APPENDIX 8-1

PEAT STABILITY RISK ASSESSMENT

GAVIN & DOHERTY
GEOSOLUTIONS

Peat Stability Risk Assessment (PSRA) for Kilgarvan Wind Farm Repowering

Client	**MKO**
Document Ref.	22022-R-01-PSRA-02
Project Title	Kilgarvan Wind Farm Repowering
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REVISION SUMMARY

Rev	Date	Section(s)	Detail of Change
01	06/12/2023	[Section]	[Enter details]
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EXECUTIVE SUMMARY

Gavin and Doherty Geosolutions Ltd. (GDG) was commissioned by McCarthy Keville O'Sullivan (MKO) (hereafter the "Client") to undertake a Peat Stability Risk Assessment (PSRA) for the proposed Kilgarvan Wind Farm Repowering (the Proposed Development). In accordance with planning guidelines compiled by the Department of the Environment, Heritage and Local Government (DoEHLG), where peat is present on a proposed wind farm development, a peat stability assessment is required.

The findings of the peat assessment showed that the site has an acceptable margin of safety and is suitable for the Proposed Development.

Consultation with published GSI maps, and the observations from site investigations indicate that a large proportion of the site consists of Bedrock at Surface, with Blanket Peat covering significant areas of the Proposed Development. Peat depths are generally shallow across the site, with an average depth of 0.8m recorded. There are areas of deeper peat recorded up to a depth of 6.5m localised between generally east-west oriented spines of bedrock outcrop. These areas of deep peat have been avoided by optimising the proposed layout for the site.

A desk study, site walkovers, ground investigation campaigns, stability analyses and a risk assessment were carried out to assess the risks posed by peat failures. The risks were assessed following the principles in Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments (Scottish Executive, 2017).

GDG carried out a desk and site-based assessment of a previous landslide at the site which occurred in October 2012. A forensic report carried out following the landslide (AGEC, 2012) was provided by the client and suggests that there were several contributing factors to the landslide mainly, excessive rainfall over a short period of time, uncontrolled release of water from V-notch drains upslope of the failure location and, a steep existing road cutting into an area of natural steep sloping ground.

The purpose of the stability analysis is to determine the stability, i.e. the Factor of Safety (FoS) of the peat slopes. The FoS provides a direct measure of the degree of stability of a peat slope. A FoS of less than 1.0 indicates that a slope is unstable; an acceptable FoS for slopes is 1.3 or greater.

A risk assessment was carried out considering the FoS value calculated in the stability analysis along with other factors that could influence the stability of peat, considering how damaging a peat slide would be to this particular site's environment.

The site was found to have both acceptable factors of safety and levels of risk against peat instability, with the exception of Turbine 6, where a small are of FoS <1 was identified at the turbine foundation location. Three areas, referred to as *safety buffers* (see Section 4.6.1), have been highlighted and will have restricted construction activities and should not be used for the storage of peat or soil. In addition, four peat stockpile restrictions (PSR) are proposed and presented in Appendix L.

1 INTRODUCTION

1.1 BACKGROUND

Gavin and Doherty Geosolutions Ltd. (GDG) was commissioned by McCarthy Keville O'Sullivan (MKO) to undertake a Peat Stability Risk Assessment (PSRA) for the Kilgarvan Wind Farm Repowering Project, hereafter referred to as the "Proposed Development". The Proposed Development layout is presented in Appendix A.

1.2 STATEMENT OF AUTHORITY

GDG has been involved in many wind farm developments in both Ireland and the UK at various stages of development, i.e. preliminary feasibility, planning, peat stability assessment, design and construction. In addition to this, the GDG team, made up of engineering geologists, geomorphologists, geotechnical engineers and environmental scientists, have developed expertise in landslide hazard mapping, including leading a recent national landslide hazard mapping pilot study which included extensive landslide runout and hazard mapping and calculation in Irish blanket peat.

GDG brings together state of the art research and direct industry experience and offers a bespoke engineering service, delivering the most progressive, reliable, and efficient designs across a wide variety of projects and technical areas, including offering forensic engineering and expert witness services to the Insurance and Legal sectors. Our clients include large civil engineering contractors, renewable energy developers, semi-state bodies and engineering and environmental consulting firms.

GDG has been involved in many wind farm developments in both Ireland and the UK at various stages of development i.e. preliminary feasibility, planning, peat stability assessment, design and construction. The GDG team, made up of engineering geologists, geomorphologists, geotechnical engineers and environmental scientists, have developed expertise in the design and construction of developments in areas of peat.

The members of the GDG team involved in this assessment include:

- Paul Quigley. Paul is a Chartered Engineer with over 25 years of experience in geotechnical engineering and a UK Registered Engineering (RoGEP) Advisor. He has worked on a wide variety of projects for employers, contractors and third parties, gaining a range of experience including earthworks for major infrastructure schemes in Ireland and overseas, roads, tunnelling projects, flood protection schemes, retaining wall and basement projects, ground investigations and forensic reviews of failures. Paul is adept at designing creative solutions for difficult problems and has published numerous peer-reviewed technical papers. He has also acted as an independent expert for several legal disputes centred on ground-related issues. He is a reviewer for the ICE Geotechnical Engineering Journal, a member of the Eurocode 7 review panel at NSAI and a former Chairman of the Geotechnical Society of Ireland.
- John O'Donovan. John leads the onshore renewable sector at GDG. He completed his PhD in Imperial College investigating the use of DEM to model wave propagation techniques to measure small strain soil stiffness. Following completion of the PhD John spent 2.5 years working with BH's Ground Engineering Group. He has over 10 years' experience in

engineering and 7 years in his current role. At GDG John manages onshore wind farm projects and solar farm projects. John specialises in dealing with difficult ground conditions and providing robust designs for projects in peat land areas. John also works on the landfall and onshore aspects of offshore windfarms including cable routing and onshore substation foundation design.

- Stephen Curtis. Stephen is a Senior Engineering Geologist on the onshore renewable team. He has over seven years of experience in both site investigation contracting and geotechnical consultancy environments. He is Chartered with the Institute of Geologist of Ireland (IGI) and the European Association of Geographers. Stephen has worked on multiple renewable energy projects; primarily solar and wind farm projects in Ireland the UK for over four years. He has been involved in the feasibility study, planning, design and construction stages of wind and solar farm developments with a particular focus on geotechnical risk management, and mitigation for construction in upland peat areas and Irish glacial ground conditions.
- Alastair Lewis. Alastair is a Civil Engineer with over twenty-five years' experience in civil and ground engineering. He oversees the delivery of multi-disciplinary development infrastructure projects including, brownfield development, ground engineering, earthworks platforming, mining remediation, SUDS, sewerage, flooding, bridges, windfarms, and roads. As head of infrastructure, he developed engineering strategies in the property and energy sectors with particular reference to planning and environmental requirements. He has design experience of major earthworks and mine stabilisation schemes and extensive experience in assessment of abandoned mine workings.
- Chris Engleman. Chris is a Geologist with a Master's degree in Geological Sciences from the University of Leeds. He has four years of industry experience within the onshore renewables sector and the field of geological mapping with a particular focus on Quaternary geology; predominantly working on projects for peat stability and management, ground investigation, rock and soil logging, GIS mapping and geotechnical design. Chris has worked on several renewable energy projects; particularly wind and solar, for over two years.
- Brian McCarthy. Brian is a Civil Engineer within the infrastructure team in GDG with two years of post-graduate experience. Brian holds a Master's degree in Civil, Structural and Environmental Engineering from University College Cork and is a member of the Institution of Engineers of Ireland. Brian has worked on various renewable energy and infrastructural projects in Ireland and the UK and has carried out peat probing on a number of projects throughout Ireland.

1.3 PROPOSED DEVELOPMENT

The Proposed Development is located, approximately 5.5km northeast of the village of Kilgarvan Co. Kerry and approximately 6km west of Coolea, Co. Cork. It covers approximately 775 hectares in total. For a more detailed description of the Proposed Development location, please see Chapter 1, Section 1.1.2 of the EIAR.

A detailed map of the proposed site's administrative locations is provided in **Error! Reference source not found.**.

A full description of the Proposed Development is included in Chapter 4.

This report examines the peat stability risk at the site of the Proposed Development, located within the EIAR Site Boundary as defined in Chapter 4 of the EIAR. The “Proposed Development” or “the site” as referred to in this report is in reference to all land within the EIAR Site Boundary as defined in the EIAR.

1.4 OVERVIEW OF PEAT LANDSLIDES

1.4.1 PEAT LANDSLIDE TYPES

Two general groups of peat landslides are typically referred to in the literature: peat slides and bog bursts. Some descriptions of each type are provided in Table 1-1.

Table 1-1: Peat Landslide Types

Characteristics	Peat slide	Bog burst
Outstanding characteristic	Shallow translational failures	Particularly fluid failures without necessarily a clear scar margin. The liquefied basal material is expelled through surface tears followed by settlement of the overlying mass.
Mechanism	Shear failure along discrete shear surfaces, typically at the peat-substrate interface	Subsurface creep, swelling
Peat depth	≤ 2 m	≥ 1.5 m
Slope angle	5 – 15° (moderate)	2 – 10° (gentle), where deeper peat is more likely
Spatial distribution	Scotland, England and Wales	Ireland

The slope angle within the Proposed Development site ranges from 0° to 61° (see Figure F-2 in Appendix F). Evidence of past landslides has not been identified within the Proposed Development site and the near surroundings during the fieldwork, however a peat landslide was recorded in October 2012 (Section 2.6.1). This landslide was visible on the available Google Earth imagery available from 2010 onwards, however no additional landslides were identified during this analysis (please see section 2.5).

According to the GSI landslide inventory (GSI, 2023), the closest landslide is located about 1 km southeast of the nearest turbine (T11) and less than 400m from the EIAR Site Boundary. The area of the slides is 224m^2. Figure 1-1 shows the landslide event closest to the EIAR Site Boundary. The locations of the past landslide events identified in the GSI landslide archive are shown in Figure G- 2 in Appendix G.

The landslide event is located on the outside bank of a bend on the River Glanloe. The information on the date, cause, severity or consequence of the event is not recorded with in the landslide archive. The landslide location and geometry are indicative of a shallow slip (less than one metre). The landslide is located at the maximum erosive face of the river (external side of the river’s curvature). It is interpreted due to the morphology and location that the toe of the soil was eroded causing the instability slope and hence the landslide. The GSI Quaternary mapping data (2023) suggest that the area is composed of glacial till material. The plan area of the landslide is less than

250m^2 and the suspected shallow landslide depth suggest that the volume of disturbed material is relatively small. The failure may have caused a small blockage to the river and disruption flow but would likely to have has a negligible impact on the receiving river environment.

Figure 1-1: GSI landslide inventory (2023) landslide event close to site boundary.

A peat slide event occurred at the site of the Existing Kilgarvan Wind Farm in 2012. A forensic report outlining the potential causes mitigation and remediation of this landslide event is outlined in a forensic report "*Geotechnical site assessment Report for Kilgarvan Windfarm*" by Applied Ground Engineering Consultants (AGEC Ltd) in October 2012. According to the report, the landslide was cause by several contributing factors mainly an excessive volume of rainfall over a short period of time, the unmanaged release of drainage water onto a peat surface, and a steep road cutting. The findings of the AGEC 2012 report and the subsequent GDG inspection of the failure area are summarised in Sections 2.8.1 and 3.1 respectively. Figure 1-2 shows a photo of the impacts of the 2012 landslide in the immediate aftermath of the failure.

Although there is no additional evidence of landslides within the Proposed Development site outside of the reported event in 2012, this does not necessarily mean that landslides have never occurred at the Proposed Development site. It is noted that the geomorphological features associated to peat landslides (peat slides and bog bursts) are softened with time through erosion, drying and re-vegetation (Feldmeyer-Christe & Küchler, 2002; Mills, 2003).

Figure 1-2: Photo of effects of 2012 landslide (AGEC, 2012)

1.4.2 CONTROLS OF PEAT INSTABILITY

The spatial and temporal occurrence of landslides, including peat landslides, is controlled by a combination of *conditioning* and *triggering factors*.

The conditioning factors explain the spatial distribution of landslides and are related to the inherent properties of the terrain, such as soil type, slope angle, curvature (convex/concave) of the slopes and drainage.

The triggering factors explain the frequency of landslides. They can be distinguished between fast and slow triggers:

- Fast triggers:
    - Intense rainfall (the most frequent trigger);
    - Snowmelt (very frequent trigger);
    - Rapid ground accelerations (e.g. from blasting rock);
    - Undercutting of peat by natural processes (e.g. fluvial) or man-made; or
    - Loading the peat.

- Slow triggers:
    - Low intensity but constant rainfall;
    - Afforestation / Deforestation (wildfires, pollution-induced vegetation change); or
    - Weathering (physical, chemical, biological).

Slow triggers can start landslides by themselves and can also act as *preparatory factors* for fast triggers by lowering their threshold to start landslides.

1.4.3 PRE-FAILURE INDICATORS

The presence of conditioning factors and low-pace triggers before failure is often indicated by ground conditions, features and morphologies that can be identified remotely or during the fieldwork by the geomorphologist or through basic monitoring techniques.

According to the updated guidelines provided by the Scottish Executive (2017), the following critical features are indicative of the susceptibility or proneness to failure in peat environments:

- Presence of historical and recent failure scars and debris;
- Presence of features indicative of tension (e.g. cracks);
- Presence of features indicative of compression (e.g. ridges, thrusts, extrusion features);
- Evidence of peat creep (typically associated with tension and compression features);
- Presence of subsurface drainage networks or water bodies;
- Presence of seeps and springs;
- Presence of artificial drains or cuts down to substrate;
- Presence of drying and cracking features;
- The concentration of surface drainage networks;
- Presence of soft clay with organic staining at the peat and (weathered) bedrock interface; and
- Presence of iron pans or similar hardened layers in the upper part of the mineral substrate.

Other evidence of peat instability not related to landslides has been considered, namely quaking peat in horizontal areas with very low bearing capacity. Evidence of ongoing peat harvesting was not identified on site.

1.4.4 PEAT STABILITY RISK ASSESSMENT WORKFLOW

GDG has carried out the PSRA for the Proposed Development site following the principles set out in the "*Proposed electricity generation developments: peat landslide hazard best practice guide"* (Scottish Executive, 2017). This guide has been used in this report as it provides best practice methods to identify, mitigate and manage peat slide hazards and associated risks in respect of consent applications for electricity generation projects.

Figure 1-3 shows a workflow diagram showing the general methodology for the PSRA. The methodology can be summarised into the following steps:

1. Completion of the desk study.
2. Undertaking a walkover and fieldwork to:
    - Carry out geo-investigations especially concentrated at the proposed infrastructure areas, including peat probing and hand shear vane testing, Russian core sampling and trial pitting;

- Record geological and geomorphological features, including exposures of the soil profile and evidence of peat instability; and
- Record hydrologic and vegetation features.

3. Risk assessment, including:
   - Interpolation of the peat probe values and generation of the peat depth map;
   - Creation of the Factor of Safety (FoS) maps using a deterministic approach (Bromhead, 1986) for drained and undrained conditions;
   - Qualitative hazard assessment by combining the FoS with observations of the peat condition identified both on aerial imagery and during fieldwork.
   - Qualitative consequences assessment;
   - Calculation of the peat landslide risk by multiplying hazards and consequences;
   - Reclassification of the risk values into four classes:
     - Negligible;
     - Low;
     - Medium; and
     - Serious.
4. Proposal of actions required for each infrastructure element.

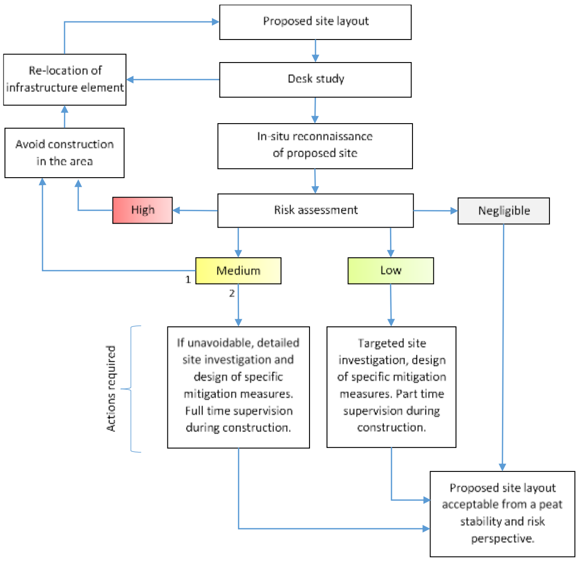

Figure 1-3: Workflow of the PSRA methodology for the acceptability of the proposed site layout

2 DESK STUDY

For a preliminary site suitability analysis and background knowledge of local peat stability and ground conditions, the following sources of information have been used:

1. Geology and Quaternary sediments (subsoils);
2. Soils;
3. Moisture;
4. Hydrogeology;
5. Multi-temporal aerial / Satellite imagery;
6. Topography;
7. Landslide inventories and landslide susceptibility;
8. Hydrology;
9. Land cover and land use;
10. Relevant academic literature and publications.

2.1 BEDROCK GEOLOGY

According to the GSI bedrock geological map of Ireland at 1:100,000 scale (Figure B- 1) (GSI, 2018a), the bedrock under the Proposed Development site is grey to purple sandstone and purple siltstone of the Gun Point Formation. The Gun Point Formation is Upper Devonian (Fammenian) in age. The lithology is characterised by green-grey to purple, medium to fine-grained sandstones (locally pebbly), interbedded with green and red to purple siltstones and fine sandstones.

The far northwest of the site around T6 is underlain by green sandstone and purple siltstone from the Glenflesk Chloritic Sandstone Formation. The Glenflesk Chloritic Sandstone Formation is also Upper Devonian in age, but slightly older than the Gun Point Formation (Frasnian). The lithology is characterised by green, mostly medium-grained sandstone, conglomerate and pebbly sandstone, together with green and purple siltstone.

The bedrock is encountered as outcrop or subcrop throughout the Proposed Development site, with more prolific bedrock outcropping in the southern part of the site, particularly around T2. Rock is mapped as outcropping along the southern part of the access route. The bedrock outcrops encountered within the site often form prominent east-west ridges, with steep bedrock slopes common. Small scale, localised depressions occasionally occur in between bedrock ridges.

2.2 QUATERNARY SEDIMENTS

The map of Quaternary Sediments at 1:50,000 scale shown in Figure B- 2 in Appendix B (GSI, 2023) indicates that the majority of the wind farm site is located on bedrock outcrop or subcrop, with pockets of blanket peat encountered throughout the site. It is important to note that the GSI mapping only considers the first layer >1m in thickness, so peat may still be encountered in areas mapped by the GSI as bedrock. The majority of the site access road is mapped as peat. The southern area of the site contains some soils classified Lithosols and Peats.

Alluvial deposits are not mapped within the site; however, it is expected that some form of alluvium would be present adjacent to most of the watercourses that cross the site. Alluvium follows the River Roughty, which runs in a westward direction to the southwest of the EIAR Site Boundary.

One small pocket of Glacial Till derived from Devonian sandstones is mapped just inside the southern area of the EIAR Site Boundary, and additionally along the northernmost 1km of the access track. The Glacial Till typically comprises a heterogenous mix of sand, gravel, cobbles, and boulders, and is often held in an over consolidated clay matrix.

2.3 SOIL COMPOSITION

The Irish soil map at 1:250,000 scale is shown in Figure C- 1 in Appendix C (EPA, Teagasc, & Cranfield University, n.d.). The site is covered by peat (association 1xx), rock and association 410b lithosols.

It is noted that the presence or absence of peat cover in the regional scale maps must not be taken as exact. The depth and extent of peat deposits may vary over short distances as a function of local underlying geology, past and ongoing geomorphological activity, and management history. Therefore, these maps have been complemented by peat probes and field observations which are described in Section 3.

2.4 MOISTURE

Water reaching a slope can produce the following processes:

- Lubrication. It reduces the friction along discontinuities (joints or stratification) in rock or soil (Wu, 2003). In clay soils, lubrication is due to the presence of water that produces a repulsion or separation between the clay particles.
- Softening. It mainly affects the physical properties of filler materials in fractures and fault planes in rocks.
- Pore pressure. Water in soil pores exerts pressure on soil particles, changing the effective pressure and the shear strength. The negative impact of pore pressure changes is particularly evident in partially saturated or unsaturated soils, where the increase in moisture content causes the development of a wetting front that converts beneficial negative suction stresses within the capillary structure of the soil to a fully saturated positive pore pressure. When soil is saturated, capillary stresses and adhesion between particles diminish and, as a result, soil shear strength decreases.
- Confined water pressures. The confined underground water acts as an uplifting pressure on the impermeable layers, decreasing the shear strength and producing hydrostatic pressures on the layers where permeability changes. These lifting stresses can cause material deformation or failure, and pore pressure decreases soil resistance.
- Fatigue failure due to fluctuations in the water table. Some landslides occur in episodes of rain with lower intensity than previous ones. This phenomenon is explained by Santos et al.

(1997) as a case of soil fatigue due to cyclical pore pressures. In temperate climates, seasonal variations in temperature can lead to slight variations in the water table. These changes are much more significant in tropical climates (Xue & Gavin, 2008).

- Washing away of cement material. The groundwater flow can remove the soluble cement (e.g., calcium carbonate) from the soil and thus, decreases the cohesion and the friction angle. This process is usually progressive.

- Density increase. The presence of water in soil pores increases the bulk density and weight of the materials in the slope. Therefore, shear stress increases and the slope safety factor decreases.

- Internal hydraulic forces. The movement of groundwater currents creates hydrodynamic pressure on the ground in the direction of flow. This force acts as a destabilizing element on the groundmass and can appreciably decrease the safety factor of the slope. The hydrodynamic or seepage/flow force can also cause the movement of the particles and the destruction of the soil mass (piping).

- Collapse. Collapsible soils (alluvial soils deposited very rapidly and wind soils or loess) are very sensitive to changes in humidity. When water content increases, their volume decreases, and the microstructure collapses.

- Desiccation cracks. Changes in humidity can cause cracking, and these cracks can determine the extension and location of the surface of failure and have a very important effect on the safety factor or possibility of sliding.

- Piping in clays. Some clayey soils disperse and lose their cohesion when saturated. The result can be the total collapse of the soil structure and the activation of landslides.

- Chemical weathering: Processes of ion exchange, dissolution, hydration, hydrolysis, corrosion, oxidation, reduction and precipitation (Wu, 2003).

- Erosion. The detachment, dragging, and deposition of soil particles by water flows modifies the relief and the stresses on slopes and can produce the activation of a landslide, especially when erosion undercuts slopes.

The *Normalized Difference Moisture Index Colorized* GIS service or the United States Geological Survey (USGS) has been used to estimate levels of moisture in the soil across the Proposed Development site. This service is based on the analysis of multispectral Landsat 8[1] OLI images. Using on-the-fly processing, the raw digital number (DN) values for each Landsat band are transformed to

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[1] Landsat 8 includes 8-band multispectral scenes at 30-meter resolution which are typically used for mapping and change detection of agriculture, soils, moisture, vegetation health, water-land features and boundary studies.

scaled (0 - 10000) apparent reflectance values and then, the Normalised Difference Moisture Index is obtained using Equation 2.4-1 (Gao, 1996):

$$\text{NDMI} = (\text{Band } 5^{2} - \text{Band } 6^{3}) / (\text{Band } 5 + \text{Band } 6) \qquad \textbf{Equation 2.4-1}$$

Figure D- 1 in Appendix D illustrates the levels of estimated soil moisture across the Proposed Development site. Wetlands and other vegetated areas with high levels of moisture appear as dark blue (e.g. along the SW-NE valley). Regions of high elevation (e.g. north sector) and slopes which face east exhibit lower values of moisture and are represented as light blue and green. It is noted that satellite RADAR and aerial LiDAR images also provide estimates of terrain moisture. However, these have not been used in this report due to their high cost and the time frame for this project.

2.5 HYDROGEOLOGY

The GSI Hydrogeology map at 1:100,000 scale (Figure E- 1 in Appendix E) indicates that the entire Site is located on locally important aquifers in the Gun Point and Glenflesk Chloritic Sandstone Formation. These are defined as bedrock, which is moderately productive only in local zones, and are capable of supplying locally important abstractions (e.g. smaller public water supplies, group schemes), or as having good yields (100-400 m^3/d). In locally important bedrock aquifers, groundwater predominantly flows through fractures, fissures, joints or conduits. Figure E- 1 in Appendix E shows that the area surrounding the site contains numerous bedrock faults which may act as conduits for groundwater flow.

The site has not been mapped for the GSI Subsoil Permeability Map (Figure E- 2 in Appendix E). Some areas close to the EIAR Site Boundary are mapped as being of “Medium” permeability, however.

2.6 MULTITEMPORAL AERIAL/SATELLITE IMAGERY

The aerial / satellite imagery used for this report is the ESRI orthophoto (OTF) and the Google Earth multi-temporal imagery (2010 onwards, Figure 2-1). This imagery has been used to:

- Identify any evidence of peat failures;
- Identify pre-conditioning factors for failure (where visible at the resolution of the imagery);
- Observe, where possible, vegetation cover, drainage regime and dominant drainage pathways; and
- Identify evidence for land management practices with the potential to influence ground conditions (e.g. burning, artificial drainage, peat cutting and forestry).

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[2] Near Infrared (NIR)

[3] Short Wave Infrared 1 (SWIR1)

It is noted that the time-lapse of the available imagery is too short to identify old peat instability evidence that may have been eroded or re-vegetated with time or changes in land management.

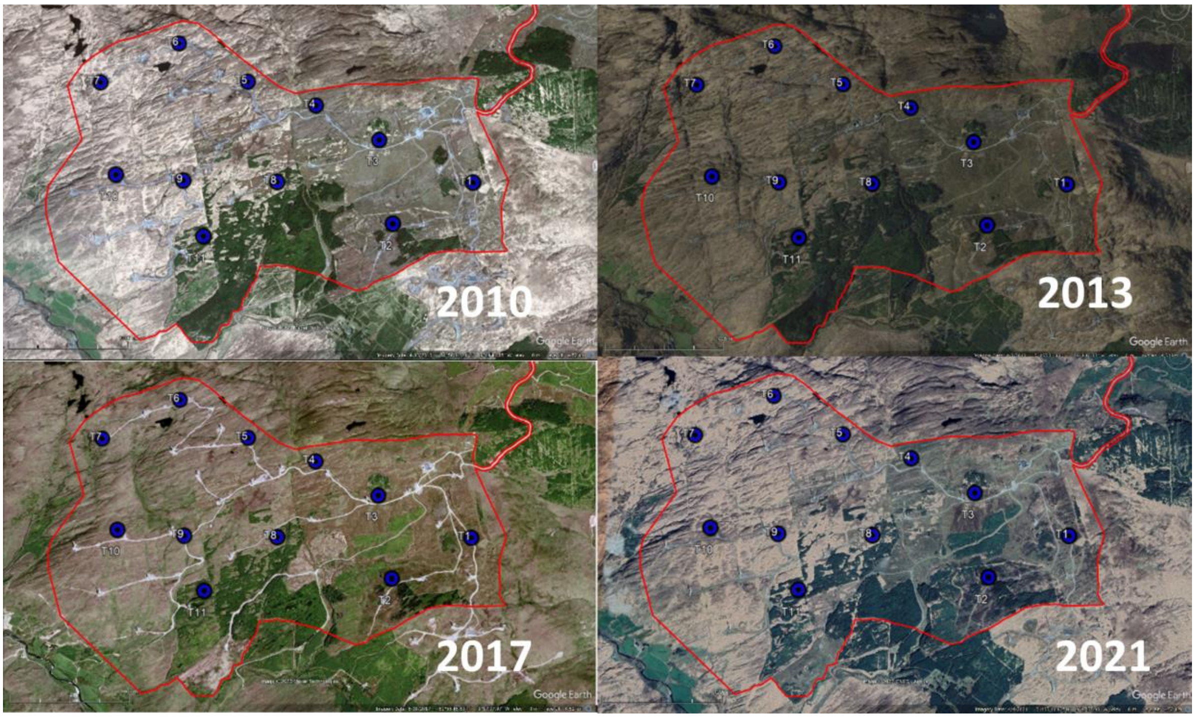


Figure 2-1: Multi-temporal aerial/satellite imagery (Google Earth, various dates). The proposed turbine layout is displayed as blue dots.

2.7 TOPOGRAPHY

Bluesky (2018) topographic data was used to analyse the topography of the Proposed Development site. The digital elevation model generated from this data is shown in Figure F- 1 in Appendix F.

The topography of the site is dominated by the high ground, sloping down towards the valley of the River Roughty (SE-NW) just to the southwest of the EIAR Site Boundary. Several watercourses run across the site, ranging from E-W to N-S in orientation, generating small depressions and valleys within the slope. The bedrock outcrops within the site typically form E-W oriented ridges, with localised depressions occasionally forming between ridge sets. The topography of the site can be described as an undulated hill. The elevation varies between 117 m to 507 mOD (meters above ordnance datum).

One additional map has been derived from the generated digital elevation model (DEM):

- The slope angle map shown in Figure F- 2 in Appendix F which shows that the slope angles range between 0° and 61°.

2.8 LANDSLIDE MAPPING

The GSI landslide inventory (GSI, 2022), the multi-temporal aerial / satellite imagery, the DEM, the landslide susceptibility map (GSI, 2016b), the rainfall information of Met Éireann data 1981-2010 have been used for this part of the desk study. Reports provided by the client for the existing Kilgarvan Wind Farm site were also used in the examination of ground conditions and landslide mapping, these reports are provided in Appendix N including:

- *Peat failure at Kilgarvan Windfarm* (AGEC, 2012), and
- *Geotechnical site assessment Report for Kilgarvan Windfarm* (AGEC, 2013),

Figure G- 1 (Appendix G) illustrates the landslide susceptibility (GSI, 2016b) across the Proposed Development site. This map was obtained by using an empiric probabilistic method at a regional scale and does provide input into site-specific scale engineering studies. For instance, turbines T1, T2, T5, T8 and T11 are located in a sector of *moderately high* susceptibility (orange colour) due to the high slope angle in this sector. However, the field visits and project scale stability analysis carried out by the project team suggest that the areas of the Proposed Development are suitably stable following particular guidelines (Scottish Executive, 2017).

Figure G- 2 (Appendix G) depicts the spatial relationship between records of previous landslide events (GSI, 2016a, 2018b) and rainfall across Ireland from the Met Éireann (2018) average annual rainfall dataset. While the site is in a region of high rainfall and relatively steep topography, there is no record of past landslide events from the national landslide database nor was any evidence observed during fieldwork for this project. However, a peat landslide was recorded on the site in October 2012 (please see Section 2.8.1), in which rainfall was a significant contributing factor. Additionally, there are nine landslide events in the database within 5km of the EIAR Site Boundary, with the closest landslide according to the GSI database occurring on steep ground on the north side of a watercourse approximately 400m outside of the Proposed Development EIAR Site Boundary. Many of the landslides within a 5km buffer from the site are located beside rivers at the maximum erosive face (external side of the river's curvature). The likely cause of these landslide instabilities is from the undermining of the steep riverbanks by fluvial erosion.

A notable exception to this is the Fuhiry landslide, which took place approximately 5km southeast of the EIAR Site Boundary in 1997. This landslide was a peat slide which occurred following a period of heavy rain and flooding, with failure occurring at the interface between peat and gravel. The slide took place in a woodland area and caused infrastructure damage. The slide area was 4,075m^2 according to the GSI landslide database (GSI, 2018b).

2.8.1 EXISTING PEAT STABILITY ASSESSMENT

An assessment report of a landslide event which occurred at the site in October 2012 has been made available by the client. The assessment report and associated site inspection was carried out by AGEC on October 25th, 2012, giving a brief overview of the characteristics of the failure and indicating a possible cause and mitigations required (AGEC, 2012).

Following the assessment of the failure location, an assessment of the peat stability condition across the full windfarm layout was carried out by AGEC and is summarised in the "*Geotechnical site assessment Report for Kilgarvan Windfarm*" (AGEC, 2013).

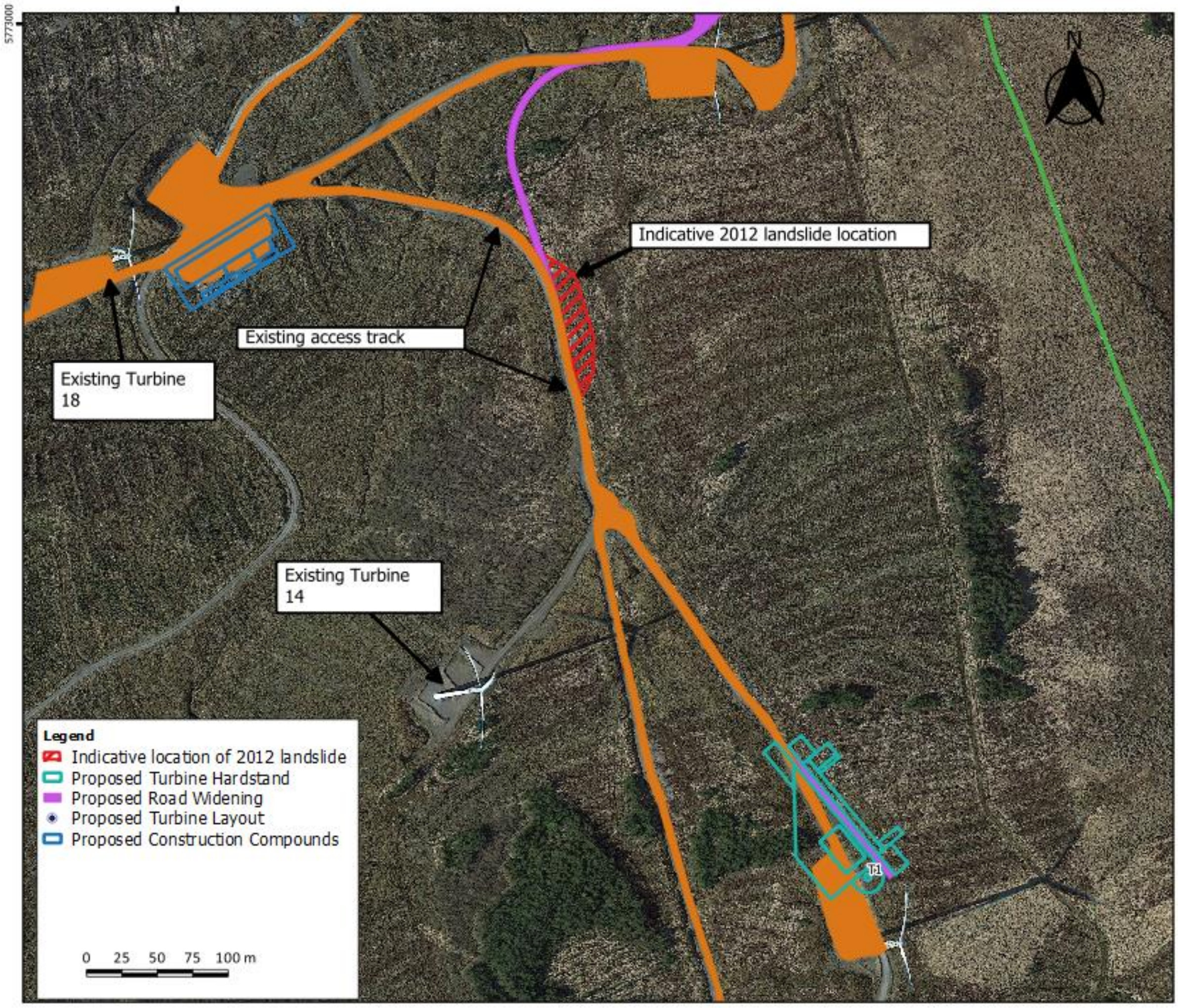


Figure 2-2: Location of 2012 Landslide.

2.8.1.1 EXISTING LANDSLIDE ASSESSMENT

AGEC carried out an assessment of a peat failure event which occurred at the access track to existing T14 (location shown in Figure 2-2). The failure occurred following a period of excessive rainfall on the 17th/18th of October 2012, triggering a translational slide causing material to fall onto the adjacent (downslope) access track, partially blocking access. The failure occurred on a pre-failure slope of approximately 8°, was rectangular in plan up to 6m wide and extending approximately 26m along the access track. The peat failure volume is estimated at approximately 170m^3, with an extended disturbed area of approximately 450m^3 (Figure G- 3 in Appendix G).

The report summarised that the main contributing factors to the peat failure are as follows:

- Excessive rainfall over a short period of time,
- Installation of V-notch surface drains perpendicular to the slope contours discharging concentrated water flows onto the peat surface, and
- A steep road cutting (1(V):2(H) or higher within peat material.

Shear vanes carried out as part of this assessment suggest a high undrained shear strength result for the peat material, with an undrained shear strength value of 21kPa.

The report suggests the failure occurred at the surface interface between the peat material and the underlying mineral soil, likely caused by the water infiltrating the peat surface increasing in porewater pressure and a decrease in effective shear strength at the lower peat boundary.

The report outlines the following: remediation, mitigation, and monitoring:

- Installation of monitoring posts/ sighting lines at the head of the failure scar,
- Clearing of all nearby drains of any debris material to enable draining of the peat material, and
- Installation of a stone buttress at the toe of the failure slope area.

During the site visits, GDG carried out an inspection of the 2012 peat failure area to inspect the current condition of the area. The details and findings of this inspection are outlined in Section 3.1 and 3.2.

2.9 HYDROLOGY

According to the Ordnance Survey Ireland (OSi) shapefile of rivers, lakes and catchments/basins (Figure H- 1, Appendix H), the site is located within the watershed of 4 no. WFD sub-catchments:

- River Roughty
- River Flesk
- River Loo
- River Sullane

The vast majority of the site falls within the catchment of the River Roughty. Further details are outlined in the *Land*, *Soils, Geology & Water* chapters of the EIA report.

2.10 LAND COVER AND LAND USE

According to the Corine Land cover map shown in Figure I- 1 in Appendix I, the surrounding landscape of the Proposed Development site comprises transitional wetland scrubs and blanket peat wetlands, with a small area of pastureland to the southwest of the EIAR Site Boundary. The Proposed Development is planned on the same site as the Existing Kilgarvan Wind Farm.

3 SITE RECONNAISSANCE AND GROUND INVESTIGATION

GDG visited the site on several locations between March 2021 and October 2023 to conduct site walkovers, peat probing and to supervise ground investigation (GI) works being carried out by subcontractors. An indication of the site conditions of bedrock ridges and confined peat patches, along with a generally undulating topography are shown in Figure 3-1 and Figure 3-2.

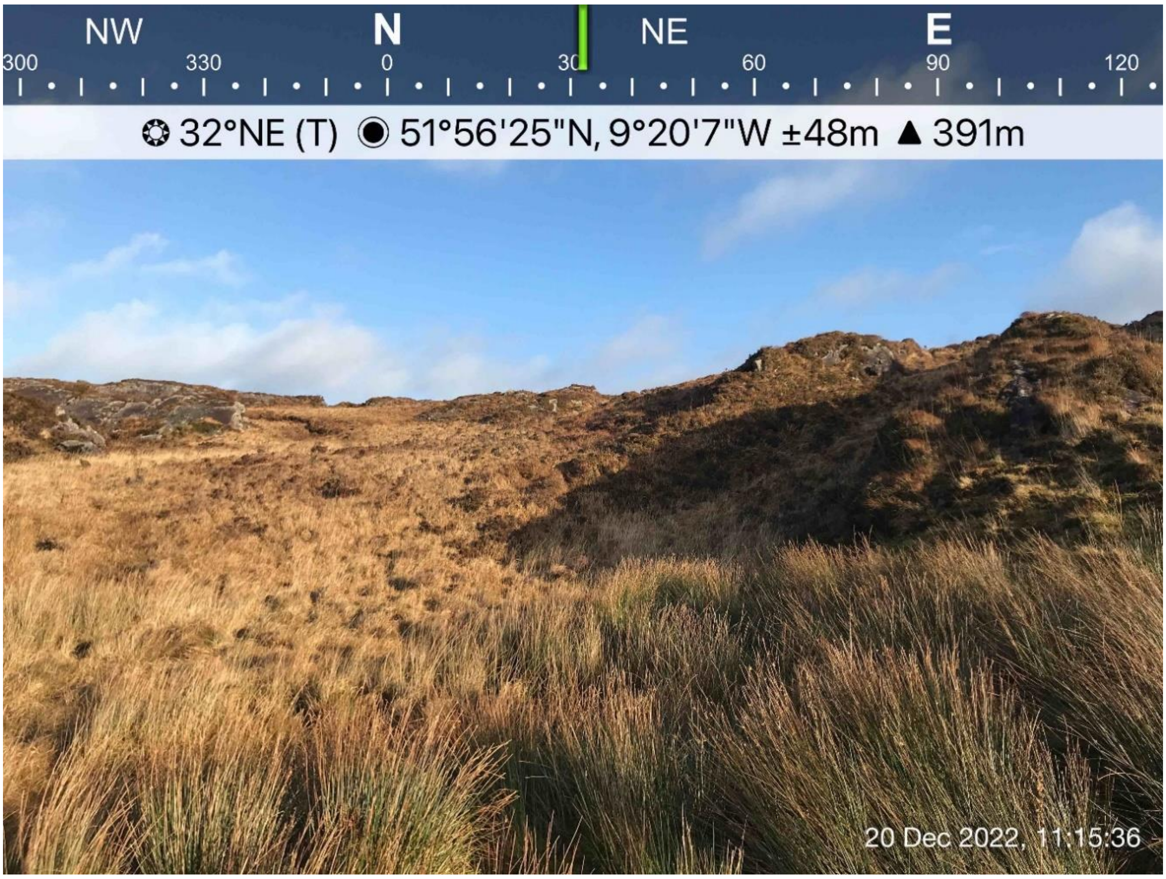


Figure 3-1: Undulating Bedrock and Peat Topography Close to T5.

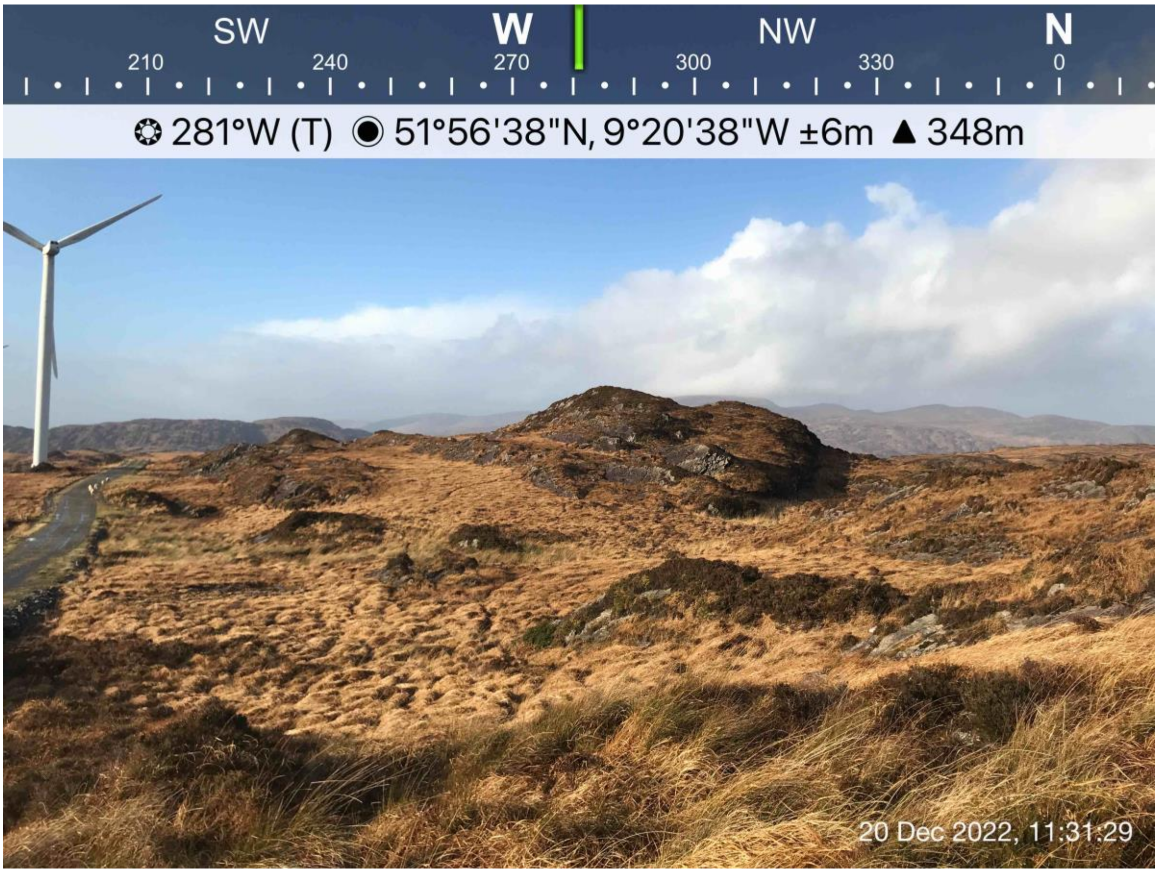


Figure 3-2: Undulating Bedrock and Peat Topography Close to Proposed T6.

The ground investigation (GI) works carried out specifically for this development was carried out between May and January 2023 and consisted of seven ground investigations (GI) carried out on the site:

1. GDG (May 2022): 125 peat probes and 15 shear vanes.
2. MKO (June 2022): 123 peat probes.
3. HES (July 2022): 54 Peat Probes.
4. GDG (August 2022): 57 peat probes, 39 shear vanes and 13 trial pits.
5. MKO (October 2022): 131 Peat probes,
6. GDG (December 2022): 30 peat probes
7. HES (January 2023): 10 peat probes

Previous to the GI carried out specifically for the Proposed Development, there were three separate existing ground investigation projects received from the client related to the design and development of the Existing Kilgarvan Wind Farm:

1. Malone O'Regan McGuillicuddy (2005): *18 trial pits carried out at the Kilgarvan I wind farm site,*
2. MWP (2007): *75 trial pits at the Inchicoosh site,*
3. MWP (2008):*47 gouge core samples and 27 peat probes at the Lettercannon site.*

In summary, a total of 764 intrusive ground investigation locations were used in the assessment of the site conditions. For trial pit logs please see Appendix J.1.

The investigation locations (Figure J- 1 to Figure J- 3 in Appendix J) considered the following criteria:

- Spatial distribution of the proposed infrastructure;
- Distance between probe points to avoid interpolation of peat depths across large distances;
- Changes in slope angle, as peat depths are likely to be shallower on steeper slopes;
- Changes in vegetation, which can reflect changes in peat condition;
- Changes in hydrological conditions; and
- Changes in land use.

No evidence of any previous landslides or peat instability was identified during the walkovers, although a previous instability was recorded in the site records. A further assessment of the area of the 2012 landslide event can be found in Section 3.1.

A raster map was created in GIS software presenting the interpolated peat depth across the site from the peat probe points using the Inverse Distance Weighted (IDW) method. This interpolated raster of peat depth is represented in Figure J- 4 to Figure J- 6 in Appendix J.

Table J- 1 to Table J- 11 in Appendix J present the observations made at the proposed infrastructure.

3.1 INSPECTION OF 2012 PEAT FAILURE AREA

GDG carried out an inspection of the 2012 peat failure area. This inspection carried out in August 2022 was composed of:

- inspection of the peat conditions,
- inspection of the drainage and stone buttress conditions ,
- peat probes, and
- shear vanes.

The inspection was carried out on the 8th of August 2022, following an extended period of hot, dry weather. The conditions observed of the peat may vary largely seasonally or depending on weather, with very dry peat and drainage conditions noted during the inspection.

The following observations were made during the inspection:

- A stone buttress has been constructed on the uphill side of the access road at the failure location (Figure 3-3). This buttress is composed of a coarse granular stone and boulder material and is approximately 1.8m high, extending the full height of the roadside peat cutting.
- Peat depths in the area of the slip vary between 0.8 and 1.8m.
- Shear vane results vary between 8kPa and 24kPa, with an average of 15kPa.

- Some evidence of surface peat cracking and deformation was visible in the area uphill of the stone buttress. It is not apparent is these surface cracks are recent or from the original peat failure.
- Timber posts thought to be monitoring posts were present at the site (Figure 3-4). These are generally spaces approximately 5m apart and appears relatively straight and without large deviation. However, some rows were incomplete and missing posts. It is not defined if these are monitoring posts or if they were installed for another reason such as tree planting or fencing.
- Vegetation is present in the area of the failure and evidence of the failure or subsequent movements may have since disappeared due to vegetation regrowth/coverage.

Figure 3-3: Photo of stone buttress at 2012 peat failure location.

Figure 3-4: Peat surface cracks. Note monitoring posts in background of photo.

3.2 FAILURE INSPECTION CONCLUSIONS

The findings of the peat probes and shear vanes carried out by GDG in August 2022, correlate with those in the AGEC (2013) report. The peat strength appears to be relatively high and indicative of a well-drained peat material.

No evidence of excessive or recent instability was identified during the walkover of the 2012 peat failure area. However, it is noted that vegetation growth may conceal any signs of these instabilities. Some evidence of surface peat crack or tension cracks were identified in the peat. These would allow for percolation of water within the peat body and could aid in the weakening of the peat body.

The stone buttress appears to be well constructed with no evidence of erosion, settlement or damage. The buttress appears of a sufficient strength and height to provide adequate toe support to upslope peat body, while also allowing the drainage of water.

The peat appeared well drained, without flowing water or uncontrolled release of water flows. However, the inspection was carried out following an extended period of dry weather.

4 PEAT STABILITY ASSESSMENT

The peat stability assessment is one of the inputs required for the peat hazard assessment and risk calculation. This section presents:

- A review of the general approaches to assess peat stability;
- The concept of Factor of Safety;
- The methodology adopted for this report and the parameters required; and
- The resulting FoS is used to delineate safety buffers and peat stockpile restricted areas.

4.1 MAIN APPROACHES TO ASSESS PEAT STABILITY

The main approaches for assessing peat stability for wind farm developments include the following:

1. Qualitative geomorphological judgement; and
2. Quantitative assessment:
    a. Empirical probabilistic approach.
    b. Physically based deterministic approach (Factor of Safety - FoS).

Approach 1 is subjective and thus not adopted for this study. Approach 2a is objective and quantitative but is more appropriate for land planning and decisions making studies at a regional scale. Additionally, the method does not provide an engineering indication of physical stability as Approach 2b does.

In this report, the peat stability risk assessment is carried out by using the Approach 2b: deterministic (FoS) approach (Bromhead, 1986).

4.2 THE FACTOR OF SAFETY (FOS) CONCEPT

The factor of safety is a measure of the stability of a slope. For any slope, the degree of stability depends on the balance between the landslide driving forces (weight of the slope) and its inherent shear strength, illustrated in Figure 4-1.

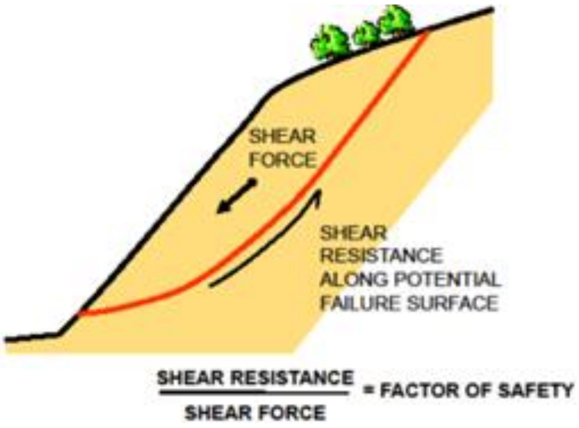


Figure 4-1: Balance of forces in a slope (Scottish Executive, 2017).

Therefore, the factor of safety provides a direct measure of the degree of stability of a slope by the ratio of the shear resistance along a potential surface of failure and the landslide driving forces acting on such surface. Multiple potential surfaces of failure are possible, but the FoS assigned to a slope is that of the surface of failure with the lowest value of FoS.

- FoS < 1 indicates a slope is unstable and prone to fail.
- FoS = 1 indicates a slope is theoretically stable but not safe.
- FoS ≥ 1.3 indicates the acceptable safety threshold. The previous code of practice for earthworks BS 6031:1981 (British Standards Institution, 1981) provided advice on the design of earthworks slopes. It stated that for a first-time failure with a good standard of site investigation, the design FoS should be greater than 1.3. This way, the slope is stable and safe.

As a general guide, the FoS limits for peat slopes assumed in this report are summarised in Table 4-1.

Table 4-1: Factor of Safety limits assumed in this report.

Factor of Safety limits	Slope stability
FoS < 1	Unstable
1 ≤ FoS <1.3	Stable but not safe
FoS ≥ 1.3	Stable and safe

Eurocode 7 (EC7) (IS EN 1997-1:2005) now serves as the reference document and basis for design geotechnical engineering works. The design philosophy used in EC7 applies partial factors to soil parameters, actions and resistances. Unlike the traditional FoS approach, EC7 does not provide a direct measure of stability, as global factors of safety are not used.

Therefore, to provide a direct measure of the peat stability across the site, the previous FoS method has been used for this assessment, rather than EC7 partial factors.

4.3 METHODOLOGY ADOPTED AND PARAMETERS

The stability of a peat slope is dependent on several factors working in combination, namely the slope angle, the shear strength of the peat, the depth of the peat, the pore water pressure and the loading conditions. An adverse combination of these factors could potentially result in peat failure. An adverse value of one of the above-mentioned factors alone is unlikely to result in peat failure. The infinite slope model (Skempton and DeLory, 1957) is used to combine these factors to determine a factor of safety for peat sliding in the Proposed Development area. This model is based on a translational slide, which is a reasonable representation of the dominant mode of movement for peat failures.

To determine the stability of the peat slopes in the Proposed Development area, undrained (short-term stability during construction) and drained (long-term stability during operation) analyses have been carried out.

4.3.1 UNDRAINED CONDITIONS

The undrained loading condition applies in the short-term during construction and until construction induced pore water pressures dissipate.

Undrained shear strength values (c_u) for peat are used for the total stress analysis. Based on the findings of the Derrybrien failure, undrained loading during construction was found to be the critical failure mechanism.

Among the shear strength values obtained by GDG by using the hand shear vane tests in the Proposed Development site, the lowest registered value was 8 kPa. However, based on GDG's experience in the assessment of similar blanket peats and values reviewed in the literature, a more conservative value of 5 kPa has been adopted for the undrained shear strength (C_u). The shear vane testing was carried out in summer and is not considered to be representative of winter undrained conditions.

The formula used to determine the factor of safety for the undrained condition in the peat (Bromhead, 1986) is as follows:

$$F = \frac{c_u}{\gamma z sin\alpha cos\alpha} \qquad \text{Equation 4.3-1}$$

Where,

F = Factor of Safety;

c_u = Undrained strength (5 kPa in the study area);

γ = Bulk unit weight of the material (assumed 10 kN/m^3);

z = Depth to failure plane assumed as the depth of peat (this is the interpolated raster of peat depth); and

α = Slope angle (in each pixel of 1 m. This is obtained from the 1-m DEM provided by BlueSky).

4.3.2 DRAINED CONDITIONS

The drained loading condition applies in the long-term. The condition examines the effect of the change in groundwater level as a result of rainfall on the existing stability of the natural peat slopes.

A drained analysis requires effective cohesion (c') and effective friction angle (ø') values for the calculations. These values can be difficult to obtain because of the disturbance experienced when sampling peat and the difficulties in interpreting test results due to the excessive strain induced within the peat. To determine suitable drained strength values, a review of published information on peat was undertaken. Table 4-2 shows a summary of the drained parameters used in published literature. Based on GDG's experience in the assessment of similar raised peats, and the values reviewed in the literature, it was considered appropriately conservative to use design values below the averages, namely c' = 4 kPa and ø' = 25°.

The formula used to determine the factor of safety for the drained condition in the peat (Bromhead, 1986) is as follows:

$$F = \frac{c' + (\gamma z - \gamma_w h_w)\cos^2\alpha \tan\phi'}{\gamma z \sin\alpha \cos\alpha} \qquad \text{Equation 4.3-2}$$

Where:

F = Factor of Safety;

c' = Effective cohesion (4 kPa);

γ = Bulk unit weight of the material (10 kN/m^3);

z = Depth to failure plane assumed as the depth of peat (this is the interpolated peat depth);

γ_w = Unit weight of water (9.81 kN/m^3);

h_w = Height of the water table above the failure plane (= z i.e.at surface level);

α = Slope angle (in each pixel. This is obtained from the 1-m contour lines provided by the Client);

ϕ' = Effective friction angle (25°).

Table 4-2: Effective cohesion and friction angle values from the literature

Reference	Cohesion, c' (kPa)	Friction Angle, ø'
Hanrahan et al. (1967)	5 to 7	36 to 43
Rowe and Mylleville (1996)	2.5	28
Landva (1980)	2 to 4	27.1 to 32.5
Landva (1980)	5 to 6	-
Carling (1986)	6.5	0
Farrell and Hebib (1998)	0	38
Farrell and Hebib (1998)	0.61	31
Rowe, Maclean and Soderman (1984)	3	27
McGreever and Farrel (1988)	6	38
McGreever and Farrel (1988)	6	31
Hungr and Evans (1985)	3.3	-
Madison et al. (1996)	10	23
Dykes and Kirk (2006)	3.2	30.4
Dykes and Kirk (2006)	4	28.8
Warburton et al (2003)	5	23.9
Warburton et al (2003)	8.74	21
Entec (2008)	3.8	36.8
Komatsu et al (2011)	8	34
Zhang and O'Kelly (2014)	0	28.9 to 30.3

Several general assumptions were made as part of the analysis:

1. Peat depths are based on the maximum peat depths recorded in each probe from the walkover surveys.
2. The slope angles derived from the DEM, as outlined in Section 2.7, accurately represent slope angles on site.
3. The surface of failure is assumed to be parallel to the ground surface.
4. The peat stability is calculated in pixels of 5m across the fringe containing information of peat depth and the proposed infrastructure.

Two surcharging conditions are considered for the stability analysis:

- No surcharging load; and
- Surcharging load of 10 kPa, equivalent to 1 m of stockpiled or side-cast peat.

4.4 FOS RESULTS

The factors of safety obtained for the two different conditions (undrained and drained) and for the two surcharge scenarios (no surcharge and 1 m of peat surcharge) are presented in both table format and map format.

Table K- 1 and Table K- 2 in Appendix K show the FoS calculation process in the proposed turbine sites only for undrained and drained conditions, respectively. The FoS calculation for the rest of the site, i.e. the proposed temporary construction compounds, existing and upgraded access roads, and borrow pit (more than 5000 pixels of 5m), has been carried out semi-automatically in GIS by implementing Equation 4.3-1 and Equation 4.3-2 in the GIS raster calculator.

4.4.1 FOS FOR UNDRAINED CONDITIONS

The spatial distribution of the FoS values calculated for undrained conditions (no surcharge) is shown in Figure K- 7 to Figure K- 9 in Appendix K. At almost every turbine location and construction compound, the pixels exhibit a FoS > 1.3 (green: stable and safe). An isolated small section of the hardstand area for T4 shows a FoS value between 1 and 1.3 (yellow: stable but not safe. This risk area is caused by local factors which have been examined in more detail in Section 4.5.

4.4.2 FOS FOR UNDRAINED CONDITIONS AND SURCHARGE OF 10KPA

Figure K- 10 to Figure K- 12 in Appendix K depict the spatial distribution of the FoS values calculated for undrained conditions and with a 10 kPa surcharge. The 10kPa simulated the placement of 1m of peat material on the ground surface. In terms of factor of safety results, the undrained condition with the 10kPa surcharge is considered to be the critical stability scenario. Almost all of the pixels are shown to be stable and safe (FoS > 1.3, green), but there are some small areas along access roads and, within or beside the hardstands of T1, T2, T5, and T7, which show a FoS value between 1 and 1.3 (yellow: stable but not safe), while T4, T6 T8, and T10 show a FoS of <1 (red: unstable). A small area of FoS <1 (red: unstable) is calculated at the T6 turbine location, however the average FoS across the T6 foundation is >1. These low FoS areas are caused by localised factors which have been examined in more detail in Section 4.5. Where required, additional mitigation, including exclusion zone and peat storage restriction areas have been scheduled which the designer and contractor must adhere to at the construction stage.

4.4.3 FoS FOR DRAINED CONDITIONS

The spatial distribution of the FoS values calculated for drained conditions (no surcharge) is shown in Figure K- 1 to Figure K- 3 in Appendix K. At almost every turbine location and construction compound, the pixels exhibit a FoS > 1.3 (green: stable and safe). A small section of the hardstand area for T4 and T8 shows a FoS value between 1 and 1.3 (yellow: stable but not safe. This risk area is caused by local factors which have been examined in more detail in Section 4.5.

4.4.4 FoS FOR DRAINED CONDITIONS AND SURCHARGE OF 10KPA

The spatial distribution of the FoS values calculated for drained conditions (with a 10kPa surcharge) is shown in Figure K- 4 to Figure K- 6 in Appendix K. A small section of the hardstand area for T4 shows a FoS value between 1 and 1.3 (yellow: stable but not safe. This risk area is caused by local factors such as bedrock outcrop which have been examined in more detail in Section 4.5.

