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PEEL WIND FARMS (YELL) LIMITED

BEAW FIELD WIND FARM

PEAT SLIDE RISK ASSESSMENT APPENDIX 12.2

March 2016

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1 INTRODUCTION

1.1.1 In accordance with The Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2000, windfarm developers in Scotland are required to assess the risk from peat slides during earthworks located on peatlands and to demonstrate how these risks will be managed during all stages of the development. This report presents the peat slide risk assessment for the 'Proposed Development' of the Beaw Field Wind Farm located on the Isle of Yell, Shetlands. The Site and project descriptions are presented in Chapters 2 and 3 of the main Environmental Statement (ES).

1.1.2 The assessment follows the approach for the first pass assessment of hazard and risk using guidance from the Scottish Executive Peat Landslide Hazard and Risk Assessments (2006[1]), further referred to as 'the SE guidance'. The purpose of the assessment is to identify areas of significant peat failure risk and high environmental sensitivity to determine the requirements for mitigation measures and detailed geotechnical investigation prior to construction.

1.2 Peat Failure Characteristics and Mechanisms

1.2.1 The SE guidance describes the characteristic mechanisms of peat landslides in detail, but a summary is provided here to give background to the assessment. Peat landslides represent one end of a spectrum of natural processes of peat degradation. Longer term processes of degradation include incision and upslope extension of gully networks by water action, development of subsurface piping creating extensive sub-surface voids, desiccation cracking and wind erosion of the top surface of peat deposits, and structural damage caused by burning of frost action. Anthropogenic activity, including burning, farming (grazing), afforestation and construction may also act to damage the peat resource.

1.2.2 The SE guidance distinguishes two types of mass movement of peat (or peat failures) "peat slides" and "bog bursts". MacCulloch (2006[2]) distinguishes additional kind, "peat slips".

1.2.3 Peat slide generally occurs during a period of high rainfall following earlier period of dry weather. The most common explanation is that during dry weather the water table reduces with the peat horizon, which results in drying and cracking of the surface layer. During a subsequent period of high rainfall, surface water enters the cracks and penetrates deeper into the peat deposit. The volume of free flowing

water can alter peat strength and lubricate the sliding surface within the peat or at the boundary of peat and mineral subsoil or bedrock. This results in a shallow translational failure (characterised by mostly linear movement along a flat surface) with a shear failure mechanism operating within a discrete shear plane at the peat-substrate interface. The peat surface may break up into large rafts and smaller blocks which are transported down slope mainly by sliding. Peat slides tend to occur in shallow peat (up to 2.0m) on steeper slopes (5° to 15°).

1.2.4 Bog burst is a particular fluid failure (characterised by flow of liquefied deposit) involving the rupture of the peat blanket surface or margin due to breakdown of the underlying drainage channels in an unconfined peat area. They are characterised by pear shaped areas of disturbed blanket bog, downslope of the area of subsidence, there is usually a block and slurry runout zone. Bog bursts correspond in appearance and mechanism to spreading failures and tend to occur in deeper peat (greater than 1.5m) on shallow slopes (2° to 10°). A bog burst typically affects areas of less than one hectare, however it can also trigger a larger “slide” event.

1.2.5 Peat slip is a failure of the peat as a direct result of the construction method, they tend to be small and have little or no impact on the surrounding environment. However, they can be a contributory factor to peat slides and bog bursts leading to an increased likelihood of significant effects.

1.2.6 A number of hydrological and geomorphological preparatory factors operate in peatlands which act to make peat slopes increasingly susceptible to failure without necessarily initiating failure. Triggering factors change the state of the slope from marginally stable to unstable and can be considered as the ‘cause’ of failure.

1.2.7 Preparatory Factors (reduction of peat stability in the medium to long term):

- Increase in mass of the peat slope through progressive vertical accumulation;
- Increase in mass of the peat slope through increase in water content;
- Reduction in shear strength of peat or substrate from changes in physical structure caused by progressive creep and vertical fracturing (tension cracking), chemical or physical weathering or clay dispersal in the substrate;
- Loss of surface vegetation and associated tensile strength; and
- Increase in buoyancy of the peat slope through formation of sub surface pools or water-filled pipe networks.

1.2.8 Triggering Factors (Initiation of slope failures, which may be slow to rapid):

- Intense rainfall causing development of transient high pore-water pressures along pre-existing or potential rupture surfaces;
- Snow melt;
- Rapid ground accelerations (earthquakes) causing a decrease in shear strength;
- Alterations to drainage patterns generating high pore water pressures;
- Peat extraction at the toe of the slope, i.e. fluvial incision, cut slopes, etc., reducing the support of the upslope material; and
- Peat loading commonly due to stockpiling or plant during construction causing an increase in shear strength.

1.2.9 Peat slide is a process that also occurs naturally. There are several natural factors which affect the likelihood of peat slide, they include relief, peat strength and depth, slope gradient, hydrology, vegetation cover and climate.

1.2.10 Relief, which is the combination of slope gradient and variation in elevation can result in confines and unconfined zones, where undulating or hummocky terrain exists, the natural relief has the potential to mitigate the occurrence of a peat slide. However, convex sloping hillsides (unconfined) can increase the hazard potential.

1.2.11 Peat strength is a major factor determining peat resistance to slide however, due to the influence of fibres within the deposits and of stratification with depth, i.e. fibrous through to amorphous, etc., reliable shear strength values are difficult to determine.

1.2.12 Peat depth is the main indicator of potential slips, however, when combined with other instability indicators, peat has the potential to fail should conditions coincide with development related activity.

1.2.13 Slope gradient: As mentioned previously gradients greater than 2° have a greater likelihood of failure, either by bog burst or peat slide. Deposits with a shallower gradient are less susceptible to failure. Deep peat does not form on slopes greater than 20°, therefore such areas are not at risk.

