Technical Appendix 9.3.1: Geotechnical Assessment: Peat Slide Risk Assessment;

Unshinagh Wind Farm

Stage 2 - Peat Slide Risk Assessment

27 September 2021

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Renewable Energy Systems Limited

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Contents

1. Introduction

This report details the Peat Stability Assessment undertaken at the proposed Unshinagh Wind Farm. The proposed wind farm development comprises x14 wind turbine generators, along with ancillary infrastructure and access tracks. The report is accompanied by the following map information:

- Figure A.1 Aerial Imagery & Site Layout
- Figure A.2 Superficial Geology
- Figure A.3 Solid Geology
- Figure A.4 Slope Angle
- Figure A.5 Major Geomorphological Features
- Figure A.6 Interpolated Peat Depth
- Figure A.7 Environmental Impact Zonation
- Figure A.8 Peat Stability Risk Zonation
- Figure A.9 Factor of Safety

In addition to this report a Peat Management Plan (Doc No. 1262629) and a Mining Risk Assessment (Doc No. 1262642) have been produced for the proposed development.

1.1. Reporting Experience

Report Author: - Sam Fisher is a Geotechnical Engineer at Natural Power and engineering geologist by training (MSc Engineering Geology) with greater than 5 years of relevant geotechnical experience. Sam has completed multiple peat slide risk assessments for wind energy projects across the UK.

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

1.2. Objectives & Scope

This Peat Slide Risk Assessment (PSRA) comprises a semi-quantitative peat stability risk assessment. The primary objectives of this report are:

- Present a desk study pertinent to the subject of peat stability assessment at the Proposed Development;
- Report on walkover survey and geomorphological mapping exercise to inform the assessment;
- Identify any areas of existing instability or which may pose a risk to the Proposed Development;
- Qualitative and quantitative peat slide risk assessment;
- Provide robust and targeted recommendations for any future construction process and mitigate any potential contributory factors to elevated risk of instability.

This report and survey work has been undertaken in general accordance with the Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Development, second edition, published by the Scottish Government in April 2017.

The Peat Stability Risk Assessment utilises data and visual reconnaissance assessment collected during two main phases of site survey. This data and information are combined with desk study and review of all salient published materials. The following data sources have been integrated into this assessment: (Table 1.1).

Table 1.1: PSRA Data Sources

Data Source	Location	Date
GSNI – Onshore Geological Map Data: (Linear Features, Mass movement deposits, Artificial ground, superficial deposits, bedrock geology, faulting,1:50,000 scale)	http://mapapps2.bgs.ac.uk/geoindex/home.html	2021
GSNI – Engineering Geology Viewer: 1:1M Superficial Engineering Geology; 1:1M Bedrock Engineering Geology	http://mapapps.bgs.ac.uk/engineeringgeology/home.html	2021
GSNI – Hydrogeological Map: 1:625,000 Scale	http://www.largeimages.bgs.ac.uk/iip/hydromaps.html?id=scotland.jp2	1988
UKSO– UK Soil Observatory, originally mapped at 1:250,000 scale	http://www.ukso.org/static-maps/soils-of-northern-ireland.html	2006
Historical Ordnance Survey of Northern Ireland (OSNI), Historical mapping	https://apps.spatialni.gov.uk/PRONIApplication/	Various
Historical Aerial Photograph Data ESRI Satellite World Imagery Google Earth Professional	https://server.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer/tile/{z}/{y}/{x}	2021
Online news archival search	Various web-based search engines	2021
Department for Infrastructure – Flood Maps NI	https://dfi-ni.maps.arcgis.com/apps/webappviewer/index.html	2021

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

- Desk Study and review of existing site information carried out in March 2021, including desk-based mapping and site modelling.
- Site reconnaissance survey (March 2021). This comprised a walkover survey of the site and identification of potential geo-hazards.
- Desk based aerial image review of open-source available Google Earth and Bing Aerial Images (March 2021).
- Development-wide peat probing survey comprising: An initial site wide peat probe survey within the turbine envelope on a grid resolution of 100m (March 2021), Phase I survey.
- Detailed peat probing survey covering areas of peatland and designed infrastructure at higher resolution (August and September 2021).
- Assessment of peat undrained shear strength through in-situ hand shear vane testing across representative turbine locations within the design envelope (August 2021).

- Development-wide mapping and assessment of salient features such as active, incipient or relic instability within the peat deposits, geomorphological features, peat depth and composition (August 2021).
- Quantitative slope stability assessment based on in-situ shear strength data.
- Assessment of the potential risk of peat failure across the turbine envelope.
- Comparison of the potential risk of peat failure with the site hydrological model including proximity to watercourses and sensitivity of those features.
- Recommendations for detailed design/construction control with specific examination the need for measures to mitigate potential peat failure as part of any future wind farm development.

1.3. Detailed Description of Development

The proposed development occupies a 5.5km^2 area situated 3.5km south west of Carnlough, Co Antrim Northern Ireland. At the time of writing the development will comprise x14 Wind Turbines with associated infrastructure including foundations, hardstanding's, internal track network and ancillary infrastructure.

Wind turbines are likely to be installed on reinforced concrete slab foundations depending on ground conditions.

Each wind turbine requires an area of hard standing (a "crane pad") to provide a level and firm base for the construction phase at the location of each turbine.

There would be a temporary construction compound / storage area to provide a secure area for site office facilities and storage of materials and compounds. This would be constructed adjacent to the site track, with a hardcore base surrounded by a security fence and locked gates. All temporary features would be removed from Site and all areas disturbed by the works would be reinstated in accordance with a Construction Management Plan.

Transformers to step-up the voltage exported from each turbine would either be placed within the wind turbines themselves, or in a small secure external transformer housing placed next to each wind turbine tower, depending on the final turbine choice. High voltage and control cables would be placed in trenches (dimensions to be determined by the ground conditions, but typically 0.5 m x 1 m deep) routed alongside the access tracks.

A single storey substation building would be built and will house the switchgear and control equipment, in addition to acting as a secure storage space. Parking spaces will be included in the design.

A grid connection would be required to feed the electricity generated by the wind farm into the distribution or Transmission network for the operational period of the wind farm. The final details of the grid connection including the precise route and an assessment of any impacts on the environment would be determined by the Distribution Network Operator (DNO) at a later date. The new grid connection may be subject to a separate design and consent process. Wind farms are typically connected to the grid via underground cable connections.

Onsite borrow pits are not currently proposed within this development.

1.4. Location

Regional and local setting is shown below in Figure 1.1: Regional Figure 1.1 and Figure 1.2. Access is from the Slane road to the southeast of the site.

Source: Natural Power, Google Earth Professional

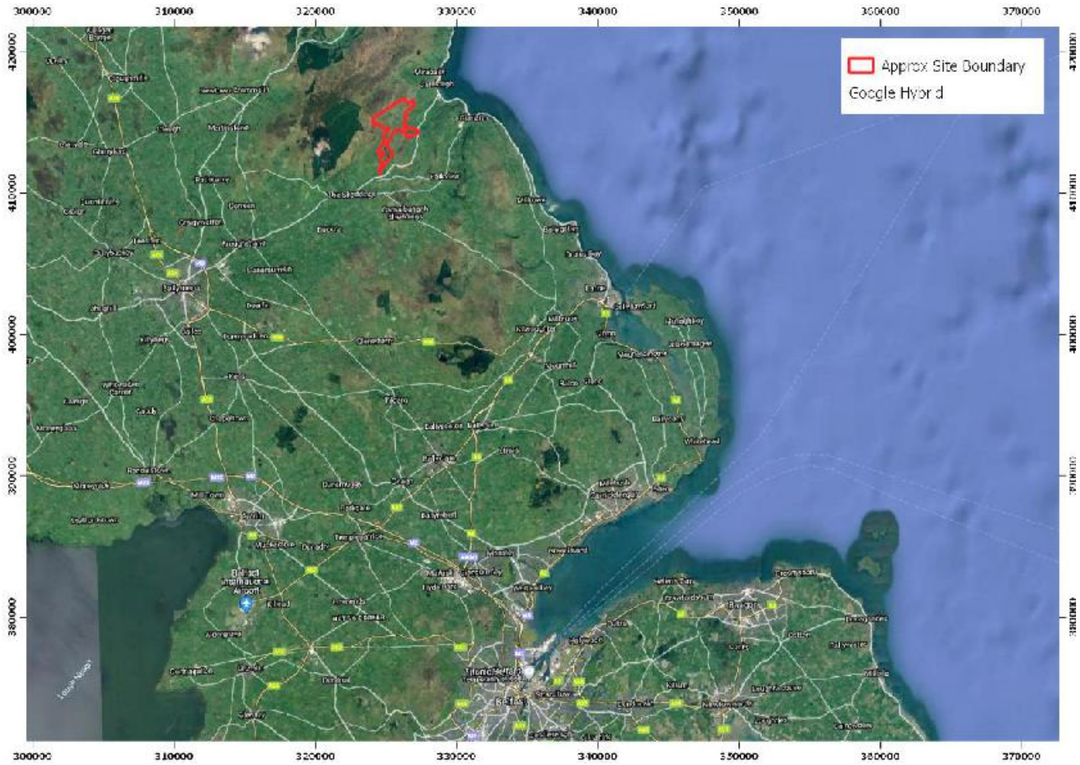


Figure 1.1: Regional Setting

Source: Site Boundary and Turbine coordinates supplied by RES, Google Earth Professional

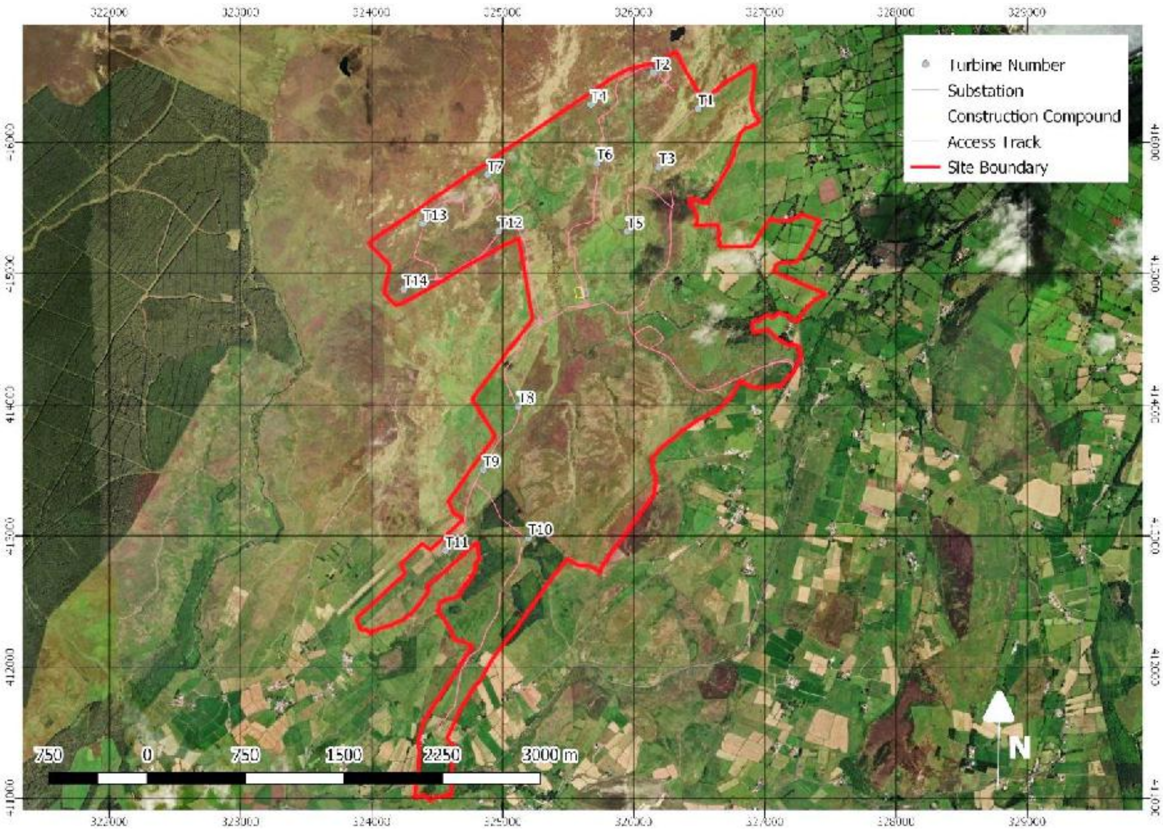


Figure 1.2: Site Layout with approximate Turbine Locations

1.5. Terrain Description

The proposed development occupies mostly south-east facing low and upland slopes, extending from 190m AoD to 320m AoD across the site. Terrain below 250m AoD is predominantly used for agriculture. Higher elevations have sporadic heather and coarse vegetation coverage.

Across the southern section of the proposed development are small compartments of commercial forestry. Small watercourses form the local topography of the area with mostly gentle slopes. The Geomorphological Map (Figure A.5) Identifies the steeper slopes. A topographic map of the proposed development is displayed in Figure 1.3 below.

Source: NPC 1:50,000 OS Mapping

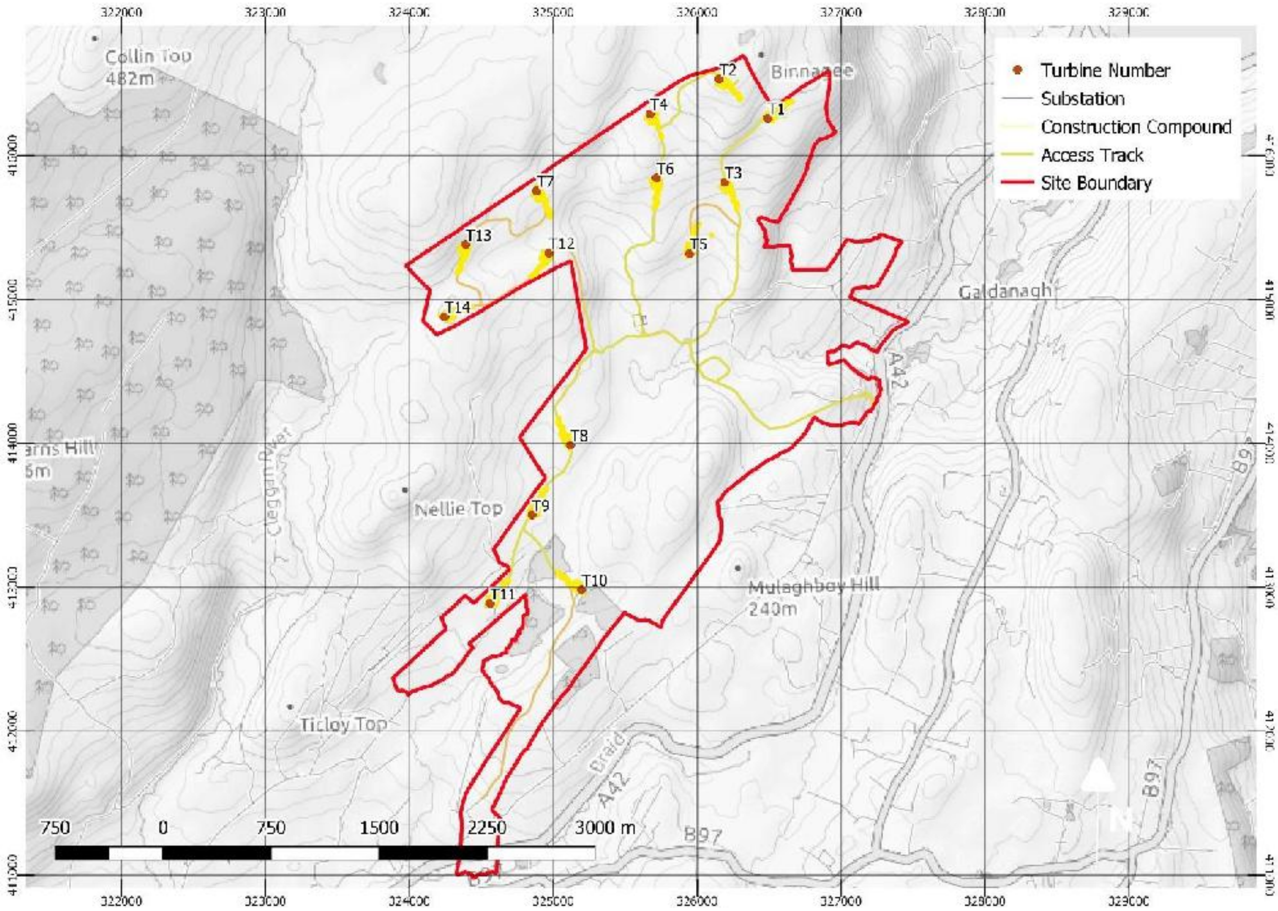


Figure 1.3: Site Topography

1.6. Site Photographs

The following series of images provide an overview of the terrain for the proposed Unshinagh Wind Farm.

Source: Natural Power, Phase II Study (September 2021)

Figure 1.4: View North from the approximate location of T3 towards Binnagee summit.

Source: Natural Power, Phase II Study (September 2021)

Figure 1.5: View southwest from the approximate location of T10. Terrain indicative of the southern side of the development area.

Source: Natural Power, Phase II Study (September 2021)

Figure 1.6: View over the possible Aughareamlagh Workings south east of T8.

Source: Natural Power, Phase II Study (September 2021)

Figure 1.7: Typical upland terrain across the north of the site.

2. Survey Methodology

2.1. Data Review

In preparation of this report, an initial desk-based assessment has been undertaken to allow subsequent surveys to be targeted. Table 1.1 highlights the key sources of information for this report.

Online searches for local peat or major landslides returned several instances within the region (Detailed in Natural Power Report no.1246507). None however had similar ground conditions or were in close proximity to the site.

Readily accessible aerial imagery records dating to 2001 do not show any major changes occurring through to the present day. A detailed review of the historical aerial imagery along with the available historical mapping is described in the Natural Power Desk Study Report Section 2.2.1 (Report no. 1246507).

Natural Power's project directory and online sources were searched for reports of peat slide incidents on adjacent wind farm developments. These searches did not provide any pertinent information.

2.2. Geomorphology

Reconnaissance and geomorphological mapping were carried out during March 2021. This exercise provided opportunity for geotechnical engineers to visualise the terrain, access geological and soil exposures, examine slope systems, vegetation cover and record any hydrological features impacting peat stability.

The culmination of this survey and desk-based review of aerial photographs was the production of a geomorphology map, 14431UKC_PSRA_005, Appendix A.5. This map was used in the qualitative stability risk assessment and maps the major features across the development pertinent to the risk model.

2.3. Peat Survey

The soil probing coverage has allowed for:

- Stage 1 probe survey implementing a 100 m grid of probes across the Proposed Development infrastructure areas.
- Stage 2 prove survey with detailed coverage of proposed wind farm infrastructure locations.
  - 50m intervals along tracks with probing at 10-20m offset to capture data across the construction corridor;
  - 10m grid spaced probes across turbine centres extending 50m in each cardinal direction;
  - 20m grid spacing across temporary infrastructure locations.

Peat depths were recorded using probes inserted into the peat and measuring the depth to refusal. This provides a wide-ranging dataset, but the data carries the following limitations:

- Peat probes may record depth to obstructions (e.g., tree roots, rock clasts) and not the true depth of the peat;
- Peat probes may over-estimate peat depth where the underlying soil strata is very soft;
- Peat probes can underestimate peat depth in very dry peat deposits due to early refusal of the probe;
- Peat probes do not differentiate between peat and mineral sub-soils.

Detailed peat probing survey was focussed at locations of peat (where visual evidence and probes record depths of >0.5 m). In-situ hand shear vane tests were conducted to provide an estimate of undrained shear strength within the peat at relevant turbine locations. Supplementary to this, peat cores have been taken at select locations to provide confirmation of probe depth correlation, material classification and morphology.

Peat depth mapping is shown on drawing: 14431UKC_PSRA_006, Appendix A.6. To prepare the interpolated peat depth mapping; a spatial interpolation method termed 'Ordinary Kriging' was applied.

This is a statistical interpolation function examines point data (and weights the surrounding measured values) to derive a prediction for unmeasured locations. Ordinary Kriging is considered generally acceptable for geological / soil science applications. Limitations of the Kriging method are widely accepted to be:

- Confidence in the output related to number and density of points within the input dataset.
- Search window needs to be set to limit influence of distant data points.

The interpolation parameters and peat depth data set are deemed suitable for informing the peat slide risk assessment. Figure A.6 appended to this report, indicates interpolated peat depth across site, a total of 1,195 peat probe data points were acquired during the phase one and two surveys.

2.4. Slope Mapping

Terrain Slope Angle Map (14431UKC_PSRA_004) is comprised from digital elevation model data, carrying a grid resolution of 5m. The risk assessment considers slope angle in two aspects. Firstly, the slope angle is used to screen the site for instability within the slope stability analysis numerical calculation. This is adjoined to qualitative assessment of the slope in terms of a contributory factor to failure. This combined approach ensures a robust assessment of the risk.

3. Geology & Environment

3.1. Superficial Deposits

The GSNI online viewer indicates only parts of the site to be covered with superficial deposit. Figure 3.1 below shows the GSNI Superficial Geology layer.

Source: GSNI 1:10,000 Superficial Geology

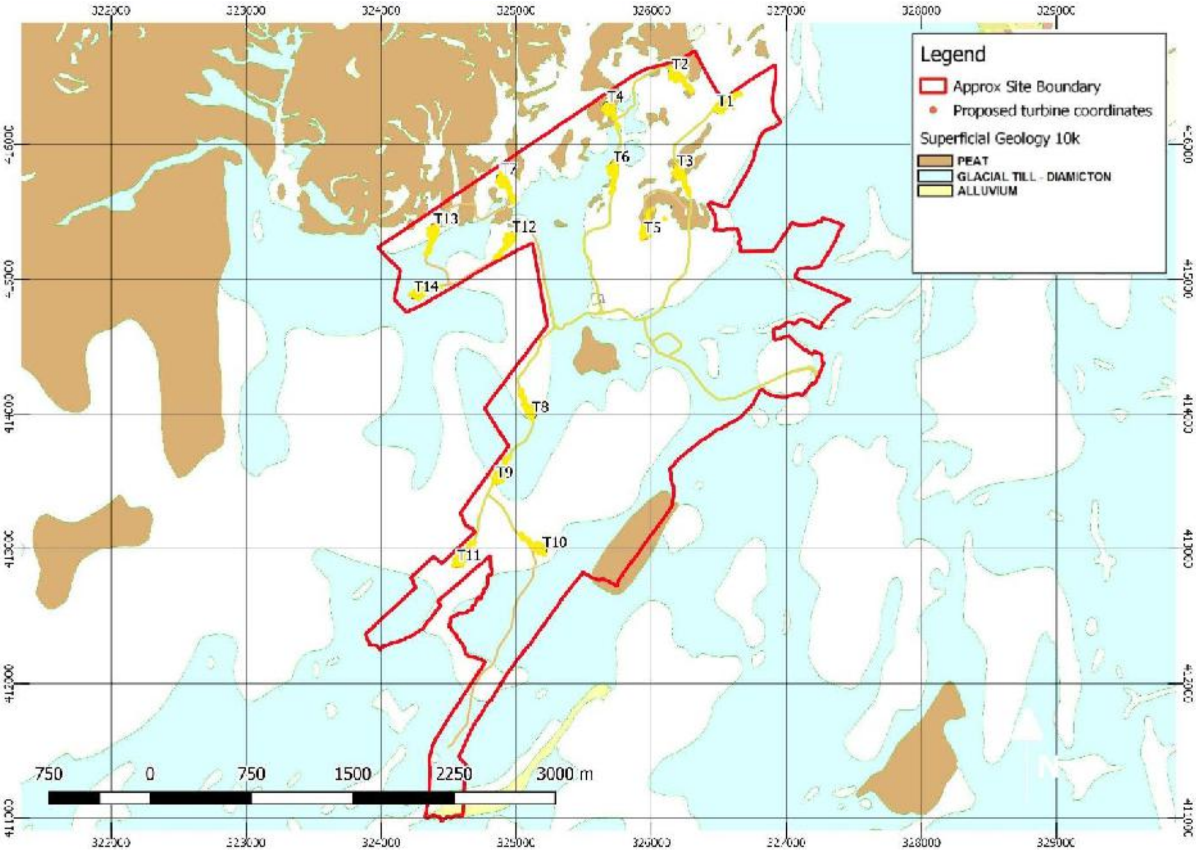


Figure 3.1: Superficial Geology Map

Glacial deposits are present along the two main watercourses within the site boundary. There are also similar deposits mapped across the southern most part of the development. Peat deposits are mapped in disseminated patches in the upper half of the main slope system.

