthropogenic removal of support material below peat body. This could also be caused by decreased strength of slope materials on a temporal basis.
- Additional loading of slope; reduction in slope stability due to increasing of mass of slope above the peat body. This could be a result of development design or ancillary activities such as stockpiling of materials or heavy plant movement.
- Alteration to drainage patterns; increasing the mass of the peat body and lubricating the transition zone, potentially also increasing pore-water pressure at base of peat body. Can be a particular concern when intense rainfall follows a prolonged dry period, as fissures in peat body may enable rapid ingress to the transition zone. Prolonged wet periods in autumn and winter months in Ireland are considered as having a greater probability for peatslide events[5] and seasonal accumulation of snow may also be a factor, in terms of both weight and snowmelt input.
- Vibration; construction activities such as piling, stockpiling of materials or traffic, including heavy plant, movement. Potentially also caused by earth movement at susceptible geological locations.

2.1.10 Examples of mass peat instability can occur involving peat of less than 1.00 m depth and on relatively low gradient slopes (<5°), where appropriate combinations of conditions occur. Where depths are relatively shallow and gradients relatively shallow, events may be expected to be more limited in terms of area, volume of material and run-out distance. Peatslide events often commence on a susceptible slope and then follow drainage pathways downslope, with sediment release into such receptors.

2.1.11 There are a number of geotechnical variables in relation to peat properties. Those applicable to the FoS stability methodology applied by WSP are detailed below. The FoS calculation and method is discussed further in **Section 1.4** of this report. These variables include both site data and values based on academic literature. Where using literature values, conservative values are typically applied as a precautionary approach, which can then be potentially refined where there is justification to do so from further site information:

[5] Boylan, N., Jennings, P. & Long, M (2008). Peat slope failure in Ireland. Quarterly Journal of Engineering Geology and Hydrogeology, Volume 41, 2008.

- Depth of peat – measured onsite, to full depth with an accuracy of +/- 0.05 m;
- Slope angle – measured using site Digital Terrain Model (DTM) data at 5 m resolution, for both peat probes and using mean values for grid cells. The slope angles have been assessed as follow:
  - Little or no slope: 0° – 4°;
  - Gentle slope: 5° – 9°;
  - Moderate slope: 10° - 15°;
  - Steep slope: >15°;
- Shear strength of peat – shallow shear vane tests were undertaken onsite as part of the detailed assessment, but fibre content in peat is likely to over-estimate results and data was not available from base of peat body. Literature values suggest an expected pressure (expressed as force per area) range between 4 - 20 Kilonewton / square metre (kN/m^2)[5], with higher values for less humified/decomposed peat.
- Cohesive strength of peat – back-calculated using site-specific data using a 99th percentile value from the site depth data, this parameter largely dictates the shear strength of the peat in the FoS calculation. As above, literature values of shear strength suggest a range between 4 – 20 kN/m^2 [5].
- Undrained bulk density of peat – values for in situ peat range from 900 – 1300 kg/m^3 quoted in various papers and reports, with a typical value of 1,000 kg/m^3 (1.0 Mg/m^3) referenced in a number of papers [5].
- Bulk density of water – Standard scientific value of 1,000 kg/m^3.
- Water table depth as ratio of peat depth – a value of 1 represents water level being constantly at surface, this is conservative as the water level will vary temporally and geographically across the Site, often dropping below ground level.
- Angle of internal friction – a number of variables are present in peat (particularly fibre content and water content), a lower angle is more susceptible to movement on a slope. At 'quaking bog' locations, where the peat takes the form of a slurry beneath a surface mat of vegetation, the angle of internal friction will be very low (less than 5°) as the peat will effectively act as a fluid, however peat values of up to 58° are quoted in literature[5].

2.1.12 It is important to note that there are a number of limitations and concerns with regard to use of in situ shallow shear vane testing of peat and peaty soils, including the presence and orientation of fibres (e.g. vegetation matter) which may lead to an over-estimation of shear strength and that shear vane results from greater depth would be anticipated to record lower shear strength, due to higher level of decomposition and associated loss of structural integrity. The degree of peat decomposition, i.e. classified via Von Post, is considered to be a better practical indicator of shallow shear strength for peat bodies. However, it is considered that shallow shear vane data can provide useful data to enable comparison of different locations across a project area.

2.1.13 The Von Post classification system is a field-based method for characterising the level of peat humification/decomposition across 10 classes, with H1 categorised as completely undecomposed peat and H10 categorised as completely decomposed peat. Amorphous catotelmic peat is generally considered to be classified as H6 - H10, i.e. strongly decomposed or greater on this scale[3].

2.1.14 There are a number of recognised indicators that may occur in advance of mass peat instability, with the factors below particularly applicable to low velocity peat slides:

- the development of tension fracture cracking across the slope or in semi-circular patterns, particularly if these reach to base of peat;
- boggy ground or new springs appearing at the base of slopes;
- sudden reactivation of spring lines;
- peat creep or compression features, such as bulging of ground;
- displacement and leaning of trees, fence posts, dykes etc.; and

- breaking of underground services.

2.2 Information Sources

2.2.1 A desk study was undertaken, reviewing available information on the ground conditions within the Site; sources included:

- Ordnance Survey (OS) digital raster mapping, 1:50,000 and 1:25,000 scale;
- OS Historical mapping, 1:25,000 scale;
- OS Terrain 5 DTM data (5 m resolution);
- British Geological Survey DiGMap-GB 1:50,000 digital geological mapping, bedrock, superficial and linear geology;
- British Geology Survey GeoSure Landslide Hazards dataset 1:50,000 digital mapping;
- British Geological Survey Hydrogeological Map of Scotland, 1:625,000 scale;
- James Hutton Institute Soil Maps of Scotland, 1:250,000 scale;
- Aerial Imagery via Bing Aerial https://www.bing.com/maps/aerial, with this image also available via https://zoom.earth/#view=55.25042,-4.567607,14z/layers=esri (June 2018 image date);
- Aerial Imagery via ESRI World Imagery, embedded in ArcGIS software - https://www.arcgis.com/home/item.html?id=10df2279f9684e4a9f6a7f08febac2a9 (December 2009 image date, approximate); and
- Soil Survey of Scotland 1:250,000 Sheet 6 South West Scotland, mapping of soil types.

2.3 Site Context

2.3.1 The Proposed Development is an approximately 18 km long corridor, orientated north-south, commencing at the existing Dunoon Substation and extending south to Sandback, within the Argyll and Bute Council area. The Proposed Development footprint is a mixture of conifer woodland plantations, acid grassland and shrub heathland, the current land use is rough grazing and forestry. There are a number of existing forestry tracks. Peat is recorded in isolated pockets across the Site, notably in open areas coincident with lower slopes.

2.3.2 Elevation of the Site undulates, with slopes above 25 degrees at the northern extent, reaching a peak at Meall Dubh, 435 m above ordnance datum (AOD). There are a number of watercourses which are situated within or border the Site, including the Knap Burn, River Finart, Stronchullin Burn, River Eachaig and Little Eachaig River. Further geomorphology and hydrology information is provided within **Chapter 10: Hydrology, Hydrogeology, Geology and Soils** of the EIA.

2.3.3 The Proposed Development predominately follows the existing OHL from the existing Dunoon Substation to the Loch Long crossing.

2.3.4 The Proposed Development will utilise a combination of existing forestry tracks and new, permanent and temporary access tracks. Existing forestry tracks shall require upgrade and widening (widths depending on the track condition, ranging from 0.5 m to 1.5 m). There will be a requirement for a network of temporary access tracks to be created within the Proposed Development to service the infrastructure. These are shown on **Figure 3.1: Overhead Line and Access Tracks** of the EIA.

2.3.5 Slope gradients across the Site range from moderate to steep (up to 20°), with steepest slopes noted at the Am Binnein and Creag Mhor, in north and central part of the Site, respectively.

2.4 Baseline Conditions

2.4.1 Baseline conditions in the Site are discussed in detail within **Chapter 10: Hydrology, Hydrogeology, Geology and Soils** of the EIA Report. This chapter should be referred to for this information.

2.4.2 Cross-sections of Site topography showing infrastructure have been provided in **Annex E**.

2.5 Geology and Hydrology

2.5.1 Baseline information for geology and hydrology is provided in **Chapter 10: Hydrology, Hydrogeology, Geology and Soils** of the EIA.

2.5.2 Bedrock geology, superficial deposits (superficial geology) and hydrology features are presented on **Figure 10.1.1 Bedrock Geology**, **Figure 10.1.2 Superficial Geology** and **Figure 10.1.3 Hydrology Overview**, respectively.

2.5.3 The peat on the Site, where present, is predominantly characterised as blanket peat and peaty podzols (with associated habitat known blanket bog communities, wet heathland and rough grassland communities).

2.5.4 It is considered that extreme rainfall events are a likely trigger for mass peat instability, as identified in **Section 2.1 Literature Review**. Such events can occur at any time of year, although those occurring after prolonged dry periods may introduce higher risk as dry peat conditions may be more vulnerable to water ingress to base.

2.5.5 Drains are present throughout the Site, these have not been mapped for the project, with OS 1:10,000 mapped channels used in GIS and discussed during the assessment. Local drainage channels would be anticipated to reduce slope soil moisture content and reduce mass of peat; however, it is acknowledged that cut drainage channels could remove slope support (if located mid-slope or at base of slope). Drainage discharge locations can exacerbate erosion processes if flows converge at sensitive locations.

2.5.6 With much of the Site being subject to commercial forestry activities, some of which is recent, the ground conditions are heavily influenced by these practices in specific localities.

2.6 Carbon Rich Soils, Deep Peat and Priority Peatland Habitats

2.6.1 The NatureScot Carbon and Peatland Map[6], a GIS vector dataset covering Scotland, presents the importance of these environmental interests. They have been derived using a matrix of soil carbon categories (derived from Soil Survey of Scotland maps) and peatland habitat types (derived from Land Cover of Scotland 1988 map).

2.6.2 With regard to Scottish Planning Policy[7], carbon-rich soils, deep peat and priority peatland habitat Importance Categories (also referred to as Classes) 1 and 2 from the Carbon and Peatland Map are within Group 2 (‘areas of significant protection’), where development should demonstrate that effects can be substantially overcome by siting, design or other mitigation.

2.6.3 The mapping indicates that no Class 1 is identified within the Site, with Class 2 ‘nationally important carbon-rich soils, deep peat and priority peatland habitat’ covering approximately 10% of the Site; in the central area between Stronchullin Hill and Meall Dubh.

2.6.4 Class 0 covers the majority of the Site, with pockets of Classes 3, 4 and 5 present across the entire Site. Classes 0, 3, 4 and 5 are not classified as priority peatland habitat.

2.6.5 The outcomes of the more detailed peat survey, discussed below, provide site-specific peat depth information which supersedes the higher-level characterisation from the NatureScot Carbon and Peatland Map dataset[6]. This more detailed peat information was used to inform the design of the layout of the Proposed Development and the subsequent assessment (see **Figure 10.1.5 Peat**).

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[6] NatureScot (2016). *Carbon and Peatland Map*. [online] Available at: https://www.nature.scot/professional-advice/planning-and-development/planning-and-development-advice/soils/carbon-and-peatland-2016-map [Accessed in November 2022].

[7] Scottish Government (2014). *Scottish Planning Policy*. Available at: https://www.gov.scot/publications/scottish-planning-policy/

2.7 Aerial Photography

2.7.1 The Bing Aerial imagery from 2018 and the earlier imagery from ArcGIS World Imagery show eroding peat morphology and evidence of modification to soil and peat north-west of Stronchullin Hill, from commercial forestry activities and other local developments.