1.2.14 The site hydrology determines surface and subsurface drainage pathways presence of which may lead to an increased peat mass due to the absorption of water, thus increasing the likelihood of failure.

1.2.15 Presence of vegetation cover generally reduces the risk of peat slide by strengthening the peat with roots.

1.2.16 Of climatic factors, the intense rainfall events are the often associated with peat failures. The water from precipitation infiltrates into the peat deposits causing increase of pore water pressures, which decreases the peat shear strength. Other effects of precipitation which may contribute to peat failure are swelling of peat deposit, which also reduces its shear strength, and ponding of water on the surface, which increases the loading.

Geomorphological Characteristics of Potential Instability

1.2.17 Evident and/or potential areas of instability: The presence of any of the geomorphological characteristics, mentioned below, signify an increased peat instability risk in the area. However, areas which display none of the characteristics may still be at risk of peat failure.

1.2.18 The following geomorphological characteristics are also indicative of potential instability:

- Historical failure scars and debris;
- Tension cracking and tearing;
- Compression ridges/thrusts or extrusions;
- Peat creep;
- Subsurface drainage (piping);
- Seeps and springs;
- Cracking due to drying;
- Concentration of subsurface drainage networks; and
- The presence of organic clays at the base of the peat.

2 METHODOLOGY

2.1 Peat Survey

2.1.1 Peat survey was carried out on a 250m grid spacing over the entire Study Area (see Appendix 12.1) and on a 50m grid spacing to increase the accuracy of baseline data within areas of the Site where both turbines and associated infrastructure would be located (see Chapter 12: Soils and Peat, and Figures 12.1 and 12.2).

2.1.2 The following characteristics predispose peat deposits to failure, Warburton et al. (2004[3]):

- A peat layer overlying an impervious or very low permeability clay or mineral base;
- A convex slope or a slope with a break of slope at its head;
- Proximity to local drainage either from seepage, groundwater flow, flushes, pipes or streams; and
- Connectivity between surface drainage and the peat/impervious interface.

2.1.3 For the purpose of the assessment it is assumed that all the peat overlies low permeability base and that the slopes are convex. Proximity to local drainage is addressed not in the hazard assessment but through the exposure which is classified partly on the distance from watercourses. Connectivity between surface drainage and the peat/impervious surface is inferred from peat instability indicators which are considered additionally to peat depth and slope parameters.

2.1.4 The slope gradient and peat depth hazard scale values (Table 1 and Table 2) are taken from MacCulloch (2006[2]), with the description of probabilities following the SE guidance terminology.

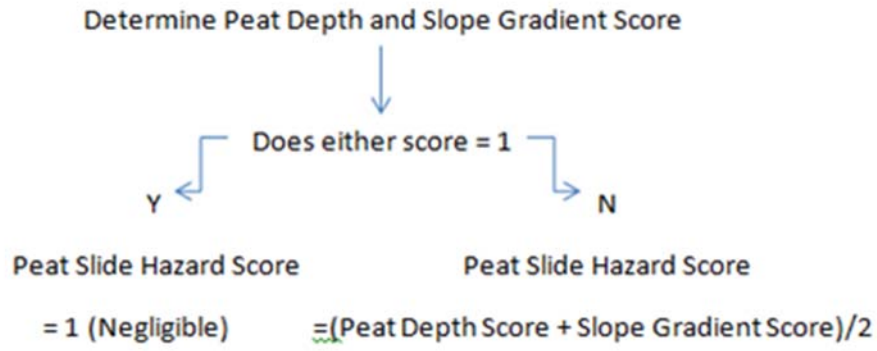
Table 1 Slope gradient hazard scale

Scale	Value/Indicator	Hazard (probability of contributing to peat movement)
1	<3°	Negligible
2	4–9°	Unlikely
3	10–15°	Likely
4	16–20°	Probable
5	>20°	Almost certain

Table 2 Peat depth hazard scale

Scale	Value/Indicator	Hazard (probability of contributing to peat movement)
1	<0.50m	Negligible
2	0.50–1.00m	Unlikely
3	1.00–1.50m	Likely
4	1.50–2.00m	Probable
5	>2.00m	Almost certain

2.1.5 Following this ranking the scores from each factor, apart from if either score is equal to 1 are added together, the total being divided by two to give an average hazard for the two primary factors:



2.1.6 Separate to this ranking system, a third score may be deemed appropriate to use where, for example, local peat conditions indicate higher level of hazard than would initially be apparent from the depth and gradient data alone.

2.1.7 While factors such as land management, surface hydrology, groundwater levels and flows play part in peat stability, they are not considered separately in this assessment because there is not methodology to quantify their impact. Their aspects are covered in other observations, for example land management and surface hydrology is reflected in the condition of the plant cover and presence of gullies and streams. Groundwater levels and flows are addressed by identification of peat instability indicators, such as sips, springs, piping, flushes and soakaways. Therefore their separate inclusion in the assessment would result in double counting of their contribution, for example, groundwater conditions would be characterised by subsurface piping, which would also be one of the peat instability indicators.

2.2 Exposure

2.2.1 Exposure is defined as the impact and consequences that the event may have on the environment. It was classified based on distance of the project components from sensitive receptors (MacCulloch, 2006[2]). The criteria were modified by addition of "Very low" category where the distance was over 150m.

Table 3 Exposure classification of the peat slide impact receptors

Scale	Exposure	Distance from property/people, public road, water courses, and other sensitive areas (e.g. SSSI)
1	Very low	>150m
2	Low	100m< ≤150m
3	Medium	50m< ≤100m
4	High	≤50m

2.3 Hazard Ranking

2.3.1 Hazard ranking was obtained using the SE guidance formula:

$$Hazard\ Ranking = Hazard\ \times Exposure$$

as shown in Table 4, below.