Glacial Deposits – are described as 'Till – Diamicton' deposited within the last 2 million years. Made up of material ranging from clay to large boulders, this material is generally poorly sorted and undifferentiated. 2 shows an example glacial deposit taken during the Natural Power site walkover.

The BGS online engineering viewer description is summarised as follows: Firm to hard gravelly sandy CLAY with many cobbles and boulders. Often fissured, with occasional interbeds of sand and gravel. Generally low permeability. Foundations are generally good, but there is potential for differential settlement. Excavation is easy, with material staying stable if dry. May be suitable for general cohesive fill depending on grading, plasticity and water content. During the site investigation it is important to determine the deposit thickness and lithological variation. Presence of laminated silts and clay, as well as any water bearing strata.

Source: NATURAL POWER site walkover (ING 324972, 415422)

Figure 3.2: Example of glacial till exposed in a small steam

Peat – Localised peat deposits are present across the site, generally in relatively flat topographic depressions. Figure 3.3 shows peat depth collected during Natural Powers' Phase I and II peat probing survey.

The BGS online engineering viewer description is summarised as follows: Very soft to firm fibrous amorphous PEAT. Some deposits may be worked. Very low to moderate permeability. Very poor foundation conditions, very weak and highly compressible. Acidic groundwater could interact with buried steel and concrete. Floating or piled foundations should be considered, or removal of peat cover. Easy digging with specialist low ground pressure machinery. Will require immediate support and dewatering. Dewatering will lead to surface lowering and oxidation of peat. Unsuitable for fill. Site investigation should determine depth and extent of deposits, ground water acidity should be determined prior to concrete selection.

Peat Coverage

Determined by the Natural Power Phase I and 2 surveys and is shown in the figure below.

Source: NATURAL POWER Phase I and II peat survey. Peat layer based on 100m peat probe grid.

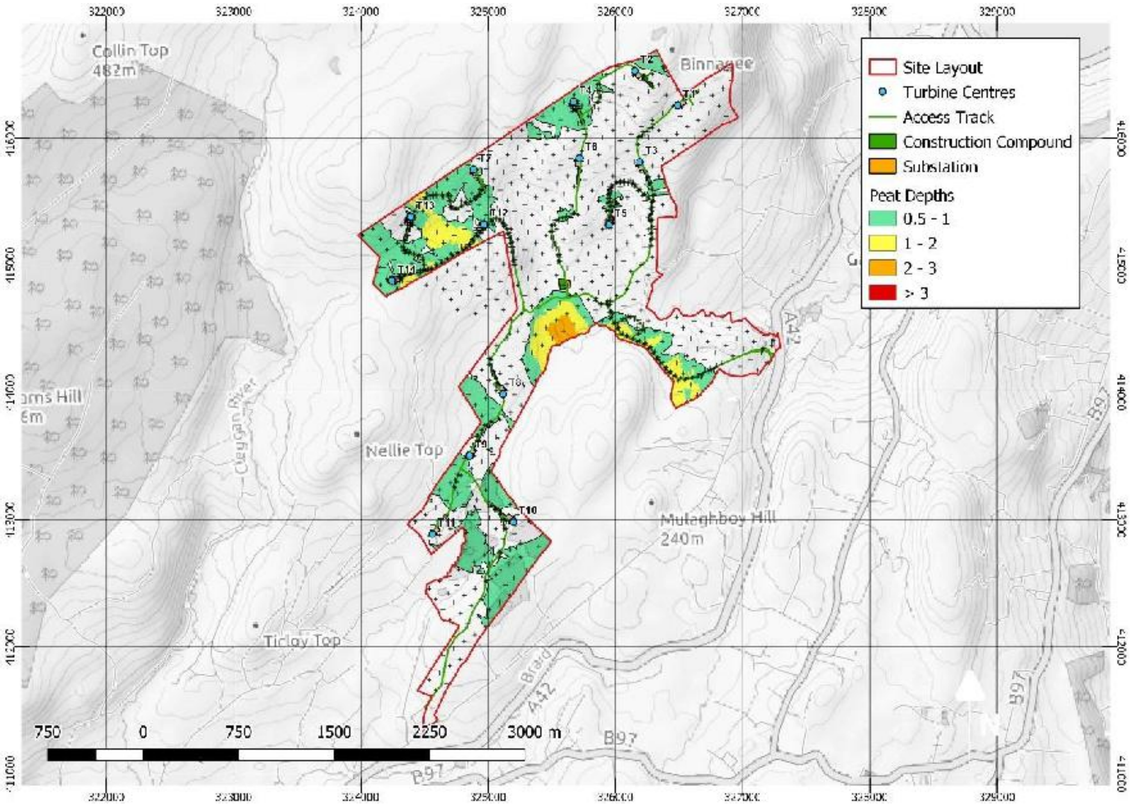


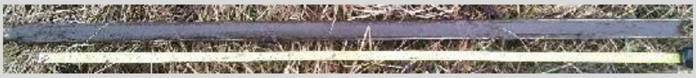
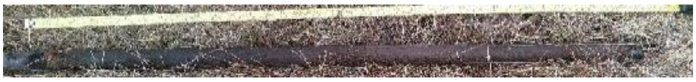
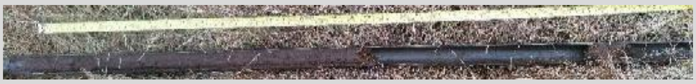
Figure 3.3: Peat Depth Map

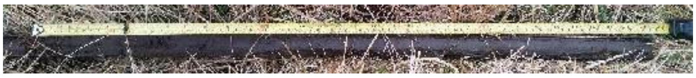
Peat details

x10 peat cores were carried out across the site. Each core was carried out in an area of deep peat, or in areas where it was ambiguous as to whether the depth probed was peat. Additionally, peat cores were undertaken at T4, T12 and T14 were detailed probing indicated depths greater than 0.50m at the turbine base. Each core is photographed, given a general description, water content estimate (B) and Von Post rating (H) (Table 3.1)

Table 3.1: Core Descriptions and Shear Strength Tests

Core and Depths	Descriptions and photos	HSV	Shear (kPa)	Re-moulded (kPa)
Core 1				
0.00 – 0.10mbgl	Very soft black pseudofibrous plastic slightly spongy PEAT (H6/B3)	0.5m	29	18
0.10 - 0.30mbgl	Very soft brown fibrous plastic PEAT (H2/B4)	1.0m	23	17
0.30 - 1.40mbgl	Firm brown fibrous spongy PEAT (H4/B3)	1.5m	18	16
1.40 - 4.40mbgl	Soft black pseudofibrous plastic PEAT (H5/B2) 3.40 - 4.40m Wood fragments	2.0m	38	30
0.00 - 1.00mbgl		2.5m	44	35
1.00 – 2.00mbgl		3.0m	48	30
2.00 – 3.00mbgl		3.5m	56	40
3.00 – 4.00mbgl		4.0m	65	40
4.00 – 4.40mbgl		4.5m	65	60
Core 2				
0.00 - 1.20mbgl	Very soft brown pseudofibrous plastic PEAT (H6/B3)	0.5m	23	12
1.20 - 4.00mbgl	Very soft brown fibrous plastic PEAT (H4/B5)	1.0m	12	10
4.00 - 5.00mbgl	Very soft dark brown amorphous plastic PEAT (H6/B4)	1.5m	14	9
5.00 - 6.00mbgl	Very soft dark brown amorphous plastic PEAT (H8/B3)	2.0m	9	8
0.00 - 1.00mbgl		2.5m	12	9
1.00 – 2.00mbgl		3.0m	12	11
2.00 – 3.00mbgl		3.5m	11	10

Core and Depths	Descriptions and photos	HSV	Shear (kPa)	Re-moulded (kPa)
3.00 – 4.00mbgl		4.0m	12	14
4.00 – 5.00mbgl		4.5m	15	13
5.00 – 6.00mbgl		5.0m	18	15
Core 3				
0.00 - 0.30mbgl	Firm black pseudofibrous spongy PEAT (H6/B2)	0.5m	44	27
0.30 - 1.80mbgl	Soft dark brown pseudofibrous plastic PEAT (H6/B3)	1.0m	36	25
0.00 - 1.00mbgl		1.5m	60	37
1.00 – 1.80mbgl				
Core 4				
0.00 - 0.30mbgl	Soft black pseudofibrous spongy PEAT (H4/B3)	0.5m	35	24
0.30 - 3.40mbgl	Soft black pseudofibrous plastic PEAT (H5/B3)	1.0m	25	22
3.40 - 3.70mbgl	Very soft grey CLAY	1.5m	41	33
0.00 - 1.00mbgl		2.0m	45	33
1.00 – 2.00mbgl		2.5m	50	37
2.00 – 3.00mbgl		3.0m	50.5	41
3.00 – 3.70mbgl				
Core 5				
0.00 - 0.40mbgl	Soft black fibrous spongy PEAT (H3/B2)	0.5m	22	12
0.40 - 2.00mbgl	Very soft dark brown pseudofibrous plastic PEAT (H4/B3)	1.0m	25	17
2.00 - 3.00mbgl	Very soft dark brown amorphous plastic PEAT (H6/B3)	1.5m	45	35
0.00 - 1.00mbgl		2.0m	39	28
1.00 – 2.00mbgl		2.5m	46	28
2.00 – 3.00mbgl				

Core and Depths	Descriptions and photos	HSV	Shear (kPa)	Re-moulded (kPa)
Core 6				
0.00 - 0.05mbgl	Soft grey clayey TOPSOIL	No Peat		
0.05 - 0.40mbgl	Soft light brown CLAY			
0.00 – 0.40mbgl				
Core 7				
0.00 - 0.30mbgl	Soft grey amorphous plastic PEAT (H6/B3)	No Peat		
0.30 - 0.80mbgl	Soft dark grey slightly sandy CLAY			
0.00 – 0.80mbgl				
Core 8 – T4				
0.00 – 0.30mbgl	Very soft brown fibrous spongey PEAT (H3/B3)	0.5m	14	9
0.30 – 1.00mbgl	Soft dark brown psuedo-fibrous plastic PEAT (H6/B3)	1.0m	18	11
1.00 – 1.50mbgl	Very soft dark brown pseudo-fibrous plastic PEAT (H7/B4)	1.5m	53	26
0.00 – 1.00mbgl				
1.00 – 1.50mbgl				
Core 9 – T14				
0.00 – 0.10mbgl	Firm to soft brown pseudo-fibrous spongey PEAT (H3/B3)	0.50m	34	18
0.10 – 0.40mbgl	Firm to soft dark brown psueod-fibrous plastic PEAT (H6/B2)	0.80m	60	43
0.40 – 0.60mbgl	Firm dark brown psuedo-fibrous to amorphous plastic PEAT (H8/B2)			
0.00 – 0.60mbgl				
Core 10 – T12				
0.00 – 0.05mbgl	Soft brown fibrous spongey to plastic PEAT (H3/B2)	Insufficient peat depth for HSV testing.		
0.05 – 0.40mbgl	Soft dark brown pseudo-fibrous plastic PEAT (H5/B2)			
0.00 – 0.40mbgl				

Source: NATURAL POWER peat survey. Shear values have been corrected for vane size.

Peat deposit characteristics vary across the site. Cores 6 and 7 were taken to ground truth peat probe data, as can be seen the ground in these locations has a significant layer of soft clay.

Shear values are generally low to medium strength across the locations, with Core 2 being the exception with extremely low shear strengths. This area was waterlogged which could be attributing to the low values.

None of the deposits are considered dry, and have humification levels between H3 and H8.

3.2. Peat Depth Analysis

Natural Power carried out 559 peat probes across the site during the Phase I peat survey and 636 peat probes during the Phase II peat survey. **Error! Reference source not found.** presents the combined data collected across both surveys.

Table 3.2: Peat probe data

Peat Depth	Number of probes	% (Of total)
0.0m < x ≤ 0.5m	801	67%
0.5m < x ≤ 1.0m	253	21%
1.0m < x ≤ 2.0m	114	10%
2.0m < x ≤ 3.0m	20	2%
> 3.0m	7	1%

Source: Natural Power peat probing survey data. (Each percentage has been rounded to the nearest whole number, so may not equal 100%) Total probes 1195.

The collected peat probe depths compare well with the BGS data, showing discrete pockets of deeper peat. The deepest pockets of peat in excess of 5.0m have been avoided in the scheme layout. The deepest recorded peat during the Phase II survey is east of turbine T12 to a maximum depth of 2.90m.

The majority of the site has no peat or depths below 0.5m. Following the peat coring it is shown that the peat probe can be pushed into very soft clays giving false probe depths at some locations. Turbines with probing depths less than 0.50m are considered to not be peat and rather peat soil or topsoils. The peat depth interpolation map is appended to this report (Figure A.6).

Peat Depth at Turbine Bases

Table 3.3 summarises the peat depths recorded across the proposed wind turbine location, construction compound and substation.

Table 3.3: Overview of Peat Depths at Turbines and Anciallary Structures

Depth Range	0 – 0.10m	1.0 – 2.0m	2.0m – 3.0m	>3.0m
Location	**Peat Depth (m)**	**Peat Depth (m) Hardstanding**	**Slope Geometry (Degrees)**	**Comments**
T1	0.00	0.00	4	Located in exposed upland
T2	0.30	0.30	6	Located in exposed upland
T3	0.25	0.25	8	Located in farmed grassland
T4	0.30	0.70	8	Located in exposed upland
T5	0.10	0.20	5	Located in farmed grassland
T6	0.20	0.20	7	Located in exposed upland

Depth Range	0 – 0.10m	1.0 – 2.0m	2.0m – 3.0m	>3.0m
T7	0.00	0.00	6	Located in exposed upland
T8	0.30	0.30	3	Located in farmed grassland
T9	0.40	0.40	2	Located in farmed grassland
T10	0.00	0.00	6	Located in farmed grassland
T11	0.20	0.20	7	Located in exposed upland
T12	0.40	0.45	7	Located in exposed upland
T13	0.60	0.50	11	Located in exposed upland
T14	0.35	0.70	6	Located in exposed upland
Substation	0.00	0.00	5	Located in farmed grassland
Compound	0.00	0.00	5	Located in farmed grassland

Source: Natural Power

Peat Depth at Turbine Bases

The peat depths across the proposed access tracks are generally low, with a site wide average of 0.50m. Deeper areas are confined to localised pockets Table 3.4 summarises the mean peat depth along discrete sections of the proposed wind farm access tracks where the risk ranking is elevated, and the mean peat depths are greater than 0.50m.

Table 3.4: Overview of Peat Depths at High Risk Track areas

Depth Range	0 – 0.10m	1.0 – 2.0m	2.0m – 3.0m	>3.0m
Location	Average Peat Depth (m)			Comments
T7 to T13	0.70			Located in exposed upland terrain
T13 to T14	0.70			Located in exposed upland terrain
T8 to T9	0.50			Located in farmed grassland
T11 Spur	0.65			Located in farmed grassland
T14 to T12	1.00			Located in exposed upland terrain
South East Access	0.80			Located in farmed grassland

Source: Natural Power

Estimation of Peat Shear Strength

x7 shear tests were carried out at core locations where peat depths allowed. Each test was carried out using a Geonor H-60 Hand Shear Vane Tester using a 33mm steel vane. **Error! Reference source not found.** shows the HSV results alongside the peat core information. Locations for each peat core are presented on Map A6 in the appendices.

Figure 3.4 depicts the peak undrained shear strength data against depth.

Source: Natural Power

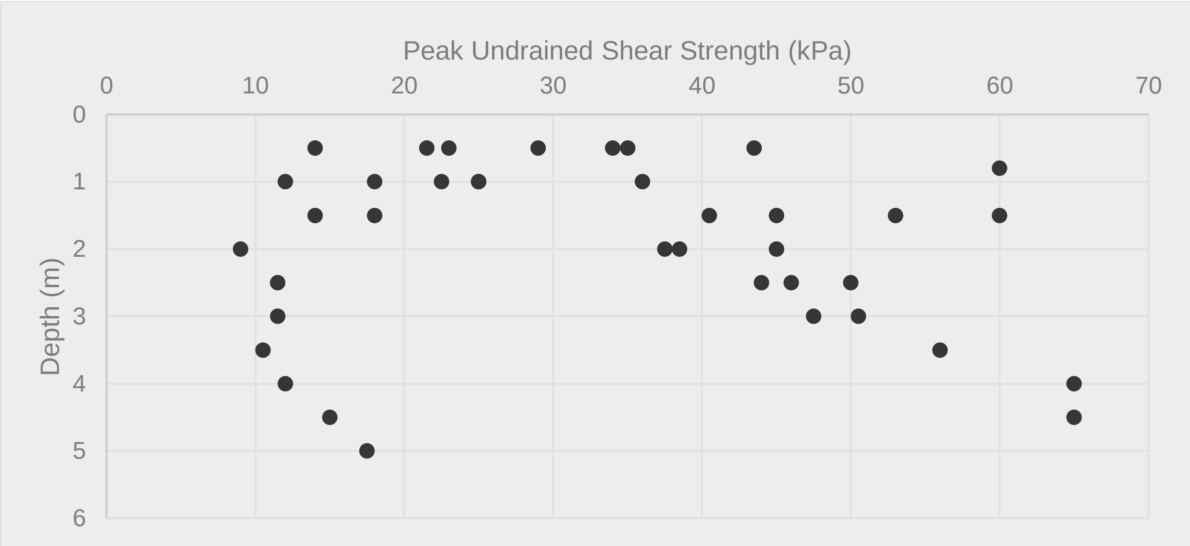


Figure 3.4: Peak undrained shear strength against depth across the site.

The peat undrained shear strength is seen to be highly variable within the peat deposits with no clear trend against depth. In the absence of specific test readings at the majority of the turbine bases a very conservative value of 9kPa (extremely low strength) is considered appropriate for the site wide slope analysis.

Humification of Peat

The peat cores undertaken on site are presented in within Table 2.1. The peat has been characterised according to the von post classification (Von Post & Granland, 1926), Table 3.5 sets out the Von Post classification.

Table 3.5: Von Post Classfication

Degree of Humification	Peat Description
H1	Completely unconverted and mud-free peat which when pressed in the hand only gives off clear water. Plant remains are easily identified.
H2	Practically unconverted and mud free peat which when pressed in the hand gives off almost clear colourless water. Plant remains are still easily identifiable.
H3	Very slightly decomposed or very slightly muddy peat which when pressed in the hand gives off marked muddy water, but no peat substance passes through the fingers. The pressed residue is thickish. Plant remains have lost some of their identifiable features.
H4	Slightly decomposed or slightly muddy peat which when presses in the hand gives off marked muddy water. The pressed residue is thick. Plant remains have lost more of their identifiable features.
H5	Moderately decomposed or muddy peat. Growths structure evident but slightly obliterated. Some amorphous peat substance passes through the fingers when pressed but, mostly muddy water. The pressed residue is very thick.

Degree of Humification	Peat Description
H6	Moderately decomposed or very muddy peat with indistinct growth structure. When pressed approximately 1/3 of the peat substance passes through the fingers. The remainder extremely thick but with more obvious growth structure than in the case of unpressed peat
H7	Fairly well decomposed or markedly muddy peat but the growth structure can just be seen. When pressed about half the peat substance passes through the fingers. If water is also released this is dark and peaty.
H8	Well decomposed or very muddy peat with very indistinct growth structure. When pressed about 2/3 of the peat substance passes through the fingers and at times a thick liquid. The remainder consists mainly of more resistant fibres and roots.
H9	Practically completely decomposed or mud-like peat in which almost no growths structure is evident. Almost all the peat substance passes through the fingers as a uniform paste when pressed.
H10	Completely decomposed or mud peat where no growth structure can be seen. The entire peat substance passes through the fingers when pressed.

Source: Von Post & Granland, 1926.

The peat encountered on site is variable with von post classifications between H3 and H8 generally becoming increasingly decomposed within the deeper peat deposits

3.3. Solid Geology

The BGS online viewer indicates the site is underlain by the Upper and Lower Basalt Formation. Figure 3.5 below shows the GSNI Solid Geology layer.

Source: GSNI 1:10000 Solid Geology

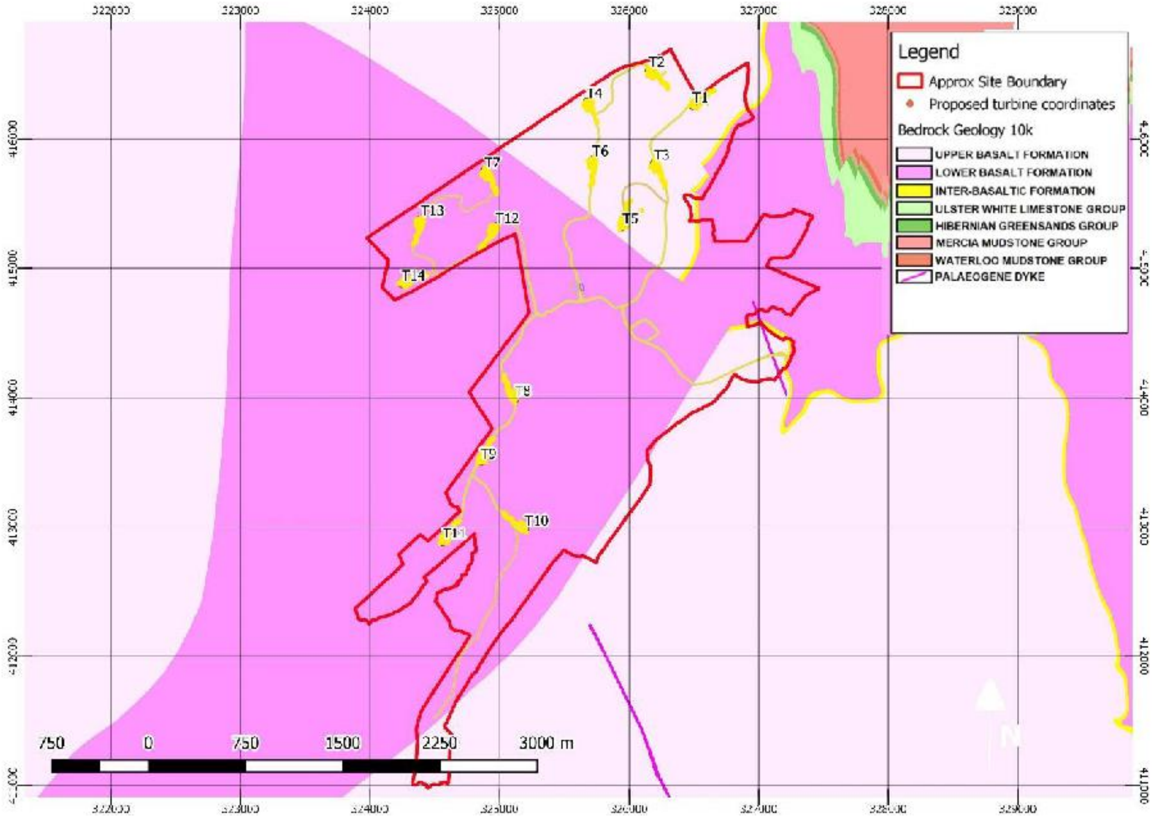


Figure 3.5: Solid Geology Map

The Lower Basalt is present under the majority of the site, with an inferred fault separating it from the Upper Basalt in the northeastern side of the site. This was confirmed during the site survey, basaltic lava flows were identified at all outcrops exposed on site.