2.7.2 Aerial imagery was reviewed for features such as peat landslides, peaty debris slides, gully head failures and collapsing peat banks, with particular attention to features within 100 m of proposed infrastructure. A number of features identified from aerial photography such as artificial drainage channels, tree windfall and soil changes.

2.7.3 There were four individual polygons identified through aerial imagery that indicated potential historic peat slides within the Site. During peat stability assessment fieldwork, the survey team did not observe any evidence of previous peat instability when crossing these areas, however, one feature is located at the northern extent of the Proposed Development and was not visited due to the moderate risk of UXO and tree windfall. These features are considered to be more likely to have been the result of erosion or land use practices, which may include peat cutting, borrow pits, drainage or vehicle passage.

2.7.4 The local features described above have been incorporated on **Figure 10.1.13 Geomorphology**.

2.7.5 Aerial Photography of the Site is provided as Figure **10.1.4 Aerial Photography**.

2.8 GeoSure Landslide Hazards

2.8.1 GeoSure Landslide Susceptibility data from the British Geological Survey was entered into GIS and areas identified as being categorised as GeoSure Landslide Susceptibility Classes D or C were related to the Site and latterly to infrastructure locations. The definitions for these classes are as follows:

- GeoSure Landslide Susceptibility Class D; slope instability problems are probably present or have occurred in the past. Land use should consider specifically the stability of the Site; and
- GeoSure Landslide Susceptibility Class C; slope instability problems may be present or anticipated. Site investigation should consider specifically the slope stability of the Site.

2.8.2 A number of towers were identified within the Site within or close to Class C and D zones, especially at the northern and central areas. Site visits in June, July, August and November 2022 were undertaken to verify peat instability features in close proximity to planned infrastructure.

2.8.3 The GeoSure hazard dataset has been incorporated alongside other geomorphology data collated and presented on **Figure 10.1.13 Geomorphology** and on datasheets provided in Annex B.

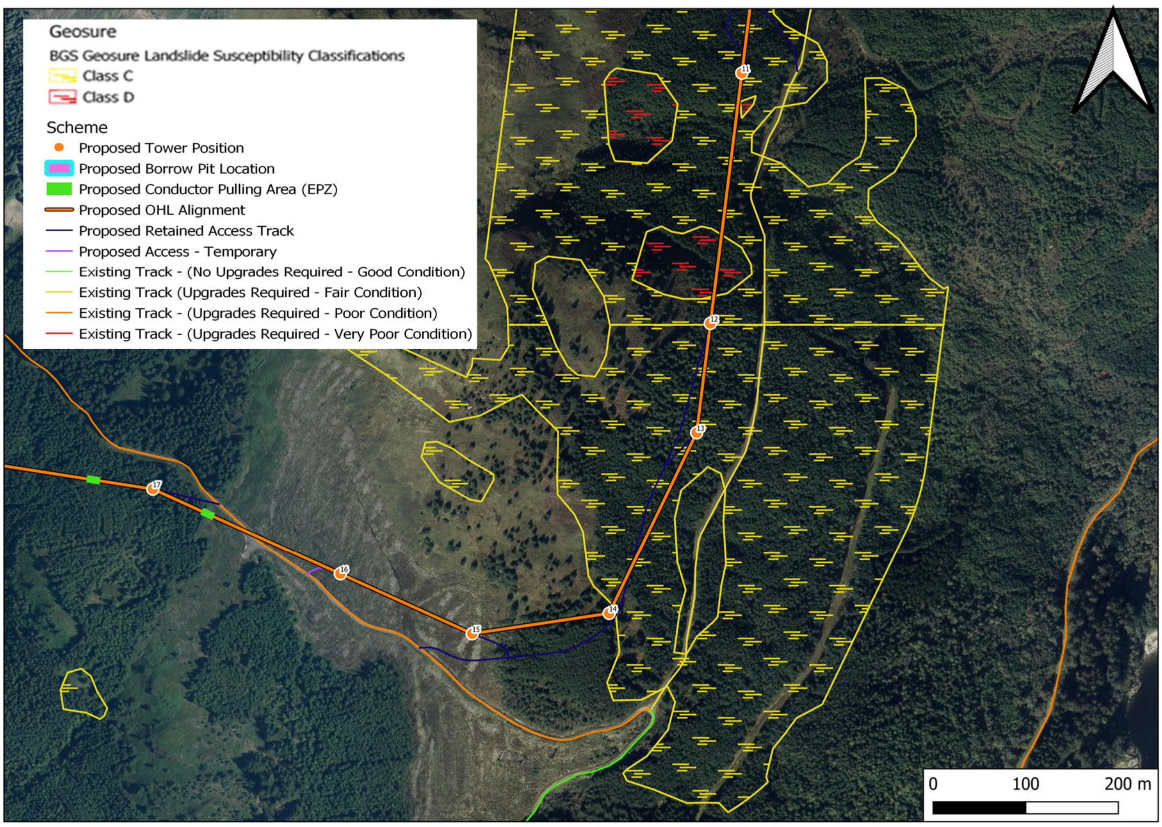
2.9 Historical Information

2.9.1 OS historical mapping was reviewed and identifies heathland and moorland or rough hill pasture land use, with some pockets of forest.

2.9.2 The GeoSure dataset alongside the aerial photography provided a useful indication of landslide or potential landslide locations. **Image 10.1** displays Site aerial imagery with GeoSure data overlain.

2.9.3 During site visits, surveyors did not observe any evidence of previous peat instability within the Site, including previous modifications relating to drainage, land use and constructed forestry access tracks.

Image 2.1: GeoSure and Aerial Image Data, Am Binnein



3. SITE RECONNAISSANCE AND FIELD SURVEYS

3.1.1 Walkover and peat probing surveys were carried out at two stages. The survey during June, August and November 2022 focussed on gaining a good overall understanding of the Site and collecting representative peat depth data, including the majority of infrastructure locations.

3.1.2 The site visit in July 2022 focussed on the areas identified with higher risk of peat instability during the peat stability assessment. The survey collated multiple sets of site data concurrently, with supplementary peat probing alongside peat coring. These items have been discussed separately but integrated visits enabled a better understanding of peat features at specific locations.

3.1.3 The weather during the site visits was generally good. There were no occasions where frozen conditions prevented peat depth results being accurately recorded.

3.2 Site Reconnaissance

3.2.1 **Photographs 3.1** to **3.6** provide images and descriptive text of representative features at the Site, identifying the range of landforms observed. It should be noted that these photos provide context and do not necessarily indicate the location of infrastructure, which has been located to avoid the steepest and deeper peat areas, where possible. Additional photographs are provided in **Annex B**. There were no locations on the Site where mass peat instability was observed.

Photograph 3.1: Looking west towards existing forestry track cutting on the eastern slopes of Cruach a' Chaise, from NGR 220110, 691032.

Photograph taken at approximately 190 m AOD showing existing forestry track cutting, approximately 150 m downslope of proposed Tower 7.

Providing evidence of peat depths of less than 0.50 m.

Measured peat depths in the area range from 0.10 to 0.80 m. At the road cutting location, the slope angle is approximately 20°.

There were no signs of instability.

This area is discussed as Peat Stability Assessment (PSA) Area B in **Annex B**.

Photograph 3.2: Exposed and eroding peat banks. Looking west towards the proposed OHL, from Cnap Reamhar, taken at NGR 217357, 687633.

Photograph taken at approximately 320 m AOD, 70 m east of peat core C01 location, at Cnap Reamhar in the central part of the Site. The eroded peat banks indicate a local peat depth of approximately 1.00 m. This situation is typical on the central part of the Site, based on depth records and a number of exposures on slopes.

Deep peat deposits were identified close to this location during the surveys. Measured peat depths in the area range from 0.20 to 4.00 m. At the location where the photograph is taken, the slope angle is approximately 4°, increasing to 20° upslope.

This is not considered a mass movement feature, with no signs of instability apparent.

This area is discussed as PSA Area E in **Annex B**.

Photograph 3.3: Looking east towards the existing overhead line from the western slopes of the Stronchullin Hill, taken at NGR 216361, 686437.

Photograph taken at approximately 405 m AOD at peat core C02 location on the western slopes of the Stronchullin Hill, where deep peat deposits were identified during the surveys.

Measured peat depths in the area range from 0.20 to 2.50 m. At the location where the photograph is taken, the slope angle is approximately 9°, increasing to 20° upslope where shallower peat was encountered. The slope gradient is gentle to moderate, with no signs of instability noted in the vicinity of the existing overhead line.

There are a number of small streams formed on the steeper slopes, which discharge to the Inverchapel Burn.

Vegetation at this location is dominated by grassland.

This area is discussed as PSA Area F in Annex B.

Photograph 3.4: Looking west towards the existing forestry tack from the lower slopes of Finbrack Hill, taken at NGR 214676, 680290.

Photograph taken at approximately 150 m AOD on the lower slopes of Finbrack Hill in the southern part of the Site.

Measured peat depths across this area range from 0.65 to 2.67 m. At the location where the photograph is taken, the slope angle is approximately 5°, increasing up to 7° where deeper peat deposits are noted. The slope gradient is gentle to moderate, with no signs of instability noted.

The vegetation on the slopes is grassland, showing a recent clear-felled area with legacy forestry drainage. Tree roots are likely to bind the surface soil.

This area is discussed as PSA Area K in Annex B.

Photograph 3.5: Looking north-east towards Coulport from the existing forestry track on the northern slopes of Cruach a' Chaise, taken at NGR 219811, 690600.

Photograph taken at approximately 180 m AOD, from the northern slopes of Cruach a' Chaise, where shallow peat deposits were identified during the surveys.

Measured peat depths in the area range from 0.00 to 0.50 m. At the location where the photograph was taken, the slope angle is approximately 30°. The slope gradient is steep, with no signs of instability noted.

Vegetation at this location is dominated by forestry conifer plantation.

This area is discussed as PSA Area A in Annex B.

Photograph 3.6: Looking upstream at Allt Mhill Odhair, taken at NGR 217689, 688691.

Photograph taken at approximately 37 m AOD at Allt Mhill Odhair, showing a semi-natural channel within forestry in the north-central part of the Site. The watercourse is located within an incised channel eroding into the peat. The slope gradient is steep at 30°, and the flow observed was fast at the time of visit.

3.3 Peat Depth Survey

Fieldwork

3.3.1 The peat depth survey for the Proposed Development was undertaken in two phases, Phase 1 and Phase 2, in line with the guidance on Developments on Peatland[3].

3.3.2 Initially, peat probing was undertaken in June and August 2022 focussing on the proposed tower locations. This allowed a representative dataset of peat depths on a variety of landforms, including adjacent to watercourse channels and peatland features, across a range of peat depths and slope angles. Further peat probing targeting the amended northern alignment was undertaken in November 2022.

3.3.3 WSP's approach does not include for the wider grid-based format that Scottish Government guidance[3] suggests, with peat probing conducted to provide representative coverage of various landforms and then focussed peat probing on the planned development area. Additional data was collected where a higher level of initial risk, in terms of peat stability, was determined.

3.3.4 This deviation from the Scottish Government standard approach[3] to peat survey is based on WSP's experience on previous energy EIA projects, based on an initial 50 m x 50 m grid coverage of the entire Site. WSP believe that an appropriate level of detail can be obtained by a more targeted approach.