Table 4 Hazard ranking

Score	Hazard Ranking	Action Suggested
1–4	Insignificant	Project should proceed with monitoring and mitigation of peat landslide hazards at these locations as appropriate
5–10	Significant	Project may proceed pending further investigation to refine assessment and mitigate hazard through micrositing or redesign at these locations
11–16	Substantial	Project should not proceed unless hazard can be avoided or mitigated at these locations, without significant environmental impact, in order to reduce hazard ranking to significant or less
17–20	Serious	Avoid project development at these locations

2.3.2 The hazard ranking was then used to prepare a Draft Geotechnical Risk Register (see Table 6) for the Proposed Development to facilitate monitoring and review of the risks as they are discovered and assessed. The register is a dynamic document to assist the management of geotechnical risk in a structured fashion for each of identified hazard zone. In the peat slide risk assessment, the word 'significant' defines a hazard zone where development may proceed pending further investigation to refine the assessment and mitigation through micrositing and design.

3 BASELINE

3.1 Peat Depth and Condition

3.1.1 The results of the surveys are reported in Chapter 12: Soils and Peat and peat depths and survey points are presented in Figures 12.1 and 12.2. Slope gradients within the Site are shown on Figure A12.2.1.

3.1.2 The hydrology of the Site is considered in Chapter 15: Hydrology and Hydrogeology. From this study, the catchments which may be affected by a potential peat failure(s) are: Burn of Arisdale, Burn of Hamnavoe, Burn of Evrawater sub-catchment, Burn of Kettlester Catchment, Green Burn and Burn of Holligarth Catchment, Burn of Guddon sub-catchment, Burn of Horsewater and Burn of Hummelton Catchment, and Burn of Neapaback Catchment.

3.1.3 Peat condition is of particular importance for peat slide risk assessment, in particular the presence of potential indicators of peat instability. Generally, there were few such indicators present within the Study Area. The main indicator identified during baseline surveys were collapsed piping features evident on the slopes in the Burn of Aris Dale catchment, between Arisdale and Sundrabister. This area is to the west of

the turbines and associated infrastructure required for the Proposed Development and will not be disturbed during the construction phase. Therefore, there is no risk of construction related peat slide in this area.

3.1.4 Peat degradation is widespread across the Site (see Chapter 12: Soils and Peat) resulting in numerous surface features such as gullies, hags, extensive areas of bare peat and underlying bedrock. The characteristics of these forms of peat degradation are not considered conducive to peat slide. This is because the gullies are generally wide and their network is intensive which provides channels for rapid runoff, not allowing for the water to flow to a failure plane which could facilitate internal erosion of the slopes through subsurface piping. The gullies are generally stable as indicated by their revegetation (see Plate 1 and Plate 2).

Plate 1: Extensive gully network near T8, with evidence of vegetation as the slopes have stabilised after erosion.

Plate 2: Eroding hags and extensive gully network characteristic near T15, resulting in rapid surface run-off during periods of rainfall.

4 PEAT SLIDE RISK ASSESSMENT

4.1.1 Due to the presence of peat across the Site, (see Appendix 12.1), the design criteria also directed the location of turbines and infrastructure to minimise the depth of peat deposits potentially affected. The gradient over majority of the Site is less than 9° (which is unlikely to contribute to a peat landslide, Table 1). The design criteria favoured the location of turbines on shallow slopes on areas of level ground. The access tracks, which pass through steeper areas between Turbines 1 and 2, 11 and 7, and 15 and 17 vary in length. Borrow pits are located on sloping land to facilitate the design of quarry extraction (see Figures 3.16-3.19). The maximum design criteria of a 9° gradient is only exceeded in BP2, located on south west Beaw Field slope, however it is only present at the top edge of the borrow pit and does not coincide with presence of deep peat deposits.

4.1.2 The qualitative assessment of peat landslide hazard combining the gradient with peat depth is presented in Figure A12.2.2. The qualitative hazard ranking, which combines the hazard and exposure scores, is presented in Figure A12.2.3. The

Proposed Development was divided into hazard zones corresponding to the project components. In case of tracks additional subsections were introduced to define separate zones where hazard ranking was different, see Figure A12.2.4.

4.1.3 The SE guidance states that in locations where the hazard is rated as substantial, the project should not proceed unless that hazard can be avoided or mitigated, without significant environmental impact, in order to reduce the hazard ranking to significant or less. Where the hazard is rated as significant the project may proceed pending further investigation to refine assessment and mitigate hazard through micro-siting or redesign. Where the hazard is rated as insignificant, the project should proceed with monitoring and mitigation of peat landslide hazards at these locations as appropriate.

4.1.4 Table 5 provides a summary of the slope and peat depth scores, hazard, exposure, and hazard ranking for each of the project components (47 in total). It also contains brief description of ground features relevant for peat slide risk assessment such as presence of eroding hags and gullies, and degree of peat surface degradation due to grazing. Those features were described based on information contained in Appendix 12.1, site inspection conducted during summer 2015, and aerial imagery.