The BGS online engineering viewer description is summarised as follows: very strong jointed fine grained basaltic rock. May be locally altered to very weak clay. Low permeability with flow through discontinuities. May include other fine grained mafic rocks and interbedded tuffs. Foundations are very good in fresh or slightly weathered rock, but highly weathered rock and presence of palaeosols may need to be accounted for. Highly weathered material may be excavatable, but fresher material may require blasting. Suitable for granular fill. It should be noted that some basalts may exfoliate to a slight extent after long periods of weathering. During the site investigation it is important to determine the nature of discontinuities, as well as the presence of highly weathered zones and/or tuff layers and palaeosols.

During the site survey x5 outcrops were noted to have exposed lava flows and palaeosols. Figure 3.6 shows a photo of one exposure. A 3m thick basaltic lava flow is shown to the left of the outcrop. This is overlying a red lens-like palaeosol on the right of the exposure. Examples of these are present throughout the site, and likely extend below the surface.

The basalt is very strong, and generally massive with frequent fractures. The palaeosol material is highly weathered, weak to medium strong, highly fractured. The extent of these likely permeates throughout all the upper and lower basalts. More photos can be found in Section **Error! Reference source not found. Error! Reference source not found.**, outcrop locations are presented on Map A3.

Source: NATURAL POWER site survey, photo taken at outcrop 3

Figure 3.6: Lava flow covering underlying palaeosol

Presence of these geological features will require a targeted ground investigation to inform the foundation design.

The Basalt layers are underlain by the Ulster White Limestone. Due to the unknown thicknesses of basalt it is important to highlight, as this can be a particularly problematic strata. Hazards include, weak layers, voids, as well as variable water content.

The BGS online engineering viewer description is summarised as follows: Weak to strong porous fine-grained CHALK and CHALKY LIMESTONE. Flint nodules and beds are frequent, and thin clay/mudstone beds. Lots of discontinuities present throughout. Weathers to calcareous silt. Dissolution hollows and pipes present under thin superficial cover. Very high to medium permeability. Potentially good foundation conditions, but largely dependent on nature and thickness of weathered zone. Possible presence of dissolution cavities. Soakaways near karstic structures are not advisable. Generally requires ripping and blasting, weathered material can be excavated with hard digging. Clay infills may give rise to stability problems. May be suitable for selected granular fill but can degrade quickly by weathering if used in association with wet cohesive soil. During the site investigation it is important to determine the extent of the weathered zone and presence of discontinuities. Location of karstic features is very important and may require geophysical methods to get the appropriate resolution. In-situ loading tests may be advisable to assess bearing strength.

3.4. Hydrogeology

The proposed development is primarily underlain by tertiary basalts, with a portion of the eastern access track underlain by Chalk and Hibernian Greensands.

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

The Chalk and Hiberian Greensand under the basalts are classified as highly productive aquifers (not extensive), which is a regionally important aquifer up to 150m thick. Due to the karstic characteristics of the limestones, the flow is confined to relatively large, fractured pathways allowing yields at springs of up to 32 L/s, yields in boreholes are typically less, around 5 L/s.

Care should be taken when drilling not to puncture this boundary unless absolutely necessary.

3.5. Hydrology, Flooding and Draining

The Northern Ireland Department for Infrastructure Flood Map does not show any significant flooding across the proposed development.

Small tributary streams at 400-500m intervals run down the main site. These feed into an unnamed tributary of the Glen Cloy River, at and east of Carrigvohil Loughs, flowing east. The Ticloy Water flows west from Carrigvohil Loughs. Watercourses are presented on Map A5 appended to this report.

Each mapped watercourse has a small flood plain up to a maximum of 25m from the main channel. Surface water occurrences are disseminated across the site, generally in small topographical depressions and near existing loughs.

Artificial drains are present in the first part of the south western access route. This could show that the area has been drained to allow for the tree plantations and farming. This would mean the area has been altered from its natural state.

4. Peat Slide Hazard – Risk Assessment Method

4.1. Processes Contributing to Peat Instability

The key principals of the peat slide risk assessment are presented below. Discussions of the factors which contribute to peat failure have been presented in Table 4.1.

Table 4.1: Contributory Factors to Peat Instability

Factor	Discussion
Groundwater Infiltration	There are two processes which may facilitate groundwater infiltration: • Periods of drying, resulting in cracking of the peat surface; and • Slope creep resulting in additional tension cracks. Drying out of the upper peat, particularly in areas of thinner peat, is likely to result in the development of near-surface cracks which could facilitate ingress of water into the peat.
Surface Loading	Any mechanisms which increase the surface load on a peat deposit can increase the likelihood of failure. This can include surface water ponding and surcharge loading, for example; construction works, stockpiling and forestry operations.
Vegetation Loss	Loss of vegetation can have a negative impact, making the peat susceptible to weathering, increasing rates of infiltration and a loss of strength.
Soil Weathering/Erosion	Weathering can weaken in-situ peat materials and destabilise a slope system. This may be in the form of weathering of peat or underlying mineral soils which could reduce shear strength at the peat/ mineral soil interface. Vertical cracking and slope creep may slowly break down peat structure over long periods of time. This can develop into peat 'hagging', which is a strong indication that natural weathering processes are ongoing. Peat hags expose the peat to increased weathering rates and may provide preferential surface water flow pathways. There was no marked peat hagging across the Site.
Precipitation	The likely failure mechanism following a period of heavy rainfall is linked to the infiltration of surface water. There is a resulting build-up of pore water pressures within the soils and therefore reduced effective shear strength. This may be focussed within the peat deposit or at the interface between the peat and underlying mineral soil. Secondary effects may include swelling of the peat deposit and increased loading due to surface water ponding. Snow and subsequent melt can have a similar effect.
Slope Morphology	There are three main effects arising from slope morphology: Firstly, the concentration of tensile stress at the apex of a convex slope predisposes the slope for failure initiation at that point. In a convex slope the material lower down supports the material above which is held in compression. A concave slope has the opposite characteristics as material at the base maintains the apex in tension. Secondly, at the point of maximum slope convexity, because of favourable down-slope drainage conditions, a body of relatively well-drained and relatively strong peat material develops. This body of peat acts as a barrier providing containment for growth of peat upslope. This relatively well drained body of peat can subsequently fail due to a build-up of lateral pressure on the upslope face. In this scenario the slope is not supported from below so eventually the lateral pressures exceed the forces resisting sliding. The apex or point of convexity is also a likely initiation point for slope failure due to the slope tension being concentrated at this point. Thirdly a failure mechanism, analogous to a piping failure underneath a dam, is postulated where springs are present in locations immediately down-slope of the relatively well drained peat body. Under these circumstances high pore pressure gradients within the peat can lead to hydraulic failure and undermining of the relatively well drained peat body resulting in a breach and loss of lateral support to peat upslope. Evolving slope morphology can be significant; for example, in the case of slope undercutting by water erosion. Any mechanism by which mass is removed from a slope toe or deposited on a slope crest will contribute to instability.

Factor	Discussion
Peat Depth & Slope Angle	Peat slides correspond in appearance and mechanism to translational landslides and tend to occur in shallow peat (up to 2.0m) on slopes between (5° – 15°). A great majority of recorded peat landslides in Scotland, England & Wales are of the peat slide type. MacCulloch, (2005) highlights that a slope angle of 20° appears to be the limiting gradient for the formation of deep peat. Therefore, the risk assessment has assigned slope angles >20° to be an unlikely contributory factor to failure. Slope angle indicators and corresponding probability factors have been similarly adapted from MacCulloch, (2005). Boylan et al, (2008) indicates that most peat failures occur on slope angles between 4° and 8°. It is postulated that this may correspond to the slope angles that allow a significant amount of peat to develop that over time becomes potentially unstable. Thus, for this assessment <3degrees has been assigned a low risk.
Hydrology	Natural watercourses and artificial drainage measures have often been identified as a contributory factor of peat failure. Preferential drainage paths may allow the migration of water to a failure plane therefore triggering failure when groundwater pressures become elevated. Within a peat mass, sub surface peat pipes can enable flow into a failure plane and facilitate internal erosion of slopes. It is also noted that in some instances, agricultural works can lead to the disturbance of existing drainage networks and cause failures. Drainage ditch networks are present across parts of the Site as a result of historical upland agricultural drainage practices.
Existing / Relict Failures	The presence of relict failures and any indication of previous instability are often important, indicating that site conditions exist that are conducive to peat failure. Relict peat slides may be dormant over long periods and be re-activated by any number of the contributory factors discussed in this table.
Anthropogenic Effects	Human impact on peat environments can include a range of affects associated with wind farm construction. Activities such as drainage, access tracks across peat, peat cutting, and slope loading are all examples. Rapid ground acceleration is one such example where shear stress may be increased by trafficking or mechanical vibrations.

Source: Natural Power

4.2. Peat Failure Modes

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

The potential for peat failure across the development is examined with respect to the activities envisaged during construction and operation of the wind farm. There are several classification systems for the mass movement of peat that were drawn together by PLHRAG, (2017).

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

- Peat Flows & Bog Bursts: are debris flows involving large quantities of water and peat debris. These flow down slope using pre-existing channels and are usually associated with raised bog conditions.
- Peat Slides: comprise intact masses of peat moving bodily down slope over comparatively short distances. A slide which intersects an existing surface water channel may evolve into a debris flow and therefore travel further down-slope. Slides are historically more common within blanket bog settings.

Due to the discrete areas of peat recorded across the development widespread instability comprising peat flows and bog bursts are considered unlikely at this stage. Smaller scale peat slides and debris flows are therefore the focus of the study and characterised by the definition above.

4.3. Geotechnical Principles

The main geotechnical parameters that influence peat stability are:

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

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

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

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

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

- The groundwater is resting at ground level;
- Minimum acceptable factor of safety required is 1.3;
- Failure plane assumed at the basal contact of the peat layer;
- Slope angle on base of sliding assumed to be parallel to ground surface and that the depth of the failure plane is small with respect to the length of the slope;
- Thus, the slope is considered as being of infinite length with any end effect ignored;
- The peat is homogeneous.

The analysis method for a planar translational peat slide along an infinite slope was for calculated using the following equation in total stress terms highlighted by MacCulloch, (2005) and originally reported by Barnes, (2000):

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

Where:

- F = Factor of Safety (FoS)
- Cu = Undrained shear strength of the peat (kPa)
- γ = Bulk unit weight of saturated peat (kN/m^3)
- z = Peat depth in the direction of normal stress
- β = Slope angle to the horizontal and hence assumed angle of sliding plane (degrees)

Undrained shear strength values (Cu) are used throughout this assessment. Effective strength values are not applicable for the case of rapid loading of the peat during short term construction phase of works hence the formula cited above, has been adopted. Drawing 14431UKC_PSRA_009, Appendix A.9 maps out the calculated FoS for the Proposed Development when applying a conservative 9kPa as the undrained shear strength for peat soils. This mapping includes the predicted FoS where a 20 kPa surcharge is applied to the surface. The factor of safety map shows no part of the proposed development footprint to fall below a factor of safety of 1.4.

4.4. Risk Assessment Method

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

This guidance clearly acknowledges risk assessment as an iterative process and as such this assessment should be updated throughout the development and as more information becomes available particularly as pre-construction phases are reached.

A semi quantitative risk assessment has been used to determine the risk of peat failure. The methodology is defined in PLHRAG, (2017) and has been augmented with methods set out by Clayton (2001) & MacCulloch, (2005) Risk factors are summarised on Table 4.2.

The assessment uses the numerical stability analysis and presents results for factor of safety (FoS) across the Proposed Development. The calculated FoS, is complimented with an assessment of the slope angle, peat depth and key geomorphological features. A peat slide risk map has been produced using GIS computation of these factors. (14431UKC_PSRA_008, Appendix A.8). The risk map is used screening wide areas of the study area, additional engineering judgement has been applied according to discrete conditions within Table 6.1 of this report.

Table 4.2: Risk Factors

Contributory Factor	Comment	Criteria	Probability	Scale
Peat Depth* (A)	Peat slides tend to occur in shallow peat (up to 2.0m) on A great majority of recorded peat landslides in Scotland, England & Wales are of the peat slide type.	0 – 0.5 m	Negligible	1
		>3.0 m	Unlikely	2
		0.5 – 1.0 m	Likely	3
		2.0 – 3.0 m	Probable	4
		1.0 – 2.0 m	Almost certain	5
Slope Angle* (B)	It has been acknowledged that peat slide tends to occur in shallow peat (up to 2.0m) on slopes between 5o and 15o. Slopes above 20o tend to be devoid of peat or only host a thin veneer deposit.	0 – 3º	Negligible	1
		>20º	Unlikely	2
		4 – 9º	Likely	3
		16 – 20º	Probable	4
		10 – 15º	Almost certain	5
FoS* (C)	Values are from Infinite slope model using Cu characteristic value of 14kPa derived from hand shear vane in-situ testing. Slope angle and peat depth also input to this factor.	≥ 1.3	Negligible	1
		1.29-1.20	Unlikely	2
		1.10-1.19	Likely	3
		1.00-1.09	Probable	4
		<1.0	Almost certain	5
Cracking (D)	Visual assessment undertaken in the field during detailed probing survey and covers the same extends of this survey. Field workers examined for evidence of any major crack networks which may allow surface water to penetrate the peat mass. Reticulate cracking was not investigated as this normally requires intrusive ground investigation to remove the surface fibrous layer.	None	Negligible	1
		Few	Unlikely	2
		Frequent	Likely	3
		Many	Probable	4
		Continuous	Almost certain	5
Groundwater (E)	Challenging to evaluate without very detailed mapping and/or intrusive data. Look for entry / exit points. Evidence of surface hollows, collapse features at surface reflecting evidence of sub-surface peat	None	Negligible	1
		Few	Unlikely	2
		Frequent	Likely	3
		Many	Probable	4

Contributory Factor	Comment	Criteria	Probability	Scale
	pipe network, audible indicators including the sound of sub-surface running ground water surrounding proposed infrastructure locations	Continuous	Almost certain	5
Surface *Hydrology (F)	Ranging from wet flushes to running burns to hags. Must be evaluated in conjunction with the season and weather preceding the site visit. Artificial drains (grips) have also been identified across the Site. Their presence is generally linked to historical peat cutting sites which are factored into the risk assessment.	None Few Frequent Many Continuous	Negligible Unlikely Likely Probable Almost certain	1 2 3 4 5
Previous Instability (G)	Visual survey, scale and age are important as small to medium relict failures may be easy to detect but very large ones may require remote imaging. Recent failures should be obvious due to the scar left.	None Few Frequent Many Continuous	Negligible Unlikely Likely Probable Almost certain	1 2 3 4 5
Land Management (H)	Anthropogenic influences: forestry operations and removal of vegetation can be associated with de-stabilising peat deposits. This can occur as a result to surface disturbance and remoulding of peat through excavation, vehicle movements and loading. Changes in land use activities may also be associated with changes in drainage conditions. Criteria based on evidence of disturbance of peat deposit, i.e. broken surface, scarring or disrupted hydrology.	None Few Frequent Many Continuous	Negligible Unlikely Likely Probable Almost certain	1 2 3 4 5

Note: Denotes where risk factor applied to GIS model only*

Environmental Impact Zones based on proximity buffer zones applied to the main watercourses within the Proposed Development. Watercourses have been determined to be a primary sensitive receptor to a peat failure event. Table 4.3 denotes the potential impact scales to the environment. Location of existing or planned infrastructure downslope from Proposed Development is also qualitatively assessed in Table 4.7/8.

The distance to main watercourses has been used as the primary means of impact assessment within the risk assessment. Where watercourses are ephemeral/transient or minor artificial features they were not included as direct receptors. The impact distances are based on experience and guidance values provided within MacCulloch, F. (2006).

The approach advocated by MacCulloch is to divide the survey area into Environmental Impact Zones driven by site specific criteria and survey information. It is noted that defining a definitive distance for impact is extremely challenging due to the complex nature of terrain, peat depth, flow mechanics will all influence the flow path characteristics. At present there exists no defined method to accurately define the flow distances. Therefore Table 4.3 within report provides a framework estimate for the purposes of repeatable and representative semi quantitative risk mapping. Natural Power considers this approach alongside the multitude of site-specific factors which are considered during the risk assessment a valid approach for this development.

Distances to the main watercourses have been assessed within GIS and input to the risk mapping. The proximity classes are based on Table 4.3 within the report.

Table 4.3: Environmental Impact Zonation

Criteria	Potential Impact	Scale
Proposed access road/turbine within 50m of watercourse	High	4
Proposed access road/turbine within 50-100m of watercourse	Medium	3
Proposed access road/turbine within 100-150m of watercourse	Low	2
Proposed access road/turbine greater than 150m from watercourse	Negligible	1

Source: Natural Power

For each main infrastructure element, the Risk Ranking is assessed from the combined probability of occurrence for the main contributory factors which are greater than (1), multiplied by the highest impact scale. Table 4.4 identifies the risk ranking based on concepts of PLHRAG, (2017).

The risk to existing or proposed infrastructure has been scoped out and is not considered a determining factor to the severity of a peat slide over the proposed development. This is due to the spacing of the proposed layout and the large distance from existing settlements.

Access track sections have screened through the GIS based stability risk model and the elevated risk sections reviewed with further risk analysis and control measures. It is important to highlight that the full scope of the proposed infrastructure layout has been subject to field survey and review of stability risk factors.

Table 4.4: Risk Rankinng and Actions

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

Source: Natural Power

5. Stability Analysis of Peat Slopes

5.1. Introduction

Assessing the desk study information, site layout and ground investigation data; a preliminary infinite slope analysis and subsequent peat slide risk assessment has been undertaken. Slope stability was assessed at each turbine location using slope angle measurements, peat depth, and undrained shear strength measured using an in-situ hand shear vane. This assessment should be viewed as semi – quantitative as it draws on both qualitative assumptions and numerical parameters.

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

5.2. Numerical Slope Analysis

A preliminary numerical slope analysis has been undertaken. Numerical slope stability was assessed across the development location using slope angle measurements (DTM derived), peat depth, and the minimum undrained shear strength measured using an in-situ hand shear vane. In addition, a 20 kPa surcharge has been modelled thus the sensitivity of slopes to failure is assessed under construction conditions. GIS modelling was used to produce a factor of safety (FoS) map for the proposed development (14431UKC_PSRA_009, Appendix A.9).

The numerical stability analysis indicates no potential for translational peat slide at proposed turbine and infrastructure locations under current equilibrium and modelled surcharge loading conditions. The natural slope condition has been calculated to be stable and was observed to be so around the wind turbine locations during the field survey.

In the absence of more detailed sub-surface data, the surface slope angle has been used as a reference to the likely slope surface angle at the base of the peat in the analysis. Further advanced in-situ test methods should be considered as part of a detailed site investigation phase usually carried out post-consent. The potential of disturbing sensitive peat deposits during pre-construction survey access should also be considered during future phases of intrusive investigation work.

The FoS accounts for a 20 kPa surcharge representing scenarios at infrastructure such as temporary storage stockpiles. The Peat Management Plan (PMP) details mitigation measures for peat stockpiling. Slope stability assessments would be carried out during design phase for site tracks, hardstands and other relevant structures ensuring the proposed design results are safe, stable and environmentally compliant. It is Natural Power's view that, if during design phase structures are proposed (i.e. floating tracks) additional numerical stability assessment should be carried out by the appointed designer.

6. Peat Slide Risk Assessment

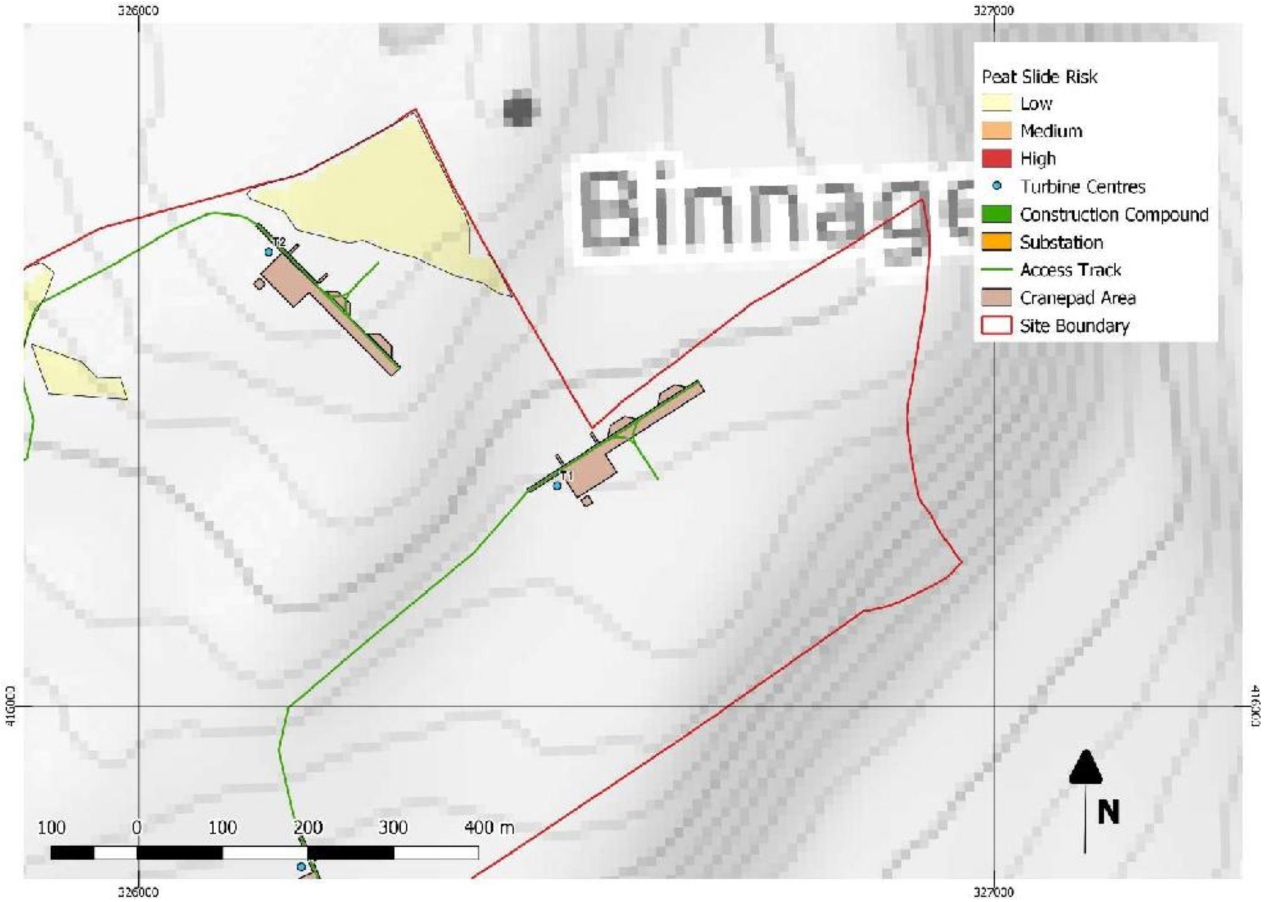
Risk rankings for the proposed wind farm infrastructure positions are presented in Table 6.1. Across each turbine the qualitative risk scoring has been provided along with key inset map information.

The peat slide risk map, 14431UKC_PSRA_008, Appendix A.8; provides a representation of the risk zonation across the Site and includes all infrastructure elements. The map is based on a Site wide GIS analysis and should not be viewed in isolation without the narrative of this report. The Risk Mapping does not show residual risk following implementation of targeted or routine control measures.

The indicative residual risk rating is provided assuming implementation of appropriate mitigation measures. Further detail of the risk assessment is highlighted within the preliminary geotechnical risk register presented in Table 6.3.