3.3.5 WSP targeted peat surveys within the Site, focussing on the provisional layout locations, during the initial survey work. Though resulting in a reduced spatial density in peat depth data, we consider that sufficient and representative peat depth data was collated for the Site. This approach aligns with our standard development-focussed and risk-based approach to peat surveys for energy projects, conducted on recent projects such as Carrick, Harestanes Extension and Clash Gour. Each of these are Section 36 developments and the peat data was accepted as thorough and robust by the Scottish Environment Protection Agency (SEPA) and Scottish Government appointed Peat Stability Advisor.

3.3.6 The first stage was undertaken to establish the nature and extent of peat on site to enable design input. This involves probing for uncapped peat depth data focusing peat survey efforts within the developable area of the site, utilising any provisional layout locations during this Phase 1 work. This resulted in peat probing at an approximate frequency of every 50 m alongside the OHL. This also included the production of a conjectural peat grid-based map for the Site.

3.3.7 Following data gathering and processing of the peat depth results, areas of confirmed or suspected deeper peat were identified and initial observations relating to peat stability were made (using the FoS technique detailed later in this report but with the abbreviated dataset available at this stage).

3.3.8 Following feedback on the design, plus input from other disciplines, a number of changes were suggested for the layout and the Site was revisited during November 2022. This information fed into the final design decision.

3.3.9 Additional peat probing (Phase 2) was undertaken as part of the peat stability risk assessment visit in July 2022, alongside other peat-related data collation, including shallow shear vane tests and peat coring for Von Post assessment, to further inform the understanding of peat characteristics and stability factors at identified locations of concern.

3.3.10 The peat depths were measured using Van Walt peat probing rods, consisting of multiple connecting 0.94 m fibreglass sections, with depths measured via tape measure to an accuracy of ±0.05 m. The rods were pushed into the ground until they could be pushed no further, with the depth recorded. There were 998 peat depths recorded on the Site, with no results exceeding the depth of peat probes, the deepest record being 4.00 m, located 100 m south-west from proposed tower 28.

3.3.11 The collected data from the initial peat probing survey are summarised in **Table 3.1**; 72.4% of the points probed had a peat depth result of less than 0.50 m (non-peat), with 90.8% of the results less than 1.00 m and 95.8% less than 1.50 m, the average peat depth was 0.39m. The peat depth results are mapped and presented as **Figure 10.1.5 Peat** and in more detail on **Figure 10.1.5a-c**.

Table 3.1: Results of the Peat Probing Survey

Peat/Soil Depth Range (m)	Number of locations surveyed	Percentage of locations surveyed	Average depth in range (m)
0.0 to <0.5	723	72.4%	0.16
≥0.5 to <1.0	183	18.4%	0.67
≥1.0 to <1.5	50	5.0%	1.19
≥1.5 to <2.0	20	2.0%	1.72
≥2.0 to <2.5	13	1.3%	2.17
≥2.5 to <4.0	8	0.8%	2.84
≥4.0	1	0.1%	4.00
Total / Aggregate	998	100.0%	0.39

3.3.12 There are sections of the Proposed Development with limited peat probing data within the route, with spacing exceeding 100 m in a number of locations, due to a health and safety and asset protection constraints (see **Figure 10.1.5 Peat**). The main constraints in the Site are the UXO Moderate risk, existing OHL and access constraints due to tree windfall. Eleven peat depth records were limited to 1.00 m depth due to UXO risk and the associated precautionary methodology, as advised by competent personnel escorting the WSP peat survey team. These eleven limited results are considered unlikely to skew the recorded average and are likely to largely represent depths between 1.00 and 1.50 m, based on local records.

3.3.13 Peat depth data is relatively consistent across the Site, with probing placed on the margins of the constraints buffer, as close as possible to the proposed towers. Further peat probing and stability assessment shall be undertaken pre-construction to confirm findings and any refined data collated in a number of PSA Areas (see **Annex B**).

Indicative Peat Depth Mapping

3.3.14 The use of a regular grid for terrain analyses of this type is a standard recognised GIS technique and is widely applied in a range of situations. A grid system allows the application of a systematic process across the terrain, where a set of relevant properties need to be assigned to each particular location. In this analysis, these properties include slope angle and peat depth.

3.3.15 The resolution of DTM and base mapping must be taken into account, as using a very fine grid with a resolution identical to or finer than the DTM would return spurious results with a false indication of accuracy. For the Proposed Development, a 50 m grid was used in line with WSP's established peat stability analysis method as this is a fine enough scale to provide an appropriate level of detail for analysis but also sufficiently large to gain meaningful results from the 5 m resolution DTM and derived slope model.

3.3.16 To inform the refinement of the infrastructure layout, the results of the initial peat probing survey were used to produce an extrapolated indicative peat depth map for the Site, creating a grid of 50 m x 50 m cells overlaid across the Site and applying a peat depth category to each. The peat depth ranges used are detailed in **Table 3.2**. Following final design, the peat depth grid was cropped to limit data to that within 250 m of the Proposed Development footprint, this dataset includes the alignment, towers, existing access tracks (very poor condition) and borrow pits, including data gathered upslope and downslope of locations of concern. The Proposed Retained Access Track and Temporary Access Track are included within the peat depth grid.

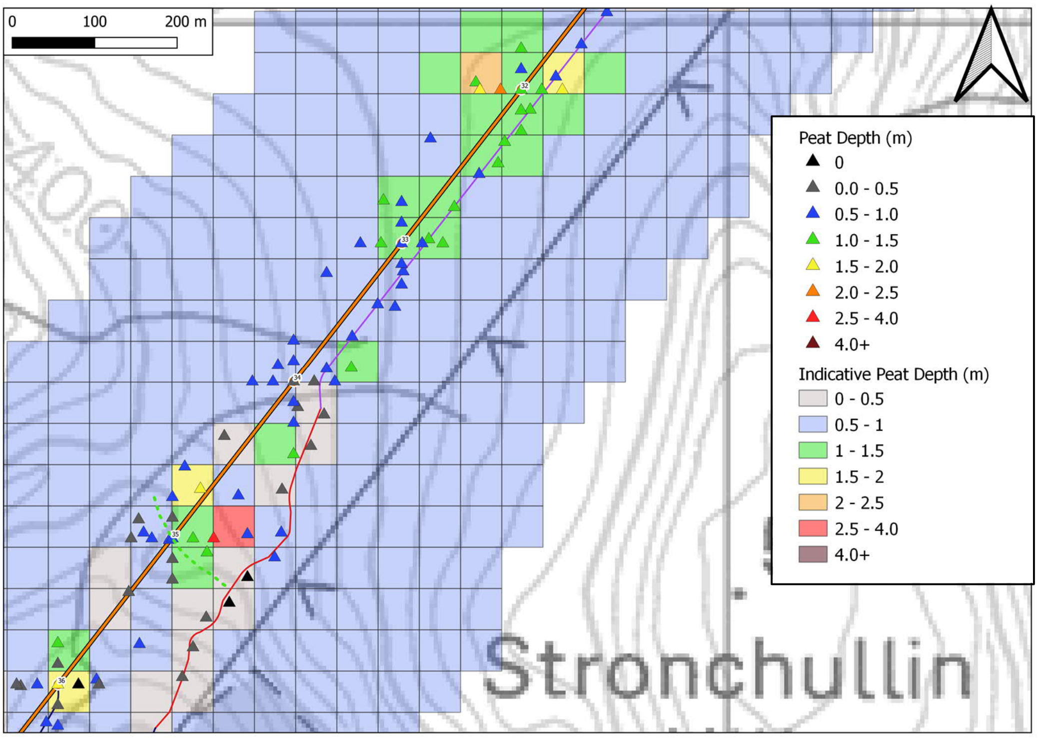
Table 3.2: Indicative Peat Depth Categories

Peat Depth Range (m)	Peat Depth Category
0.0 to <0.5	No Peat
0.5 to <1.0	Shallow
1.0 to <1.5	Moderate
1.5 to <2.0	Moderately Deep
≥2.0 to <2.5	Deep
2.5 to <4.0	Very Deep
≥4.0	Exceptionally Deep

3.3.17 Peat depth category names and ranges were chosen in the context of energy projects development; for example, the threshold between considering cut-and-fill and floating access track construction is typically around 1.00 m - 1.50 m peat depth. Equally, the practicalities of installing towers in peat more than 2.50 m deep makes this a less attractive option. The threshold for very shallow peat of 0.50 m is based on the Soil Survey of Scotland definition[8], as used in the Scottish Government guidelines[2].

3.3.18 **Image 3.2** shows an enlarged portion of the peat depth mapping. Each cell is 50 m x 50 m with peat categories colour coded as per **Table 3.2**. The full indicative peat depth map across the Site is included as **Figure 10.1.5 Peat** and **Figures 10.1.5a-c**.

Image 3.2: Sample of Indicative Peat Depth Map, Stronchullin Hill



3.3.19 From observation, it is clear that both slope and elevation have an influence on the development of peat, although the exact mechanism is not definitive and there is no mathematical growth/ decay model for the development and depth of peat. However, slope and elevation factors may be used intuitively when extrapolating from peat sampling data in the creation of an indicative peat depth map. It is often evident

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[8] The James Hutton Institute (1982). *Handbook to Soils Mapping Sheet 6: South West Scotland*. Soil Survey of Scotland. [online] Available at: https://www.hutton.ac.uk/sites/default/files/files/soils/Soil250k_6_South_West_Scotland_full.pdf [Accessed in November 2022].

that deeper peat is generally found in flatter areas such as valleys, plateaux and hollows. Flat areas on hill summits tend to have relatively little peat; this is possibly due to a combination of exposure and slow growth rate as well as better drainage. Steep slopes also generally have less peat, owing for the most part to their better drainage and more rapid runoff.

3.3.20 As can be seen from **Image 3.2** and **Figure 10.1.5 Peat**, **Figure 10.1.5a Peat Northern**, **Figure 10.1.5b Peat Central** and **Figure 10.1.5c Peat Southern**, where a cluster of peat probing points is all within the same peat depth category this has been taken as a good indication of the general peat depth in the surrounding area and the indicative peat depth map has been coloured accordingly. However, where clusters of peat probing points have returned depths in a range of depth categories a cautious approach has been taken, with the indicative peat depth map being classified in line with the deepest category of peat found in the area. This leads to a conservative indicative peat depth map.

3.3.21 The peat depth category breakdown for both the actual probing data and the extrapolated grid is given in **Table 3.3**. On **Table 3.3**, the rows representing indicative peat depth grid data for 'measured depths' represents those cells generally closest to the planned infrastructure and thus more representative of site conditions underlying and close to the Proposed Development.

Table 3.3: Peat Depth Category Breakdown

Peat Depth Range (m)		<0.50	0.50 - <1.00	1.00 - <1.50	1.50 - <2.00	2.00 - <2.50	2.50 - <4.00	≥4.00	Total
Probing Data	No. of points	723	183	50	20	13	8	1	998
	% of points	72.4%	18.4%	5.0%	2.0%	1.3%	0.8%	0.1%	100.0%
Indicative Peat Depth Grid	No. of cells	1,186	3,119	60	17	10	8	1	4,401
	% of cells	27.0%	70.9%	1.4%	0.4%	0.2%	0.2%	0.0%	100.0%
Indicative Peat Depth Grid (measured depths)	No. of cells	397	134	42	16	8	8	1	606
	% of cells	65.5%	22.1%	6.9%	2.6%	1.3%	1.3%	0.3%	100.0%

3.4 Peat Cores and Shear Vane Data

3.4.1 Peat core locations were selected to specifically target areas where peat depths had previously been recorded that exceeded 1.00 m, close to the final design, with core data collected in July 2022 using a Russian corer and details provided in **Table 3.4**.