4.5 ASSESSMENT AND INTERPRETATION OF FoS RESULTS

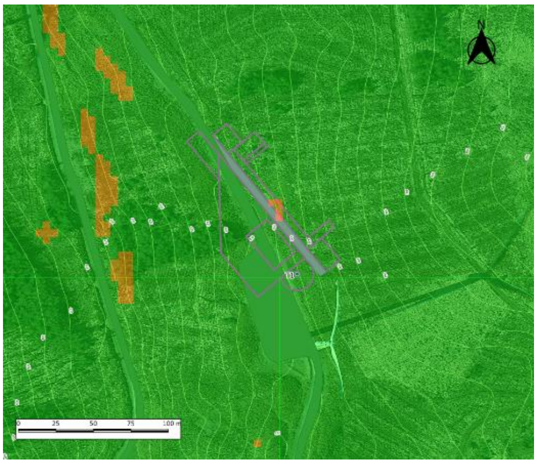
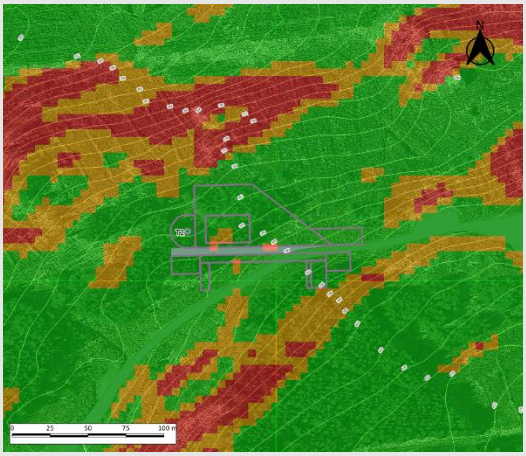
The interpretation of the factor of safety analysis and accurate assessment of the peat stability conditions is a semi-automated approach which combines the developed polygon areas of the FoS results, areas of risk identified during the site walkovers and potential risk areas identified from the examination of peat depths and site topography. It is noted that the results from all FoS analyses (drained/undrained, with and without surcharge) are used, highlighting any areas indicative as having a FoS of less than 1.3 in the worst-case surcharged condition with 10kPa. These areas were then cross examined with the observations from the site visits and topographic models.

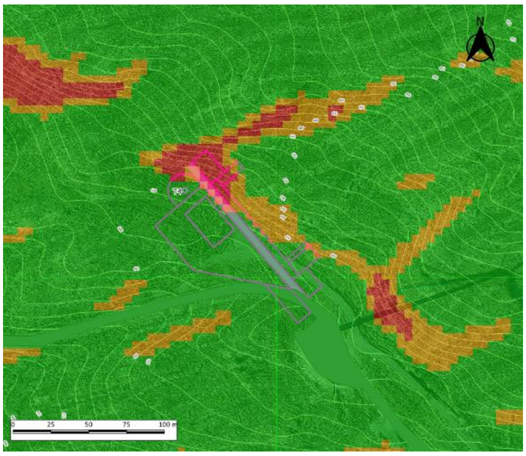
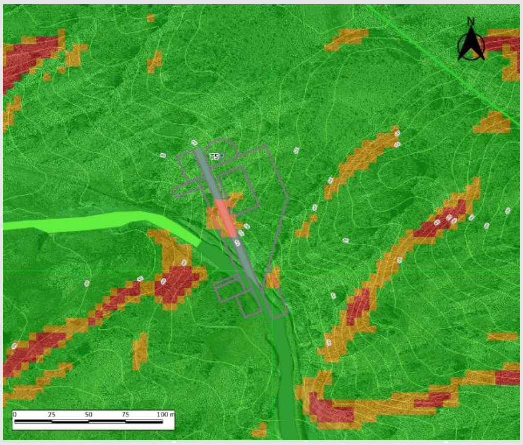
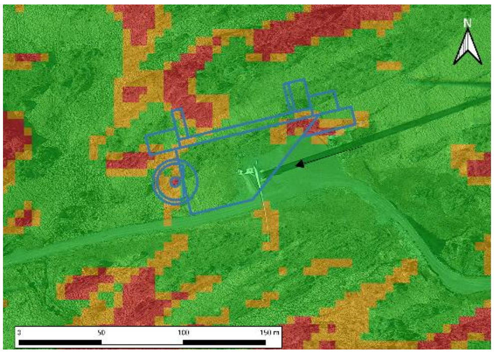
Much of the site at the Proposed Development contains bedrock outcrop which cannot be entirely captured in the FoS model and areas of steep bedrock outcrop may be identified as having a peat instability risk although there is no hazard. For this reason, the locations need to be assessed on site and ‘ground truthed’ to identify true hazards.

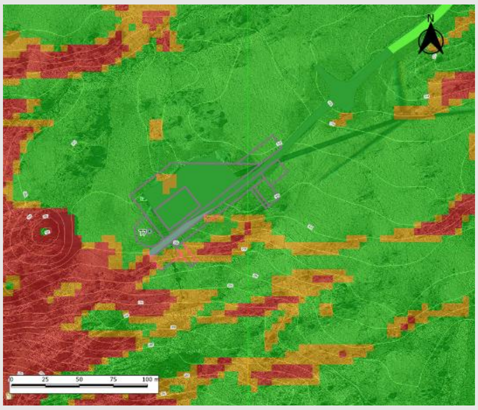
This analysis was used throughout the development process to aid in the citing and design of the Proposed Development layout including turbines, hardstands, and other key infrastructure locations.

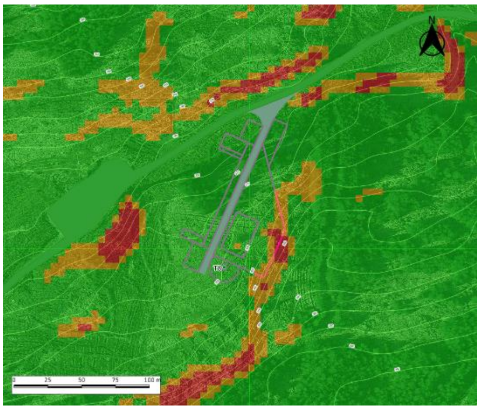
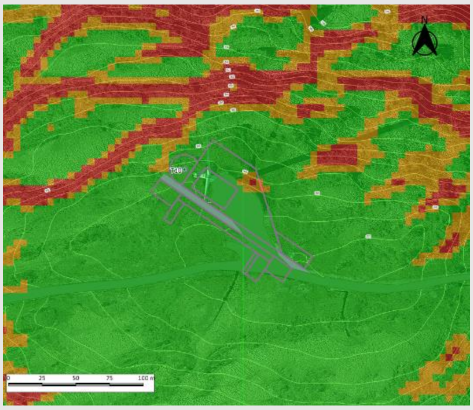
Localised areas where low FoS results (FoS<1.3) are observed at key infrastructure, including turbines T1, T2, T4, T5, T6, T8 and T10, are summarised in Table 4-3. As the undrained conditions is the critical stability case observed at the site, these figures are shown using this scenario. However, the FoS of all elements of the site was examined in both the drained and undrained conditions.

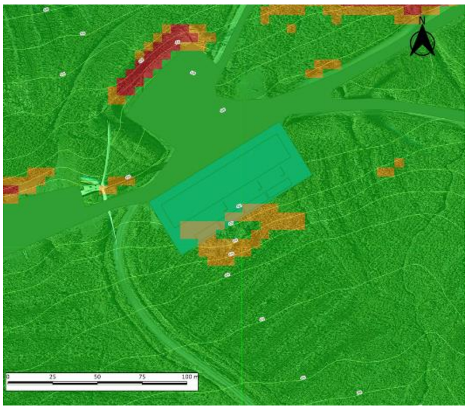
Table 4-3: Low FoS results at key infrastructure.

Location	Risk and mitigation	Undrained surcharged FoS analysis
T1	The area at the hardstand for T1 suggests a FoS <1.3 with the application of a surcharge. This instability is caused by local variation in the slope in an area of little to no peat (>0.5m depth). Having inspected the site during a site walkover, this is not all considered to be a true risk area. The area surrounding Turbine 1 is thought to be suitable for construction and diligent peat reinstatement.	
T2	The area at the hardstand for T2 suggests a FoS <1.3 with the application of a surcharge. The low FoS results here are caused by a localised area of deep peat (~2m). Much of the hardstand area is proposed for excavate and replace, so should be stabilised by excavating to a bearing strata. The area downslope of the T2 hardstand indicates a Factor of safety results <1.3 and <1.0 with surcharge. This is due to a steep gradient and variable peat depths of 0m to 1.2m. This area could be vulnerable to propagated landslide with a large clear fetch area. However, the area 10m E of the hardstand and turbine area suggest placement of 1m of peat material is suitable. The area surrounding Turbine 2 is thought to be suitable for construction and diligent peat reinstatement.	

Location	Risk and mitigation	Undrained surcharged FoS analysis
T4	The area at the hardstand for T4 suggests a FoS <1 with the application of a surcharge, and a FoS of <1.3 without surcharge. The lower FoS results here are caused by an existing localised steep bedrock slope face to the north of the hardstand, and a localised area 1.7m to 2m of peat in the northern margins of the hardstand area. The peat here is topographically contained within areas of bedrock outcrop and existing founded road. The peat in these areas will be excavated to a competent stratum for the construction of the hardstand platform, thus eliminating the hazard.	
T5	The area at the hardstand for T5 suggests a FoS <1.3 with the application of a surcharge. The lower FoS results here are caused by a localised bedrock ridge with steeply sloping sides. Having inspected the site during a site walkover, this is not all considered to be a true risk area. The area surrounding Turbine 5 is thought to be suitable for construction and diligent peat reinstatement.	
T6	The area around the T6 turbine foundation is highly sensitive, indicating a factor of safety of <1 with the application of surcharge in a small number of pixels. The area of instability is indicated by locally thick peat coverage and steep slopes to the west of the existing hardstand area. The area west of the turbine is a locally deep	

Location	Risk and mitigation	Undrained surcharged FoS analysis
	area of thick peat, on top of bedrock. The peat in these areas will be excavated to a competent stratum for the construction of the hardstand platform, thus eliminating the hazard. However, due to the locally steep ground gradients and the potential for a propagating peat landslide downslope of this, the storage of peat material should be restricted at the western, downslope side of the T6 turbine and hardstand area.	
T7	The area at the south end of the hardstand for T7 suggests a FoS <1.3 with the application of a surcharge. The lower FoS results here are caused by steep bedrock slopes, and a small area of local pocket of peat (1m in depth) in a topographical hollow close to the existing hardstand area. The peat in these areas will be excavated to a competent stratum for the construction of the hardstand platform, which should negate the risk at the turbine location. However, due to the steep ground gradients and the potential for a propagating peat landslide downslope of this, the storage of peat material should be restricted at the southern, downslope side of the T7 turbine and hardstand area.	

Location	Risk and mitigation	Undrained surcharged FoS analysis
T8	The area at the eastern section of the hardstand for T8 suggests a FoS <1 with the application of a surcharge. The low FoS results here are caused by a localised area of deep peat (~1.9m), and a locally steep slope, which a site walkover confirmed was largely bedrock at the surface. The peat in these areas will be excavated to a competent stratum for the construction of the hardstand platform. **Due to the steep nature of the topography, the storage of peat material should be restricted at the eastern, downslope side of the T8 turbine and hardstand area.**	
T10	The area at the northeastern edge of the hardstand for T10 suggests a FoS of <1with the application of surcharge. The low FoS results here are caused by local peat depths of ~1m, along with a locally steep bedrock slope. The hardstand area is predominantly located on the existing turbine hardstand and surrounding shallow bedrock. **Due to the steep nature of the topography, the storage of peat material should be restricted at the northern slopes of the T10 turbine and hardstand area.**	

Location	Risk and mitigation	Undrained surcharged FoS analysis
Eastern temporary construction compound	The southern section of the eastern construction compound suggests a FoS of <1.3 with the application of surcharge. The lower FoS results here are caused by a localised bedrock and engineered fill slope from the existing road and hardstand. Having inspected the site during a site walkover, this is not all considered to be a true risk area. The area surrounding the eastern temporary construction compound is thought to be suitable for construction and diligent peat reinstatement.	

4.6 SAFETY BUFFERS AND STOCKPILE RESTRICTIONS

From the site reconnaissance and the calculations of the FoS for the peat slopes, two safety buffers and four main peat stockpile restriction (PSR) areas are proposed. It is noted that the results from the various analyses carried out often identified the same areas as having a FoS < 1.3.

4.6.1 SAFETY BUFFER AREAS

Safety Buffer zones are areas identified during the development phase of the wind farm which are highlighted as possessing a potential instability risk. The development of the safety buffer zones is a semi-automated approach which combines the developed polygon areas of the FoS results, areas of risk identified during the site walkovers and potential risk areas identified from the examination of peat depths and site topography. It is noted that the results from all FoS analyses (drained/undrained, with and without surcharge) are used, highlighting areas indicative as having a FoS < 1.3 in the worst-case surcharged condition with 10kPa. This analysis was used throughout the development process to aid in the siting and design of the Proposed Development layout and ensuring that turbines, hardstands, and other key infrastructure locations are only developed in stable and safe locations.

In addition to the semi-automated FoS-derived safety buffer zones, some features were highlighted during site visits and site reconnaissance which were added to the buffer areas. These features include:

- The area surrounding the 2012 landslide; GDG have reviewed the existing appraisal of the landslide area and in August 2022 carried out a site assessment of the area. The findings of the original landslide appraisal report (AGEC, 2012) are summarised in Section 2.8.1 of this report, and the findings of GDG's assessment are in Section 3.1 of this report. The AGEC (2012) report suggest that some of the potentially disturbed material has been left insitu and that the previous slip surface of the slide may still remain being supported by the stone buttress. GDG suggest that no works be carried out directly in the area of the 2012 landslide and the reinstatement buttress at the toe of the slope.

- The area of quaking and or buoyant bog identified southwest of turbine T6. This area has an existing floated road insitu across a locally deep peat body above the small lake waterbody (Lough Nabirria). Although no further excavation or loading is proposed for this area as part of the Proposed Development, the area has been highlighted as sensitive to instability and a peat and plant safety buffer area has been suggested here.

Where the Proposed Development layout and the safety buffer zone have overlapped or are in close proximity further assessment of the localised risk has been assessed as outlined in Table 4 and where required further mitigation measures have been scheduled such as peat storage restriction areas.

Outside of the Proposed Development layout, where construction is not required as part of the Proposed Development, the safety buffer areas should be treated as peat storage and plant restriction areas and construction activities should not be carried out in these areas without further assessment.

Safety buffer areas are outlined Appendix L, Figure L- 1 to Figure L- 3.

4.6.2 PEAT STORAGE RESTRICTION ZONES

Although the peat stability results and safety buffers have been considered in the design of the wind farm infrastructure, there are some locations where construction is required within a safety buffer zone. The stability assessment results at these locations suggest FoS values <1.3 in the surcharged scenario only and have FoS results >1.0 in the analysis without the surcharge. This suggests that the areas are of a low instability risk in their natural state but are unsuitable for the storage of peat or other materials.

Peat and over burden storage restriction (PSR) areas are identified at some access roads and in areas at or adjacent to some turbine hardstands. The location of peat stockpile restriction areas are shown in Figure L- 1 to Figure L- 3 in Appendix L

Locations where PSR areas are identified are as follows:

- Area west and downslope of Turbine 6 turbine and hardstand areas,
- Area east and downslope of Turbine 8 turbine and hardstand areas,
- Area north and downslope of Turbine 10 turbine and hardstand areas,
- Area surrounding section of new road adjacent to the location of the 2012 landslide, and
- Areas of sloping planar bedrock outcrop. Peat should not be placed on planar faces of bedrock outcrop as this will provide little friction resistance, particularly following periods of rainfall, and could create a slip face at the peat bedrock boundary.

Outside of the Proposed Development layout, where construction is not required as part of the Proposed Development, the safety buffer areas should be treated as peat storage and plant restriction areas and construction activities should not be carried out here without further assessment.

5 PEAT STABILITY RISK ASSESSMENT

A peat stability risk assessment (PSRA) is carried out at each of the proposed structures taking into consideration the landslide hazard probability and potential consequences at each location. The production of a PSRA for the access road is not possible as it is a linear structure, but the same considerations were used in the design and assessment of the stability of the access road alignment.

5.1 RISK DEFINITION

Risk is the potential or probability of adverse consequences, including economic losses, environmental or social harm or detriment. Risk is expressed as the product of a hazard (e.g., peat landslides) and its adverse consequences (Lee & Jones, 2004; Corominas et al., 2014) (Equation 5.1-1). Some use approximate synonyms and refer to risk as the product of the likelihood and the impact or the product of susceptibility and the exposure.

$$\text{Risk} = (\text{Hazard}) \times (\text{Adverse Consequences}) \qquad \text{Equation 5.1-1}$$

5.2 GENERAL METHODS FOR RISK ASSESSMENT

There are various levels of risk assessment, ranging between:

- Detailed quantitative risk assessments (QRA) where the objective is to generate more precise measures of the risks (e.g., expressing risk as a specific probability of loss). These require a large amount of quantitative input and time; and

- High-level qualitative assessments where the objective is to develop an approximate estimate of the risks, particularly in relative terms (e.g., low, medium and high levels of risk).

Qualitative risk assessments are typically used for PSRA reports, given the availability of information and the time frame. To apply Equation 5.1-1, the quantitative information (e.g., FoS) and the qualitative information (e.g. geomorphic observations relevant to the stability of peat) that determine the hazard and the consequences need to be transformed into subjective ratings. The following sections address the calculation of the two risk components: hazard and consequence.

5.3 HAZARD ASSESSMENT

Landslide hazard is the likelihood or probability of landslide occurrence in each location and a given period. The likelihood or hazard of peat landslides has been determined according to the guidelines for geotechnical risk management given by Clayton (2001), taking into account the approach of MacCulloch (2005) and using the available data from the desk study, site reconnaissance and site investigations.

The hazard is calculated from a variety of weighted factors, including the FoS and thirteen secondary factors related to geomorphic observations, topography, hydrology, vegetation, peat workings, existing loads and slide history (Appendix M). These secondary factors are difficult to quantify in a stability calculation but may contribute to peat instability.

In accordance with the Scottish Guidance (2017), each hazard factor has been reclassified into one of four classes with rating values ranging from 0 to 3 (Appendix M). A rating of 0 indicates that the hazard factor is not relevant; ratings 1, 2 and 3 indicate low, moderate and high correlation to peat slide hazard, respectively.

Weighting values have been assigned to these factors to reflect their relative importance in peat stability. Both the rating and the weighting values have been assigned according to the expert criteria of the project team and are presented in Appendix M. The hazard score of each factor is the multiplication of its rating value and weight value. These factors and their corresponding weightings are presented in Table 5-1.

The hazard values for a given wind farm element are the sum of the scores of all the hazard factors divided by the maximum hazard value possible to obtain a normalised hazard value ranging from 0 to 1 (see tables in Appendix M). Hazard is grouped into four categories: Negligible, low, medium and high.

Table 5-1: Factors affecting peat stability and hazard.

Hazard factors			Role in peat stability	Weight
Factor of Safety			This is the most critical factor, including the slope angle, the peat depth, the peat density, the peat cohesion in the drained and undrained conditions, as well as the effective friction angle. This is the complete factor. See Section 4.2 for further details.	10
Secondary factors	Topography	Curvature Plan (across the slope)	This represents the curvature across the slope and the funnelling / dispersion of the runoff.	1
		Curvature Profile (downslope)	This represents the curvature down-slope and, therefore, the capacity of water retention and infiltration. Convex slopes are typically more prone to landslides.	
	Hydrology	Distance from watercourse (m)	This tends to affect the likelihood of landslides, especially in sectors where this distance is short.	
		Moisture index (NDMI)	This Landsat-derived factor indicates the water content or moisture of the vegetation, which can be considered as a proxy of the terrain moisture.	

Hazard factors			Role in peat stability	Weight
		Evidence of piping	The presence of piping is clear evidence of potential peat instability.	
		The direction of existing drainage ditches	Drainage ditches that are aligned cross slope can affect the overall stability of a slope face.	
	Vegetation	Bush	This is an indicator of the type of peat at the site and the hydrological nature of the site.	
		Forestry	The vigour of forestry is another indicator of peat stability, with stunted trees more frequent in unstable sectors.	
	Peat workings	Peat cuts presence	This factor evaluates the effect of various peat workings on the stability of the peat.	
		Peat cuts vs contour lines	Where the peat cuts parallel the contour lines, the potential instability increases.	
	Existing loads	Roads	Side-cast of solid roads and floating roads pose a load to the peat blanket.	
	Slide history	Distance to previous slides (km)	This suggests that landslides at the site are likely if a peat slide has occurred at the site or within a 10-kilometre radius. The weight assigned is doubled the weights for the other secondary factors	2
		Evidence of peat movement (e.g. tension cracks, compression features).	This factor evaluates the effect of any existing peat movement indicators on-site, such as tension cracks. The weight assigned is doubled the weights for the other secondary factors	

5.4 ADVERSE CONSEQUENCES ASSESSMENT

The impacts of peat landslides on the wind farm elements, surrounding environment, and existing assets may typically generate a variety of adverse consequences. This report assessed these consequences qualitatively following the Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments (Scottish-Executive, 2017).

Table 5-2 summarises the consequences considered for the PSRA of the Proposed Development.

Table 5-2: Consequences considered for the PSRA.

Consequence factors	Description	Weight
Volume of potential peat flow (function of distance from the nearest watercourse and peat depth in the area)	This is the second most heavily weighted factor. It is estimated based on the distance from the nearest defined watercourse and the depth of peat in the area. The longer the distance and the deepest the peat depth, the larger landslide.	3
Downslope features	This factor accounts for the type/shape of downslope features that may hamper or favour the propagation downhill of the peat flow.	1
Proximity from the defined valley (m)	This is the distance from the site to the nearest defined river valley. Rivers close to potential landslide sectors are more vulnerable to a landslide event.	
Downhill slope angle	This factor accounts for the runout distance as a matter of slope angle.	
Downstream aquatic environment	Reflects the severity of a peat slide event's impact on the receiving aquatic environment.	
Public roads in the potential peat flow path	Rates the impact of a peat slide striking a public road.	
Overhead lines in the potential peat flow path	Rates the impact of a peat slide striking a service line.	
Buildings in the potential peat flow path	Rates the impact of a peat slide striking a habitable structure.	
Capability to respond (access and resources)	Rates the capability of the site staff to respond to a peat instability event.	

The nine consequence factors considered have been reclassified in the same fashion the hazard factors were reclassified (Appendix M). A rating of 0 indicates that the consequence factor is not relevant and a rating of 3 indicates high consequences.

‘Volume of potential landslide’ has been assigned a weight of 3 to reflect its relative importance in the potential consequences. The rest of the factors have been assigned a weight of 1. Both the rating and the weighting values have been assigned according to the expert criteria of the project team.

The score of each consequence factor is the multiplication of its rating value and its weight value (Appendix M).

The consequences value for a given wind farm element is the sum of the nine consequences scores. This total value is then divided by the maximum consequence value possible to obtain a normalised consequence value ranging from 0 to 1 (see tables in Appendix M). Consequences are grouped into four categories: Negligible, low, medium and high.

5.5 RISK CALCULATION

Risk in each wind farm infrastructure element is calculated with Equation 5.1-1, i.e. multiplying the scores of the hazard and the scores of the consequences. The risk rating ranges between 0 and 1, and the following levels of risk rating have been distinguished (Figure 5-1 and Figure 5-2):

- High (0.6 to 1): Avoid project development at these locations. Mitigation is generally not feasible.
- Medium (0.4 to 0.6): Project should not proceed unless risk can be avoided or mitigated at these locations without significant environmental impact to reduce risk ranking to low or negligible.
- Low (0.2 to 0.4): Project may proceed pending further investigation to refine assessment and mitigate hazard through relocation or re-design at these locations.
- Negligible (0 to 0.2): Project should proceed with monitoring and mitigation of peat landslide hazards at these locations as appropriate.

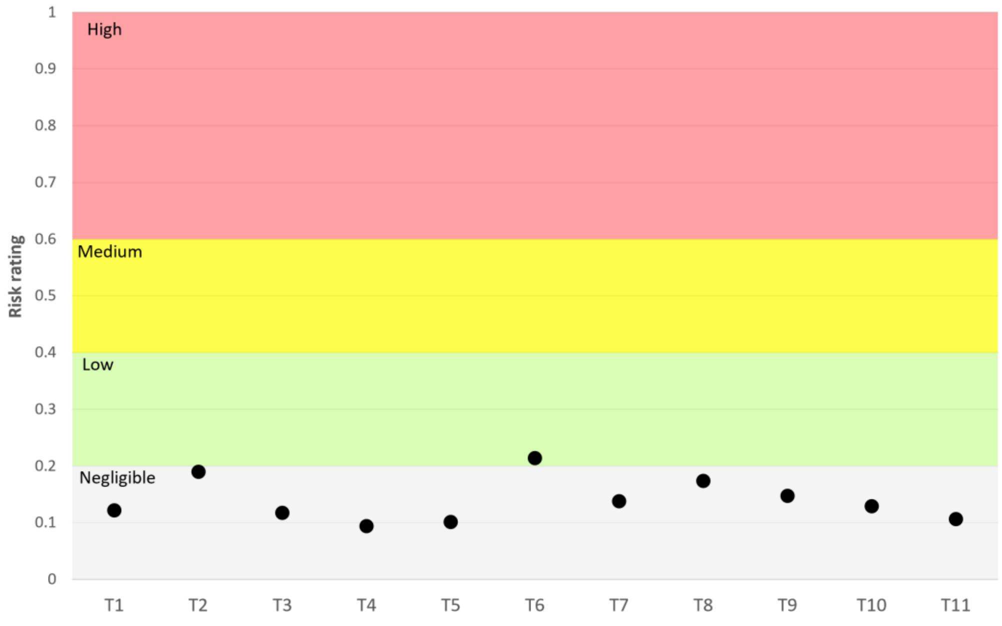


Figure 5-1: Risk ratings at the proposed turbine locations.

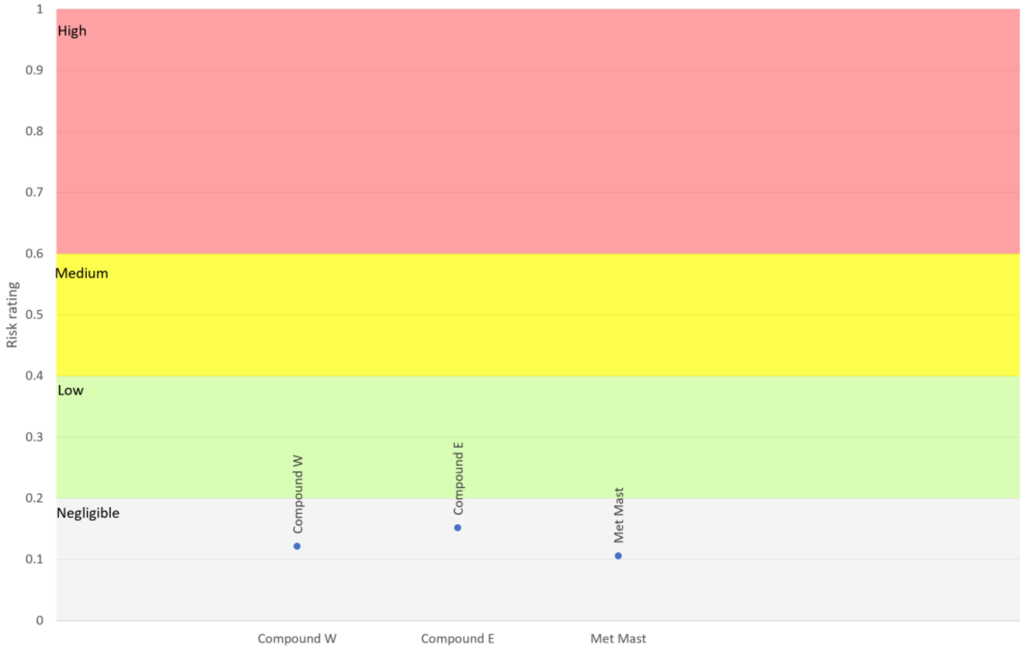


Figure 5-2: Risk ratings at the proposed infrastructure element sites.

Appendix M gathers the risk calculation process at each turbine considering the four scenarios of hazard: Undrained; undrained with a surcharge of 1 m; drained; and drained with a surcharge of 1 m. Figure 5-1 and Figure 5-2 summarise the risk rating obtained at the turbines and compound locations. All the turbines and compounds aside from T06 are located in sectors of negligible risk. T06 is in an area of low risk. This is still considered to be an acceptable risk rating and the project may proceed pending further investigation to refine assessment and mitigate hazard through detail design at the location.

It is stressed that the resulting risk rating does not indicate a probability of losses due to landslides; it simply expresses a rating.

6 GEOTECHNICAL RISK REGISTER

Table 6-1: Geotechnical Risk Register.

Ref.	Hazard	Risk	Mitigation
1	Overestimation of soil strength parameters	The collapse of the dried peat berm/ peat slippage	The soil parameters are based on the hand shear vane test carried out by GDG at each turbine location. Shear vane testing was carried out at 0.5m intervals through the peat to assess variation within the peat body. The interpreted undrained shear strength values take into account a conservative reduction factor for the influence of the fibres within the peat. Extensive sampling ground investigation at infrastructure location including trial pitting and

Ref.	Hazard	Risk	Mitigation
			Russian coring to assess the composition and strength of the peat and collect samples for testing. The derived values were compared with a literature review of the most common general drained and undrained parameters for each type of soil and on the descriptions. It is expected that further testing and assessment of the peat during further ground investigation campaigns will be required before construction. This will allow for a robust understanding of the ground conditions and the detail design of access roads and structures. An extensive testing protocol should be developed by Construction stage contractor and the design team. These tests shall be observed by a suitably qualified engineer and reported to the owner's engineer. It would be expected that an observational approach will be required when constructing on peat due to the limitations associated with testing and verifying its strength and the contractor is required to frequently inspect the peat material and providing proof of inspection.
2	Underestimation of peat depth	The collapse of berm/peat slippage	Extensive ground investigation including trial pitting and peat probing has been carried out across the site. GI locations have been carried out at location where access was possible. Access was limited to some areas of the site with restriction relating to forestry and terrain limiting coverage. Due to the rapid local variation from bedrock to deep peat and the overall size of the site, it is possible that some patches of either shallow or deep peat may have been missed by the GI undertaken up to present. Further GI will be required at these locations during the detail and construction stage to assess peat depths. This will be carried out by the detail designer and Contractors team. The design team shall develop their own testing criteria to satisfy and de-risk the possibility of larger peat depth occurring at these locations.
3	Failure to identify existing instability/ peat deformation at the site	Failure of peat slope due to loading or agitation of existing instability	Assessment of satellite imagery and topographical data for evidence of past landslide events was carried out as part of the desk study, finding no evidence of past instabilities or landslide events within the site area. The Geological Survey of Ireland (GSI) landslide database was examined identifying several landslide events in the local

Ref.	Hazard	Risk	Mitigation
			region within 5km of the site, the closest approx. 400m from the EIAR Site Boundary and 1km from the nearest turbine, turbine 11. A report was provided by the client investigating a landslide event within the site, which has since been mitigated. The findings of this are outlined in the report and are considered in the assessment at this site. During the site walkovers the site GDG engineers examined the landscape and the areas surrounding the proposed infrastructure for evidence of instability or past landslide events. No additional past landslide or instability events were identified. Although there is no additional evidence of landslides within the Proposed Development site, this does not necessarily mean that landslides have never occurred at the site. It is noted that the geomorphological features associated to peat landslides (peat slides and bog bursts) are softened with time through erosion, drying and re-vegetation, particularly given the forestry and harvesting activities which have taken place at this Site. Access was limited to some areas of the site with restriction relating to dense forestry and terrain limiting visibility and inspection areas. Further inspection will be required during the detail design and construction stage to inspect for peat instabilities. This will be carried out by the detail designer and Contractors team. The design team shall develop their own inspection and testing criteria to satisfy and de-risk the possibility of larger peat depth occurring at these locations.
4	Failure due of excessive loading of peat	The collapse of peat berm/peat slippage	The peat stability analysis factor of safety exercise examines the peat in the drained and undrained condition both without and with the addition of a surcharge equating to 1m of peat loading. Areas indicative of a low or moderate FoS result with the 1m peat surcharge within or adjacent to the proposed infrastructure have been designated as peat storage restriction (PSR) areas as outlined in Section 4.6. Requirements for the safe and sustainable storage of peat material are outlined in the associated Peat management Plan (PMP) document (GDG,2023).

Ref.	Hazard	Risk	Mitigation
			The requirements and restrictions for peat storage outlined in this document must be adhered to during the construction stage.
5	Variation in the ground water conditions at the site	Instability of peat slippage	The ground water conditions were examined during the walkovers and within the trial pit locations. Areas of saturated surface peat were identified during the walkovers as outlined in Section 4 and these have been considered in the risk assessment and findings of the report. Water strikes, peat water content and groundwater conditions are noted in the trial pit locations (GDG, 2022). The groundwater conditions and peat moisture content may vary seasonally and/or more frequently with the immediate weather conditions. Long term groundwater monitoring across should be considered in further design stage ground investigations and further lab testing of the peat in its insitu condition will need to be assessed for the construction design.

7 CONCLUSIONS AND RECOMMENDATIONS

Following the guidance of the Scottish-Executive (2017), a review of the published thematic geographic information (e.g. geology, soils, protected areas) and relevant background literature was undertaken for the Proposed Development. The available desk information such as the topographic models (Bluesky, 2018) and Geological Survey of Ireland quaternary soils mapping and landslide susceptibility datasets (GSI, 2023) would suggest that the area is moderate to highly sensitive to landslide and peat failures. Site reconnaissance and site investigations were carried out to validate and enhance the desk study information. Based on the revision of the available data, the fieldwork and GDG's professional judgement, it is concluded that peat slides are unlikely on the site with diligent peat management and careful consideration of the peat conditions at the site at the design and construction stage.

A deterministic Factor of Safety was calculated across the proposed element locations, and from this, a robust peat stability risk assessment (PSRA) was performed. The findings of the peat assessment showed that the site has an acceptable margin of safety and is suitable for the proposed turbine locations.

GDG carried out a desk and site-based assessment of a previous landslide at the site which occurred in October 2012. A forensic report carried out following the landslide (AGEC, 2012) suggests that there were several contributing factors to the landslide mainly, excessive rainfall over a short period of time, uncontrolled release of water from V-notch drains upslope of the failure location and, a steep existing road cutting into an area of natural steep sloping ground (ca.8 degrees). The 2012 instability as stabilised with the placement of a stone buttress and a monitoring campaign. GDG suggests that no construction activities be carried out in the area of the 2012 landslide and that the existing stone buttress remain undisturbed.

The peat stability risk for the proposed infrastructure is low to negligible. However, the results of the factor of safety deterministic calculation and the site walkover allowed for the identification of safety buffers and peat stockpile restriction (PSR) areas outlined in Section 4.6 and shown in Appendix L. These must be adhered to in future stages of the Proposed Development.

All earthworks shall be designed by a competent geotechnical designer which shall be informed by a detailed ground investigation.

Construction works shall follow the recommendations of the Peat Management Plan, reference; Appendix 4-2. During construction, it is strongly recommended to carry out frequent monitoring works, especially after heavy rainfall events or prolonged rainfall.

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Zhang, L., & O'Kelly, B. C. (2014). The principle of effective stress and triaxial compression testing of peat. *Proceedings of the Institution of Civil Engineers-Geotechnical Engineering*, *167*(1), 40-50.

Appendix A LOCATION AND ADMINISTRATIVE LIMITS

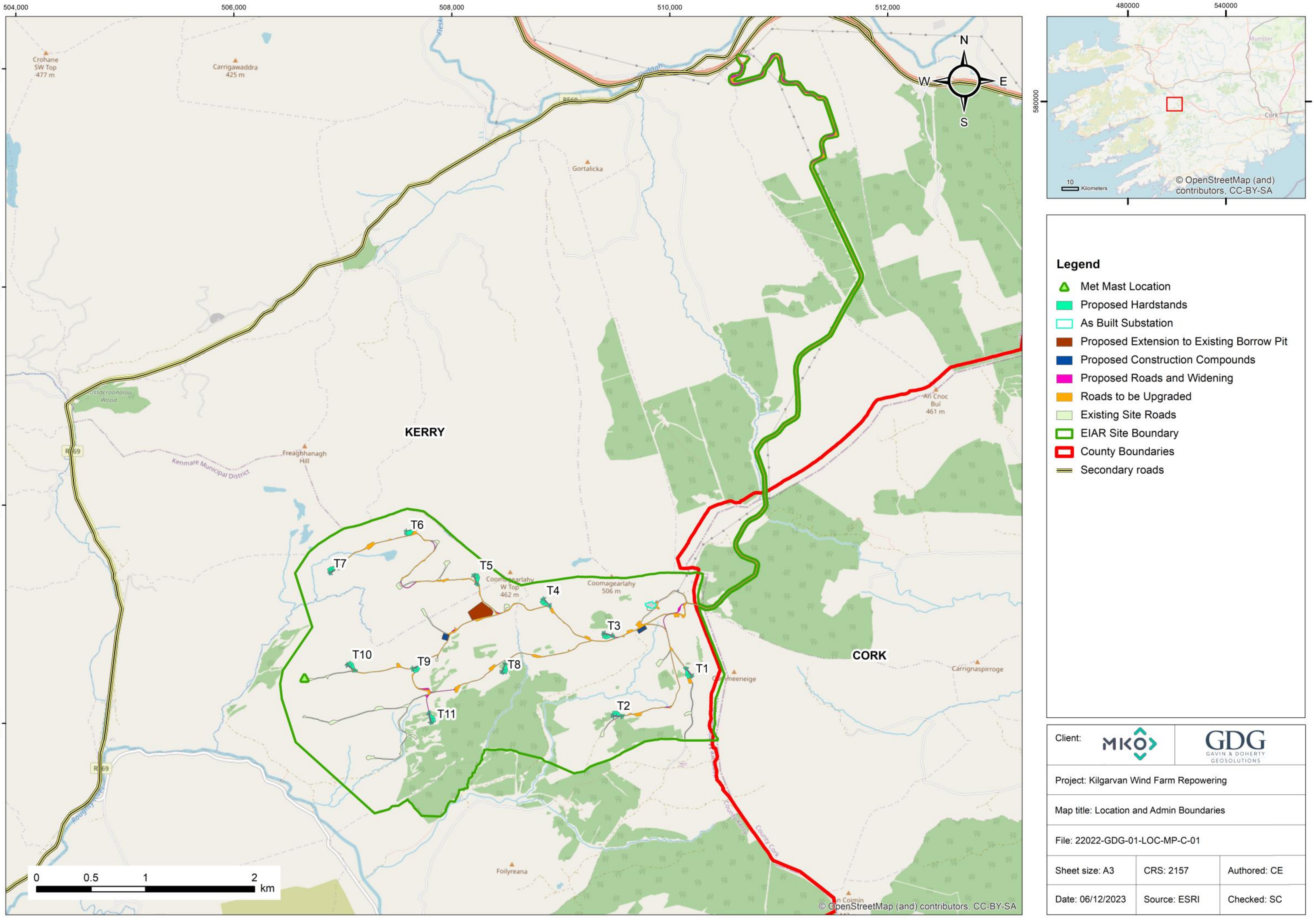


Figure A-1: Site location and Admin Boundaries

Appendix B GEOLOGY

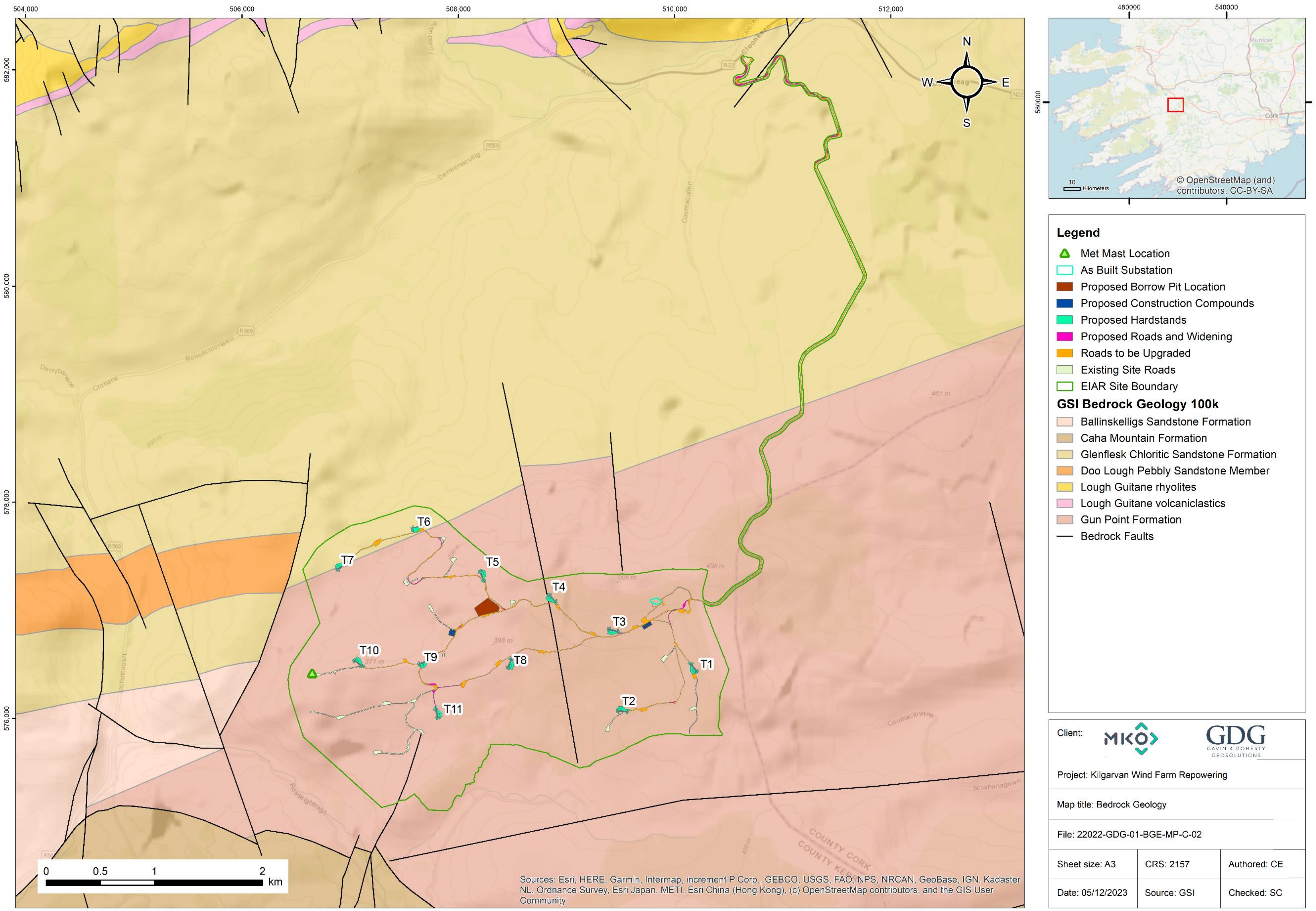


Figure B- 1: Bedrock Geology.

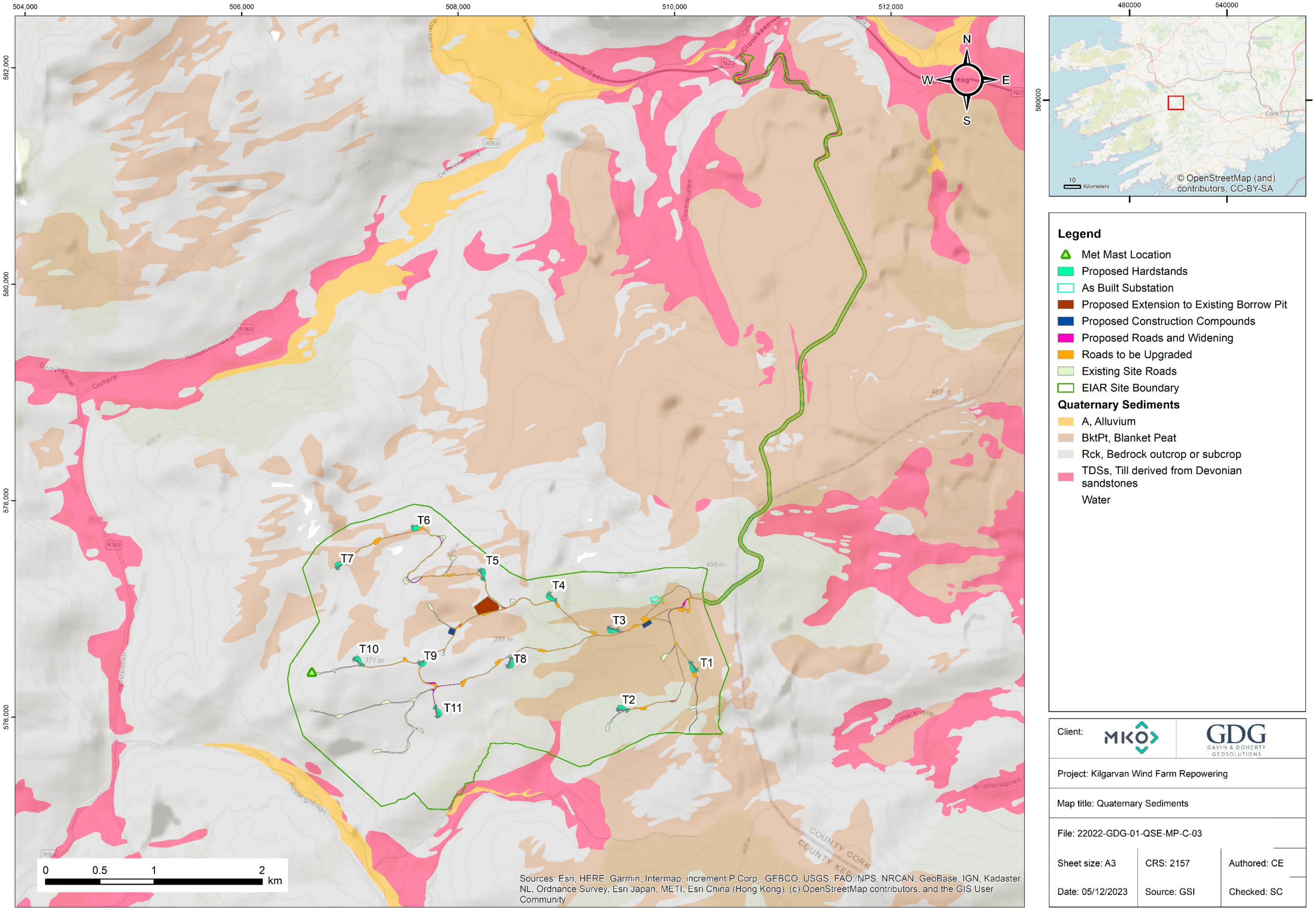
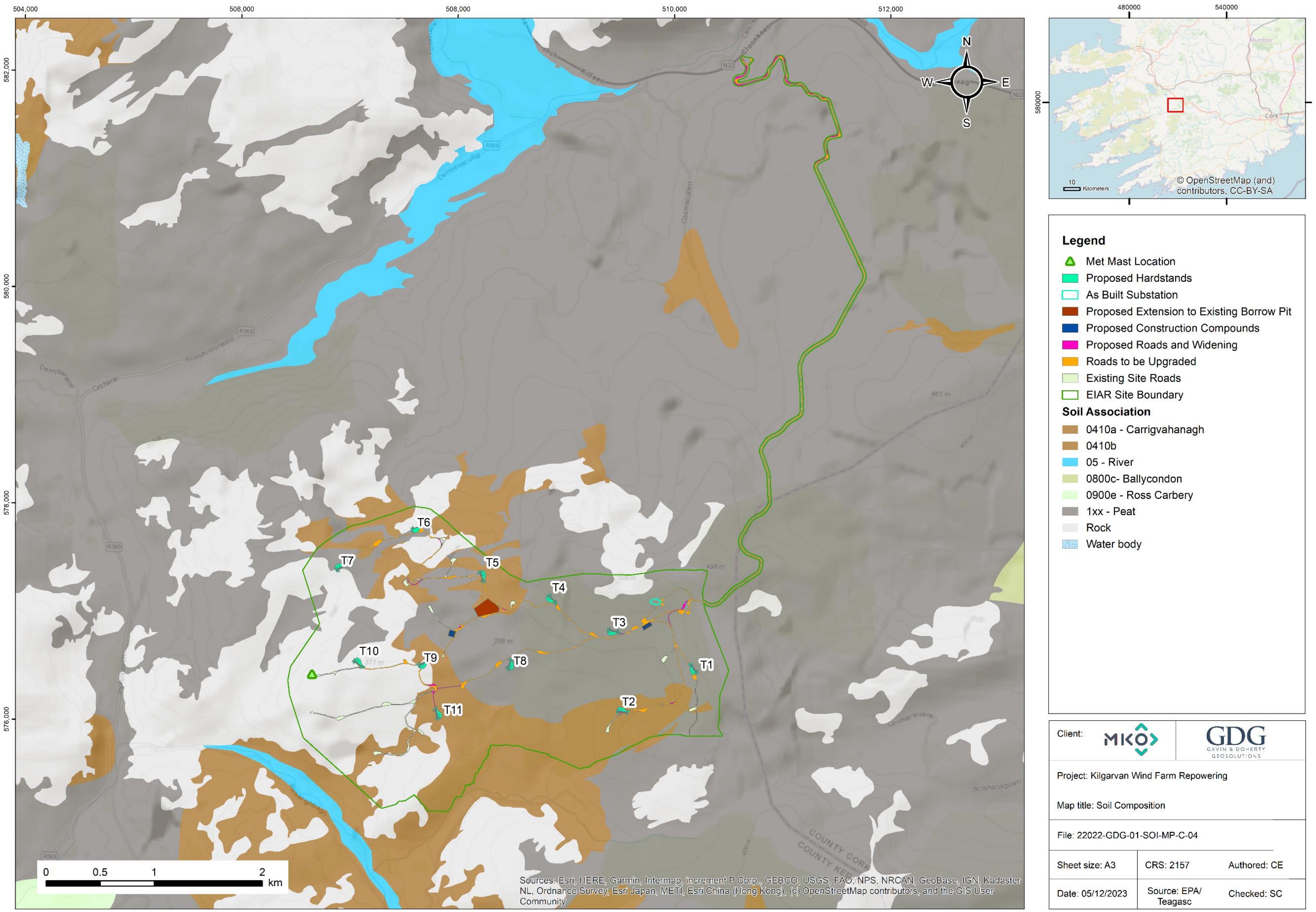


Figure B- 2: Quaternary Sediments.

Appendix C SOILS



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Figure C- 1: Soil Composition.

Appendix D MOISTURE

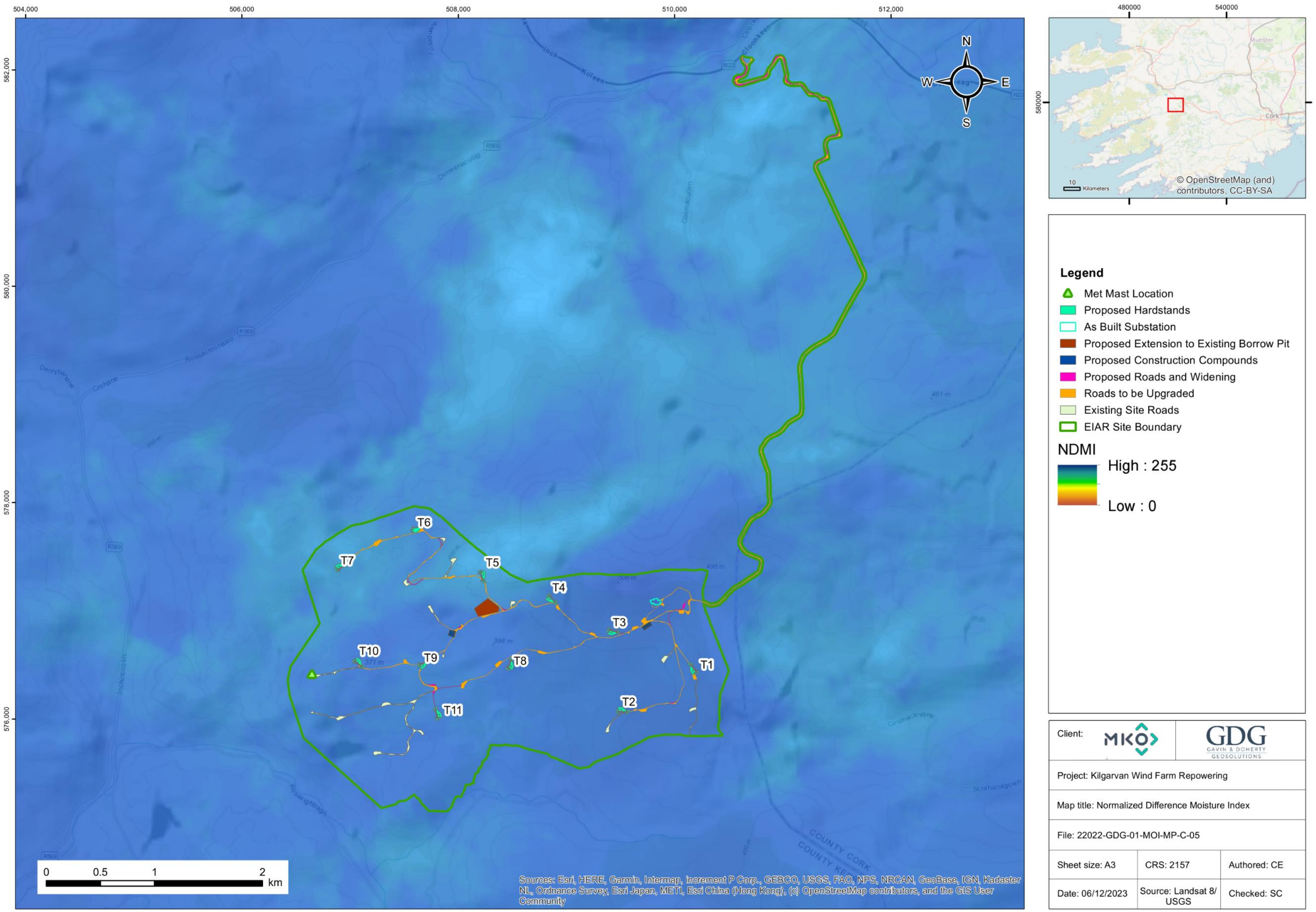
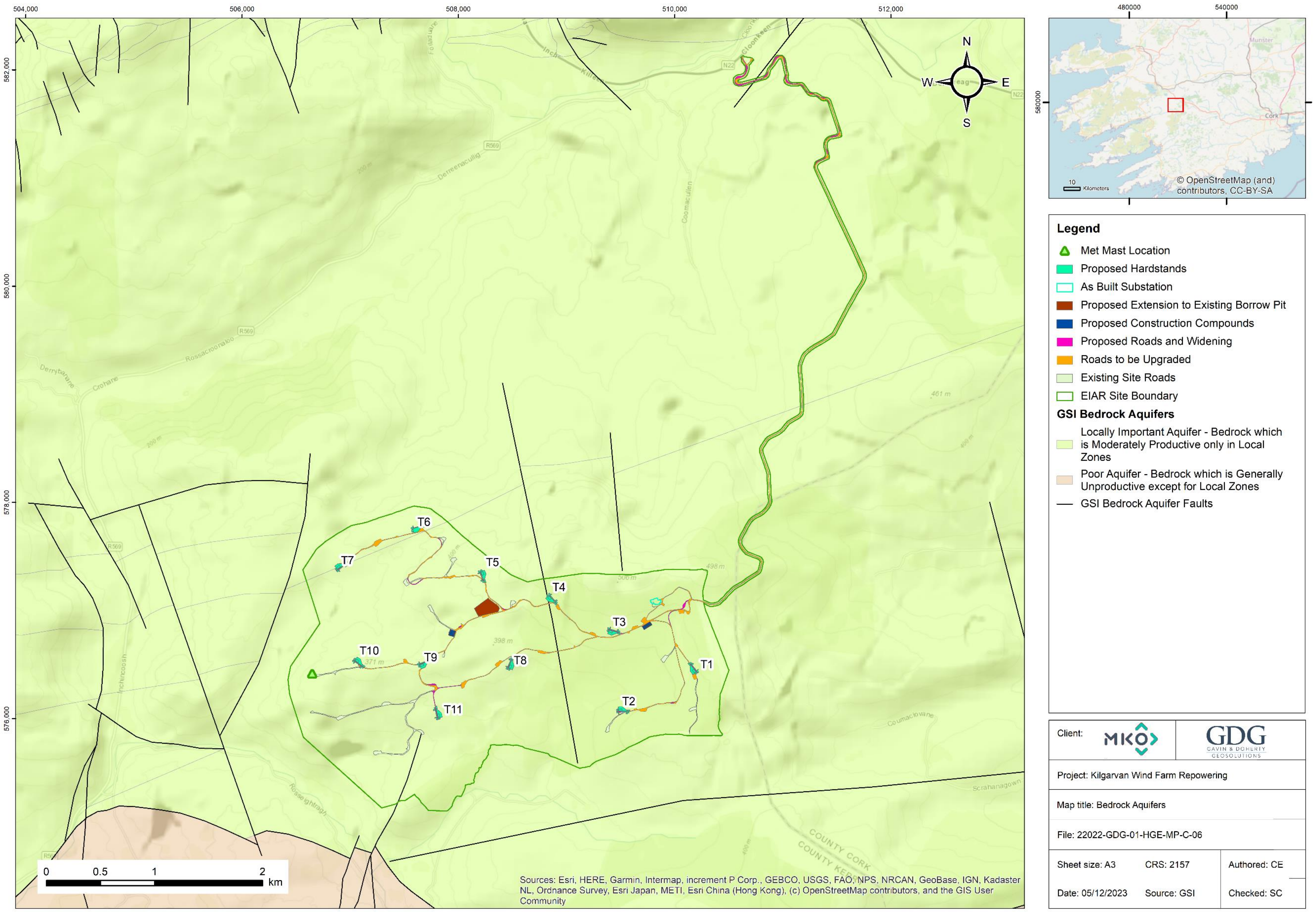


Figure D- 1: Normalised Difference Moisture Index

Appendix E HYDROGEOLOGY



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Client: MKO GDG

Project: Kilgarvan Wind Farm Repowering

Map title: Bedrock Aquifers

File: 22022-GDG-01-HGE-MP-C-06

Sheet size: A3
CRS: 2157
Authored: CE
Date: 05/12/2023
Source: GSI
Checked: SC

Figure E- 1: Bedrock Aquifers.

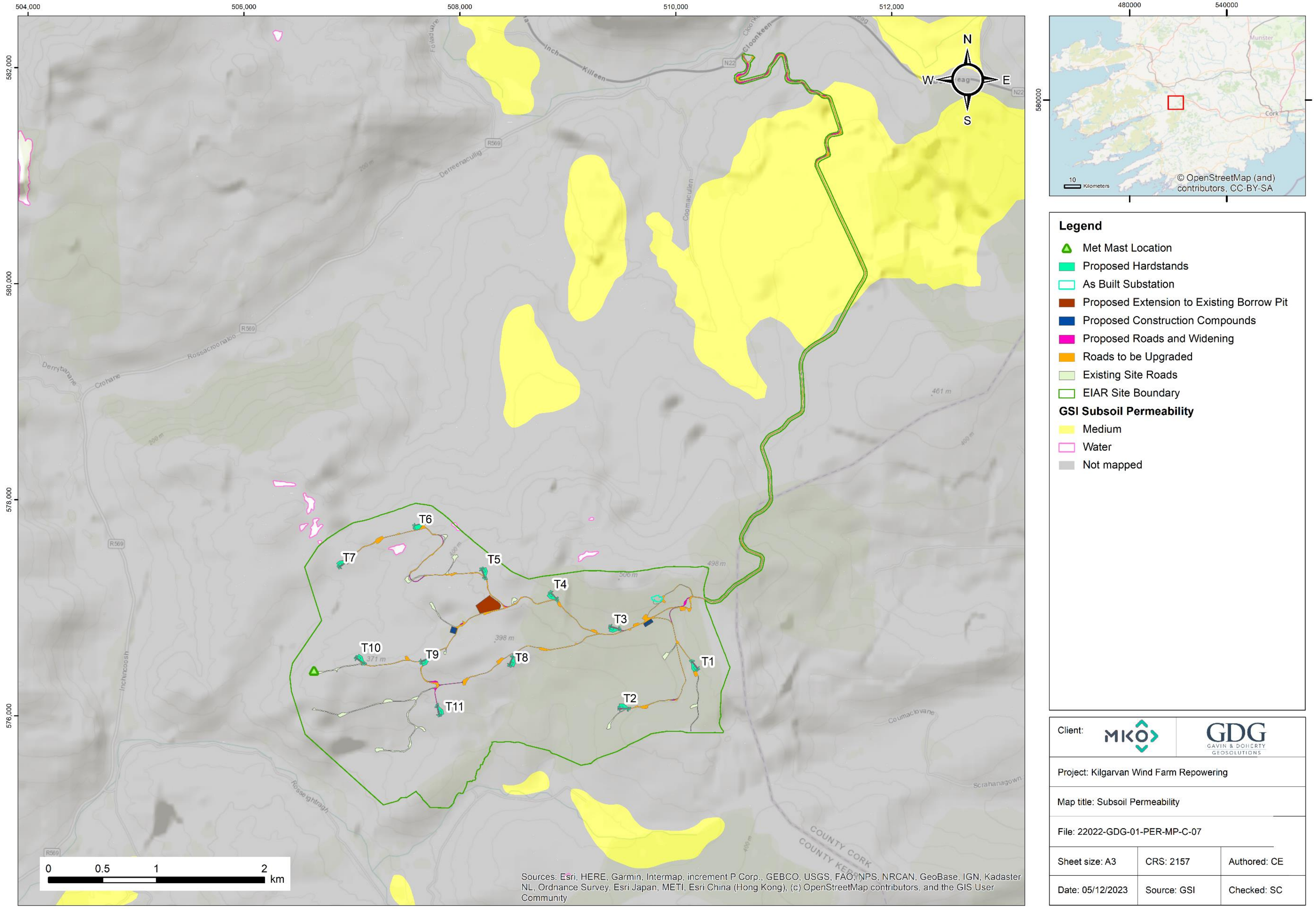


Figure E- 2: Subsoil Permeability.