Table 6.1: Hazard Ranking Proposed Turbine Location

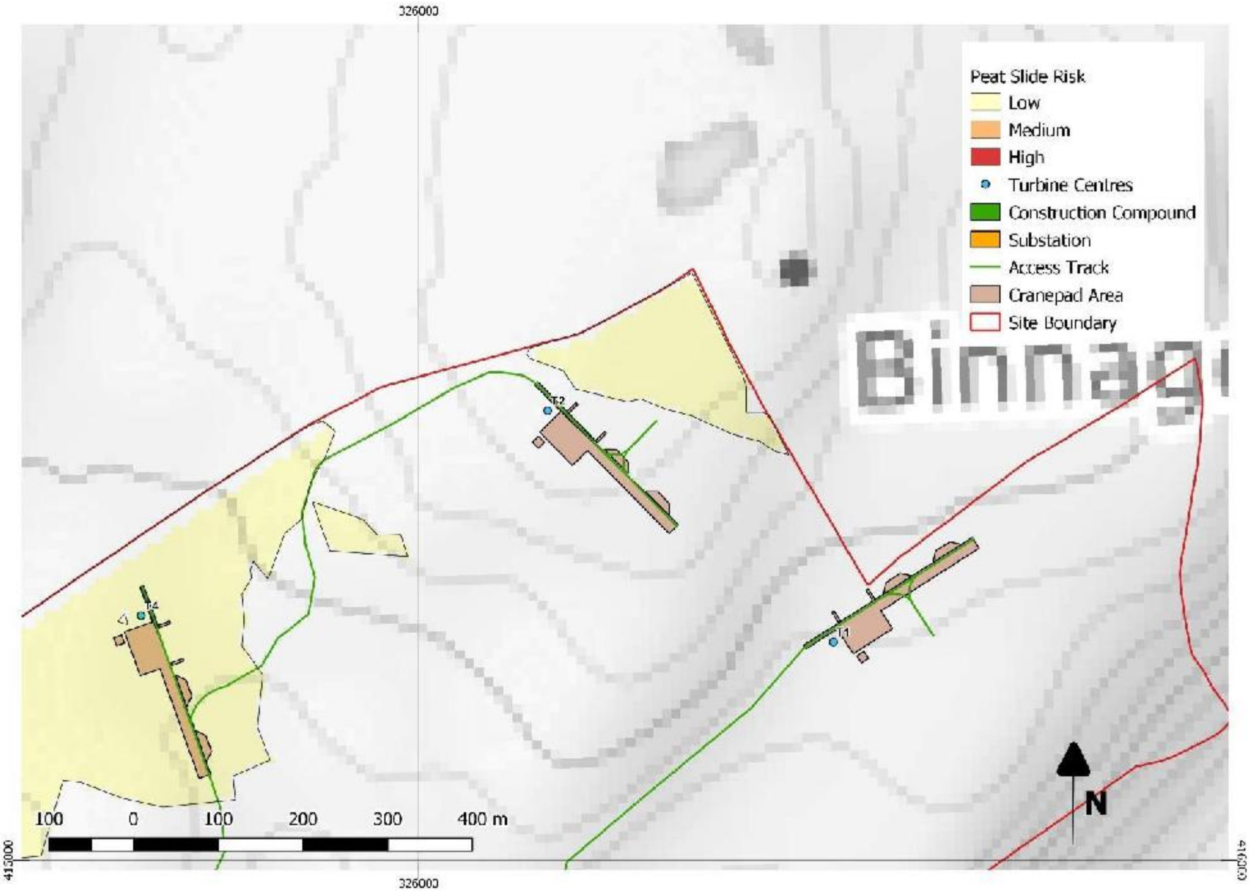
WTG ID	Development Infrastructure	Environmental	Contributary Factors (Probability/Exposure		Risk Ranking
T01	1	2	Peat Depth (Mean = 0.0m)	1	**0 (Negligible) No Peat**
			Slope Angle (4°)	3	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	



T01 Location – Google Aerial Imagery – 1:5000 Scale

Location Specific Mitigation:

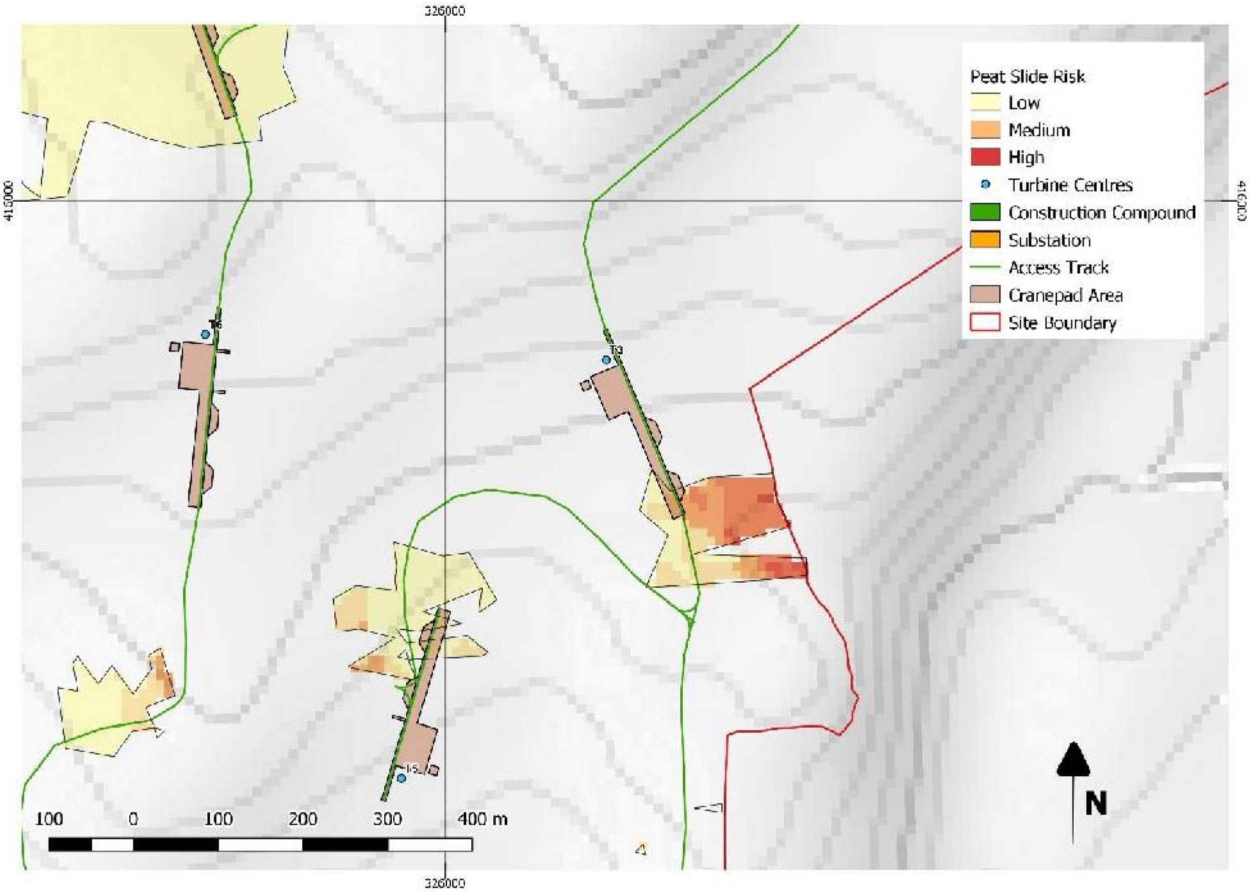
WTG ID	Development Infrastructure	Environmental	Contributary Factors (Probability/Exposure		Risk Ranking
T02	1	1	Peat Depth (Mean = 0.30m)	1	0 (Negligible) No Peat
			Slope Angle (<7°)	3	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	



T02 Location – Google Aerial Imagery – 1:5000 Scale

Location Specific Mitigation:

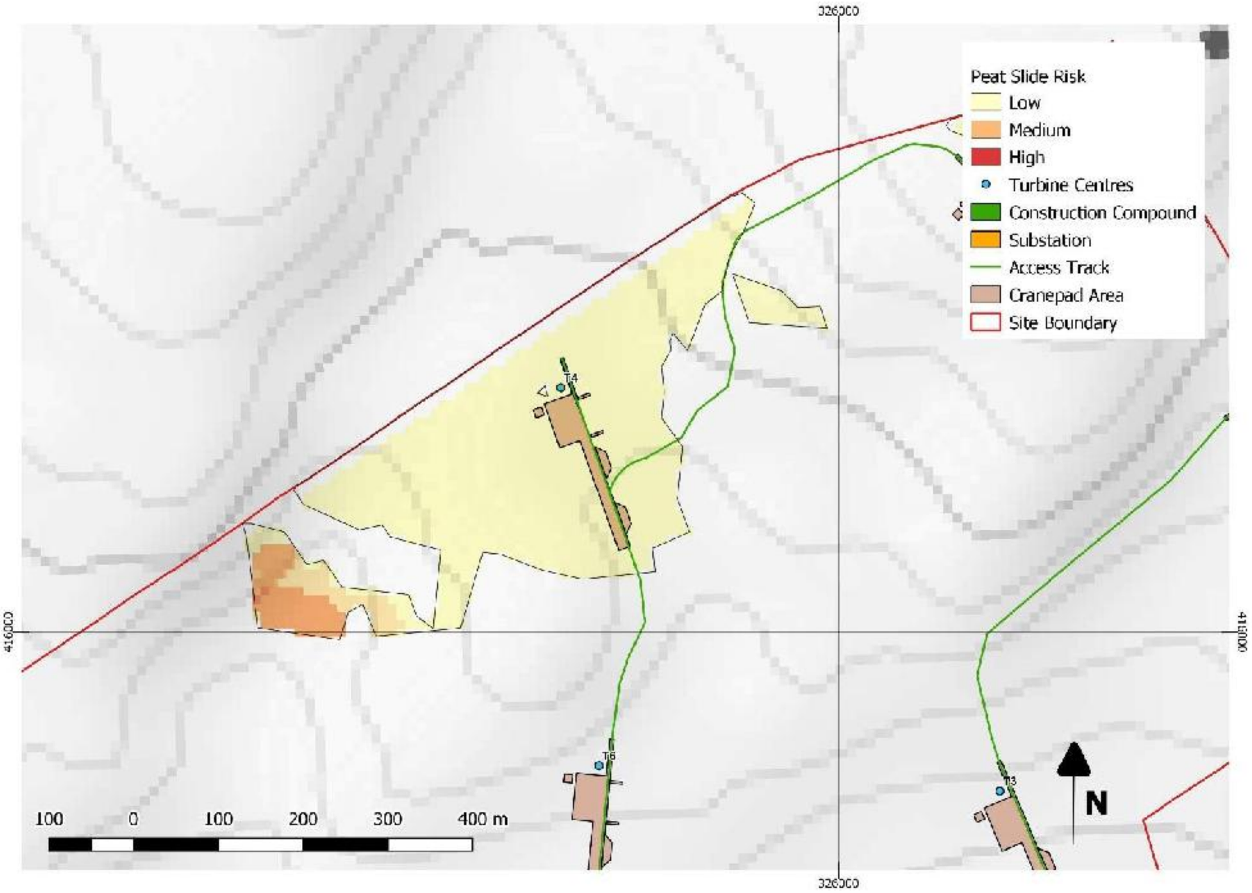
WTG ID	Development Infrastructure	Environmental	Contributary Factors (Probability/Exposure)		Risk Ranking
T03	1	1	Peat Depth (Mean = 0.25m)	1	**0 (Negligible) No Peat**
			Slope Angle (8°)	3	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	



T03 Location – Google Aerial Imagery – 1:5000 Scale

Location Specific Mitigation:

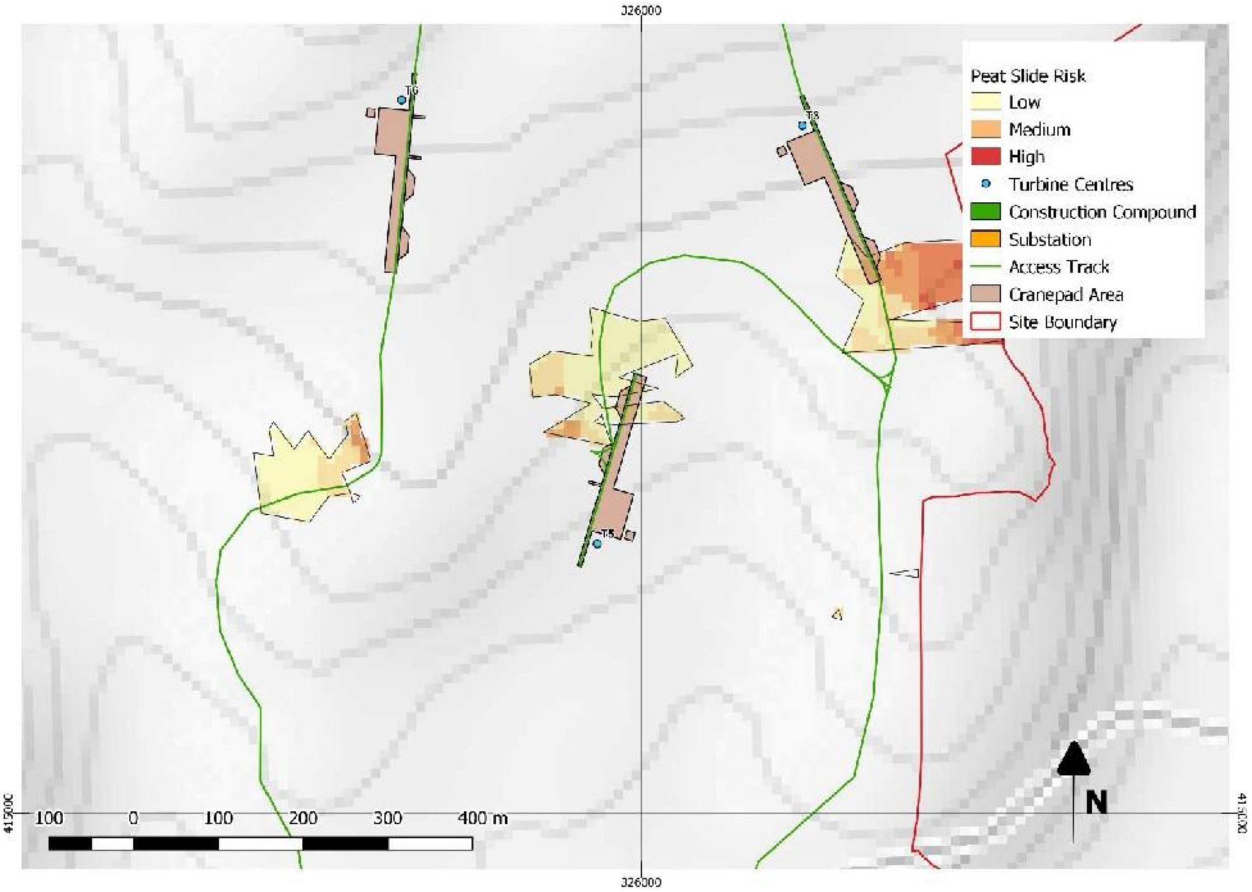
WTG ID	Development Infrastructure	Environmental	Contributory Factors (Probability/Exposure		Risk Ranking
T04	1	1	Peat Depth (Mean = 0.70m)	3	6 (Low) 1x (3+3) =6
			Slope Angle (8°)	3	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	



T04 Location – Google Aerial Imagery – 1:5000 Scale

Location Specific Mitigation:

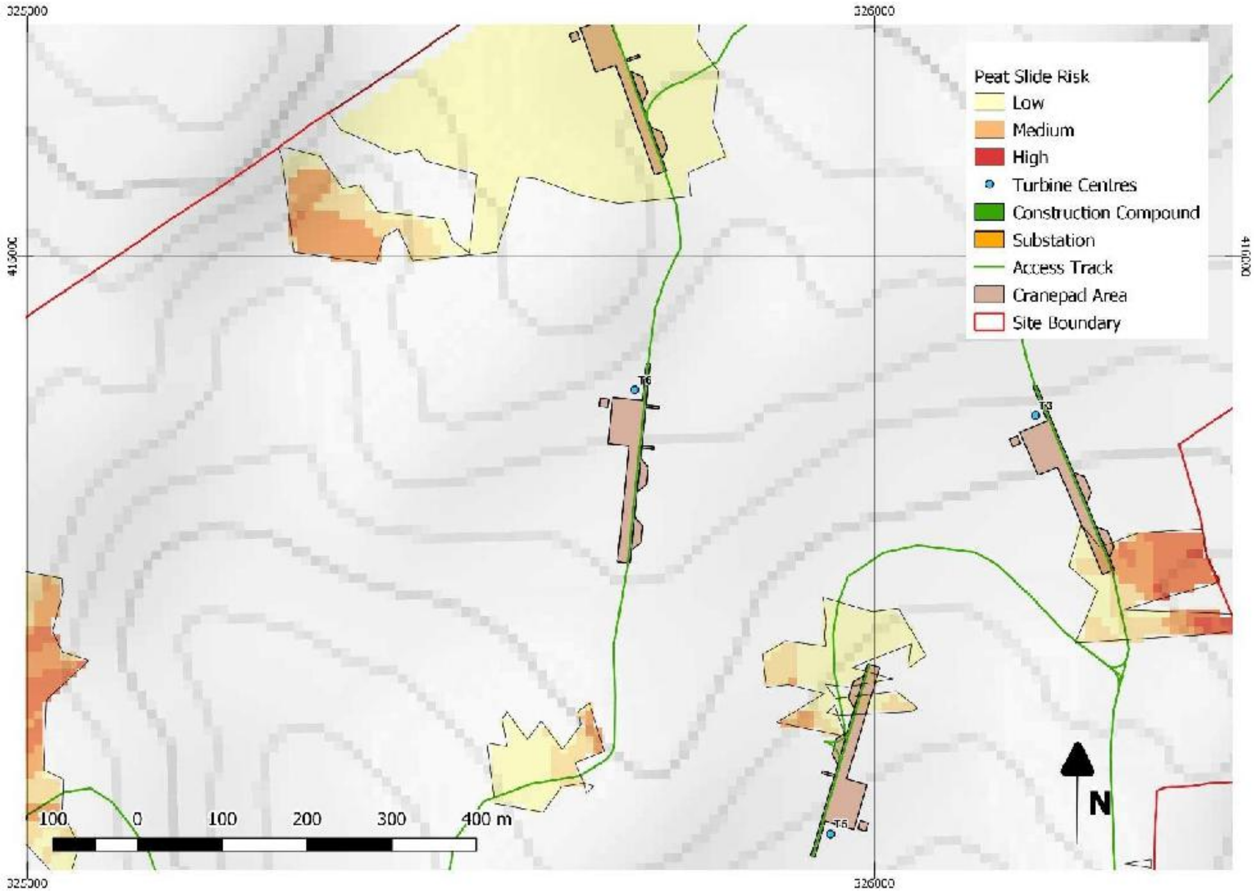
WTG ID	Development Infrastructure	Environmental	Contributary Factors (Probability/Exposure)		Risk Ranking
T05	1	3	Peat Depth (Mean = 0.10m)	1	0 (Negligible) No Peat
			Slope Angle (5°)	3	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	



T05 Location – Google Aerial Imagery – 1:5000 Scale

Location Specific Mitigation:

WTG ID	Development Infrastructure	Environmental	Contributary Factors (Probability/Exposure		Risk Ranking
T06	1	3	Peat Depth (Mean = 0.20m)	1	0 (Negligible) No Peat
			Slope Angle (7°)	3	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	

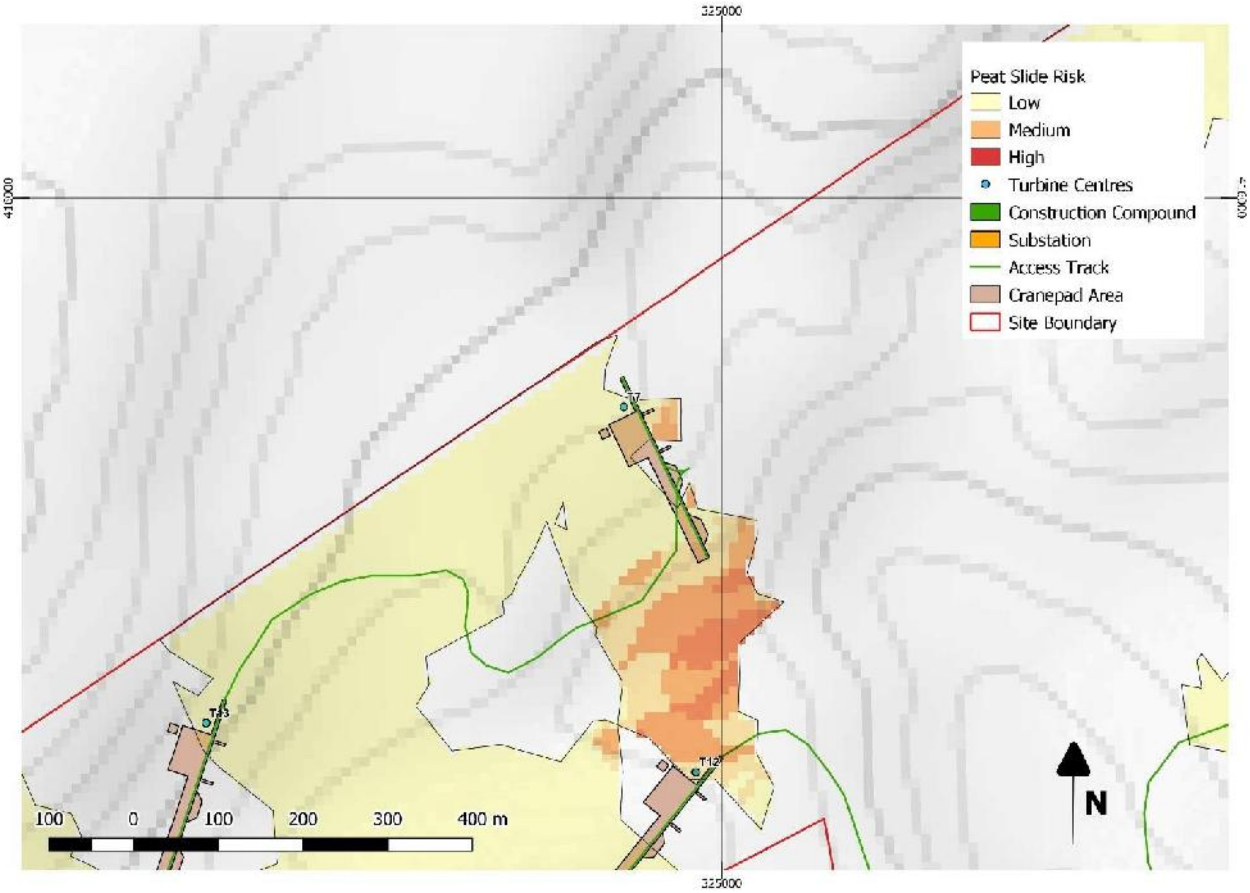


T06 Location – Google Aerial Imagery – 1:5000 Scale

Elevated Environmental factor due to the close proximity to a water course.