3.4.2 Two of the five cores locations exhibited a Von Post value of H6 humification degrees, suggesting that amorphous catotelmic peat may be present at depths ranging from 1.52 m to 1.85 m, but less humified material was identified at the rest of core locations at shallower depths.

3.4.3 Shear vane results provide information on the shear strength of the soil, which for peat is typically dictated by cohesive strength characteristics[5]. Shear strength of peat is generally considered to range between 4 – 20 kN/m^2, as indicated by the Scottish Government Guidance[5], with Site results of 15 – 29 kN/m^2, broadly similar to the literature expectation (or greater, which is likely to represent peaty soils or *in situ* fibres at test location). These were collected adjacent to core locations at shallow depths (0.95 m to 1.85 m). However, it is important to note that there are a number of limitations and concerns with regard to use of in situ shallow shear vane testing of peat and peaty soils, as discussed in **Section 1.2.1 Literature Review Section**, with a lower bound value of 4 kN/m^2 from literature review considered more appropriate and conservative. The shear vane used was calibrated in 2016, however, this equipment is safely boxed and not in regular use and is considered reasonably accurate for the purpose of establishing general peat characteristics. The Von Post classification is considered a more pragmatic indicator of shear strength characteristics from field data.

3.4.4 Amorphous catotelmic peat has been considered present for the Proposed Development, with a threshold depth of 1.50 m, given overall core data.

3.4.5 The geotechnical input (peat probing and coring surveys) provided to date does not replace geotechnical site investigations that would take place prior to construction commencing to inform the detailed site design, with the above information intended to provide design advice and the basis for assessment for the purposes of the application submission.

3.4.6 Peat core locations are presented on **Figure 10.1.6 Peat Core Locations**, with photographs for C01-C05 provided in **Annex D**. Data from these sources were applied to the datasheet locations provided in **Annex B**.

Table 3.4: Peat Core and Additional Ground Investigation Data

Peat Core ID	National Grid Reference (NGR)	Core Depth (m)	Core Description and Results	Core Location Information
C01	NGR 217300, 687676	1.85	Von Post H6 – Moderately Highly Decomposed. Considered amorphous catotelmic peat. Approximately one third of peat expressed, roots and plant material distinct. Very small amount of turbid water expressed. Shallow shear vane results taken at 0.30 m depth: - 60 division: 19 kN/m²; - 78 division: 25 kN/m²; - 72 division: 23 kN/m².	No visual evidence of instability, low gradient. Grassland with minor channels across the area. Peat core shown on **Photograph 10.19**, **Annex D**. This core location is shown on **Photograph 10.2** in the **Site Reconnaissance Section**. This core location is noted on PSA Area E in **Annex B**.
C02	NGR 216361, 686437	1.51	Von Post H5 – Moderately Decomposed. Grass roots evident. Some peat expressed, with no water coming through, very mushy residue. Shallow shear vane results taken at 0.30 m depth: - 90 division: 29 kN/m²; - 78 division: 25 kN/m²; - 81 division: 26 kN/m².	No visual evidence of instability, low gradient. Peat eroded as a result of surface water run-off. Grassland with minor channels across the area. Peat core shown on **Photograph 10.20**, **Annex D**. This core location is shown on **Photograph 10.3** in the **Site Reconnaissance Section**. This core location is noted on PSA Area F in **Annex B**.

Peat Core ID	National Grid Reference (NGR)	Core Depth (m)	Core Description and Results	Core Location Information
C03	NGR 215880, 685766	1.35	Von Post H3 – Very Slightly Decomposed. Plant structure distinct. No peat expressed through fingers, muddy brown water expressed. Shallow shear vane results taken at 0.30 m depth: - 50 division: 16 kN/m²; - 55 division: 18 kN/m²; - 51 division: 16 kN/m².	No visible evidence of instability in vicinity to the core. Topography levels in this area, sloping towards the north-east. Grassland with flush zone across and surface water channels. Peat core shown on **Photograph 10.21**, **Annex D**. This core location is noted on PSA Area G in **Annex B**.
C04	NGR 215743, 685251	0.95	Von Post H5 – Moderately Decomposed. Plant structure quite indistinct. Small amount of peat expressed through fingers, very muddy water expressed. Shallow shear vane results taken at 0.30 m depth: - 80 division: 26 kN/m²; - 85 division: 27 kN/m²; - 80 division: 26 kN/m².	No visible signs of instability locally. Flush zone surrounded by heathland. Topography is gentle to moderate, sloping towards the north. Peat core shown on **Photograph 10.22**, **Annex D**. This core location is noted on PSA Area G in **Annex B**.
C05	NGR 214676, 680290	1.52	Von Post H6 - Moderately Highly Decomposed. Considered amorphous catotelmic peat. Approximately one third of peat expressing through fingers, plant structure distinct on the sample and strong turbid water expressed. Shallow shear vane results taken at 0.30 m depth: - 48 division: 15 kN/m²; - 59 division: 19 kN/m²; - 52 division: 17 kN/m².	No visible evidence of instability, low gradient. Overgrown clear-felled area. Peat core shown on **Photograph 10.23**, **Annex D**. This core location is noted on PSA Area K in **Annex B**.

4. FACTOR OF SAFETY ANALYSIS

4.1.1 To establish the stability of peatland areas, WSP applies the 'Factor of Safety' methodology. This procedure involves the application of site data (peat depth and slope angle) alongside 'values for a number of further variables, with the more sensitive of these being the values allocated for cohesive strength and in situ (undrained) bulk density of peat. The values applied are based on literature review and are generally considered conservative, in accordance with a purposefully precautionary approach.

4.1.2 This PLHRA initially determines areas considered of greatest risk of slope failure, based on FoS slope stability calculations, these areas were then considered in greater detail, including site visits to gather further information.

4.1.3 Using the collated data an initial analysis of slope stability can be carried out using the infinite slope model. The stability of a slope can be assessed by calculating the FoS, *F* which is the ratio of the sum of resisting forces (shear strength) and the sum of the destabilising forces (shear stress):

$$F = \frac{c' + (\gamma - m\gamma_w) z \, Cos^2 \beta \, Tan\phi}{\gamma \, z \, Sin\beta \, Cos\beta}$$

4.1.4 Where *c'* is the effective cohesion, γ is the unit weight of saturated peat, γ_w is the bulk density of water, *m* is the height of the water table as a fraction of the peat depth, *z* is the peat depth in the direction of normal stress, β is the angle of the slope to the horizontal and φ' is the effective angle of internal friction.

4.1.5 The FoS, *F*, represents the ratio of the forces resisting a slide to the forces causing the material to slide. If $F > 1$ then the slope is stable and normally if $F > 1.4$ then there is a degree of comfort that the slope would not fail. The boundary value of 1.4 is in agreement with the current recommendations of Eurocode 7[9].

4.1.6 To get an indication of the stability of the peat at the proposed pole locations, the FoS can be calculated for each peat probing location. In addition, to gain a better view of peat stability in the areas surrounding the infrastructure, FoS calculations can be carried out for the grid cells of the indicative peat depth map in the vicinity of the infrastructure. To do this, we must know or be able reasonably to infer the parameters for the FoS equation for each probing location and grid cell.

4.1.7 The slope angle, β, can be derived from the DTM for the Site. With the peat probing locations, a single slope angle value is generated for each point, whilst the DTM is interrogated for maximum, minimum and mean slope values for each grid cell. The mean slope angle has been used in the grid FoS calculations, although the other statistics provide useful supporting information on the variability of slope within the cells.

4.1.8 The actual peat depth measurements recorded for each probing location are used in calculating the point FoS values. For the grid-based FoS assessment it is necessary to convert the indicative peat depth ranges into a specific figure for each range for use within the calculation (where no measured depth was recorded) and using the maximum depth record for cells with measured depths. Taking a conservative approach, the upper bound of each range has been used, where actual data is not held. Measured peat probing depth records are presented as a histogram in **Image 4.1**, with reference to **Tables 3.1** and **3.3**; 72.4% of results are less than 0.50 m and 90.8% are less than 1.00 m.

4.1.9 The bulk density of water, γ_w, is known to be 1.00 Mg/m^3.

[9] BSI (2004 & 2007). Geotechnical design. Eurocode 7: BS EN 1997-1: 2004 & BS EN 1997-2: 2007, British Standards Institute.

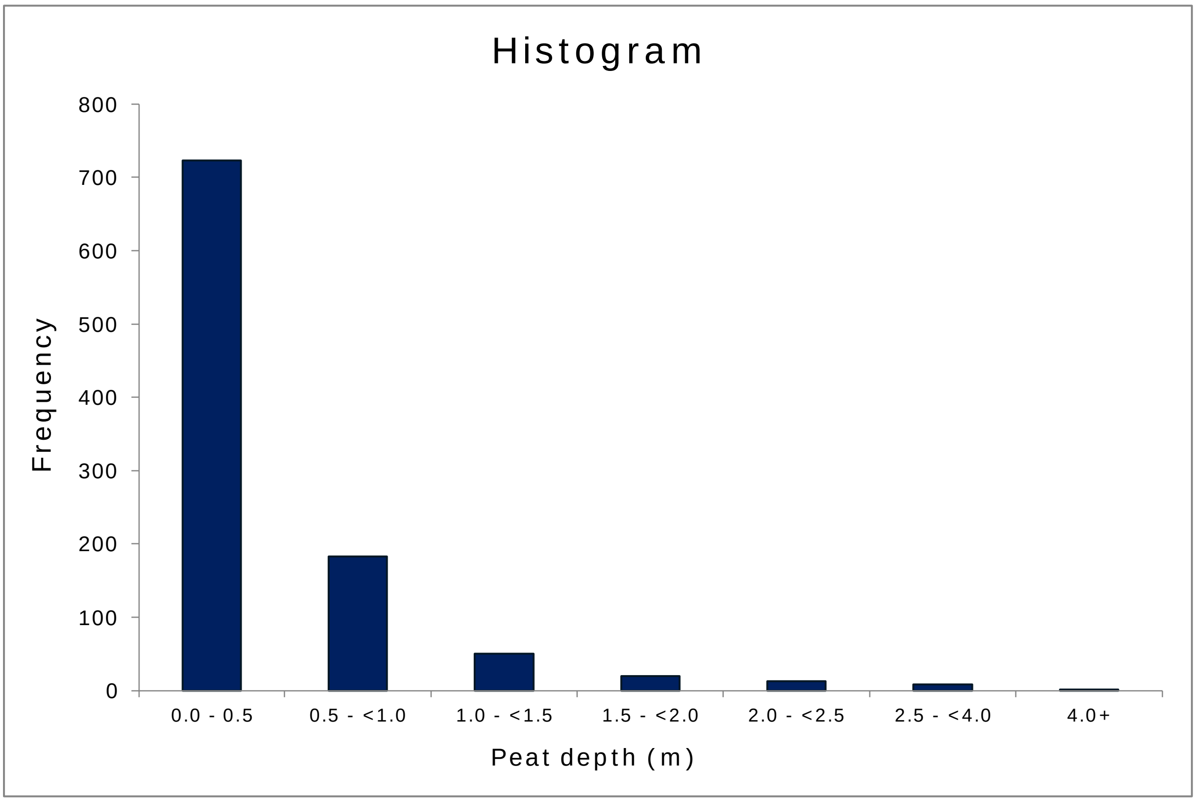
4.1.10 The bulk density of peat is known to vary with the level of decomposition. A literature review has found quoted in situ undrained bulk densities ranging from 0.50 to 1.40 Mg/m^3. Laboratory analyses undertaken on samples collected by or on behalf of WSP from other projects have returned bulk density values generally ranging between 0.80 and 1.40 Mg/m^3. Based on this experience and also after reviewing externally published values Lindsay[10], Dykes & Wamburton[4] and [10] Scottish Government guidance[2] an average wet bulk density value of 1.00 Mg/m^3 has been applied for the initial FoS calculations.