Table 5 Summary hazard ranking for the components of the Proposed Development

Project component	Slope score	Depth score	Hazard	Other factors	Exposure	Score and hazard ranking
Turbines, hard standing & crane pad						
T1	2	4	3	Peat flush zone transitioning into acid grassland, high grazing pressure	3	9
T2	2	3	2.5	Moderate grazing pressure	2	5
T3	2	3	3	Eroding hags, gullies	3	9
T4	1	4	1	Eroding hags, gullies, frequent bare peat	4	4
T5	1	4	1	Eroding hags, gullies, bare peat	1	1
T6	2	4	3	Eroding hags, gullies, frequent bare peat	1	3
T7	2	4	3	Eroding hags, gullies, frequent bare peat	2	6
T8	2	4	3	None recorded	1	3
T9	2	4	3	None recorded	1	3
T10	2	3	2.5	Eroding hags, gullies	3	7.5
T11	2	3	2.5	None recorded	3	7.5
T12	2	3	3	None recorded	1	3
T13	2	4	3	Eroding hags, gullies, bare peat/rock, high grazing pressure	1	3
T14	1	2	1	Eroding hags, gullies, extensive bare peat, high grazing pressure	1	1
T15	1	4	1	High grazing pressure	1	1
T16	2	1	1	Eroding hags, gullies	1	1
T17	2	2	2	Moderate grazing pressure	2	4
Borrow pits						
BP1	2	1–2	1.5	Peat cutting, frequent bare ground, high grazing pressure	3	4.5
BP2	3–4	2–3	3	Moderate grazing pressure	2	6
BP3	2–3	4	3	Eroding hags, gullies, frequent bare peat	1	3
BP4	3	2	2	Frequent bare peat, high grazing pressure	2	4
Site compound	1	1–2	1	Large area of exposed bedrock	1	1
Substation	1	2	1	Frequent bare peat and mineral soil, high grazing pressure	1	1.5
Anemometry mast	2	2	2	Low grazing pressure	2	4
Telecommunications Tower	1	1	1	Moderate grazing pressure	1	1
Access tracks						
A001 (4360m) divided into subsections: A-H						
A001-A (1000m)	1–3	1–3	1–3	Eroding hags and gullies, frequent bare peat and mineral soil, high grazing pressure	1	3

Table 5 Summary hazard ranking for the components of the Proposed Development

Project component	Slope score	Depth score	Hazard	Other factors	Exposure	Score and hazard ranking
A001-B (200m)	2	3	2.5	High grazing pressure	4	10
A001-C (500m)	2	1–2	2	Frequent bare peat and mineral soil, high grazing pressure	2	4
A001-D (250m)	1–2	1–2	2	Eroding hags and gullies, frequent bare peat and mineral soil, moderate grazing pressure	4	8
A001-E (400m)	1	1-2	1	Eroding hags and gullies, frequent bare peat and mineral soil, moderate grazing pressure	3–4	3
A001-F (350m)	2	2–4	3	Eroding hags and gullies, frequent bare peat and mineral soil, high grazing pressure	3–4	12
A001-G (1150m)	1–2	1–2	1.5	Eroding hags and gullies, frequent bare peat and mineral soil, high grazing pressure	1–4	4.5
A001-H (400m)	1–3	1–5	3.5	Eroding hags and gullies, moderate grazing pressure	2–4	10.5–14
A002 (2110m) divided into subsections: A-C						
A002-A (500m)	2–3	1–3	3	Peat cutting, high grazing pressure	1–3	9
A002-B (1200m)	1–2	1–4	3	Eroding hags and gullies, frequent bare peat	1	3
A002-C (800m)	2–3	1–4	3	Eroding hags and gullies, moderate grazing pressure	1–4	9–12
A003 (730m)	2	1–5	3.5	Eroding hags and gullies,	1	3.5
A004 (310m)	2	3–4	3.5	None recorded	1	3.5
A005 (310m)	1–2	2–3	2.5	Eroding hags and gullies,	4	10
A006 (400m)	1–2	1–3	2.5	High grazing pressure,	4	10
A007 (110m)	1–2	1	1	Eroding hags and gullies, high grazing pressure	1	1
A008 (670m)	1–3	3–4	3	Eroding hags and gullies, peat cutting, frequent bare peat, mineral soil and rock, high grazing pressure	1–2	6
A009 (230m)	1–2	4	3	None recorded	1	3
A010 (50m)	1	3–4	2.5	Eroding hags and gullies, moderate grazing pressure	1	2.5
A011 (100m)	2	4–5	3.5	Eroding hags and gullies, frequent bare peat	1	3.5
A012 (270m)	2	4	3	Frequent bare ground	2	6
A013 (790m)	1–2	1–2	2	Moderate grazing pressure	1	2

Note: values for the slope, peat depth, and exposure are maximum for the extent of the project component. The maximum scores for individual parameters may not coincide spatially therefore, hazard and hazard ranking is worst case and often lower if the maximum values do not coincide spatially.

4.1.5 Out of 47 project component locations within the Site there are no areas where the hazard was ranked as serious (the highest hazard ranking). The hazard was ranked insignificant and significant for 11 and 6 turbine locations, respectively. The hazard was ranked insignificant for borrow pits 1, 3 and 4, and significant for borrow pit 2. The hazard was ranked insignificant for the site compound, substation, anemometry

mast, and telecommunications tower. The hazard was ranked as insignificant, significant and substantial, 14, 7, and 3 access tracks (sections or subsections), respectively.

4.1.6 Three areas where the hazard was rated as substantial are the access track subsections A001-F, A001-H, and A002-C (see Figure A12.2.4). Section A001-F is characterised by a gradient up to 3° and an approximately 50m section of 4–9° gradient, which coincides with high and medium exposure zone due to proximity to the Burn of Evrawater and its unnamed tributary which follows the track in this section. The area is heavily eroded with areas of bare peat and mineral soil, and under a high grazing pressure. The 400m long section A001-H includes approximately 200m long traverse across a 10–15° gradient slope, which gradually decrease to approximately 100m long subsection of a flat land at the crossing of watercourse fed off Swarta Shun located to the south west of the track. The gradient then increases again to 4–9° on a 100m subsection terminating at T17. In total, on approximately 100m subsection the hazard was ranked as substantial due to the combination of a 1–2m deep peat, the slope and proximity to the watercourse.

4.1.7 The 800m long section A002-C crosses two areas where the hazard was ranked as substantial, the first area is a discreet spot of deeper peat located to the east of T2 and the track subsection crossing it is 50m long. The second area is more extensive and is located west of T1 on the east slopes of Canis Dale, the 100m long track subsection which terminates at T1 follows close to the east boundary of this area. The hazard was ranked substantial due to combination of peat depth, slope and proximity to watercourses. The 100m section of this access track lies at the border between the areas where the hazard was ranked substantial and significant.