Location Specific Mitigation:

WTG ID	Development Infrastructure	Environmental	Contributary Factors (Probability/Exposure		Risk Ranking
T07	1	1	Peat Depth (Mean = 0.0m)	1	0 (Negligible) No Peat
			Slope Angle (6°)	3	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	



T07 Location – Google Aerial Imagery – 1:5000 Scale

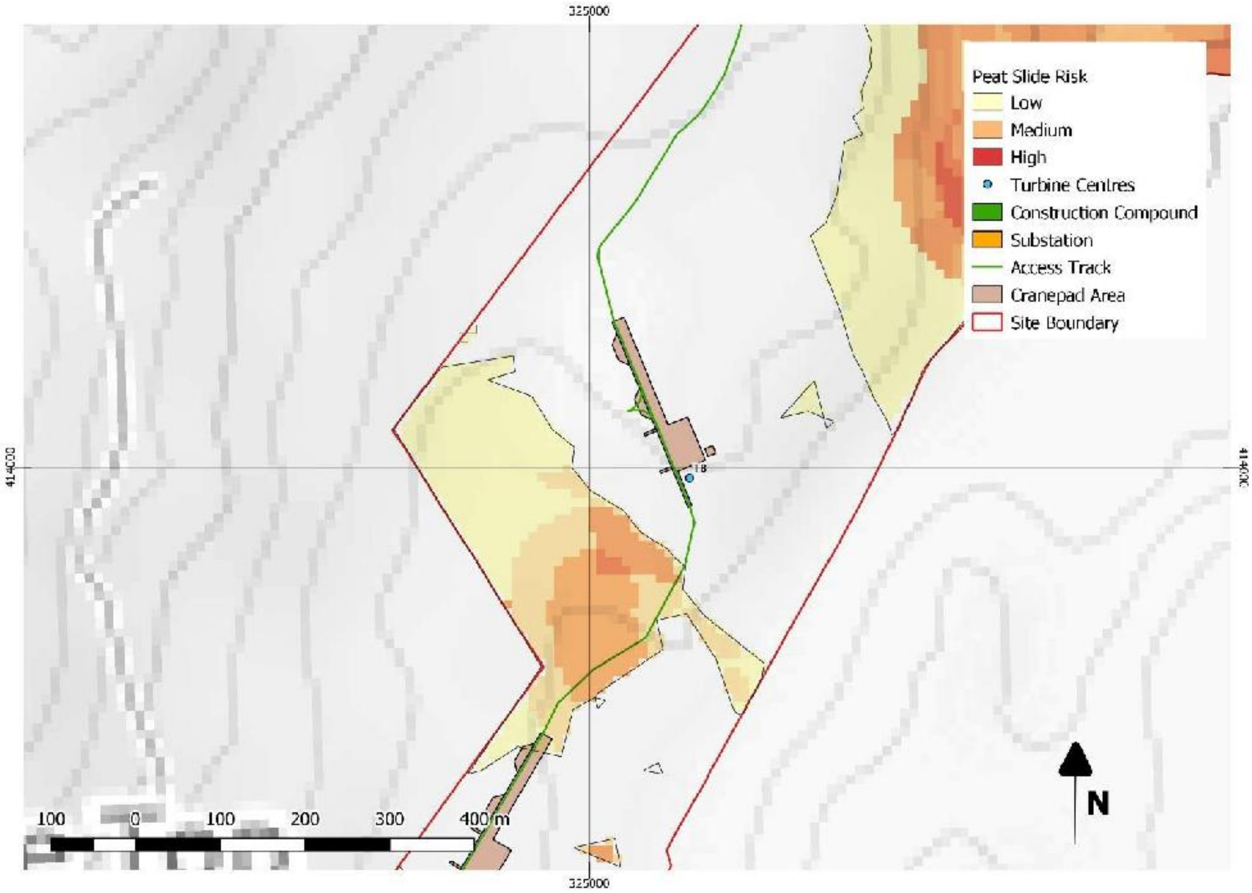
Location Specific Mitigation:

Turbine foundation is within area of negligible risk however the hardstand area extends into areas of elevated risk due to increasing peat depths. Targeted mitigation maybe required in this area, in the form of:

Exclusion areas defining avoidance of stockpiling or earthworks to the south and east of infrastructure.

Divert drainage design outfalls away from the south-east and the deeper peat deposits.

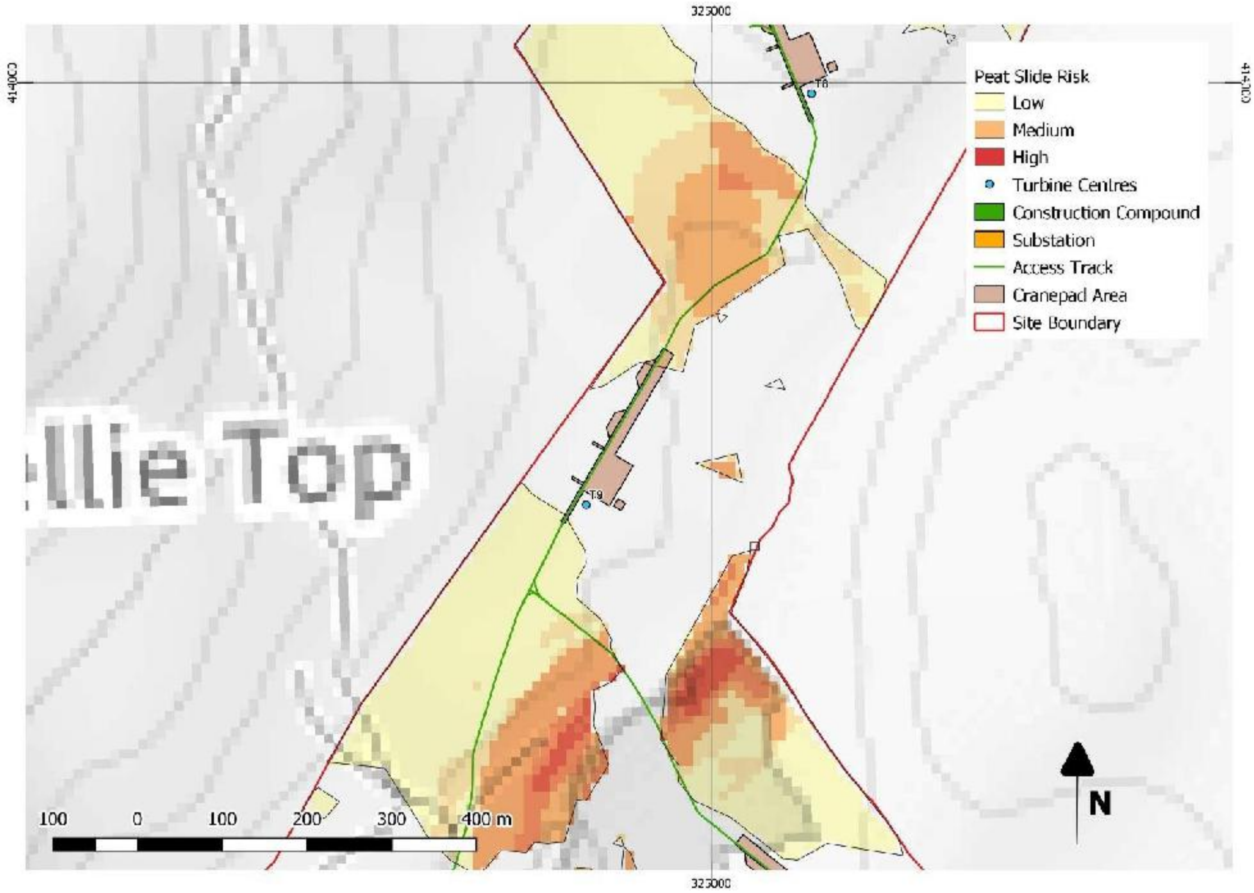
WTG ID	Development Infrastructure	Environmental	Contributary Factors (Probability/Exposure)		Risk Ranking
T08	1	1	Peat Depth (Mean = 0.30m)	1	0 (Negligible) No Peat
			Slope Angle (3°)	1	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	



T08 Location – Google Aerial Imagery – 1:5000 Scale

Location Specific Mitigation:

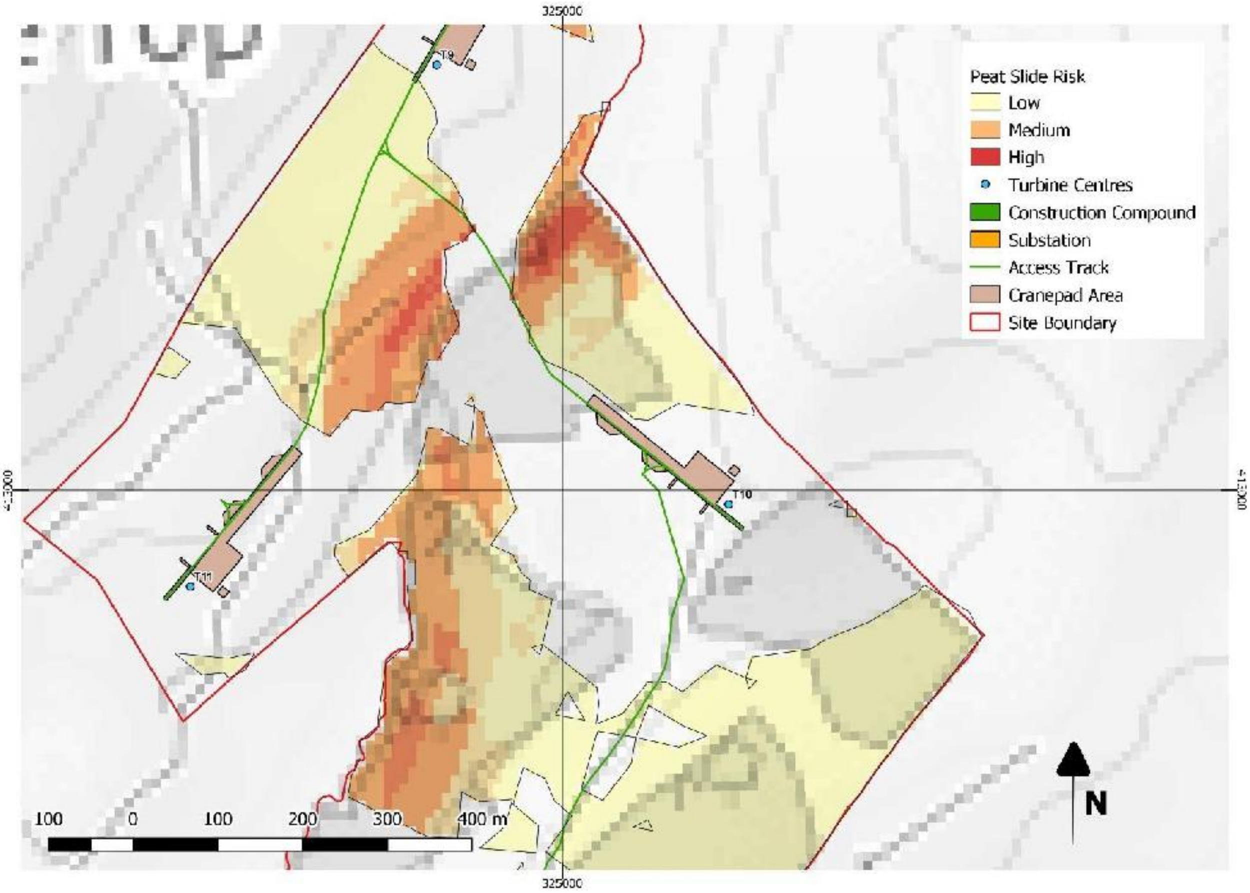
WTG ID	Development Infrastructure	Environmental	Contributary Factors (Probability/Exposure)		Risk Ranking
T09	1	1	Peat Depth (Mean = 0.40m)	1	0 (Negligible) No Peat
			Slope Angle (2°)	1	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	



T09 Location – Google Aerial Imagery – 1:5000 Scale

Location Specific Mitigation:

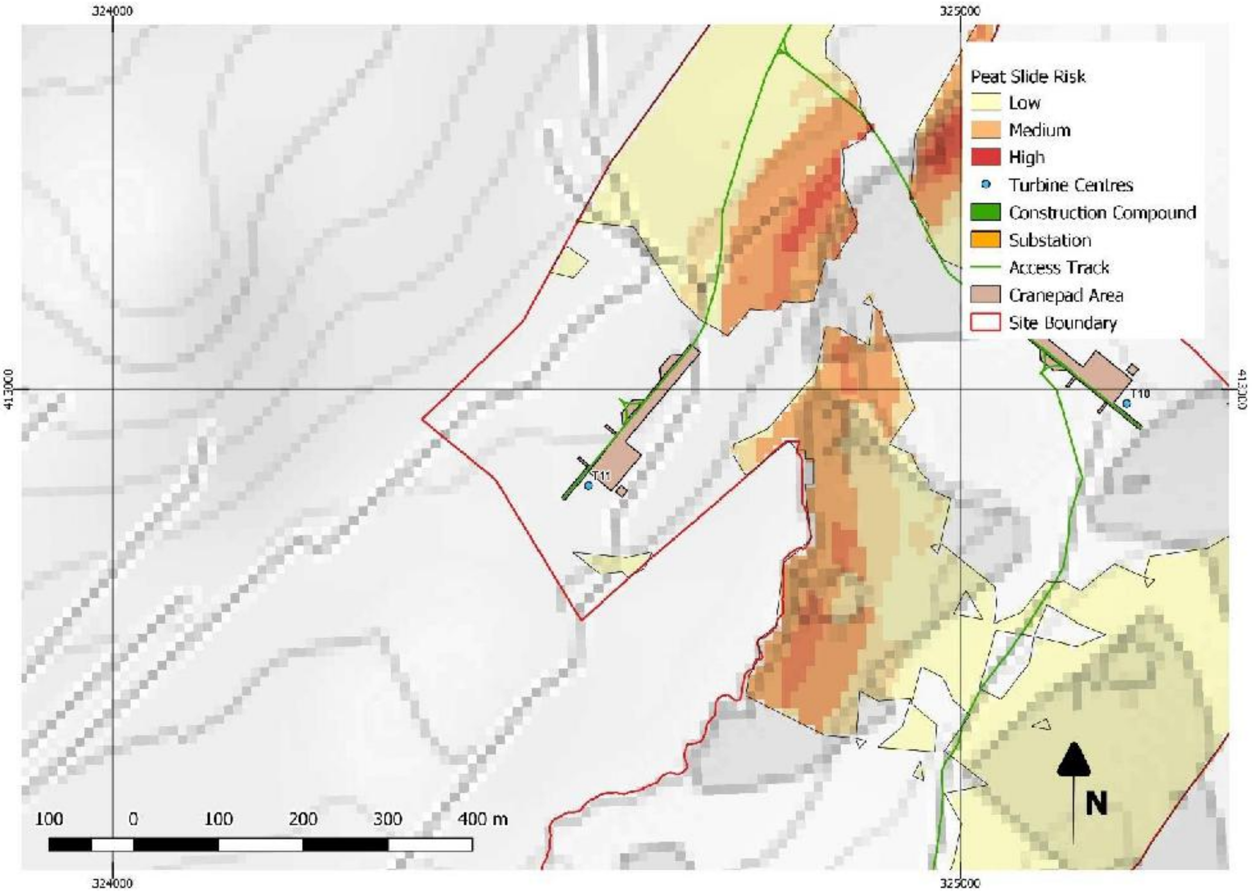
WTG ID	Development Infrastructure	Environmental	Contributary Factors (Probability/Exposure		Risk Ranking
T10	1	1	Peat Depth (Mean = 0.0m)	1	0 (Negligible) No Peat
			Slope Angle (6°)	3	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	



T10 Location – Google Aerial Imagery – 1:5000 Scale

Location Specific Mitigation:

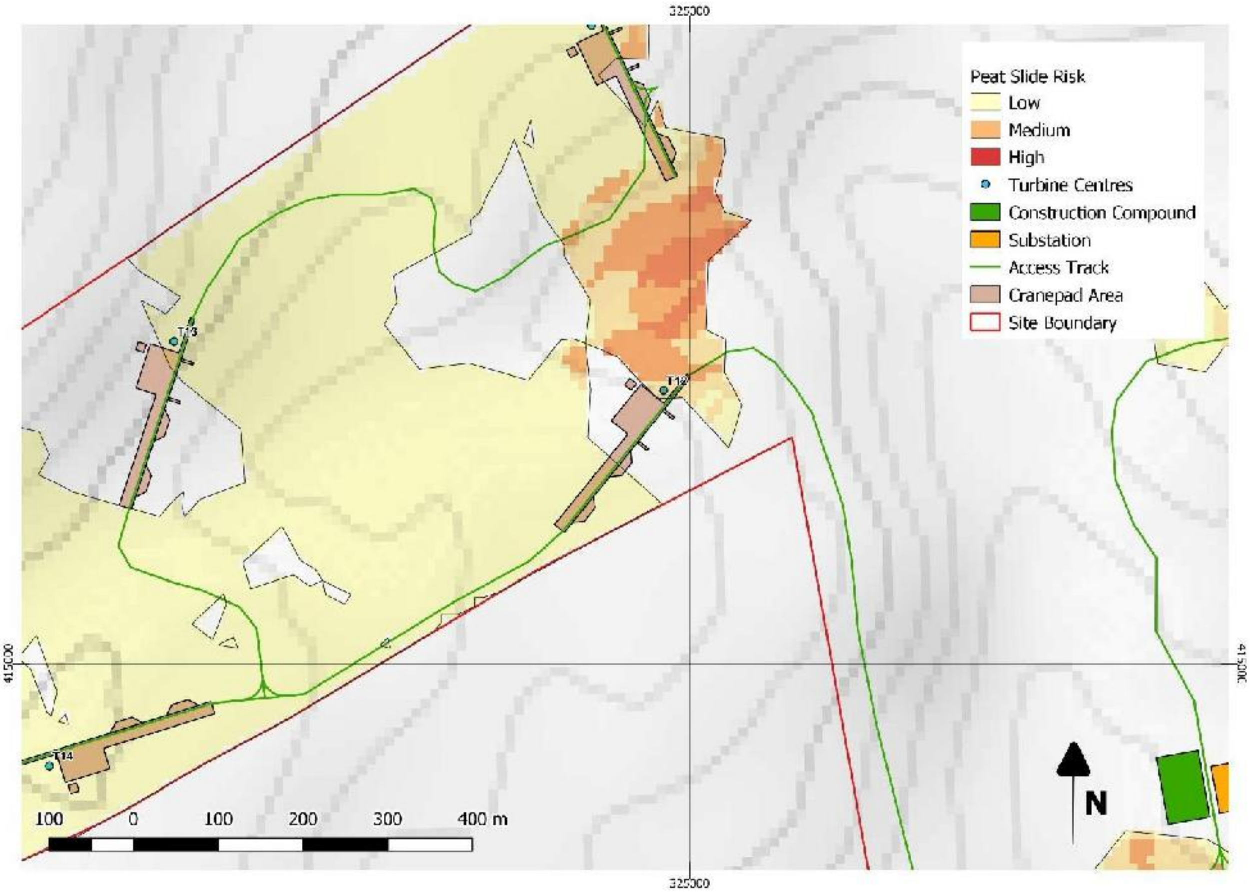
WTG ID	Development Infrastructure	Environmental	Contributary Factors (Probability/Exposure)		Risk Ranking
T11	1	1	Peat Depth (Mean = 0.20m)	1	0 (Negligible) No Peat
			Slope Angle (7°)	3	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	



T11 Location – Google Aerial Imagery – 1:5000 Scale

Location Specific Mitigation:

WTG ID	Development Infrastructure	Environmental	Contributary Factors (Probability/Exposure		Risk Ranking
T12	1	2	Peat Depth (Mean = 0.40m)	1	2 x (3) = 6 (Low)
			Slope Angle (7°)	3	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	



T12 – Google Aerial Imagery – 1:5000 Scale

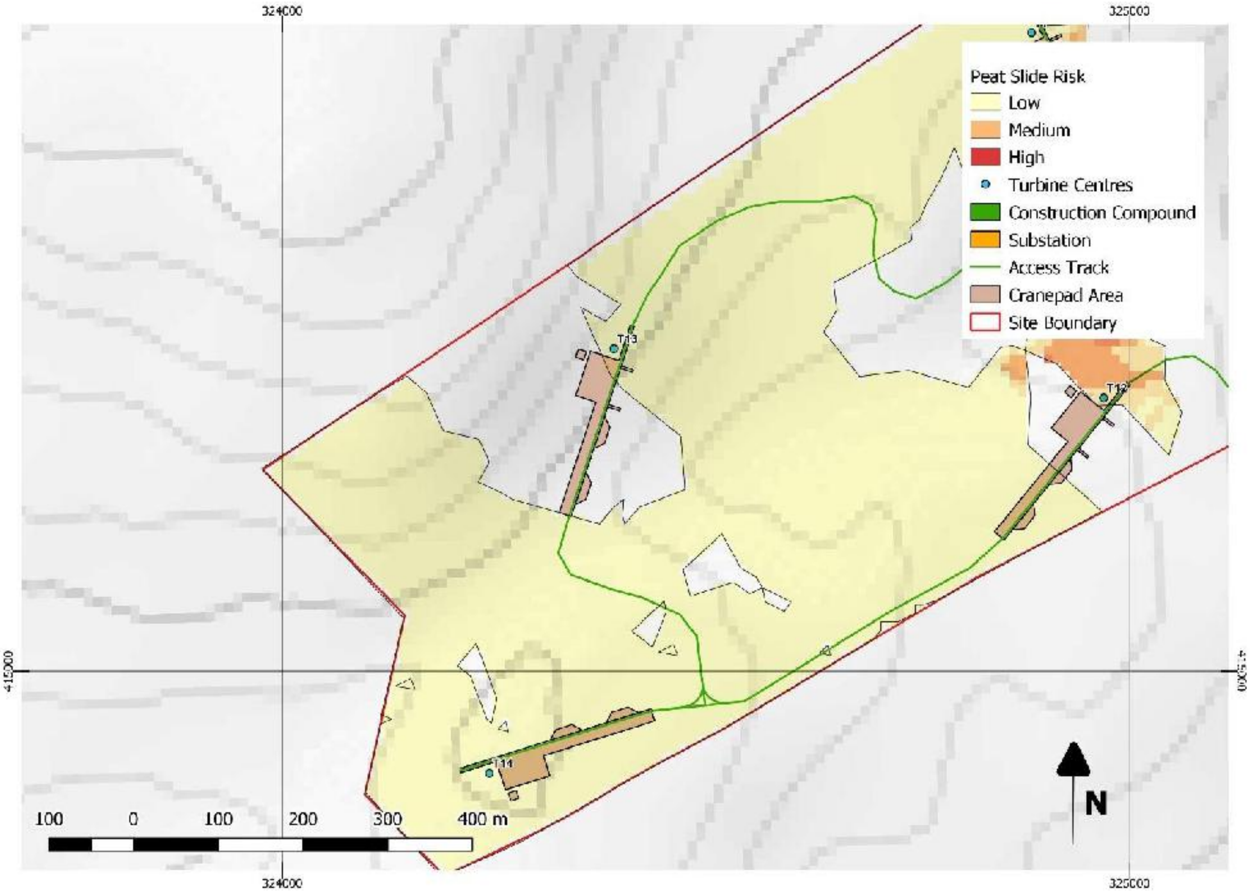
Location Specific Mitigation:

Environmental factor is elevated to “2” due to the proximity to a significant watercourse. The turbine foundation centre is within shallow peat deposits however there are areas of elevated risk downslope, to the north-east of the turbine, due to increasing peat depths. Targeted mitigation maybe required in this area, in the form of:

Exclusion areas defining avoidance of stockpiling or earthworks to the north and east of infrastructure.

Divert drainage design outfalls away from the north-east and the deeper peat deposits.