4.1.11 If it is assumed that the Site is covered by a variety of soils, including peaty gleys, peaty podzols, brown earths and alluvial soils. Where present, it is assumed that the peat must be completely saturated, with a water table at or close to the surface. Consequently, a water table ratio, *m*, of 1.0 has been chosen, which is considered conservative given most of the Site exhibits drier conditions, but may occur locally during or following heavy rainfall 'trigger' events.

4.1.12 The angle of internal friction in peat also varies, decreasing with increasing decomposition and moisture content. For the FoS calculations, a φ' value of 5° has been selected as per WSP's conservative approach.

4.1.13 Finally, a value for the effective cohesion, *c'*, must be derived. Literature values for *c'* in peat vary widely, generally ranging from 4 – 20 kN/m^2. To provide an indication of the cohesive strength of the peat at this Site, a back-calculation using the FoS equation and actual peat depth probing data for the Site has been completed. The techniques involved are discussed below.

Image 4.1: Peat Probe Depth Histogram



4.2 Estimation of Cohesive Strength

4.2.1 A range of field and laboratory tests can be carried out to determine the effective cohesion of a material. However, owing to its fibrous and thixotropic nature and the variation in strength with decomposition, peat is a particularly difficult material to analyse both in the field and in the

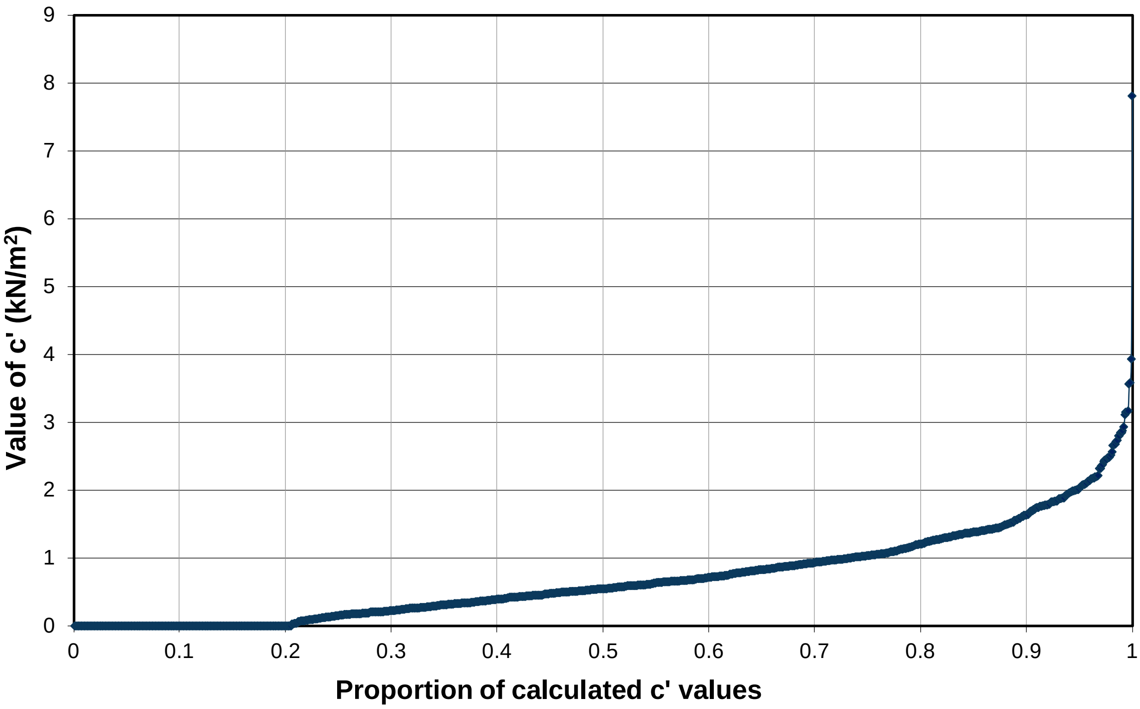
[10] Lindsay, R.A (2010). *Peatbogs and Carbon, a critical synthesis. RSPB Scotland* [online] Available at: http://www.rspb.org.uk/images/peatbogs_and_carbon_tcm9-255200.pdf [Accessed in November 2022].

laboratory. An alternative approach to assessing the strength of the peat is to rearrange the FoS equation to calculate a value of *c'* at actual peat probing locations. Essentially, this approach assumes that if the hillside is stable then the material must have at least a certain minimum strength.

4.2.2 Each peat probing location visited is known to have been stable at the time of the visit and therefore must have a FoS of at least 1. If we assume conservatively that *F*=1 and use values for the other parameters as discussed above, the FoS equation can be rearranged to allow derivation of a value for *c'* at each probing location. Slope angles for the probing points are generated from the DTM. It is important to note that the value of *c'* calculated for each location represents the minimum cohesive strength necessary for the peat to be stable at that location. In fact, the shear strength may be, and in most cases probably is, considerably higher.

4.2.3 In the Study Area, 998 locations have been probed during the different phases of fieldwork, *c'* values for each of these have been calculated and the distribution of these values is shown in Image 4.2. For example, reading from the graph, 0.8 (or 80%) of the probing locations require a theoretical *c'* value of 1.20 kN/m^2 or less to be stable and retain peat on the slope.

Image 4.2: Estimate of Minimum Cohesive Strength, *c'*



4.2.4 From this work it is possible to state, with reasonable confidence, that across the Site as a whole the shear strength of the peat is unlikely to be less than 2.85 kN/m^2 as this is the value of the 99th percentile point on the graph.

4.2.5 A similar approach was undertaken for determining the 99th percentile for grid cells, determined as 4.48 kN/m^2, this value being higher than the point data due to inclusion of indicative depths for a number of cells.

4.2.6 The basis for applying these calculation details depends upon:

- The deliberate choice of conservative values for assumed parameters such as bulk density and water table level, coupled with the assumption of an FoS of 1 when back-calculating *c'* values.
- Recognition of what the calculations are stating, which is that these are the minimum strengths that would be required, not the actual in situ strengths. Therefore, where slopes are gentle and the peat shallow, very little shear strength is required to ensure stability of the slope. This accounts for the vast majority of the lower values.

- Assuming a reasonable degree of homogeneity for peat properties, particularly strength, across the Site. This seems reasonable, except for very shallow peat where the acrotelm, which is more fibrous, represents a significant proportion of the total depth. Such areas are, in any case, unlikely to be areas of concern.
- Given the above considerations, it is the higher strength values that are relevant. If this were not the case, then one would expect large areas of the Site to be denuded of peat as it would not have the strength to adhere to the hillsides.

4.2.7 For the purposes of the FoS Assessment *c'* values of 4.48 kN/m^2 and 2.85 kN/m^2 have been used. These values are comparable with estimates derived from other sites around Scotland. Compared with literary values of 4 – 20 kN/m^2, the actual effective cohesion of the peat at the Site may be higher than 2.85 kN/m^2, with 4.48 kN/m^2 being more representative, with the application of these site-derived values ensuring a reasonably conservative initial assessment using data from the Site in tandem with an understanding of literary values.

4.3 FoS Stability Results

4.3.1 Having assigned measured or inferred values to each parameter in the FoS equation, it is now possible to calculate the FoS value for each probing location coinciding with proposed infrastructure and for each cell of the indicative peat depth grid in the vicinity of the infrastructure. The results of the FoS assessment for the probing points and site grid are summarised in **Table 4.1**. The FoS assessment maps generated with these values are shown across the Site as series **Figure 10.1.7 Factor of Safety**.

4.3.2 Once again, the grid cell values where measured data is available is considered more representative as is generally closer to the planned infrastructure.

Table 4.1: Summary of FoS Assessment

Factor of Safety	No Peat in Grid (less than 0.5 m)	≥3.0	1.4 - <3.0	1.0 - <1.4	<1.0	Total
Probing Data (points)	723	76	149	39	11	998
% of Probing Points	72.4%	7.6%	15.0%	3.9%	1.1%	**100.0%**
Grid Cells	1,186	738	1,675	756	46	4,401
% of Grid Cells	26.9%	16.8%	38.1%	17.2%	1.0%	**100.0%**
Grid Cells (with measured data)	397	98	94	13	4	606
% of Grid Cells (with measured data)	65.5%	16.2%	15.5%	2.1%	0.7%	**100.0%**

4.3.3 In selecting the 99th percentile value of the back-calculated *c'* strengths, one is implicitly condemning 1.0% of the sample locations to failure, plus any similar cells across the Site as a whole. As can be seen, there are a very small number of cells with a FoS value of less than 1; in theory these should either have failed or currently be failing. In reality, this is unlikely to be the case and these results are a consequence of the conservative approach adopted. Also, a low number of points and cells have a FoS between 1.0 and 1.4, where stability can be considered marginal. The cells that fall into both these categories are scattered mostly in clusters across the Site, the majority are at a reasonable distance from Site infrastructure and therefore based upon conservatively estimated, rather than actual, peat depths.

4.3.4 Note that where peat depth is less than 0.50 m, these cells were not considered as peat and are removed from further stability investigation.

4.3.5 To summarise, 95.0% of the peat probing locations on the Site have a FoS of 1.4 or greater (including locations with peat less than 0.50 m depth), where stability can be assumed with a degree of comfort. Related to grid cells with measured depths (i.e. predominantly those grid cells closest to infrastructure), cell locations with FoS values greater than 1.4 (including cells with peat less than 0.50 m depth) represent 97.2% of the Site, again these are locations where stability can be assumed with a degree of comfort.

4.3.6 As discussed within the **Peat Depth Survey Section**, UXO risk and health and safety and asset protection constraints limited the collation of point data used for FoS. This has resulted in a number of grid cells without measured peat data coincident with Proposed Development infrastructure. Further peat probing and stability assessment shall be undertaken pre-construction to confirm findings and any refined data collated in a number of PSA Areas (see **Annex B**).

4.3.7 The results demonstrate that the vast majority of the OHL infrastructure would be built in areas where there is a degree of comfort in inferring stability. The cells identified as having marginal stability are generally clustered into areas where deeper peat are coincident with moderate slopes, or very steep slopes occur with 0.50 – 0.99 m peat present. In order to satisfy safety precautions due to the Moderate UXO Risk at the northern extent of the Site, eleven peat probes which would have exceeded 1.00 m were stopped at this depth.

5. INITIAL RISK ASSESSMENT

5.1.1 Based on the data collated from the desk study, reconnaissance survey, peat probing and FoS stability analysis the peat stability risk across the site can be classified. The Guidelines[2] define risk as a function of likelihood and consequence and this has been applied by WSP as:

Risk = Likelihood x Adverse Consequence

5.1.2 The risk level is derived by applying a matrix of likelihood and consequence outcomes to derive a risk value ranging from 'Negligible' to 'High Risk'. Additionally, where peat is not present (such as organic soils with depth less than 0.50 m) these areas were identified as 'N/A – Not Peat'.

5.1.3 Central to WSP's analysis is a grid model of the Study Area, using 50 m x 50 m individual cell dimensions. It is therefore essential to have processes that assign likelihood and consequence ratings to the cells and build a map of spatial variability across the Study Area. The rationale for evaluating likelihood and consequence is given in the following sections.