Appendix F TOPOGRAPHY

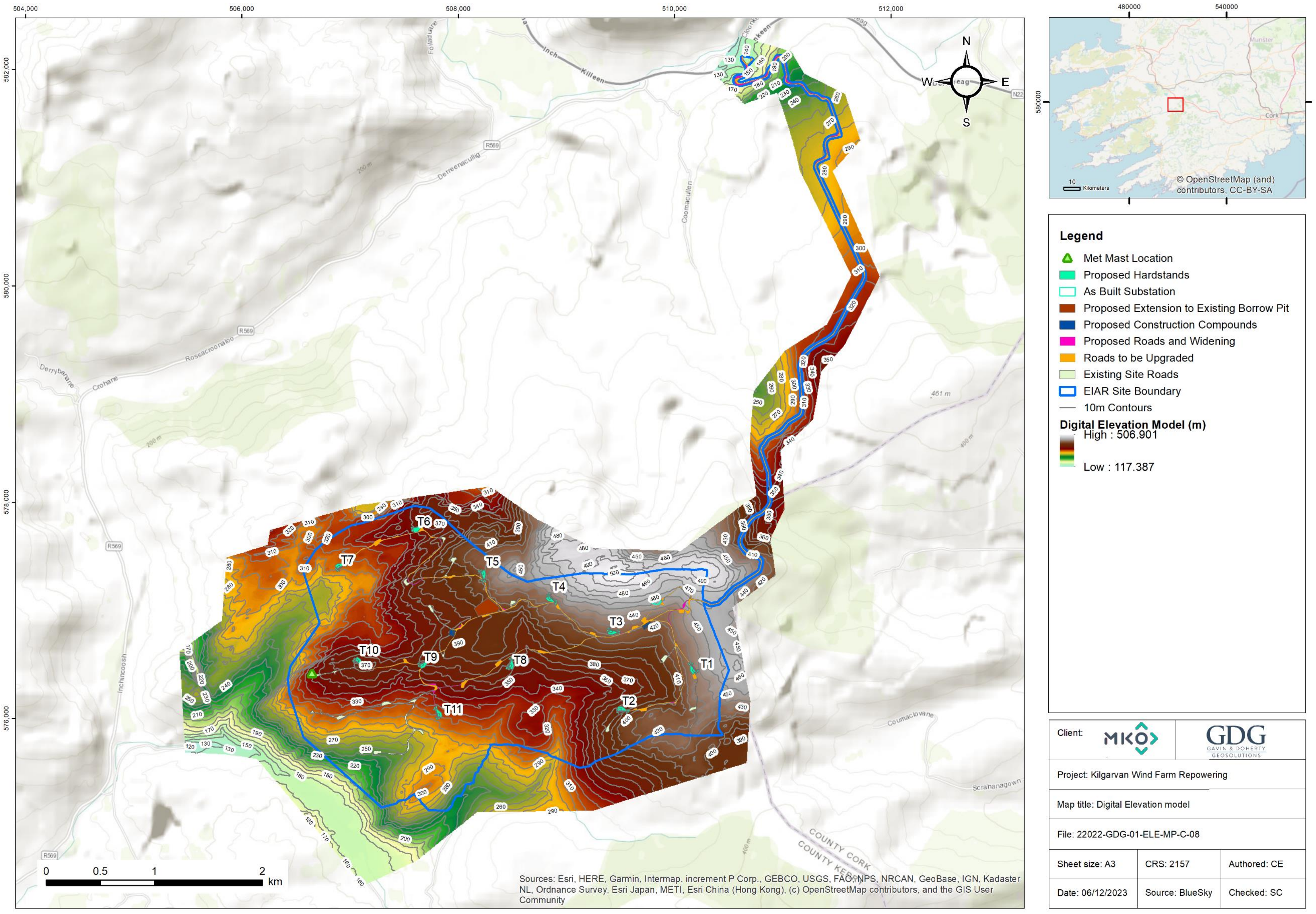
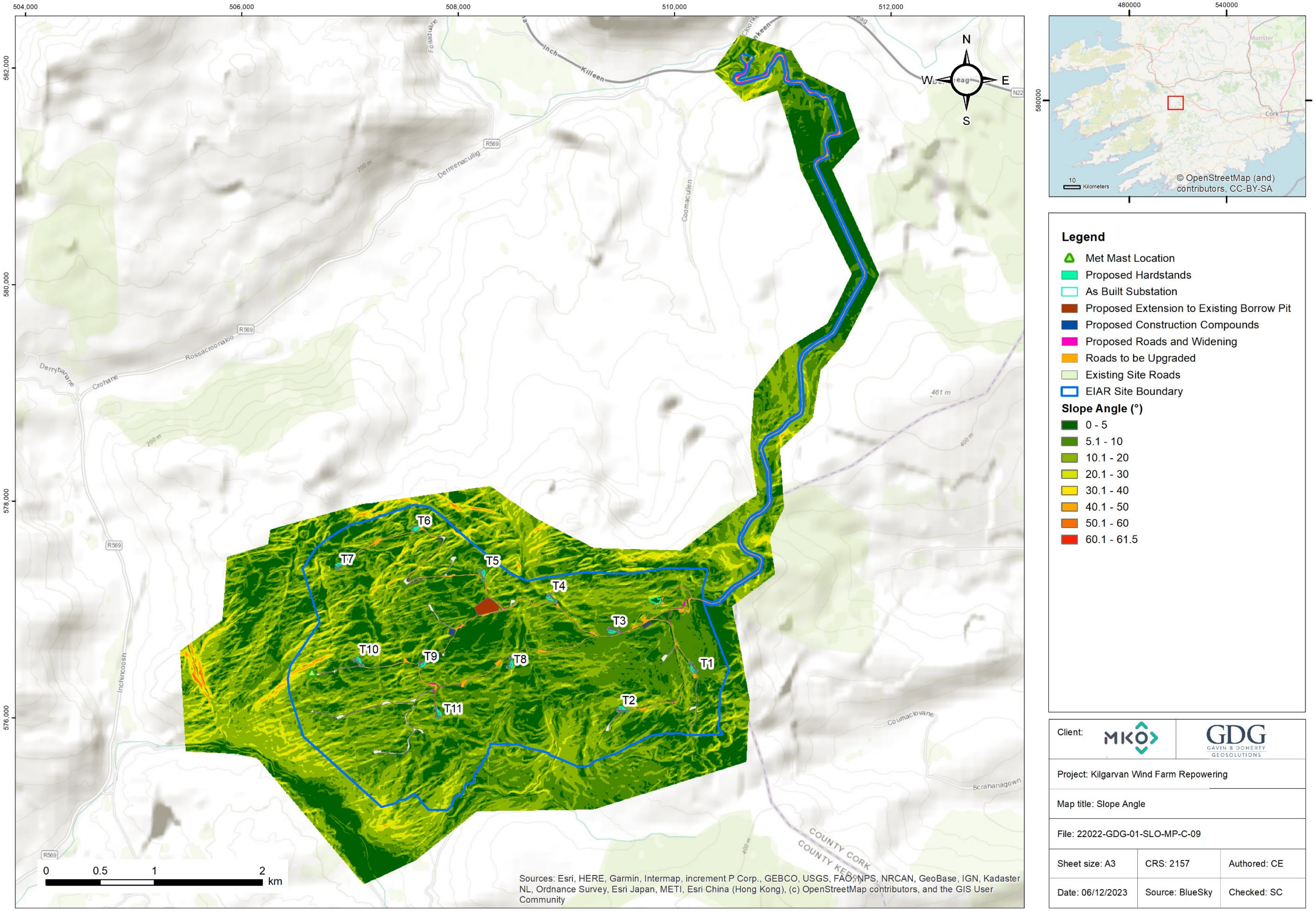


Figure F- 1: Digital Elevation Model.



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Figure F- 2: Slope Angles.

Appendix G SLOPE INSTABILITY MAPPING

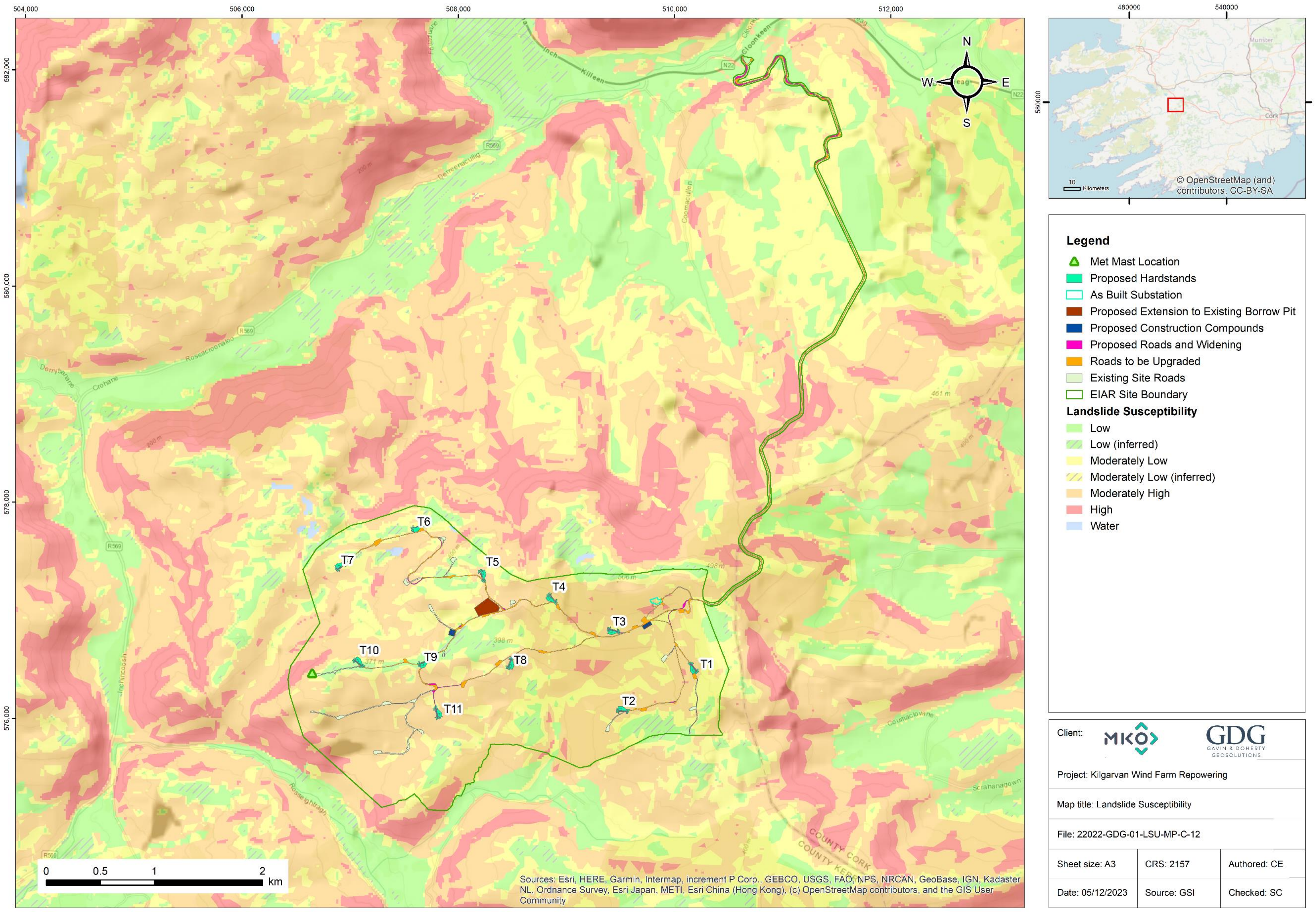
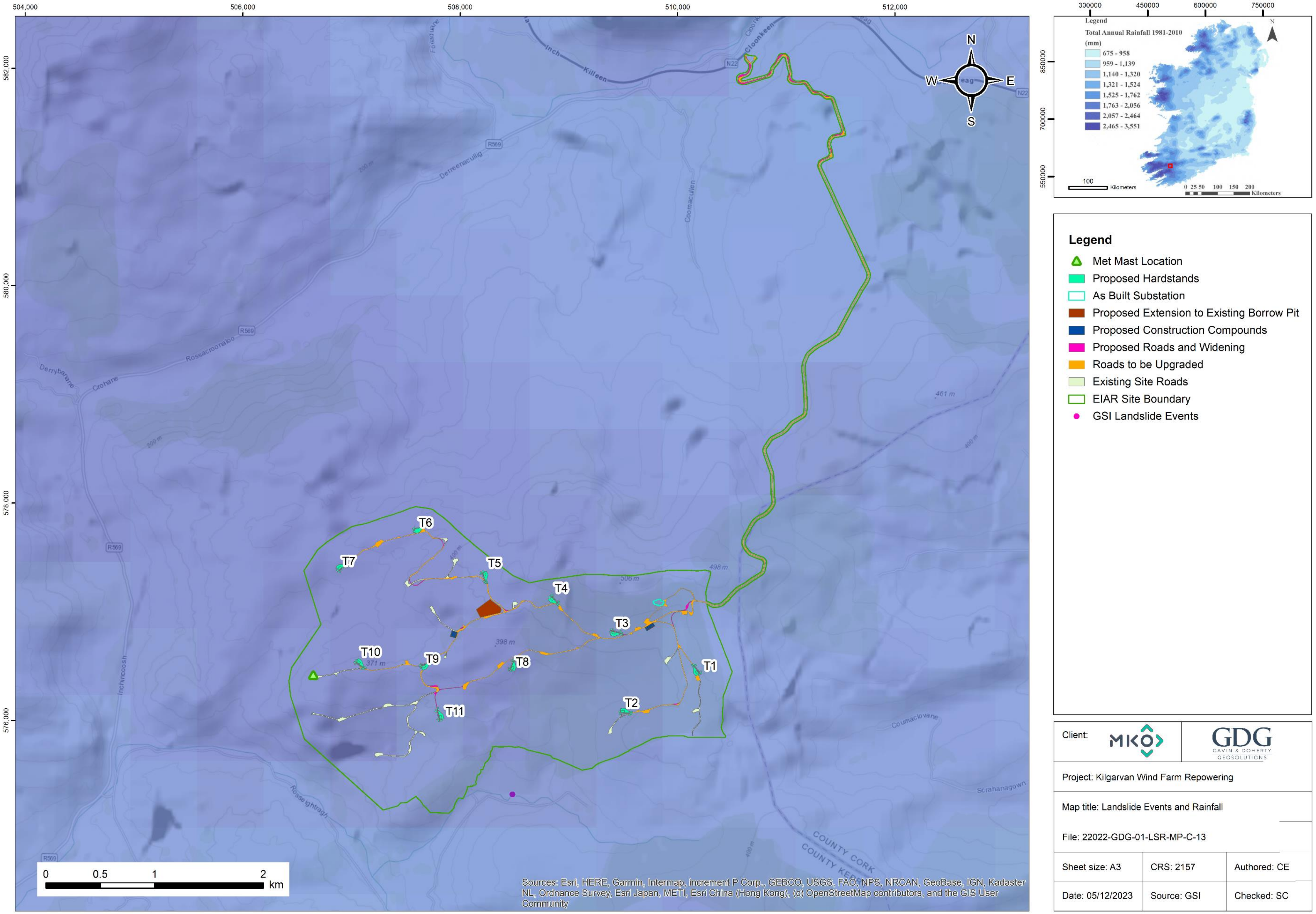


Figure G- 1: Landslide Susceptibility.



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Client:

Project: Kilgarvan Wind Farm Repowering

Map title: Landslide Events and Rainfall

File: 22022-GDG-01-LSR-MP-C-13

Sheet size: A3	CRS: 2157	Authored: CE
Date: 05/12/2023	Source: GSI	Checked: SC

Figure G- 2: Landslide Events and Rainfall.

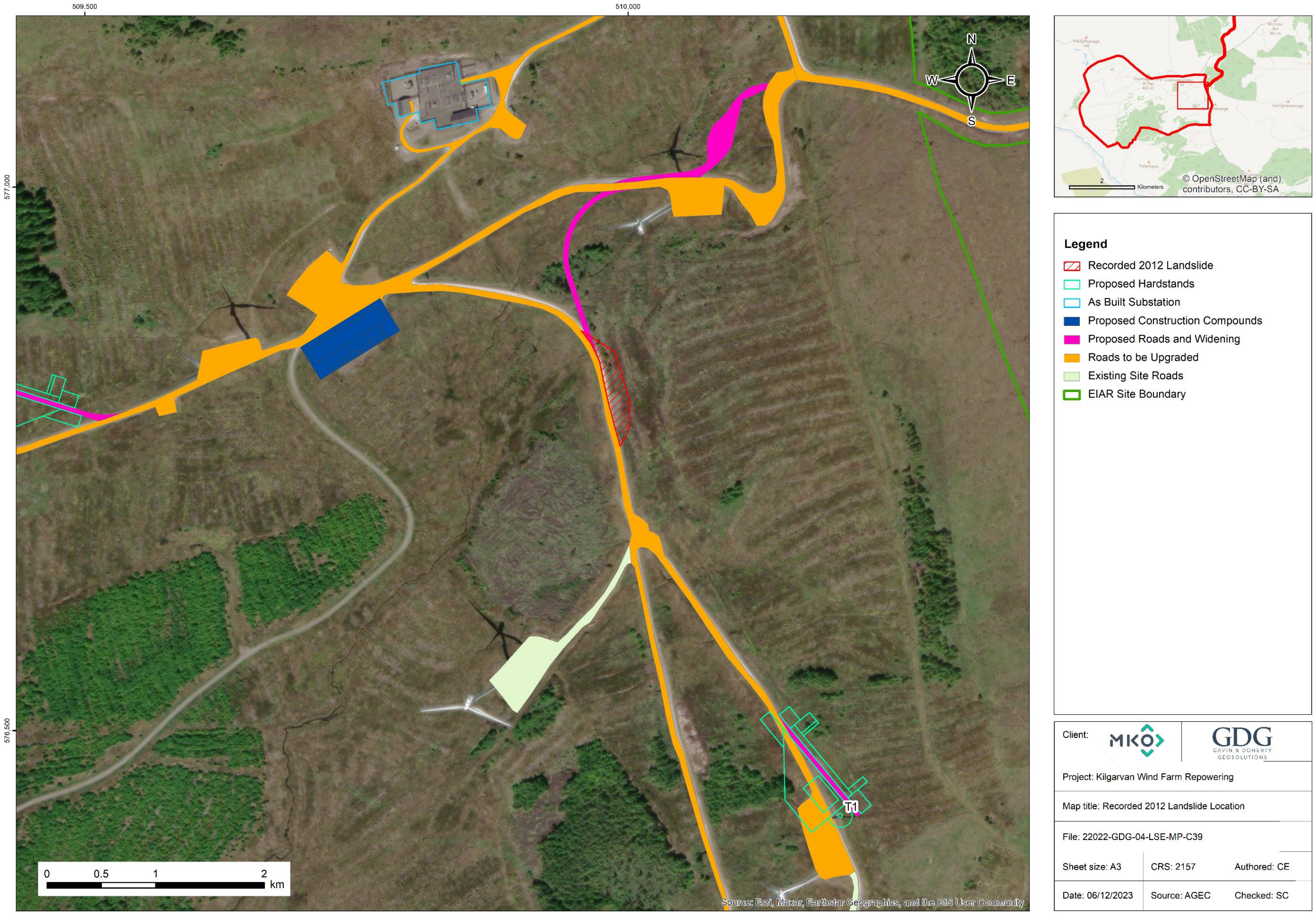


Figure G- 3: 2012 Landslide Location.

Appendix H HYDROLOGY

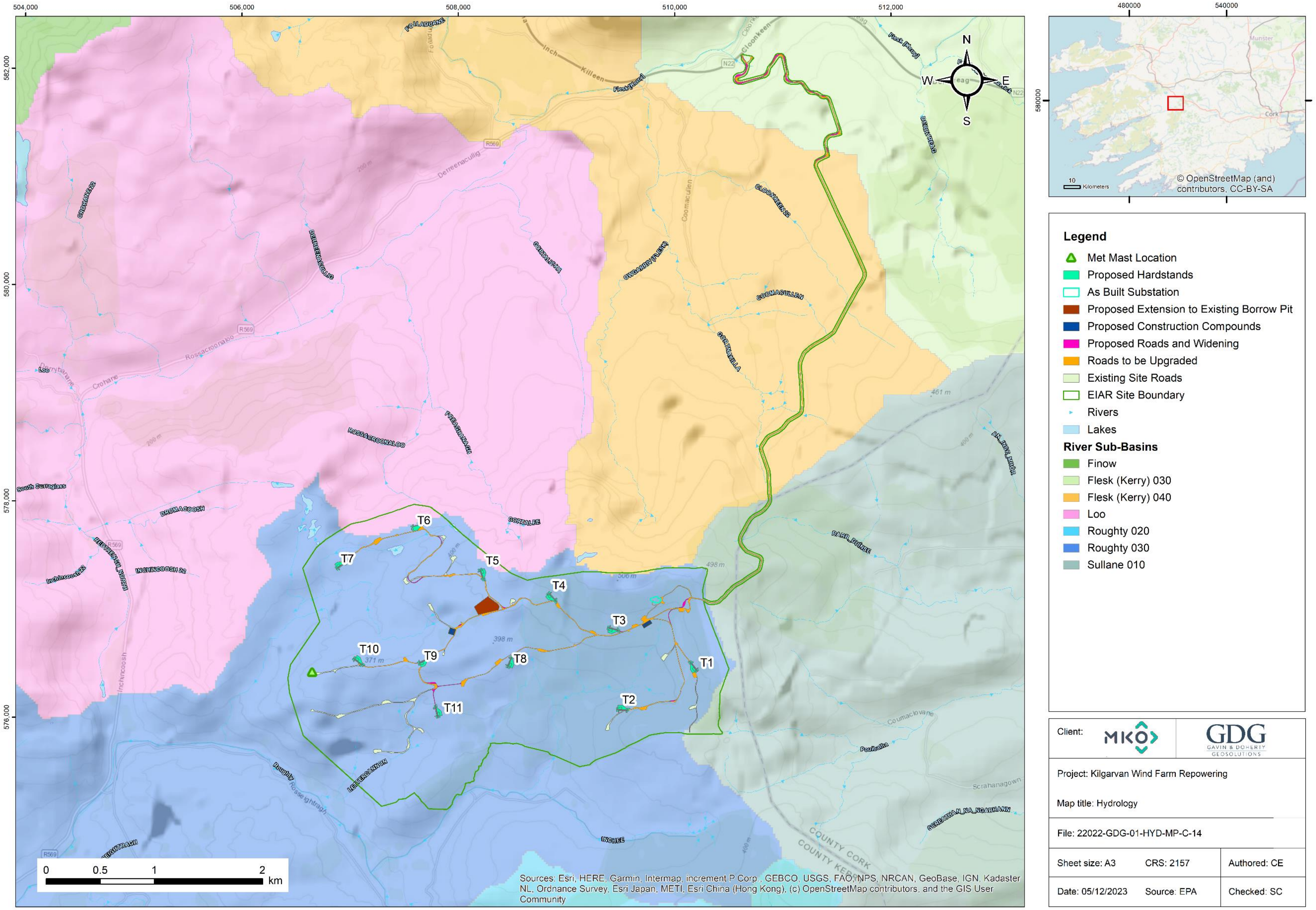
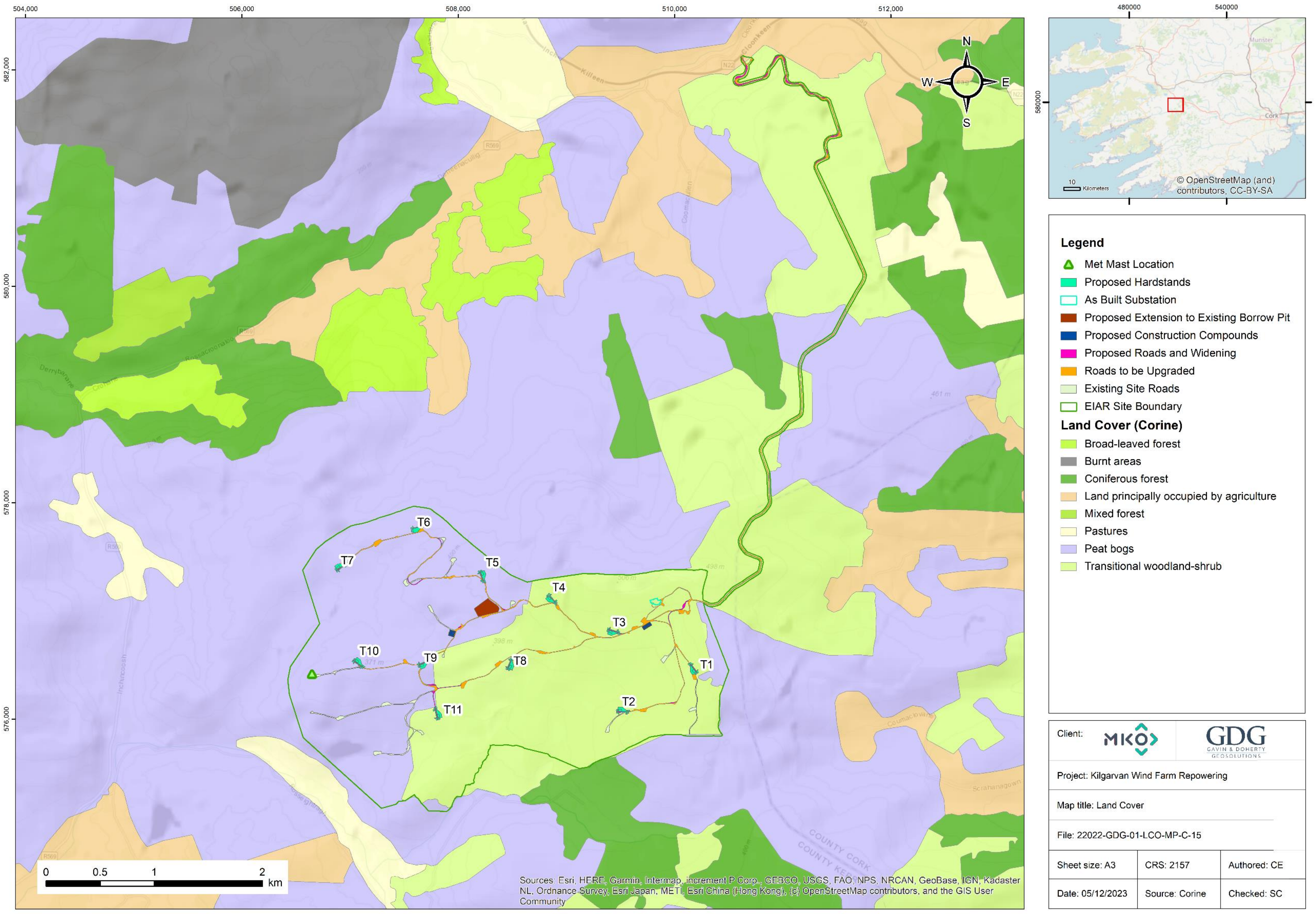


Figure H- 1: Hydrology -Rivers and Sub-Basins.

Appendix I LAND COVER AND LAND USE



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Figure I- 1: Corine Land Cover.

Appendix J GEO-INVESTIGATIONS

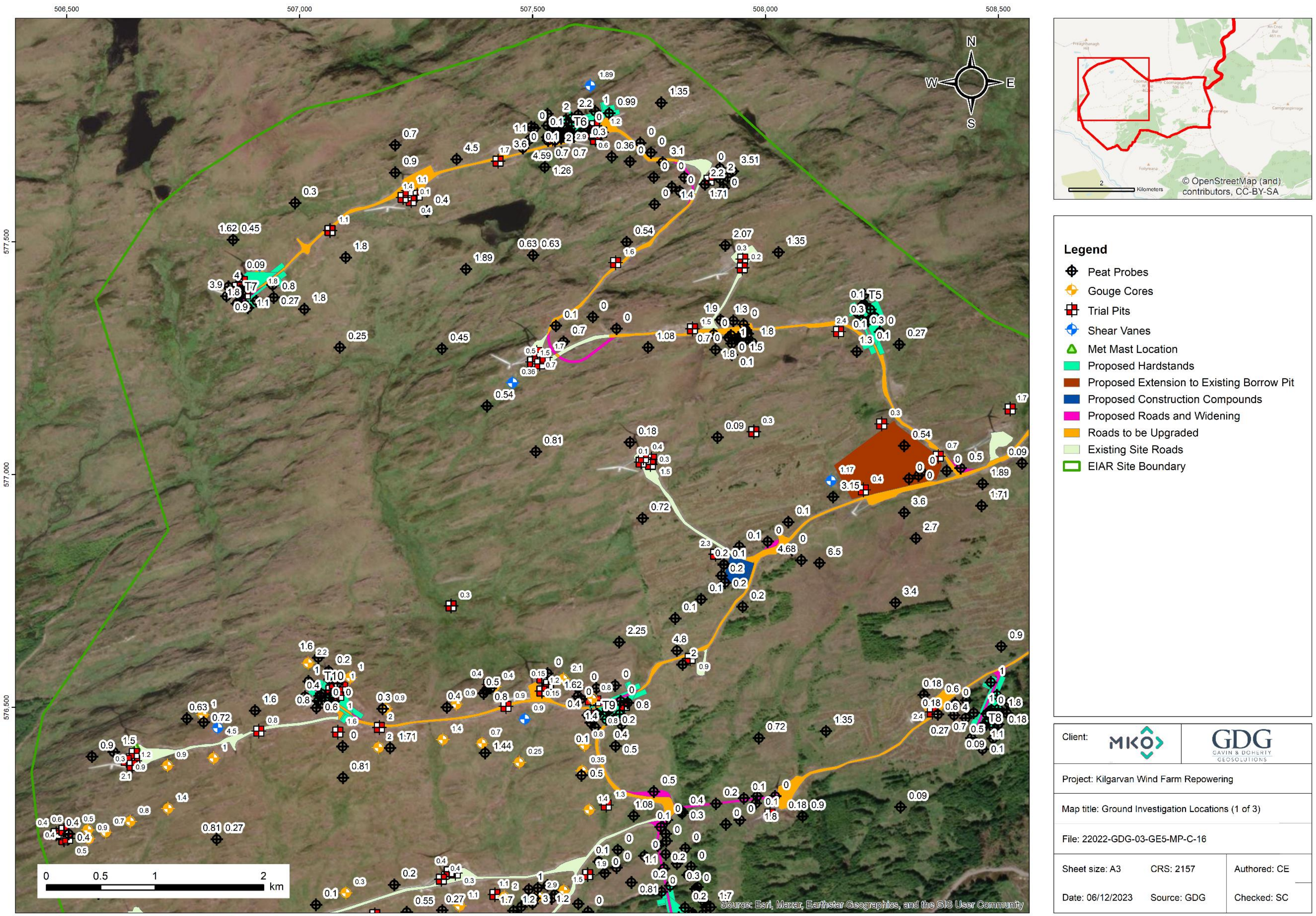
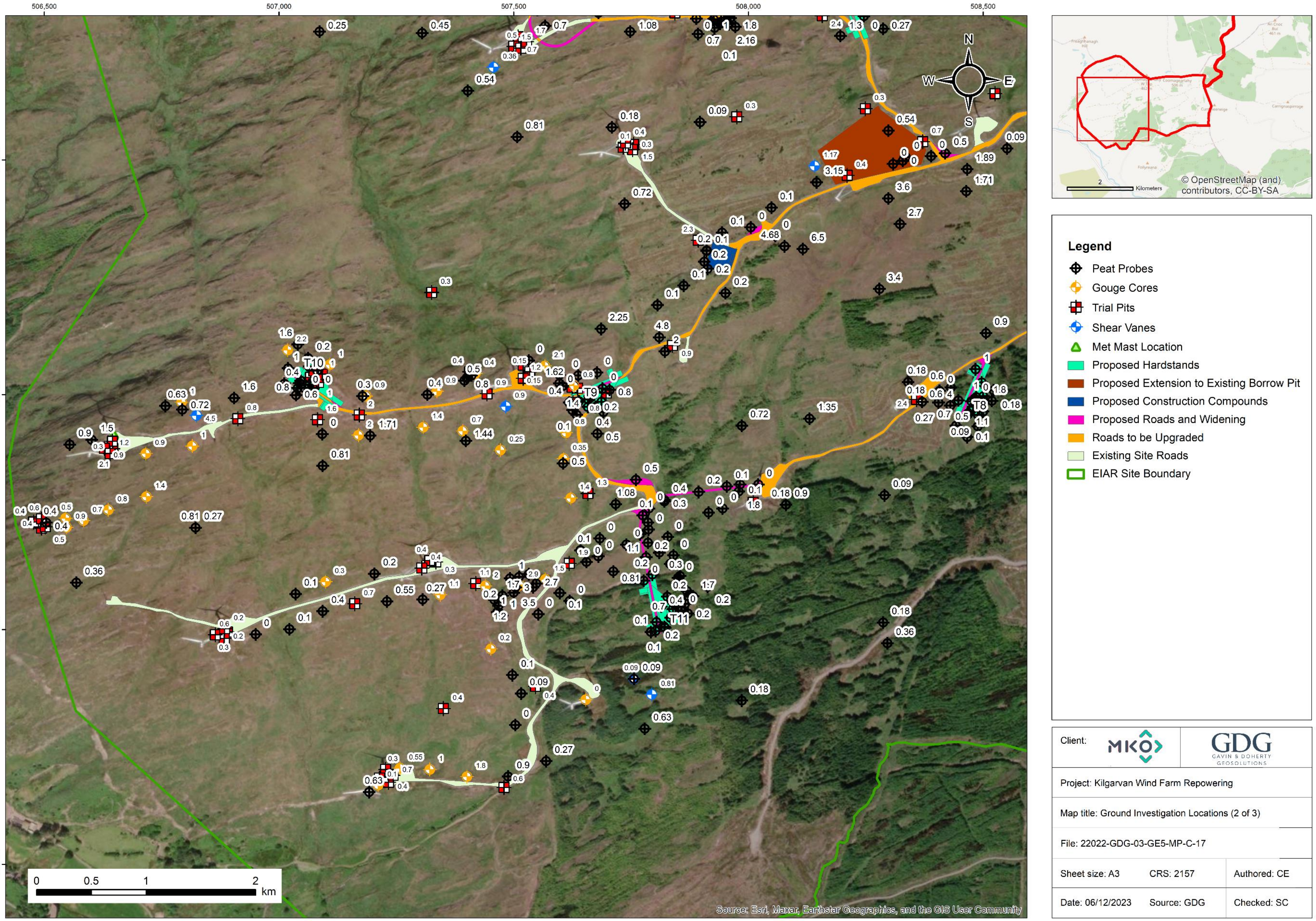


Figure J- 1: Ground Investigation Locations (1 of 3).



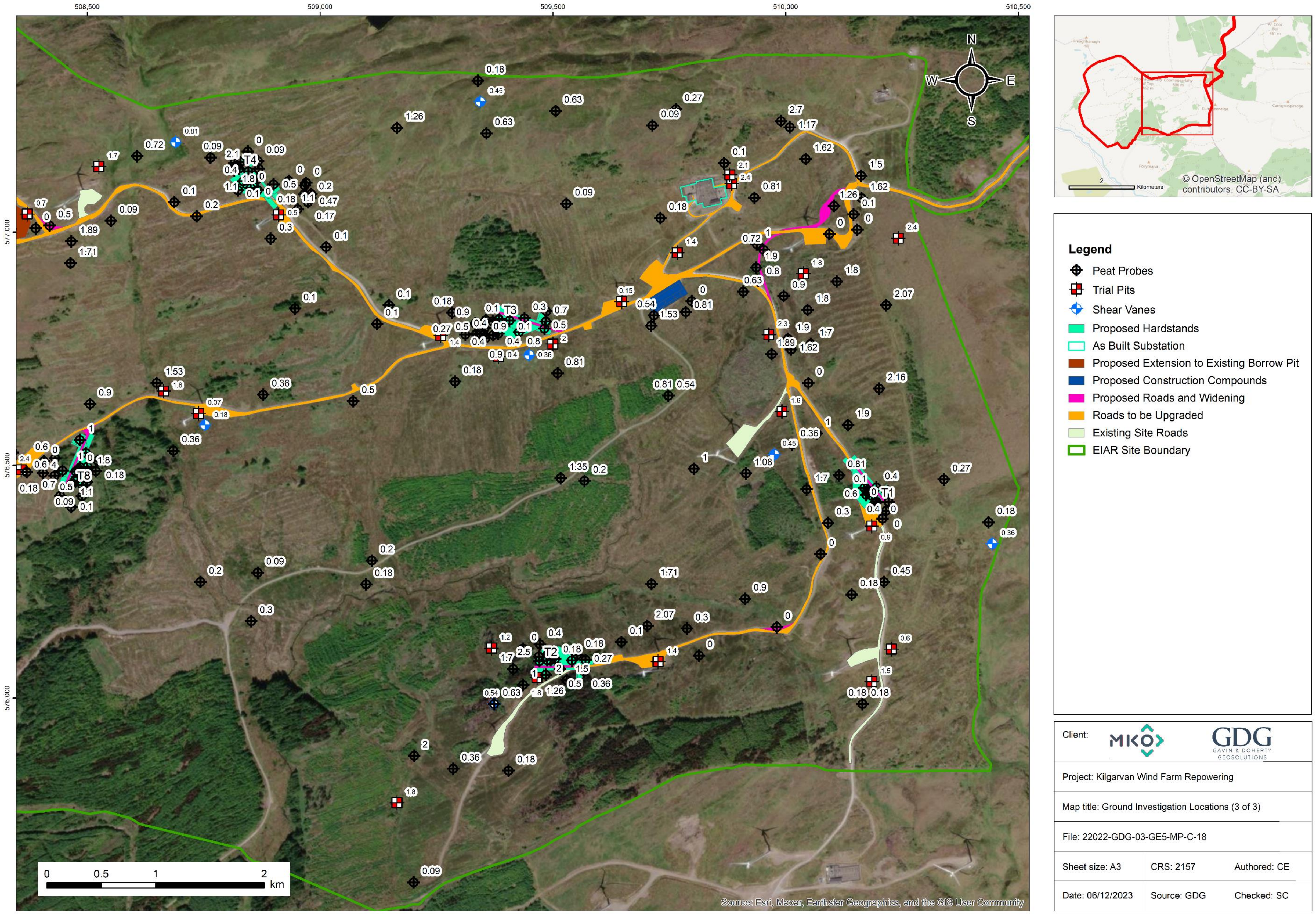
Project: Kilgarvan Wind Farm Repowering

Map title: Ground Investigation Locations (2 of 3)

File: 22022-GDG-03-GE5-MP-C-17

Sheet size: A3	CRS: 2157	Authored: CE
Date: 06/12/2023	Source: GDG	Checked: SC

Figure J- 2: Ground Investigation Locations (2 of 3).



Legend

- ⌖ Peat Probes
- ⊞ Trial Pits
- ⊕ Shear Vanes
- 🟩 Proposed Hardstands
- ☐ As Built Substation
- 🟫 Proposed Extension to Existing Borrow Pit
- 🟦 Proposed Construction Compounds
- 🟪 Proposed Roads and Widening
- 🟧 Roads to be Upgraded
- ▭ Existing Site Roads
- ☐ EIAR Site Boundary

Client: MKO GDG Gavin & Doherty Geosolutions

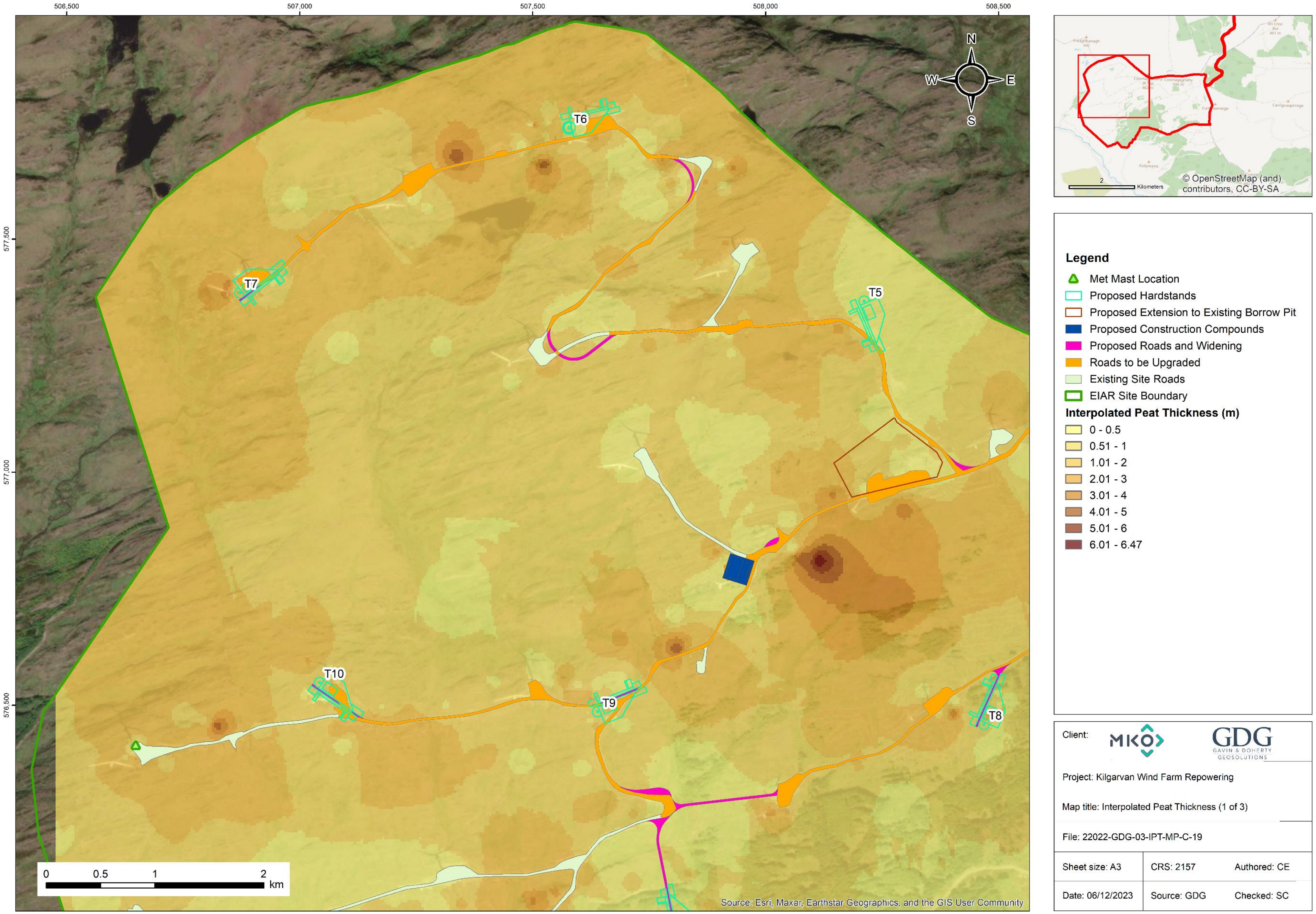
Project: Kilgarvan Wind Farm Repowering

Map title: Ground Investigation Locations (3 of 3)

File: 22022-GDG-03-GE5-MP-C-18

Sheet size: A3	CRS: 2157	Authored: CE
Date: 06/12/2023	Source: GDG	Checked: SC

Figure J- 3: Ground Investigation Locations (3 of 3).



Project: Kilgarvan Wind Farm Repowering

Map title: Interpolated Peat Thickness (1 of 3)

File: 22022-GDG-03-IPT-MP-C-19

Sheet size: A3	CRS: 2157	Authored: CE
Date: 06/12/2023	Source: GDG	Checked: SC

Figure J- 4: Interpolated Peat Thickness (1 of 3).

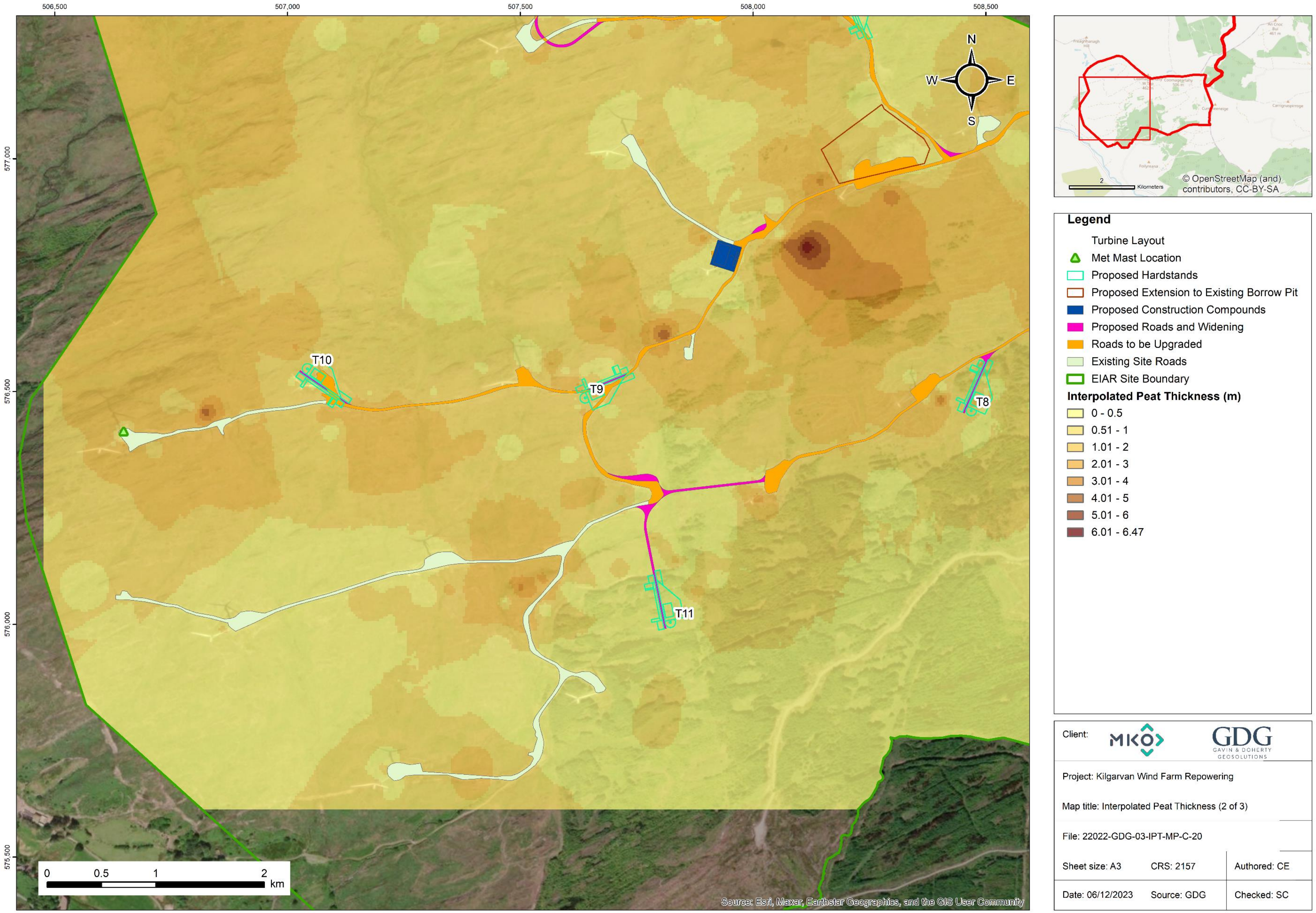


Figure J- 5: Interpolated Peat Thickness (2 of 3).

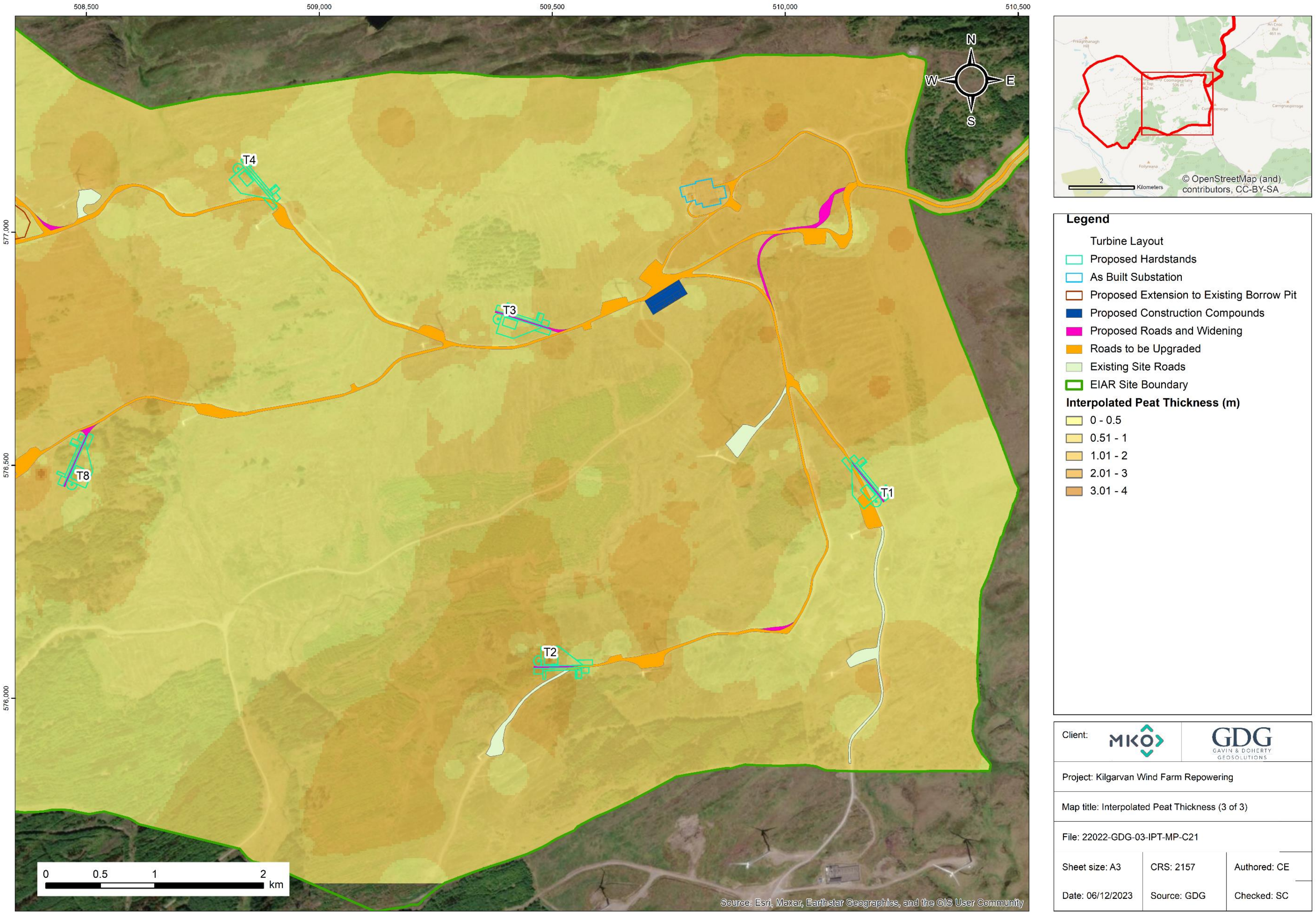
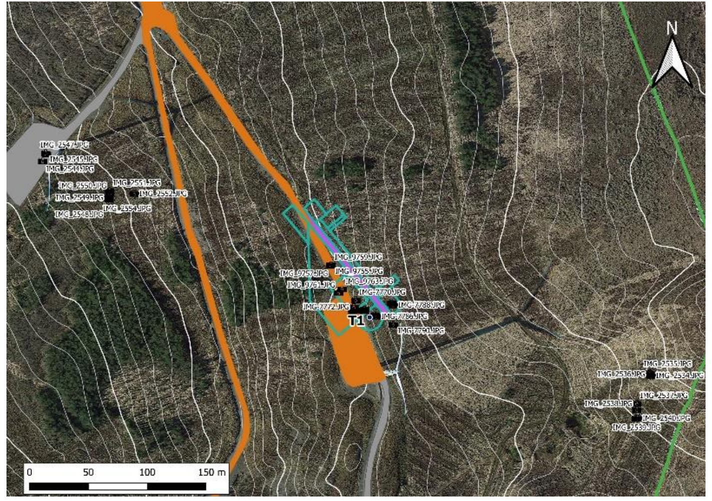


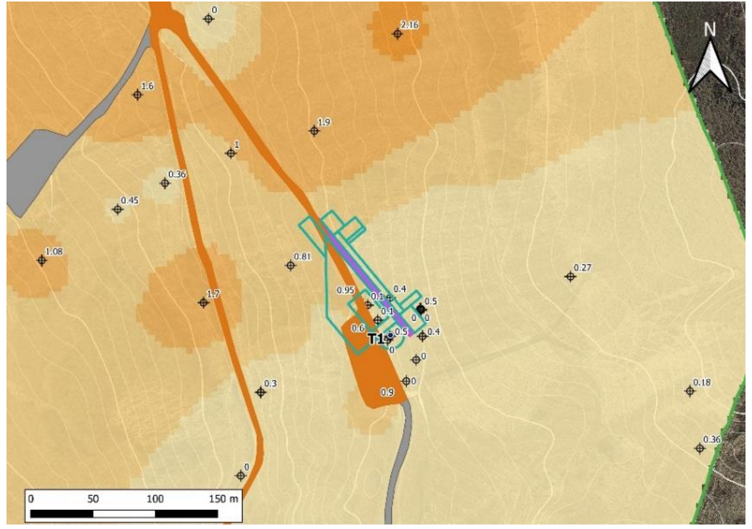
Figure J- 6: Interpolated Peat Thickness (3 of 3).

Table J- 1: Site reconnaissance of the Turbine 1 site.

Imagery



Peat geo-investigation



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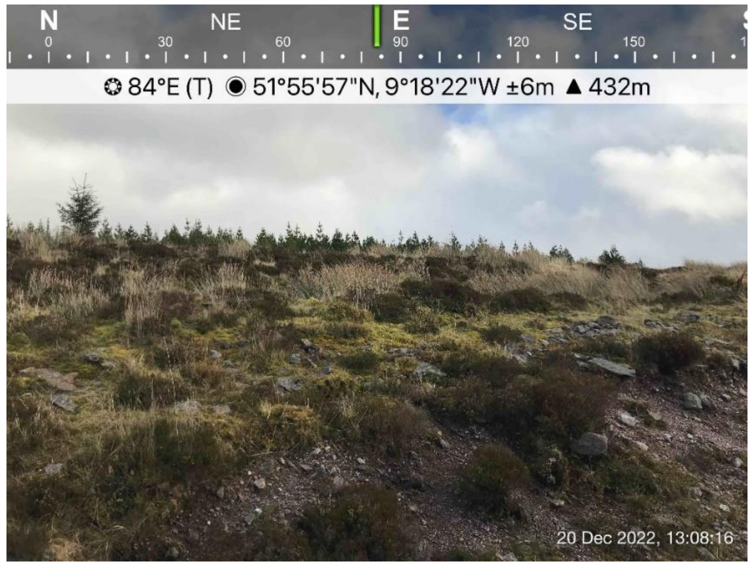


Shared legend

📷 Geotagged Photos
Contour Lines (2m)
Contour Lines (10m)

Wind Farm Layout
◉ Turbine Locations
🟩 Site Boundary
▢ Hardstand Locations
🟪 As Built Substation

🟫 Proposed Borrow Pit Location
🟦 Construction Compounds
🟧 Roads to be Upgraded
🟪 Proposed Roads and Widening
⬜ Existing Site Roads
- - - Existing 110kV OHL

Peat Depth (m)
▢ <= 0.5
▢ 0.5 - 1
▢ 1 - 2
▢ 2 - 3
▢ 3 - 4
🟫 > 4

⌖ Peat Probe and Trial Pit Locations (Depth in m)

Description

Date of the satellite images: 2020. [Google].

Date of the ground-based pictures: 20th of December 2022 [GDG].

Geomorphology: T1 is located on a heathland sloping towards the west.

Peat: The peat depth at T1 is 0.17 m and slope angle of 11.1 degrees.

Instability evidences: No.

IMG-7780.JPG

IMG_7774.JPG

IMG_7778.JPG

Table J- 2: Site reconnaissance of the Turbine 2 site.