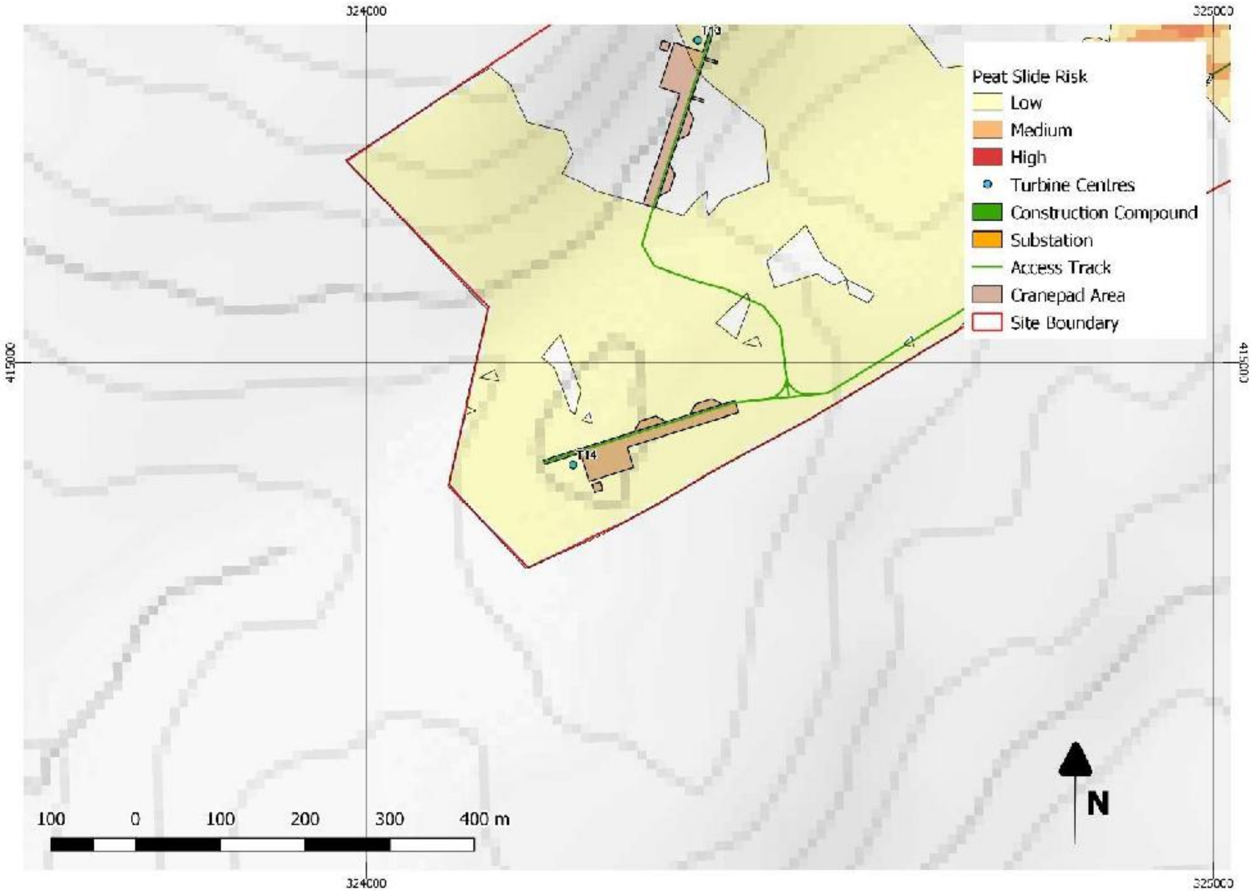
WTG ID	Development Infrastructure	Environmental	Contributary Factors (Probability/Exposure		Risk Ranking
T13	1	1	Peat Depth (Mean = 0.60m)	3	**6 (Low)** **1 x (3+3) = 6**
			Slope Angle (9°)	3	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	



T13 – Google Aerial Imagery – 1:5000 Scale

Location Specific Mitigation:

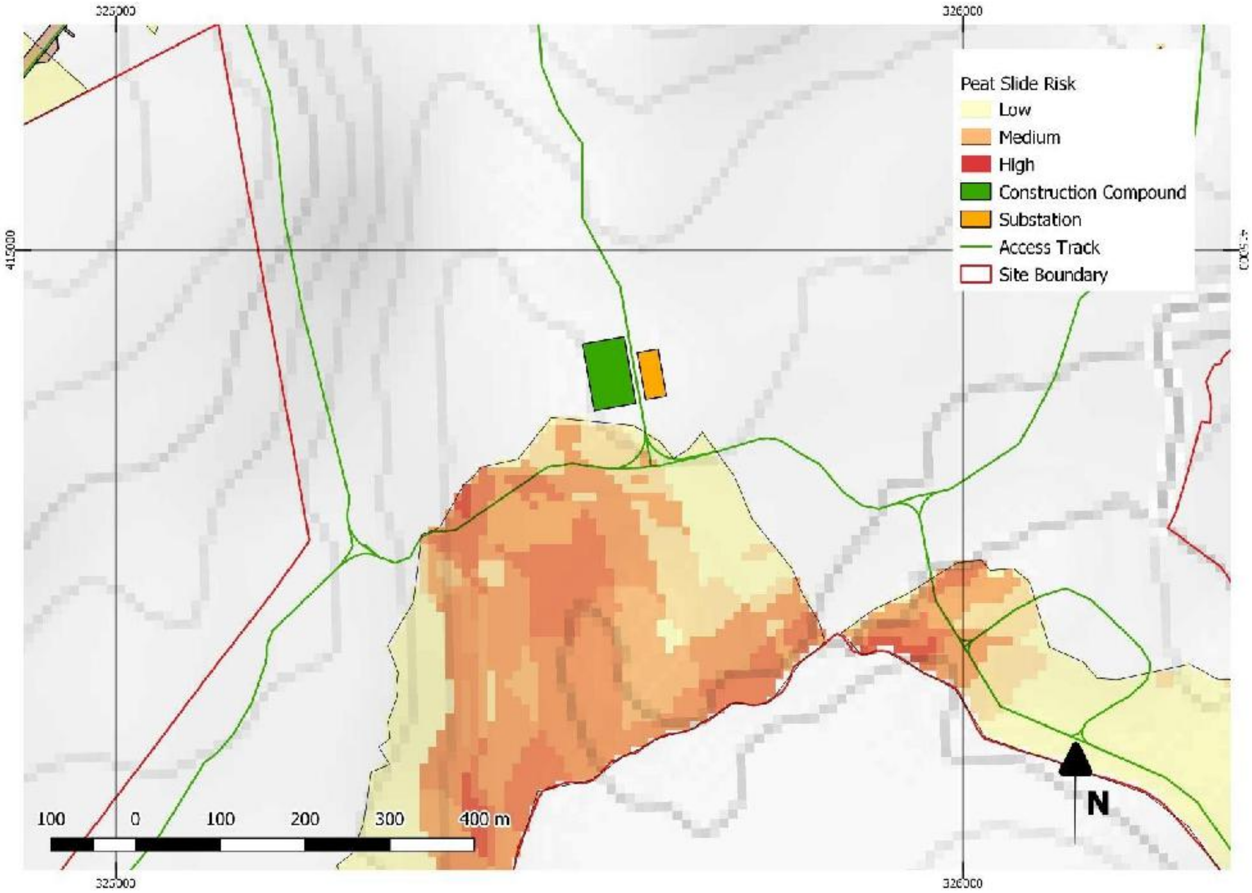
WTG ID	Development Infrastructure	Environmental	Contributary Factors (Probability/Exposure)		Risk Ranking
T14	1	1	Peat Depth (Mean = 0.70m)	3	6 (Low) 1 x (3+3) = 6
			Slope Angle (6°)	3	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	



T14 – Google Aerial Imagery – 1:5000 Scale

Location Specific Mitigation:

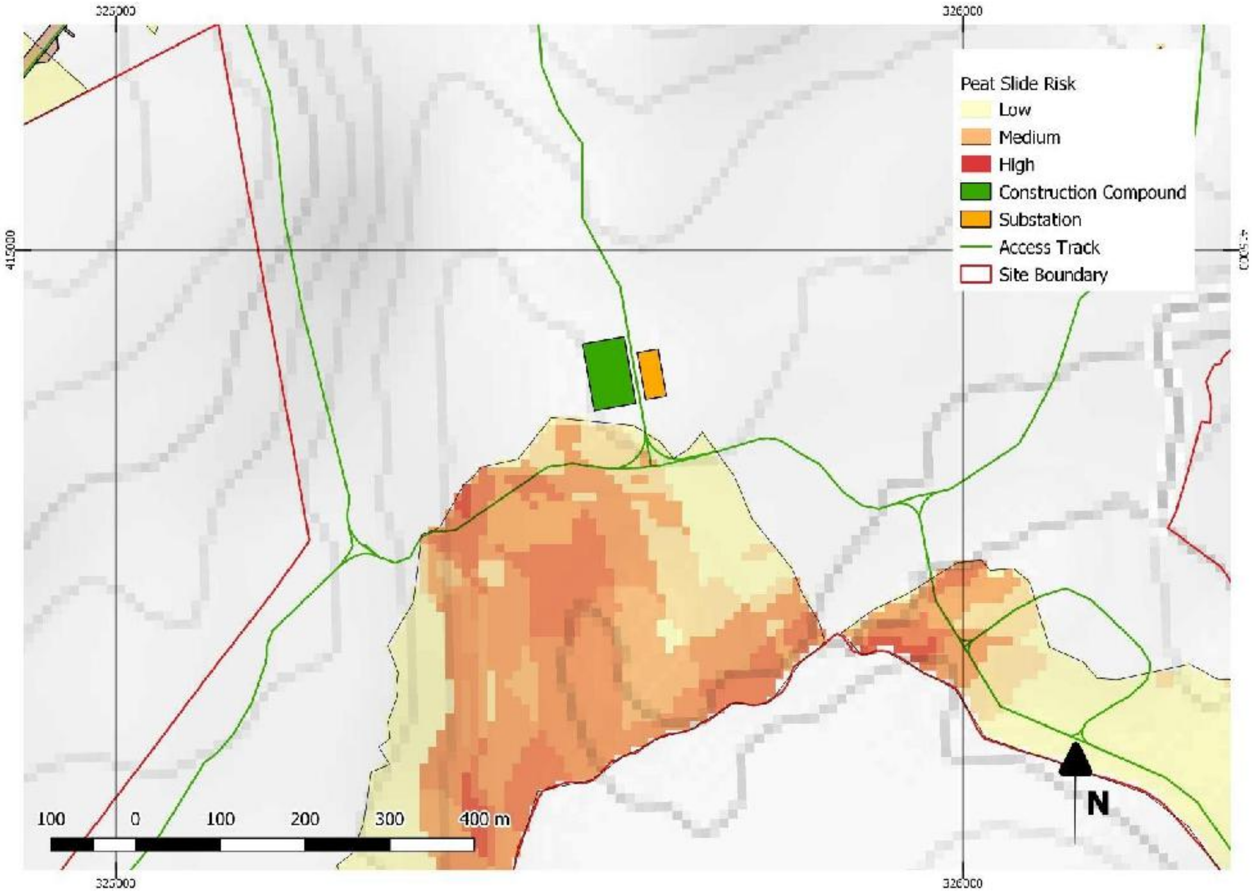
WTG ID	Development Infrastructure	Environmental	Contributary Factors (Probability/Exposure		Risk Ranking
Substation	1	1	Peat Depth (Mean = 0.00m)	1	0 (Negligible) No Peat
			Slope Angle (°)	1	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	



Substation – Google Aerial Imagery – 1:5000 Scale

Location Specific Mitigation:

WTG ID	Development Infrastructure	Environmental	Contributary Factors (Probability/Exposure)		Risk Ranking
Construction Compound	1	2	Peat Depth (Mean = 0.00m)	1	0 (Negligible) No Peat
			Slope Angle (°)	1	
			FoS (Min = Cu_{min} > site mean)	1	
			Peat cracking / Infiltration	1	
			Groundwater Flow	1	
			Hydrology	1	
			Previous Instability	1	
			Land Management	1	



Construction Compound – Google Aerial Imagery – 1:5000 Scale

Location Specific Mitigation:

Source: Natural Power

6.1.1. Turbine Bases

Table 6.2 below summarises the risk assessment outcome and hazard ranking assignments for each turbine location. The principal contributory factors and impact scales used to derive these assignments are also stated.

Table 6.2: Risk Assessment Outcome and Hazard Ranking Assignment

Turbine ID	Risk Ranking Baseline	Principal Contributary Factors in Risk Assessment	Risk Ranking and Targeted Mitigation and Best Practice Construction
T01	**0**	No Peat.	Negligible
T02	**0**	No Peat.	Negligible
T03	**0**	No Peat.	Negligible
T04	**6 (Low)**	Peat depth and slope angle.	Negligible
T05	**0**	No Peat.	Negligible
T06	**0**	No Peat.	Negligible
T07	**0**	No Peat.	Negligible
T08	**0**	No Peat.	Negligible
T09	**0**	No Peat.	Negligible
T10	**0**	No Peat.	Negligible
T11	**0**	No Peat.	Negligible
T12	**6 (Low)**	Nearby watercourse and slope angle.	Negligible
T13	**6 (Low)**	Peat depth and slope angle.	Negligible
T14	**6 (Low)**	Peat depth and slope angle.	Negligible
Substation	**0**	No Peat.	Negligible
Construction Compound	**0**	No Peat.	Negligible

Source: Natural Power

The risk assessment reflects the probability of peat material entering the surface water course and being entrained to an offsite receptor without any mitigation. The wider geomorphological assessment and evidence from recorded peat depths would indicate that a large-scale translational mass movement of peat deposits is very unlikely.

6.1.2. Access Tracks

In addition to the turbine bases the sections of track have also been reviewed across the site. The highest risk areas would be where track alignments cross watercourses and the steep slopes around the watercourse if peat is present. The areas of highest risk can be seen in Figure A.8. The areas of track with the deepest peat are around Turbines T13, T14 and T12 and along the south-eastern access track where there are very localised deep peat deposits.

The following control measures are required in order to reduce the risk level to low:

- Cross track drainage which prevents any ponding or build-up of groundwater pressure within the peat upslope or beneath the access infrastructure. Where possible existing drainage systems should be utilised and maintained (including artificial drains);
- No stockpiling or surcharging of the peatland along this specific access track section;
- A system of ongoing monitoring throughout the construction phase should be in effect to monitor any movement in the peat. A rapid reaction strategy should be developed to ensure measures can be deployed to protect the watercourse in the event of any movement. This may include installation of downslope retaining systems to prevent peat material entering the watercourse and robust watercourse protection measures at the crossing point.

6.2. Peat Slide Pathways

The assessment considers environmental receptors (main watercourses) to be the primary focus of the risk assessment. Minor or ephemeral watercourses have been assessed not to be primary receptors or unlikely to transmit peat slide material to offsite receptors, these have been excluded. Where relevant onsite proposed infrastructure and additional assets (water supplies) have been assessed. (Figure 6.1)

Notwithstanding the point above, this report examines the terrain and the potential evolution of any triggered peat slide event. The determination has been that entrained peat flows would primarily be channelled along the main watercourse's downslope of proposed infrastructure.

Source: OS 1:25,000, Natural Power

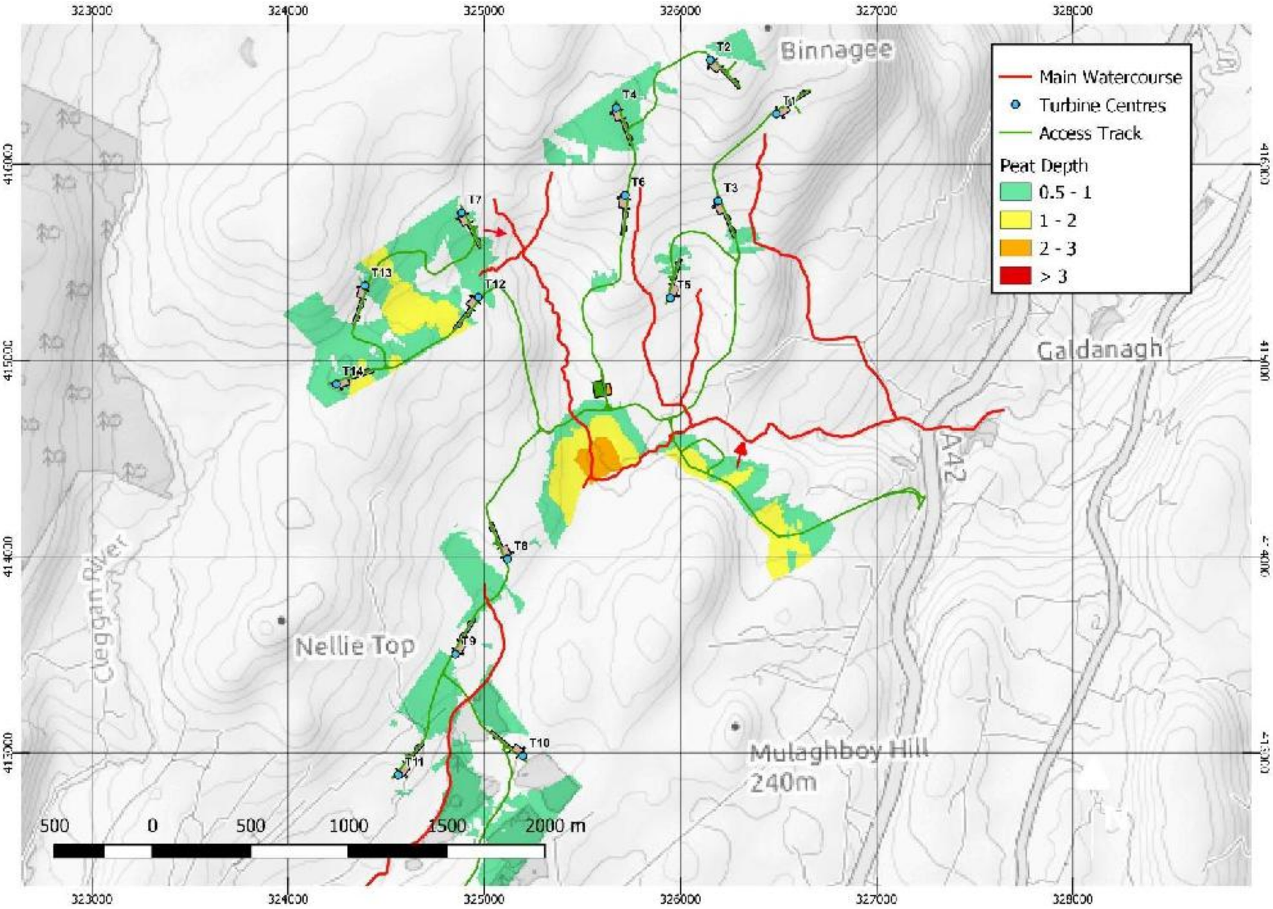


Figure 6.1: Primary Peat Slide Pathways & Indicative Peat Depth

The risk of run out and significant damage to the wider hydrological environmental is deemed low, providing the relevant control measures outlined in his report are implemented at the site.

6.3. Preliminary Geotechnical Risk Register

The preliminary risk register for development wide hazards is listed in Table 6.3 below. Key. Control measures for the hazards have also been identified. A geotechnical risk register should be utilised on an individual turbine basis throughout the construction phase and amended accordingly as new information is received.

Table 6.3: Preliminary Geotechnical Risk Register

Hazard	Cause	Location	Consequence
Peat Landslide / Bog Burst / Peat Flow	High rainfall, and increased surface water infiltration leading to build up of pore water pressure	**Site Wide**	Instability of peat deposits and underlying superficial deposits around earthworks. Contamination of natural watercourses and damage to hydrological systems. Harm to personnel and damage to plant / equipment; Destruction of built infrastructure
Mitigation	Due consideration given to prevailing ground and weather condition when scheduling construction works. I.e. avoid opening new excavation during heavy precipitation and ensure sufficient drainage measures are in place to support construction activities. Ensure a contingency is in place to concentrate on more suitable construction activities during wet weather. The drainage design should be such that its construction is in sequence with providing necessary drainage to new areas of excavation and construction in advance of works. I.e. ensure cut-off ditches are in place prior to opening new excavation. The drainage design should as far as practicable preserve the natural hydrological regime and should not inundate areas with run-off which were previously not subjected to such affects. Monitoring weather forecast with site specific weather station; Monitoring (visual) regular site inspection to detect early indications of ground movement (tension cracks, groundwater issues).		
Peat Landslide / Bog Burst / Peat Flow	Concentrated loads placed at the top of slope system or on marginally stable peat deposits	**T13** **T4** **Site Wide**	Contamination of natural watercourses and damage to hydrological systems; Rapid ground movement and mobilisation of material down slope of construction operations; Harm to personnel, plant and equipment; Destruction of temporary or permanent construction works;
Mitigation	At these locations, robust and strict controls on the phasing and pace of construction must be in place. This would be most effectively managed through the CMS. Plant operatives should be briefed in detail regarding the side-casting and stockpiling of materials. Higher risk areas particularly at T06 and T08 should be demarked by high visibility ticker tape or similar as a warning not to stockpile any materials in the deeper peat areas. Ensure the peat depth contour mapping is available and has a high visibility during construction; A programme of frequent inspections should be implemented during excavation and access track construction works. This should be carried out by suitably experienced and qualified personnel. Where stockpiles are placed in suitable areas, these should be closely monitored through the use of high accuracy GPS level and visual survey.		
Peat Landslide / Bog Burst / Peat Flow	Increased subsurface groundwater flow and 'piping' failure beneath natural peat deposits, temporary and permanent earthworks	**Site Wide**	Localised instability associated with temporary and permanent earthworks; Triggering of mass movement of peat material down slope causing harm to personnel, plant and equipment;
Mitigation	Ensure geotechnical design prevents blockages of groundwater flow. This may be achieved through the use of free draining fills and ensuring temporary and permanent earthworks do not cause the build-up of groundwater pressures.		

Hazard	Cause	Location	Consequence
	A programme of geotechnical inspections should be implemented throughout construction phase. Ensuring focus extends beyond immediate areas of construction, both up-slope and down-slope to detect any unforeseen effects on stability		
Bearing Capacity Failure (Peat Surface)	Increased loading of low shear strength deep peat deposits	**Site Wide**	Localised instability and settlement associated with temporary and permanent earthworks; Triggering of mass movement of peat material down slope causing harm to personnel, plant and equipment; Contamination of natural watercourses and damage to hydrological systems from peat material mobilised down slope;
Mitigation	Due consideration given to the prevailing ground and weather conditions when scheduling site works Ensure detailed peat depth contour plan to be used in construction planning and design; Use of appropriate plant machinery (low ground pressure and long reach to avoid over loading peat deposits) A programme of geotechnical inspections will be implemented during excavation works Geotechnical monitoring post-construction		
Peat Failure	Mass movement of temporary storage mounds and bunds	**T4 , T13 , T14** **Access Track**	Localised instability and settlement associated with temporary and permanent earthworks Triggering of mass movement of peat material down slope causing harm to personnel, plant and equipment;
Mitigation	Storage site selection and stockpile design by a suitably qualified and experienced geotechnical engineer; Routine maintenance and inspection of peat storage mounds		
Creep, long term settlement of structures	Tracks or hardstand founded on peat and or poor or variable foundation soils	**T4 , T14** **Access Track**	Ongoing settlement and damage of infrastructure, e.g. damage to access track running surface.
Mitigation	Contingency of routine maintenance of infrastructure and drainage elements to ensure longer term issues do not cause a build-up of effects leading to higher level consequences e.g. larger scale instability		

Source: Natural Power

7. Conclusions

There exist predominantly shallow or an absence of peat soils with discrete areas of deeper peat at the proposed development. The following construction related factors to peat slide are highlighted for consideration:

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

The peat depths across the site are in the majority <0.5m. It should be noted that where peat probes indicate shallow depths 0.1m to 0.5m that the deposits are likely to be composed of a topsoil and mineral subsoil. Peat accumulations therefore have been proven to be isolated and in discrete locations.

The mean un-drained shear strength determined across the Development is (33kPa). This indicates peat of low shear strength. A conservative characteristic value of 9kPa has been used in the slope stability modelling (representing the minimum recorded value).

The risk ranking produced in this report are a combination of the overall likelihood with the potential environmental/impact effect of a peat instability event. With increased proximity to watercourses exposure of such an event is vastly increased as watercourses act as a sensitive off-site receptor and can carry peat debris to further offsite receptors. In addition, where relevant the position of proposed internal site infrastructure and assets has been considered.

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

The risk assessment should be reviewed prior to construction and further refined following intrusive ground investigation and detailed infrastructure design.

8. Recommendations

The peat slide risk assessment cites key control measures which are required to ensure the risk of peat slide remains at residual (low) levels. However, there should be wider consideration of these measures across all areas of the proposed development which may be influenced by the proposed construction. This is critical where infrastructure may impact terrain and slope conditions beyond the proposed working areas.