5.2 Likelihood

5.2.1 In WSP's method, the primary and non-subjective measure of likelihood of slope stability is the FoS calculation. Low FoS value slopes are of greater stability concern, slopes with FoS values greater than 1.4 are generally regarded as 'safe'.

5.2.2 Within FoS analysis, the parameter which may be considered to have the greatest uncertainty is the shear strength of the peat. The derivation of this parameter has been discussed above. The back-calculation approach is more conservative (i.e. gives a safer assumption) than that commonly derived from in situ shear vane tests, which have known limitations when applied to peat. For the initial risk assessment, the likelihood is based solely on FoS, enabling an objective, reasonably cautious initial 'screening' approach to likelihood. The initial likelihood criteria and classification of cells is provided on **Tables 5.1** and **5.2**, respectively.

Table 5.1: Criteria Relating to Initial Likelihood Values

Likelihood	Factor of Safety
Almost certain	Not applied at initial likelihood stage, better determined in conjunction with additional data available from a specific peat stability survey of such areas
Probable	FoS <1.0
Likely	FoS is between 1.0 and <1.4
Unlikely	FoS is between 1.4 and <3.0
Negligible	FoS 3.0+
N/A – No Peat	Soil at depth shallower than 0.50 m or confirmed as non-peat material

Table 5.2: Summary of Initial Likelihood Grid Classification

Likelihood							
	Almost Certain	Probable	Likely	Unlikely	Negligible	Not Peat	Total
No. of Grid Cells	***Not Applied***	46	756	1,675	738	1,186	4,401
% of Grid Cells	*Not Applied*	1.0%	17.2%	38.1%	16.8%	26.9%	100.0%
No. of Grid Cells (with measured peat depth)	***Not Applied***	4	13	94	98	397	606
% of Grid Cells (with measured peat depth)	*Not Applied*	0.7%	2.1%	15.5%	16.2%	65.5%	100.0%

5.2.3 The initial likelihood classification of grid cells across the Site is presented as **Figure 10.1.8 Initial Likelihood**.

5.2.4 The results of the initial likelihood grid cell categorisations reflect the characteristics of the Site. The topography generally exhibits more than 15° slope angles, with some steeper slopes on the eastern slopes of Creachan Mor at the northern extent of the Site, where gradients may exceed 25° for extended distances. Measured peat depths confirm that much of the steeper areas of the Site have shallow or no peat recorded (i.e. less than 0.50 m depth), with peat depths greater than 1.50 m typically restricted to slope angles of less than 5°. However, a few isolated zones of deeper peat were noted on steeper slopes, with these coincident locations being the main driver for higher FoS values at this Site.

5.3 Adverse Consequence

5.3.1 The Guidelines[2] identify that 'Consequence' relates to impact upon receptors, this would include property, existing infrastructure and assets, environmental features and/or the Proposed Development infrastructure. These terms need to be taken in their broader context if an itemised list of receptors is to be considered which would include:

- existing public and private infrastructure (roads, bridges, buildings, business facilities, etc.);
- terrestrial ecology;
- aquatic ecology and water quality;
- archaeology; and
- proposed internal infrastructure (access tracks, towers, cabling, etc.).

5.3.2 In order to include nearby receptors (shown on **Figure 10.1.9 Receptors**), the Site (grid) extends at least 250 m beyond the Proposed Development. This enables consideration of features outwith the Proposed Development.

5.3.3 These features have varying dimensions of costs and magnitude caused by an occurrence of mass peat instability, but in addition there may be irretrievable personal, societal or habitat losses:

- Costs: the only quantification provided within the Guidelines is in terms of project costs, which are easier to apply to infrastructure assets than to ecology. If ecology is of relatively minor importance for a particular site, economic impacts or delays in the construction programme may be the main drivers.

- Magnitude: naturally occurring peatslides have been observed to range in size from small-scale, localised slides involving tens of square metres to large-scale slides involving thousands of square metres and with run-out distances of km. Consequently, magnitude may be expressed in terms of area, peat volume and run-out distance and receptor. Provided sufficient peat probing has been undertaken and an indicative peat depth map produced, areas and peat volumes can be derived using professional judgement given local ground conditions. The associated run-out distance is of less significance than the receptor damaged and again should be considered taking account of local conditions to arrive at a realistic outcome.

5.3.4 **Table 5.3** assembles the above considerations to outline the degrees of consequence. Using the table, the three columns are considered, and professional judgement applied, to identify the appropriate 'Consequence' rating. The consequence values were identified and applied using mapping software to escalate the value based on local receptors, with the default (starting) position being that each grid cell was considered of 'Low' consequence, taking a reasonably precautionary approach.

5.3.5 The consequence classification of cells is provided in **Table 5.4**. The consequence classification of grid cells is presented as **Figure 10.1.10 Consequence**.

Table 5.3: Criteria Relating to Consequence Values

Consequence	Habitat	Internal Infrastructure	Public/Private Infrastructure
Extremely High	Large loss/damage to valued terrestrial and/or aquatic habitat, i.e. within designated sites. Large loss/damage to archaeological designated sites.	N/A	Damage to property: domestic/public building or business (*within 100 m*). Impact on railways or A class road or bridges, including lower category roads which provide key transport corridors in remote locations (*within 100 m*). Impact on public utilities, water, gas, electricity, telecoms, etc. (*within 100 m*).
High	Medium loss/damage to valued terrestrial and/or aquatic habitat, i.e. designated sites (*within 100 m*). Medium loss/damage to archaeological designated sites (*within 100 m*).	Damage to substation and/or control building *(within 100 m).*	Damage to minor/unclassified public roads or bridges *(within 100 m)*. Impact on private utilities, local electrical connection, water and wastewater *(within 100 m).*
Moderate	Small loss/damage to valued terrestrial and/or aquatic habitat. Large loss/damage to common terrestrial and/or hydrology features shown on 1:10,000 OS mapping (*within 50 m*). Peat grid cells identified with peat depth 1.50 m+.	Damage to planned towers (*within 100 m*). Damage to section of new access track, construction compound and borrow pits *(within 50 m)* which would require repair to enable functionality. Damage to car parking (*within 50 m*). Interruption to construction or operation of development.	Damage to section of existing unclassified access track, or bridge *(within 100 m).*

Consequence	Habitat	Internal Infrastructure	Public/Private Infrastructure
Low *Default Position*	Medium loss/damage to common terrestrial and/ or hydrology features shown on 1:10,000 OS mapping.	Minor damage to section of access track which does not necessitate immediate repair for access.	Minor damage to assets.
Very Low *Not Applied*	Small temporary loss/damage to common terrestrial and/or aquatic habitat.	No damage to assets.	No damage to assets.

Table 5.4: Summary of Consequence Grid Classification

	Consequence					
	Extremely High	High	Moderate	Low	Very Low	Total
No. of Grid Cells	1,823	1,206	871	501	0	4,401
% of Grid Cells	41.4%	27.4%	19.8%	11.4%	0.0%	100.0%
No. of Grid Cells (with measured peat depth)	209	231	150	16	0	606
% of Grid Cells (with measured peat depth)	34.5%	38.2%	24.7%	2.6%	0.0%	100.0%

5.3.6 The location of the Site alongside an existing overhead line means that the locations with 'Extremely High' and 'High' consequence of a peat landslide are focused upon existing overhead line and roads. The majority of the 209 grid cell locations (with measured peat depths) which were identified with 'Extremely High' consequence are located within 100 m of the existing overhead line, with 132 cells of them identified as non-peat soils (less than 0.50 m depth).

5.4 Initial Risk Assessment Outcomes

5.4.1 The likelihood (solely based on FoS) and consequence values were applied to the Site for the initial risk assessment, with the results shown on **Figures 10.1.8 Initial Likelihood** and **10.1.10 Consequence**, respectively, provided in **Annex A** of this document. A summary of the cell counts was provided in **Tables 5.2** and **5.4** for each classification.

5.4.2 The Guidelines' risk scoring is determined via a matrix table, combining likelihood and consequence. This has been provided as **Table 5.5** and replicates Table 5.3 in the guidance[2]. An initial risk value has been derived for each grid cell through combining the Likelihood and Consequence ratings using the matrix in **Table 5.5**. A summary of the grid cell counts for each risk category is provided in **Table 5.6**.

5.4.3 Higher initial risk value cells are typically located on steeper slopes or where peat depths greater than 1.50 m were recorded, in close proximity to the existing overhead line, roads, planned infrastructure and/or watercourse receptors (shown on **Figure 10.1.9 Receptors**).

5.4.4 As can be seen on **Table 5.6**, the vast majority of the Site has been assessed as having 'Low', 'No Risk' or 'Negligible' risk of peatslide hazard at the initial risk assessment stage (97.8% of cells with measured peat depth).

5.4.5 When considering the grid cells with measured peat depth, which are cells where peat probing data was collected and include all cells where infrastructure is planned, 0.2% recorded a 'High' initial risk and 2.0% of cells recorded a 'Moderate' initial risk.

5.4.6 'High' and 'Moderate' risk cells tend to cluster together and are typically located where peat depths greater than 1.50 m were recorded on steeper slopes and in close proximity to the existing overhead line ('High' risk) or planned infrastructure or watercourse receptors ('Moderate' risk).

5.4.7 **Figure 10.1.11 Initial Risk** shows the planned infrastructure layout overlaid on the Initial Risk mapping, from which 'High' or 'Moderate' risk of peat instability are identified as red or orange cells, respectively. After review of Initial Risk locations to exclude those outwith close proximity to planned infrastructure, regarded as highly unlikely to be adversely affected by the Proposed Development, the remaining cells cluster into twelve peat stability assessment areas (PSA Areas A – L) and further location-specific information has been focused on these in the Revised Risk Assessment and datasheets provided in **Annex B**:

- Two areas were initially identified as being at potentially 'High' risk of peat landslide (red cells), with likelihood defined by factor of safety values <1 combined with 'Extremely High' consequence values – PSA Areas D and F.
- Ten areas were initially identified as being at potentially 'Moderate' risk of peat landslide (orange cells), with likelihood defined by factor of safety values between 1 and <1.4 combined with 'Extremely High' and 'High' consequence values – PSA Areas A, B, C, E, G, H, I, J, K and L.

Table 5.5: Risk Matrix Based on Likelihood and Consequence Values

		Adverse Consequence				
		Extremely High	High	Moderate	Low	Very Low
Peat Landslide Likelihood (over Development Lifetime)	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

Table 5.6: Summary of Initial Risk Assessment Outcomes and Actions

Initial Risk	Number of Grid Cells	% of Grid Cells	Number of Grid Cells (with measured peat depth)	% of Grid Cells (with measured peat depth)	Suggested 'Guideline' Actions (Table 5.4[2])
High	13	0.3%	1	0.2%	*"Avoid project development at these locations".*
Moderate	480	10.9%	12	2.0%	*"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".*

Initial Risk	Number of Grid Cells	% of Grid Cells	Number of Grid Cells (with measured peat depth)	% of Grid Cells (with measured peat depth)	Suggested 'Guideline' Actions (Table 5.4[2])
Low	2,118	48.1%	128	21.1%	*"Project may proceed pending further investigation to refine assessment and mitigate hazard through relocation or re-design at these locations*".
Negligible	604	13.7%	68	11.2%	*"Project should proceed with monitoring and mitigation of peat landslide hazards at these locations as appropriate*".
N/A No Risk (No Peat)	1,186	27.0%	397	65.5%	Non-peat material, no peatslide risk.
Total Cells:	4,401	100.0%	606	100.0%	

5.4.8 In order to verify these initial risk findings, it was considered appropriate to conduct a site visit to specific locations where initial risk of 'Moderate' and 'High' had been determined. This 'ground truthing' exercise was to ensure that these outcomes were considered reasonable as part of a sensitivity analysis of the theoretical data.