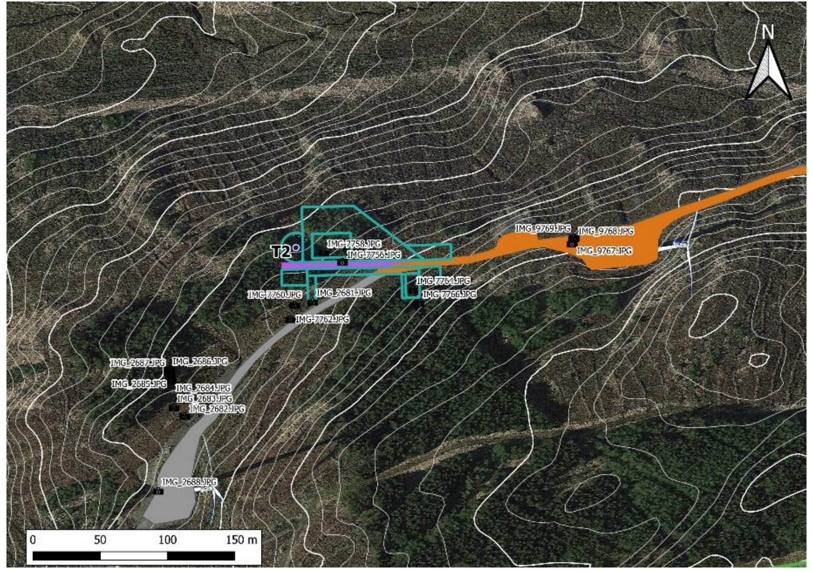
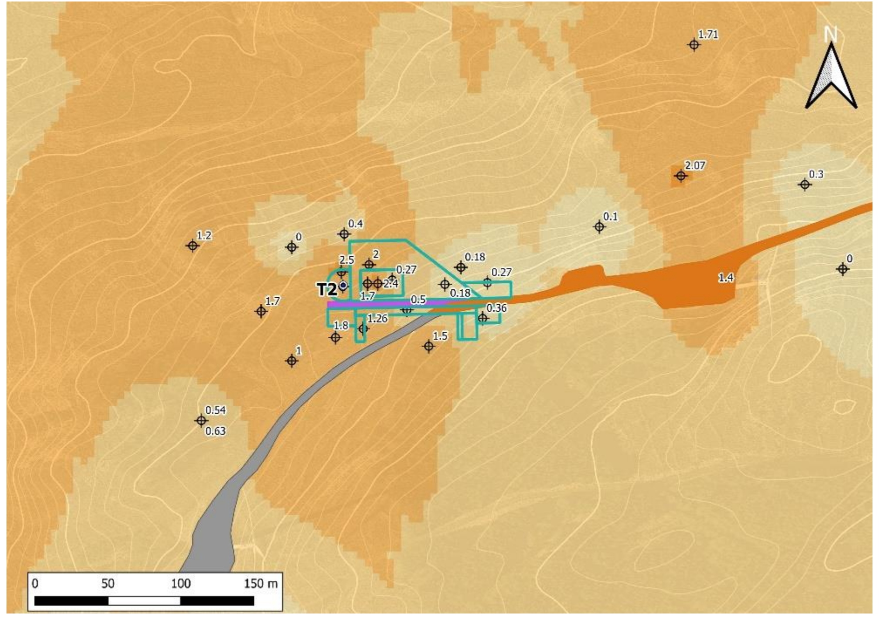
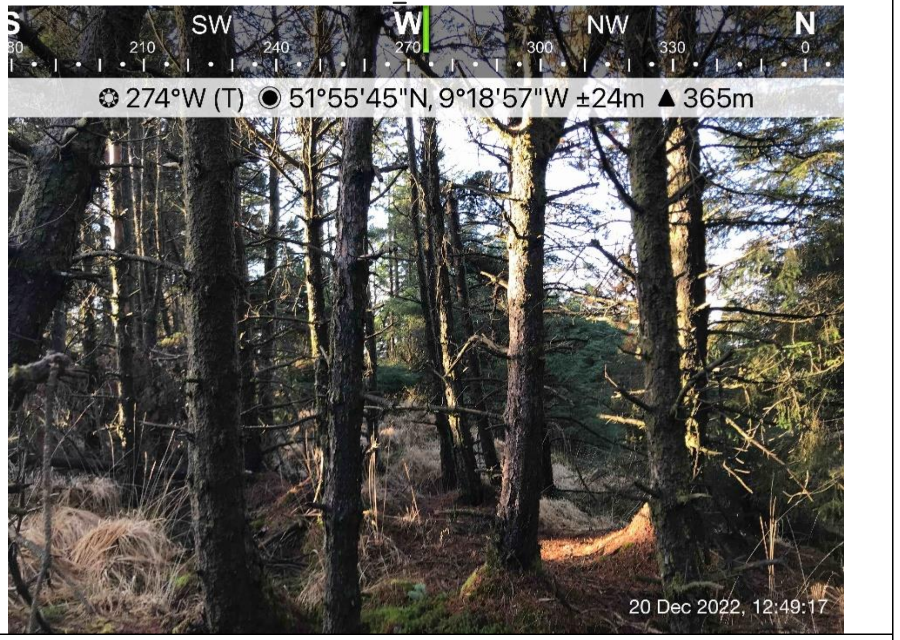
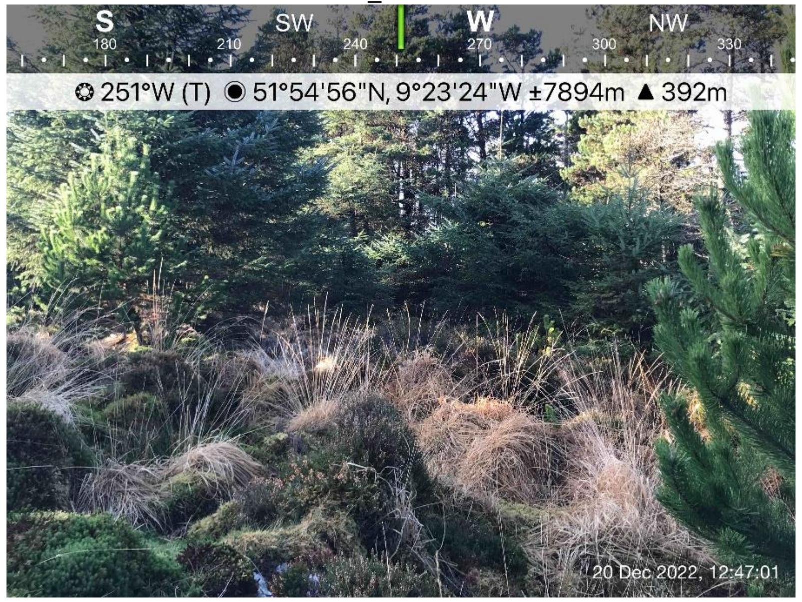
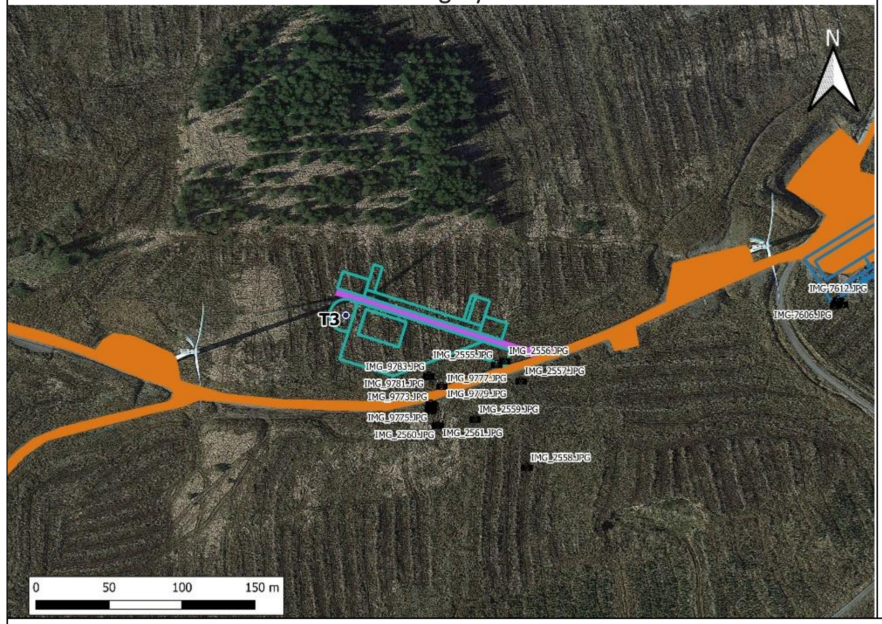
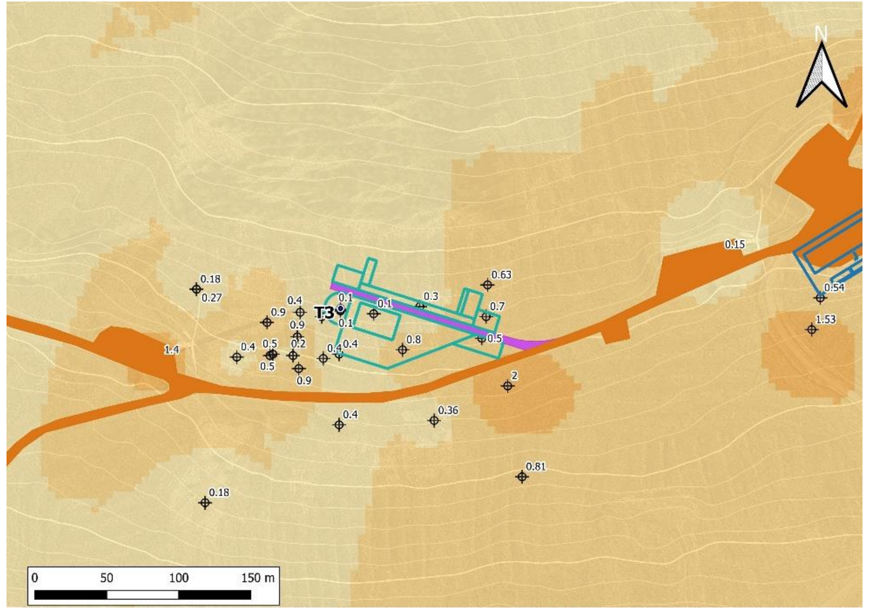
Imagery	Peat geo-investigation	IMG_7758.JPG
		
Shared legend 📷 Geotagged Photos Contour Lines (2m) Contour Lines (10m) **Wind Farm Layout** ◉ Turbine Locations 🟩 Site Boundary ▭ Hardstand Locations 🟪 As Built Substation 🟫 Proposed Borrow Pit Location 🟦 Construction Compounds 🟧 Roads to be Upgraded 🟪 Proposed Roads and Widening ⬜ Existing Site Roads - - - Existing 110kV OHL Peat Depth (m) ▨ <= 0.5 ▨ 0.5 - 1 ▨ 1 - 2 ▨ 2 - 3 ▨ 3 - 4 ▨ > 4 ⌖ Peat Probe and Trial Pit Locations (Depth in m)		
Description **Date of the satellite images:** 2020. [Google]. **Date of the ground-based pictures:** 20th of December 2022 [GDG]. **Geomorphology**: T2 is located in forestry and slopes down towards the north. **Peat**: The interfered peat depth at T2 and across its hardstanding varies from 1 m to 2 m with a slope angle of 7.8 degrees **Instability evidences**: No.	IMG-7760.JPG 	IMG_7754.JPG 

Table J- 3: Site reconnaissance of the Turbine 3 site.

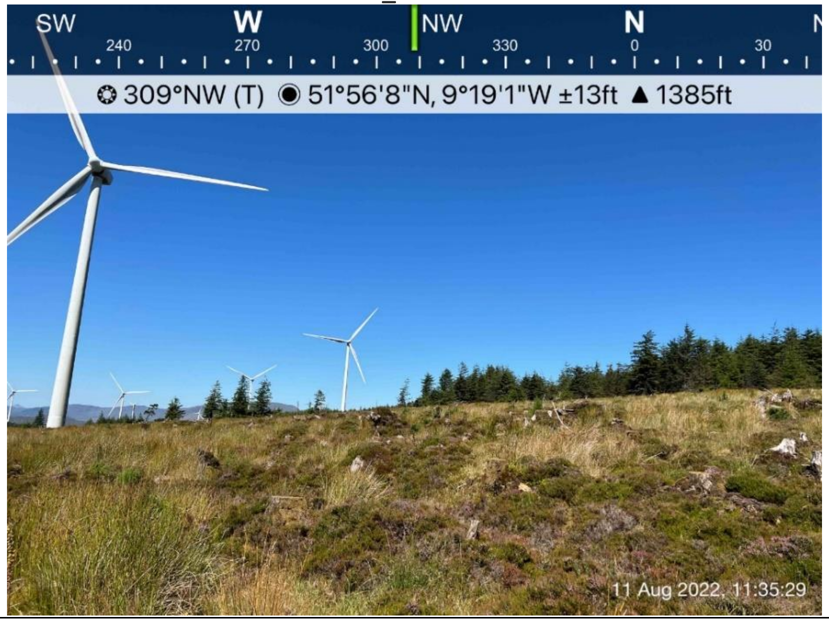
Imagery



Peat geo-investigation



IMG_9781.JPG



Shared legend

Geotagged Photos
Contour Lines (2m)
Contour Lines (10m)

Wind Farm Layout
● Turbine Locations
▭ Site Boundary
▭ Hardstand Locations
▨ As Built Substation

▨ Proposed Borrow Pit Location
▨ Construction Compounds
▨ Roads to be Upgraded
▨ Proposed Roads and Widening
▨ Existing Site Roads
- - - Existing 110kV OHL

Peat Depth (m)
▨ <= 0.5
▨ 0.5 - 1
▨ 1 - 2
▨ 2 - 3
▨ 3 - 4
▨ > 4

⌖ Peat Probe and Trial Pit Locations (Depth in m)

Description

Date of the satellite images: 2020. [Google].

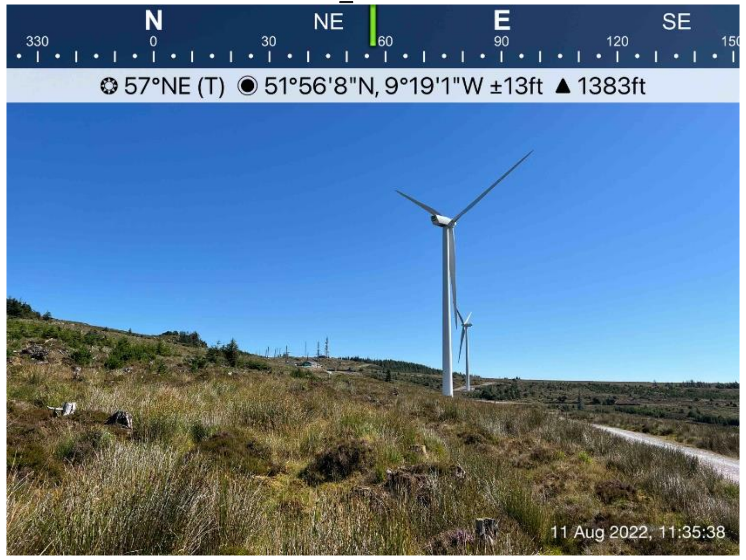
Date of the ground-based pictures: 11th of August 2022 [GDG].

Geomorphology: T3 is located on heathland, sloping to the south.

Peat: The peat depth is 0.12 m at T3 location, with a slope angle of 6.5 degrees.

Instability evidences: No.

IMG_9783.JPG



IMG_09777.JPG

Table J- 4: Site reconnaissance of the Turbine 4 site.

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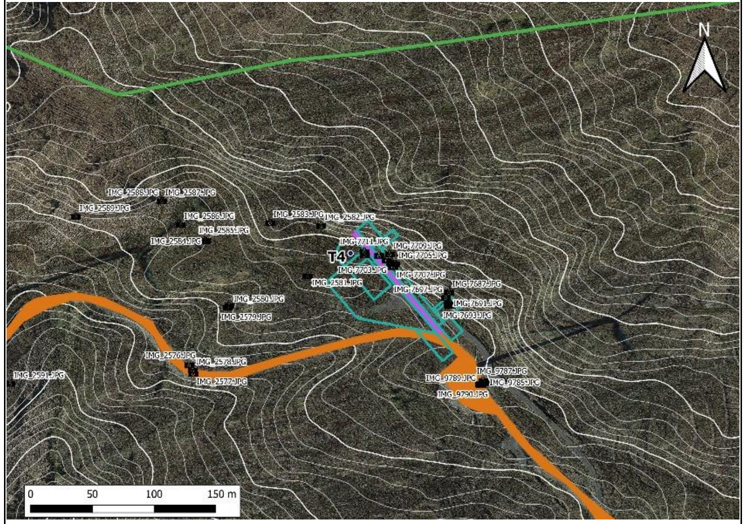
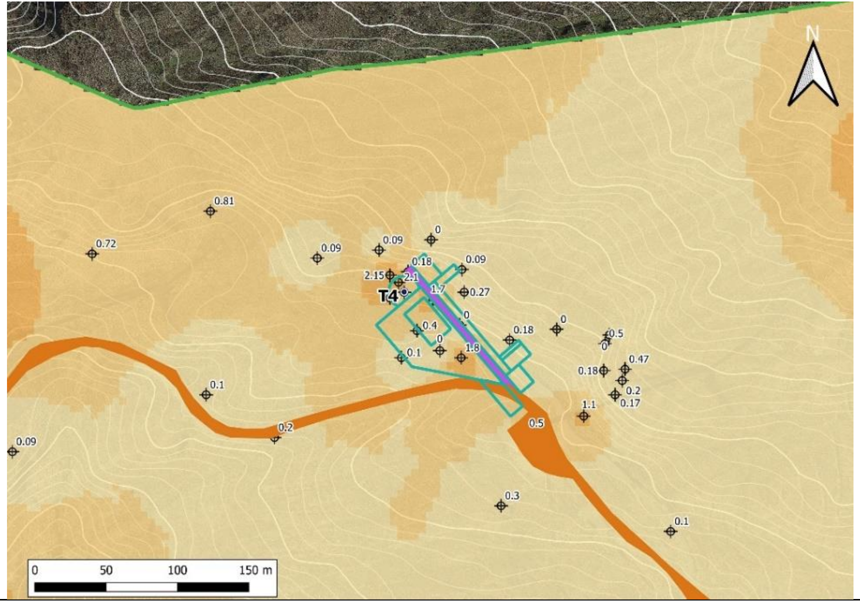
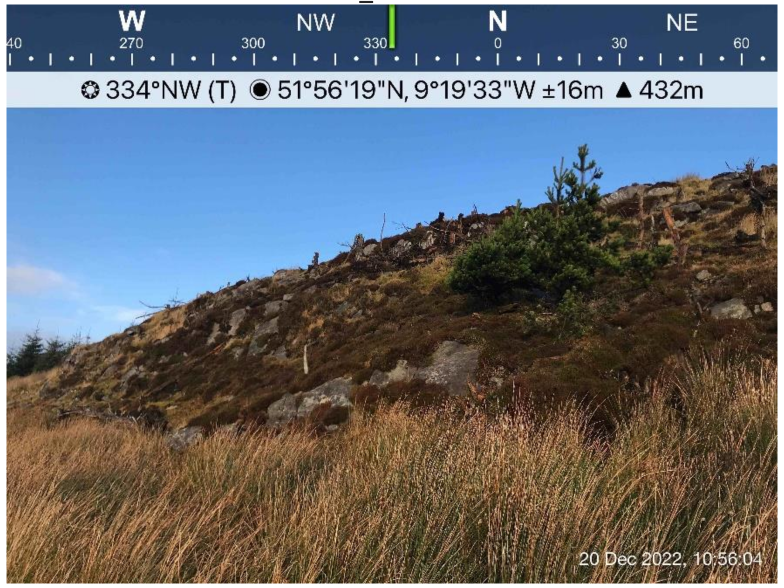
 </td>
<td>Peat geo-investigation
 </td>
<td>IMG_7711.JPG
 </td>
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📷 Geotagged Photos
— Contour Lines (2m)
— Contour Lines (10m)
Wind Farm Layout
◉ Turbine Locations
🟩 Site Boundary
▭ Hardstand Locations
🟪 As Built Substation
🟫 Proposed Borrow Pit Location
🟦 Construction Compounds
🟧 Roads to be Upgraded
🟪 Proposed Roads and Widening
⬜ Existing Site Roads
- - - Existing 110kV OHL
Peat Depth (m)
▨ <= 0.5
▨ 0.5 - 1
▨ 1 - 2
▨ 2 - 3
▨ 3 - 4
🟫 > 4
⌖ Peat Probe and Trial Pit Locations (Depth in m)</td>
<td></td>
</tr>
<tr>
<td>Description

Date of the satellite images: 2020. [Google].

Date of the ground-based pictures: 20th of December 2022 [GDG].

Geomorphology: The topography is variable, with steep bedrock outcrop ridges, and gently sloping peat land.

Peat: The peat depth in this sector varies from 0-2 m, with the deeper peat (>1.5m) localised in small depressions. Slope angle of 5.9 degrees.

Instability evidences: No.</td>
<td>IMG_7713.JGP
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<td>IMG_7707.JPG
 </td>
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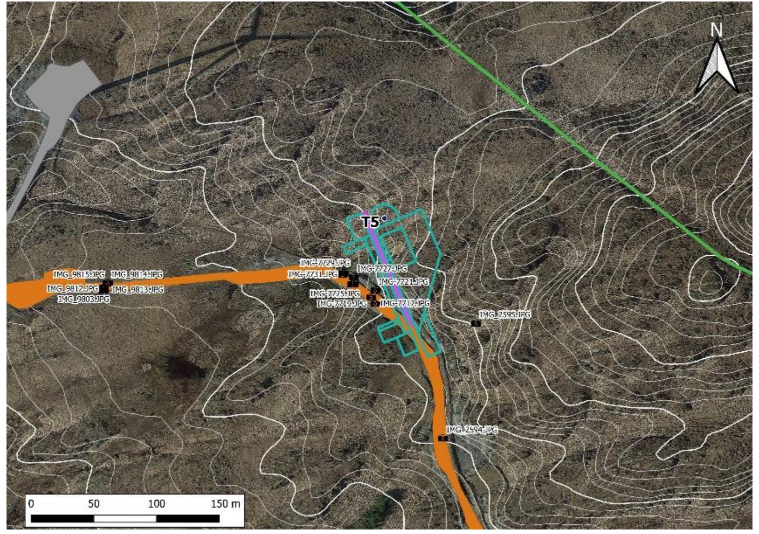
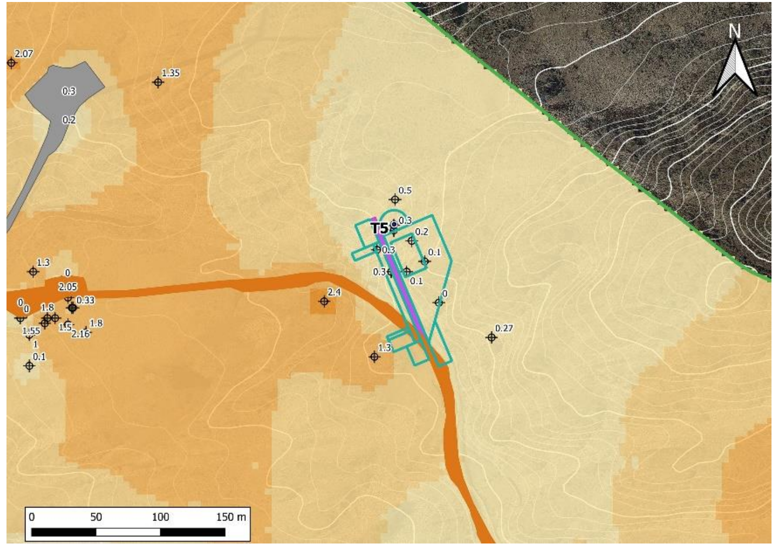
</table>

Table J- 5: Site reconnaissance of the Turbine 5 site.

Imagery



Peat geo-investigation



IMG_7729.JPG

Shared legend

- 📷 Geotagged Photos
- — Contour Lines (2m)
- — Contour Lines (10m)

Wind Farm Layout

- ◉ Turbine Locations
- ▭ Site Boundary
- ▭ Hardstand Locations
- ■ As Built Substation
- ■ Proposed Borrow Pit Location
- ■ Construction Compounds
- ■ Roads to be Upgraded
- ■ Proposed Roads and Widening
- ■ Existing Site Roads
- - - - Existing 110kV OHL

Peat Depth (m)

- ■ <= 0.5
- ■ 0.5 - 1
- ■ 1 - 2
- ■ 2 - 3
- ■ 3 - 4
- ■ > 4

⌖ Peat Probe and Trial Pit Locations (Depth in m)

Description

Date of the satellite images: 2020. [Google].

Date of the ground-based pictures14th of March 2022 [GDG].

Geomorphology: Moderated slope facing SE (right side of the road).

Peat: Peat depths of 0.12m the hardstand and turbine location .Slope angle of 13.3 degrees.

Instability evidences: No.

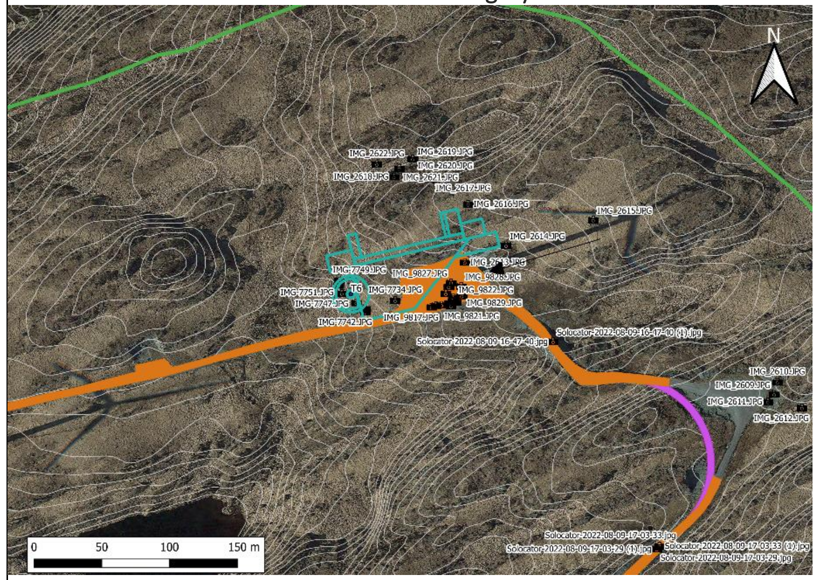
IMG_7731.JPG

IMG_7725.JPG

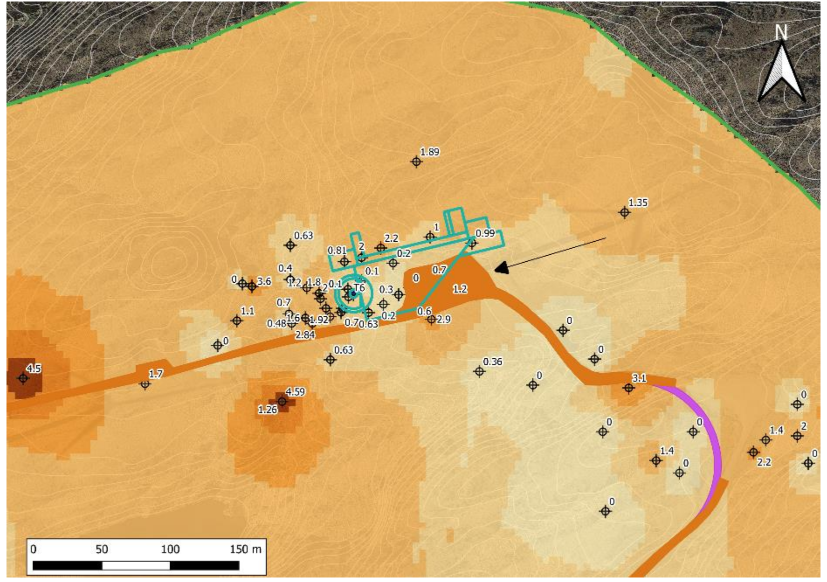
IMG_7723.JPG

Table J- 6: Site reconnaissance of the Turbine 6 site.

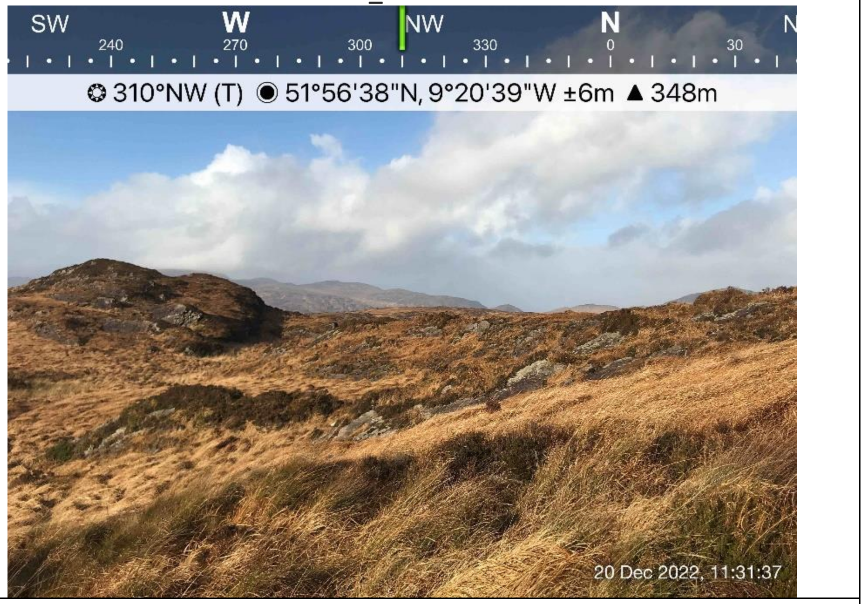
Imagery



Peat geo-investigation



IMG_7740.JPG



Shared legend

📷 Geotagged Photos
Contour Lines (2m)
Contour Lines (10m)

Wind Farm Layout

◉ Turbine Locations
🟩 Site Boundary
▭ Hardstand Locations
🟪 As Built Substation

🟫 Proposed Borrow Pit Location
🟦 Construction Compounds
🟧 Roads to be Upgraded
🟪 Proposed Roads and Widening
⬜ Existing Site Roads
- - - Existing 110kV OHL

Peat Depth (m)

▭	<= 0.5
▭	0.5 - 1
▭	1 - 2
▭	2 - 3
▭	3 - 4
▭	> 4

⌖ Peat Probe and Trial Pit Locations (Depth in m)

Description

Date of the satellite images: 2020. [Google].

Date of the ground-based pictures: 11th of August/20th of December 2022 [GDG]

Geomorphology: Varied terrain, with rocky outcrop ridges and generally flat depressions with blanket peat.

Peat: Depths of 0.44 m at the turbine and 2m at the northern boundary of the hardstanding. Slope angle is 16.6 degrees at the turbine location.

Instability evidences: No.

IMG_9822.JPG

IMG_7734.JPG

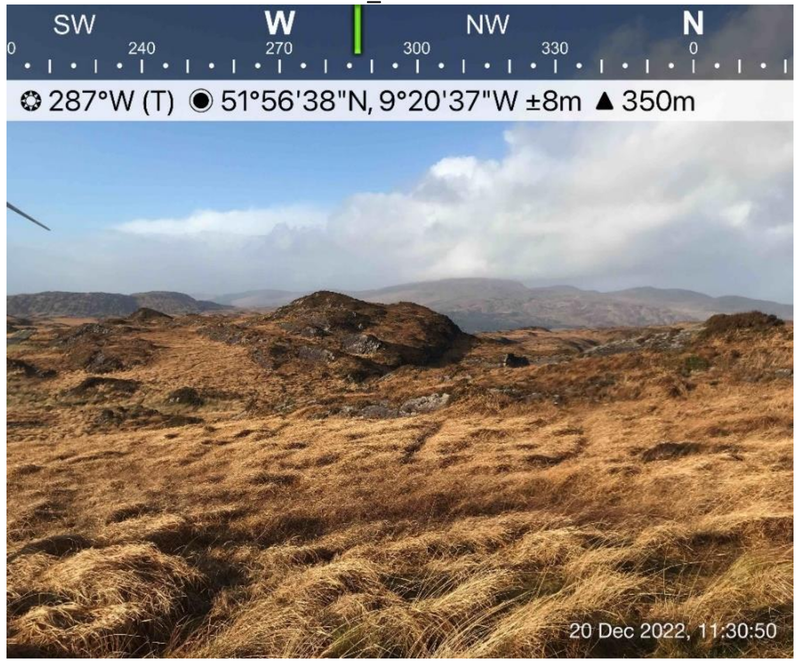
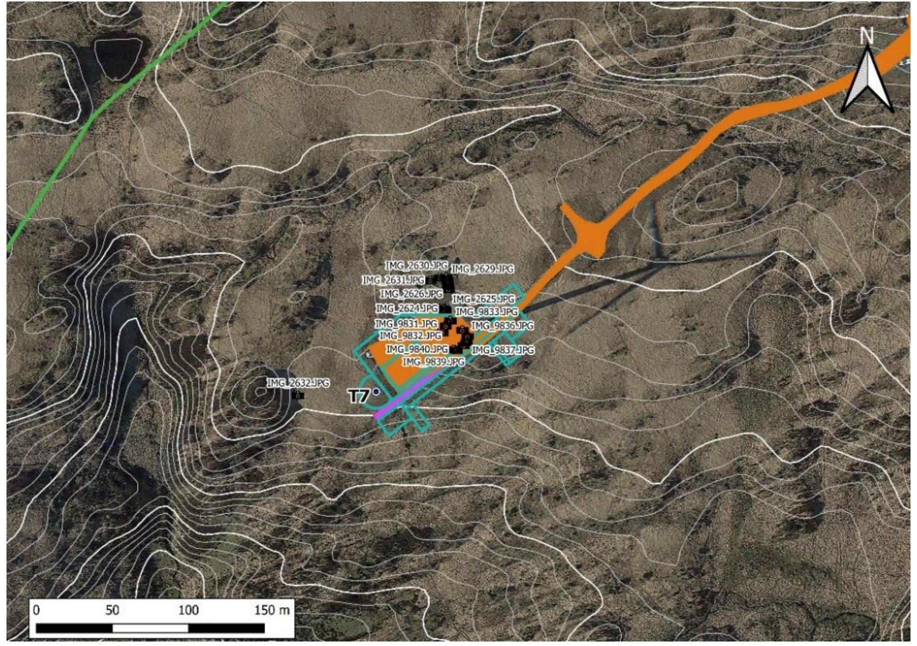
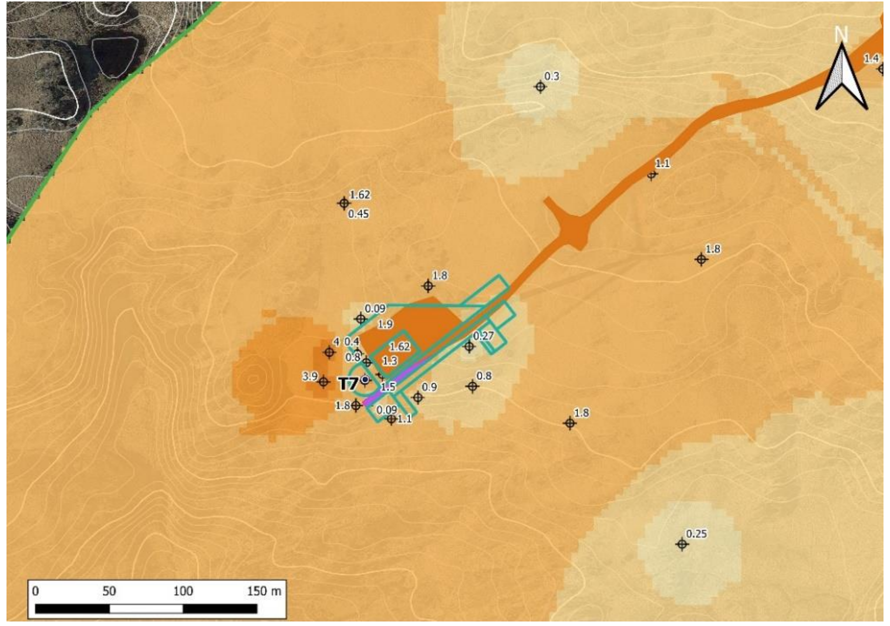


Table J- 7: Site reconnaissance of the Turbine 7 site.

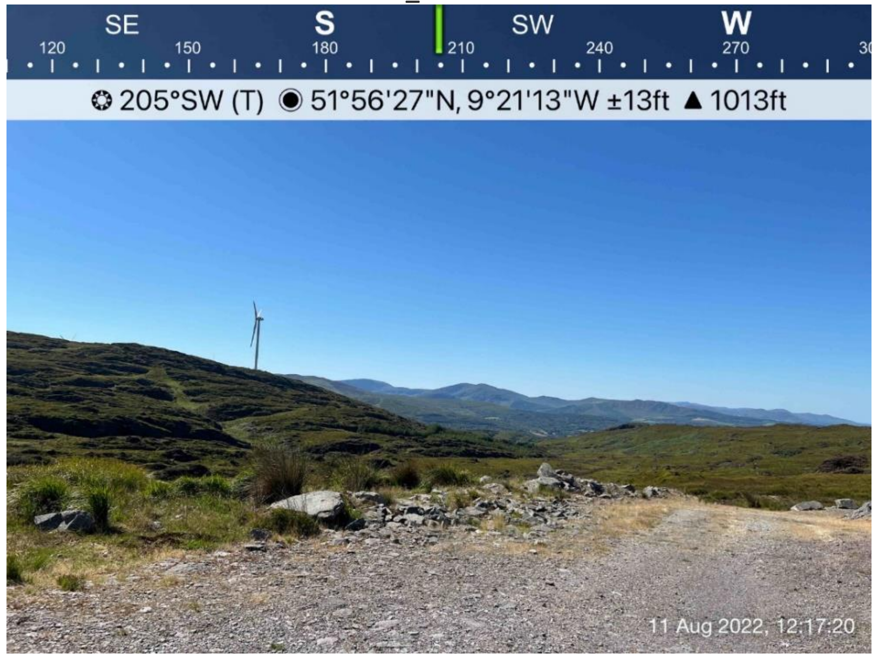
Imagery



Peat geo-investigation



IMG_9838.JPG



Shared legend

- 📷 Geotagged Photos
- Contour Lines (2m)
- Contour Lines (10m)

Wind Farm Layout

- ● Turbine Locations
- 🟩 Site Boundary
- ▢ Hardstand Locations
- 🟪 As Built Substation
- 🟫 Proposed Borrow Pit Location
- 🟦 Construction Compounds
- 🟧 Roads to be Upgraded
- 🟪 Proposed Roads and Widening
- ⬜ Existing Site Roads
- - - - Existing 110kV OHL

Peat Depth (m)

- <= 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4
- ⌖ Peat Probe and Trial Pit Locations (Depth in m)

Description

Date of the satellite images: 2020. [Google].

Date of the ground-based pictures: 27th of April and 11th August 2022 [GDG].

Geomorphology: Varied terrain, with rocky outcrop ridges, and flat peatland areas. Much of the location consists of existing hardstand.

Peat: Peat depth varies from 0.09 to 2m across the hardstands and turbine location. Slope angle of 2.3 degrees.

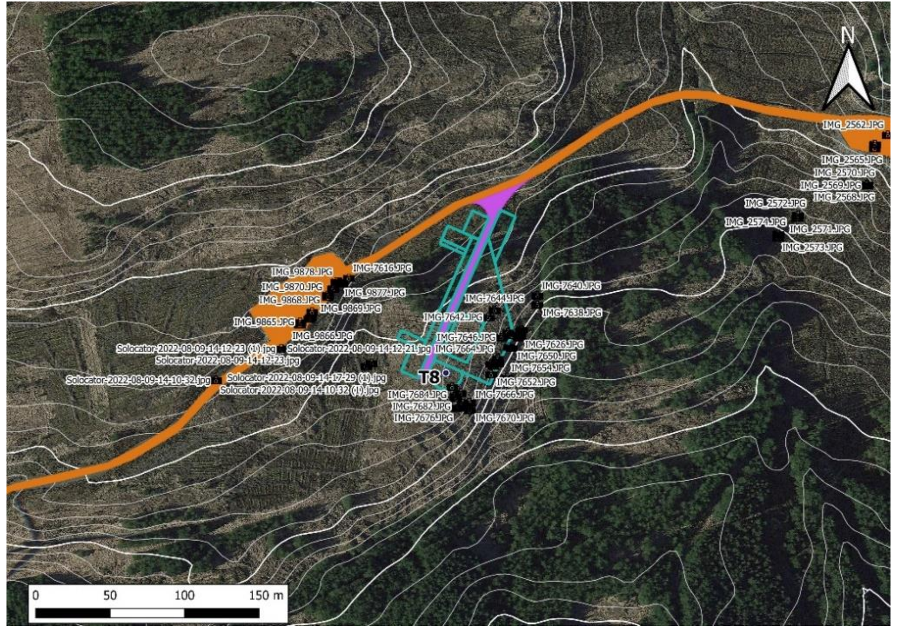
Instability evidences: No.

IMG_9840.JPG

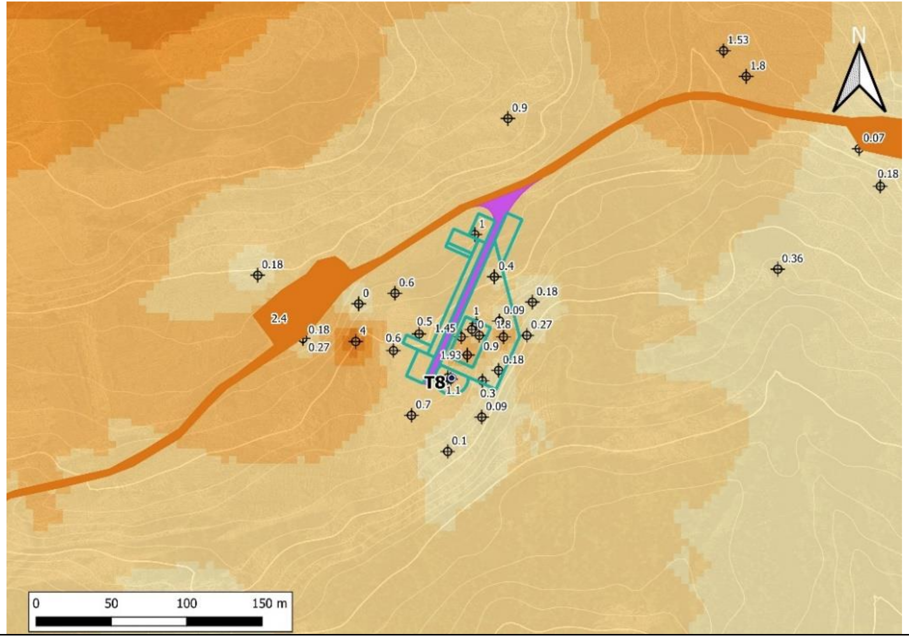
IMG_2632.JPG

Table J- 8: Site reconnaissance of Turbine 8 site.

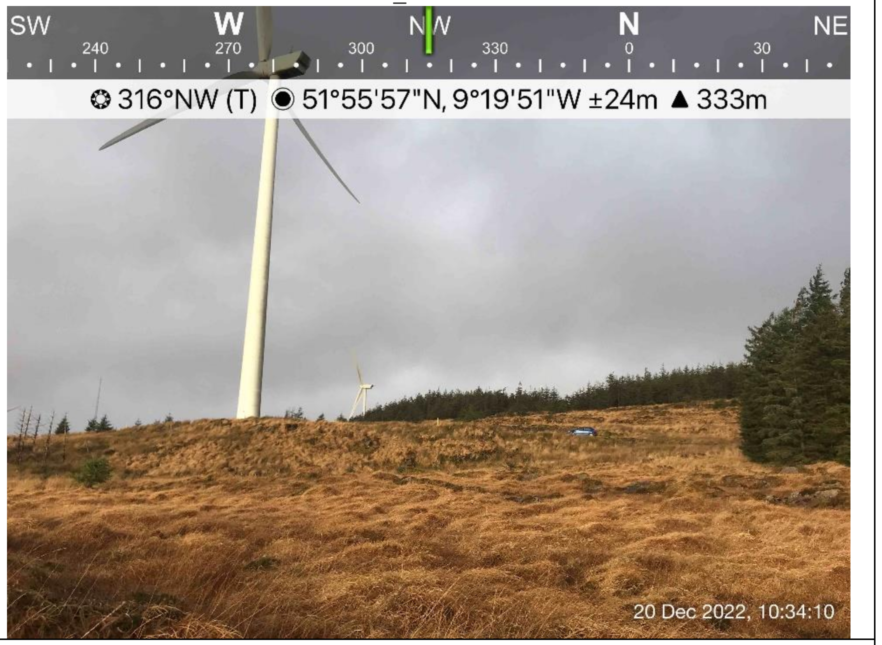
Imagery



Peat geo-investigation



IMG_7684.JPG



Shared legend

- ◘ Geotagged Photos
- — Contour Lines (2m)
- — Contour Lines (10m)

Wind Farm Layout

- ◉ Turbine Locations
- 🟩 Site Boundary
- ▢ Hardstand Locations
- 🟪 As Built Substation

- 🟫 Proposed Borrow Pit Location
- 🟦 Construction Compounds
- 🟧 Roads to be Upgraded
- 🟪 Proposed Roads and Widening
- ⬜ Existing Site Roads
- - - - Existing 110kV OHL

Peat Depth (m)

- ▭ <= 0.5
- ▭ 0.5 - 1
- ▭ 1 - 2
- ▭ 2 - 3
- ▭ 3 - 4
- 🟫 > 4

⌖ Peat Probe and Trial Pit Locations (Depth in m)

Description

Date of the satellite images: 2020. [Google].

Date of the ground-based pictures: 22nd of December 2022 [GDG].

Geomorphology: Mixed terrain, with bedrock outcrop, sloping down to the east.

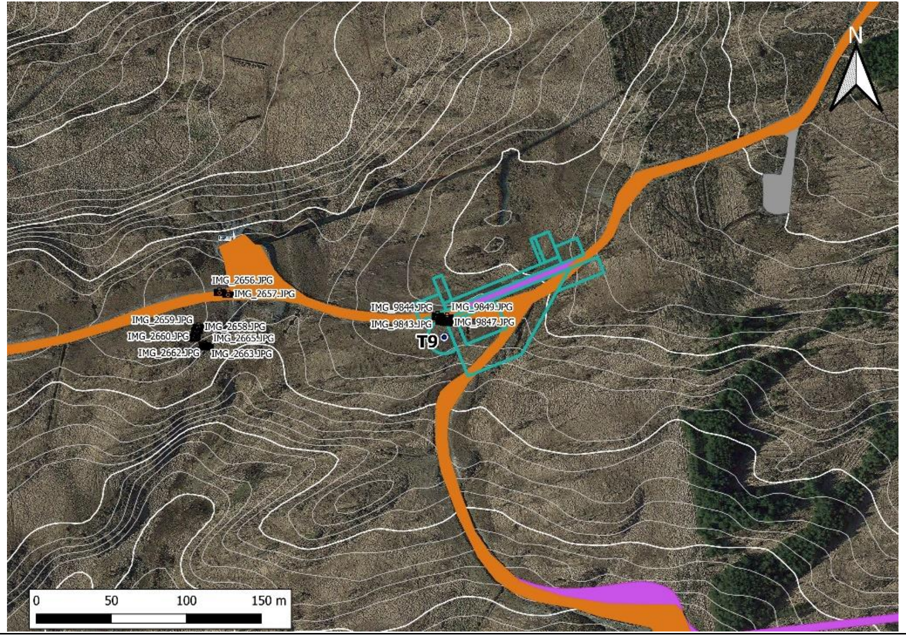
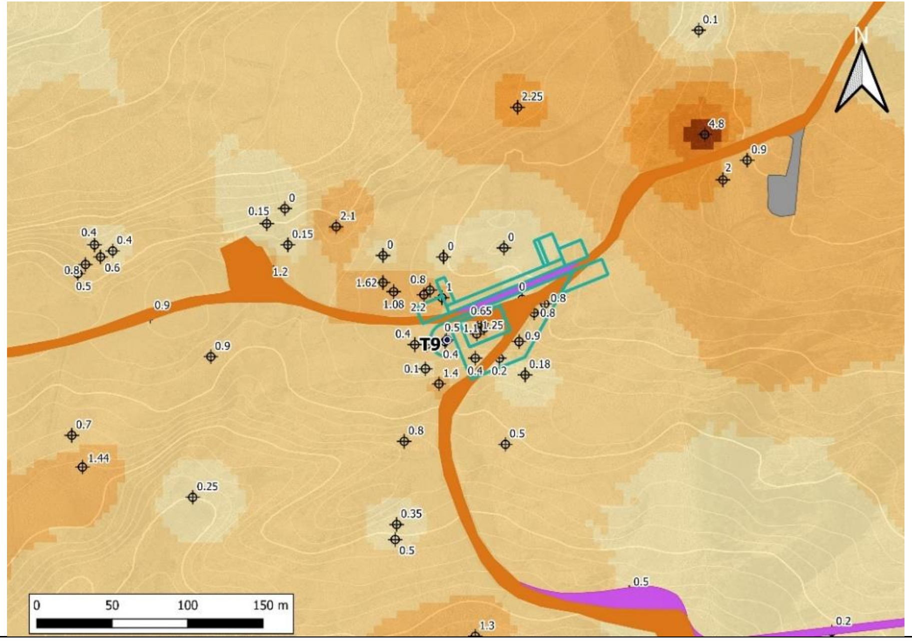
Peat: Depth ranges between 0 and 1.93m across the hardstand and the turbine location. Slope of 4.7 degrees at turbine location.

Instability evidence: No.

IMG_7646.JPG

IMG_7644.JPG

Table J- 9: Site reconnaissance of Turbine 9 site.

<table>
<tr>
<td>Imagery
 </td>
<td>Peat geo-investigation
 </td>
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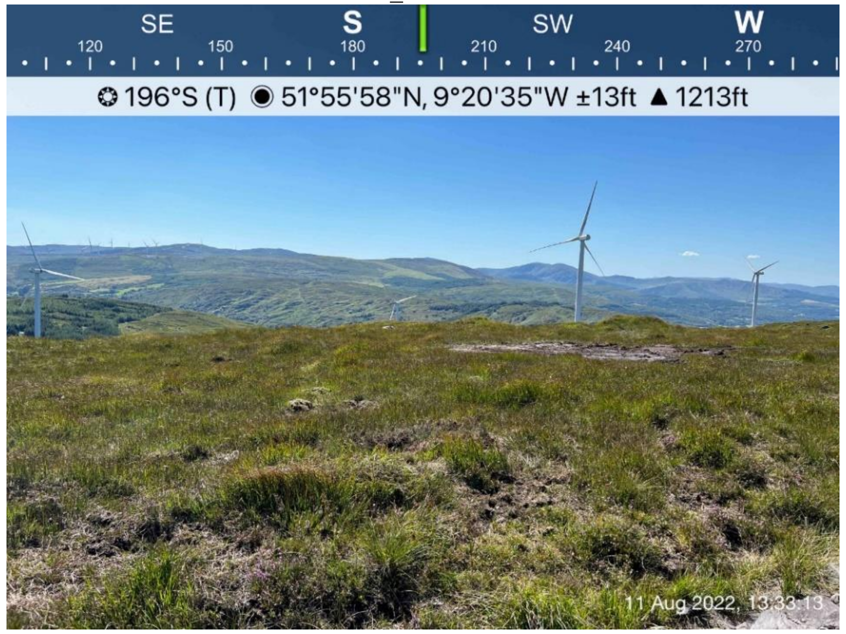
 </td>
</tr>
<tr>
<td colspan="2">Shared legend
📷 Geotagged Photos
— Contour Lines (2m)
— Contour Lines (10m)
Wind Farm Layout
◉ Turbine Locations
▭ Site Boundary
▭ Hardstand Locations
■ As Built Substation
■ Proposed Borrow Pit Location
■ Construction Compounds
■ Roads to be Upgraded
■ Proposed Roads and Widening
■ Existing Site Roads
- - - Existing 110kV OHL
Peat Depth (m)
■ <= 0.5
■ 0.5 - 1
■ 1 - 2
■ 2 - 3
■ 3 - 4
■ > 4
⌖ Peat Probe and Trial Pit Locations (Depth in m)</td>
<td></td>
</tr>
<tr>
<td>Description

Date of the satellite images: 2020. [Google].

Date of the ground-based pictures: August 11th, 2022 [GDG].

Geomorphology: Generally flat terrain, gently sloping to the south.

Peat: Depth ranges between 0 and 1.25 m with a value of 0.42 at the turbine location. Slope angle of 5 degrees at the turbine location.

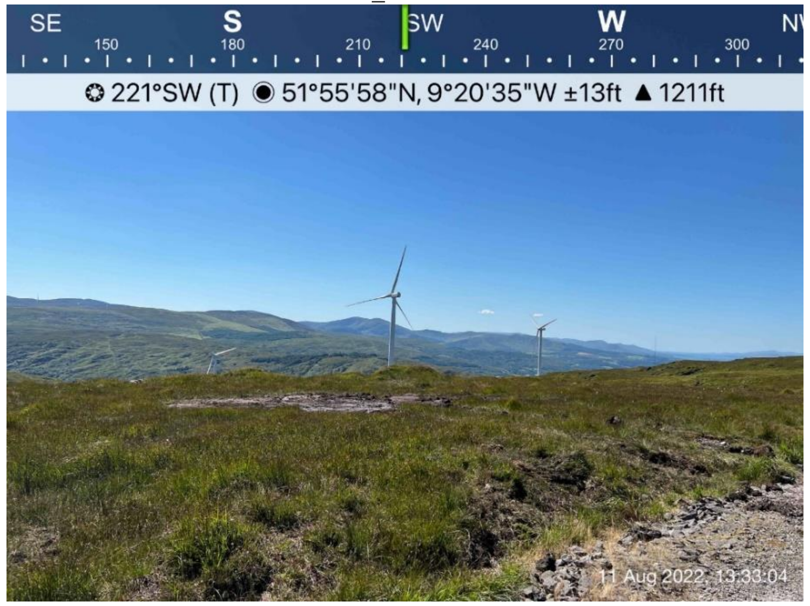
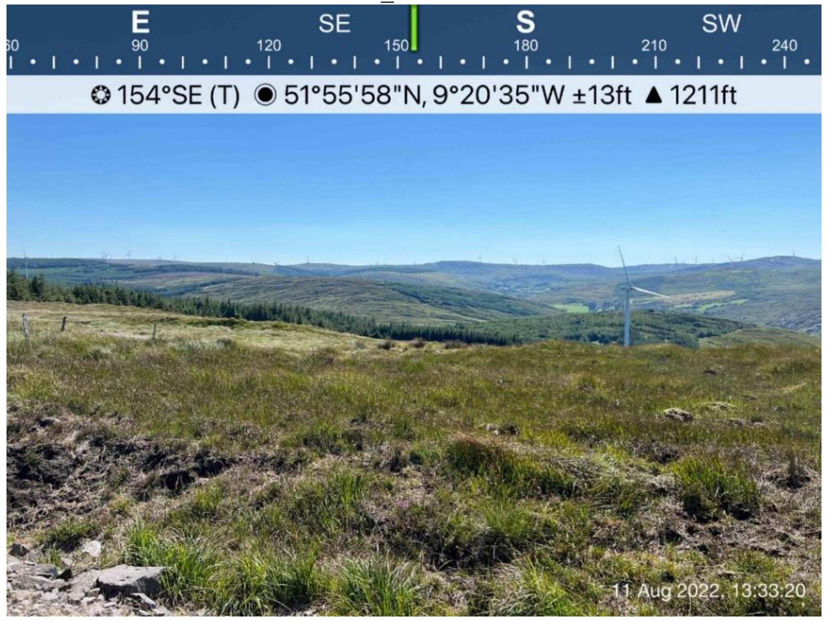
Instability evidences: No.</td>
<td>IMG_9844.JPG
 </td>
<td>IMG_9846.JPG
 </td>
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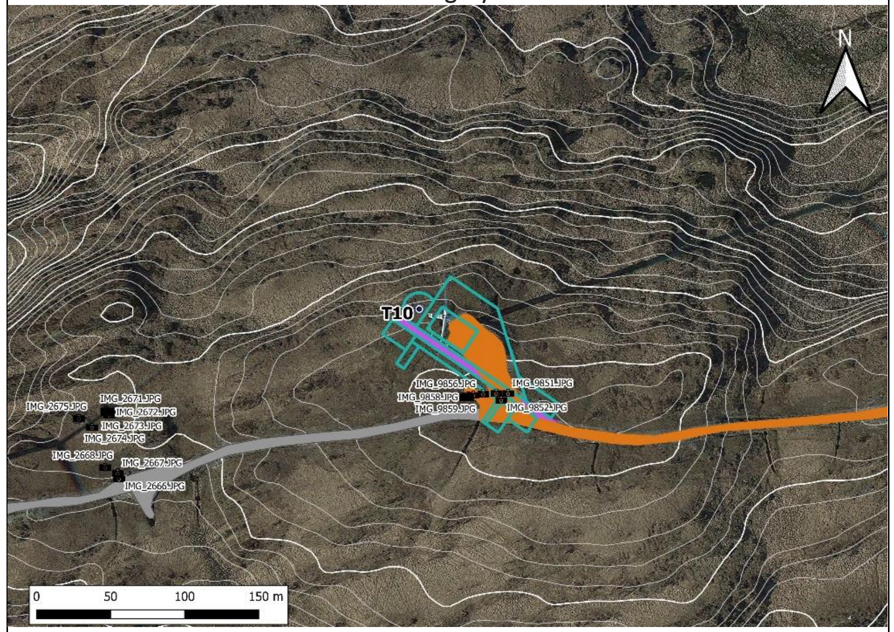
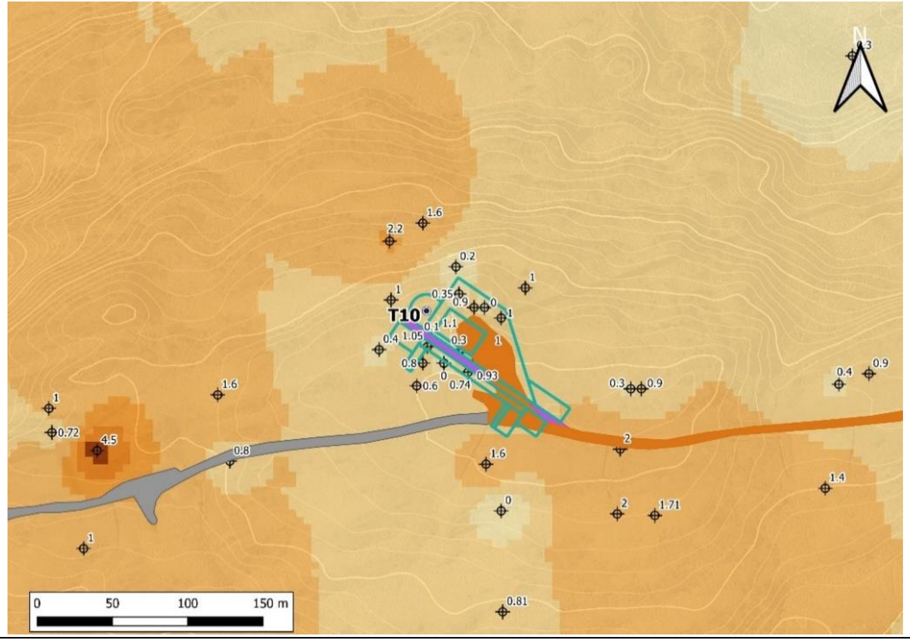
Table J- 10: Site reconnaissance of Turbine 10 site.

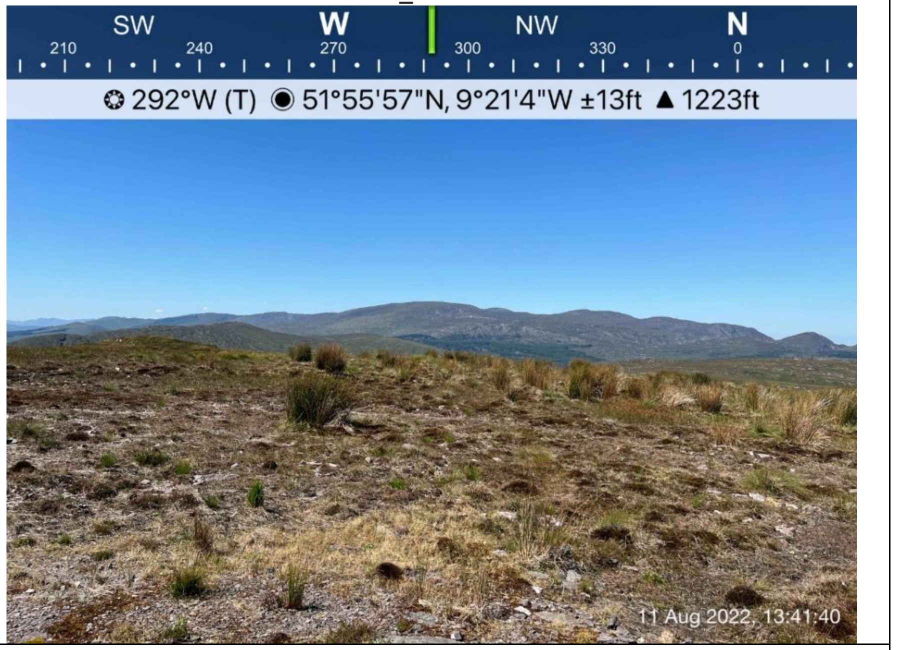
Imagery



Peat geo-investigation



IMG_9856.JPG



Shared legend

- Geotagged Photos
- Contour Lines (2m)
- Contour Lines (10m)

Wind Farm Layout

- ● Turbine Locations
- 🟩 Site Boundary
- ▢ Hardstand Locations
- 🟪 As Built Substation
- 🟫 Proposed Borrow Pit Location
- 🟦 Construction Compounds
- 🟧 Roads to be Upgraded
- 🟪 Proposed Roads and Widening
- ⬜ Existing Site Roads
- - - - Existing 110kV OHL

Peat Depth (m)

- <= 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- \> 4

⌖ Peat Probe and Trial Pit Locations (Depth in m)

Description

Date of the satellite images: 2020. [Google].

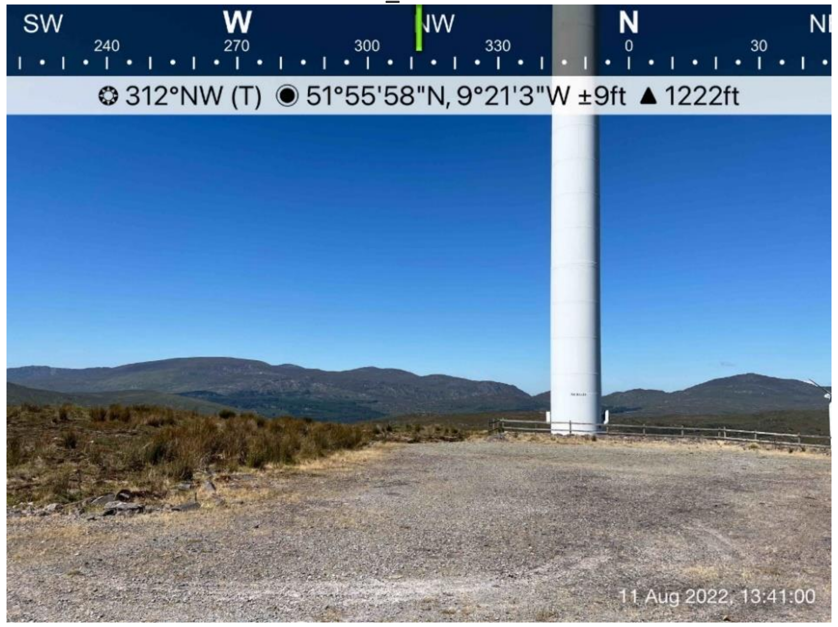
Date of the ground-based pictures: 11th of August 2022 [GDG].

Geomorphology: Generally flat, with some bedrock ridges. Slopes to north just north of the turbine location.

Peat: Peat dept5h varies from 0-1 m across the hardstand, with a depth of 0.55m at the turbine location. Slope angle of 9.9 Degrees in the vicinity of the turbine location

Instability evidence: No.

IMG_9851.JPG



IMG_9858.JPG

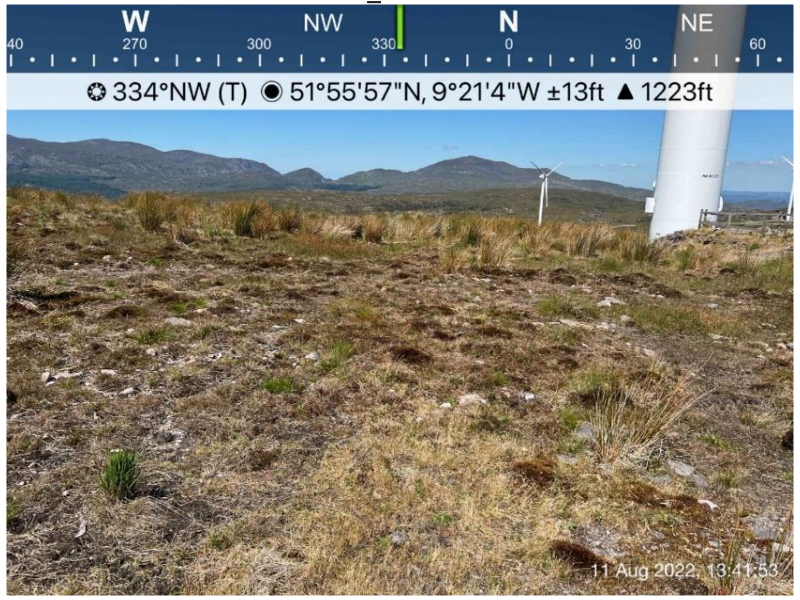
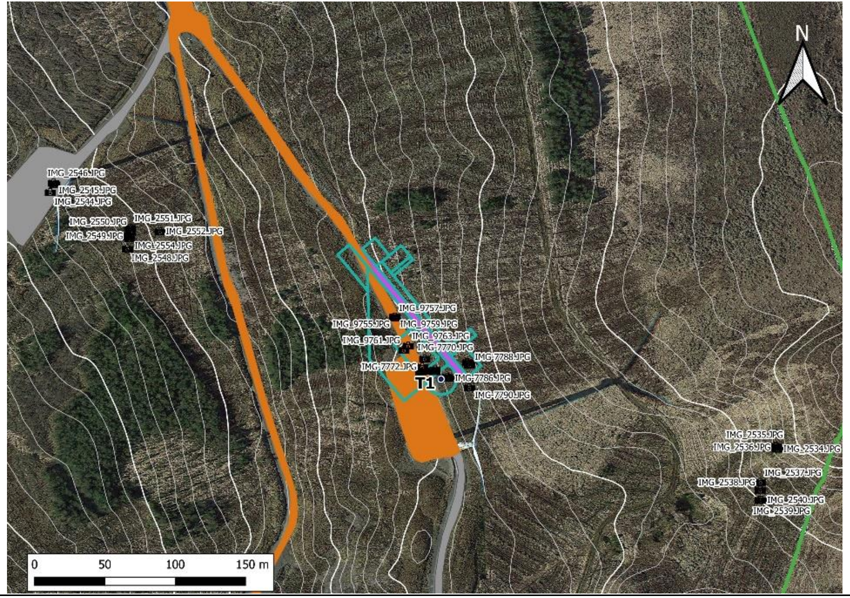
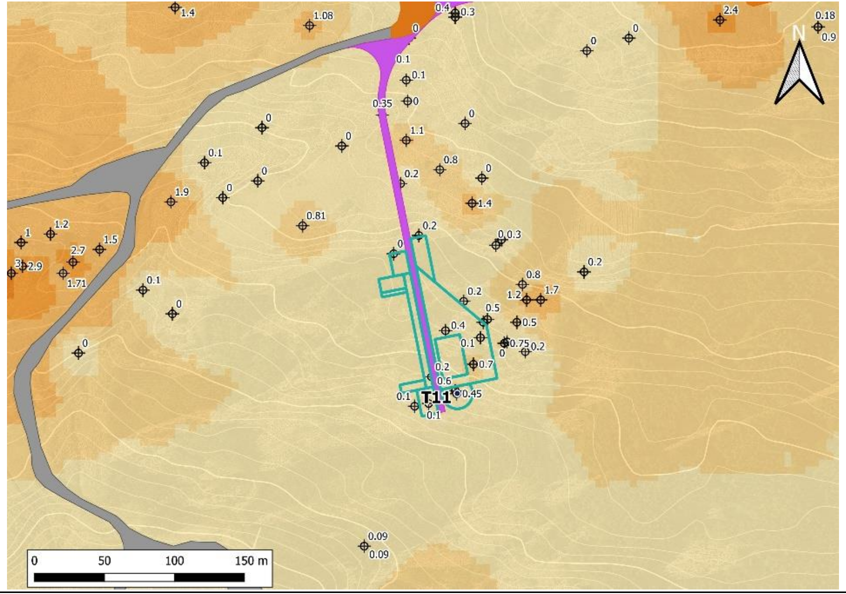


Table J- 11: Site reconnaissance of Turbine 11 site.