- A detailed intrusive ground investigation would be carried out (post-consent) and as part of the pre-construction phase of development. This investigation would seek to further characterise the peat deposits with emphasis on, in-situ shear strength testing and targeted undisturbed sampling and laboratory testing. All peat samples recovered should be classified in accordance with the Von Post system, (Hobbs, 1986) and current British and Eurocode standards for site investigation. Further investigation of the peat sub-soil interface would also be carried out.
- Groundwater level information would be collated as part of any future ground investigation;
- The results of a detailed ground investigation should be assessed with respect to refining the peat stability assessment at infrastructure locations where peat slide risk is elevated. All pertinent control measures and mitigation measures should be revised, and their implementation supervised following the results of the ground investigation and construction design phase of works;
- Continued assessment and monitoring throughout the construction phase of works and at suitable intervals post construction should be implemented to ensure the control measures are suitable and are providing adequate mitigation against peat instability;
- Construction practices should be managed through the Construction Method Statement (CMS) and within the wider context of the Construction Environmental Management Plan (CEMP). The CMS should be prepared by the appointed principal contractor and reviewed by a suitably experienced geotechnical engineer who has read and understood this report. The following general recommendations are provided in line with the, Good practice during wind farm construction, (2019) guidance:
  - Avoid peat arisings being placed as local concentrated loads on peat slopes without first establishing the stability condition of the ground and slope system. Stockpiling on areas of deep peat and in close proximity to steep slopes should be avoided.
  - Avoidance of uncontrolled and concentrated surface water discharge onto peat slopes as this may act as contributory factor to failure. All water discharged from excavations during construction phase should be directed away from all areas identified as susceptible to peat failure and should managed by a suitably designed site drainage management plan.
  - All excavations where required should be adequately supported to prevent collapse and the destabilising peat deposits adjacent to excavations.
  - A system of daily reporting should be established during construction and utilised to monitor the geotechnical performance of slopes including peat, sub-soil and bedrock. This should be implemented and undertaken by a suitable experienced and qualified geotechnical engineer. Post construction this monitoring procedure should be curtailed to allow for annual or ad-hoc inspection as required.

8.1. Floating Track Construction

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

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

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

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

8.2. Cut/Fill Track Construction

Across the main area of Development not affected by deep peat; the construction of proposed access tracks should be considered by excavation and replacement method, MacCulloch, (2006). Excavated peat is removed and targeted for suitable re-use. Aggregate would be used to form the subgrade and running surface of the track.

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

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

8.3. General Earthworks

It has been identified that there is a requirement for the excavation of peat soils and superficial deposits during construction of the wind farm. Initially the vegetated peat layer and any topsoil should be stripped and temporarily stockpiled away from areas of deep peat and instability risk. The design of this stockpile must be agreed by a suitably qualified geotechnical engineer. When working in areas of deep peat (i.e. >0.5m) no peat or overburden should be stored on such deposits as this may lead to instability. The following options for peat storage may be considered:

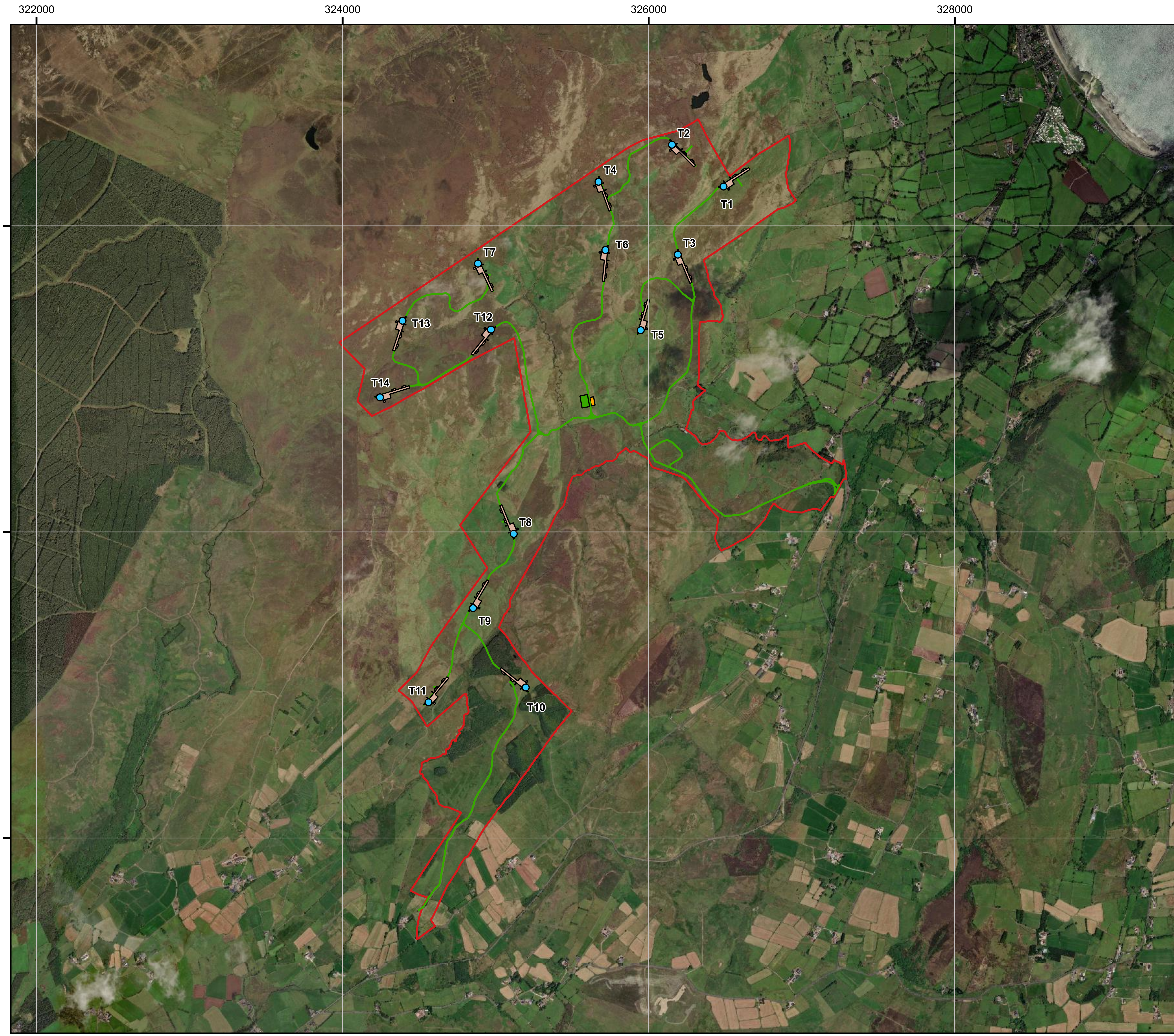
- Dedicated peat storage areas designed under the advisement of a suitable qualified geotechnical engineer and conform to up-to-date regulations and waste directives.
- Re-use of peat in dressing-off of batters on access tracks, finishing of cable trenching works, the landscaping of turbine bases. Peat must be re-used to ensure stability and its long terms sustainability i.e. the prevention of drying of desiccation.
- Excavated glacial till and weathered rock may be used as backfill to turbine bases should material be deemed geotechnically suitable. All related works must be carried out in accordance with an agreed CEMP and conform to site restoration plans.
- For in-situ and undisturbed peat; site vehicle movements must be minimised across such areas, throughout construction and post construction. Observation and monitoring for settlement, deformation, or signs of failure along access tracks and critical working areas must be implemented. This may be achieved with a network of settlement plates and survey markers which can be periodically re-surveyed, and any differential movements identified. It is recommended that all earthworks are designed in accordance with current national standards. Such measures would be focused on zones of deep peat and areas at elevated peat slide risk.

The following risk mitigation is recommended with regards to peat storage:

- Storage site selection and stockpile design would be undertaken by a suitably qualified and experienced engineer;
- Temporary storage of peat in a single dedicated area shall be avoided;
- Peat storage on areas of low / negligible peat slide risk only
- Peat storage height shall not exceed 0.5m without dedicated stability assessment;
- Routine maintenance and inspection of peat storage areas would be undertaken;

A. Maps

- Figure A.1 Aerial Imagery
- Figure A.2 Superficial Geology
- Figure A.3 Solid Geology
- Figure A.4 Slope Angle
- Figure A.5 Geomorphological Features
- Figure A.6 Interpolated Peat Depth
- Figure A.7 Environmental Impact Zonation
- Figure A.8 Peat Stability Risk Zonation
- Figure A.9 Factor of Safety



Project:

Unshinagh Wind Farm, Co. Antrim, Northern Ireland

Title:

Map A1: Aerial Imagery

Key

- Site boundary
- Proposed turbine
- Proposed track
- Proposed crane pad
- Proposed construction compound
- Proposed substation

Scale @ A3: 1:25,000

Coordinate System: TM65 Irish National Grid

0 0.25 0.5 0.75 1 km

N

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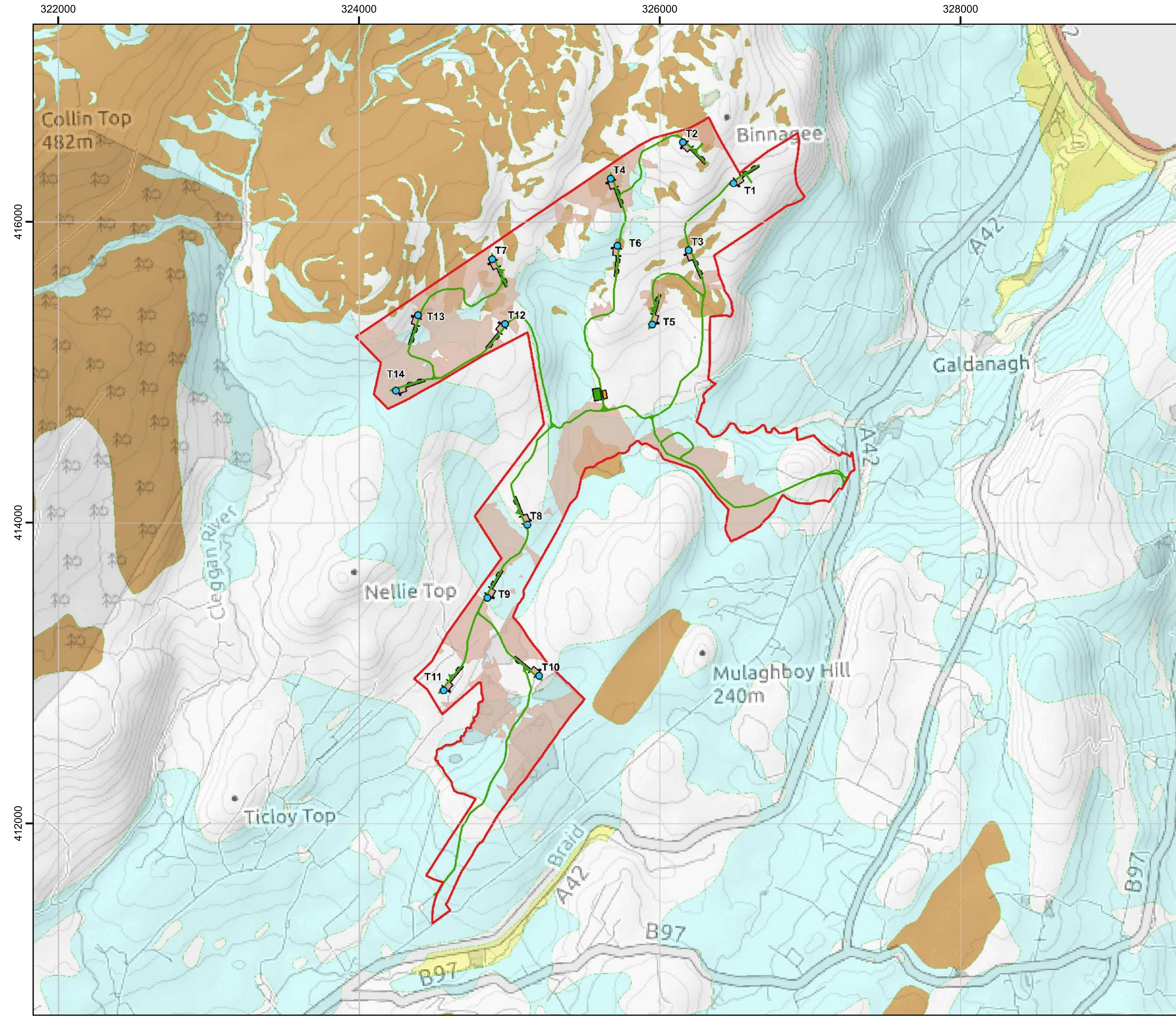

Project:

Unshinagh Wind Farm, Co. Antrim, Northern Ireland

Title:

Map A2: Superficial Geology

Key

- Site boundary
- Proposed turbine
- Proposed track
- Proposed crane pad
- Proposed compound
- Proposed substation
- Areas of peat exceeding 0.5 m depth (Natural Power survey data)

Superficial Deposits

- Glacial Till - Diamicton
- Peat
- Alluvium
- Raised Beach Deposits

Scale @ A3: 1:25,000

Coordinate System: TM65 Irish National Grid

0 0.25 0.5 0.75 1 km

N

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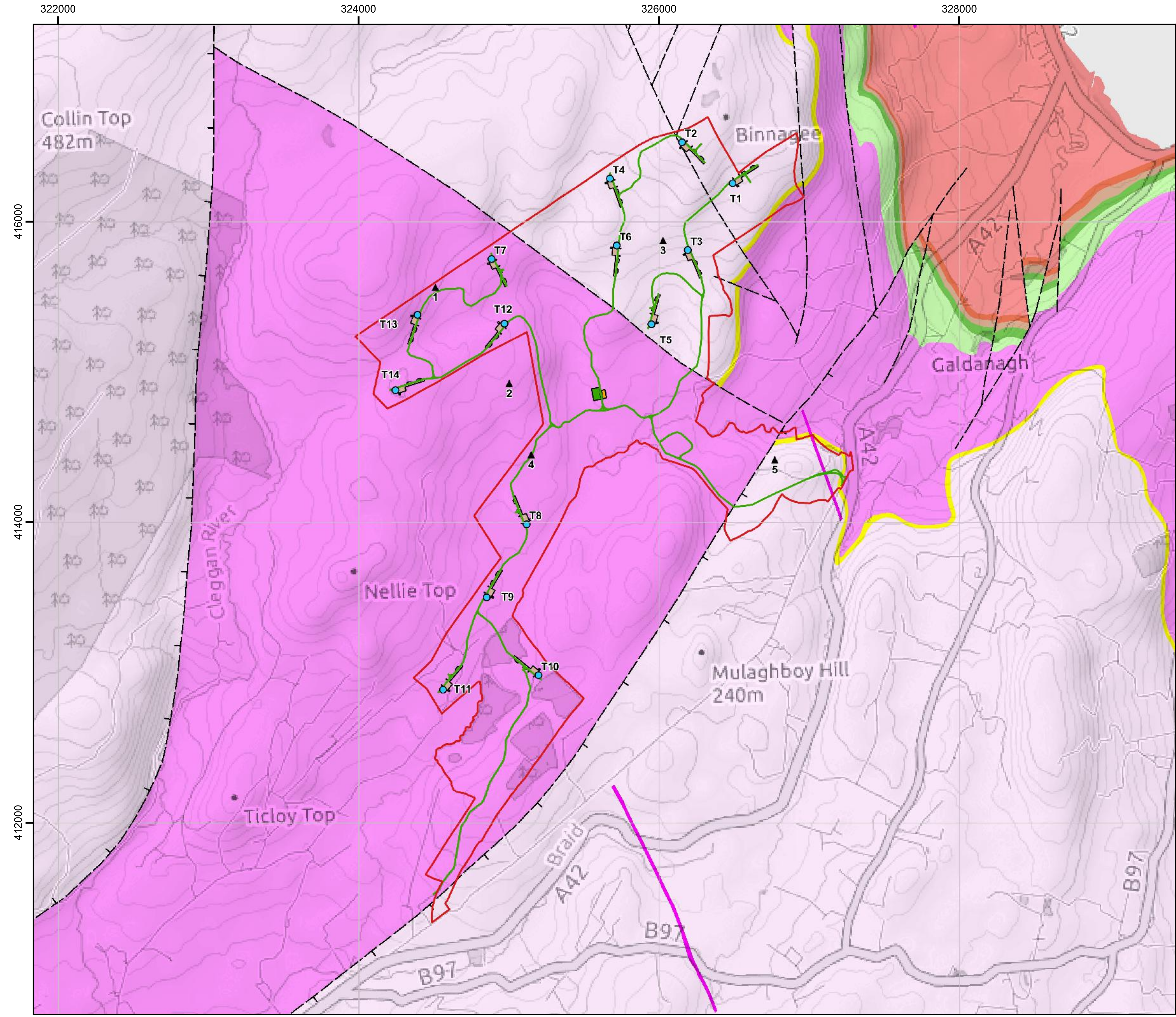

Project:

Unshinagh Wind Farm, Co. Antrim, Northern Ireland

Title:

Map A3: Solid Geology

Key

- Site boundary
- Proposed turbine
- Proposed track
- Proposed crane pad
- Proposed construction compound
- Proposed substation
- Palaeosol exposure
- Inferred fault
- Inferred fault (ticks on downthrow side)

Bedrock

- Upper Basalt formation
- Lower Basalt formation
- Inter-Basaltic formation
- Ulster White Limestone group
- Hibernian Greensands group
- Mercia Mudstone group
- Penarth group
- Waterloo Mudstone group
- Palaeogene dyke

Scale @ A3: 1:25,000

Coordinate System: TM65 Irish National Grid

0 0.25 0.5 0.75 1 km

N

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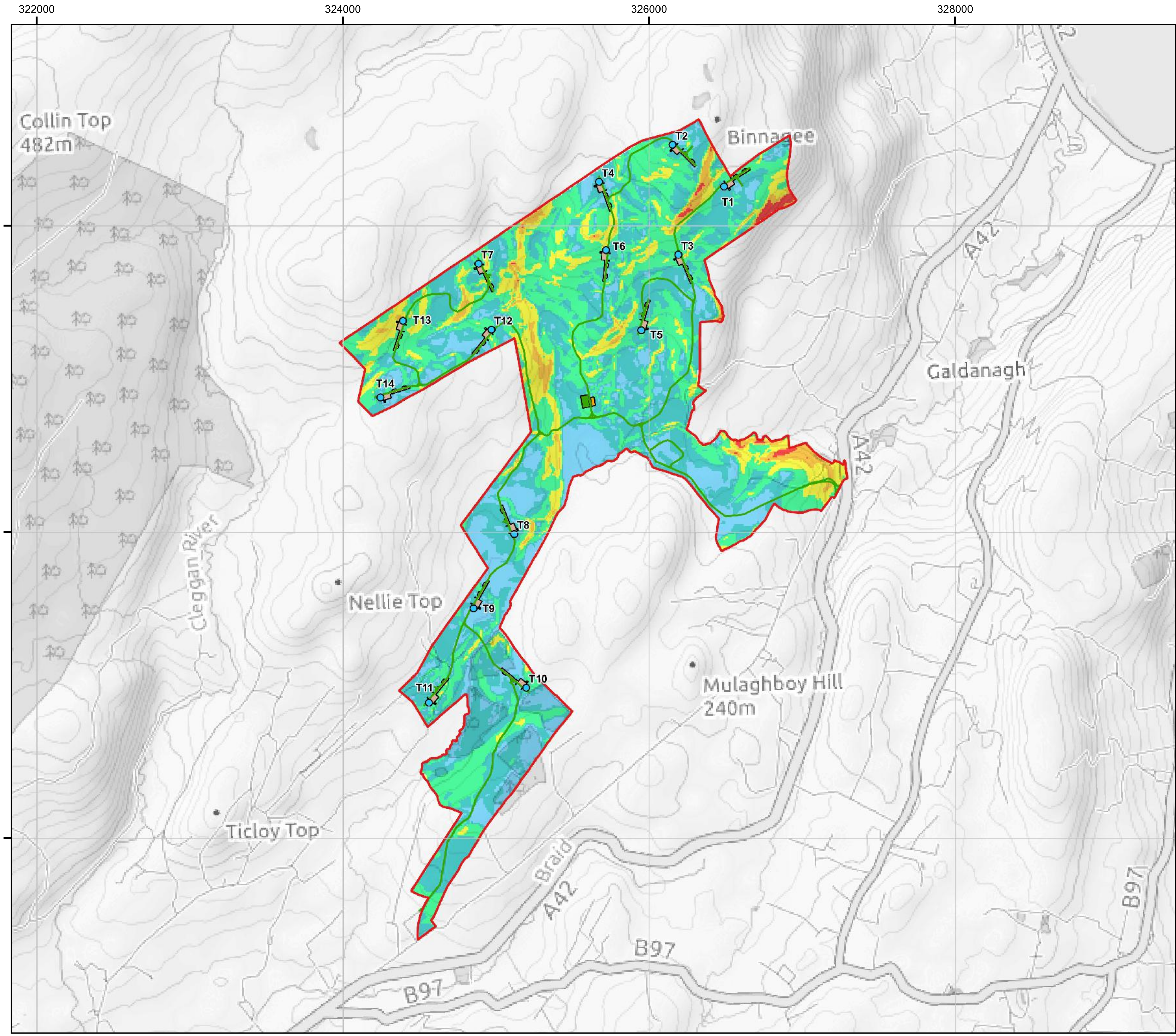

Project:

Unshinagh Wind Farm, Co. Antrim, Northern Ireland

Title:

Map A4: Slope Angle

Key

- Site boundary
- Proposed turbine
- Proposed track
- Proposed crane pad
- Proposed construction compound
- Proposed substation

Slope angle (˚)

- <= 2
- 2 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- > 20

Scale @ A3: 1:25,000

Coordinate System: TM65 Irish National Grid

0 0.25 0.5 0.75 1 km

N

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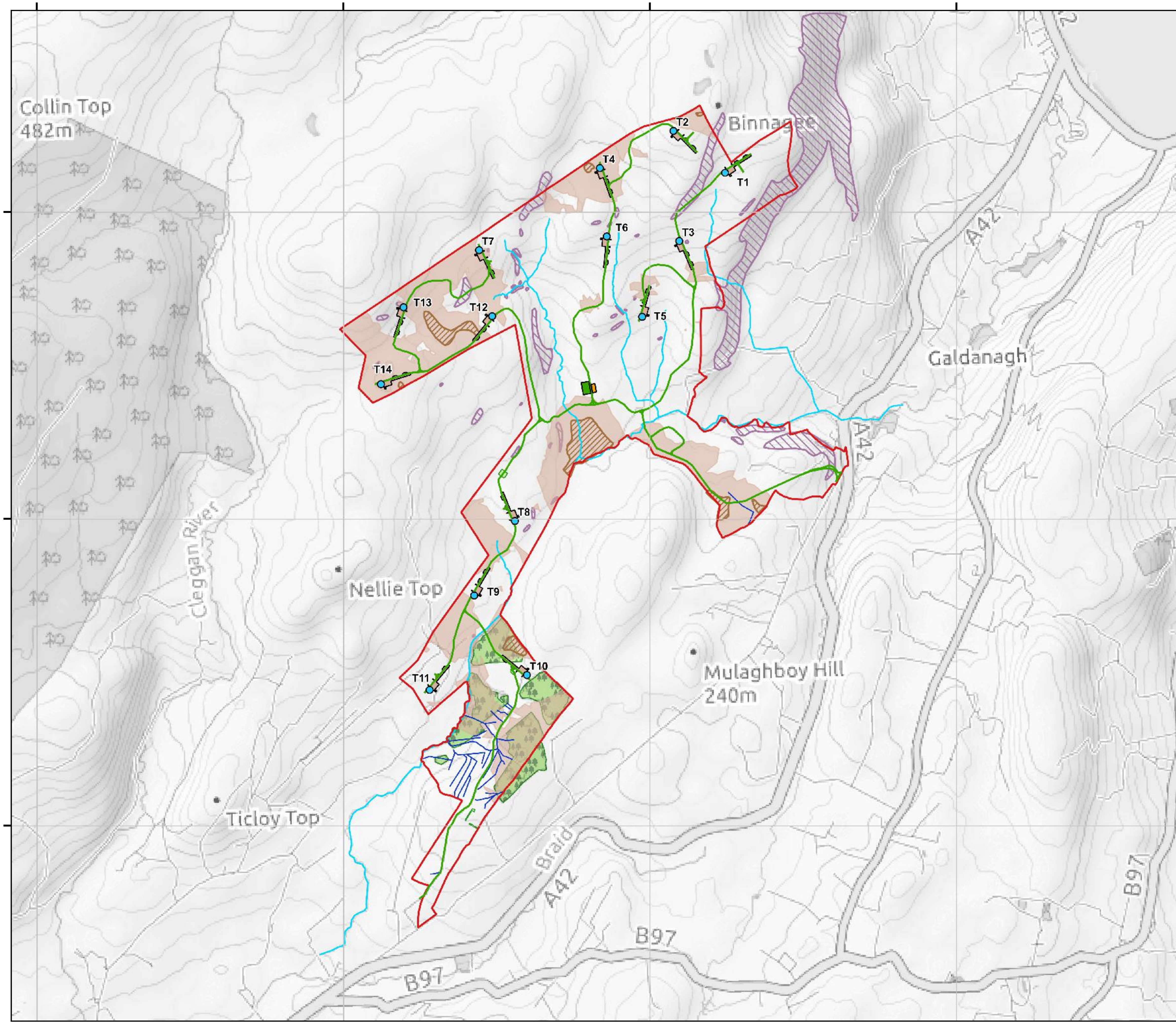