5.4.9 Twelve areas of the Site were identified for such confirmation and revised risk evaluation via 'Detailed Assessment', at locations adjacent to the Proposed Development; PSA Areas A, B, C, D, E, F, G, H, I, J, K and L.

6. DETAILED ASSESSMENT AND REVISED RISK ASSESSMENT

6.1.1 For each of the twelve PSA Areas, a Detailed Assessment has been undertaken and reported on individual datasheets. This includes description of the peat depths, FoS values, local characteristics including geomorphology and geotechnical information, aerial images and available photographs. These datasheets also identify site-specific mitigation, considering the additional information gathered at each of the PSA Areas. The individual datasheets are provided in **Annex B**, with an overview of the locations presented in **Figure 10.1.12 Detailed Assessment Area**.

6.1.2 The detailed assessment datasheets display the FoS values for grid cells (each cell measuring 50 m x 50 m), with cells highlighted where FoS values are less than 1.4. The probe location triangles are coloured to represent peat depth ranges (as per colour-coding on **Tables 3.1 – 3.3**) and each probe point also includes a background square coloured to identify the FoS category. Other appropriate GIS data provided on the aerial background image is listed on the legend at the beginning of **Annex B**.

6.1.3 The FoS value was the primary driver for assigning a likelihood to each grid cell in the model, as discussed for the initial risk assessment, however, regional and local context information may provide additional data that justifies changing the likelihood category at the revised risk assessment stage for locations of concern. These contextual factors are consolidated into **Table 6.1**, which provides rationale to assigning revised likelihood values to refine the assessment process:

- Regional context; in a regional context some areas have a higher propensity for peatslide events than others and this may be evident from historical records, if reliable. Regional climatic factors influence the development of peat, its coverage and depth; at a site-level peat depths are determined from peat probing fieldwork rather than generalisations. Although the regional context does not provide any spatial differentiation within the Study Area, it may influence the level of caution applied.
- Local context; the variability of local factors material to the development of peatslides may be considered. The primary local factors not already incorporated into the FoS calculations include convex slopes, breaks of slope, drainage patterns, landuse, grazing intensity and incidental events such as fire, which may alter the likelihood of peatslides. These factors may operate across the whole Study Area, in which case they offer no spatial differentiation, but if localised to specific parts of the Site may be helpful in spatial characterisation. Identification of instability identified from aerial photography and confirmed by 'ground truthing' as non-peatslide events, such as peaty debris slides, may be relevant as these forms of instability are not caused by peat instability (rather, are due to the slope failure of material underlying the peat layer). The guidance[2] included suggestions of probability values, these have been included in italics as a contextual reference.

Table 6.1: Criteria Relating to Revised Likelihood Values

Likelihood/ Hazard	Regional Context	Local Context
Almost Certain	The wider region (if it consists of similar condition units to the Study Area) has several historic peatslides. Study Area has several historic peatslides.	FoS <1.0 Ancillary considerations: ✓ Locally, indications of incipient mass peat instability such as tension cracks, bulges, misaligned fences or trees etc; ✓ Peat depths on slopes consistently over 1.50 m; ✓ Topography: convex breaks in slope; extensive unconfined slopes; ✓ Drainage: converging flow paths; large contributing area; peat pipes; ✓ GeoSure Landslide Hazard Class D; *Probability of mass peat instability event occurrence during lifetime of scheme considered greater than 1 in 3.*
Probable	Study Area has evidence of historic peatslide.	FoS <1.0 Ancillary considerations: ✓ Locally, indications of incipient mass peat instability; ✓ Peat depths on slopes consistently over 1.00 m; ✓ Topography: convex breaks in slope; extensive unconfined slopes; ✓ Drainage: converging flow paths; large contributing area; peat pipes; ✓ GeoSure Landslide Hazard Class D; *Probability of mass peat instability event occurrence during lifetime of scheme considered between 1 in 3 – 1 in 10.*
Likely	Study Area has evidence of historic peatslide.	FoS is between 1.0 and 1.4 Ancillary considerations: ✓ Locally, no adjacent indications of incipient mass peat instability but some within 100 m; ✓ Peat depths on slopes consistently over 1.00 m; ✓ Topography: generally rounded/undulating landforms; ✓ Drainage: suspicious absence of surface channels indications of peat pipes; ✓ GeoSure Landslide Hazard Class C; *Probability of mass peat instability event occurrence during lifetime of scheme considered between 1 in 10 – 1 in 100.*
Unlikely	Study Area has no evidence of past peatslides.	FoS is between 1.4 and 3.0 Ancillary considerations: ✓ Locally, no indications of incipient mass peat instability ✓ Isolated peat depths over 1.00 m on slopes; ✓ Topography: generally rounded/undulating landforms; ✓ Drainage: natural well-defined channels; artificial improvements to drainage; ✓ Not GeoSure Landslide Hazard Class D or C; *Probability of mass peat instability event occurrence during lifetime of scheme considered between 1 in 100 – 1 in 10,000,000.*

Likelihood/ Hazard	Regional Context	Local Context
Negligible	The wider region (if it consists of similar condition units to the Study Area) has no historic peatslides. Study Area has no evidence of historic peatslides.	FoS > 3.0 Ancillary considerations: ✓ Locally, no indications of incipient mass peat instability; ✓ Peat depths less than 1.00 m on slopes; ✓ Topography: concave or no break in slope; small confined slopes or pockets; ✓ Drainage: diverging flow paths; small contributing area; natural well-defined channels; artificial improvements to drainage; ✓ Not GeoSure Landslide Hazard Class D or C; *Probability of mass peat instability event occurrence during lifetime of scheme considered less than 1 in 10,000,000.*
N/A – No Peat		Soil at depth shallower than 0.50 m or confirmed as non-peat material.

6.1.4 To aid the revised risk assessment process, geomorphology data was collated to identify grid cells with potential landslide features identified on aerial photography, grid cells with peat depths greater than 1.50 m, BGS GeoSure Landslide Hazard classes D and C, slope angles greater than 8º and detailed assessment-specific locations where convex breaks in slope were apparent from DTM data. These features are displayed with planned infrastructure on **Figure 10.1.13 Geomorphology**.

6.1.5 A series of individual GIS images are also presented in **Annex C** as **Images A2** to **L4** for the PSA Areas. These display aerial imagery, OS background mapping and DTM data for each area, as used by the assessment team.

6.1.6 Where aerial photography and/ or GeoSure Landslide Hazards noted features close to infrastructure but not previously flagged by the initial likelihood approach (i.e. not initially classed as 'High' or 'Moderate' likelihood based solely on FoS values), enlarged Detailed Assessment datasheet locations were included to confirm local characteristics in representative areas and check appropriate revised risk level. PSA Areas incorporate GeoSure and Aerial Photography data.

6.1.7 In addition to good practice and design measures, there are also a number of area-specific mitigation measures that are proposed to be deployed to reduce risk (generally the likelihood aspect) at particular locations, with further details in **Section 1.8**.

6.1.8 The revised risk information on the twelve individual datasheets (**Annex B**) reflects refinement, following consideration of specific characteristics for each area, using applicable ground investigation information and the identification and application of any appropriate mitigation measures during design, construction and operation.

6.1.9 Potential runout distances and volumes of material for each datasheet have been estimated, factoring-in local conditions, with these estimates recorded within the Detailed Assessment datasheets, alongside identified receptors within and outwith the Site Boundary.

6.2 Revised Risk Assessment Outcomes

6.2.1 Following Detailed Assessment of the 12 PSA Areas highlighted for sensitivity analysis, taking account of local ground conditions and application of appropriate good practice and area-specific mitigation measures, their likelihood was reduced from Probable/Likely to Unlikely. With reference to **Table 5.5**, this results on a revised risk of 'Low' for each of these locations.

6.2.2 Following the revised risk assessment process, **Table 6.2** records the updated risk outcomes and these are also shown on **Figure 10.1.14 Revised Risk**.

Table 6.2: Revised Risk Outcomes

Revised Risk	Number of Grid Cells	% of Grid Cells	Number of Grid Cells (with measured peat depth)	% of Grid Cells (with measured peat depth)	Suggested 'Guideline' Actions
High	8	0.2%	0	0.0%	*"Avoid project development at these locations".*
Moderate	302	6.9%	0	0.0%	*"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".*
Low	2,304	52.3%	142	23.4%	*"Project may proceed pending further investigation to refine assessment and mitigate hazard through relocation or re-design at these locations".*
Negligible	603	13.7%	68	11.2%	*"Project should proceed with monitoring and mitigation of peat landslide hazards at these locations as appropriate".*
N/A No Risk (No Peat)	1,184	26.9%	396	65.4%	Non-peat material, no peatslide risk.

6.2.3 Following the revised risk assessment process, eight High revised risk cells were identified. No areas within 100 m of the proposed infrastructure are considered to be above 'Moderate' revised risk (with the vast majority of the Site considered 'Low' risk or non-peat) in terms of peat stability assessment.

7. ASSESSMENT ASSUMPTIONS

7.1.1 Following previous peat stability report feedback from the Scottish Government Peat Stability Independent Assessor (Ironside Farrar) from similar sites, this section identifies key assumptions which have been applied during the preparation of this deliverable.

7.1.2 The key variables and most sensitive factors in the FoS analysis are peat depth and slope angle, which are directly applied using a large dataset of site information focussed on planned pole positions, applying a back-calculated *c'* (cohesive strength) specific to site data and conservative lower-bound literature values for other calculation inputs. Thus, the assessment of peat stability at this EIA stage follows an inherently conservative approach. The site visits to ascertain revised risk act as a form of sensitivity analysis, as the method bases initial probability directly upon FoS outcomes for the initial risk stage and typically leads to the identification of locations which can be justifiably reduced to a lower probability and potentially lower revised risk, following the collation of ancillary local information.

7.1.3 This assessment focussed upon undrained peat, at the detailed design stage it may be deemed appropriate to also conduct analysis for drained peat for representative locations including the twelve PSA Areas.

7.1.4 Existing drainage features have been identified, where relevant, in the **Annex B** Datasheets and would be included in the Geotechnical Risk Register. Similarly, drains are recorded where applicable to PSA Datasheets. These channels are not all shown on mapping, with maps using OS information. Should additional channel mapping be considered appropriate at the detailed design stage, this could be undertaken.

7.1.5 For OHL development, less excavated peat is anticipated to arise than for other developments involving extensive foundations. Any excavated material would be reused locally, when possible. Peat would be re-used in as short a timescale as feasible, the detailed design would include details of plans for temporary storage of peat and associated methodologies for excavation/ transfer/ storage/ reuse. The Geotechnical Risk Register would include peat storage as a specific risk, with applicable controls that would be kept up to date with current good practice and lessons learned from Site works.

8. MITIGATION AND GOOD PRACTICE MEASURES

8.1.1 The purpose of the PLHRA is to identify areas of the Site which are potentially at most risk of peat instability and thereafter assess potential construction impacts. Where avoidance through design is not possible, mitigation measures require to be implemented to avoid or reduce the risk of peat instability. In addition to specific mitigation measures which may be deployed at particular locations, itemised in the specific detailed assessment datasheets, there are a number of generic construction good practice measures that would be applied, where applicable, as additional data becomes available at the pre-construction stage. A number of these potential actions are set out in **Table 8.1**.