5 MITIGATION AND RISK REGISTER

5.1 General mitigation measures

5.1.1 The Proposed Development would include a suite of embedded (design) mitigation measures which resulted in minimal peat slide risk across the study area. These include the avoidance of areas of deep peat and slopes greater than 9°. The exposure was minimised by locating the project infrastructure away from watercourses and waterbodies, ecologically sensitive areas, historic monuments and buildings.

5.1.2 Location specific mitigation measures are listed for each project component in Table 6. The main mitigation measures and their potential application to the project components are:

Detailed Assessment:

- Design ground investigation: This should include further detailed probing, possible ground-probing radar investigation, mapping of the underlying soil profiles and trial excavation pits where necessary. Any information gathered would still only be indicative of the characteristics and properties of peat due to its unpredictable nature;
- Managing the ground investigation: Ongoing continuous evaluation of the Geotechnical Risk Register (see Table 6) throughout the construction and life of the project;
- Produce a factual report on results: The report should contain details of the ground investigation, including details of other field work carried out with any additional information such as laboratory test results for physical or geotechnical properties; and
- Analyse and design/re-design: This would depend upon the results on the ground investigation.

5.1.3 The mitigation measures contained in the Draft Geotechnical Risk Register will be secured through an Ecological Clerk of Works (ECoW) in line with the Peat Restoration and Management Plan (PRMP) contained in the Construction Environmental Management Plan (CEMP) prepared in detail post-consent (see Appendix 3.6: Outline CEMP).

Avoidance

5.1.4 The SE guidance suggests that areas exhibiting serious or substantial hazard ranking should be avoided, for example by relocating infrastructure within the development area. For the Proposed Development there is very limited potential for avoidance as the locations of the infrastructure have been carefully chosen to result in minimal environmental impacts including peat slide risk, however some adjustment may still be possible in locations where only a boundary of substantial slide risk area would be affected, such as access track subsection A002-C. Since the approach to the assessment carried out here was conservative, it is possible that a detailed

investigation would result in the hazard rating in those areas to be downgraded even without adjustment.

Engineering mitigation measures to minimise the hazard (likelihood) of peat slide

5.1.5 The peat depth and slope gradient cannot be subject to engineering control without damage to the peat itself, however there are engineering measures that can minimise the risks associated with potential triggers, such as intensive rainfall events:

- Drainage: targeted drainage measures isolating areas of susceptible peat from upslope water supply, re-routing of soakaways and gullies around critical areas.
- Construction management: work method statements subject to an environmental check, weather forecasting and monitoring, as well as stop-conditions specifying length, frequency and intensity of rainfall after which peat working should cease.
- Periodic review of peat condition and reassessment of the risk during construction.

Engineering mitigation measures to minimise peat landslide impacts

- Catch wall fences: are positioned down the slope of the suspected or known slide prone area to reduce the movement of peat.
- Catch ditches: like the fences their purpose is to slow down or stop peat movement. It is preferable that they are cut in non-peat material. They can be paired with fences.

5.2 Mitigation measures in areas with substantial hazard ranking

5.2.1 Section A001-F will involve two watercourse crossings: WX3 and WX4 (see Figure 3.13). These watercourse crossings will require supporting structures such as gabion basket headwalls, or concrete-filled sand bag headwalls. These structures will support material either side of the watercourse crossing point and allow the track to cross each watercourse. Due to degraded nature of the peat in this area only small scale peat failures (slips), rather than widespread peat slides, will be a risk during construction. The crossing point retaining structures, in conjunction with the slope gradient in this area being parallel to the watercourses will result in adequate protection to them and reduce the hazard ranking from substantial to significant.

5.2.2 Similarly to subsection A001-F, the construction of the access track subsection A001-H requires a watercourse crossing. Apart from the watercourse crossing support structures, such as gabion basket headwalls, or concrete-filled sand bag headwalls, catch fences will be used. These mitigation measures will reduce the hazard ranking in this area from substantial to significant.

5.2.3 In the area where subsection A002-C is to be located, detailed geotechnical investigation will inform the decision to microsite the route of the access track to Turbine 1 eastwards, without significant environmental impact, therefore reducing the substantial hazard ranking to significant.

5.2.4 All areas where hazard was ranked as substantial and significant will be subject to detailed ground investigation post-consent to provide more accurate assessment and design detailed mitigation measures appropriate for each area if required.

5.3 Geotechnical Risk Register

5.3.1 Draft Geotechnical Risk Register was prepared for the Proposed Development to facilitate monitoring and review of the risks as they are discovered and assessed. The Risk Register is a dynamic document to assist the management of geotechnical risk in a structured fashion for each of identified hazard zones (Table 6).

Table 6: Draft Geotechnical Risk Register for the components of the Proposed Development

Project Component	Hazard	Hazard Ranking	Control Measures
T1	3	9	Detailed ground investigation. Maintain hydrology, re-routing drains. Installation of catch fences down the slope. Monitoring system in place to assess movement of surrounding peatland area.
T2	2.5	5	Detailed ground investigation. Maintain hydrology, re-routing drains. Monitoring system in place to assess movement of surrounding peatland area.
T3	3	9	Detailed ground investigation. Maintain hydrology, re-routing drains. Monitoring system in place to assess movement of surrounding peatland area.
T4	1	4	Monitoring and good working practice.
T5	1	1	Monitoring and good working practice.
T6	3	3	Monitoring and good working practice.
T7	3	6	Detailed ground investigation. Maintain hydrology, re-routing drains. Monitoring system in place to assess movement of surrounding peatland area.
T8	3	3	Monitoring and good working practice.
T9	3	3	Monitoring and good working practice.
T10	2.5	7.5	Detailed ground investigation. Maintain hydrology, re-routing drains. Monitoring system in place to assess movement of surrounding peatland