Imagery	Peat geo-investigation	Solocator-2022-08-09-15-48-23 (1).JPG
		
Shared legend 📷 Geotagged Photos — Contour Lines (2m) — Contour Lines (10m) **Wind Farm Layout** ◉ Turbine Locations 🟩 Site Boundary ▢ Hardstand Locations 🟪 As Built Substation 🟫 Proposed Borrow Pit Location 🟦 Construction Compounds 🟧 Roads to be Upgraded 🟪 Proposed Roads and Widening ⬜ Existing Site Roads - - - Existing 110kV OHL Peat Depth (m) ▨ <= 0.5 ▨ 0.5 - 1 ▨ 1 - 2 ▨ 2 - 3 ▨ 3 - 4 ▨ > 4 ⌖ Peat Probe and Trial Pit Locations (Depth in m)		
Description **Date of the satellite images:** 2020. [Google]. **Date of the ground-based pictures:** 9th of August 2022 [GDG]. **Geomorphology**: The site slopes to the southwest and is partially forested. **Peat**: The peat depth at the turbine location is 0.58m, and ranges from 0-0.7m across the hardstand. **Instability evidences**: No.	Solocator-2022-08-09-15-48-20 (1).JPG 	Solocator-2022-08-09-15-50-07 (1).JPG 

J.1 TRIAL PIT LOGS

GDG
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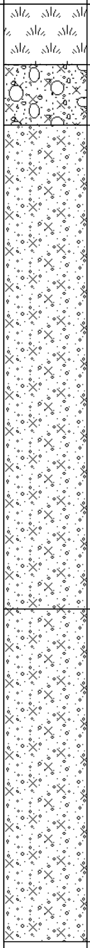
GEOSOLUTIONS

Trial Pit Log

TrialPit No
TP01
Sheet 1 of 1

Project Name: Kilgarvan Wind Farm	Project No. 22022	Co-ords: 509383.00 - 576733.00 Level: 411.00	Date 08/08/2022
Location: Kilgarvan Co.Kerry		Dimensions (m):	Scale 1:25
Client: Orsted/MKO		Depth 3.10	Logged



Water Strike	Samples & In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
	Depth	Type	Results				
							Dark brown PEAT
				0.20	410.80		Pale pinkish grey-brown gravelly silty SAND. Sand is fine to coarse. Gravel is fine to medium.
				0.40	410.60		Pale pinkish grey silty sandy GRAVEL. Sand is fine to coarse. Gravel is fine to coarse.
				2.00	409.00		Pale pinkish grey silty sandy GRAVEL with occasional angular cobbles. Sand is fine to coarse. Gravel is fine to coarse.
				3.10	407.90		End of Pit at 3.10m

Remarks:

Stability:

AGS

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GEOSOLUTIONS

Trial Pit Log

TrialPit No
TP02
Sheet 1 of 1

Project Name: Kilgarvan Wind Farm	Project No. 22022	Co-ords: 509992.00 - 576615.00 Level: 411.00	Date 08/08/2022
Location: Kilgarvan Co.Kerry		Dimensions (m): Depth 2.80	Scale 1:25
Client: Orsted/MKO			Logged

Water Strike	Samples & In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
	Depth	Type	Results				
						▨	Dark reddish brown fibrous PEAT with some occasional wood (H4)
				0.60	410.40	▨	Dark brown pseudo fibrous Peat (H6)
				1.60	409.40	▨	Light brown gravelly SILT. Gravel is fine t medium.
				1.80	409.20	▨	Light reddish grey silty sandy GRAVEL with occasional cobble. Sand is fine to coarse. Cobbles are angular or sandstone.
				2.80	408.20		End of Pit at 2.80m

Remarks:

Stability:

AGS

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Trial Pit Log

TrialPit No
TP03
Sheet 1 of 1

Project Name: Kilgarvan Wind Farm	Project No. 22022	Co-ords: 509466.00 - 576044.00 Level: 380.00		Date 08/08/2022
Location: Kilgarvan Co.Kerry		Dimensions (m):		Scale 1:25
Client: Orsted/MKO		Depth 2.60		Logged

Water Strike	Samples & In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
	Depth	Type	Results				
				1.10	378.90		Soft fibrous PEAT (H6)
				1.80	378.20		Soft pseudofibrous PEAT (H8)
				2.60	377.40		Greyish brown slightly gravelly slightly sandy SILT with some organic material. Sand is fine to medium. Some occasional cobbles from 2.0m.
							End of Pit at 2.60m

1
2
3
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5

Remarks:

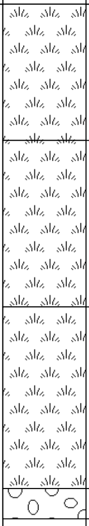
Stability:

AGS

Trial Pit Log

TrialPit No
TP04
Sheet 1 of 1

Project Name: Kilgarvan Wind Farm
Project No. 22022
Co-ords: 507082.00 - 576447.00
Level: 342.00
Date 09/08/2022
Location: Kilgarvan Co.Kerry
Dimensions (m):
Depth 1.70
Scale 1:25
Client: Orsted/MKO
Logged

Water Strike	Samples & In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
	Depth	Type	Results				
							Dark brown fibrous PEAT (H4)
				0.45	341.55		Dark brown pseudofibrous spongy PEAT (H7)
				1.00	341.00		Dark brown pseudofibrous spongy PEAT (H8)
				1.60	340.40		Large SANDSTONE boulder
				1.70	340.30		End of Pit at 1.70m

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2
3
4
5

Remarks:

Stability:

GDG
GAVIN & DOHERTY
GEOSOLUTIONS

Trial Pit Log

TrialPit No
TP05
Sheet 1 of 1

Project Name: Kilgarvan Wind Farm	Project No. 22022	Co-ords: 509767.00 - 576956.00 Level: 427.00	Date 08/08/2022
Location: Kilgarvan Co.Kerry		Dimensions (m):	Scale 1:25
Client: Orsted/MKO		Depth 2.70	Logged

Water Strike	Samples & In Situ Testing Depth	Type	Results	Depth (m)	Level (m)	Legend	Stratum Description
						▨	Very dark brown pseudofibrous PEAT with strong organic odour (H7)
				1.00	426.00	▨	Very dark brown pseudofibrous PEAT with strong organic odour (H8)
				1.40	425.60	▨	Light reddish grey sandy gravelly SILT with occasional angular cobble. Sand is fine to coarse. Gravel is fine to coarse.
				2.70	424.30		End of Pit at 2.70m

1
2
3
4
5

Remarks:

Stability:

AGS

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Trial Pit Log

TrialPit No
TP06
Sheet 1 of 1

Project Name: Kilgarvan Wind Farm	Project No. 22022	Co-ords: 508664.00 - 576659.00 Level: 362.00		Date 08/08/2022
Location: Kilgarvan Co.Kerry		Dimensions (m):		Scale 1:25
Client: Orsted/MKO		Depth 2.30		Logged

Water Strike	Samples & In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
	Depth	Type	Results				
						▨	Dark reddish brown fibrous spongey PEAT (H6)
				1.80	360.20	▨	Pale pinkish grey silty sandy GRAVEL with occasional angular cobbles. Sand is fine to coarse. Gravel is fine to coarse.
				2.30	359.70		End of Pit at 2.30m

1
2
3
4
5

Remarks:

Stability:

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Trial Pit Log

TrialPit No TP07
Sheet 1 of 1

Project Name: Kilgarvan Wind Farm	Project No. 22022	Co-ords: 509500.00 - 576760.00 Level: 413.00	Date 08/08/2022
Location: Kilgarvan Co.Kerry		Dimensions (m): Depth 4.00	Scale 1:25
Client: Orsted/MKO			Logged

Water Strike	Samples & In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
	Depth	Type	Results				
				0.40	412.60	▨	Dark brown fibrous PEAT with high timber content [suspected previous side cast material]
				2.00	411.00	▨	Dark brown fibrous PEAT (H6)
				3.10	409.90	▨	Pale pinkish grey sandy gravelly SILT.
				4.00	409.00	▨	Pale pinkish grey sandy gravelly SILT with occasional angular cobbles
							End of Pit at 4.00m

Remarks:

Stability:

AGS

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GEOSOLUTIONS

Trial Pit Log

TrialPit No
TP08
Sheet 1 of 1

Project Name: Kilgarvan Wind Farm
Project No. 22022
Co-ords: 507626.00 - 576483.00
Level: 365.00
Date 09/08/2022

Location: Kilgarvan Co.Kerry
Dimensions (m):
Depth 1.90
Scale 1:25

Client: Orsted/MKO
Logged

Water Strike	Samples & In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
	Depth	Type	Results				
				0.90	364.10	▨	Dark brown pseudofibrous spongy PEAT (H6)
				1.00	364.00	▨	Dark black amorphous PEAT with rare fibres (H9)
				1.70	363.30	▨	Brown sandy silty GRAVEL with medium cobble content. Sand is fine to coarse. Gravel is fine to coarse.
				1.90	363.10	▨	Pinkish-grey angular COBBLES with GRAVELS. Gravels and fine to coarse [weathered rock]
							End of Pit at 1.90m

Remarks:

Stability:

AGS

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GEOSOLUTIONS

Trial Pit Log

TrialPit No
TP08A
Sheet 1 of 1

Project Name: Kilgarvan Wind Farm	Project No. 22022	Co-ords: 507636.00 - 576514.00 Level: 365.00	Date 09/08/2022
Location: Kilgarvan Co.Kerry		Dimensions (m): Depth 1.10	Scale 1:25
Client: Orsted/MKO			Logged

Water Strike	Samples & In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
	Depth	Type	Results				
				1.00	364.00		Dark brown fibrous PEAT (H4)
				1.10	363.90		Large SANDSTONE boulder
							End of Pit at 1.10m

Remarks:

Stability:

GDG
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GEOSOLUTIONS

Trial Pit Log

TrialPit No
TP08B
Sheet 1 of 1

Project Name: Kilgarvan Wind Farm

Project No.
22022

Co-ords: 507624.00 - 576516.00
Level: 367.00

Date
09/08/2022

Location: Kilgarvan Co.Kerry

Dimensions (m):
Depth
2.40

Scale
1:25

Client: Orsted/MKO

Logged

Water Strike	Samples & In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
	Depth	Type	Results				
							Dark brown fibrous PEAT (H4)
				2.20	364.80		Grey angular SANDSTONE boulders and cobbles
				2.40	364.60		End of Pit at 2.40m

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2
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4
5

Remarks:

Stability:

AGS

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GEOSOLUTIONS

Trial Pit Log

TrialPit No
TP09
Sheet 1 of 1

Project Name: Kilgarvan Wind Farm	Project No. 22022	Co-ords: 510227.00 - 576105.00 Level: 423.00	Date 08/08/2022
Location: Kilgarvan Co.Kerry		Dimensions (m):	Scale 1:25
Client: Orsted/MKO		Depth 2.20	Logged

Water Strike	Samples & In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
	Depth	Type	Results				
							Black spongey PEAT with wood and fibres (H6)
				0.60	422.40		Reddish grey-blown sandy gravelly SILT with medium cobble content. Sand is fine to coarse. Cobbles are angular of sandstone.
				2.20	420.80		End of Pit at 2.20m

Remarks:

Stability:

AGS

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GEOSOLUTIONS

Trial Pit Log

TrialPit No
TP12
Sheet 1 of 1

Project Name:	Kilgarvan Wind Farm	Project No. 22022	Co-ords: 507543.00 - 577721.00 Level: 229.00	Date 09/08/2022
Location:	Kilgarvan Co.Kerry		Dimensions (m):	Scale 1:25
Client:	Orsted/MKO		Depth 1.70	Logged

Water Strike	Samples & In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
	Depth	Type	Results				
							Dark brown fibrous PEAT (H4)
				0.40	228.60		Dark brown pseudofibrous spongy PEAT (H7)
				1.60	227.40		Large SANDSTONE boulder
				1.70	227.30		End of Pit at 1.70m

Remarks:

Stability:

GDG
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GEOSOLUTIONS

Trial Pit Log

TrialPit No
TP13
Sheet 1 of 1

Project Name: Kilgarvan Wind Farm	Project No. 22022	Co-ords: 509964.00 - 576780.00 Level: 421.00	Date 08/08/2022
Location: Kilgarvan Co.Kerry		Dimensions (m):	Scale 1:25
Client: Orsted/MKO		Depth 3.50	Logged

Water Strike	Samples & In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description
	Depth	Type	Results				
				0.50	420.50		Dark brown fibrous PEAT with high timber content [suspected previous side cast material]
				0.55	420.45		Dead grass and organic material [Previous grass surface]
				1.00	420.00		Dark brown fibrous spongey PEAT (H4)
				2.30	418.70		Dark brown fibrous spongey PEAT (H6)
				3.50	417.50		Grey slightly silty sandy GRAVEL with occasional angular cobble. Gravel is fine to coarse. Sand is fine to coarse.

End of Pit at 3.50m

1
2
3
4
5

Remarks:

Stability:

AGS

Appendix K FACTOR OF SAFETY

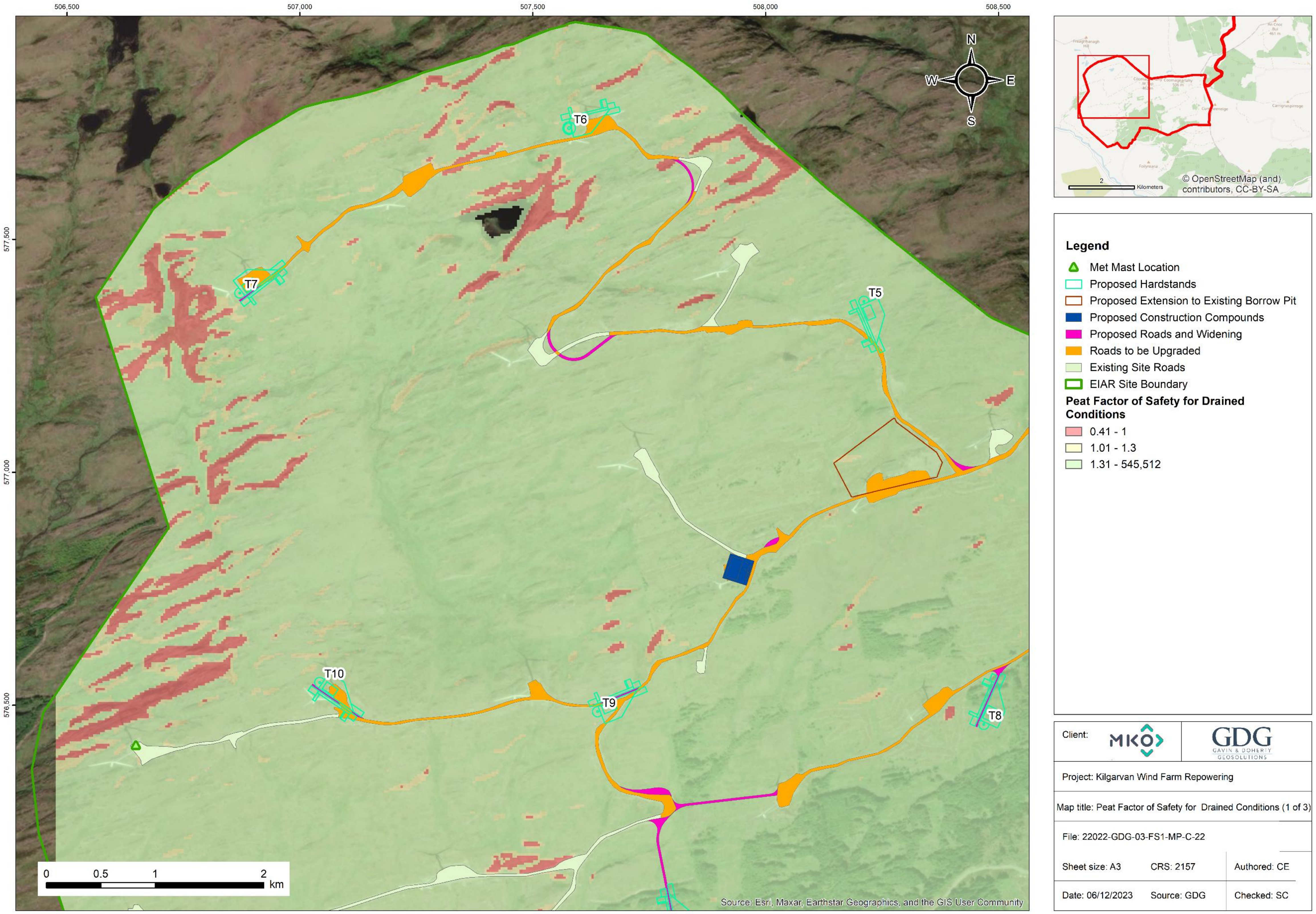


Figure K- 1: Peat Factor of Safety for Drained Conditions (1 of 3).

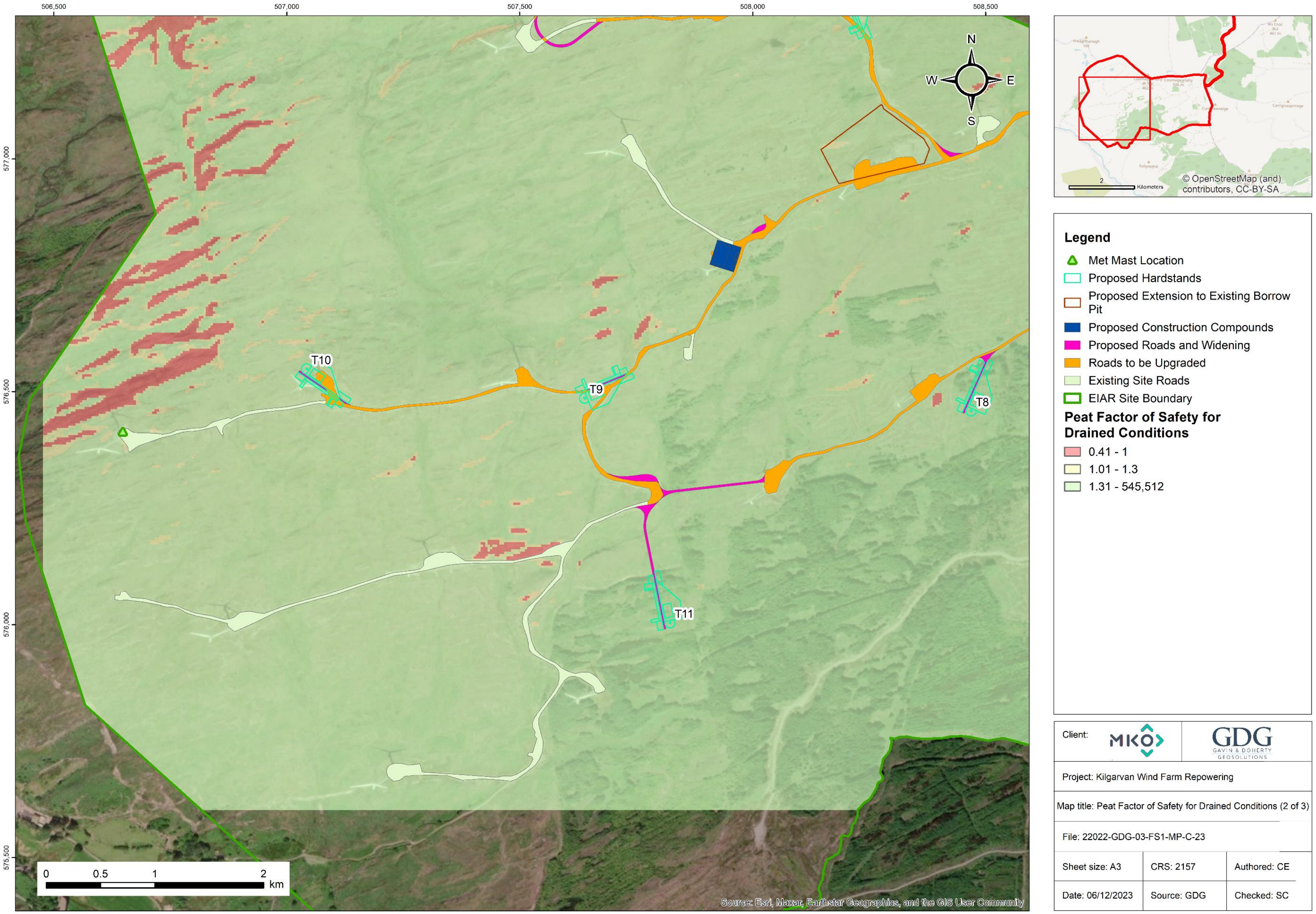


Figure K- 2: Peat Factor of Safety for Drained Conditions (2 of 3).

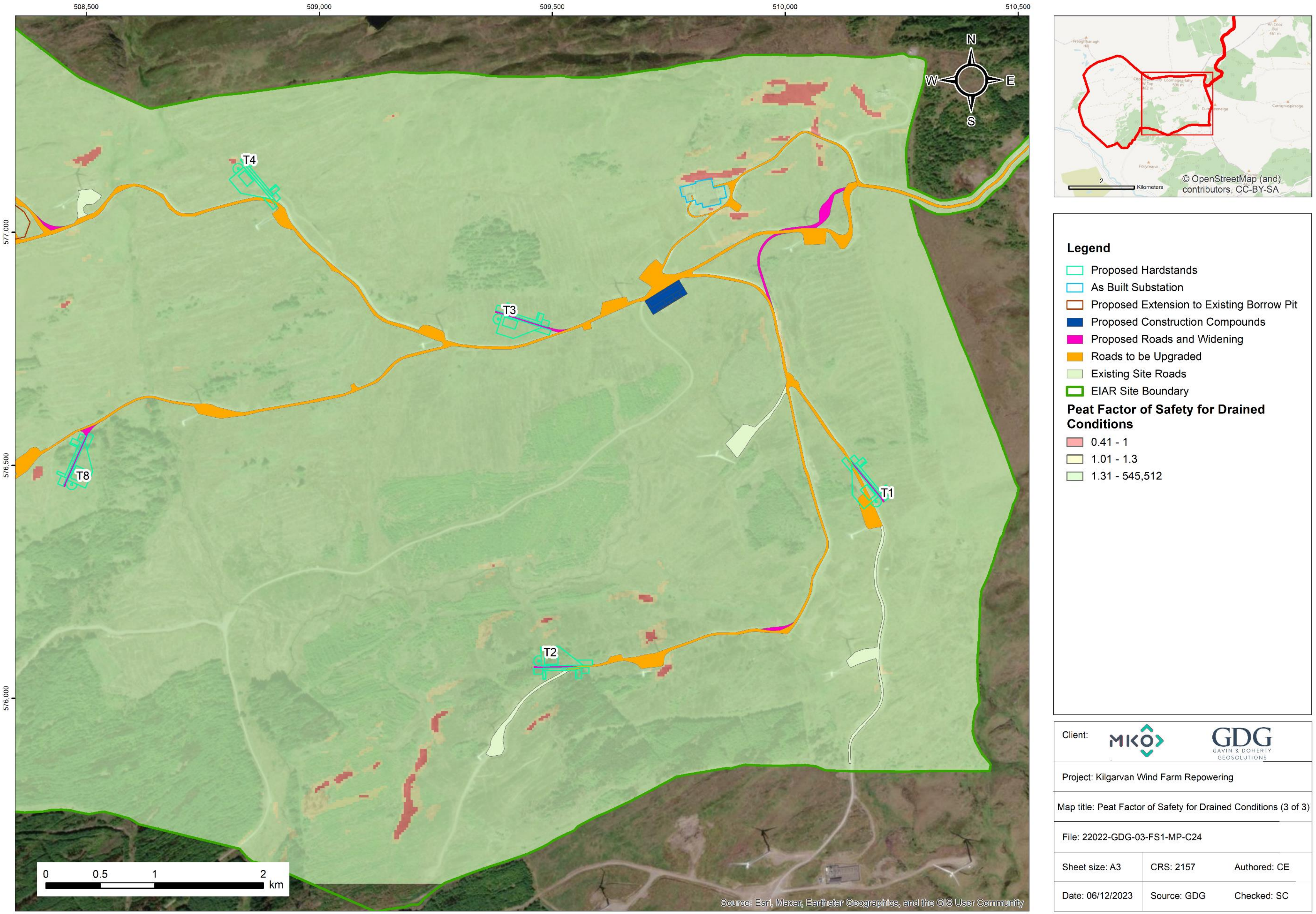
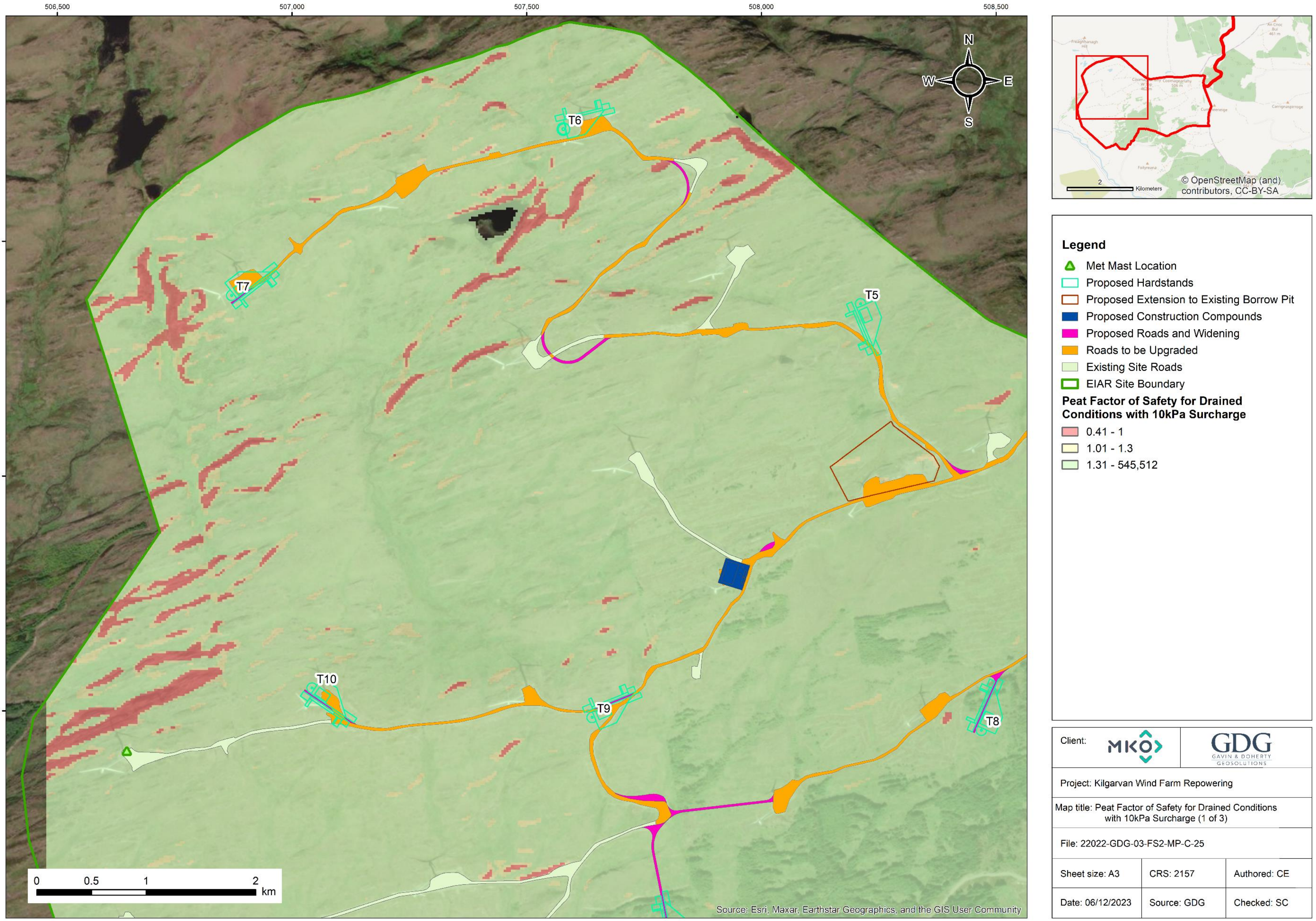


Figure K- 3: Peat Factor of Safety for Drained Conditions (3 of 3).



Project: Kilgarvan Wind Farm Repowering

Map title: Peat Factor of Safety for Drained Conditions with 10kPa Surcharge (1 of 3)

File: 22022-GDG-03-FS2-MP-C-25

Sheet size: A3	CRS: 2157	Authored: CE
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Figure K- 4: Peat Factor of Safety for Drained Conditions with 10kPa Surcharge (1 of 3).

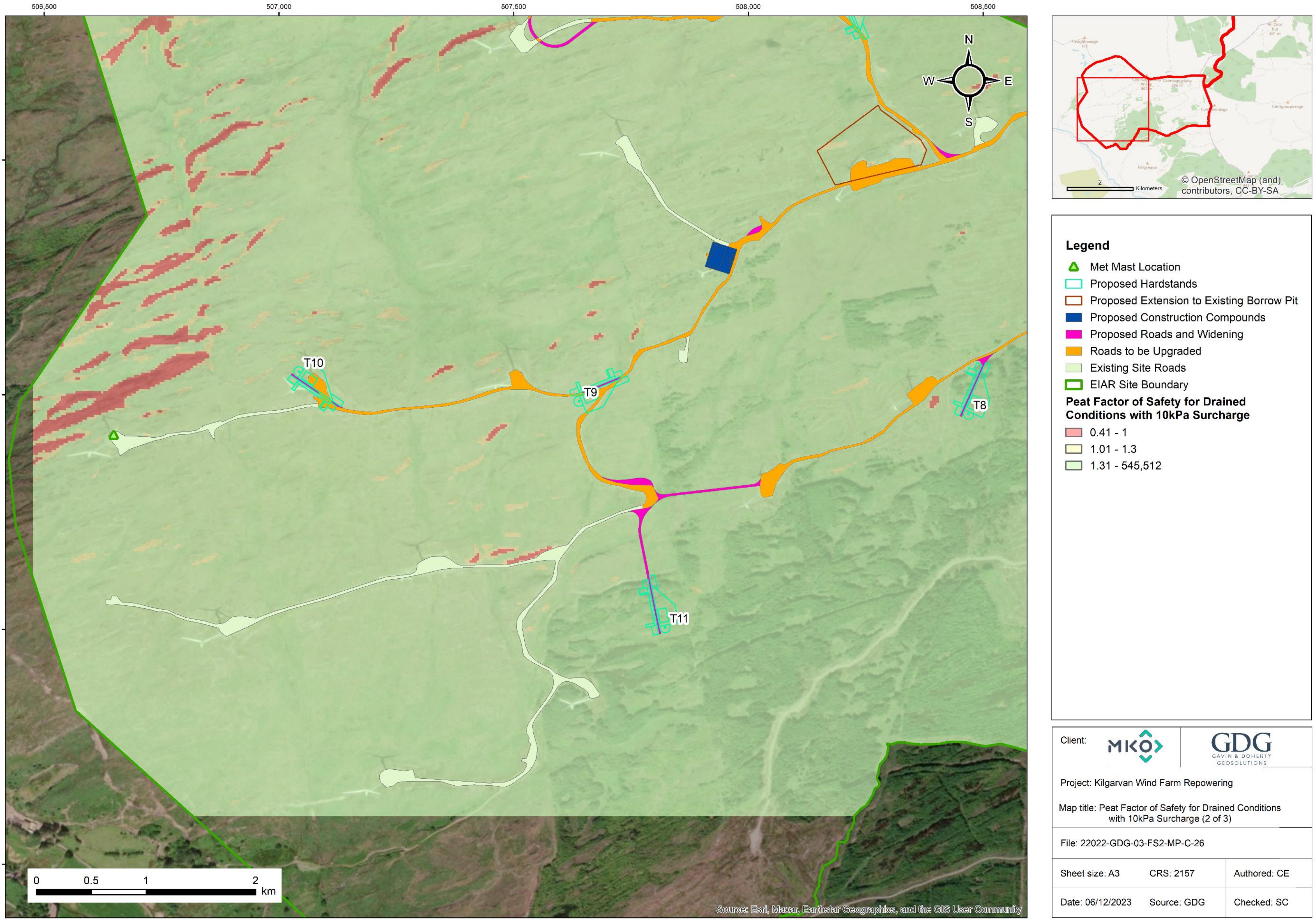


Figure K- 5: Peat Factor of Safety for Drained Conditions with 10kPa Surcharge (2 of 3).

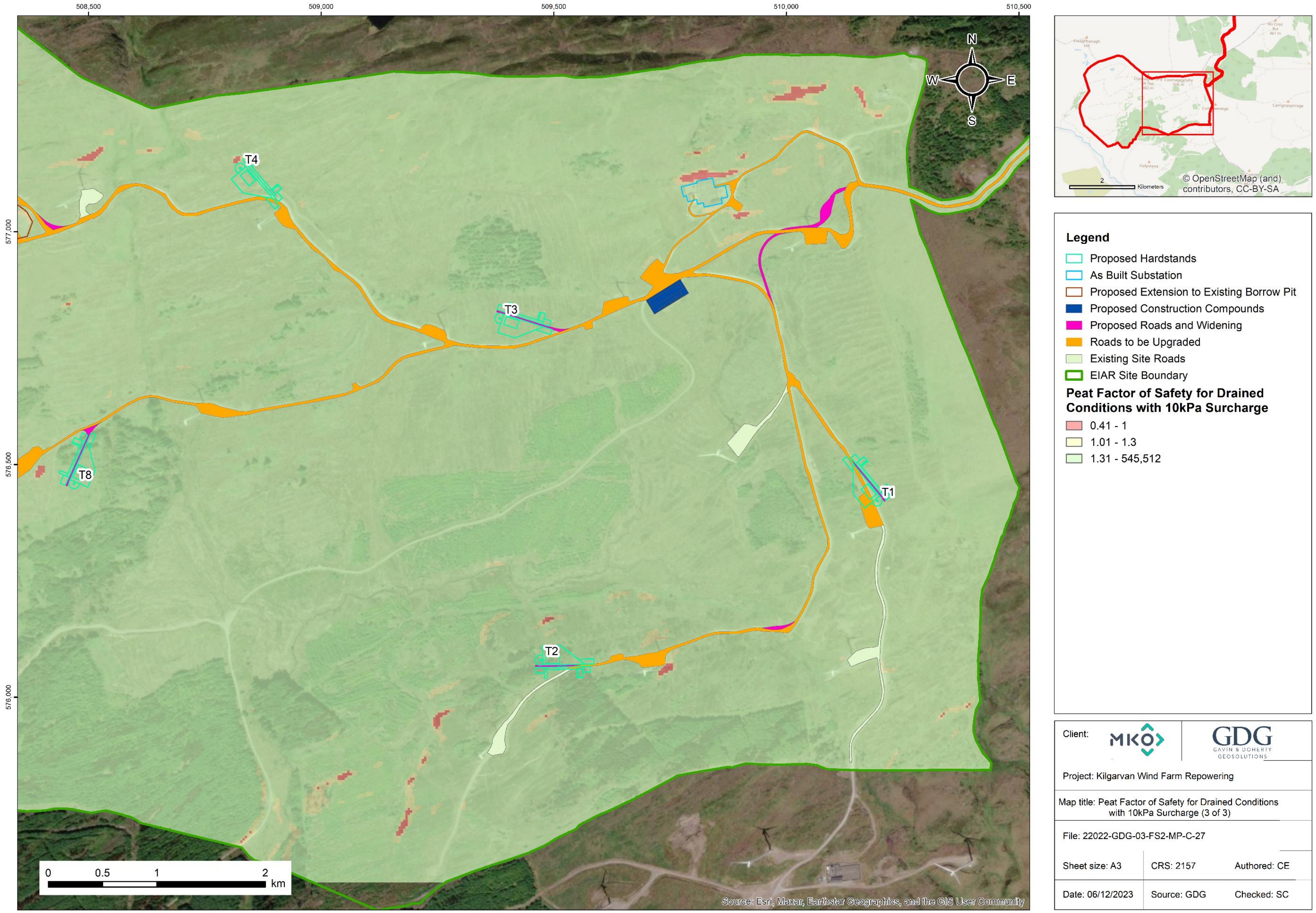


Figure K- 6: Peat Factor of Safety for Drained Conditions with 10kPa Surcharge (3 of 3).

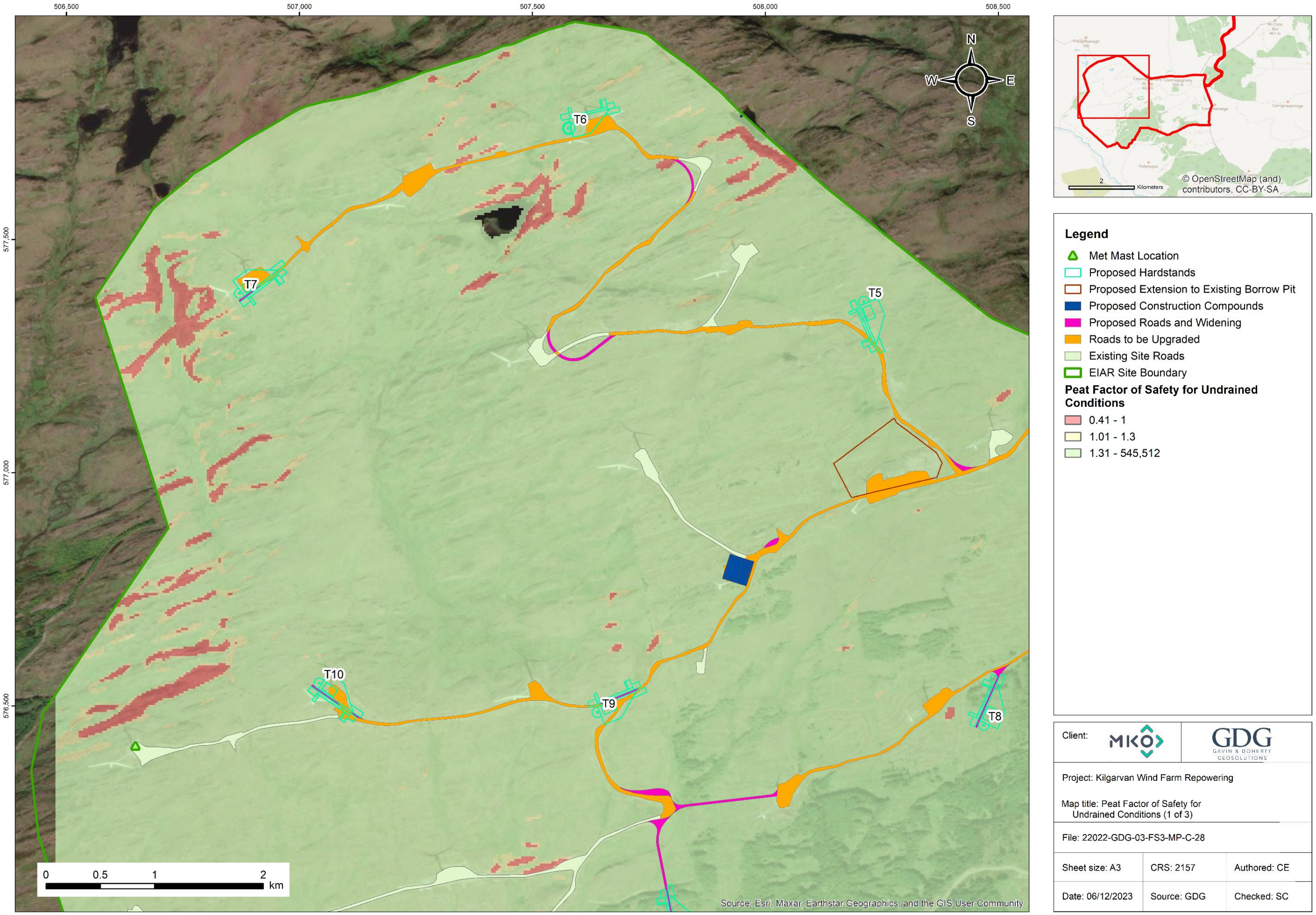
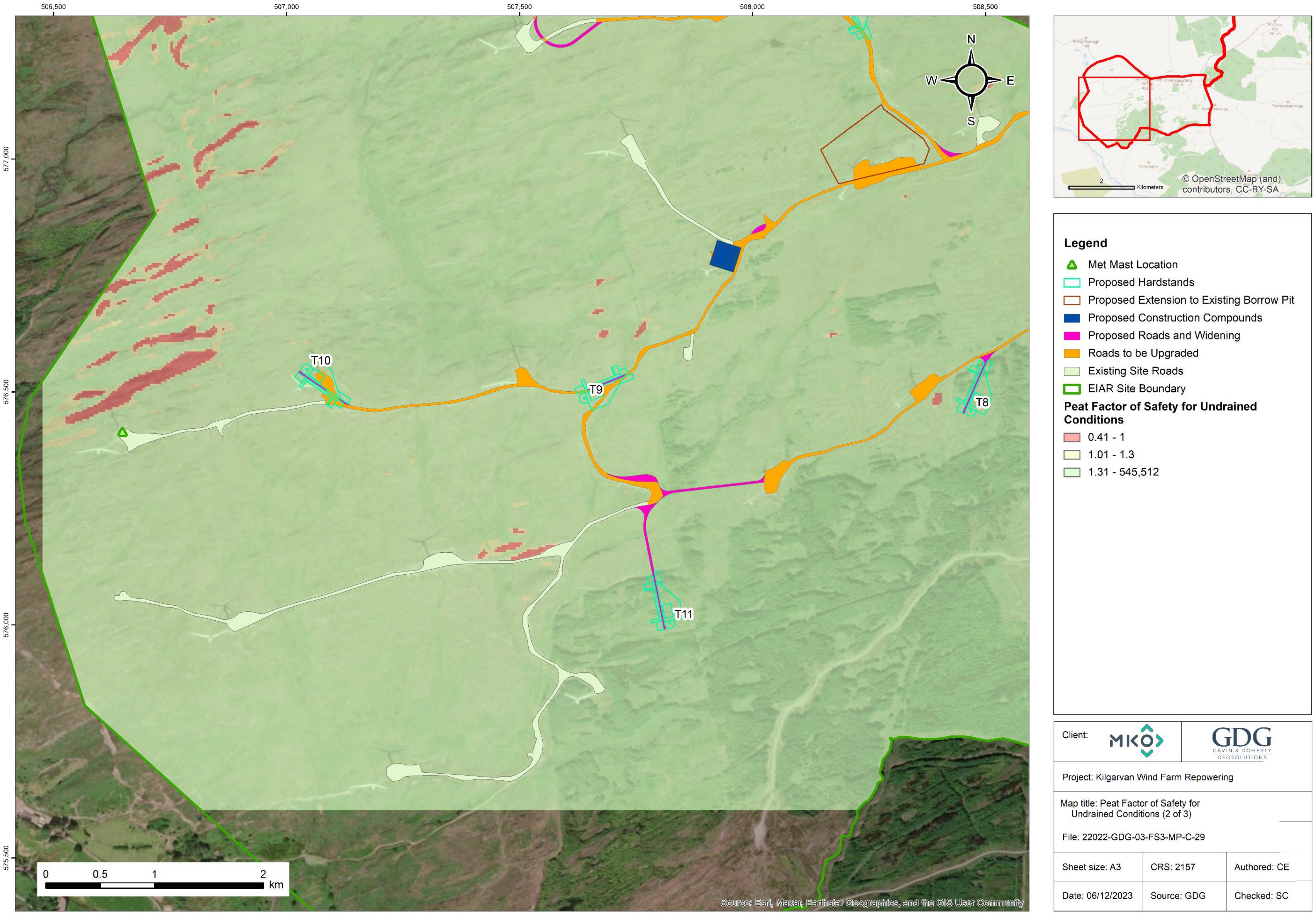


Figure K- 7: Peat Factor of Safety for Undrained Conditions (1 of 3).



Project: Kilgarvan Wind Farm Repowering

Map title: Peat Factor of Safety for Undrained Conditions (2 of 3)

File: 22022-GDG-03-FS3-MP-C-29

Sheet size: A3	CRS: 2157	Authored: CE
Date: 06/12/2023	Source: GDG	Checked: SC

Figure K- 8: Peat Factor of Safety for Undrained Conditions (2 of 3).

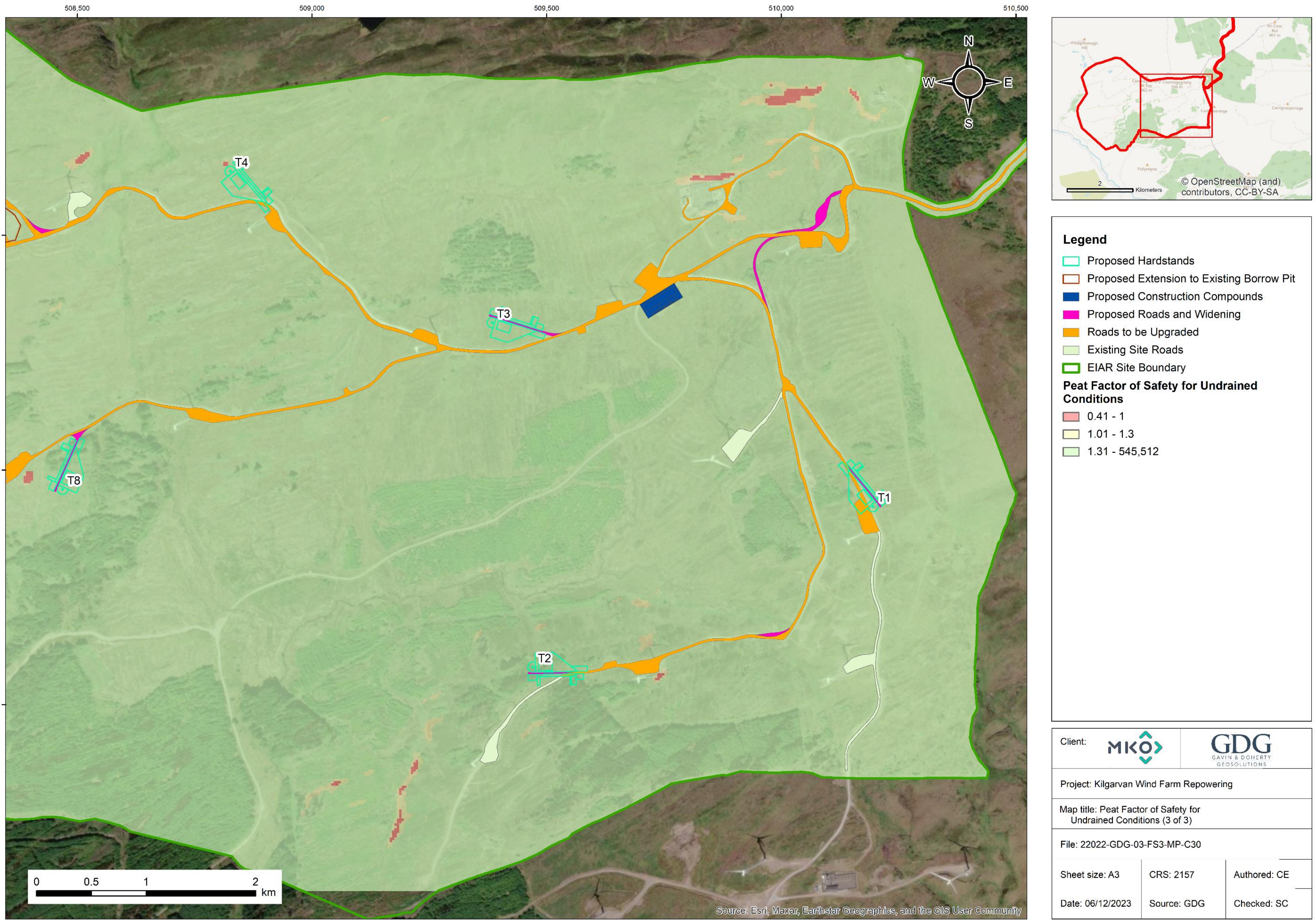


Figure K- 9: Peat Factor of Safety for Undrained Conditions (3of 3).

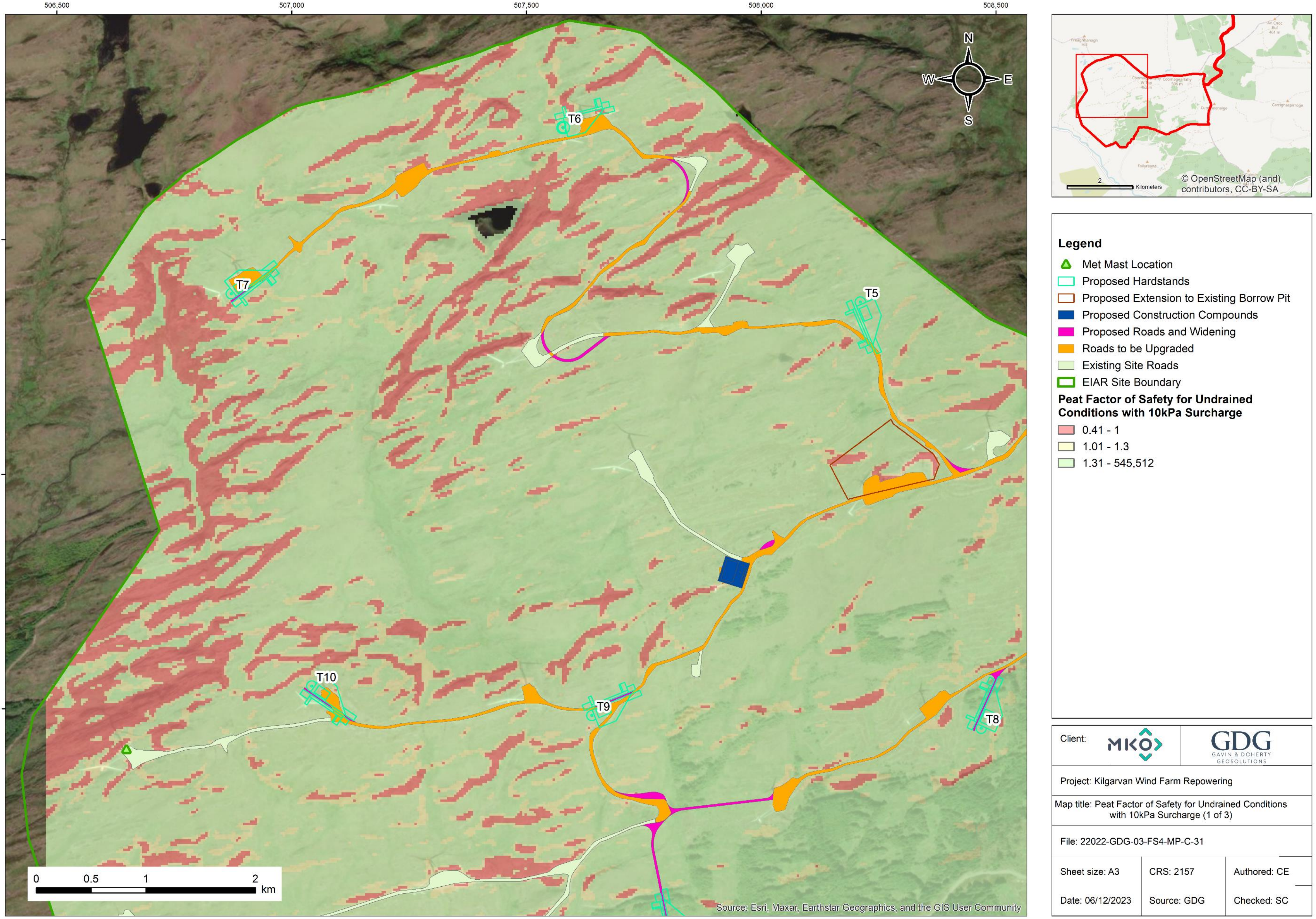


Figure K- 10: Peat Factor of Safety for Undrained Conditions with 10kPa Surcharge (1 of 3).

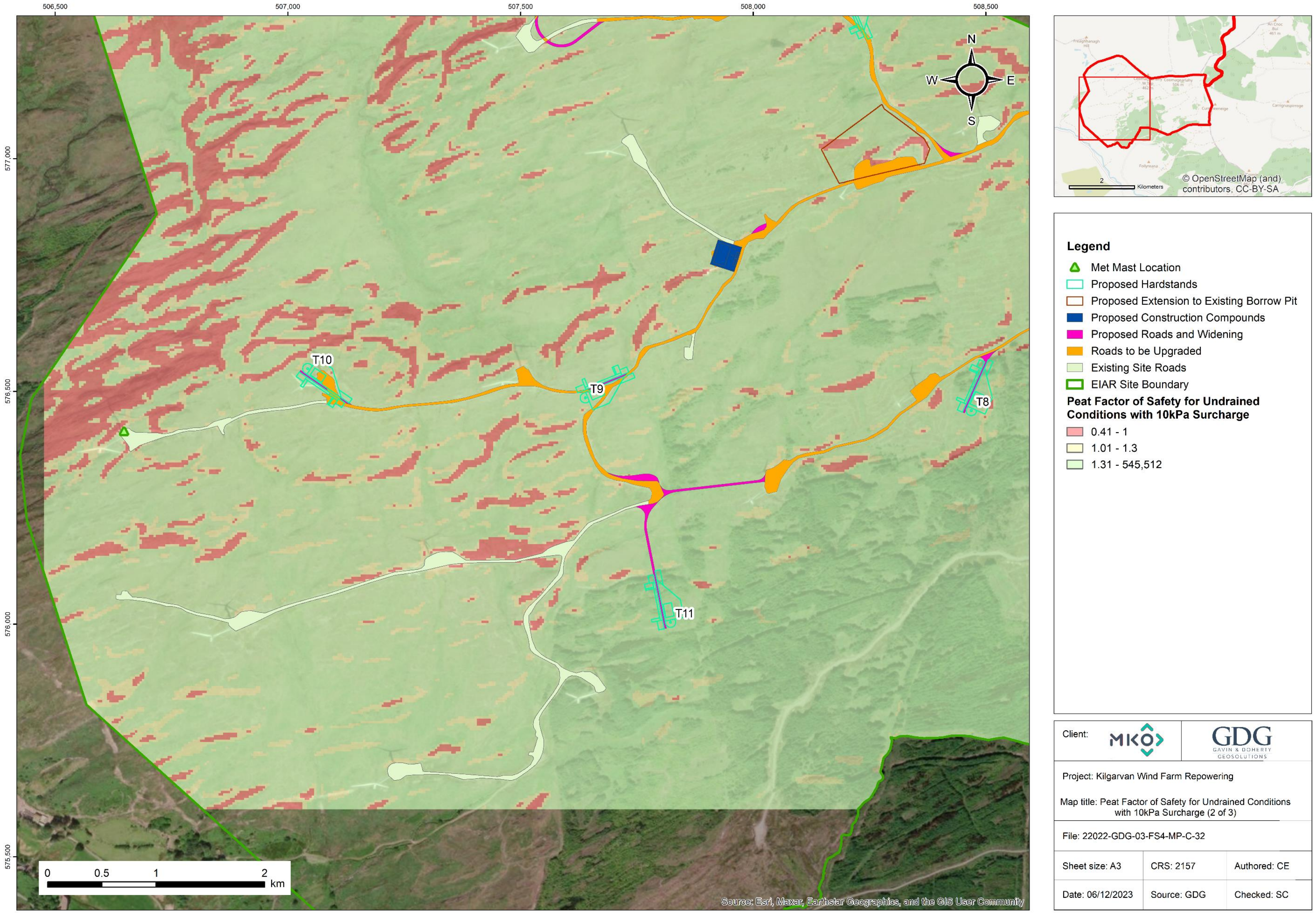


Figure K- 11: Peat Factor of Safety for Undrained Conditions with 10kPa Surcharge (2 of 3).

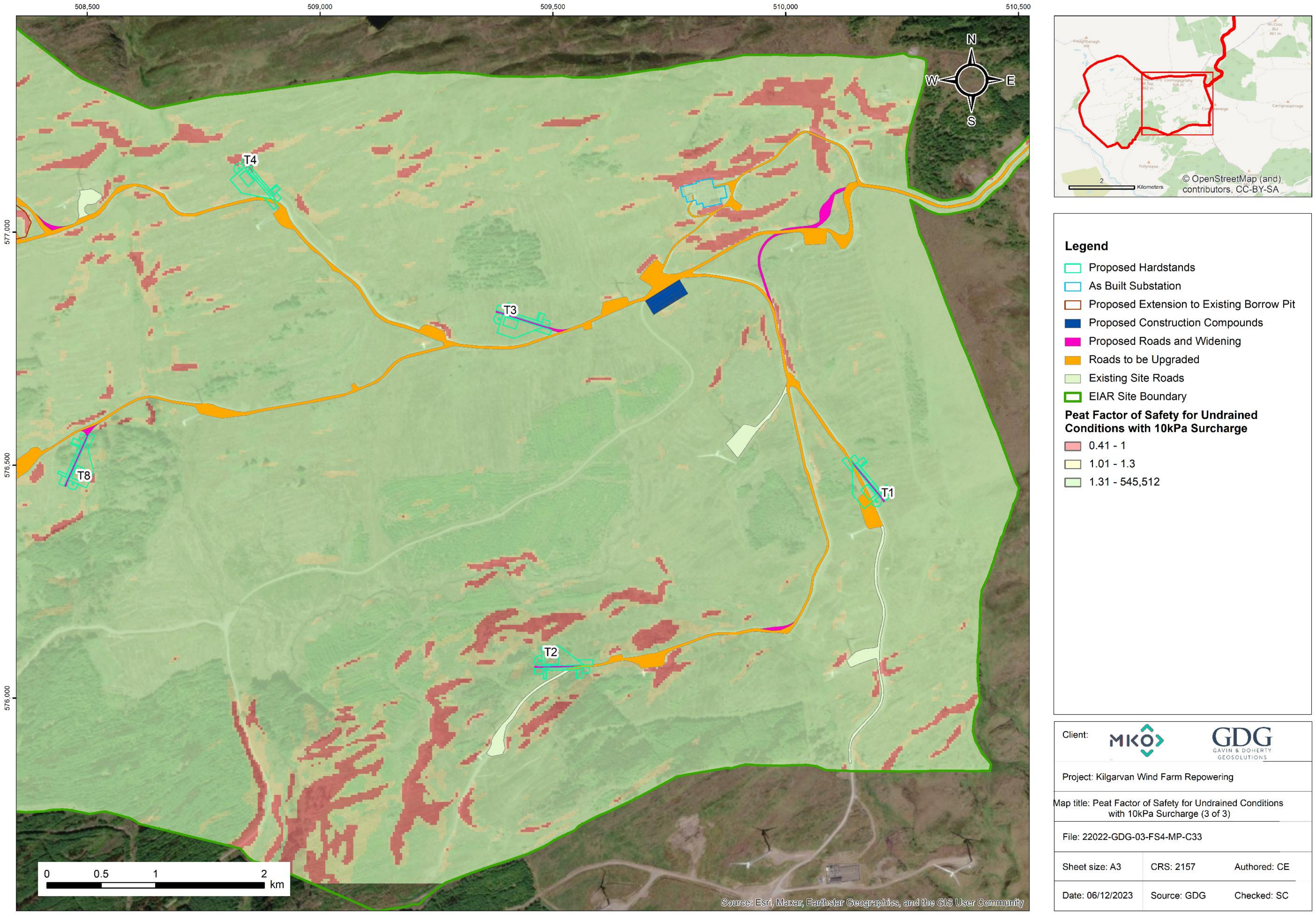


Figure K- 12: Peat Factor of Safety for Undrained Conditions with 10kPa Surcharge (3 of 3).

Table K- 1: Calculation of Factor of Safety for undrained conditions (with and without surcharge).