8.1.2 With reference to **Table 8.1**, the area-specific mitigation measures identified for the Proposed Development are 1, 2, 5, 12, 13 and 17.

8.1.3 Good practice guidance documents, such as Floating Roads on Peat[11], Managing Geotechnical Risk[12] and Peat Landslide Hazard and Risk Assessments: Best Practice guide for Proposed Electricity Generation Developments[2] would be consulted to inform the design and construction processes. All site investigation work would be undertaken in compliance with relevant British Standards (BS), including BS 5930:1999[13] and BS 6031:2009[14].

8.1.4 Onsite construction staff are often the best placed to provide advance notification of potential problems, provided sufficiently trained and with an appropriate reporting mechanism. There are a number of recognised indicators for slope failures and these may indicate a potential peatslide or the commencement of a peatslide event, as outlined in **Section 1.2** of this report. The suspected identification of any of these indicators should be assessed by specialist peat stability or geotechnical personnel.

8.1.5 Additional items to those identified in **Table 8.1** may be introduced as further site data becomes available at pre-construction and construction stages.

[11] FCE & SNH N (2010). *Floating Roads on Peat. Scottish Natural Heritage and Forestry Civil Engineering*. [online] Available at: http://www.roadex.org/wp-content/uploads/2014/01/FCE-SNH-Floating-Roads-on-Peat-report.pdf [Accessed in November 2022].

[12] Clayton, C. R. I. (2001). *Managing Geotechnical Risk: Improving Productivity in UK Building & Construction*. Thomas Telford, London.

[13] BSI (1999). *Code of practice for site investigations. BS 5930:1999, British Standards Institute*.

[14] BSI (2009). *Code of practice for earthworks. BS 6031: 2009, British Standards Institute*.

Table 8.1: Good Practice and Mitigation Measures

Potential Actions	Good Practice	PSA Area-Specific Mitigation Measures, as applicable
1. Geotechnical specialist onsite during the construction phase to undertake advance inspection, carry out regular slope monitoring and provide ongoing advice at locations of concern.	✓	PSA A - L
2. Maintain and update geotechnical risk register or similar management system.	✓	PSA A - L
3. Construction staff should be made aware of peatslide indicators and emergency procedures (see below).	✓	
4. Emergency procedures should include steps to be taken on detection of any evidence of potential peat instability.	✓	
5. Microsite the tower or access track in order to avoid the area of concern (subject to non-violation of other constraints).	✓	PSA E, F and H
6. Ensure that good groundwater and surface water control, such as moor gripping or drainage ditches, is in place in advance of construction activities.	✓	
7. Installation of stand-pipes / piezometers to monitor ground water levels and pore pressures.	✓	
8. Ensure artificial drainage does not concentrate flows onto slopes, gully heads or into excavations.	✓	
9. Ensure that sediment control measures are incorporated into all artificial drainage measures and including specific scour protection mitigation where steep slopes or high activity erosion processes are identified. Concrete aprons, rip rap, gabion/reno mattress or geotextile mats may be applicable options, depending on watercourse characteristics and sensitivities.	✓	
10. Earthmoving activities should be restricted during and immediately after heavy and/or prolonged rainfall events, including use of weather forecasting and re-programming of construction activities as applicable. Particular care should be taken when heavy rainfall events are predicted following a prolonged dry spell.	✓	
11. The construction plan should minimise the extent and duration of open excavations and bare ground.	✓	
12. Avoid placing excavated material or other forms of loading on or immediately above breaks of slope or any other potentially unstable slopes.	✓	PSA A - L
13. Avoid removing slope support, particularly where slope stability has been highlighted as of concern. Consider floating access track at appropriate locations to avoid removing slope support.	✓	PSA A - L
14. Establish / re-establish vegetation as soon as possible to improve slope stability and provide sediment transport control.	✓	
15. Consider limiting loads crossing newly created peat embankments to enable pore water pressure in both embankment and underlying peat to reduce to pre-construction levels and original shear strength.	✓	
16. Modify slope geometry to provide a 'weighted toe'.	✓	

Potential Actions	Good Practice	PSA Area-Specific Mitigation Measures, as applicable
17. Use of retaining structures, such as gabion terracing to support specific slopes.		PSA A - L
18. In locations where limited opportunity for avoidance or other mitigation to reduce likelihood, the application of debris nets, catch fences, catch ditches and/or deflection systems to protect receptors and reduce adverse consequences. Such installations should be subject to routine inspection and maintenance.	✓	
19. Forestry clearance activities should be undertaken following good practice, including careful positioning of log piles to avoid overloading of slope, sediment control and consideration of retaining tree roots *in situ* for soil stabilisation in appropriate locations.	✓	
20. Borrow pit blasting activities to take account of any peat stability locations of concern in the proximity, including seeking alternative methods that avoid blasting. If sensitive peat stability receptors are identified, there are a number of methods to manage, mitigate and monitor, such as careful placement, charge size, vibration monitoring and pre- and post-blasting slope monitoring.	✓	

9. SUMMARY AND RECOMMENDATIONS

9.1.1 Peat depth probing in conjunction with slope angle mapping is a cost-effective method to establish peat depth and peat stability profiles across large areas. Combining this with aerial photograph interpretation and GeoSure datasets enables potential evidence of mass movement events to be efficiently identified.

9.1.2 The Proposed Development is underlain by peat of varying depths and shallower peaty soil, with an average depth across the Study Area of 0.39 m. Slope angles vary, with steep slopes evident across a number of areas of the Site, predominantly at the northern scheme extent. Where deeper peat coincides with these slopes, especially at convex break of slope positions, the likelihood of peatslide increases. Areas identified as of higher likelihood for instability were primarily related to steep slopes, deeper peat deposits or lack of peat depth records (due to UXO risk or other constraints) requiring application of precautionary indicative peat depths.

9.1.3 The conservative nature of the methodology applied leads to initial risk identification, based on FoS analysis, of the least stable areas on any specific site, initially considered of 'Moderate' or 'High' risk, with this risk level relative to the remainder of the Site. Other locations of concern were avoided as part of the design process planned for the Proposed Development. In order to review the initial risk, twelve areas with initial 'High' and 'Moderate' risk locations at proposed infrastructure were identified and visited as part of the detailed assessment and revised risk process.

9.1.4 Site visits occurred at two phases of the Proposed Development design, in July and August 2022, to inform evolving iterative design, assessment and reporting processes and in August 2022 the purpose of the visit was to 'ground truth' to establish peatland and stability characteristics at particular locations of interest, including the twelve PSA Areas identified. Further site data collated included humification testing, using the von Post classification system to establish fibrous and structural condition of peat at various locations and depths, landform descriptions, additional peat probing and shallow shear vane data.

9.1.5 Annex B provides datasheets for the twelve locations identified for 'Detailed Assessment'. PSA Areas D and F were evaluated as of initial 'High' risk with FoS values less than 1.0, including extended coverage where GeoSure data suggested potential instability. PSA Areas A, B, C, E, G, H, I, J, K and L were evaluated as of initial 'Moderate' risk with FoS values between 1.0 and 1.4. At these 12 locations further information was collated to refine the risk, with individual datasheets prepared to provide local details and discuss initial and revised risk assessment outcomes.

9.1.6 Following the Detailed Assessment process, 'Low' risk was confirmed for the locations visited. This takes account of local ground conditions and appropriate micrositing to avoid/ minimise disturbance of deeper peat and coincident breaks of slope, alongside slope monitoring, slope support measures and drainage controls as area-specific mitigation. No areas within 100 m of the proposed infrastructure are considered to be above 'Low' revised risk (with the vast majority of the Site considered 'Low' risk or non-peat) in terms of peat stability assessment. Revised risk outcomes for the Site are shown on **Figure 10.1.14 Revised Risk**.

9.1.7 The Guidelines[2] quote the following requirements, for which 'Low' risk applies to this Site:

- High risk - 'Avoid project development at these locations'
- Moderate risk - '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'
- Low risk - 'Project may proceed pending further investigation to refine assessment and mitigate hazard through relocation or re-design at these locations'
- Negligible risk - 'Project may proceed with monitoring and mitigation of peat landslide hazards at these locations as appropriate'

9.1.8 Further geotechnical investigation is proposed as part of the Site investigations, which would take place post-submission and prior to construction. This is standard practice and would inform the final, detailed design of the Development, along with detailed mitigation, such as specific drainage designs including routes and discharge locations, to be implemented during construction, undertaken by an appropriately qualified geotechnical engineer. Any additional areas of concern identified by surveys pre-construction, should be added to the areas for further investigation. Due to the Moderate UXO Risk, the methodology for the geotechnical investigation (including additional peat depth surveys) at the northern extent will have to be agreed and supervised by an UXO Engineer.

9.1.9 Whilst good practice and specific mitigation measures have been identified in this document in order to minimise risk, the suggested techniques are not exhaustive and it is expected that a design consultancy and contractor would use these and other techniques, as appropriate, to effectively manage the peat stability risk.

9.1.10 Management of peat stability risk would remain a consideration throughout the subsequent detailed design processes, including additional site investigation, pre-construction activities and during construction, subject to the development receiving consent. A key issue is that the design remains 'live' and subject to ongoing optimisation, with the iterative design process continuing into construction phase. The contractor is able to microsite to reduce peat instability risk, whilst taking account of other local environmental and engineering constraints.

9.1.11 The need for risk management has been emphasised throughout this report. Risk management would include the regular review of the Geotechnical Risk Register, supported by appropriate actions within the contractor's Construction Method Statement (CMS) and Construction Environmental Management Plan (CEMP), in due course.

10. TECHNICAL AUTHORS AND EXPERIENCE

10.1.1 The authors of this report were Stuart Bone BSc (Hons.) MSc PIEMA CWEM CEnv and Marta Ibanez Garcia BSc MSc PIEMA.

10.1.2 Stuart Bone is a Chartered Environmentalist (CEnv) and Chartered Water and Environmental Manager (CWEM) holding chartered status since 2005 and is also a Practitioner Member of the Institute of Environmental Management & Assessment (PIEMA). Stuart has a BSc (Hons.) in Environmental Geography from the University of Aberdeen and a MSc in Marine Resource Development and Protection from Heriot-Watt University. Stuart has over 20 years environmental experience, delivering PLHRA and other soil and water EIA deliverables in the renewable energy sector since 2006, becoming a technical lead on these deliverables in 2012. Stuart has a strong understanding of peat morphology, geomorphological processes, environmental data collection, FoS stability analysis and risk assessment both from project experience and from his academic background. Stuart has a thorough familiarity of the latest guidance and promotes early data collation and stability interpretation to inform the iterative design process in accordance with good risk management principles. Stuart has provided technical reporting and guidance, supervision and in-depth review at every stage of this PLHRA process.

10.1.3 Marta Ibanez Garcia is a qualified Environmental Scientist with a BSc and MSc in Environmental Management from Abertay University. She has been a Practitioner Member of the Institute of Environmental Management & Assessment (PIEMA) since 2017 and is currently working towards Chartership. She has seven years' experience in environmental impact assessment, and delivering peat stability assessments, including planning and conducting fieldwork, since 2018. She worked previously in Quality and Environmental Management Systems implementation. Marta has been the joint report author and also responsible for planning peat surveys, conducting fieldwork, data interpretation and processing peat stability outcomes using QGIS software. Marta organised the peat depth surveys and visited the Site in July 2022 and August 2022 to supervise associated fieldwork and review detailed assessment locations.