Table 6: Draft Geotechnical Risk Register for the components of the Proposed Development			
Project Component	**Hazard**	**Hazard Ranking**	**Control Measures**
			area.
T11	2.5	7.5	Detailed ground investigation. Maintain hydrology, re-routing drains. Monitoring system in place to assess movement of surrounding peatland area.
T12	3	3	Monitoring and good working practice.
T13	3	3	Monitoring and good working practice.
T14	1	1	Monitoring and good working practice.
T15	1	1	Monitoring and good working practice.
T16	1	1	Monitoring and good working practice.
T17	2	4	Monitoring and good working practice.
Borrow pits			
BP1	1.5	4.5	Monitoring and good working practice.
BP 2	3	6	Removal of peat from entire borrow pit area before the deposit working commences. Monitoring and good working practice.
BP 3	3	3	Monitoring and good working practice.
BP 4	2	4	Monitoring and good working practice.
Site Compound	1	1	No peat slide specific measures required.
Substation	1	1.5	No peat slide specific measures required.
Anemometry mast	2	4	Monitoring and good working practice.
Telecommications Tower	1	1	No peat slide specific measures required.
Access tracks			
A001 (4360m): A-H			
A001-A (1000m)	1–3	3	Monitoring and good working practice.
A001-B (200m)	2.5	10	Detailed ground investigation. Maintain hydrology, re-routing drains. Install catch fences to protect the watercourse at the crossing. Monitoring system in place to assess movement of surrounding peatland area.
A001-C (500m)	2	4	Monitoring and good working practice.
A001-D (250m)	2	8	Detailed ground investigation. Maintain hydrology, re-routing drains. Install catch fences to protect the watercourse at the crossing. Monitoring system in place to assess movement of surrounding peatland area.
A001-E (400m)	1.5	4.5	Monitoring and good working practice.
A001-F (350m)	3	12 10 with mitig.	Detailed ground investigation. Maintain hydrology, re-routing drains. Install support structures to protect the watercourse at the crossing. Monitoring system in place to assess movement of surrounding peatland area. It is expected that the above mitigation measures would result in downgrading of hazard ranking to significant.
A001-G (1150m)	1.5	4.5	Monitoring and good working practice.

Table 6: Draft Geotechnical Risk Register for the components of the Proposed Development			
Project Component	**Hazard**	**Hazard Ranking**	**Control Measures**
A001-H (400m)	3.5	10.5–14 10 with mitig.	Detailed ground investigation. Maintain hydrology, re-routing drains. Slope buttressing (subject to the ground investigation results). Install catch fences and support structures to protect the watercourse at the crossing. Monitoring system in place to assess movement of surrounding peatland area. It is expected that the above mitigation measures would result in downgrading of hazard ranking to significant.
A002 (2110m): A-C			
A002-A (500m)	3	9	Detailed ground investigation. Maintain hydrology, re-routing drains. Monitoring system in place to assess movement of surrounding peatland area.
A002-B (1200m)	3	3	Monitoring and good working practice.
A002-C (800m)	3	9–12 10 with mitig.	Maintain hydrology, re-routing drains. Slope buttressing. Monitoring system in place to assess movement of surrounding peatland area. Detailed ground investigation would inform the decision to move this section of track eastward. It is expected that this would reduce the hazard ranking from substantial to significant.
A003 (730m)	3.5	3.5	Monitoring and good working practice.
A004 (310m)	3.5	3.5	Monitoring and good working practice.
A005 (310m)	2.5	10	Detailed ground investigation. Maintain hydrology, re-routing drains. Monitoring system in place to assess movement of surrounding peatland area.
A006 (400m)	2.5	10	Detailed ground investigation. Maintain hydrology, re-routing drains. Monitoring system in place to assess movement of surrounding peatland area.
A007 (110m)	1	1	No peat slide specific measures required.
A008 (670m)	3	6	Detailed ground investigation. Maintain hydrology, re-routing drains. Monitoring system in place to assess movement of surrounding peatland area.
A009 (230m)	3	3	No peat slide specific measures required.
A010 (50m)	2.5	2.5	Monitoring and good working practice.
A011 (100m)	3.5	3.5	Monitoring and good working practice.
A012 (270m)	3	6	Detailed ground investigation. Maintain hydrology, re-routing drains. Monitoring system in place to assess movement of surrounding peatland area.
A013 (790m)	25	2	Monitoring and good working practice.

6 SUMMARY

6.1.1 Construction of wind farms on peatlands requires addressing specific nature of peat deposits, which makes them susceptible to landslides. This requires peat landslide (or peat failure) risk to be assessed and mitigated throughout the lifetime of a development. Peat slide risk assessment presented in this document was carried out

for the Beaw Field Wind Farm in order to provide hazard rating for each of the project components. It was carried out using the "first pass" approach as recommended by the Scottish Executive guidance (2006[1]). Hazard (likelihood) of peat failure was assessed using approach described by MacCulloch (2006[2]) with modifications (see Section 2: Methodology).

6.1.2 Current condition of the peatland at the Site was assessed during visits and surveys and it is described in detail in Chapter 11: Ecology, Chapter 12: Soils and Peat and Chapter 15: Hydrology and Hydrogeology. Briefly, the Site is dominated by peatland habitat heavily degraded by overgrazing and peat cutting. This is expressed by high peat depth variability, and abundance of erosion features, such as eroding peat hags, deep gullies and bare ground (peat, rock or mineral soil).