Project:

Unshinagh Wind Farm, Co. Antrim, Northern Ireland

Title:

Map A5: Geomorphological Features

Key

- Site boundary
- Proposed turbine
- Proposed track
- Proposed crane pad
- Proposed substation
- Proposed compound
- Mapped watercourse
- Artificial drainage
- Deep peat (≥ 2.0m)
- Steep slope (≥ 15°)
- Forestry
- Areas of peat exceeding 0.5 m depth (Natural Power survey data)

Scale @ A3: 1:25,000

Coordinate System: TM65 Irish National Grid

0 0.25 0.5 0.75 1 km

N

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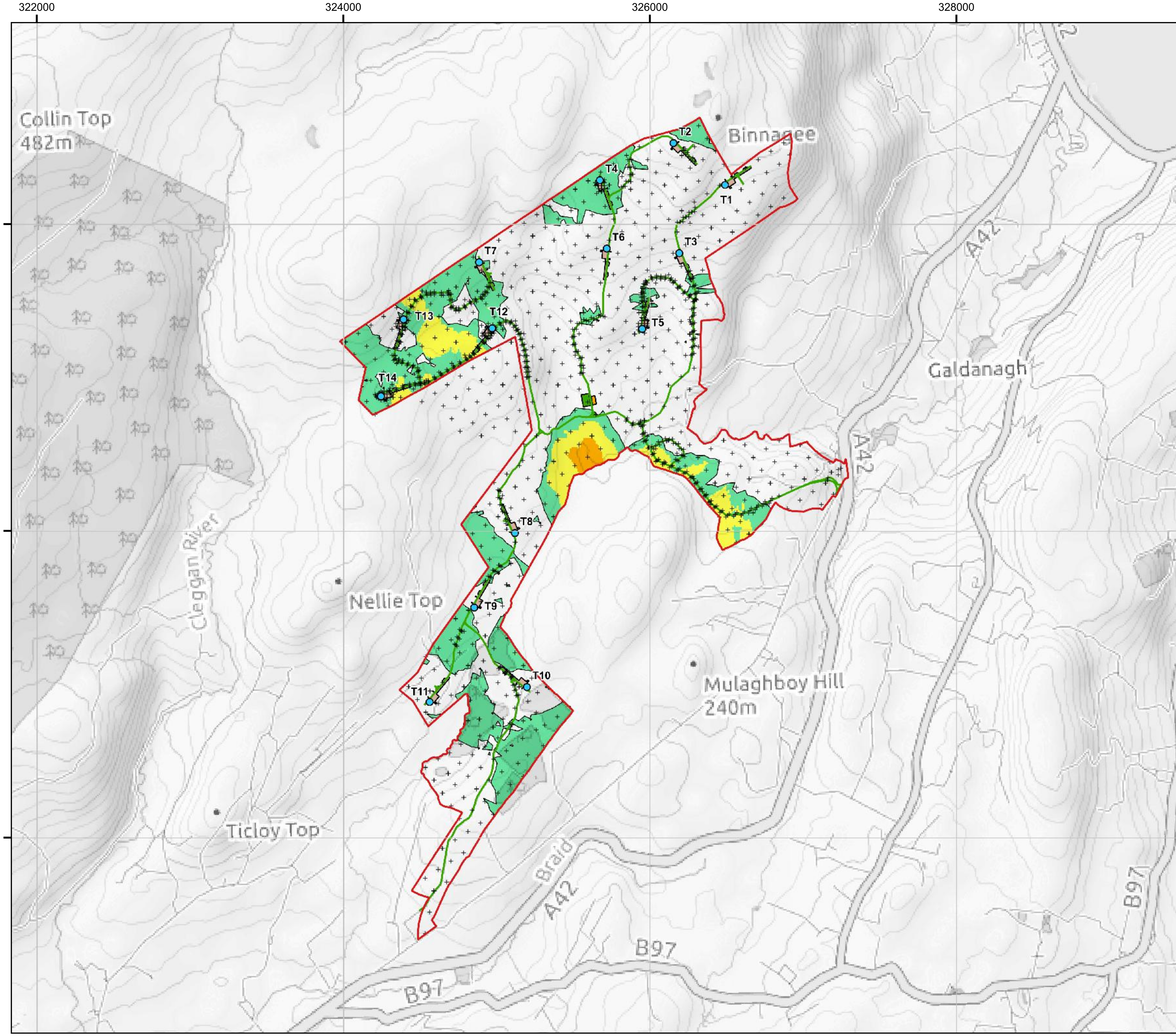

Project:

Unshinagh Wind Farm, Co. Antrim, Northern Ireland

Title:

Map A6: Peat Depth

Key

- Site boundary
- Proposed turbine
- Proposed track
- Proposed crane pad
- Proposed construction compound
- Proposed substation
- Peat probes

Peat depth (m)*

- 0.5 - 1
- 1 - 2
- 2 - 3
- > 3

* Interpolation method: Kriging

Scale @ A3: 1:25,000

Coordinate System: TM65 Irish National Grid

0 0.25 0.5 0.75 1 km

N

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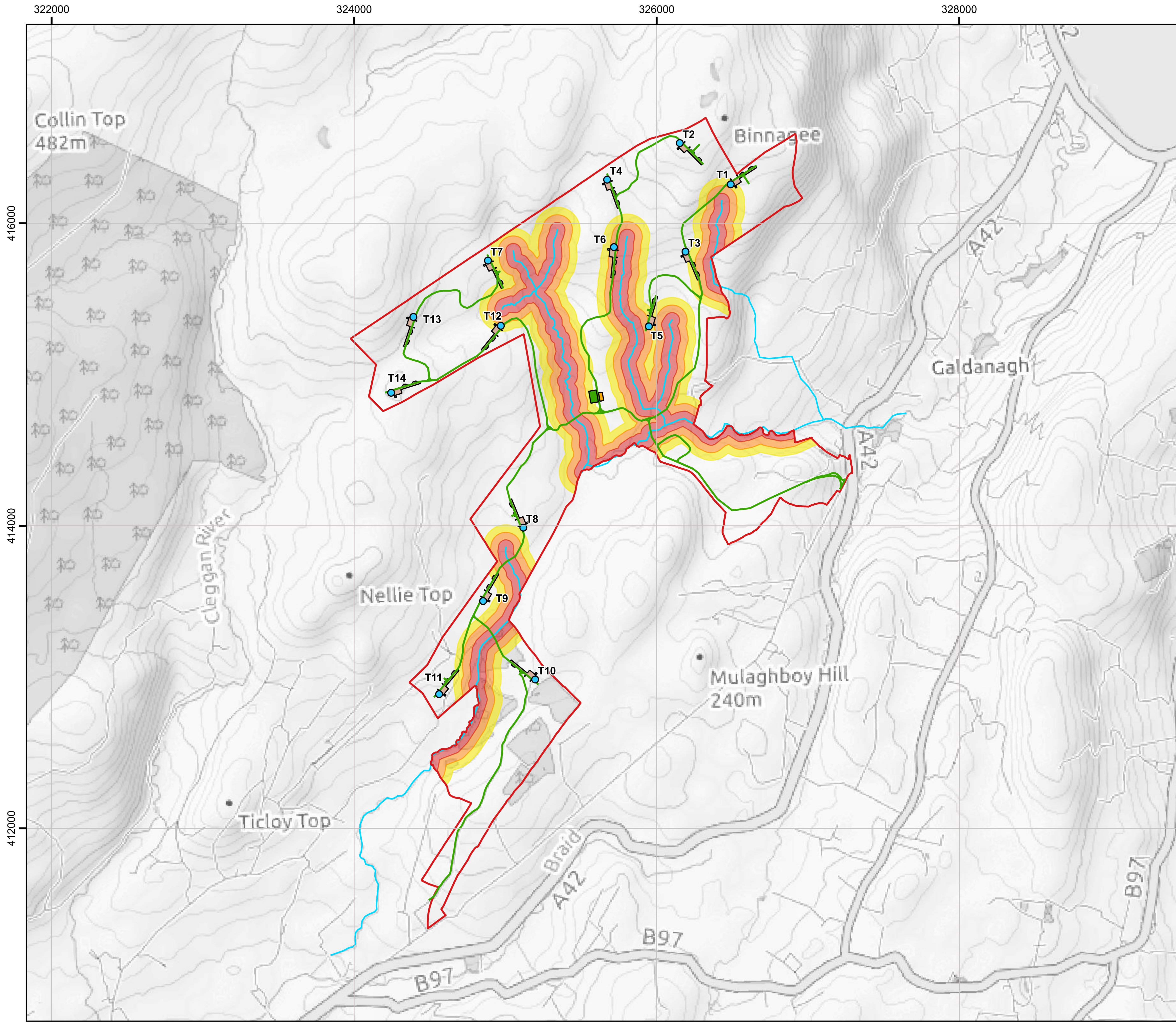

Project:

Unshinagh Wind Farm, Co. Antrim, Northern Ireland

Title:

Map A7: Environmental Impact Zonation

Key

- Site boundary
- Proposed turbine
- Proposed track
- Proposed crane pad
- Proposed construction compound
- Proposed substation
- Mapped watercourse

Proximetry to watercourse

- <50 m High impact
- 50 - 100 m Medium impact
- 100 - 150 m Low impact

Scale @ A3: 1:25,000

Coordinate System: TM65 Irish National Grid

0 0.25 0.5 0.75 1 km

N

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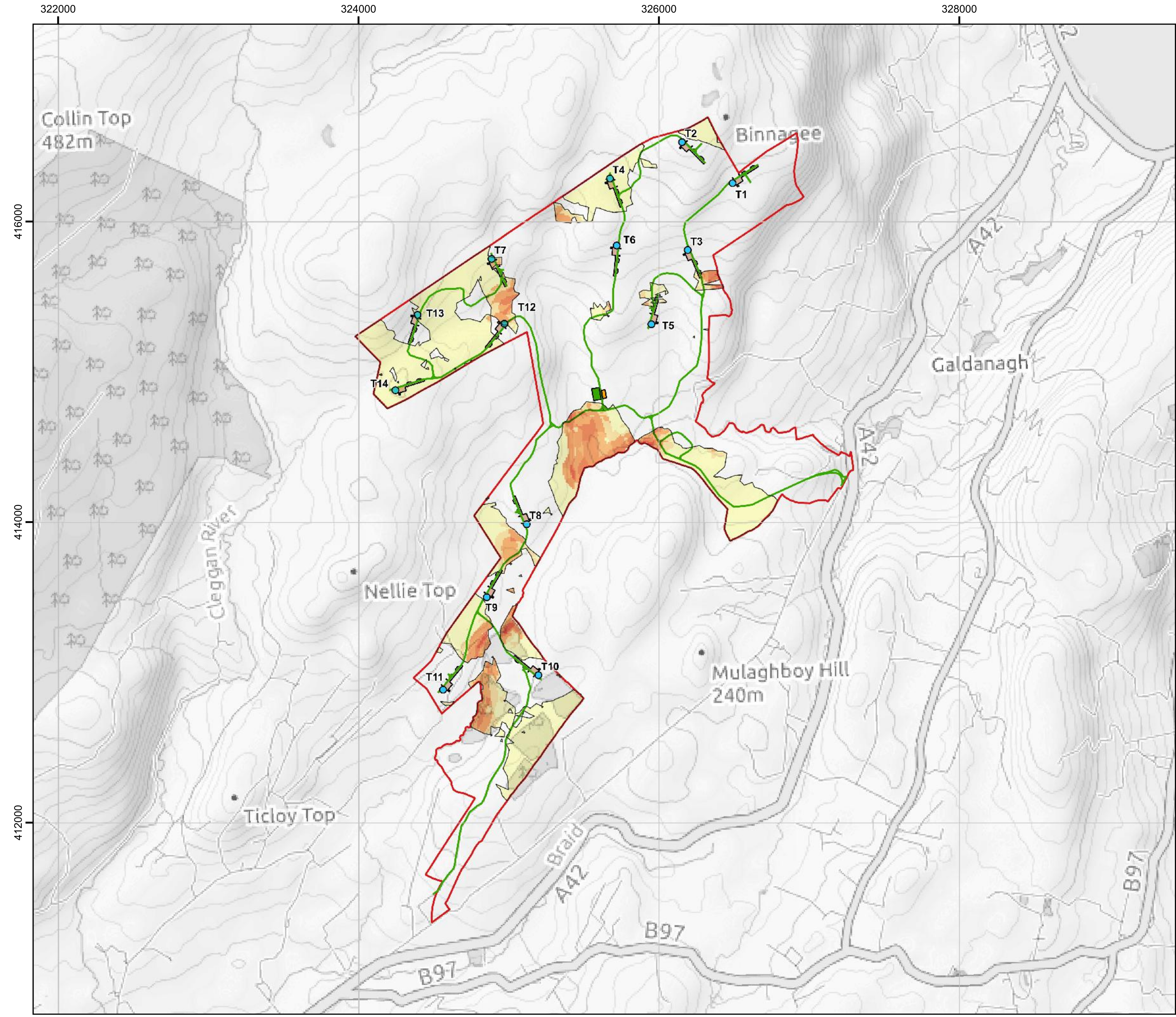

Project:

Unshinagh Wind Farm, Co. Antrim, Northern Ireland

Title:

Map A8: Peat Stability Zonation Analysis

Key

- Site boundary
- Proposed turbine
- Proposed track
- Proposed crane pad
- Proposed construction compound
- Proposed substation

Risk ranking zone

- 5 - 10 Low
- 11 - 16 Medium
- 17 - >25 High

Scale @ A3: 1:25,000

Coordinate System: TM65 Irish National Grid

0 0.25 0.5 0.75 1 km

N

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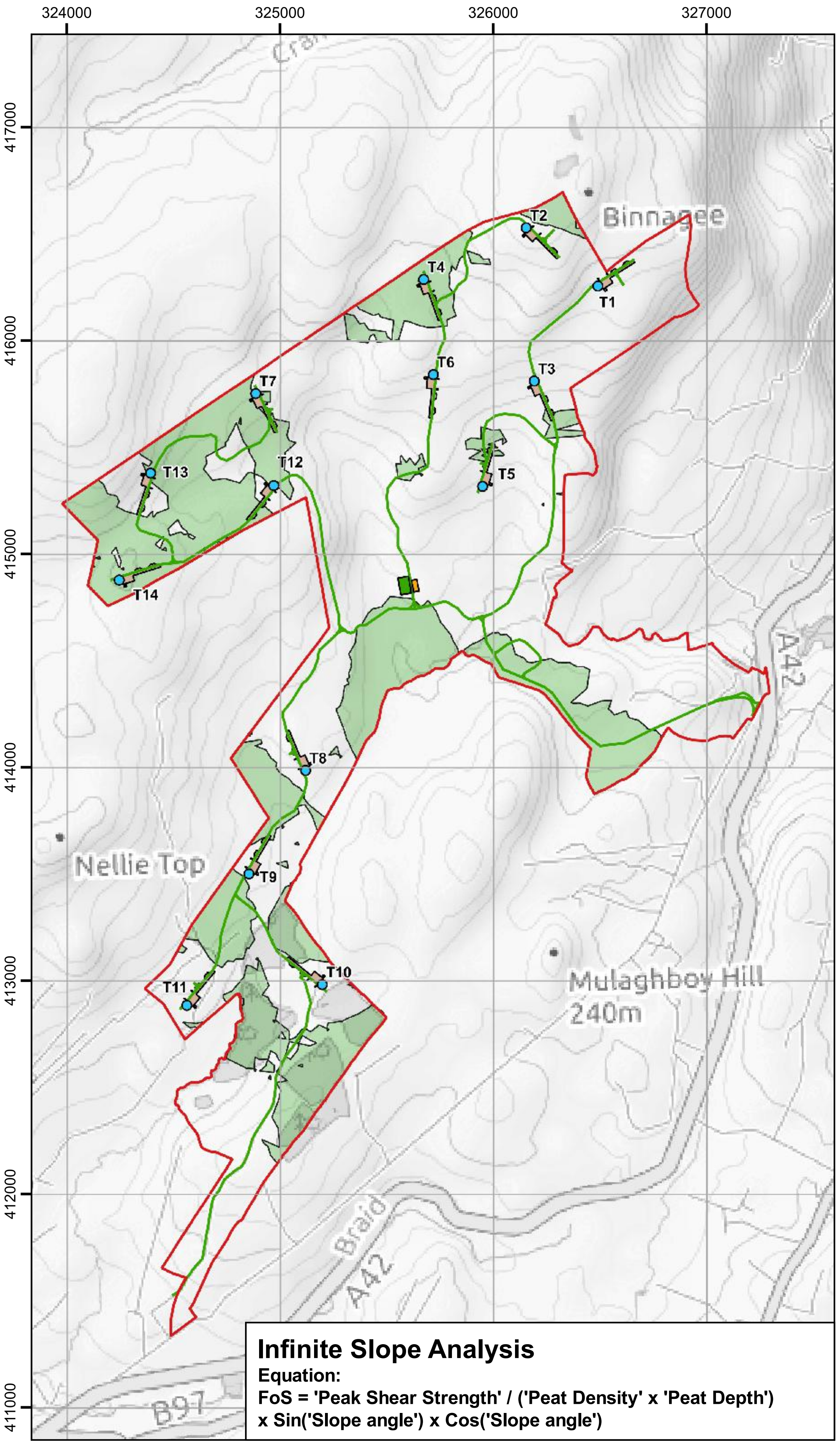
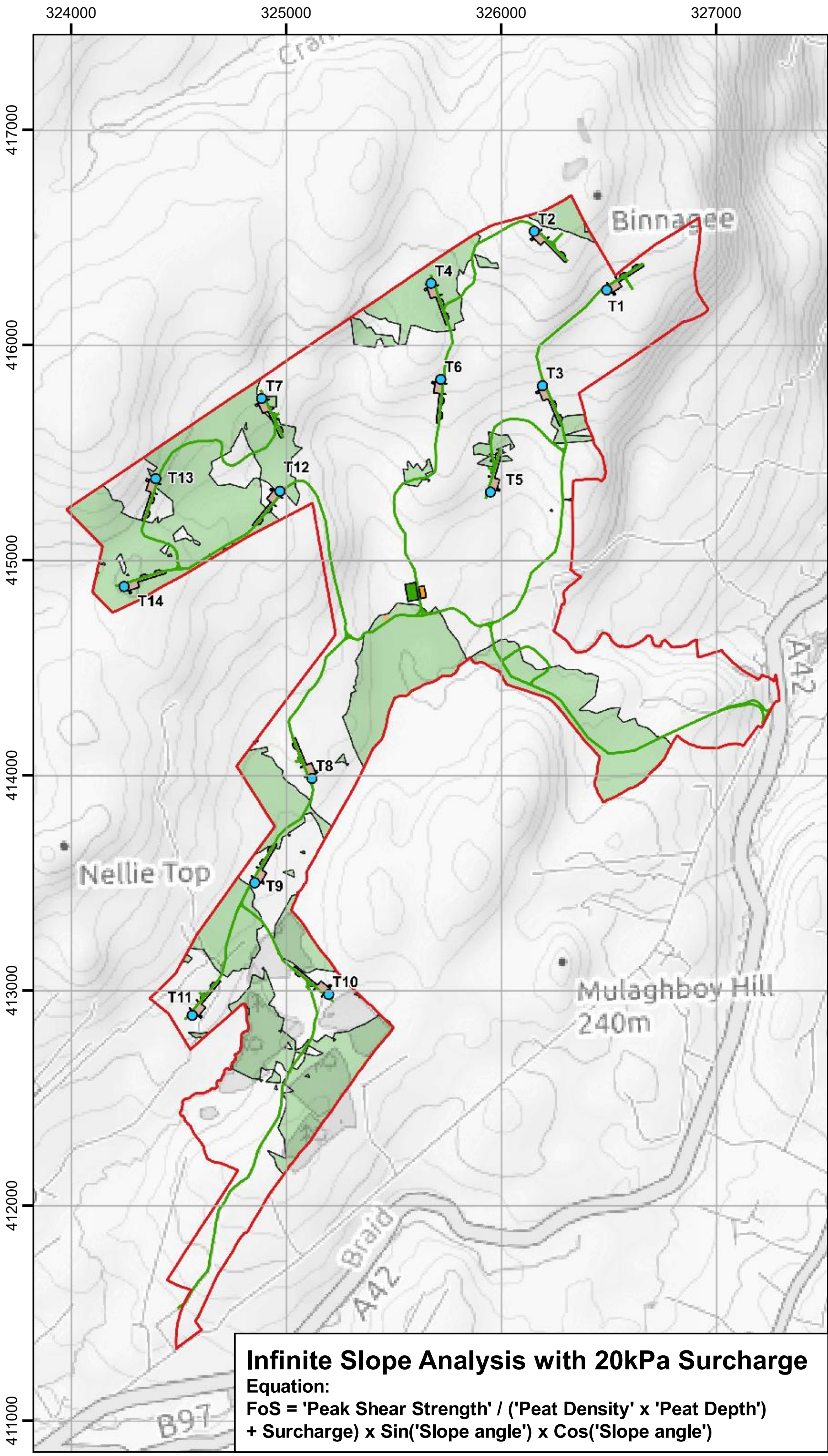


Infinite Slope Analysis
Equation:
FoS = 'Peak Shear Strength' / ('Peat Density' x 'Peat Depth') x Sin('Slope angle') x Cos('Slope angle')



Infinite Slope Analysis with 20kPa Surcharge
Equation:
FoS = 'Peak Shear Strength' / ('Peat Density' x 'Peat Depth') + Surcharge) x Sin('Slope angle') x Cos('Slope angle')

Project:

Unshinagh Wind Farm, Co. Antrim, Northern Ireland

Title:

Map A9: Factor of Safety

Key

- Site boundary
- Proposed turbine
- Proposed track
- Proposed crane pad
- Proposed construction compound
- Proposed substation

Factor of Safety (FoS)

- <= 1.0
- 1.0 - 1.3
- > 1.3

Scale @ A3: 1:25,000

Coordinate System: TM65 Irish National Grid

0 0.25 0.5 0.75 1 km

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B. In-situ Testing

- B.1 Hand Shear Vane Results

Project Name: **Unshinagh Windfarm**
Project ID : 14431UKC

HSV Results	Corrected Hand Shear Vane Results		
Location	Depth	Peak	Residual
PC1	0.5	29	18
PC1	1	23	17
PC1	1.5	18	16
PC1	2	38	30
PC1	2.5	44	35
PC1	3	48	30
PC1	3.5	56	40
PC1	4	65	40
PC1	4.5	65	60
PC2	0.5	23	12
PC2	1	12	10
PC2	1.5	14	9
PC2	2	9	8
PC2	2.5	12	9
PC2	3	12	11
PC2	3.5	11	10
PC2	4	12	14
PC2	4.5	15	13
PC2	5	18	15
PC3	0.5	44	27
PC3	1	36	25
PC3	1.5	60	37
PC4	0.5	35	24
PC4	1	25	22
PC4	1.5	41	33
PC4	2	45	33
PC4	2.5	50	37
PC4	3	51	41
PC5	0.5	22	12
PC5	1	25	17
PC5	1.5	45	35
PC5	2	39	28
PC5	2.5	46	28
PC8	0.5	14	9
PC8	1	18	11
PC8	1.5	53	26
PC9	0.5	34	18
PC9	0.8	60	43

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