Proposed infrastructure	Slope	Cos Slope	Sin Slope	Undrained shear strength	Bulk unit weight of Peat	Peat depth	Factor of Safety	Surcharge	Factor of Safety with Surcharge	Slope
	(º)			Cu (kPa)	Y (kN/m^3)	(m)		(m)		Rad
T1	10.37846	0.984	0.180	5	10	0.247405654	**11.40**	1	**2.26**	0.181138
T2	7.0362799	0.992	0.122	5	10	1.681157983	**2.45**	1	**1.53**	0.122806
T3	6.73936729	0.993	0.117	5	10	0.18943879	**22.65**	1	**3.61**	0.117624
T4	7.23556579	0.992	0.126	5	10	0.9409709	**4.25**	1	**2.06**	0.126284
T5	13.1692151	0.974	0.228	5	10	0.261214709	**8.63**	1	**1.79**	0.229846
T6	15.2	0.965	0.262	5	10	0.57501284	**3.44**	1	**1.25**	0.26529
T7	3.61226288	0.998	0.063	5	10	1.578820774	**5.04**	1	**3.08**	0.063046
T8	5.50824057	0.995	0.096	5	10	0.69386639	**7.54**	1	**3.09**	0.096137
T9	4.5788394	0.997	0.080	5	10	0.570277449	**11.02**	1	**4.00**	0.079916
T10	9.85281988	0.985	0.171	5	10	0.587495841	**5.05**	1	**1.87**	0.171964
T11	9.3743694	0.987	0.163	5	10	0.456871225	**6.81**	1	**2.14**	0.163614
CC W	7.9	0.991	0.137	5	10	0.34	**10.80**	1	**2.74**	0.137881
CCE	6.6	0.993	0.115	5	10	0.63	**6.95**	1	**2.69**	0.115192
MM	6	0.995	0.105	5	10	0.75	**6.41**	1	**2.75**	0.10472

$$F = \frac{c_u}{\gamma z \sin\alpha \cos\alpha}$$

Where,

Undrained conditions

F = Factor of Safety
c_u = Undrained strength
γ = Bulk unit weight of material
z = Depth to failure plane assumed as depth of peat
α = Slope angle

Table K- 2: : Calculation of Factor of Safety for drained conditions (with and without surcharge).

Proposed infrastructure	Drained shear strength	Bulk unit weight of Peat	Peat depth	Bulk unit weight of water	Height of water table above failure surface	Slope	Cos Slope	$\cos^2$ Slope	Sin Slope	ϕ'	Tan ϕ'	**FoS**	Surcharge (m)	**FoS Surcharge**
	Cu (kPa)	Y (kN/m^3)	(m)	Y (kN/m^3)	(m)	(º)								
T1	4	10	0.2474057	9.8	0.247405654	10.37846	0.984	0.968	0.180	25	0.466	**9.17**	1	**3.86**
T2	4	10	1.681158	9.8	1.681157983	7.03628	0.992	0.985	0.122	25	0.466	**2.03**	1	**2.68**
T3	4	10	0.1894388	9.8	0.18943879	6.739367	0.993	0.986	0.117	25	0.466	**18.20**	1	**6.22**
T4	4	10	0.9409709	9.8	0.9409709	7.235566	0.992	0.984	0.126	25	0.466	**3.48**	1	**3.58**
T5	4	10	0.2612147	9.8	0.261214709	13.16922	0.974	0.948	0.228	25	0.466	**6.94**	1	**3.02**
T6	4	10	0.5750128	9.8	0.57501284	16.306	0.960	0.921	0.281	25	0.466	**2.61**	1	**1.97**
T7	4	10	1.5788208	9.8	1.578820774	3.612263	0.998	0.996	0.063	25	0.466	**4.18**	1	**5.42**
T8	4	10	0.6938664	9.8	0.69386639	5.508241	0.995	0.991	0.096	25	0.466	**6.13**	1	**5.37**
T9	4	10	0.5702774	9.8	0.570277449	4.578839	0.997	0.994	0.080	25	0.466	**8.93**	1	**6.95**
T10	4	10	0.5874958	9.8	0.587495841	9.85282	0.985	0.971	0.171	25	0.466	**4.09**	1	**3.21**
T11	4	10	0.4568712	9.8	0.456871225	9.374369	0.987	0.973	0.163	25	0.466	**5.50**	1	**3.66**
CC W	4	10	0.34	9.8	0.34	7.9	0.991	0.981	0.137	26	0.488	**8.71**	1	**4.83**
CCE	4	10	0.63	9.8	0.63	6.6	0.993	0.987	0.115	27	0.510	**5.65**	1	**4.89**
MM	4	10	0.75	9.8	0.75	6	0.995	0.989	0.105	28	0.532	**5.23**	1	**5.13**

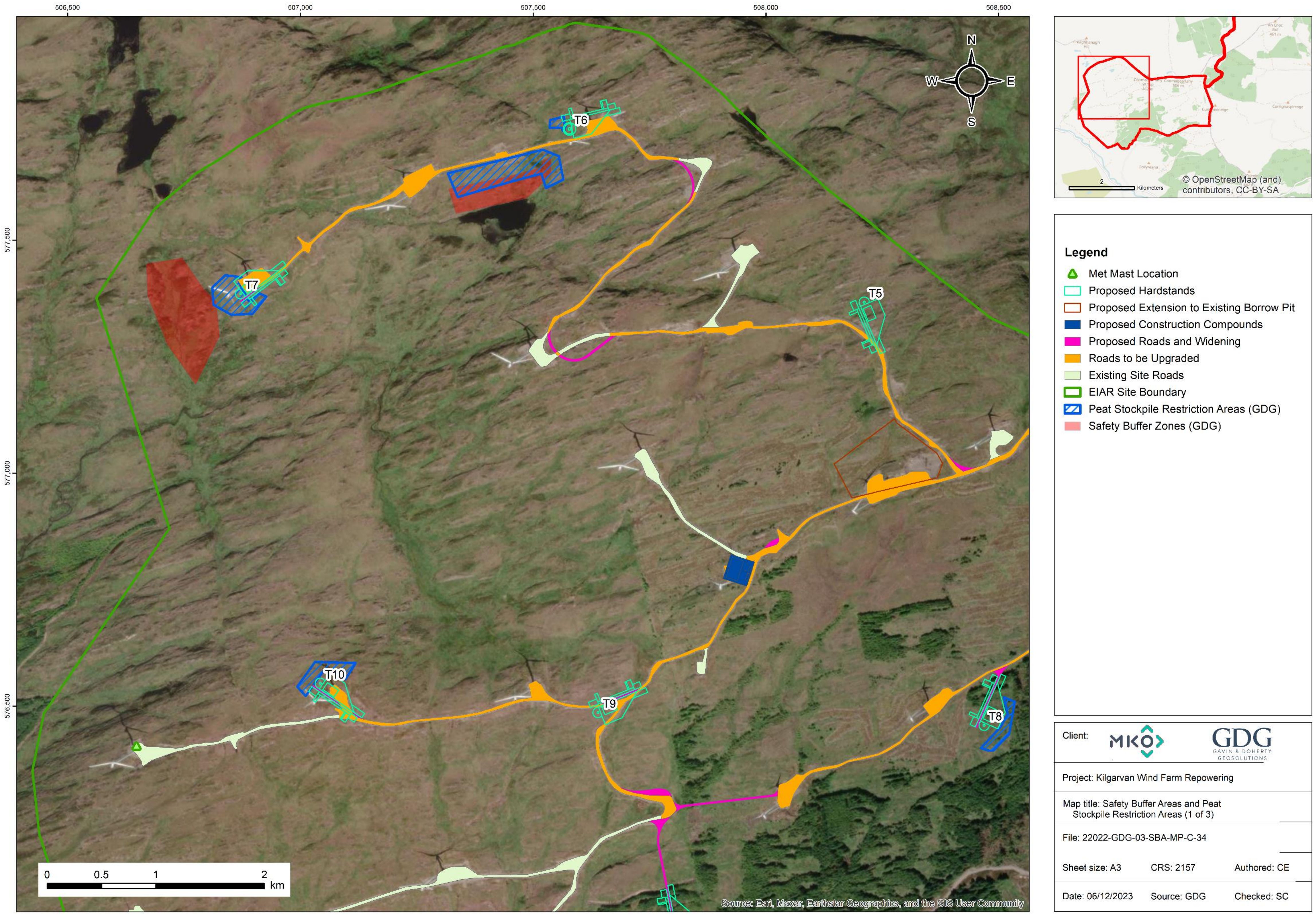
Drained conditions

$$F = \frac{c' + (\gamma z - \gamma_w h_w)\cos^2 \alpha \tan \phi'}{\gamma z \sin \alpha \cos \alpha}$$

Where,

F = Factor of Safety
c' = Effective cohesion
γ = Bulk unit weight of material
z = Depth to failure plane assumed as depth of peat
γ_w = Unit weight of water
h_w = Height of water table above failure plane
α = Slope angle
ϕ' = Effective friction angle

Appendix L SAFETY BUFFERS



Project: Kilgarvan Wind Farm Repowering

Map title: Safety Buffer Areas and Peat Stockpile Restriction Areas (1 of 3)

File: 22022-GDG-03-SBA-MP-C-34

Sheet size: A3 CRS: 2157 Authored: CE

Date: 06/12/2023 Source: GDG Checked: SC

Figure L- 1: Safety Buffer areas and Peat Stockpile Restriction Areas (1 of 3).

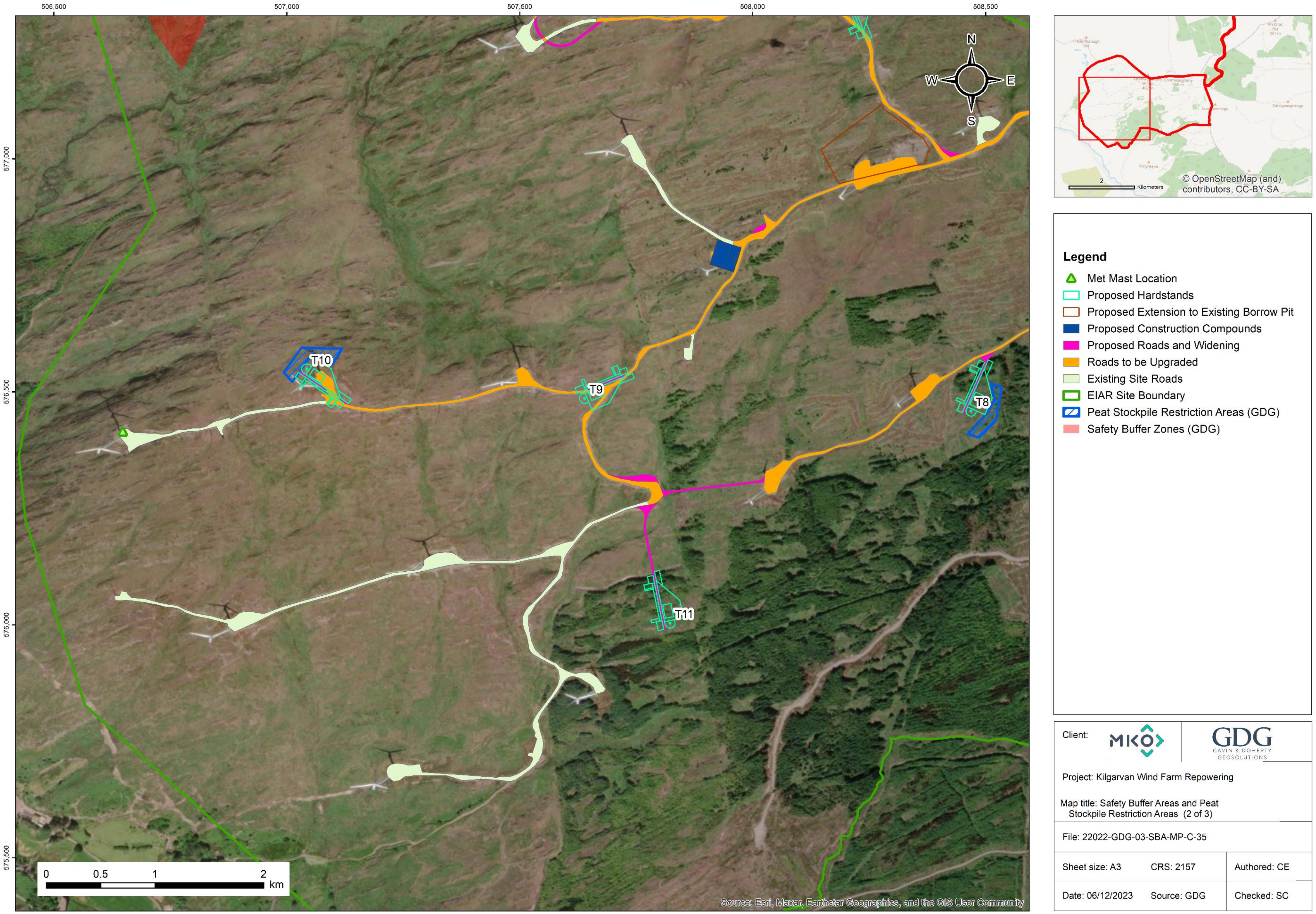


Figure L- 2: Safety Buffer areas and Peat Stockpile Restriction Areas (2 of 3).

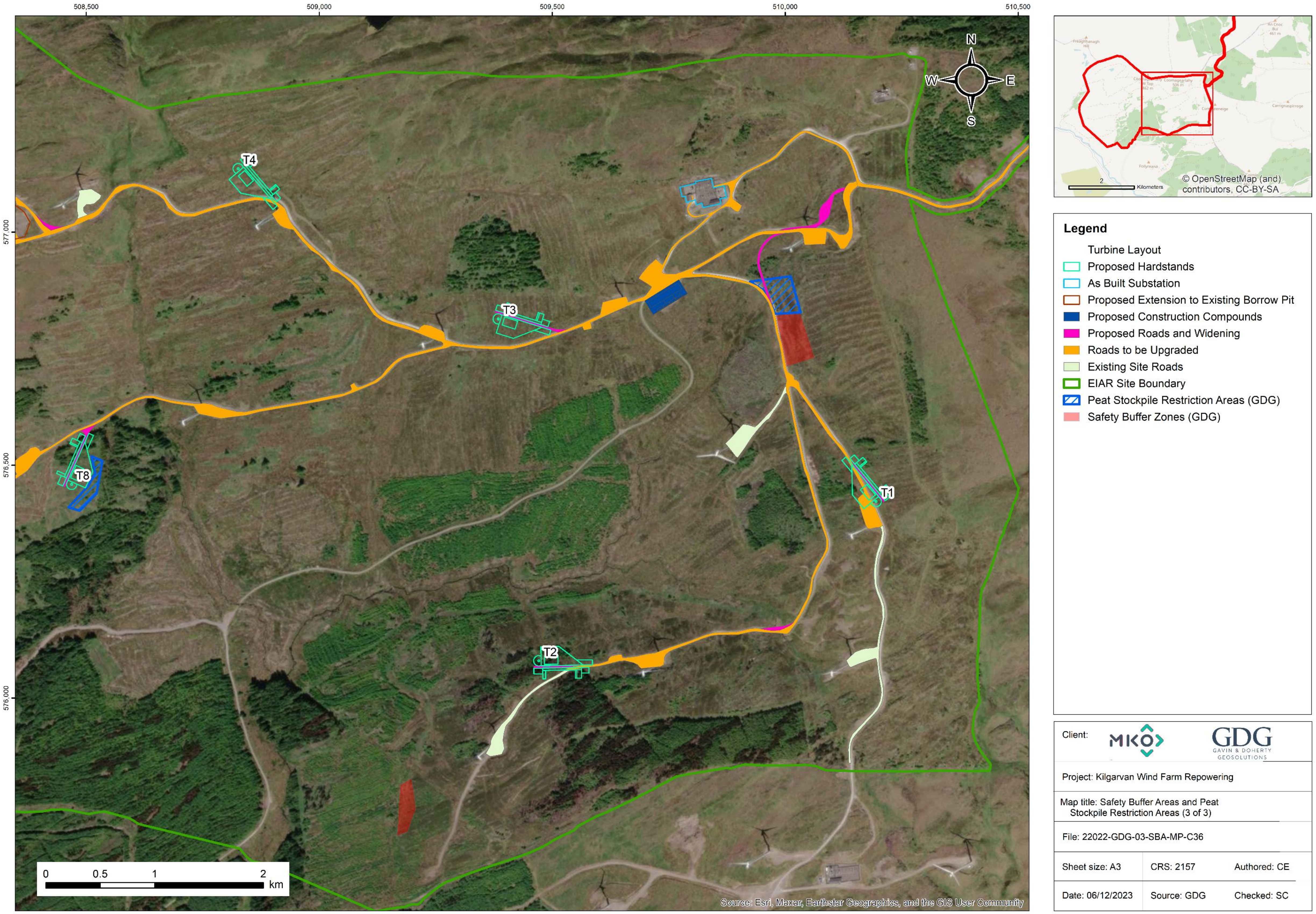


Figure L- 3: Safety Buffer areas and Peat Stockpile Restriction Areas (3 of 3).

Appendix M PEAT STABILITY RISK CALCULATION

Table M- 1: Peat Stability Risk Assessment at T1.

Peat Stability Risk Assessment (PSRA)

Kilgarvan Wind Farm

Location:	**Turbine 1**
Conditions:	**Undrained (U), undrained surcharge (US), drained (D), drained surcharge (DS)**
Inspected on:	Dec-22
Inspected by:	SC
Completed by:	CE
Date:	Nov-23

Hazard factors			Value				Rating criteria				Rating value	Weighting	Score	Comment
			U	US	D	DS	0	1	2	3				
Factor of Safety			11.4	2.26	9.17	3.86	-	≥ 1.3	1.3 - 1.0	≤ 1.0	1	10	10	Peat depth: ~0.2m. Slope angle: 10º.
Secondary factors	Slide history	Distance to previous slides (km)	On site				NA	5 - 10	< 5	On site	3	2	6	
		Evidence of peat movement (e.g. tension cracks, step features, compression features).	NA				NA	-	-	Yes	0	2	0	
	Subsoil conditions (visible in trial pits)	Subsoil type	NA				NA	Gravel / Firm glacial till	Smooth rock	Soft sensitive clay	1	1	1	Nearest TP (T20TP, 50m from turbine) records: Yellow silty CLAY with gravel.
		Peat fibres across transition to subsoil	NA				NA	Yes	Partially	No	0	1	0	No information given on logs
		Peat wetness	NA				NA	Dry / Stands well	Slowly squeezing	Extremely wet / Undiggable	0	1	0	No information given on logs
	Topography	General curvature downslope	Planar				NA	-	Planar	Convex	2	1	2	
		Distance to the convexity break (only if previous factor is Convex)	NA				NA	> 100 m	50 - 100 m	< 50 m		1	0	
		Slope aspect (for high latitudes in northern hemisphere)	SW, S, SE				NA	SW, S, SE	W, E	NW, N, NE	1	1	1	
	Hydrology	Distance from watercourse (m)	> 300				NA	> 300	200 - 300	< 200	1	1	1	
		Surface moisture index (NDMI)	96 -135				NA	0 - 96	96 -135	135 - 174	2	1	2	
		Surface water (water table level indicator)	NA				NA	Localised	Ponded in drains	Springs	0	1	0	
		Evidence of piping (subsurface flow)	NA				NA	-	-	Yes	0	1	0	
		Significant surface desiccation (previous summer was dry?)	NA				NA	-	-	Yes	0	1.5	0	
		Existing drainage ditches	NA				NA	Down slope	Varied / Oblique	Across slope	1	1	1	
		Annual rainfall	> 1400 mm/yr				NA	< 1000 mm/yr	1000 - 1400 mm/yr	> 1400 mm/yr	3	1	3	
	Vegetation	Bush	Dry heather				NA	Dry heather	Grassland	Wetlands	1	1	1	
		Forestry (if applicable)	NA				NA	Good growth	Fair	Stunted growth	0	1.5	0	
	Peat workings	Peat cuts presence	NA				NA	-	Cutaway / Turbary	Machine cut	0	1	0	
		Peat cuts vs contour lines	NA				NA	Perpendicular	Oblique	Parallel	0	1	0	
	Existing loads	Roads	Solid				NA	Solid	-	Floating	1	1	1	
	Time of year for construction		Late Summer, Autumn				NA	Spring	Winter, Early Summer	Late Summer, Autumn	3	1	3	Worse case estimated

Hazard	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Hazard $_{total}$	32
Max. possible	96
Hazard $_{0\text{-}1}$	**0.33**

Consequence factors	Value	Rating criteria				Rating value	Weighting	Score	Comment
		0	1	2	3				
Volume of potential peat flow (function of distance from nearest watercourse and peat depth in the area)	Small	NA	Small	Medium	Large	1	3	3	
Downslope hydrology features	Minor undefined watercourse	NA	Bowl / contained	Minor undefined watercourse	Valley	2	1	2	
Proximity from defined valley (m)	> 500	NA	> 500	200 - 500	< 200	1	1	1	
Downhill slope angle	Intermediate	NA	Horizontal	Intermediate	Steep	2	1	2	
Downstream aquatic environment	Sensitive	NA	Non-sensitive	Sensitive	Drinking water supply	2	1	2	
Public roads in potential peat flow path	NA	NA	Minor road	Local road	Regional road	0	1	0	
Overhead lines in potential peat flow path	NA	NA	Phone lines	Electricity (LV)	Electricity (MV, HV)	0	1	0	
Buildings in potential peat flow path	NA	NA	Farm out-houses	-	Dwelling	0	1	0	
Capability to respond (access and resources)	Fair	NA	Good	Fair	Poor	2	1	2	

Consequences	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Consequences $_{total}$	12
Max. possible	33
Consequences $_{0\text{-}1}$	**0.36**

Risk rating

Risk		**Action required**
0.00 - 0.20	Negligible	Normal site investigation
0.20 - 0.40	Low	Targeted site investigation, design of specific mitigation measures. Part time supervision during construction.
0.40 - 0.60	Medium	Avoid construction in the area if possible. If unavoidable, detailed site investigation and design of specific mitigation measures. Full time supervision during construction.
0.60 - 1.00	High	Avoid construction in this area.

Risk rating =	Hazard *	Consequences		
Risk rating =	0.33	0.36	=	**0.12**

Table M- 2: Peat Stability Risk Assessment at T2.

Peat Stability Risk Assessment (PSRA)

Kilgarvan Wind Farm

Location:	**Turbine 2**
Conditions:	**Undrained (U), undrained surcharge (US), drained (D), drained surcharge (DS)**
Inspected on:	Dec-22
Inspected by:	SC
Completed by:	CE
Date:	Nov-23

Hazard factors			Value				Rating criteria				Rating value	Weighting	Score	Comment
			U	US	D	DS	0	1	2	3				
Factor of Safety			2.45	1.53	2.0	2.68	-	≥ 1.3	1.3 - 1.0	≤ 1.0	1	10	10	Peat depth: ~1.6m. Slope angle: 7º.
Secondary factors	Slide history	Distance to previous slides (km)	On site				NA	5 - 10	< 5	On site	3	2	6	
		Evidence of peat movement (e.g. tension cracks, step features, compression features).	NA				NA	-	-	Yes	0	2	0	
	Subsoil conditions (visible in trial pits)	Subsoil type	Gravel / Firm glacial till				NA	Gravel / Firm glacial till	Smooth rock	Soft sensitive clay	1	1	1	Nearest Tp (TP03, 40m away) records: Greyish brown slightly gravelly slightly sandy SILT with some organic material. Sand is fine to medium. Some occasional cobbles from 2.0m.
		Peat fibres across transition to subsoil	NA				NA	Yes	Partially	No	0	1	0	No information given on logs
		Peat wetness	NA				NA	Dry / Stands well	Slowly squeezing	Extremely wet / Undiggable	0	2	0	No information given on logs
	Topography	General curvature downslope	Planar				NA	-	Planar	Convex	2	1	2	
		Distance to the convexity break (only if previous factor is Convex)	NA				NA	> 100 m	50 - 100 m	< 50 m	0	1	0	
		Slope aspect (for high latitudes in northern hemisphere)	NW, N, NE				NA	SW, S, SE	W, E	NW, N, NE	3	1	3	
	Hydrology	Distance from watercourse (m)	< 200				NA	> 300	200 - 300	< 200	3	1	3	150m
		Surface moisture index (NDMI)	0 - 96				NA	0 - 96	96 -135	135 - 174	1	1	1	
		Surface water (water table level indicator)	NA				NA	Localised	Ponded in drains	Springs	0	1	0	
		Evidence of piping (subsurface flow)	NA				NA	-	-	Yes	0	1	0	
		Significant surface desiccation (previous summer was dry?)	NA				NA	-	-	Yes	0	1.5	0	
		Existing drainage ditches	Varied / Oblique				NA	Down slope	Varied / Oblique	Across slope	2	1	2	
		Annual rainfall	> 1400 mm/yr				NA	< 1000 mm/yr	1000 - 1400 mm/yr	> 1400 mm/yr	3	1	3	
	Vegetation	Bush	Dry heather				NA	Dry heather	Grassland	Wetlands	1	1	1	
		Forestry (if applicable)	Good growth				NA	Good growth	Fair	Stunted growth	1	1.5	1.5	
	Peat workings	Peat cuts presence	NA				NA	-	Cutaway / Turbary	Machine cut	0	1	0	
		Peat cuts vs contour lines	NA				NA	Perpendicular	Oblique	Parallel	0	1	0	
	Existing loads	Roads	Solid				NA	Solid	-	Floating	1	1	1	
	Time of year for construction		Late Summer, Autumn				NA	Spring	Winter, Early Summer	Late Summer, Autumn	3	1	3	Worse case estimated

Hazard	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Hazard $_{total}$	37.5
Max. possible	96
Hazard $_{0\text{-}1}$	**0.39**

Consequence factors	Value	Rating criteria				Rating value	Weighting	Score	Comment
		0	1	2	3				
Volume of potential peat flow (function of distance from nearest watercourse and peat depth in the area)	Medium	NA	Small	Medium	Large	2	3	6	
Downslope hydrology features	Minor undefined watercourse	NA	Bowl / contained	Minor undefined watercourse	Valley	2	1	2	
Proximity from defined valley (m)	> 500	NA	> 500	200 - 500	< 200	1	1	1	
Downhill slope angle	Intermediate	NA	Horizontal	Intermediate	Steep	2	1	2	
Downstream aquatic environment	Sensitive	NA	Non-sensitive	Sensitive	Drinking water supply	2	1	2	
Public roads in potential peat flow path	Minor road	NA	Minor road	Local road	Regional road	1	1	1	
Overhead lines in potential peat flow path	NA	NA	Phone lines	Electricity (LV)	Electricity (MV, HV)	0	1	0	
Buildings in potential peat flow path	NA	NA	Farm out-houses	-	Dwelling	0	1	0	
Capability to respond (access and resources)	Fair	NA	Good	Fair	Poor	2	1	2	

Consequences	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Consequences $_{total}$	16
Max. possible	33
Consequences $_{0\text{-}1}$	**0.48**

Risk rating

Risk		Action required
0.00 - 0.20	Negligible	Normal site investigation
0.20 - 0.40	Low	Targeted site investigation, design of specific mitigation measures. Part time supervision during construction.
0.40 - 0.60	Medium	Avoid construction in the area if possible. If unavoidable, detailed site investigation and design of specific mitigation measures. Full time supervision during construction.
0.60 - 1.00	High	Avoid construction in this area.

Risk rating =	Hazard *	Consequences		
Risk rating =	0.39	0.48	=	**0.19**

Table M- 3: Peat Stability Risk Assessment at T3.

Peat Stability Risk Assessment (PSRA)

Kilgarvan Wind Farm

Location:	**Turbine 3**
Conditions:	**Undrained (U), undrained surcharge (US), drained (D), drained surcharge (DS)**
Inspected on:	Dec-22
Inspected by:	SC
Completed by:	CE
Date:	Nov-23

Hazard factors			Value				Rating criteria				Rating value	Weighting	Score	Comment
			U	US	D	DS	0	1	2	3				
Factor of Safety			22.7	3.61	18.2	6.22	-	≥ 1.3	1.3 - 1.0	≤ 1.0	1	10	10	Peat depth: ~0.1 m. Slope angle: 6.5º.
Secondary factors	Slide history	Distance to previous slides (km)	On site				NA	5 - 10	< 5	On site	3	2	6	
		Evidence of peat movement (e.g. tension cracks, step features, compression features).	NA				NA	-	-	Yes	0	2	0	
	Subsoil conditions (visible in trial pits)	Subsoil type	NA				NA	Gravel / Firm glacial till	Smooth rock	Soft sensitive clay	0	1	0	No trial pits at location
		Peat fibres across transition to subsoil	NA				NA	Yes	Partially	No	0	1	0	No trial pits at location
		Peat wetness					NA	Dry / Stands well	Slowly squeezing	Extremely wet / Undiggable	0	2	0	No trial pits at location
	Topography	General curvature downslope	Planar				NA	-	Planar	Convex	2	1	2	
		Distance to the convexity break (only if previous factor is Convex)	NA				NA	> 100 m	50 - 100 m	< 50 m	0	1	0	
		Slope aspect (for high latitudes in northern hemisphere)	SW, S, SE				NA	SW, S, SE	W, E	NW, N, NE	1	1	1	
	Hydrology	Distance from watercourse (m)	< 200				NA	> 300	200 - 300	< 200	1	1	1	
		Surface moisture index (NDMI)	0 - 96				NA	0 - 96	96 -135	135 - 174	2	1	2	
		Surface water (water table level indicator)	NA				NA	Localised	Ponded in drains	Springs	0	1	0	
		Evidence of piping (subsurface flow)	NA				NA	-	-	Yes	0	1	0	
		Significant surface desiccation (previous summer was dry?)	NA				NA	-	-	Yes	0	1.5	0	
		Existing drainage ditches	NA				NA	Down slope	Varied / Oblique	Across slope	0	1	0	
		Annual rainfall	> 1400 mm/yr				NA	< 1000 mm/yr	1000 - 1400 mm/yr	> 1400 mm/yr	3	1	3	
	Vegetation	Bush	Dry heather				NA	Dry heather	Grassland	Wetlands	1	1	1	
		Forestry (if applicable)	NA				NA	Good growth	Fair	Stunted growth	0	1.5	0	
	Peat workings	Peat cuts presence	NA				NA	-	Cutaway / Turbary	Machine cut	0	1	0	
		Peat cuts vs contour lines	NA				NA	Perpendicular	Oblique	Parallel	0	1	0	
	Existing loads	Roads	NA				NA	Solid	-	Floating	1	1	1	
	Time of year for construction		Late Summer, Autumn				NA	Spring	Winter, Early Summer	Late Summer, Autumn	3	1	3	Worse case estimated

Hazard	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Hazard $_{total}$	30
Max. possible	93
Hazard $_{0-1}$	**0.32**

Consequence factors	Value	Rating criteria				Rating value	Weighting	Score	Comment
		0	1	2	3				
Volume of potential peat flow (function of distance from nearest watercourse and peat depth in the area)	Small	NA	Small	Medium	Large	1	3	3	
Downslope hydrology features	Minor undefined watercourse	NA	Bowl / contained	Minor undefined watercourse	Valley	2	1	2	
Proximity from defined valley (m)	> 500	NA	> 500	200 - 500	< 200	1	1	1	
Downhill slope angle	Intermediate	NA	Horizontal	Intermediate	Steep	2	1	2	
Downstream aquatic environment	Sensitive	NA	Non-sensitive	Sensitive	Drinking water supply	2	1	2	
Public roads in potential peat flow path	NA	NA	Minor road	Local road	Regional road	0	1	0	
Overhead lines in potential peat flow path	NA	NA	Phone lines	Electricity (LV)	Electricity (MV, HV)	0	1	0	
Buildings in potential peat flow path	NA	NA	Farm out-houses	-	Dwelling	0	1	0	
Capability to respond (access and resources)	Fair	NA	Good	Fair	Poor	2	1	2	

Consequences	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Consequences $_{total}$	12
Max. possible	33
Consequences $_{0-1}$	**0.36**

Risk rating

Risk		Action required
0.00 - 0.20	Negligible	Normal site investigation
0.20 - 0.40	Low	Targeted site investigation, design of specific mitigation measures. Part time supervision during construction.
0.40 - 0.60	Medium	Avoid construction in the area if possible. If unavoidable, detailed site investigation and design of specific mitigation measures. Full time supervision during construction.
0.60 - 1.00	High	Avoid construction in this area.

Risk rating =	Hazard *	Consequences		
Risk rating =	0.32	0.36	=	**0.12**

Table M- 4: Peat Stability Risk Assessment at T4.

Peat Stability Risk Assessment (PSRA)

Kilgarvan Wind Farm

Location:	**Turbine 4**
Conditions:	**Undrained (U), undrained surcharge (US), drained (D), drained surcharge (DS)**
Inspected on:	Dec-22
Inspected by:	SC
Completed by:	CE
Date:	Nov-23

Hazard factors			Value				Rating criteria				Rating value	Weighting	Score	Comment
			U	US	D	DS	0	1	2	3				
Factor of Safety			4.25	2.05	3.48	3.58	-	≥ 1.3	1.3 - 1.0	≤ 1.0	1	10	10	Peat depth: ~0.9 m. Slope angle: 7º.
Secondary factors	Slide history	Distance to previous slides (km)	On site				NA	5 - 10	< 5	On site	3	2	6	
		Evidence of peat movement (e.g. tension cracks, step features, compression features).	NA				NA	-	-	Yes	0	2	0	
	Subsoil conditions (visible in trial pits)	Subsoil type	NA				NA	Gravel / Firm glacial till	Smooth rock	Soft sensitive clay		1	0	No trial pits at location
		Peat fibres across transition to subsoil	NA				NA	Yes	Partially	No		1	0	No trial pits at location
		Peat wetness					NA	Dry / Stands well	Slowly squeezing	Extremely wet / Undiggable		2	0	No trial pits at location
	Topography	General curvature downslope	NA				NA	-	Planar	Convex	0	1	0	
		Distance to the convexity break (only if previous factor is Convex)	NA				NA	> 100 m	50 - 100 m	< 50 m	0	1	0	
		Slope aspect (for high latitudes in northern hemisphere)	SW, S, SE				NA	SW, S, SE	W, E	NW, N, NE	1	1	1	
	Hydrology	Distance from watercourse (m)	200 - 300				NA	> 300	200 - 300	< 200	2	1	2	
		Surface moisture index (NDMI)	135 - 174				NA	0 - 96	96 -135	135 - 174	2	1	2	
		Surface water (water table level indicator)	Localised				NA	Localised	Ponded in drains	Springs	1	1	1	
		Evidence of piping (subsurface flow)	NA				NA	-	-	Yes	0	1	0	
		Significant surface desiccation (previous summer was dry?)	NA				NA	-	-	Yes	0	1.5	0	
		Existing drainage ditches	NA				NA	Down slope	Varied / Oblique	Across slope	0	1	0	
		Annual rainfall	> 1400 mm/yr				NA	< 1000 mm/yr	1000 - 1400 mm/yr	> 1400 mm/yr	3	1	3	
	Vegetation	Bush	Wetlands				NA	Dry heather	Grassland	Wetlands	3	1	3	
		Forestry (if applicable)	Good growth				NA	Good growth	Fair	Stunted growth	0	1.5	0	
	Peat workings	Peat cuts presence	NA				NA	-	Cutaway / Turbary	Machine cut	0	1	0	
		Peat cuts vs contour lines	NA				NA	Perpendicular	Oblique	Parallel	0	1	0	
	Existing loads	Roads	NA				NA	Solid	-	Floating	1	1	1	
	Time of year for construction		Late Summer, Autumn				NA	Spring	Winter, Early Summer	Late Summer, Autumn	3	1	3	Worse case estimated

Hazard $_{total}$	32
Max. possible	93
Hazard $_{0-1}$	**0.34**

Hazard	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Consequence factors	Value	Rating criteria				Rating value	Weighting	Score	Comment
		0	1	2	3				
Volume of potential peat flow (function of distance from nearest watercourse and peat depth in the area)	Small	NA	Small	Medium	Large	1	3	3	
Downslope hydrology features	Valley	NA	Bowl / contained	Minor undefined watercourse	Valley	1	1	1	
Proximity from defined valley (m)	< 200	NA	> 500	200 - 500	< 200	1	1	1	
Downhill slope angle	Horizontal	NA	Horizontal	Intermediate	Steep	1	1	1	
Downstream aquatic environment	Sensitive	NA	Non-sensitive	Sensitive	Drinking water supply	2	1	2	
Public roads in potential peat flow path	Minor road	NA	Minor road	Local road	Regional road	1	1	1	
Overhead lines in potential peat flow path	NA	NA	Phone lines	Electricity (LV)	Electricity (MV, HV)	0	1	0	
Buildings in potential peat flow path	NA	NA	Farm out-houses	-	Dwelling	0	1	0	
Capability to respond (access and resources)	Fair	NA	Good	Fair	Poor	0	1	0	

Consequences $_{total}$	9
Max. possible	33
Consequences $_{0-1}$	**0.27**

Consequences	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Risk rating

Risk		**Action required**
0.00 - 0.20	Negligible	Normal site investigation
0.20 - 0.40	Low	Targeted site investigation, design of specific mitigation measures. Part time supervision during construction.
0.40 - 0.60	Medium	Avoid construction in the area if possible. If unavoidable, detailed site investigation and design of specific mitigation measures. Full time supervision during construction.
0.60 - 1.00	High	Avoid construction in this area.

Risk rating = Hazard * Consequences

Risk rating = 0.34 0.27 = **0.09**

Table M- 5: Peat Stability Risk Assessment at T5.

Peat Stability Risk Assessment (PSRA)

Kilgarvan Wind Farm

Location:	**Turbine 5**
Conditions:	**Undrained (U), undrained surcharge (US), drained (D), drained surcharge (DS)**
Inspected on:	Dec-22
Inspected by:	SC
Completed by:	CE
Date:	Nov-23

Hazard factors			Value				Rating criteria				**Rating value**	**Weighting**	**Score**	**Comment**
			U	US	D	DS	0	1	2	3				
Factor of Safety			8.6	1.79	6.9	3.02	-	≥ 1.3	1.3 - 1.0	≤ 1.0	1	10	10	Peat depth: ~ 0.26m. Slope angle: 13.2º.
Secondary factors	Slide history	Distance to previous slides (km)	On site				NA	5 - 10	< 5	On site	3	2	6	
		Evidence of peat movement (e.g. tension cracks, step features, compression features).	NA				NA	-	-	Yes	0	2	0	
	Subsoil conditions (visible in trial pits)	Subsoil type	NA				NA	Gravel / Firm glacial till	Smooth rock	Soft sensitive clay	0	1	0	No trial pits at location
		Peat fibres across transition to subsoil	NA				NA	Yes	Partially	No	0	1	0	No trial pits at location
		Peat wetness	NA				NA	Dry / Stands well	Slowly squeezing	Extremely wet / Undiggable	0	2	0	No trial pits at location
	Topography	General curvature downslope	Planar				NA	-	Planar	Convex	2	1	2	
		Distance to the convexity break (only if previous factor is Convex)	NA				NA	> 100 m	50 - 100 m	< 50 m	0	1	0	
		Slope aspect (for high latitudes in northern hemisphere)	SW, S, SE				NA	SW, S, SE	W, E	NW, N, NE	1	1	1	
	Hydrology	Distance from watercourse (m)	> 300				NA	> 300	200 - 300	< 200	1	1	1	
		Surface moisture index (NDMI)	96 -135				NA	0 - 96	96 -135	135 - 174	2	1	2	
		Surface water (water table level indicator)	Ponded in drains				NA	Localised	Ponded in drains	Springs	0	1	0	
		Evidence of piping (subsurface flow)	NA				NA	-	-	Yes	0	1	0	
		Significant surface desiccation (previous summer was dry?)	NA				NA	-	-	Yes	0	1.5	0	
		Existing drainage ditches	Varied / Oblique				NA	Down slope	Varied / Oblique	Across slope	0	1	0	
		Annual rainfall	> 1400 mm/yr				NA	< 1000 mm/yr	1000 - 1400 mm/yr	> 1400 mm/yr	3	1	3	
	Vegetation	Bush	Wetlands				NA	Dry heather	Grassland	Wetlands	2	1	2	
		Forestry (if applicable)	Fair				NA	Good growth	Fair	Stunted growth	0	1.5	0	
	Peat workings	Peat cuts presence	NA				NA	-	Cutaway / Turbary	Machine cut	0	1	0	
		Peat cuts vs contour lines	NA				NA	Perpendicular	Oblique	Parallel	0	1	0	
	Existing loads	Roads	Solid				NA	Solid	-	Floating	1	1	1	
	Time of year for construction		Late Summer, Autumn				NA	Spring	Winter, Early Summer	Late Summer, Autumn	3	1	3	Worst case estimate

Hazard $_{total}$ 31

Max. possible 93

Hazard $_{0-1}$ **0.33**

Hazard	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Consequence factors	**Value**	**Rating criteria**				**Rating value**	**Weighting**	**Score**	**Comment**
		0	**1**	**2**	**3**				
Volume of potential peat flow (function of distance from nearest watercourse and peat depth in the area)	Small	NA	Small	Medium	Large	1	3	3	
Downslope hydrology features	Bowl / contained	NA	Bowl / contained	Minor undefined watercourse	Valley	1	1	1	
Proximity from defined valley (m)	> 500	NA	> 500	200 - 500	< 200	1	1	1	
Downhill slope angle	Horizontal	NA	Horizontal	Intermediate	Steep	1	1	1	
Downstream aquatic environment	Sensitive	NA	Non-sensitive	Sensitive	Drinking water supply	2	1	2	
Public roads in potential peat flow path	NA	NA	Minor road	Local road	Regional road	0	1	0	
Overhead lines in potential peat flow path	NA	NA	Phone lines	Electricity (LV)	Electricity (MV, HV)	0	1	0	
Buildings in potential peat flow path	NA	NA	Farm out-houses	-	Dwelling	0	1	0	
Capability to respond (access and resources)	Fair	NA	Good	Fair	Poor	2	1	2	

Consequences $_{total}$ 10

Max. possible 33

Consequences $_{0-1}$ **0.30**

Consequences	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Risk rating

Risk		**Action required**
0.00 - 0.20	Negligible	Normal site investigation
0.20 - 0.40	Low	Targeted site investigation, design of specific mitigation measures. Part time supervision during construction.
0.40 - 0.60	Medium	Avoid construction in the area if possible. If unavoidable, detailed site investigation and design of specific mitigation measures. Full time supervision during construction.
0.60 - 1.00	High	Avoid construction in this area.

Risk rating = Hazard * Consequences

Risk rating = 0.33 0.30 = **0.10**

Table M- 6: Peat Stability Risk Assessment at T6.

Peat Stability Risk Assessment (PSRA)

Kilgarvan Wind Farm

Location:	**Turbine 6**
Conditions:	**Undrained (U), undrained surcharge (US), drained (D), drained surcharge (DS)**
Inspected on:	Dec-22
Inspected by:	SC
Completed by:	CE
Date:	Feb-23

		Hazard factors	Value				Rating criteria				Rating value	Weighting	Score	Comment
			U	US	D	DS	0	1	2	3				
Factor of Safety			3.44	1.25	2.61	1.97	-	≥ 1.3	1.3 - 1.0	≤ 1.0	2	10	20	Peat depth: ~0.6 m. Slope angle: 16.3º.
Secondary factors	Slide history	Distance to previous slides (km)	On site				NA	5 - 10	< 5	On site	3	2	6	
		Evidence of peat movement (e.g. tension cracks, step features, compression features).	NA				NA	-	-	Yes	0	2	0	
	Subsoil conditions (visible in trial pits)	Subsoil type	Gravel / Firm glacial till				NA	Gravel / Firm glacial till	Smooth rock	Soft sensitive clay	1	1	1	One TP 40m from location (TP12) records a large sandstone boulder, and another (ITB2W) records: Grey very clayey sandy GRAVEL
		Peat fibres across transition to subsoil	NA				NA	Yes	Partially	No		1	0	No information given on logs
		Peat wetness	NA				NA	Dry / Stands well	Slowly squeezing	Extremely wet / Undiggable		2	0	No information given on logs
	Topography	General curvature downslope	Planar				NA	-	Planar	Convex	3	1	3	
		Distance to the convexity break (only if previous factor is Convex)	NA				NA	> 100 m	50 - 100 m	< 50 m	2	1	2	
		Slope aspect (for high latitudes in northern hemisphere)	SW, S, SE				NA	SW, S, SE	W, E	NW, N, NE	1	1	1	
	Hydrology	Distance from watercourse (m)	< 200				NA	> 300	200 - 300	< 200	3	1	3	
		Surface moisture index (NDMI)	96 -135				NA	0 - 96	96 -135	135 - 174	2	1	2	
		Surface water (water table level indicator)	NA				NA	Localised	Ponded in drains	Springs	3	1	3	
		Evidence of piping (subsurface flow)	NA				NA	-	-	Yes	0	1	0	
		Significant surface desiccation (previous summer was dry?)	NA				NA	-	-	Yes	0	1.5	0	
		Existing drainage ditches	NA				NA	Down slope	Varied / Oblique	Across slope	0	1	0	
		Annual rainfall	> 1400 mm/yr				NA	< 1000 mm/yr	1000 - 1400 mm/yr	> 1400 mm/yr	3	1	3	
	Vegetation	Bush	Grassland				NA	Dry heather	Grassland	Wetlands	2	1	2	
		Forestry (if applicable)	NA				NA	Good growth	Fair	Stunted growth	0	1.5	0	
	Peat workings	Peat cuts presence	NA				NA	-	Cutaway / Turbary	Machine cut	0	1	0	
		Peat cuts vs contour lines	NA				NA	Perpendicular	Oblique	Parallel	0	1	0	
	Existing loads	Roads	Floating				NA	Solid	-	Floating	3	1	3	
	Time of year for construction		Late Summer, Autumn				NA	Spring	Winter, Early Summer	Late Summer, Autumn	3	1	3	Worst case estimate

Hazard	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Hazard $_{total}$	52
Max. possible	96
Hazard $_{0-1}$	**0.54**

Consequence factors	**Value**	**Rating criteria**				**Rating value**	**Weighting**	**Score**	**Comment**
		0	1	2	3				
Volume of potential peat flow (function of distance from nearest watercourse and peat depth in the area)	Small	NA	Small	Medium	Large	1	3	3	
Downslope hydrology features	Minor undefined watercourse	NA	Bowl / contained	Minor undefined watercourse	Valley	2	1	2	
Proximity from defined valley (m)	> 500	NA	> 500	200 - 500	< 200	1	1	1	
Downhill slope angle	Intermediate	NA	Horizontal	Intermediate	Steep	2	1	2	
Downstream aquatic environment	Sensitive	NA	Non-sensitive	Sensitive	Drinking water supply	2	1	2	
Public roads in potential peat flow path	NA	NA	Minor road	Local road	Regional road	1	1	1	
Overhead lines in potential peat flow path	NA	NA	Phone lines	Electricity (LV)	Electricity (MV, HV)	0	1	0	
Buildings in potential peat flow path	NA	NA	Farm out-houses	-	Dwelling	0	1	0	
Capability to respond (access and resources)	Fair	NA	Good	Fair	Poor	2	1	2	

Consequences	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Consequences $_{total}$	13
Max. possible	33
Consequences $_{0-1}$	**0.39**

Risk rating

Risk		**Action required**
0.00 - 0.20	Negligible	Normal site investigation
0.20 - 0.40	Low	Targeted site investigation, design of specific mitigation measures. Part time supervision during construction.
0.40 - 0.60	Medium	Avoid construction in the area if possible. If unavoidable, detailed site investigation and design of specific mitigation measures. Full time supervision during construction.
0.60 - 1.00	High	Avoid construction in this area.

Risk rating = Hazard * Consequences

Risk rating = 0.54 0.39 = **0.21**

Table M- 7 Peat Stability Risk Assessment at T7.

Peat Stability Risk Assessment (PSRA)

Kilgarvan Wind Farm

Location:	**Turbine 7**
Conditions:	**Undrained (U), undrained surcharge (US), drained (D), drained surcharge (DS)**
Inspected on:	Dec-22
Inspected by:	SC
Completed by:	CE
Date:	Nov-23

Hazard factors			Value				Rating criteria				Rating value	Weighting	Score	Comment
			U	US	D	DS	0	1	2	3				
Factor of Safety			5.04	3.08	4.18	5.42	-	≥ 1.3	1.3 - 1.0	≤ 1.0	1	10	10	Peat depth: ~1.6 m. Slope angle: 3.6º.
Secondary factors	Slide history	Distance to previous slides (km)	On site				NA	5 - 10	< 5	On site	3	2	6	
		Evidence of peat movement (e.g. tension cracks, step features, compression features).	NA				NA	-	-	Yes	0	2	0	
	Subsoil conditions (visible in trial pits)	Subsoil type	Smooth rock				NA	Gravel / Firm glacial till	Smooth rock	Soft sensitive clay	2	1	2	Nearest TP (ITB5S) records: Blue/green medium grained SANDSTONE
		Peat fibres across transition to subsoil	NA				NA	Yes	Partially	No	0	1	0	No information given on log
		Peat wetness	NA				NA	Dry / Stands well	Slowly squeezing	Extremely wet / Undiggable	0	2	0	No information given on log
	Topography	General curvature downslope	Planar				NA	-	Planar	Convex	2	1	2	
		Distance to the convexity break (only if previous factor is Convex)	NA				NA	> 100 m	50 - 100 m	< 50 m	0	1	0	
		Slope aspect (for high latitudes in northern hemisphere)	NA				NA	SW, S, SE	W, E	NW, N, NE	0	1	0	
	Hydrology	Distance from watercourse (m)	> 300				NA	> 300	200 - 300	< 200	1	1	1	
		Surface moisture index (NDMI)	0 - 96				NA	0 - 96	96 -135	135 - 174	2	1	2	
		Surface water (water table level indicator)	NA				NA	Localised	Ponded in drains	Springs	0	1	0	
		Evidence of piping (subsurface flow)	NA				NA	-	-	Yes	0	1	0	
		Significant surface desiccation (previous summer was dry?)	NA				NA	-	-	Yes	0	1.5	0	
		Existing drainage ditches	NA				NA	Down slope	Varied / Oblique	Across slope	0	1	0	
		Annual rainfall	> 1400 mm/yr				NA	< 1000 mm/yr	1000 - 1400 mm/yr	> 1400 mm/yr	3	1	3	
	Vegetation	Bush	Wetlands				NA	Dry heather	Grassland	Wetlands	2	1	2	
		Forestry (if applicable)	Good growth				NA	Good growth	Fair	Stunted growth	1	1.5	1.5	
	Peat workings	Peat cuts presence	NA				NA	-	Cutaway / Turbary	Machine cut	0	1	0	
		Peat cuts vs contour lines	NA				NA	Perpendicular	Oblique	Parallel	0	1	0	
	Existing loads	Roads	NA				NA	Solid	-	Floating	1	1	1	
	Time of year for construction		Late Summer, Autumn				NA	Spring	Winter, Early Summer	Late Summer, Autumn	3	1	3	Worst case estimate

Hazard $_{total}$	33.5
Max. possible	96
Hazard $_{0-1}$	**0.35**

Hazard	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Consequence factors	**Value**	**Rating criteria**				**Rating value**	**Weighting**	**Score**	**Comment**
		0	1	2	3				
Volume of potential peat flow (function of distance from nearest watercourse and peat depth in the area)	Medium	NA	Small	Medium	Large	2	3	6	
Downslope hydrology features	Bowl / contained	NA	Bowl / contained	Minor undefined watercourse	Valley	1	1	1	
Proximity from defined valley (m)	> 500	NA	> 500	200 - 500	< 200	1	1	1	
Downhill slope angle	Horizontal	NA	Horizontal	Intermediate	Steep	1	1	1	
Downstream aquatic environment	Sensitive	NA	Non-sensitive	Sensitive	Drinking water supply	2	1	2	
Public roads in potential peat flow path	NA	NA	Minor road	Local road	Regional road	0	1	0	
Overhead lines in potential peat flow path	NA	NA	Phone lines	Electricity (LV)	Electricity (MV, HV)	0	1	0	
Buildings in potential peat flow path	NA	NA	Farm out-houses	-	Dwelling	0	1	0	
Capability to respond (access and resources)	Fair	NA	Good	Fair	Poor	2	1	2	

Consequences $_{total}$	13
Max. possible	33
Consequences $_{0-1}$	**0.39**

Consequences	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Risk rating

Risk		**Action required**
0.00 - 0.20	Negligible	Normal site investigation
0.20 - 0.40	Low	Targeted site investigation, design of specific mitigation measures. Part time supervision during construction.
0.40 - 0.60	Medium	Avoid construction in the area if possible. If unavoidable, detailed site investigation and design of specific mitigation measures. Full time supervision during construction.
0.60 - 1.00	High	Avoid construction in this area.

Risk rating =	Hazard *	Consequences		
Risk rating =	0.35	0.39	=	**0.14**

Table M- 8: Peat Stability Risk Assessment at T8.

Peat Stability Risk Assessment (PSRA)

Kilgarvan Wind Farm

Location:	**Turbine 8**
Conditions:	**Undrained (U), undrained surcharge (US), drained (D), drained surcharge (DS)**
Inspected on:	Dec-22
Inspected by:	SC
Completed by:	CE
Date:	Nov-23

Hazard factors			Value				Rating criteria				**Rating value**	**Weighting**	**Score**	**Comment**
			U	US	D	DS	0	1	2	3				
Factor of Safety			7.54	3.09	6.13	5.37	-	≥ 1.3	1.3 - 1.0	≤ 1.0	1	10	10	Peat depth: ~0.7m. Slope angle: 5.5º.
Secondary factors	Slide history	Distance to previous slides (km)	On site				NA	5 - 10	< 5	On site	3	2	6	
		Evidence of peat movement (e.g. tension cracks, step features, compression features).	NA				NA	-	-	Yes	0	2	0	
	Subsoil conditions (visible in trial pits)	Subsoil type	NA				NA	Gravel / Firm glacial till	Smooth rock	Soft sensitive clay	0	1	0	No trial pits at location
		Peat fibres across transition to subsoil	NA				NA	Yes	Partially	No	0	1	0	No trial pits at location
		Peat wetness	NA				NA	Dry / Stands well	Slowly squeezing	Extremely wet / Undiggable	0	2	0	No trial pits at location
	Topography	General curvature downslope	Convex				NA	-	Planar	Convex	3	1	3	
		Distance to the convexity break (only if previous factor is Convex)	NA				NA	> 100 m	50 - 100 m	< 50 m	2	1	2	
		Slope aspect (for high latitudes in northern hemisphere)	SW, S, SE				NA	SW, S, SE	W, E	NW, N, NE	1	1	1	
	Hydrology	Distance from watercourse (m)	< 200				NA	> 300	200 - 300	< 200	2	1	2	
		Surface moisture index (NDMI)	96 -135				NA	0 - 96	96 -135	135 - 174	2	1	2	
		Surface water (water table level indicator)	NA				NA	Localised	Ponded in drains	Springs	0	1	0	
		Evidence of piping (subsurface flow)	NA				NA	-	-	Yes	0	1	0	
		Significant surface desiccation (previous summer was dry?)	NA				NA	-	-	Yes	0	1.5	0	
		Existing drainage ditches	Across slope				NA	Down slope	Varied / Oblique	Across slope	0	1	0	
		Annual rainfall	> 1400 mm/yr				NA	< 1000 mm/yr	1000 - 1400 mm/yr	> 1400 mm/yr	3	1	3	
	Vegetation	Bush	Grassland				NA	Dry heather	Grassland	Wetlands	2	1	2	
		Forestry (if applicable)	Fair				NA	Good growth	Fair	Stunted growth	2	1.5	3	
	Peat workings	Peat cuts presence	NA				NA	-	Cutaway / Turbary	Machine cut	0	1	0	
		Peat cuts vs contour lines	NA				NA	Perpendicular	Oblique	Parallel	0	1	0	
	Existing loads	Roads	NA				NA	Solid	-	Floating	1	1	1	
	Time of year for construction		Late Summer, Autumn				NA	Spring	Winter, Early Summer	Late Summer, Autumn	3	1	3	Worst case estimate

Hazard	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Hazard $_{total}$	38
Max. possible	93
Hazard $_{0\text{-}1}$	**0.41**

Consequence factors	**Value**	**Rating criteria**				**Rating value**	**Weighting**	**Score**	**Comment**
		0	**1**	**2**	**3**				
Volume of potential peat flow (function of distance from nearest watercourse and peat depth in the area)	Small	NA	Small	Medium	Large	1	3	3	
Downslope hydrology features	Minor undefined watercourse	NA	Bowl / contained	Minor undefined watercourse	Valley	2	1	2	
Proximity from defined valley (m)	< 200	NA	> 500	200 - 500	< 200	1	1	1	
Downhill slope angle	Steep	NA	Horizontal	Intermediate	Steep	3	1	3	
Downstream aquatic environment	Sensitive	NA	Non-sensitive	Sensitive	Drinking water supply	2	1	2	
Public roads in potential peat flow path	NA	NA	Minor road	Local road	Regional road	1	1	1	
Overhead lines in potential peat flow path	NA	NA	Phone lines	Electricity (LV)	Electricity (MV, HV)	0	1	0	
Buildings in potential peat flow path	NA	NA	Farm out-houses	-	Dwelling	0	1	0	
Capability to respond (access and resources)	Fair	NA	Good	Fair	Poor	2	1	2	

Consequences	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Consequences $_{total}$	14
Max. possible	33
Consequences $_{0\text{-}1}$	**0.42**

Risk rating

Risk		**Action required**
0.00 - 0.20	Negligible	Normal site investigation
0.20 - 0.40	Low	Targeted site investigation, design of specific mitigation measures. Part time supervision during construction.
0.40 - 0.60	Medium	Avoid construction in the area if possible. If unavoidable, detailed site investigation and design of specific mitigation measures. Full time supervision during construction.
0.60 - 1.00	High	Avoid construction in this area.

Risk rating =	Hazard *	Consequences		
Risk rating =	0.41	0.42	=	**0.17**

Table M- 9: Peat Stability Risk Assessment at T9.

Peat Stability Risk Assessment (PSRA)

Kilgarvan Wind Farm

Location:	**Turbine 9**
Conditions:	**Undrained (U), undrained surcharge (US), drained (D), drained surcharge (DS)**
Inspected on:	Dec-22
Inspected by:	SC
Completed by:	CE
Date:	Nov-23

Hazard factors			Value U	Value US	Value D	Value DS	Rating criteria 0	1	2	3	Rating value	Weighting	Score	Comment
Factor of Safety			11.02	4.00	8.93	6.95	-	≥ 1.3	1.3 - 1.0	≤ 1.0	1	10	10	Peat depth: ~0.6 m. Slope angle: 4.6º.
Secondary factors	Slide history	Distance to previous slides (km)	On site				NA	5 - 10	< 5	On site	3	2	6	
		Evidence of peat movement (e.g. tension cracks, step features, compression features).	NA				NA	-	-	Yes	0	2	0	
	Subsoil conditions (visible in trial pits)	Subsoil type	Gravel / Firm glacial till				NA	Gravel / Firm glacial till	Smooth rock	Soft sensitive clay	1	1	1	Brown sandy silty GRAVEL with medium cobble content. Sand is fine to coarse. Gravel is fine to coarse.
		Peat fibres across transition to subsoil	Partially				NA	Yes	Partially	No	2	1	2	Dark black amorphous PEAT with rare fibres (H9)
		Peat wetness					NA	Dry / Stands well	Slowly squeezing	Extremely wet / Undiggable	0	2	0	No information on log
	Topography	General curvature downslope	Planar				NA	-	Planar	Convex	2	1	2	
		Distance to the convexity break (only if previous factor is Convex)	> 100 m				NA	> 100 m	50 - 100 m	< 50 m	0	1	0	
		Slope aspect (for high latitudes in northern hemisphere)	SW, S, SE				NA	SW, S, SE	W, E	NW, N, NE	1	1	1	
	Hydrology	Distance from watercourse (m)	200 - 300				NA	> 300	200 - 300	< 200	2	1	2	
		Surface moisture index (NDMI)	96 -135				NA	0 - 96	96 -135	135 - 174	2	1	2	
		Surface water (water table level indicator)	Localised				NA	Localised	Ponded in drains	Springs	1	1	1	
		Evidence of piping (subsurface flow)	-				NA	-	-	Yes	0	1	0	
		Significant surface desiccation (previous summer was dry?)	NA				NA	-	-	Yes	0	1.5	0	
		Existing drainage ditches	Varied / Oblique				NA	Down slope	Varied / Oblique	Across slope	2	1	2	
		Annual rainfall	> 1400 mm/yr				NA	< 1000 mm/yr	1000 - 1400 mm/yr	> 1400 mm/yr	3	1	3	
	Vegetation	Bush	Grassland				NA	Dry heather	Grassland	Wetlands	2	1	2	
		Forestry (if applicable)	NA				NA	Good growth	Fair	Stunted growth	0	1.5	0	
	Peat workings	Peat cuts presence	NA				NA	-	Cutaway / Turbary	Machine cut	0	1	0	
		Peat cuts vs contour lines	NA				NA	Perpendicular	Oblique	Parallel	0	1	0	
	Existing loads	Roads	Floating				NA	Solid	-	Floating	3	1	3	
	Time of year for construction		Late Summer, Autumn				NA	Spring	Winter, Early Summer	Late Summer, Autumn	3	1	3	Worse case estimated

Hazard $_{total}$ 40

Max. possible 99

Hazard $_{0-1}$ **0.40**

Hazard	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Consequence factors	**Value**	**Rating criteria** 0	1	2	3	**Rating value**	**Weighting**	**Score**	**Comment**
Volume of potential peat flow (function of distance from nearest watercourse and peat depth in the area)	Small	NA	Small	Medium	Large	1	3	3	
Downslope hydrology features	Bowl / contained	NA	Bowl / contained	Minor undefined watercourse	Valley	1	1	1	
Proximity from defined valley (m)	> 500	NA	> 500	200 - 500	< 200	1	1	1	
Downhill slope angle	Horizontal	NA	Horizontal	Intermediate	Steep	2	1	2	
Downstream aquatic environment	Sensitive	NA	Non-sensitive	Sensitive	Drinking water supply	2	1	2	
Public roads in potential peat flow path	Minor road	NA	Minor road	Local road	Regional road	1	1	1	
Overhead lines in potential peat flow path	NA	NA	Phone lines	Electricity (LV)	Electricity (MV, HV)	0	1	0	
Buildings in potential peat flow path	NA	NA	Farm out-houses	-	Dwelling	0	1	0	
Capability to respond (access and resources)	Fair	NA	Good	Fair	Poor	2	1	2	

Consequences $_{total}$ 12

Max. possible 33

Consequences $_{0-1}$ **0.36**

Consequences	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Risk rating

Risk		**Action required**
0.00 - 0.20	Negligible	Normal site investigation
0.20 - 0.40	Low	Targeted site investigation, design of specific mitigation measures. Part time supervision during construction.
0.40 - 0.60	Medium	Avoid construction in the area if possible. If unavoidable, detailed site investigation and design of specific mitigation measures. Full time supervision during construction.
0.60 - 1.00	High	Avoid construction in this area.