6.1.3 The peat slide risk assessment demonstrated that overall, out of 47 project components (turbines and hard standings, borrow pits, site compound, substation and access tracks), the hazard was ranked as:

- serious in none of the locations
- substantial in 3 locations, which is expected to be reduced to significant with appropriate mitigation (subject to geotechnical investigation);
- significant in 13 locations;
- and insignificant for 31 project components;

6.1.4 The SE guidance states that in locations where the hazard is rated as substantial, the project should not proceed unless that hazard can be avoided or mitigated, without significant environmental impact, in order to reduce the hazard ranking to significant or less. Where the hazard is rated as significant the project may proceed pending further investigation to refine assessment and mitigate hazard through micro-siting or redesign. Where the hazard is rated as insignificant, the project should proceed with monitoring and mitigation of peat landslide hazards at these locations as appropriate.

6.1.5 There are no areas within the Study Area where the hazard was ranked as serious (the highest hazard ranking), where the development would have to be avoided.

6.1.6 The design includes embedded mitigation which resulted in minimal peat slide hazard across the Development. Additional mitigation measures would be required where the hazard was ranked significant or substantial. These measures comprise:

- Detailed geotechnical site investigation to inform a Quantitative Risk Assessment to reduce the uncertainty, as per the SE guidance. This would involve trial pits, shear strength measurements and factor of safety (FOS) calculations.
- Further avoidance (micro siting), which is limited and subject to detailed geotechnical site investigation.

  Engineering measures, such as catch fences and ditches, slope buttressing.

6.1.7 Where the hazard was ranked as substantial (3 project components), appropriate mitigation measures were proposed, which are expected to reduce the potential risk during construction at each of these locations and therefore reduce the hazard ranking from substantial to significant. For significant hazard areas (13 project components), detailed geotechnical investigation and mitigation is also required, but the mitigation will be technically easier to achieve.

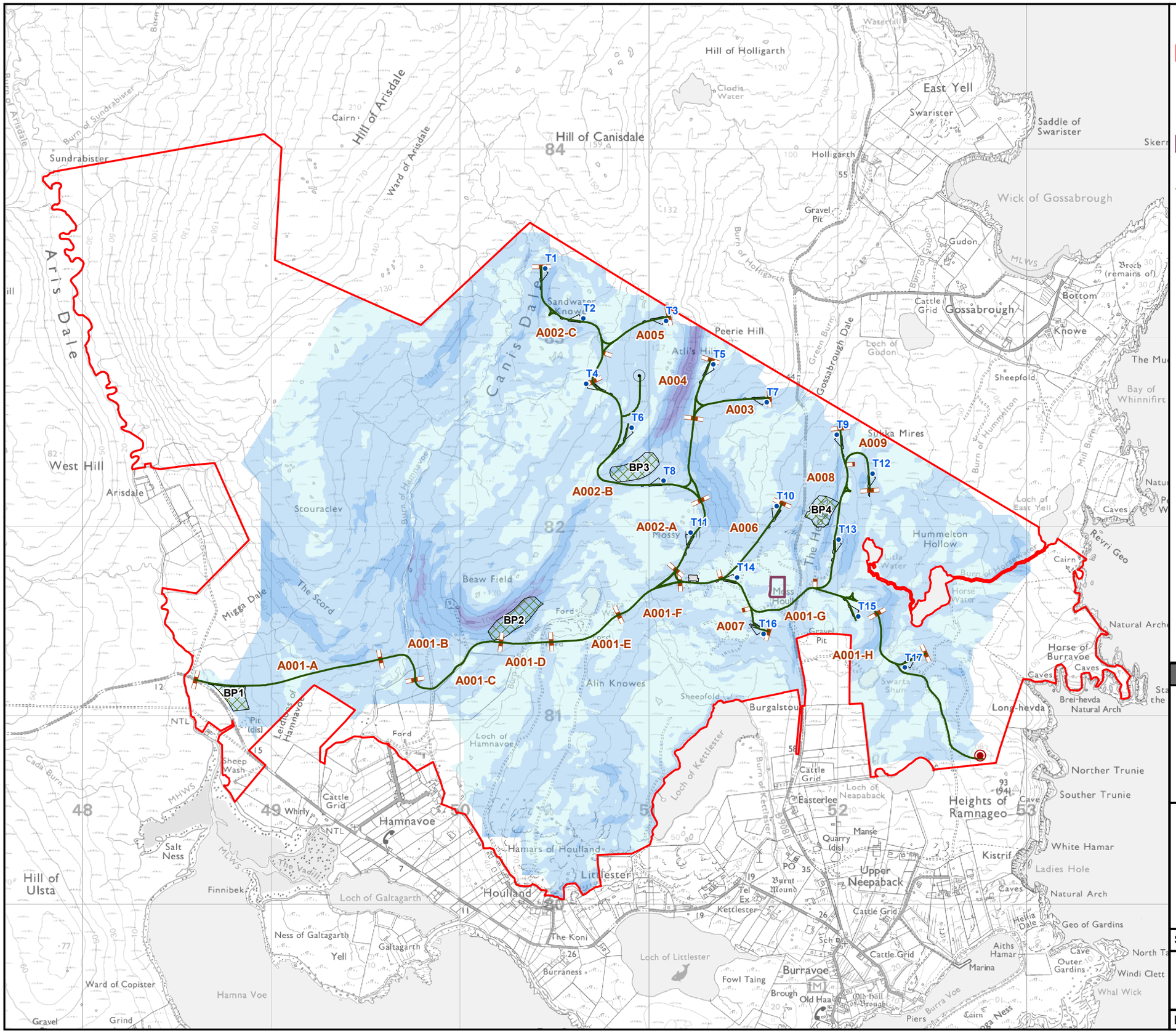
6.1.8 For the remaining 31 project components where the hazard was ranked as insignificant a varying degree of monitoring and good practice mitigation of peat landslide hazards would be required.