Risk rating = Hazard * Consequences

Risk rating = 0.40 0.36 = **0.15**

Table M- 10: Peat Stability Risk Assessment at T10.

Peat Stability Risk Assessment (PSRA)

Kilgarvan Wind Farm

Location:	**Turbine 10**
Conditions:	**Undrained (U), undrained surcharge (US), drained (D), drained surcharge (DS)**
Inspected on:	Dec-22
Inspected by:	SC
Completed by:	CE
Date:	Nov-23

Hazard factors			Value				Rating criteria				**Rating value**	**Weighting**	**Score**	**Comment**
			U	US	D	DS	0	1	2	3				
Factor of Safety			5.05	1.87	4.09	3.66	-	≥ 1.3	1.3 - 1.0	≤ 1.0	1	10	10	Peat depth: 0.59m. Slope angle: 9.9º.
Secondary factors	Slide history	Distance to previous slides (km)	On site				NA	5 - 10	< 5	On site	3	2	6	
		Evidence of peat movement (e.g. tension cracks, step features, compression features).	NA				NA	-	-	Yes	0	2	0	
	Subsoil conditions (visible in trial pits)	Subsoil type	NA				NA	Gravel / Firm glacial till	Smooth rock	Soft sensitive clay	2	1	2	Nearest TP (LTB7W, 26m from turbine) records: Red medium grained SANDSTONE
		Peat fibres across transition to subsoil	NA				NA	Yes	Partially	No	0	1	0	No information given on log
		Peat wetness	NA				NA	Dry / Stands well	Slowly squeezing	Extremely wet / Undiggable	0	2	0	No information given on log
	Topography	General curvature downslope	Planar				NA	-	Planar	Convex	1	1	1	
		Distance to the convexity break (only if previous factor is Convex)	> 100 m				NA	> 100 m	50 - 100 m	< 50 m	0	1	0	
		Slope aspect (for high latitudes in northern hemisphere)	SW, S, SE				NA	SW, S, SE	W, E	NW, N, NE	1	1	1	
	Hydrology	Distance from watercourse (m)	< 200				NA	> 300	200 - 300	< 200	1	1	1	
		Surface moisture index (NDMI)	135 - 174				NA	0 - 96	96 -135	135 - 174	3	1	3	
		Surface water (water table level indicator)	NA				NA	Localised	Ponded in drains	Springs	0	1	0	
		Evidence of piping (subsurface flow)	NA				NA	-	-	Yes	0	1	0	
		Significant surface desiccation (previous summer was dry?)	NA				NA	-	-	Yes	0	1.5	0	
		Existing drainage ditches	Varied / Oblique				NA	Down slope	Varied / Oblique	Across slope	2	1	2	
		Annual rainfall	> 1400 mm/yr				NA	< 1000 mm/yr	1000 - 1400 mm/yr	> 1400 mm/yr	3	1	3	
	Vegetation	Bush	Dry heather				NA	Dry heather	Grassland	Wetlands	1	1	1	
		Forestry (if applicable)	NA				NA	Good growth	Fair	Stunted growth	0	1.5	0	
	Peat workings	Peat cuts presence	NA				NA	-	Cutaway / Turbary	Machine cut	0	1	0	
		Peat cuts vs contour lines	NA				NA	Perpendicular	Oblique	Parallel	0	1	0	
	Existing loads	Roads	Solid				NA	Solid	-	Floating	1	1	1	
	Time of year for construction		Late Summer, Autumn				NA	Spring	Winter, Early Summer	Late Summer, Autumn	3	1	3	Worst case estimate

Hazard	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Hazard $_{total}$	34
Max. possible	96
Hazard $_{0-1}$	**0.35**

Consequence factors	**Value**	**Rating criteria**				**Rating value**	**Weighting**	**Score**	**Comment**
		0	**1**	**2**	**3**				
Volume of potential peat flow (function of distance from nearest watercourse and peat depth in the area)	Small	NA	Small	Medium	Large	1	3	3	
Downslope hydrology features	Bowl / contained	NA	Bowl / contained	Minor undefined watercourse	Valley	1	1	1	
Proximity from defined valley (m)	> 500	NA	> 500	200 - 500	< 200	1	1	1	
Downhill slope angle	Intermediate	NA	Horizontal	Intermediate	Steep	2	1	2	
Downstream aquatic environment	Sensitive	NA	Non-sensitive	Sensitive	Drinking water supply	2	1	2	
Public roads in potential peat flow path	Minor road	NA	Minor road	Local road	Regional road	1	1	1	
Overhead lines in potential peat flow path	NA	NA	Phone lines	Electricity (LV)	Electricity (MV, HV)	0	1	0	
Buildings in potential peat flow path	NA	NA	Farm out-houses	-	Dwelling	0	1	0	
Capability to respond (access and resources)	Fair	NA	Good	Fair	Poor	2	1	2	

Consequences	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Consequences $_{total}$	12
Max. possible	33
Consequences $_{0-1}$	**0.36**

Risk rating

Risk		**Action required**
0.00 - 0.20	Negligible	Normal site investigation
0.20 - 0.40	Low	Targeted site investigation, design of specific mitigation measures. Part time supervision during construction.
0.40 - 0.60	Medium	Avoid construction in the area if possible. If unavoidable, detailed site investigation and design of specific mitigation measures. Full time supervision during construction.
0.60 - 1.00	High	Avoid construction in this area.

Risk rating =	Hazard *	Consequences		
Risk rating =	0.35	0.36	=	**0.13**

Table M- 11: Peat Stability Risk Assessment at T11.

Peat Stability Risk Assessment (PSRA)

Kilgarvan Wind Farm

Location:	**Turbine 11**
Conditions:	**Undrained (U), undrained surcharge (US), drained (D), drained surcharge (DS)**
Inspected on:	Dec-22
Inspected by:	SC
Completed by:	CE
Date:	Jan-23

Hazard factors			Value				Rating criteria				Rating value	Weighting	Score	Comment
			U	US	D	DS	0	1	2	3				
Factor of Safety			6.8	2.1	5.5	3.7	-	≥ 1.3	1.3 - 1.0	≤ 1.0	1	10	10	Peat depth: ~0.45 m. Slope angle: 9.4º.
Secondary factors	Slide history	Distance to previous slides (km)	On site				NA	5 - 10	< 5	On site	3	2	6	
		Evidence of peat movement (e.g. tension cracks, step features, compression features).	NA				NA	-	-	Yes	0	2	0	
	Subsoil conditions (visible in trial pits)	Subsoil type	NA				NA	Gravel / Firm glacial till	Smooth rock	Soft sensitive clay		1	0	No trial pit at location
		Peat fibres across transition to subsoil	NA				NA	Yes	Partially	No		1	0	No trial pit at location
		Peat wetness					NA	Dry / Stands well	Slowly squeezing	Extremely wet / Undiggable		2	0	No trial pit at location
	Topography	General curvature downslope	NA				NA	-	Planar	Convex	0	1	0	
		Distance to the convexity break (only if previous factor is Convex)	NA				NA	> 100 m	50 - 100 m	< 50 m	0	1	0	
		Slope aspect (for high latitudes in northern hemisphere)	SW, S, SE				NA	SW, S, SE	W, E	NW, N, NE	1	1	1	
	Hydrology	Distance from watercourse (m)	< 200				NA	> 300	200 - 300	< 200	2	1	2	
		Surface moisture index (NDMI)	135 - 174				NA	0 - 96	96 -135	135 - 174	3	1	3	
		Surface water (water table level indicator)	Localised				NA	Localised	Ponded in drains	Springs	1	1	1	
		Evidence of piping (subsurface flow)	NA				NA	-	-	Yes	0	1	0	
		Significant surface desiccation (previous summer was dry?)	NA				NA	-	-	Yes	0	1.5	0	
		Existing drainage ditches	NA				NA	Down slope	Varied / Oblique	Across slope	0	1	0	
		Annual rainfall	> 1400 mm/yr				NA	< 1000 mm/yr	1000 - 1400 mm/yr	> 1400 mm/yr	3	1	3	
	Vegetation	Bush	Grassland				NA	Dry heather	Grassland	Wetlands	2	1	2	
		Forestry (if applicable)	Good growth				NA	Good growth	Fair	Stunted growth	1	1.5	1.5	
	Peat workings	Peat cuts presence	NA				NA	-	Cutaway / Turbary	Machine cut	0	1	0	
		Peat cuts vs contour lines	NA				NA	Perpendicular	Oblique	Parallel	0	1	0	
	Existing loads	Roads	NA				NA	Solid	-	Floating	0	1	0	
	Time of year for construction		Late Summer, Autumn				NA	Spring	Winter, Early Summer	Late Summer, Autumn	3	1	3	Worse case estimate

Hazard	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Hazard $_{total}$	32.5
Max. possible	93
Hazard $_{0-1}$	**0.35**

Consequence factors	Value	Rating criteria				Rating value	Weighting	Score	Comment
		0	1	2	3				
Volume of potential peat flow (function of distance from nearest watercourse and peat depth in the area)	Small	NA	Small	Medium	Large	1	3	3	
Downslope hydrology features	Bowl / contained	NA	Bowl / contained	Minor undefined watercourse	Valley	1	1	1	
Proximity from defined valley (m)	> 500	NA	> 500	200 - 500	< 200	1	1	1	
Downhill slope angle	Horizontal	NA	Horizontal	Intermediate	Steep	1	1	1	
Downstream aquatic environment	Sensitive	NA	Non-sensitive	Sensitive	Drinking water supply	2	1	2	
Public roads in potential peat flow path	NA	NA	Minor road	Local road	Regional road	0	1	0	
Overhead lines in potential peat flow path	NA	NA	Phone lines	Electricity (LV)	Electricity (MV, HV)	0	1	0	
Buildings in potential peat flow path	NA	NA	Farm out-houses	-	Dwelling	0	1	0	
Capability to respond (access and resources)	Fair	NA	Good	Fair	Poor	2	1	2	

Consequences	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Consequences $_{total}$	10
Max. possible	33
Consequences $_{0-1}$	**0.30**

Risk rating

Risk		Action required
0.00 - 0.20	Negligible	Normal site investigation
0.20 - 0.40	Low	Targeted site investigation, design of specific mitigation measures. Part time supervision during construction.
0.40 - 0.60	Medium	Avoid construction in the area if possible. If unavoidable, detailed site investigation and design of specific mitigation measures. Full time supervision during construction.
0.60 - 1.00	High	Avoid construction in this area.

Risk rating = Hazard * Consequences

Risk rating = 0.35 0.30 = **0.11**

Table M- 12: Peat Stability Risk Assessment at Construction Compound West.

Peat Stability Risk Assessment (PSRA)

Kilgarvan Wind Farm

Location:	**Temporary Compound Site West**
Conditions:	**Undrained (U), undrained surcharge (US), drained (D), drained surcharge (DS)**
Inspected on:	Dec-22
Inspected by:	SC
Completed by:	CE
Date:	Nov-23

Hazard factors			Value				Rating criteria				Rating value	Weighting	Score	Comment
			U	US	D	DS	0	1	2	3				
Factor of Safety			10.8	2.74	9	4.83	-	≥ 1.3	1.3 - 1.0	≤ 1.0	1	10	10	Peat depth: 0.34, Slope angle: 8
Secondary factors	Slide history	Distance to previous slides (km)	On site				NA	5 - 10	< 5	On site	3	2	6	
		Evidence of peat movement (e.g. tension cracks, step features, compression features).	NA				NA	-	-	Yes	0	2	0	
	Subsoil conditions (visible in trial pits)	Subsoil type	Smooth rock				NA	Gravel / Firm glacial till	Smooth rock	Soft sensitive clay	2	1	2	Nearest TP (T1TP, 30m away from compound) records: Bed Rock.
		Peat fibres across transition to subsoil	NA				NA	Yes	Partially	No	0	1	0	No information given on log
		Peat wetness					NA	Dry / Stands well	Slowly squeezing	Extremely wet / Undiggable	0	2	0	No information given on log
	Topography	General curvature downslope	Planar				NA	-	Planar	Convex	2	1	2	
		Distance to the convexity break (only if previous factor is Convex)	NA				NA	> 100 m	50 - 100 m	< 50 m	0	1	0	
		Slope aspect (for high latitudes in northern hemisphere)	SW, S, SE				NA	SW, S, SE	W, E	NW, N, NE	1	1	1	
	Hydrology	Distance from watercourse (m)	< 200				NA	> 300	200 - 300	< 200	3	1	3	
		Surface moisture index (NDMI)	96 -135				NA	0 - 96	96 -135	135 - 174	2	1	2	
		Surface water (water table level indicator)	NA				NA	Localised	Ponded in drains	Springs	0	1	0	
		Evidence of piping (subsurface flow)	NA				NA	-	-	Yes	0	1	0	
		Significant surface desiccation (previous summer was dry?)	NA				NA	-	-	Yes	0	1.5	0	
		Existing drainage ditches	NA				NA	Down slope	Varied / Oblique	Across slope	0	1	0	
		Annual rainfall	> 1400 mm/yr				NA	< 1000 mm/yr	1000 - 1400 mm/yr	> 1400 mm/yr	3	1	3	
	Vegetation	Bush	Grassland				NA	Dry heather	Grassland	Wetlands	2	1	2	
		Forestry (if applicable)	NA				NA	Good growth	Fair	Stunted growth	0	1.5	0	
	Peat workings	Peat cuts presence	-				NA	-	Cutaway / Turbary	Machine cut	1	1	1	
		Peat cuts vs contour lines	NA				NA	Perpendicular	Oblique	Parallel	0	1	0	
	Existing loads	Roads	NA				NA	Solid	-	Floating	0	1	0	
	Time of year for construction		NA				NA	Spring	Winter, Early Summer	Late Summer, Autumn	0	1	0	Wost case estimate

Hazard	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Hazard $_{total}$	32
Max. possible	96
Hazard $_{0-1}$	**0.33**

Consequence factors	Value	Rating criteria				Rating value	Weighting	Score	Comment
		0	1	2	3				
Volume of potential peat flow (function of distance from nearest watercourse and peat depth in the area)	Small	NA	Small	Medium	Large	1	3	3	
Downslope hydrology features	Minor undefined watercourse	NA	Bowl / contained	Minor undefined watercourse	Valley	2	1	2	
Proximity from defined valley (m)	> 500	NA	> 500	200 - 500	< 200	1	1	1	
Downhill slope angle	Intermediate	NA	Horizontal	Intermediate	Steep	2	1	2	
Downstream aquatic environment	Sensitive	NA	Non-sensitive	Sensitive	Drinking water supply	2	1	2	
Public roads in potential peat flow path	NA	NA	Minor road	Local road	Regional road	0	1	0	
Overhead lines in potential peat flow path	NA	NA	Phone lines	Electricity (LV)	Electricity (MV, HV)	0	1	0	
Buildings in potential peat flow path	NA	NA	Farm out-houses	-	Dwelling	0	1	0	
Capability to respond (access and resources)	Fair	NA	Good	Fair	Poor	2	1	2	

Consequences	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Consequences $_{total}$	12
Max. possible	33
Consequences $_{0-1}$	**0.36**

Risk rating

Risk		Action required
0.00 - 0.20	Negligible	Normal site investigation
0.20 - 0.40	Low	Targeted site investigation, design of specific mitigation measures. Part time supervision during construction.
0.40 - 0.60	Medium	Avoid construction in the area if possible. If unavoidable, detailed site investigation and design of specific mitigation measures. Full time supervision during construction.
0.60 - 1.00	High	Avoid construction in this area.

Risk rating =	Hazard *	Consequences		
Risk rating =	0.33	0.36	=	**0.12**

Table M- 13: Peat Stability Risk Assessment at Construction Compound East.

Peat Stability Risk Assessment (PSRA)

Kilgarvan Wind Farm

Location:	**Temporary compound site East**
Conditions:	**Undrained (U), undrained surcharge (US), drained (D), drained surcharge (DS)**
Inspected on:	Dec-22
Inspected by:	SC
Completed by:	CE
Date:	Nov-23

Hazard factors			Value				Rating criteria				**Rating value**	**Weighting**	**Score**	**Comment**
			U	US	D	DS	0	1	2	3				
Factor of Safety			6.95	2.69	5.7	4.89	-	≥ 1.3	1.3 - 1.0	≤ 1.0	1	10	10	Peat depth: ~0.6 m. Slope angle: 5.1º.
Secondary factors	Slide history	Distance to previous slides (km)	On site				NA	5 - 10	< 5	On site	3	2	6	
		Evidence of peat movement (e.g. tension cracks, step features, compression features).	NA				NA	-	-	Yes	0	2	0	
	Subsoil conditions (visible in trial pits)	Subsoil type	Gravel / Firm glacial till				NA	Gravel / Firm glacial till	Smooth rock	Soft sensitive clay	1	1	1	Nearest TP (T18TP, 50m away from compound) records: Firm yellow CLAY with gravel.
		Peat fibres across transition to subsoil	NA				NA	Yes	Partially	No	0	1	0	No information given on log
		Peat wetness					NA	Dry / Stands well	Slowly squeezing	Extremely wet / Undiggable	0	2	0	No information given on log
	Topography	General curvature downslope	Planar				NA	-	Planar	Convex	2	1	2	
		Distance to the convexity break (only if previous factor is Convex)	NA				NA	> 100 m	50 - 100 m	< 50 m	0	1	0	
		Slope aspect (for high latitudes in northern hemisphere)	NW, N, NE				NA	SW, S, SE	W, E	NW, N, NE	3	1	3	
	Hydrology	Distance from watercourse (m)	< 200				NA	> 300	200 - 300	< 200	3	1	3	
		Surface moisture index (NDMI)	96 -135				NA	0 - 96	96 -135	135 - 174	2	1	2	
		Surface water (water table level indicator)	NA				NA	Localised	Ponded in drains	Springs	0	1	0	
		Evidence of piping (subsurface flow)	NA				NA	-	-	Yes	0	1	0	
		Significant surface desiccation (previous summer was dry?)	NA				NA	-	-	Yes	0	1.5	0	
		Existing drainage ditches	NA				NA	Down slope	Varied / Oblique	Across slope	0	1	0	
		Annual rainfall	> 1400 mm/yr				NA	< 1000 mm/yr	1000 - 1400 mm/yr	> 1400 mm/yr	3	1	3	
	Vegetation	Bush	Wetlands				NA	Dry heather	Grassland	Wetlands	3	1	3	
		Forestry (if applicable)	NA				NA	Good growth	Fair	Stunted growth	0	1.5	0	
	Peat workings	Peat cuts presence	NA				NA	-	Cutaway / Turbary	Machine cut	0	1	0	
		Peat cuts vs contour lines	NA				NA	Perpendicular	Oblique	Parallel	0	1	0	
	Existing loads	Roads	Solid				NA	Solid	-	Floating	1	1	1	
	Time of year for construction		Late Summer, Autumn				NA	Spring	Winter, Early Summer	Late Summer, Autumn	3	1	3	Worst case estimate

Hazard	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Hazard $_{total}$	37
Max. possible	96
Hazard $_{0-1}$	**0.39**

Consequence factors	**Value**	**Rating criteria**				**Rating value**	**Weighting**	**Score**	**Comment**
		0	1	2	3				
Volume of potential peat flow (function of distance from nearest watercourse and peat depth in the area)	Small	NA	Small	Medium	Large	1	3	3	
Downslope hydrology features	Minor undefined watercourse	NA	Bowl / contained	Minor undefined watercourse	Valley	2	1	2	
Proximity from defined valley (m)	> 500	NA	> 500	200 - 500	< 200	1	1	1	
Downhill slope angle	Intermediate	NA	Horizontal	Intermediate	Steep	2	1	2	
Downstream aquatic environment	Sensitive	NA	Non-sensitive	Sensitive	Drinking water supply	2	1	2	
Public roads in potential peat flow path	Minor road	NA	Minor road	Local road	Regional road	1	1	1	
Overhead lines in potential peat flow path	NA	NA	Phone lines	Electricity (LV)	Electricity (MV, HV)	0	1	0	
Buildings in potential peat flow path	NA	NA	Farm out-houses	-	Dwelling	0	1	0	
Capability to respond (access and resources)	Fair	NA	Good	Fair	Poor	2	1	2	

Consequences	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Consequences $_{total}$	13
Max. possible	33
Consequences $_{0-1}$	**0.39**

Risk rating

Risk		**Action required**
0.00 - 0.20	Negligible	Normal site investigation
0.20 - 0.40	Low	Targeted site investigation, design of specific mitigation measures. Part time supervision during construction.
0.40 - 0.60	Medium	Avoid construction in the area if possible. If unavoidable, detailed site investigation and design of specific mitigation measures. Full time supervision during construction.
0.60 - 1.00	High	Avoid construction in this area.

Risk rating =	Hazard *	Consequences		
Risk rating =	0.39	0.39	=	**0.15**

Table M- 14: Peat Stability Risk Assessment at Met Mast.

Peat Stability Risk Assessment (PSRA)

Kilgarvan Wind Farm

Location:	**Temporary compound site East**
Conditions:	**Undrained (U), undrained surcharge (US), drained (D), drained surcharge (DS)**
Inspected on:	Dec-22
Inspected by:	SC
Completed by:	CE
Date:	Nov-23

Hazard factors			Value				Rating criteria				Rating value	Weighting	Score	Comment
			U	US	D	DS	0	1	2	3				
Factor of Safety			6.4	2.8	5.2	5.13	-	≥ 1.3	1.3 - 1.0	≤ 1.0	1	10	10	Peat depth: ~0.75 m. Slope angle: 6º.
Secondary factors	Slide history	Distance to previous slides (km)	On site				NA	5 - 10	< 5	On site	3	2	6	
		Evidence of peat movement (e.g. tension cracks, step features, compression features).	NA				NA	-	-	Yes	0	2	0	
	Subsoil conditions (visible in trial pits)	Subsoil type	NA				NA	Gravel / Firm glacial till	Smooth rock	Soft sensitive clay	0	1	0	
		Peat fibres across transition to subsoil	NA				NA	Yes	Partially	No	0	1	0	
		Peat wetness					NA	Dry / Stands well	Slowly squeezing	Extremely wet / Undiggable	0	2	0	
	Topography	General curvature downslope	NA				NA	-	Planar	Convex	0	1	0	
		Distance to the convexity break (only if previous factor is Convex)	NA				NA	> 100 m	50 - 100 m	< 50 m	0	1	0	
		Slope aspect (for high latitudes in northern hemisphere)	NA				NA	SW, S, SE	W, E	NW, N, NE	0	1	0	
	Hydrology	Distance from watercourse (m)	> 300				NA	> 300	200 - 300	< 200	1	1	1	
		Surface moisture index (NDMI)	96 -135				NA	0 - 96	96 -135	135 - 174	2	1	2	
		Surface water (water table level indicator)	NA				NA	Localised	Ponded in drains	Springs	0	1	0	
		Evidence of piping (subsurface flow)	NA				NA	-	-	Yes	0	1	0	
		Significant surface desiccation (previous summer was dry?)	NA				NA	-	-	Yes	0	1.5	0	
		Existing drainage ditches	NA				NA	Down slope	Varied / Oblique	Across slope	0	1	0	
		Annual rainfall	> 1400 mm/yr				NA	< 1000 mm/yr	1000 - 1400 mm/yr	> 1400 mm/yr	3	1	3	
	Vegetation	Bush	Dry heather				NA	Dry heather	Grassland	Wetlands	1	1	1	
		Forestry (if applicable)	NA				NA	Good growth	Fair	Stunted growth	0	1.5	0	
	Peat workings	Peat cuts presence	NA				NA	-	Cutaway / Turbary	Machine cut	0	1	0	
		Peat cuts vs contour lines	NA				NA	Perpendicular	Oblique	Parallel	0	1	0	
	Existing loads	Roads	Solid				NA	Solid	-	Floating	1	1	1	
	Time of year for construction		Late Summer, Autumn				NA	Spring	Winter, Early Summer	Late Summer, Autumn	3	1	3	Worst case estimate

Hazard	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Hazard $_{total}$	27
Max. possible	93
Hazard $_{0-1}$	**0.29**

Consequence factors	Value	Rating criteria				Rating value	Weighting	Score	Comment
		0	1	2	3				
Volume of potential peat flow (function of distance from nearest watercourse and peat depth in the area)	Small	NA	Small	Medium	Large	1	3	3	
Downslope hydrology features	Minor undefined watercourse	NA	Bowl / contained	Minor undefined watercourse	Valley	2	1	2	
Proximity from defined valley (m)	> 500	NA	> 500	200 - 500	< 200	1	1	1	
Downhill slope angle	Horizontal	NA	Horizontal	Intermediate	Steep	1	1	1	
Downstream aquatic environment	Sensitive	NA	Non-sensitive	Sensitive	Drinking water supply	2	1	2	
Public roads in potential peat flow path	Minor road	NA	Minor road	Local road	Regional road	1	1	1	
Overhead lines in potential peat flow path	NA	NA	Phone lines	Electricity (LV)	Electricity (MV, HV)	0	1	0	
Buildings in potential peat flow path	NA	NA	Farm out-houses	-	Dwelling	0	1	0	
Capability to respond (access and resources)	Fair	NA	Good	Fair	Poor	2	1	2	

Consequences	
0.0 - 0.3	Negligible
0.3 - 0.5	Low
0.5 - 0.7	Medium
0.7 - 1.0	High

Consequences $_{total}$	12
Max. possible	33
Consequences $_{0-1}$	**0.36**

Risk rating

Risk		**Action required**
0.00 - 0.20	Negligible	Normal site investigation
0.20 - 0.40	Low	Targeted site investigation, design of specific mitigation measures. Part time supervision during construction.
0.40 - 0.60	Medium	Avoid construction in the area if possible. If unavoidable, detailed site investigation and design of specific mitigation measures. Full time supervision during construction.
0.60 - 1.00	High	Avoid construction in this area.

Risk rating =	Hazard *	Consequences		
Risk rating =	0.29	0.36	=	**0.11**

Appendix N EXISTING GEOTECHNICAL REPORTS

GEOTECHNICAL

SITE ASSESSMENT REPORT

FOR

KILGARVAN WIND FARM, CO. KERRY

Prepared for:

Bórd Gáis Éireann

January 2013

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ACRONYMS AND SYMBOLS

AGEC	Applied Ground Engineering Consultants Ltd
BGE	Bórd Gáis Éireann
BS	British Standard
c'	Effective cohesion
c_u	Undrained strength
EC7	Eurocode 7
FoS	Factor of Safety
kPa	Kilopascals
m bgl	Metres below ground level
m	Metres
mOD	Metres ordnance datum
$ø'$	Effective angle of shearing resistance
PHRAG	Peat Hazard and Risk Assessment Guide

1 INTRODUCTION

1.1 Background & Objectives

Applied Ground Engineering Consultants Ltd (AGEC) were engaged in October 2012 by Bórd Gáis Éireann to undertake a geotechnical assessment of the Kilgarvan wind farm site with respect to peat instability following a peat failure that occurred in a localised area of the site on the 17/18th of October 2012.

A report on the peat failure was produced by AGEC (2012). The mitigation measures and recommendations regarding the peat failure should be read in conjunction with this report.

The Kilgarvan wind farm site is located approximately 10km southeast of Killarney, Co. Kerry. The wind farm comprises 28 wind turbines with associated infrastructure (Figure 1). The associated infrastructure includes a substation and access roads.

For the purpose of this report the Kilgarvan wind farm site is the amalgamation of three smaller and adjacent wind farm sites; the original Kilgarvan wind farm as well as the Inchincoosh and the Lettercannon wind farms.

AGEC undertook the assessment following the principles in Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments (Scottish Executive, 2007). The Peat Hazard and Risk Assessment Guide (PHRAG) is used in this report as it provides best practice methods to identify, mitigate and manage peat slide hazards and associated risks in respect of consent applications for electricity generation project.

The best practice guide was produced following peat failures in the Shetland Islands, Scotland in September 2003 but more pertinently following the peat failure in October 2003, during the construction of a wind farm at Derrybrien, County Galway, Ireland.

The geotechnical assessment of the Kilgarvan site included the following activities:

(1) Walkover survey of the site.

(2) Stability assessment of the natural peat slopes.

(3) Findings of the above to assess the potential risk of a peat slide, in particular at turbine locations and along access roads.

(4) Factor of safety plan.

(5) Risk zonation plan for site.

(6) Mitigation measures to prevent future peat failures/movements.

(7) Site contingency measures should peat movement/failure occur.

1.2 Peat Failure Definition

Peat failure in this report refers to a significant mass movement of a body of peat that would have an adverse impact on the operation of the wind farm and the surrounding environment. Peat failure excludes localised movement of peat that such as (say) stream bank slump, creep movement or erosion type events.

There are several classification systems for mass movement of peat (Hutchinson, 1988; Dykes and Warburton, 2006). Using the former system this defines two dominant types of peat failure namely:

(1) Peat flows, or as they are more commonly known 'bog bursts'. This is a type of debris flow which involves large quantities of water and peat debris which flow down-slope usually following existing surface water channels. Bursts are usually associated with raised bogs where there is an upper fibrous layer over a lower body of very weak amorphous peat.

(2) Peat slides. These comprise a mass of intact peat that moves bodily downslope, usually over a comparatively short distance. Where the slide becomes channelised with a subsequent breakdown of debris this may result in a debris flow which can travel a significant distance. Records indicate that slides usually affect upland peat.

The peat failure which occurred at the Kilgarvan site on 17/18th of October 2012 would be classified as a peat slide.

2 SITE DESCRIPTION

The wind farm comprises 28 operational wind turbines with associated infrastructure (Figure 1).

The site is predominantly an upland blanket peat area with numerous rock outcrops and varying peat depth. Intermediate deep pockets of peat are typically present between the rock outcrops.

Peat depths recorded at/near the infrastructure envelope on site during the walkover survey ranged from 0 to 3.9m with an average peat depth of about 1.0m.

The deepest peat recorded during the site walkover was in a localised area adjacent to turbine TIN2. It should be noted that peat deposits of similar depth or deeper are likely to be present in other areas of the site.

The site is undulating with elevations varying from approximately 110 to 506mOD across the site based on ordnance surveys plans. Recorded slope angles at/around the turbine locations varied from 1 to 15 degrees. Localised steeper slopes are present across the site however peat thicknesses in these areas are typically shallow.

Most of the access roads constructed on site are founded on competent stratum beneath the peat. A localised area of floating access road was noted on site between the site entrance of the Inchincoosh site and the junction to turbine TIN3.

The site is drained by a number of watercourses/streams and their tributaries which drain typically in a westerly direction the main watercourse, the Roughty River. A lake called Lough Nabirria is located in the north of the site.

3 DESK STUDY AND SITE WALKOVER

3.1 Desk Study

The main relevant sources of interest with respect to the site include:

- Literature review of peat failures
- Previous Ground investigations

The desk study also included a review of published literature on peat failures in the vicinity of the site.

A review of the previous ground investigations/reports at the site by Malone Regan McGillicuddy (MRG, 2004) and Ground Investigations Ireland (GII, 2007) was also was carried out.

3.2 Site Walkover

As part of the assessment of potential peat failure/instability at the site, AGEC carried out a site reconnaissance. This comprised a walk-over inspection of the site with recording of salient features with respect to peat instability and an assessment of peat thickness and peat strength on the site.

The following features were considered and inspected on site:

- Active, incipient or relict instability (where present) within the peat deposits
- Presence of shallow valley or drainage line
- Wet areas
- Any change in vegetation
- Peat depth
- Slope inclination and break in slope
- Storage of excavation arisings on site
- Drainage at/near the infrastructure locations
- Stressed, cracked or slumping peat

The survey covered the peat slopes in the immediate surrounding area of the infrastructure envelope of the site (i.e. turbine and access road locations) that are located within the site boundary (Figure 1).

The method adopted for carrying out the site reconnaissance relied on experienced practitioners carrying out a visual assessment of the site supplemented with measurement of slope inclinations and inspection and logging of peat conditions.

4 FINDINGS OF DESK STUDY AND SITE WALKOVER

4.1 Previous Failures

The walkover carried out at the site has been used in conjunction with a desk study review to assess the susceptibility of the site to peat failure.

A peat failure occurred in a localised area of the site on the 17/18th of October 2012 upslope of an access road near turbine T14 (AGEC, 2012), see Figure 3. The likely triggering event of the peat slide was heavy rainfall. The slope v-ditches constructed perpendicular to the slope contours above the head of the failure likely contributed to the peat failure by discharging concentrated flows of water onto the peat surface.

Excluding the peat failure described above, the nearest recorded peat failure is located some 6km to the south of the site in a mountain valley area called Fuhiry. The failure is reported to have occurred in 1997, no indication of the failure mechanism is given.

Another peat failure located some 22km to the northeast of the site occurred within an area called Knocknageeha and was described as a large peat flow due to an unreinforced excavation. The failure occurred on 28th December 1896 and is a relatively well-known historic failure.

Other failures recorded by Geological Survey of Ireland (GSI) that occurred in County Kerry are at Ballyhoolohan in 1900 and Kanturk in 1840. The failures at Ballyhoolohan and Kanturk are located northeast of the site some 30 and 38km respectively. The failure mechanisms for both these failures are unreported.

The presence of relict peat failures or clustering of relict failures within an area is an indicator that particular site conditions exist that pre-dispose a site to failure. In general, there are no recorded notable peat failures on the Kilgarvan site.

4.2 Previous Ground Investigations

The Kilgarvan wind farm site is the amalgamation of three, smaller adjacent wind farm sites, the original Kilgarvan wind farm as well as the Inchincoosh and the Lettercannon wind farms. Ground investigations were carried out on these sites separately between 2004 and 2007.

At the original Kilgarvan site, 6 no. trial pits were initially carried out by Malone O'Regan McGillicuddy (MRG, 2004). No location plan was available for these trial pits. Ground conditions typically encountered were described as soft brown/black Peat underlain by blue/grey clayey Gravel or Clay with gravel.

Later in March 2005, 24 no. trial pits were carried out close to the location of the proposed turbines at the Kilgarvan site. Ground conditions typically encountered were described as soft brown/black Peat underlain by firm yellow Clay with gravel or blue/grey clayey Gravel.

75 no. trial pits were carried out at Inchincoosh and Lettercannon sites by Ground Investigations Ireland (GII, 2007) in November 2007. Ground conditions typically

encountered were described as consisting of dark brown/black Peat underlain by clayey sandy Gravel which was underlain by Sandstone rock.

Only the ground investigations received from BGE were reviewed as part of the desk study. It should be noted that other previous ground investigations may be present for the sites mentioned above.

4.3 Findings of Site Walkover

A walk-over inspection of the site was carried out on 31st October and 1st November 2012.

The walkover was carried out by a geotechnical engineer experienced in peat failure assessment. The weather during the site walkover was mainly dry with some snow showers.

The main findings from the site walkover are as follows:

(1) The site is predominantly an upland blanket peat area with numerous rock outcrops and varying peat depth (Photos 1 & 2).

(2) Peat depths recorded at/near the infrastructure envelope on site during the walkover survey ranged from 0 to 3.9m with an average peat depth of about 1.0m. The deepest peat recorded during the site walkover was in a localised area adjacent to turbine TIN2. It should be noted that peat deposits of similar depth or deeper may be present in other areas of the site.

(3) Slope angles recorded at/around the turbine locations varied from 1 to 15 degrees. Localised steeper slopes are present across the site however peat thicknesses in these areas are typically shallow.

(4) Localised areas of waterlogged peat are present across the site. This is not unexpected given the rainfall at the time of year that the inspection took place and the type of terrain present on site.

(5) Localised areas of quaking (or buoyant) peat were recorded adjacent to turbines T3, TIN3 and TIN5 and alongside the floating access road between the site entrance of the Inchincoosh site and the junction to turbine TIN3. Quaking peat is indicative of highly saturated peat, which would generally be considered to have a low strength. Quaking peat is a feature on sites that have been previously linked with peat instability. It should however be noted that due to the locations and flat terrain in the areas of the quaking peat no peat stability issues are envisaged.

(6) A localised area of mechanically cut peat was identified northwest of turbine T3 (Photo 3 & 4). The peat appears to have been mechanically cut using a sausage machine which is used to extract peat for harvesting. The machine cuts, which vary in depth, have essentially severed the acrotelm layer (upper fibrous layer of peat) where most of the intrinsic strength of peat lies. It should however be noted that due to the location and flat terrain in the area of the mechanically cut peat no peat stability issues are envisaged.

(7) No evidence of relict failures was noted on site, except for the peat failure which occurred on the site on 17/18th October 2012. See the peat failure report produced by AGEC (2012) for further details.

(8) A combination of natural and artificial drainage networks are collecting and diverting water away from the turbine bases and access roads on site. It appears that interceptor drains have been installed upslope of the turbine bases where necessary.

(9) During the site walkover, inspection of culverts carrying watercourses under the access roads showed no build-up or ponding of water and it was noted that the culverts appeared to function satisfactorily.

(10) Some slight creep movement of the peat was noted in localised areas across the site (Photo 5). This is not unexpected as creep movement in upland peat areas is a natural occurrence.

(11) On the peat slopes above the access road between turbines T18 and T20 where the peat failure occurred on 17/18th October 2012 (Figure 3), a number of slope v-ditches have been constructed perpendicular to the slope contours. This area would be considered to have an elevated or higher risk of peat instability. The following was noted in the area:

    (a) The peat depths recorded in the area during the site walkover ranged from 0.2 to 1.7m with a typical slope angle for the peat surface of 5 degrees.

    (b) The slope v-ditches constructed typically terminate above the line of the underground cable between 10 and 35m upslope of the access road and discharge concentrated flows of water onto the peat surface at these locations (Photo 6).

    (c) This concentrated flow of water will likely result in the infiltration of surface water into the peat via cracks and an increase in surface loading of the peat due to ponding of water together with possible softening of the peat (Photo 7).

    (d) In a high rainfall event, this may lead to further peat instability in this area.

    (e) See Table 1 of the report for the proposed remedial measures in this area.

(12) A summary of other peat instability and related issues identified during the site walkover are provided in Table 1 along with remedial measures.

(13) The extent and location of the low/medium and elevated or higher risk areas on site are shown on the Risk Zonation Plan (Figure 3).

4.4 Summary of Peat Instability and Related Issues

An inspection was carried out of the peat slopes at/near the infrastructure locations across the site. The purpose of the inspection was to determine if there were presently or potentially any peat instability issues on site.

A summary of these peat instability issues in relation to the infrastructure locations are given in Table 1 and are shown on Figure 3.

No peat instability or incipient instability issues were noted at the infrastructure locations however as part of the monitoring regime for the wind farm, visual inspections of these areas should be carried out, see section 7.2 of this report for further details.

Table 1 Summary of Peat Instability recorded at Infrastructure Locations

Infrastructure Element	Description of Instability/Incipient Instability	Conclusion & Remedial Measure
Floated section of access road between the entrance of the Inchincoosh site and the junction to turbine TIN3	Localised sinking of the floated access road was noted (Photo 8). Some localised bulging of the peat was evident alongside this section of floated access road, which is to be expected as the floating road sinks the peat will result in compression under the applied loading and heave of the adjacent ground.	This is a relatively minor issue and is likely to require upgrading by placing granular fill on the roads surface in the affected areas over the coming months/years to cater for site maintenance traffic.
South of T5	A large volume of water is ponding south of T5 and appears to be slowly draining to a nearby constructed v-ditch (Photo 9). The ponded water is located at the head of a slope. The additional loading at this location from the ponded water may lead to peat instability within this area.	Appropriate v-ditch drains should be installed in this area to prevent the ponding of water. It would be considered appropriate to install v-ditches in this area during a dry spell/during the summer months.
South and southeast of T17	Some localised relict tension cracks were evident to the south and southeast of the turbine base excavation in the peat. This is a minor issue and is indicative of sidewall failure of the excavation (Photo 10).	The minor peat instability noted in this area may lead to minor slumping and partial collapse of the peat excavation face and hence no invasive remedial action is envisaged. As part of the monitoring regime for the wind farm, visual inspection of this location should be carried out.
Localised sections of access road between T18 and T20 (upslope side) - **See area highlighted in yellow on Figure 3**	Steep/near vertical peat excavation faces alongside road cutting (Photo 11)	Given the previous failure in this area, the steep faces of the peat should be battered to a more stable configuration of say 1(V): 2.5(H) slope. This should be carried out in combination with the mitigation measure below.
Upslope of access road between T18 and T20 – **See area highlighted in yellow on Figure 3**	The slope v-ditches constructed in this area are discharging concentrated flows of water onto the peat surface. This concentrated flow of water will likely result in surface loading of the peat due to ponding of water together with possible softening of the peat	Appropriate slope v-ditch drains should be installed in this area to prevent ponding of water on the peat slopes. These slope v-ditches should continue towards the edge of the access road (perpendicular to the slope contours) and outfall into the v-ditch running alongside the access road. It would be considered appropriate to install the slope v-ditches during a dry spell/during the summer months. (Note: When carrying out slope v-ditch works due regard should be given to the buried underground cable and the use of either digging ditches by hand or with lightweight machinery.)

5 SITE GROUND CONDITIONS

5.1 Superficial Deposits

The site consists of predominantly upland blanket peat. Peat depths on site range from 0 to 3.9m with an average peat depth of about 1.0m.

Based on a visual inspection of the exposures present on site the ground conditions were typically described as spongy and firm brown/black fibrous and amorphous Peat overlying typically firm and stiff light brown/grey sandy gravelly Clay with cobbles overlying sandstone/siltstone (Photo 12). In localised areas of the site the peat was recorded as directly overlying bedrock.

5.2 Insitu Peat Strength Testing

As part of the site walkover, in situ peat strength was recorded at various locations across the site. The testing was carried out insitu using a Geonor H-60 hand-field vane tester.

It is important to stress from AGEC's experience that hand vanes give indicative results for insitu strength of peat. The results derived from hand vane testing should be used with caution when assessing peat strength on a site. Where a larger mechanical vane is used with rods protected against contact with the ground, such as a Geonor H-10, more representative strength values can be obtained.

The results of the vane testing carried out by AGEC are presented in Figure 4.

The hand vane results for the peat indicate undrained shear strengths in the range 6 to 50kPa, with an average value of about 18kPa. The lower bound strengths recorded would be typical of deep saturated peat and were recorded within the deeper peat deposits on site.

Peat strength at sites of known peat failures (assuming undrained loading failure) are generally very low, for example the undrained shear strength at the Derrybrien failure (AGEC, 2004) as derived from essentially back-analysis, though some testing was carried out, was estimated at 2.5kPa.

The peat vane strength data for the site has been compared with corresponding data from the well characterised and reported Derrybrien wind farm site, which was the location of a large-scale peat failure in 2003 (AGEC, 2004). Figure 4 also shows the peat strength envelope for the Derrybrien site. The comparison allows the peat conditions at the site to be correlated with a site that had a significant failure (Derrybrien). Where there is a close correlation with the peat condition at Derrybrien than there is possibly a greater likelihood of susceptibility to peat failure.

It is the lower bound peat strength values that provide an indication of the susceptibility of a site to peat failure. The undrained strengths of the peat recorded at the Kilgarvan site are greater than the lower bound values recorded at Derrybrien and hence a similar type peat failure is considered unlikely.

5.3 Bedrock

The underlying bedrock was described by the Geological Survey of Ireland (GSI) and shown on Sheet 21 (Geology of Kerry and Cork). In the area of the Kilgarvan site, there are two dominant bedrock formation types which are generally described as sandstone and siltstone. The western area of the site includes pebbly sandstone and conglomerate type formations with a localised area of green sandstone and siltstone.

These formations include;

- Gun Point formation – Grey/green sandstone and purple siltstone
- Glenfesk chloric formation – Sandstone
- Doo Lough pebbly sand stone member – Pebbly sandstone and conglomerate
- Ballinskelligs sandstone formation – Green sandstone and siltstone

There are a number of mapped faults on the western side of the site, with southeast to northwest and southwest to northeast trends with some intersecting east to west trends.

There are no working quarries mapped on or close to the wind farm site and no karst features were identified in the area.

6 PEAT STABILITY ASSESSMENT

6.1 Methodology for Peat Stability Assessment

Stability of a peat slope is dependent on several factors working in combination. The main factors that influence peat stability are slope angle, shear strength of peat, depth of peat, pore water pressure and loading conditions.

An adverse combination of factors could potentially result in peat sliding. An adverse condition of one of the above-mentioned factors alone is unlikely to result in peat failure. To assess the factor of safety for a peat slide, an undrained and drained analysis has been undertaken to determine the stability of the natural peat slopes on site.

The infinite slope model (Skempton and DeLory, 1957) is used to combine these factors to determine a factor of safety for peat sliding. This model is based on a translational slide, which is a reasonable representation of the dominant mode of movement for peat failures.

Based on the findings of the Derrybrien failure, undrained loading during construction was found to be the critical failure mechanism. The undrained loading condition applies in the short term during construction and until construction induced pore water pressures dissipate. Undrained shear strength values (c_u) for peat are used for the total stress analysis.

Some of the access roads on site are formed in cuttings in peat i.e. the in-situ peat is excavated and the access roads are founded on competent strata beneath the peat. These cuttings in peat may be subject to variations in groundwater level and therefore an effective (drained) stress analysis was also conducted.

A drained analysis requires effective cohesion (c’) and effective friction angle (ø’) values for the calculations. These values can be difficult to obtain because of disturbance experienced when sampling peat and the difficulties in interpreting test results due to the excessive strain induced within the peat. To determine suitable drained strength values a review of published information on peat was carried out.

Table 2 shows a summary of the published information on peat together with drained strength values.

Table 2 List of Effective Cohesion and Friction Angle Values

Reference	Cohesion, c' (kPa)	Friction Angle, ø' (degs)	Testing Apparatus/ Comments
Hanrahan et al (1967)	5 to 7	36 to 43	From triaxial apparatus
Rowe and Mylleville (1996)	2.5	28	From simple shear apparatus
Landva (1980)	2 to 4	27.1 to 32.5	Mainly ring shear apparatus for normal stress greater than 13kPa
	5 to 6	-	At zero normal stress
Carling (1986)	6.5	0	-
Farrell and Hebib (1998)	0	38	From ring shear and shear box apparatus. Results are not considered representative.
	0.61	31	From direct simple shear (DSS) apparatus. Result considered too low therefore DSS not considered appropriate
Rowe, Maclean and Soderman (1984)	1.1	26	From simple shear apparatus
	3	27	From DSS apparatus
Sandorini et al (1984)	4.5	28	From triaxial apparatus
McGreever and Farrell (1988)	6	38	From triaxial apparatus using soil with 20% organic content
	6	31	From shear box apparatus using soil with 20% organic content
Hungr and Evans (1985)	3.3	-	Back-analysed from failure
Madison et al (1996)	10	23	-
Dykes and Kirk (2006)	3.2	30.4	Test within acrotelm
Dykes and Kirk (2006)	4	28.8	Test within catotelm
Warburton et al (2003)	5	23.9	Test in basal peat
Warburton et al (2003)	8.74	21.6	Test using fibrous peat
Entec (2008)	3.8	36.8	Generalised values derived from various peat tests (shear box and triaxial)

From Table 2 the values for c' ranged from 1.1 to 10kPa and ø' ranged from 21.6 to 43°. The average c' and ø' values are 5kPa and 30° respectively. Based on the above, it was considered to adopt a conservative design values. For design the following general drained strength values have been used for the site:

c' = 4kPa
ø' = 25 degrees

6.2 Analysis to Determine Factor of Safety

The purpose of the analysis was to determine the Factor of Safety (FoS) of the natural peat slopes using an infinite slope analysis. The analysis was carried out at/near the turbine locations and at critical locations identified during the site walkover.

The FoS provides a direct measure of the degree of stability of the slope. A FoS of less than unity indicates that a slope is unstable, a FoS of greater than unity indicates a stable slope.

The acceptable safe range for FoS typically ranges from 1.3 to 1.4. Where there is minimal risk from a slope failure a FoS of just greater than 1 may in some cases be acceptable (Geotechnical Engineering Office, 1984). The previous code of practice for earthworks BS 6031:1981 (BSI, 1981), provided advice on design of earthworks slopes. It stated that for a first time failure with a good standard of site investigation the design FoS should be greater than 1.3.

Eurocode 7 (EC7) (IS EN 1997-1:2005) which was introduced two to three years ago now serves as the reference document and the basis for design geotechnical engineering works. The design philosophy used in EC7 applies partial factors to soil parameters, actions and resistances. Unlike the traditional approach, EC7 does not provide a direct measure of stability, since global Factors of Safety are not used.

As such, and in order to provide a direct measure of the level of safety on a site, EC7 partial factors have not been used in this stability assessment. The results are given in terms of global FoS.

For the undrained analysis in the peat shear strength values are based on a lower bound value from site of 6kPa. It should be noted that an undrained shear strength of 6kPa for the peat is considered a conservative value for the analysis and is not representative of all peat present across the site.

The bulk unit weight assumed for the peat was 10kN/m^3.

The formula used to determine the factor of safety for the undrained condition in the peat (Bromhead, 1986) is as follows:

$$F = \frac{c_u}{\gamma z \sin\alpha \cos\alpha}$$

Where,

F = Factor of Safety
c_u = Undrained strength
γ = Bulk unit weight of material
z = Depth to failure plane assumed as depth of peat
α = Slope angle

The formula used to determine the factor of safety for the drained condition in the peat (Bromhead, 1986) is as follows:

$$F = \frac{c' + (\gamma z - \gamma_w h_w)\cos^2\alpha \tan\phi'}{\gamma z \sin\alpha \cos\alpha}$$

Where,

F = Factor of Safety
c' = Effective cohesion
γ = Bulk unit weight of material
z = Depth to failure plane assumed as depth of peat
γ_w = Unit weight of water
h_w = Height of water table above failure plane
α = Slope angle
ϕ' = Effective friction angle

For the drained analysis the level of the water table above the failure surface is required to calculate the factor of safety for the slope. Since the water level in blanket peat can be variable, it is not feasible to establish its precise location throughout the site. Therefore a sensitivity analysis using water level ranging between 0 and 100% of the peat depth was conducted, where 0% equates to the peat being completely dry and 100% equates to the peat being fully saturated.

The following general assumptions were used in the analysis of peat slopes at each location:

(1) Peat depths are based on the peat depths recorded at each location from the walkover survey.
(2) Undrained shear strength values for the peat are based on the lowest c_u recorded at the site which was 6kPa. It should be noted that undrained shear strength of 6kPa for the peat is considered a conservative value for the analysis and is not representative of all peat present across the site.
(3) Slope angle on base of sliding assumed to be parallel to ground surface.

For the stability analysis two load conditions were examined, namely

Condition (1): no surcharge loading

Condition (2): surcharge of 10kPa, equivalent to 1m of stockpiled peat (assumed as a worst case). This is representative of peat placed on the natural peat slopes during construction/maintenance works at the wind farm

6.3 Results of Analysis

6.3.1 Undrained Analysis for the peat

The results of the undrained analysis for the natural peat slopes are presented in Appendix B and the results of the undrained analysis for the most critical load case (load condition 2) are shown on Figure 2.

For the Kilgarvan site the calculated FoS for load condition (1) is in excess of 1.30 for each location analysed with a range of FoS of 3.19 to in excess of 10.

The calculated FoS for load condition (2) is in excess of 1.30 for each location analysed with a range of FoS of 2.18 to in excess of 10.

6.3.2 Drained Analysis for the peat

The results of the drained analysis for the natural peat slopes are presented in Appendix B.

For the Kilgarvan site the calculated FoS for load condition (1) is in excess of 1.30 for each turbine and infrastructure location analysed with a range of FoS of 2.13 to in excess of 10.

The calculated FoS for load condition (2) is in excess of 1.30 for each location analysed with a range of FoS of 3.04 to in excess of 10.

In summary, the results of the peat stability assessment for the natural peat slopes show that the FoS's for the Kilgarvan site are acceptable and are greater than the required minimum value of 1.3 at all locations analysed.

7 FACTORS THAT INFLUENCE PEAT INSTABILITY & SOME CONTROL MEASURES

7.1 Summary of Factors that influence Peat Instability

To highlight likely contributory mechanisms involved in a peat failure a number of case histories were collated where details such as the failure type, geometry of the slope, scale of failure and weather conditions were available (Appendix C).

The following provides a summary of some of the more likely controlling mechanisms of mass movement of peat based on case study review of peat failures.

(1) *Triggered by Extreme Rainfall Events*. The dominant trigger for nearly all peat failures (flows and slides) appears to be unusually intense rainfall. Most failures are associated with extreme rainfall events, see Tomlinson & Gardiner (1982), Alexander et al. (1985), and recent failures at Pollatomish, North Mayo in Ireland (Long and Jennings, 2006) and Shetland Islands, Scotland in September 2003. The likely failure mechanism is following heavy rainfall, infiltration of surface water into the ground results in a build-up of pore pressures and reduced effective shear strength at particularly the interface between the peat and the mineral soil. Secondary effects include possibly swelling of the peat bog, increase in loading due to ponding together with possible softening.

A sequence of dry periods followed by periods of heavy rainfall has also been recorded prior to failure. In these cases, drying out of the upper peat, particularly in areas of thinner peat, is likely to have resulted in the development of near-surface cracks which could facilitate ingress of water into the peat. Some drying-out of the peat would also occur which would to a degree reduce the effective normal stress on a potential failure surface.

(2) *Slope Morphology*. A number of descriptions of bog failures, for example Mitchell (1938) and Tomlinson and Gardiner (1982), note the presence of a convex break in slope at the source of the failure.

It appears that at a slope convexity, because of the 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. Alternatively a failure mechanism, analogous to a piping failure underneath dams, has been noted where springs are present in locations immediately down-slope of the relatively well drained peat body. High pore pressure gradients within the peat can lead to undermining of the relatively well drained peat body resulting in a breach and loss of lateral support to peat upslope.

(3) *Slope Angle*. Figure C.1 (Appendix C) shows a plot of some available data of pre-failure slope angles at 30 failure sites. The failures are grouped in terms of peat slides and peat flows (bog burst).

From Figure C.1, it can be seen that failures occur at a wide range of slope angles. The wide range suggests that several other contributory factors are present at failure sites. In general, failures occur at slope angles between about 3 and 8°, though in rarer circumstances such as where peat has been effected by man interference, failures have occurred on slopes as shallow as 2°. The data suggests crudely that a natural peat failure that is without man interference, in peat has reduced likelihood of occurring on slopes below about 2°.

(4) *Drainage*. Natural drainage and man-made drainage measures designed to reduce the water content in the peat have often been identified as a contributory cause of some failures. The drainage paths have allowed the migration of surface water to a failure site therefore precipitating failure. In some instances, agricultural works led to the disturbance of an existing drainage network and eventually caused failure; see Warburton et al (2004).

(5) *Man-made Interference*. Man-made interference of peat bogs includes a range of affects associated with for example construction activity, drainage, trackways across peat, peat cutting. The failure at Derrybrien, County Galway has implicated construction activity (AGEC, 2004).

(6) *Re-current Failures*. The presence of clustering of relict failures is often noted, indicating that particular pre-existing site conditions predispose a site to failure. The combination of geological and climatic conditions that prevail at these sites is therefore somewhat unique. This suggests that the probability of first-time failures is less likely at sites with no previous history of failure.

(7) *Pre-existing Weak or Basal Layers*. Several peat failure reports identify the possibility of relatively weaker layers within the peat. In most cases, these weak layers are at the base of the peat deposit where there is usually the highest degree of peat humification and lowest relative peat strength. Alternatively, where failure is triggered by the ingress of water into the peat, there is a tendency for water to build-up at the base of the peat causing a reduction in effective stress at the base of the peat resulting in failure.

7.2 Control Measures for the Operational Stage of the Wind Farm

The following control measures should be taken into account to avoid further peat failures/movements on site during the operational stage of the wind farm.

(1) Any construction/maintenance activities on the peat slopes particularly in the area of the peat failure that occurred on the 17/18th of October 2012 should be avoided, without prior inspection from suitably qualified personnel.

(2) Any construction/maintenance activities on the peat slopes at the site should be monitored and supervised by experienced and qualified personnel.

(3) Ensure the use of experienced competent personnel for all maintenance/ construction activities on site.

(4) Following a particularly heavy rainfall event an inspection of the site should be carried out to ensure no ponding of water or blocked drains are present. The

installation of a rainfall gauge on site would provide a record of rainfall intensity. It would be prudent to carry out an inspection of the elevated or higher risk areas when a daily rainfall of over 20mm is recorded on site.

(5) Maintain a managed robust drainage system on site. This should include:

  (a) Maintenance of interceptor drains, pipe culverts and silt traps/ponds.
  (b) Where ponding is evident or there is continued blockage of drains additional drainage should be installed.

(6) Avoid the placement of loads/overburden on marginal ground.

(7) Avoidance of uncontrolled concentrated water discharge onto peat slopes identified as being unsuitable for such discharge. This information would be gathered as part of inspection following heavy rainfall events, see (4) above.

(8) A typical inspection regime for the full site during the operational stage of a wind farm would include:

  (a) Daily recording of rainfall levels by wind farm operational staff.
  (b) Monthly routine site inspection by wind farm operational staff, see (9) below.
  (c) Annual site inspection by Geotechnical Engineer.

(9) Monthly routine inspection of the site by the wind farm operational staff (or other suitably qualified personnel) should include a visual assessment of ground stability and drainage conditions. Features to make note of on site would include but not be limited to the following:

- Cracking of the peat surface (i.e. tension cracks)
- Disrupted peat surface or slumping of the peat
- Displaced or detached peat
- Excessive floating road settlement
- Closed-up (squeezing of v-ditches) drains
- Blocked drains
- Absence of water in previously flowing drains
- Springs
- Excessive ponding of water on peat slopes

(10) Regular briefing of all site staff (e.g. toolbox talks) to promote reporting of any observed change in ground conditions.

(11) Set up, maintain and report findings from monitoring systems (at the peat failure area) on a continuous basis. See AGEC (2012) report on the Peat Failure at Kilgarvan wind farm for further details.

(12) The site contingency measures given in Appendix D should be taken into consideration/implemented in the event of a peat movement/failure.

8 CONCLUSION AND RECOMMENDATIONS

8.1 Conclusions

The following conclusions are given.

(1) The Kilgarvan site comprises 28 operational wind turbines and associated infrastructure.

(2) The site is predominantly an upland blanket peat area with numerous rock outcrops and varying peat depth. Peat depths recorded at/near the infrastructure envelope on site during the walkover survey ranged from 0 to 3.9m with an average peat depth of about 1.0m.

(3) Slope angles recorded at/around the turbine locations varied from 1 to 15 degrees. Localised steeper slopes are present across the site however peat thicknesses in these areas are typically shallow.

(4) From the walkover of the site the following observations were noted:

  (a) The interceptor/v-ditch drains and culverts inspected on site during the site walkover appear to be functioning satisfactorily.

  (b) Some slight creep movement of the peat was noted in localised areas across the site. This is not unexpected as creep movement in upland peat areas is a natural occurrence.

  (c) Features which have been previously linked with peat instability were recorded on site namely mechanically cut peat and quaking (or buoyant) peat. It should however be noted that due to the locations and flat terrain in the areas of the mechanically cut and quaking peat on the Kilgarvan site no peat stability issues are envisaged.

  (d) Undrained shear strength testing of the peat was carried out as part of the site walkover. The hand vane results for the peat indicate undrained shear strengths in the range 6 to 50kPa, with an average value of about 18kPa. The lower bound strengths recorded would be typical of deep saturated peat.

  (e) No evidence of relict failures was noted on site, except for the peat failure which occurred on the site on 17/18th October 2012.

  (f) An area upslope of the access road between turbines T18 and T20, where the peat failure occurred on 17/18th October 2012, has been identified as an area with an elevated or higher risk of peat instability (Figure 3).

    (i) The slope v-ditches constructed in this area are discharging concentrated flows of water onto the peat surface.

    (ii) The concentrated flow of water will likely result in surface loading of the peat due to ponding of water together with possible softening of the peat.

    (iii) In a high rainfall event, this may lead to further peat instability in this area.

    (iv) See Table 1 in section 4.4 of this report for the proposed remedial measures in this area.

(g) A summary of other peat instability and related issues identified during the site walkover are provided in Table 1 along with remedial measures.

(5) An analysis of peat sliding instability was carried out at/near the turbine locations and at critical locations identified during the site walkover for both the undrained and drained conditions. The purpose of the analysis was to determine the Factor of Safety (FoS) of the natural peat slopes.

(a) For the undrained condition for the peat, the calculated FoS for load conditions (1) and (2) are in excess of the minimum acceptable 1.30 for each location analysed with a FoS of 2.18 or greater at all locations.

(b) For the drained condition for the peat, the calculated FoS for load conditions (1) and (2) are in excess of minimum acceptable 1.30 for each location analysed with a FoS of 2.13 or greater at all locations.

(6) The above results of the analysis of peat instability for the natural peat slopes show that the FoS's for the Kilgarvan site are acceptable and are greater than the required minimum value of 1.3 at all locations analysed.

(7) In conclusion, the wind farm site at Kilgarvan as a whole is considered to have a low risk of peat instability based on our experience of other wind farm sites. One localised area of the site has been identified as having an elevated or higher risk of peat failure/instability. The extent and location of the low/medium and elevated or higher risk areas on site are shown on the Risk Zonation Plan (Figure 3).

8.2 Recommendations

The following general recommendations are given.

(1) The remedial measures given in Table 1 within section 4.4 of this report should be taken into account and implemented.

(2) The control measures identified in section 7.2 of this report should be taken into consideration and be implemented throughout the operational stage of the wind farm.

(3) The site contingency measures/ guidelines given in Appendix D should be taken into consideration event of a peat movement/ failure.

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FIGURES

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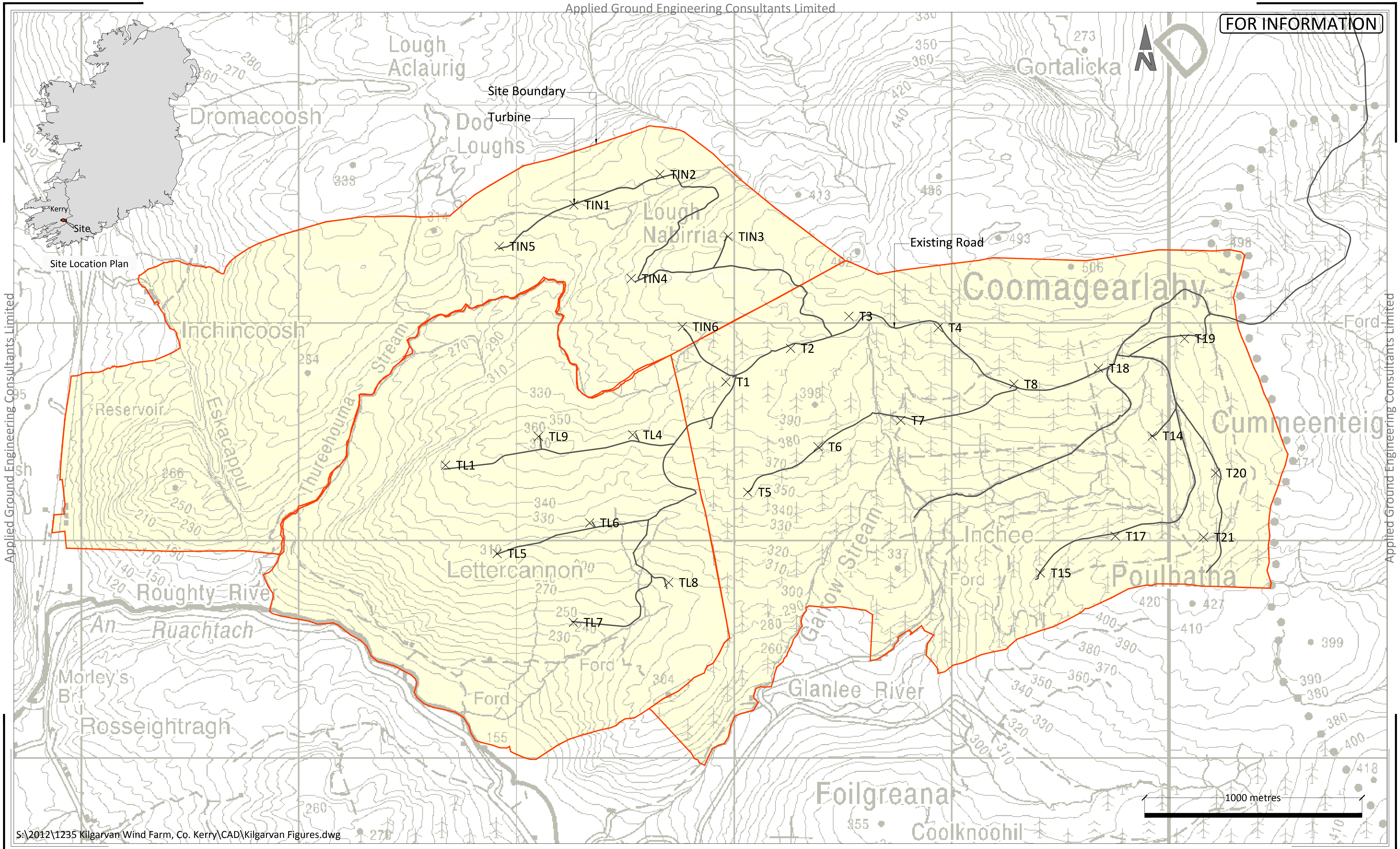
FOR INFORMATION



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Based on:

Client:
Bórd Gáis Éireann

Bord Gáis Energy
think beyond

Job:
Kilgarvan Wind Farm,
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Figure 1

Title:
Site Layout Plan

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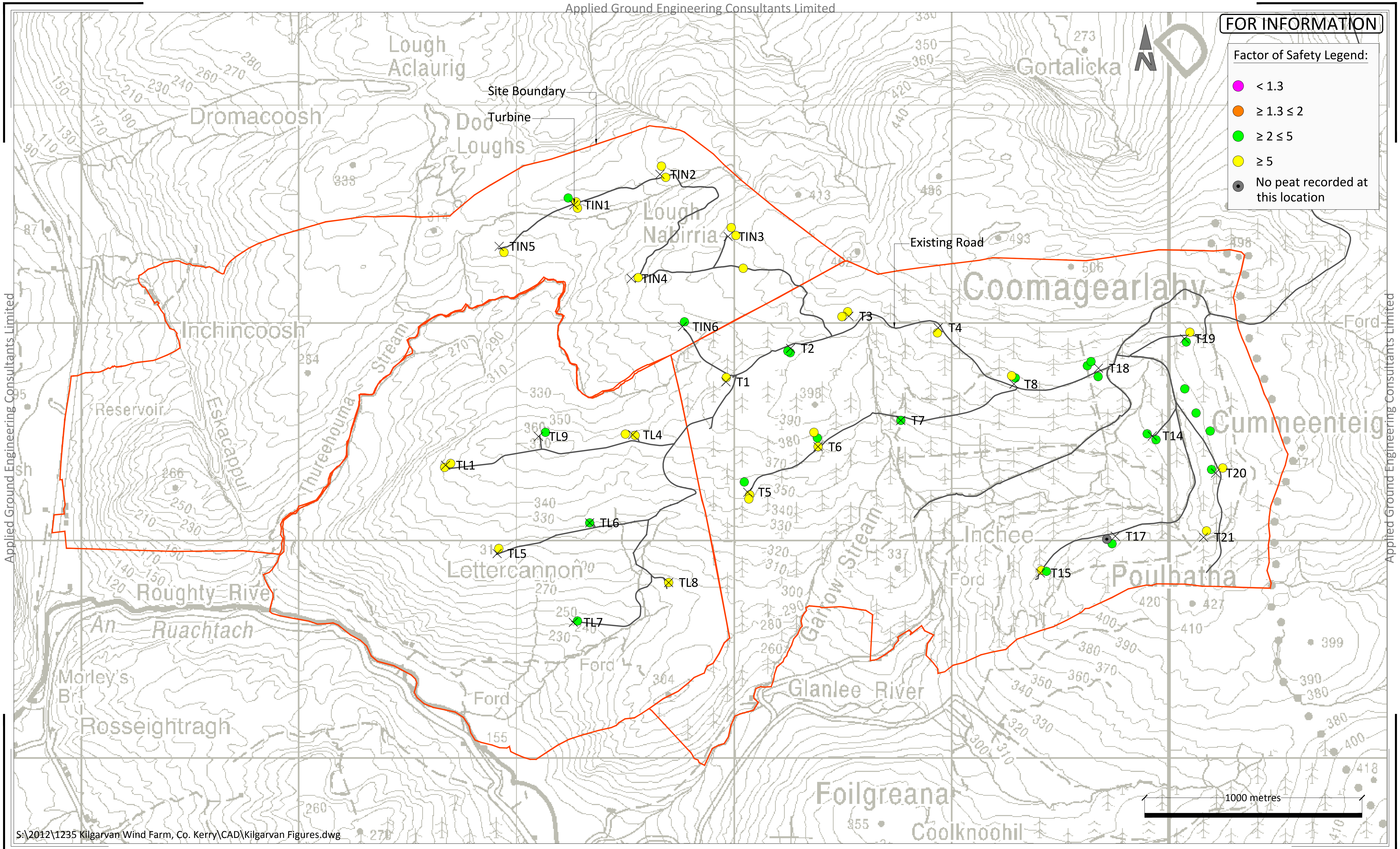

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Client:
Bórd Gáis Éireann

Job:
Kilgarvan Wind Farm,
Co. Kerry

Figure 2

Title:
Factor of Safety Plan

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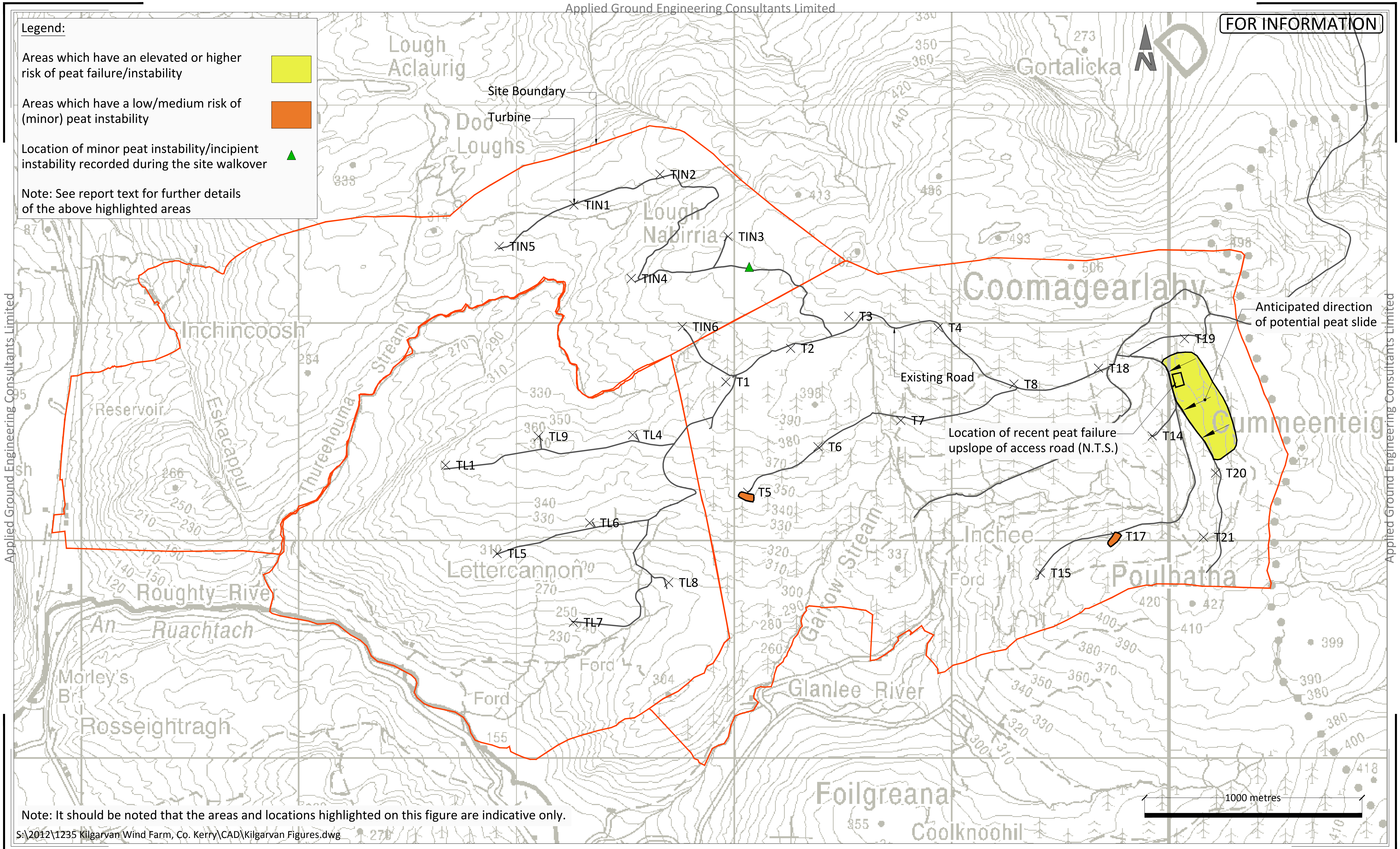
FOR INFORMATION



Legend:

Areas which have an elevated or higher risk of peat failure/instability	🟨
Areas which have a low/medium risk of (minor) peat instability	🟧
Location of minor peat instability/incipient instability recorded during the site walkover	▲

Note: See report text for further details of the above highlighted areas

Note: It should be noted that the areas and locations highlighted on this figure are indicative only.

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Scale: 1:16,000 @ A3
Checked: GK
Date: 04 January 2013
Revision: 1
Drawn: POR
Based on:

Client:
Bórd Gáis Éireann

Job:
Kilgarvan Wind Farm,
Co. Kerry

Figure 3

Title:
Risk Zonation Plan

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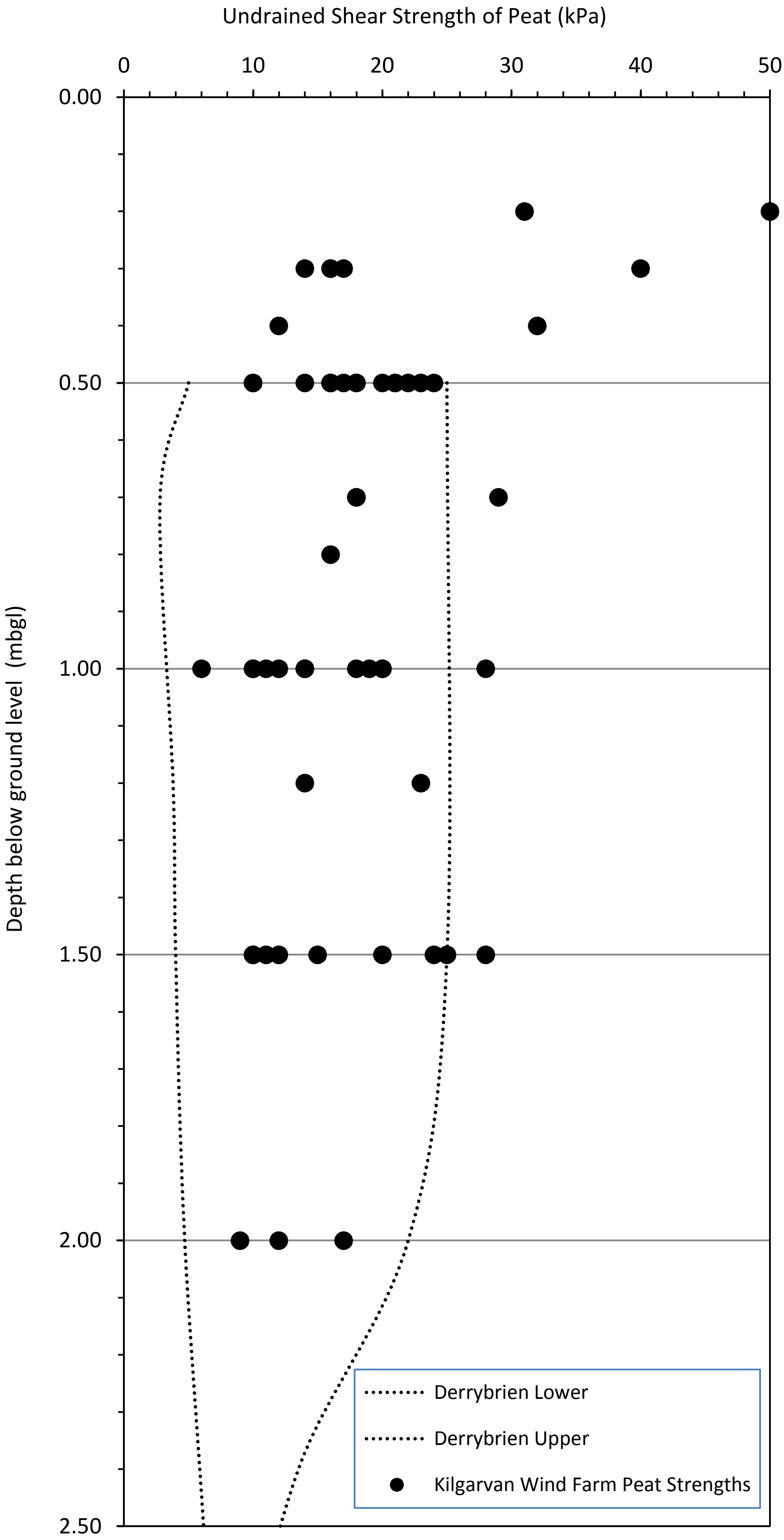


Figure 4 Undrained Shear Strength (c_u) Profile for Peat with Depth

APPENDIX A

PHOTOS FROM SITE VISIT

Photo 1 Overview of site conditions

Photo 2 Overview of site conditions

Photo 3 Mechanically cut peat northwest of turbine T3

Photo 4 Example of mechanically cut peat on site

Photo 5 Example of creep movement of peat on site

Photo 6 Slope v-ditch constructed in elevated or higher risk area on site

Photo 7 Ponding of water at termination of slope v-ditches

Photo 8 Localised sinking of the floated access road

Photo 9 Ponding of water south of turbine T5

Photo 10 Localised relict tension cracks south of turbine T17

Photo 11 Overly steep peat excavation face alongside road cutting

Photo 12 Typical ground conditions present on site

APPENDIX B

CALCULATED FACTOR OF SAFETY AT/NEAR TURBINES AND AT CRITICAL LOCATIONS ON SITE

Calculated FoS of Natural Peat Slopes for Kilgarvan Wind Farm (Undrained Analysis)

Calculation Number/ Label	**Turbine Number**	**Easting**	**Northing**	**Slope**	**Undrained shear strength**	**Bulk unit weight of Peat**	**Peat Depth**	**Surcharge Equivalent Placed Fill Depth (m)**	**Factor of Safety for Load Condition**	
				β (deg)	**c_u (kPa)**	**γ (kN/m^3)**	**(m)**	**Condition (2)**	**Condition (1)**	**Condition (2)**
At/Near Turbines and at Critical Locations on Site										
6	T18	109626	76801	8	6	10	0.8	1.8	**5.44**	**2.42**
7	T18	109643	76820	8	6	10	0.3	1.3	**14.51**	**3.35**
8	T18	109676	76751	3	6	10	1.8	2.8	**6.38**	**4.10**
9	T8	109295	76745	5	6	10	0.5	1.5	**15.36**	**4.77**
10	T8	109278	76755	5	6	10	0.3	1.3	**23.04**	**5.32**
11	T4	108937	76952	1.0	6	10	1.6	2.6	**21.49**	**13.22**
12	T3	108524	77049	1.0	6	10	0.6	1.6	**57.31**	**21.49**
13	T3	108498	77027	1.0	6	10	2.0	3.0	**17.19**	**11.46**
14	B/n T3 and TIN3	108044	77249	1.0	6	10	2.4	3.4	**14.33**	**10.11**
16	TIN3	108011	77400	2.0	6	10	0.6	1.6	**28.67**	**10.75**
17	TIN3	107989	77436	2.0	6	10	0.7	1.7	**24.58**	**10.12**
18	TIN4	107561	77206	1.0	6	10	1.8	2.8	**19.10**	**12.28**
19	TIN2	107668	77718	2.0	6	10	0.3	1.3	**57.34**	**13.23**
20	TIN2	107688	77667	1.0	6	10	3.9	4.9	**8.82**	**7.02**
21	TIN1	107282	77525	3.0	6	10	0.8	1.8	**14.35**	**6.38**
22	TIN1	107239	77572	3.0	6	10	1.3	2.3	**8.83**	**4.99**
23	TIN5	107275	77554	1.0	6	10	1.8	2.8	**19.10**	**12.28**
24	TIN5	106944	77322	1.0	6	10	2.2	3.2	**15.63**	**10.75**
25	T2	108260	76861	4.0	6	10	2.7	3.7	**3.19**	**2.33**
26	T2	108249	76868	4.0	6	10	1.6	2.6	**5.39**	**3.32**
27	T1	107966	76747	3.0	6	10	0.3	1.3	**38.27**	**8.83**
28	TIN6	107774	77003	4.0	6	10	0.9	1.9	**9.58**	**4.54**
29	TIN6	108385	76469	4.0	6	10	1.6	2.6	**5.39**	**3.32**
-	T7	108769	76550	6.0	6	10	0.4	1.4	**14.43**	**4.12**
-	T6	108388	76429	2.0	6	10	0.3	1.3	**57.34**	**13.23**
30	T6	108369	76495	2.0	6	10	1.0	2.0	**17.20**	**8.60**
31	T5	108049	76267	6.0	6	10	1.1	2.1	**5.25**	**2.75**
32	T5	108074	76208	2.0	6	10	1.8	2.8	**9.56**	**6.14**
33	T5	108070	76189	4.0	6	10	0.3	1.3	**28.74**	**6.63**
34	T19	110098	76955	5.0	6	10	0.2	1.2	**34.55**	**5.76**
35	T19	110081	76910	5.0	6	10	0.4	1.4	**17.28**	**4.94**
36	T14	109942	76461	6.0	6	10	0.6	1.6	**9.62**	**3.61**
37	T14	109901	76488	6.0	6	10	0.2	1.2	**28.86**	**4.81**
38	T20	110197	76324	5.0	6	10	0.6	1.6	**11.52**	**4.32**
39	T20	110249	76331	5.0	6	10	0.1	1.1	**69.11**	**6.28**
40	T21	110174	76042	2.0	6	10	0.3	1.3	**57.34**	**13.23**
42	T17	109740	75983	3.0	6	10	1.3	2.3	**8.83**	**4.99**
43	T17	109716	76004	**No peat recorded at this location**						
44	T15	109415	75861	2.0	6	10	0.6	1.6	**28.67**	**10.75**
45	T15	109438	75856	6.0	6	10	0.2	1.2	**28.86**	**4.81**
49	-	110191	76501	5.0	6	10	1.7	2.7	**4.07**	**2.56**
51	-	110126	76584	4.0	6	10	0.9	1.9	**9.58**	**4.54**
53	-	110074	76695	5.0	6	10	1.6	2.6	**4.32**	**2.66**
56	TL4	107547	76481	3.0	6	10	0.4	1.4	**28.70**	**8.20**
57	TL4	107502	76487	3.0	6	10	0.3	1.3	**38.27**	**8.83**
58	TL9	107135	76495	5.0	6	10	1.2	2.2	**5.76**	**3.14**
60	TL1	106671	76334	1.0	6	10	0.2	1.2	**171.92**	**28.65**
61	TL1	106699	76352	1.0	6	10	2.2	3.2	**15.63**	**10.75**
-	TL6	107338	76079	15.0	6	10	0.1	1.1	**24.00**	**2.18**
62	TL5	106920	75961	3.0	6	10	0.3	1.3	**38.27**	**8.83**
-	TL8	107701	75805	5.0	6	10	0.3	1.3	**23.04**	**5.32**
63	TL7	107282	75628	6.0	6	10	0.3	1.3	**19.24**	**4.44**

Notes:

(1) Assuming a bulk unit weight for peat of 10kN/m^3
(2) Assuming a surcharge equivalent to fill depth of 1m of peat.
(3) Slope inclination (β) based on site readings.
(4) Undrained shear strength values for the peat are based on the lowest recorded value on site i.e. 6kPa
(5) Peat depths based on peat depth probes.
(6) For load conditions see Report text.

Calculated FoS of Natural Peat Slopes for Kilgarvan Wind Farm (Drained Analysis)

Calculation Number/ Label	Turbine Number	Slope	Design c'	Bulk unit weight of Peat	Unit weight of Water	100% Water to height of Peat	Depth of In situ Peat	Friction Angle	Equivalent Total Depth of Peat (m)	Factor of Safety for Load Condition	
		α (deg)	c' (kPa)	γ (kN/m^3)	γ_w (kN/m3)	(m)	(m)	ø' (deg)	Condition (2)	Condition (1)	Condition (2)
										100% Water	**100% Water**
At/Near Turbines and at Critical Locations on Site											
6	T18	8	4	10.0	10.0	0.8	0.8	25	1.80	**3.63**	**3.46**
7	T18	8	4	10.0	10.0	0.3	0.3	25	1.30	**9.67**	**4.78**
8	T18	3	4	10.0	10.0	1.8	1.8	25	2.80	**4.25**	**5.91**
9	T8	5	4	10.0	10.0	0.5	0.5	25	1.45	**10.24**	**6.85**
10	T8	5	4	10.0	10.0	0.3	0.3	25	1.30	**15.36**	**7.64**
11	T4	1.0	4	10.0	10.0	1.6	1.6	25	2.60	**14.33**	**19.09**
12	T3	1.0	4	10.0	10.0	0.6	0.6	25	1.60	**38.20**	**31.02**
13	T3	1.0	4	10.0	10.0	2.0	2.0	25	3.00	**11.46**	**16.55**
14	B/n T3 and TIN3	1.0	4	10.0	10.0	2.4	2.4	25	3.40	**9.55**	**14.60**
16	TIN3	2.0	4	10.0	10.0	0.6	0.6	25	1.60	**19.11**	**15.51**
17	TIN3	2.0	4	10.0	10.0	0.7	0.7	25	1.70	**16.38**	**14.60**
18	TIN4	1.0	4	10.0	10.0	1.8	1.8	25	2.80	**12.73**	**17.73**
19	TIN2	2.0	4	10.0	10.0	0.3	0.3	25	1.30	**38.23**	**19.09**
20	TIN2	1.0	4	10.0	10.0	3.9	3.9	25	4.90	**5.88**	**10.13**
21	TIN1	3.0	4	10.0	10.0	0.8	0.8	25	1.80	**9.57**	**9.20**
22	TIN1	3.0	4	10.0	10.0	1.3	1.3	25	2.30	**5.89**	**7.20**
23	TIN5	1.0	4	10.0	10.0	1.8	1.8	25	2.80	**12.73**	**17.73**
24	TIN5	1.0	4	10.0	10.0	2.2	2.2	25	3.20	**10.42**	**15.51**
25	T2	4.0	4	10.0	10.0	2.7	2.7	25	3.70	**2.13**	**3.36**
26	T2	4.0	4	10.0	10.0	1.6	1.6	25	2.60	**3.59**	**4.78**
27	T1	3.0	4	10.0	10.0	0.3	0.3	25	1.30	**25.51**	**12.73**
28	TIN6	4.0	4	10.0	10.0	0.9	0.9	25	1.90	**6.39**	**6.54**
29	TIN6	4.0	4	10.0	10.0	1.6	1.6	25	2.60	**3.59**	**4.78**
-	T7	6.0	4	10.0	10.0	0.4	0.4	25	1.40	**9.62**	**5.92**
-	T6	2.0	4	10.0	10.0	0.3	0.3	25	1.30	**38.23**	**19.09**
30	T6	2.0	4	10.0	10.0	1.0	1.0	25	2.00	**11.47**	**12.41**
31	T5	6.0	4	10.0	10.0	1.1	1.1	25	2.10	**3.50**	**3.94**
32	T5	2.0	4	10.0	10.0	1.8	1.8	25	2.80	**6.37**	**8.86**
33	T5	4.0	4	10.0	10.0	0.3	0.3	25	1.30	**19.16**	**9.55**
34	T19	5.0	4	10.0	10.0	0.2	0.2	25	1.20	**23.04**	**8.28**
35	T19	5.0	4	10.0	10.0	0.4	0.4	25	1.40	**11.52**	**7.10**
36	T14	6.0	4	10.0	10.0	0.6	0.6	25	1.60	**6.41**	**5.18**
37	T14	6.0	4	10.0	10.0	0.2	0.2	25	1.20	**19.24**	**6.90**
38	T20	5.0	4	10.0	10.0	0.6	0.6	25	1.60	**7.68**	**6.21**
39	T20	5.0	4	10.0	10.0	0.1	0.1	25	1.10	**46.07**	**9.03**
40	T21	2.0	4	10.0	10.0	0.3	0.3	25	1.30	**38.23**	**19.09**
42	T17	3.0	4	10.0	10.0	1.3	1.3	25	2.30	**5.89**	**7.20**
43	T17	**No peat recorded at this location**									
44	T15	2.0	4	10.0	10.0	0.6	0.6	25	1.60	**19.11**	**15.51**
45	T15	6.0	4	10.0	10.0	0.2	0.2	25	1.20	**19.24**	**6.90**
49	T15	5.0	4	10.0	10.0	1.7	1.7	25	2.70	**2.71**	**3.68**
51	T15	4.0	4	10.0	10.0	0.9	0.9	25	1.90	**6.39**	**6.54**
53	T15	5.0	4	10.0	10.0	1.6	1.6	25	2.60	**2.88**	**3.82**
56	TL4	3.0	4	10.0	10.0	0.4	0.4	25	1.40	**19.13**	**11.82**
57	TL4	3.0	4	10.0	10.0	0.3	0.3	25	1.30	**25.51**	**12.73**
58	TL9	5.0	4	10.0	10.0	1.2	1.2	25	2.20	**3.84**	**4.52**
60	TL1	1.0	4	10.0	10.0	0.2	0.2	25	1.20	**114.61**	**41.36**
61	TL1	1.0	4	10.0	10.0	2.2	2.2	25	3.20	**10.42**	**15.51**
-	TL6	15.0	4	10.0	10.0	0.1	0.1	25	1.10	**16.00**	**3.04**
62	TL5	3.0	4	10.0	10.0	0.3	0.3	25	1.30	**25.51**	**12.73**
-	TL8	5.0	4	10.0	10.0	0.3	0.3	25	1.30	**15.36**	**7.64**
63	TL7	6.0	4	10.0	10.0	0.3	0.3	25	1.30	**12.83**	**6.37**

Notes:

(1) Assuming a bulk unit weight of peat of 10 (kN/m^3)
(2) Assuming a surcharge equivalent to fill depth of 1.0 (m)
(3) Slope inclination (β) based on site readings.
(4) FoS is based on slope inclination and shear test results obtained from published data
(5) Peat depths based on peat depth probes.
(6) For load conditions see Report text.
(7) Minimum acceptable factor of safety required of 1.3 for first-time failures based on BS: 6031:1981 Code of practice for Earthworks

APPENDIX C

CASE HISTORY OF SOME IRISH PEAT FAILURES

Location and Reference	Type (2)	Regional Slope	Comment
Derrybrien Wind Farm (AGEC, 2004)	Slide	4°	Failure initiated by placement of peat arisings onto peat surface at head of shallow valley feature. Degraded into a flow.
Straduff, Sligo (Alexander et al., 1985)	Flow	3-5°	Other failures noted in area, clay rich drift may have precipitated failures.
Tullymascreen Townland, (Alexander et al., 1985)	Flow	2-3° dipping to 7°	Turf cutting in area. Heavy rainfall noted. Volume:11,000m2
Slieve an Orra, Co. Antrim (Tomlinson & Gardner, 1982)	Slide(s)	8-17° (compound slope)	Seven slides were reported in close proximity. Slides occurred between horizons of sandy and more clayey glacial till, following heavy rain.
Carrowmaculla, Fermanagh, (Tomlinson, 1981)	Flow	2-5°	Failure took place with heavy rainfall at a break in slope, a boundary drain had been excavated at the front face.
Slieve Rushen Ballyconnell, Co. Cavan (Colhoun, 1965)	Flow	5-8°	Failure followed intense rainfall. Top layer of brown upper fibrous peat slid over lower black amorphous peat (1)
Meenacharry, Co. Donegal (Bishop & Mitchell, 1946)	Flow	5.5°	Failure caused by breach of firm dry peat located at break in slope and followed heavy rain and snow.
Wicklow Mountains, (Mitchell, 1938)	Slide	8-14°	Slide took place along interface of humified peat and bedrock.
Slieve Aughty mountains, Co. Clare (Mitchell, 1935)	Flow	4°	Failure caused by breach of firm dry peat located at convex break in slope and followed heavy rain.
Knockmageeha, Killarney, (Praeger, 1897)	Flow	2°	Large flow from 1-3m thick cutting. Unsupported trench excavation had taken place at toe and material appeared to ooze from beneath

Note:
(1) Labelled as a flow by author but description of the failure is reminiscent of sliding mode.
(2) Many slides degrade into flows therefore some of the failure types may be misclassified.

Table C.1 Case History of Some Irish Peat Failures

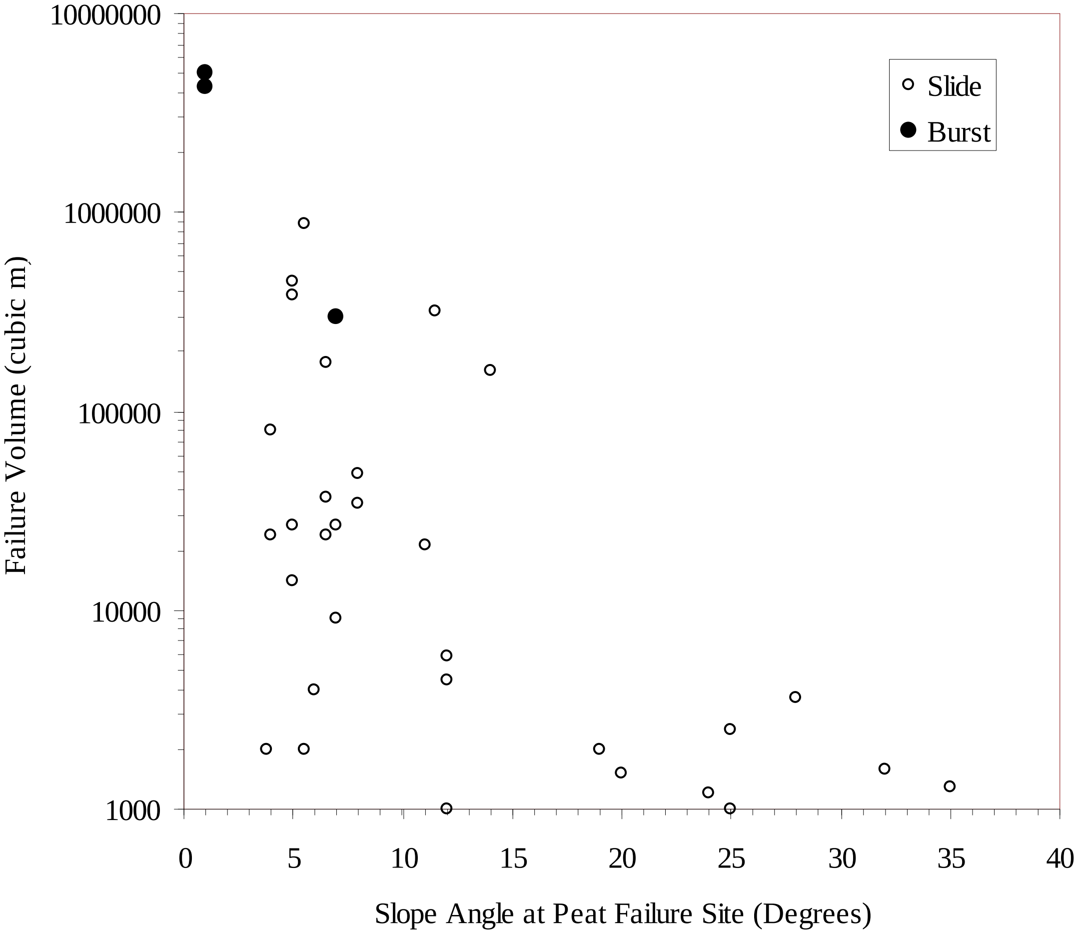


Figure C.1 Slope Angles and Failure Volumes at Sites of Some Irish Peat Failures

Notes:

(1) Peat failure data based on review of some 30 Irish failures from 19th and 20th century.

(2) Peat failure data is based on reported information or field measurement.

APPENDIX D

SITE CONTINGENCY MEASURES FOR PEAT MOVEMENT/FAILURE

SITE CONTINGENCY MEASURES

Excessive Movement

Where there is excessive movement or continuing peat movement recorded at a monitoring location or identified at any location within the site but no apparent signs of distress to the peat (e.g. cracking, surface rippling) then the following shall be carried out.

(1) All activities (if any) shall cease within the affected area.

(2) Increased monitoring at the location shall be carried out. The area will be monitored, as appropriate, until such time as movements have ceased.

(3) Re-commencement of activities shall only start following a cessation of movement and agreement with all parties.

Onset of Peat Slide

Where there is the onset or actual detachment of peat (e.g. cracking, surface rippling) then the following shall be carried out.

(1) On alert of a peat slide incident, all activities (if any) in the area should cease and all available resources will be diverted to assist in the required mitigation procedures.

(2) Where considered possible, action will be taken to prevent a peat slide reaching any watercourse. This will take the form of the construction of check barrages on land. Due to the terrain and the inability to predict locations it may not be possible to implement any on-land prevention measures, in this case a watercourse check barrage will be implemented.

(3) For localised peat slides that do not represent a risk to a watercourse and have essentially come to rest the area will be stabilised initially by rock infill, if required. The failed area and surrounding area will then be assessed by the engineering staff and stabilisation procedures implemented. The area will be monitored, as appropriate, until such time as movements have ceased.

Check Barrage

Whilst it is not anticipated that a peat slide initiated at the site will enter a watercourse, nevertheless as a contingency a check barrage procedure is included below.

The check barrage procedure deals with preventing a peat slide from moving downstream within a watercourse.

The most effective method of preventing excessive peat slide debris from travelling downstream in a watercourse is the use of a check barrage. A check barrage comprises the placement of rockfill across a watercourse. The check barrage is a highly permeable construction that will allow the passage of water but will prevent peat debris from passing through. Rockfill should comprise well-graded coarse rock pieces from about 300mm up to typically 1000mm.

The rockfill for the check barrage could be sourced from the borrow pit neat turbine T2 or from another approved borrow pit on site where rock level is close to/at the grounds surface. Currently the rock within the borrow pits is in situ and would need to be broken-out.

The sizing of the check barrage will depend on the amount of peat debris to be contained. In general due to the low speed of a peat slide there is generally little impact force and most of the lateral load is due to fluid pressure on the upslope face of the barrage.

The check barrage procedure is as follows:

(1) Access to the check barrage location shall be along the existing access roads on the wind farm site and/or along public roads. When it is necessary to form the barrage then rockfill will be placed across the watercourse to effectively block the passage of peat debris.

(2) Operatives employed to carry out the construction of the check barrage would need to be inducted by means of a briefing by on-site supervisors as to the proposed location of the check barrage.

(3) The check barrage provides containment for peat debris in the unlikely event of a major peat slide. Further remedial may be measures required and would be assessed by all parties and carried out as soon as physically possible when the location and extent of the failure is established.

(4) Where a barrage was constructed as a precaution and no peat debris reached the watercourse then the barrage should be removed as soon as any measures to prevent further peat sliding were agreed with all parties.

Details of proposed locations of check barrages, borrow pits (where rockfill material may be stored/sourced), watercourses at risk, direction of movement of anticipated peat failures in watercourses, access routes to check barrages including wind farm access roads and public roads, overhead power-lines and other constraints are shown in the Emergency Peat Slide Drawing (Figure D1).

The location of check barrages and access routes to check barrages should be confirmed by site personnel. Where necessary, locations and access routes should be revised to suit local conditions.

The size of the barrage will vary depending on the scale of the peat debris to be contained and the geometry of the watercourse at the barrage location. Typically the check barrage should fill the entire channel width of the watercourse up to a height of 3 to 4m with a crest width of typically 2m and side slopes of about 45 degrees depending on the geometry of the barrage location.

Barrage locations are shown on Figure D1 and summarised in Table D1. The barrage locations are at the downstream end of all watercourses that exit the site where there is vehicular access. These locations ensure the containment of any potential peat debris originating from the upstream catchment within the site.

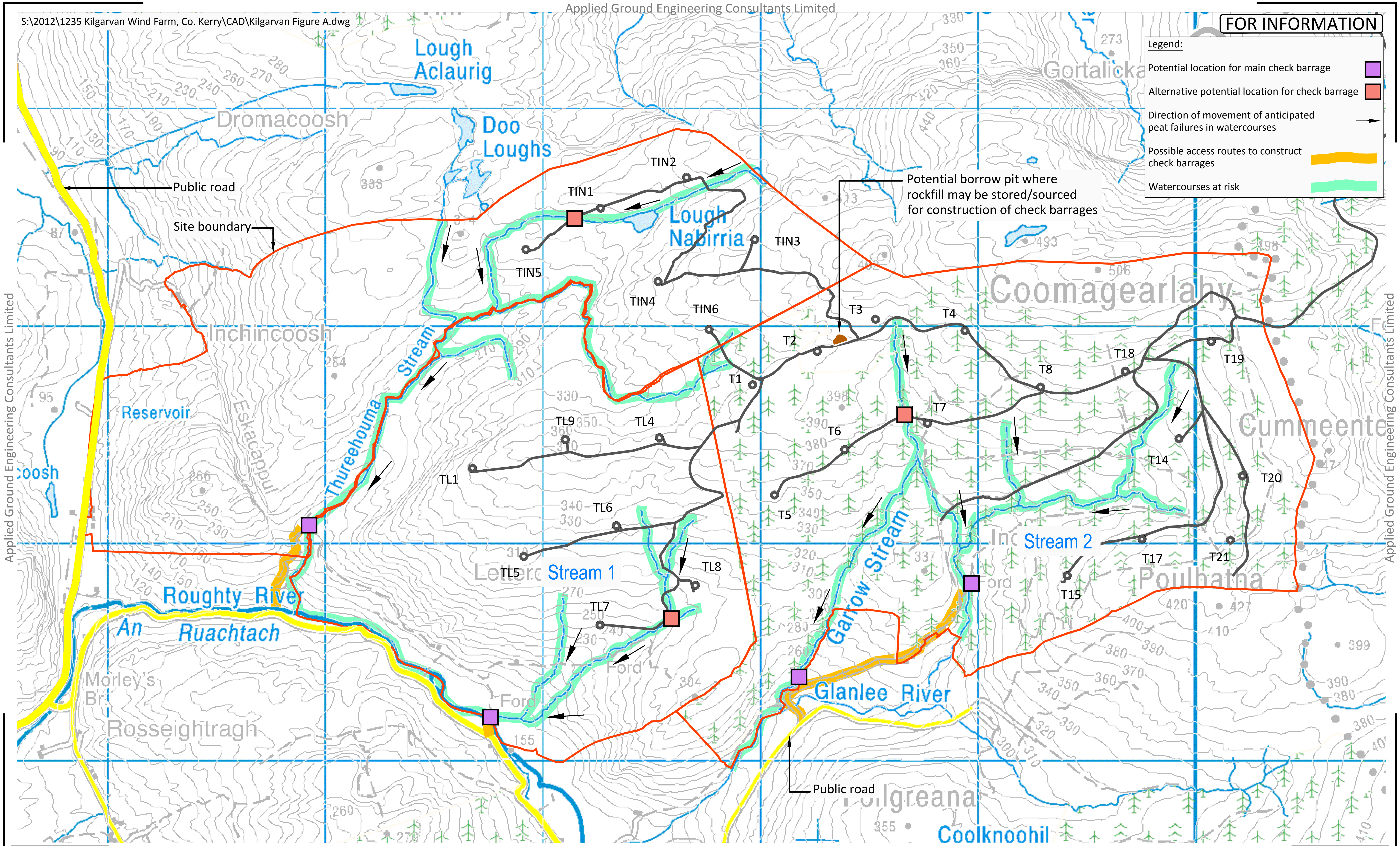
Alternative barrage locations are provided in the upper reaches of watercourses; barrages at these locations would only have a limited effect and would only be of use where a peat failure occurred upstream of these locations.

Table D1 Summary of Barrage Locations

Watercourse	Main Barrage Location	Alternative barrage Location
Thureehouma Stream	Downstream end	Between TIN1 and TIN5
Stream 1 in Lettercannon Catchment	Downstream end	Between TL7 and TL8
Garrow Stream	Downstream end	Between T6 and T7
Stream 2 in Inchee catchment	Downstream end	None

S:\2012\1235 Kilgarvan Wind Farm, Co. Kerry\CAD\Kilgarvan Figure A.dwg

FOR INFORMATION



Legend:

Potential location for main check barrage	🟪
Alternative potential location for check barrage	🟥
Direction of movement of anticipated peat failures in watercourses	→
Possible access routes to construct check barrages	🟧
Watercourses at risk	🟩

Notes:

Scale: 1:16,000 @ A3
Checked: GK
Date: 20/11/2012
Revision: 0
Drawn: POR
Based on:

Client:
Bórd Gáis Éireann

Job:
Kilgarvan Wind Farm,
Co. Kerry

Figure - D1

Title:
Emergency Peat Slide Drawing

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EMAIL MESSAGE

Our Reference: 1235_010/gk

Project: Kilgarvan Wind Farm

Subject: Report on Peat Failure

Claire,

Please find attached the report on the peat failure for discussion, which occurred at the Kilgarvan Wind Farm on the 17th/18th of October 2012.

Should you require clarification or have any queries please do not hesitate to contact me.

Yours sincerely,

Gerry Kane

Gerry Kane

KILGARVAN WIND FARM – REPORT ON PEAT FAILURE

1.0 Introduction

Applied Ground Engineering Consultants Ltd (AGEC) was requested by Bórd Gáis Éireann (BGE) to carry out a geotechnical inspection of the peat failure that occurred on the Kilgarvan Wind Farm site located approximately 10km southeast of Killarney, Co. Kerry. The site is predominantly an upland blanket peat area with numerous rock outcrops and varying peat depth.

The peat failure was reported to have occurred late on Wednesday night/Thursday morning (17th/18th October 2012) following a period of particularly heavy rainfall.

The Kilgarvan site is an operational wind farm. No construction/maintenance activities at or around the failure zone were been carried out at the time of the peat failure. AGEC inspected the failure on 25th October 2012. The weather on the day of the site visit was dry.

AGEC were contacted on Fri 19th of October by BGE following the peat failure and photos of the peat failure area were forwarded to AGEC for review. An exclusion zone around the peat failure area was set up by BGE where no works or access by site personnel was allowed until such time as the area was geotechnically assessed.

This report includes the following:

(1) Brief overview of the failure and ground conditions

(2) Cause of failure

(3) Conclusions

(4) Mitigation measures and recommendations to prevent future failures and peat movement at this location.

2.0 Overview of Failure & Ground Conditions

The failure occurred on the upslope side of an access road leading to turbine T14. The access road was constructed within a cutting formed within peat. The failure comprised the peat slope upslope of the cutting.

The following was noted during the inspection of the failure:

(1) Along the access road the side slopes within the cutting were formed in dominantly peat with an estimated pre-failure inclination of about 45 degrees (possibly steeper) and a height of about 1.5m at the failure.

(2) The mode of failure was a translational slide of peat. Upslope of the access road the slope was inclined at 4 degrees towards the access road (Photos 1 & 2). A steeper slope inclination of up to 8 degrees was present above the failed area.

(3) The failure scar was essentially rectangular in plan and was up to 6m in width (typically 3 to 4m) and extended a length of between about 25m and 28m along the access road.

(4) The material from the failure was deposited onto the access road and partially blocked a length along the road of up to 30m.

(5) The peat depth in the area around the failure ranged from 0.9 to 1.7m.

(6) Tension cracks in the peat surface behind the failure scar continued upslope for a distance of approximately 30m from the access road. The openings of the tension cracks decreased in size upslope (Photo 3).

(7) Based on an initial survey of the scar the total failure volume of detached peat was estimated at about 170m^3. The extent of the cracked/distressed peat upslope of the failure scar affected a plan area of about 450m^2, which comprised a peat volume of about 650m^3. Taking into account the detached peat and the cracked/distressed peat the total affected volume of peat in the failure was about 820m^3.

(8) During the inspection minimal ponding of water behind the deposited peat debris was recorded, any water present appeared to be draining to a v-ditch adjacent to the existing road.

(9) The basal shear surface of the failure was visible and occurred at the interface of the peat and the underlying mineral soil (Photo 4).

(10) The base of the peat located in the area of the failure was noted as being dark brown and black in colour which is typical of highly decomposed amorphous peat.

(11) Undrained and residual shear strengths were recorded in both non-intact and intact peat at/around the failure scar (Figure 1). Undrained shear strength values range from 8 to 32kPa with an average of 21kPa. Residual shear strength values ranged from 4 to 21kPa with an average of 13kPa.

The undrained strengths are relatively high and would be typical of well drained peat. These strengths also suggest that shear failure through the peat was unlikely and that failure was likely associated with movement along the interface at the base of the peat.

(12) Forestry drains run typically parallel to the slope and access road in the area of the failure.

(13) An underground cable at an offset of approximately 25m from the access road runs parallel to the access road above the head of the failure.

(14) A number of slope v-ditches have been relatively recently constructed running down the slope (i.e. perpendicular to the slope contours) above the head of the failure (Photo 5). These slope v-ditches terminate above the line of the underground cable and discharge any collected water onto the peat surface above the head of the peat failure.

(15) On the day of the site inspection a volume of water was present at the end of the slope v-ditches above the head of the failure scar (Photo 6).

3.0 Cause of Failure

The following factors are considered to have contributed to the failure.

(1) Based on discussions with site personnel, the peat failure coincided with a particularly heavy rainfall event. These site observations correspond with the rainfall records from the nearest weather stations to the site which showed a significant rainfall amount for the date (17th October 2012).[1]

(2) Rainfall records for the days of the failure (16th & 17th October 2012) show rainfall ranging from 5.1 to 23.4mm (per day).[2] The daily rainfall of 23.4mm quoted would not be considered particularly high for a 24 hour period; however it is likely that this rain fell over a short period of time.

(3) The likely triggering event of the peat slide is as a result of heavy rainfall. The surface water would have infiltrated the peat surface, most likely through existing cracks, resulting in a build-up of pore pressure and a reduction of the effective shear strength at the interface between the peat and the mineral soil.

(4) The interface of the peat and mineral soil provided a permeability contrast whereby water moving downwards through cracks within the peat encountered the mineral soil, with a lower relative permeability, that prevented further downward movement of water. This resulted in the build-up of a perched water table above the interface (mineral soil).

(5) Secondary effects of heavy rainfall include possibly swelling of the peat bog and increase in loading due to ponding together with possible softening.

(6) The slope v-ditches constructed perpendicular to the slope contours above the head of the failure likely contributed to the peat failure. The slope v-ditches terminate above the line of the underground cable (above the head of the failure scar) and would have discharged concentrated flows of water onto the peat surface.

(7) This concentrated flow of water into the head of the failure scar likely resulted in the infiltration of surface water into the peat via cracks and an increase in surface loading of the peat due to ponding of water together with possible softening of the peat.

(8) The presence of the forestry drains which run parallel to the slope contours may have allowed for the infiltration of some of the surface water into the peat; it is commonly found that peat shrinkage cracking occurs along the line of old peat drains.

(9) The presence of the peat cut face along the access road provided no toe support to the saturated peat slope above. As such, where there was a critical build-up of water

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(1) The nearest weather stations reviewed were Sherkin Island, Valentia Observatory, Roches Point, Moorepark and Shannon Airport which range in distance from 55 to 95km from the site.

(2) For the Valentia Observatory weather station for the month of October for the previous 30 years the average daily rainfall was 6mm (http://www.met.ie/climate-ireland/1981-2010/valentia.html).

within the peat slope, as occurred 17th October 2012, a peat failure at this location was likely to occur.

4.0 Conclusions

The following conclusions are provided.

(1) The failure was a translational slide of peat which was up to 6m in width and extended a length of between about 25m and 28m along the access road.

(2) The peat depth in the area around the failure scar ranged from 0.9 to 1.7m.

(3) Undrained shear strength values of the intact peat surrounding the failure ranged from 8 to 32kPa with an average of 21kPa. These undrained strengths are relatively high and would be typical of well drained peat. The strengths also suggest that shear failure through the peat was unlikely and that failure was likely associated with movement along the interface at the base of the peat.

(4) Based on an initial survey of the scar the total failure volume of peat which has become detached was estimated at about 170m³. Taking into account the detached peat and the cracked/distressed area of peat upslope of the scar the total affected volume of peat involved in the failure was about $820m^3$.

(5) The base of the peat located in the area of the failure was noted as being dark brown and black in colour which is typical of highly decomposed amorphous peat.

(6) The basal shear surface occurred at the interface of the peat and the underlying mineral soil (Photo 4).

(7) The likely triggering event of the peat slide is as a result of heavy rainfall. The surface water would have infiltrated the peat surface resulting in a build-up of pore pressure and a reduction of the effective shear strength at particularly the interface between the peat and the mineral soil. The basal shear surface occurred at this interface.

(8) The slope v-ditches constructed perpendicular to the slope contours above the head of the failure likely contributed to the peat failure by discharging concentrated flows of water onto the peat surface.

(9) The peat failure is localised within the site. In order to determine the likelihood of a similar failure occurring on site an inspection of the peat slopes in the vicinity of the infrastructure envelope will be carried out by AGEC for the Kilgarvan Wind Farm site.

5.0 Mitigation Measures & Recommendations

Based on the initial inspection of the failure the following mitigation measures are recommended.

(1) Monitoring/sighting lines should be established at the head of the failure scar and upslope of the failure scar in order to determine if there is ongoing peat movement, and whether this could result in further failure. Monitoring should be carried out regularly initially and results should be reviewed on a daily basis. See Appendix A for further details.

(2) Detached peat debris from the failure does not appear to be causing any water to pond within the failed material. However if water cannot drain naturally, it is recommended that a drain be excavated through the peat debris to allow water to flow away and prevent the build-up of hydrostatic pressures which may lead to additional adverse loading of the peat.

(3) A permanent stone buttress shall be constructed within the failure scar. The stone buttress should prevent any future peat movements occurring at this location. The buttress shall be constructed as follows:

- The stone buttress should be founded on bedrock or very stiff mineral soil.
- The buttress should be constructed of competent boulders. In order to prevent water retention occurring, the buttress should be constructed of coarse boulder fill with a high permeability.
- Adequate drainage should be installed in front of the buttress and the drainage connected to a suitable outfall.
- The side slopes of the stone buttress should be constructed at typically 45 degrees.
- The buttress should also be constructed in stages beginning with excavation on the existing access road located on the downslope side of the failure and working into the failure. This construction should be carried out incrementally with the excavation and placement of boulders. Excavations shall be kept to a minimum prior to placement of boulders.
- Supervision by a geotechnical engineer or appropriately competent person is recommended for the remedial works.

(4) The following issues should be taken into account to avoid further peat failures/movements on site.

- Any construction activities on the peat slopes in the area of the peat failure should be avoided.
- Any construction activities on the peat slopes at the site should be monitored and supervised by experienced and qualified personnel.

- Following a particularly heavy rainfall event an inspection of the site should be carried out to ensure no ponding of water or blocked drains are present. The installation of a rainfall gauge on site may indicate when an inspection is necessary. It would be prudent to carry out an inspection of the elevated or higher risk areas when a daily rainfall of over 20mm is recorded on site.
- Maintain a managed robust drainage system on site. This should include:
    a) Maintenance of interceptor drains, pipe culverts and silt traps/ponds.
    b) Where ponding is evident or there is continued blockage of drains additional drainage should be installed.
- Silt traps should be installed in the v-ditches running alongside the access road at either side of the peat failure to ensure nearby watercourses are not contaminated by surface run-off.
- Set up, maintain and report findings from monitoring systems on a continuous basis. See Appendix A for further details.

(5) An annual audit/inspection of the site should be carried out by suitably qualified personnel to ensure no new signs of peat movement or instability risks are present.

(6) In order to determine the likelihood of a further peat failure occurring on site an inspection of the peat slopes in the vicinity of the infrastructure envelope was carried out by AGEC for the site. Refer to AGEC's report titled 'Geotechnical Site Assessment Report for Kilgarvan Wind Farm, Co. Kerry' for details on contingency and mitigation measures should a peat failure occur on site, monitoring regimes for site and a checklist of features for wind farm operational staff to look out for during a typical site inspection.

Figure

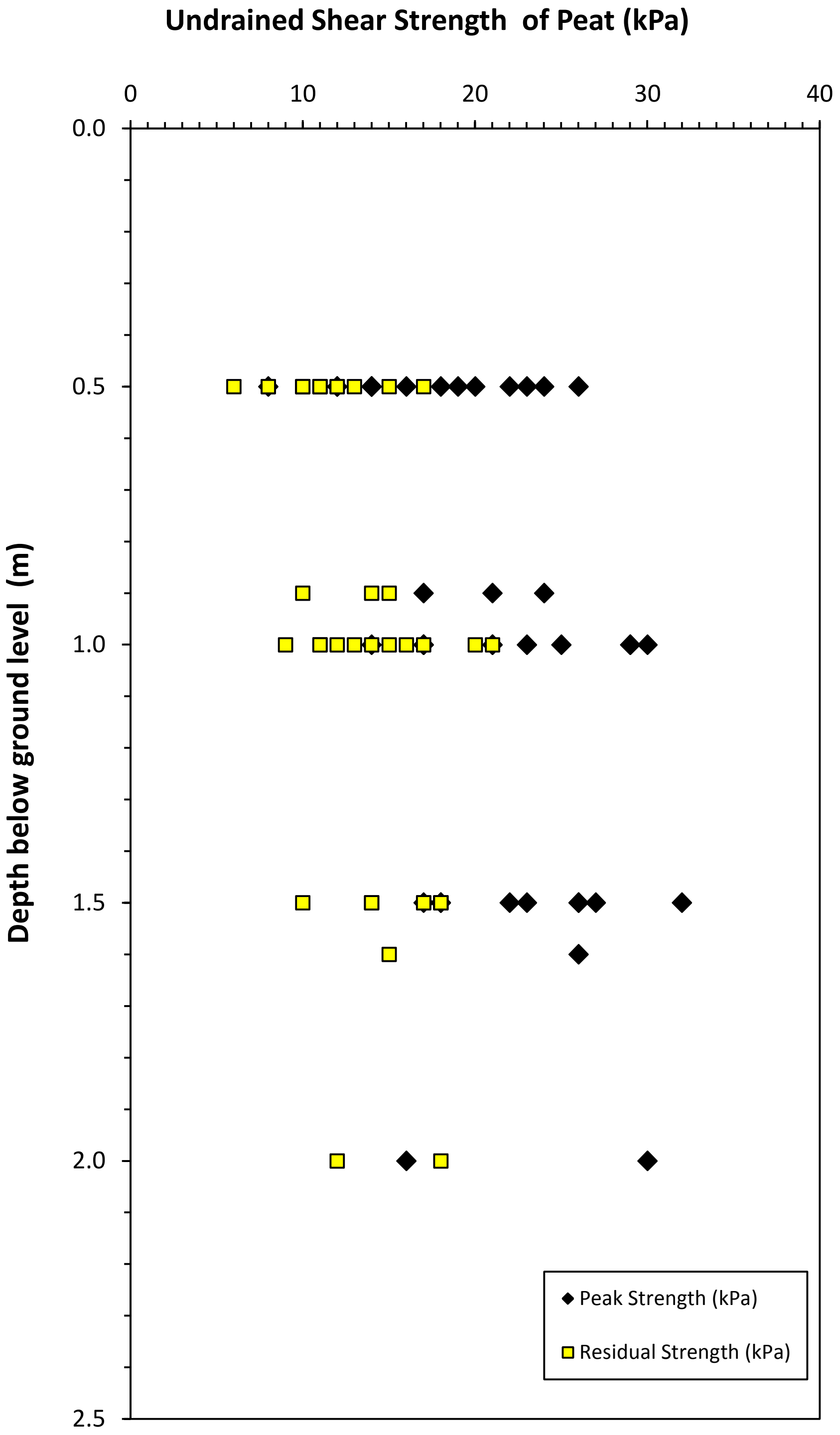

Figure 1 Undrained & Residual Shear Strengths (c_u) Profile for Peat with Depth around the Failure Scar

Note: Undrained & residual shear strength values are based on readings from hand-held shear vane

Photos

Photo 1 Extent of peat debris along the existing road

Photo 2 Overview of peat failure area

Photo 3 Tension cracks in the peat surface about 10m behind the failure scar

Photo 4 Basal shear surface of the failure

Photo 5 Slope v-ditches within the peat above the failure

Photo 6 Ponding of water at end of slope v-ditches above the failure

Appendix A – Monitoring Instrumentation

Movement Monitoring Posts

It is proposed to install three monitoring/sighting lines at the head of the failure scar and upslope of the failure scar. Details of sighting posts are given below.

(1) A line of sighting posts shall comprise:

    (a) A line of wooden stakes (typically 1 to 1.5m long) placed vertically into the peat to form a straight line.
    (b) The sighting line shall comprise 8 nos. posts at (say) 5m centres that is a line some 35m long.
    (c) A string line shall be attached to the upslope side of the first and last posts and all intervening posts shall be adjusted so they are just touching the string line.

(2) Sighting lines shall be placed with 5 to 10m intervals between the successive sighting lines.

(3) Each line of sighting posts shall be uniquely referenced with each post in the line given a reference. The post reference shall be marked on each post (e.g. reference 1-1, 1-2, 1-3, 1-4, 1-5, 1-6, 1-7, 1-8 for posts in line 1).

(4) The sighting lines shall be monitored at the beginning of each working day, and during the day where considered appropriate (e.g. working activity is concentrated at a specific location).

(5) Monitoring of the posts shall comprise sighting along the line and recording any relative movement of posts from the string line.

(6) Daily monitoring of the posts shall be carried out. If increased movements are recorded the frequency of monitoring shall be increased and appropriate action taken as required.

(7) A monitoring record shall be kept of the date, time and relative movement of each post, if any. This record shall be updated and stored as a spreadsheet.

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