6.1.9 This document and the Geotechnical Risk Register (Table 6) is an addition to Appendix 3.6: Outline Construction Environmental Management Plan (OCEMP) which contains Peat Restoration Management Plan (PRMP), and to Appendix 10.4: Outline Habitat Management Plan (OHMP), which describes ecological restoration of the Site. The implementation of the proposed mitigation measures (summarised in the Draft Geotechnical Risk Register, see Table 6), with additional measures/modifications required identified through the QRA will be ensured through the works monitoring by the Ecological Clerk of Works (ECoW).

[1] Scottish Executive (2006) Peat Landscape Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments, available at: http://www.gov.scot/resource/doc/161862/0043972.pdf (accessed: 02/11/2015).

[2] MacCulloch, F. (2006) Guidelines for the risk management of peat slips on the construction of low volume/low cost roads over peat. Forestry Civil Engineering Forestry Commission, Scotland.

[3] Warburton, J., Holden, J., Mills, A. J. (2004) Hydrological controls of surficial mass movements in peat. Earth-Science Reviews 67, 139–156.



Key

- Application Boundary
- Locations of Turbines T1 to T17
- Borrow Pits
- Hardstanding
- Compound during construction
- Substation
- Route of Access Track
- Anemometry Mast
- Radio Communications Tower
- Section Markers

Slope Gradient (Degrees)

- <3°
- 4–9°
- 10–15°
- 16–20°
- >20°

Beaw Field Wind Farm

N

PEEL

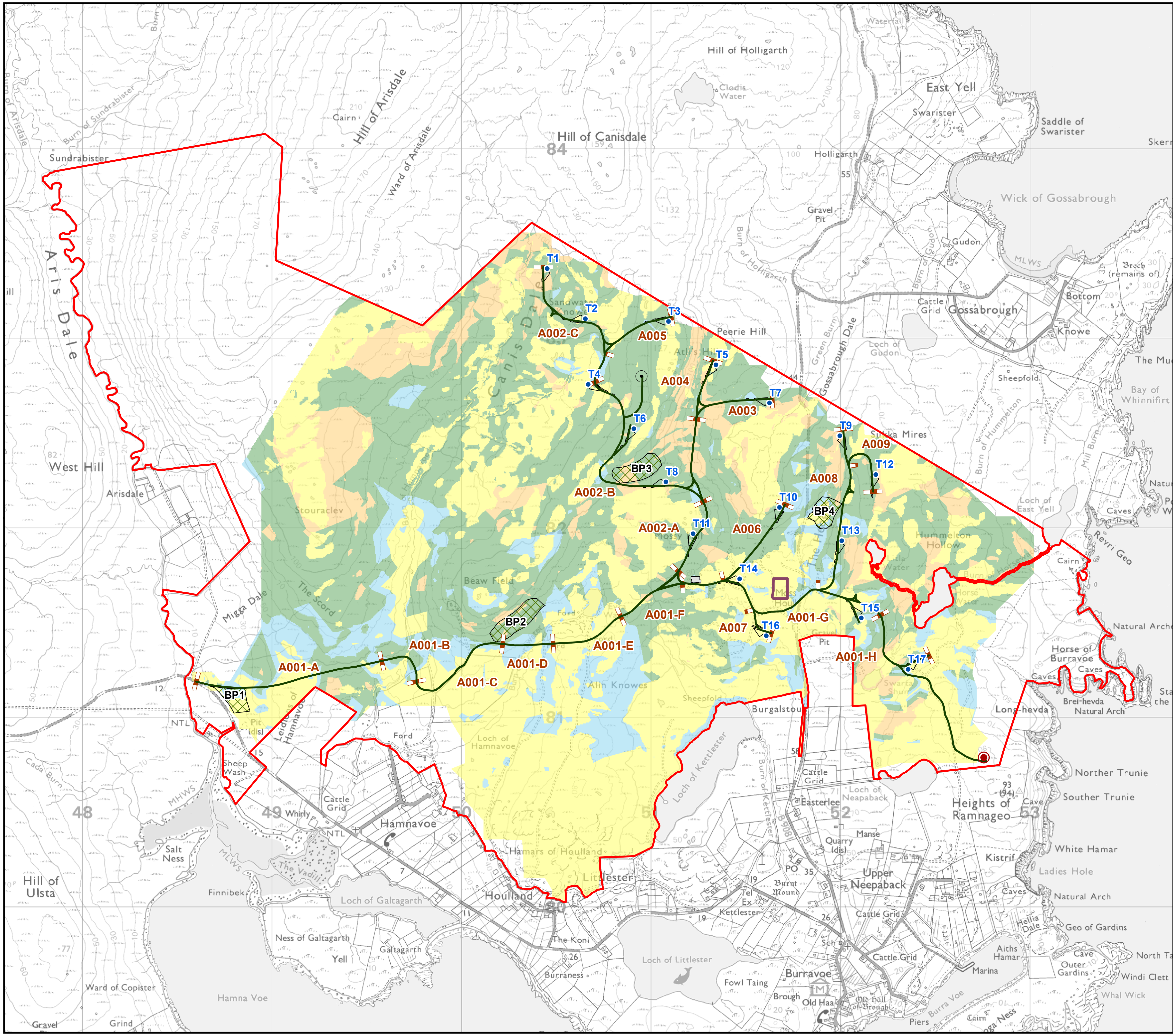
TITLE:

Slope Gradient
Figure A12.2.1

Scale: 1:20,000 @ A3

Date: 28/01/2016

Ref:



Key

- Application Boundary
- Locations of Turbines T1 to T17
- Borrow Pits
- Hardstanding
- Compound during construction
- Substation
- Route of Access
- Anemometry Mast
- Radio Communications Tower
- Section Markers

Peat Depth and Slope Gradient Score

- 0–1 Negligible
- 1–2 Unlikely
- 2–3 Likely
- 3–4 Probable
- 4–5 Certain

Beaw Field Wind Farm

N

PEEL

TITLE:

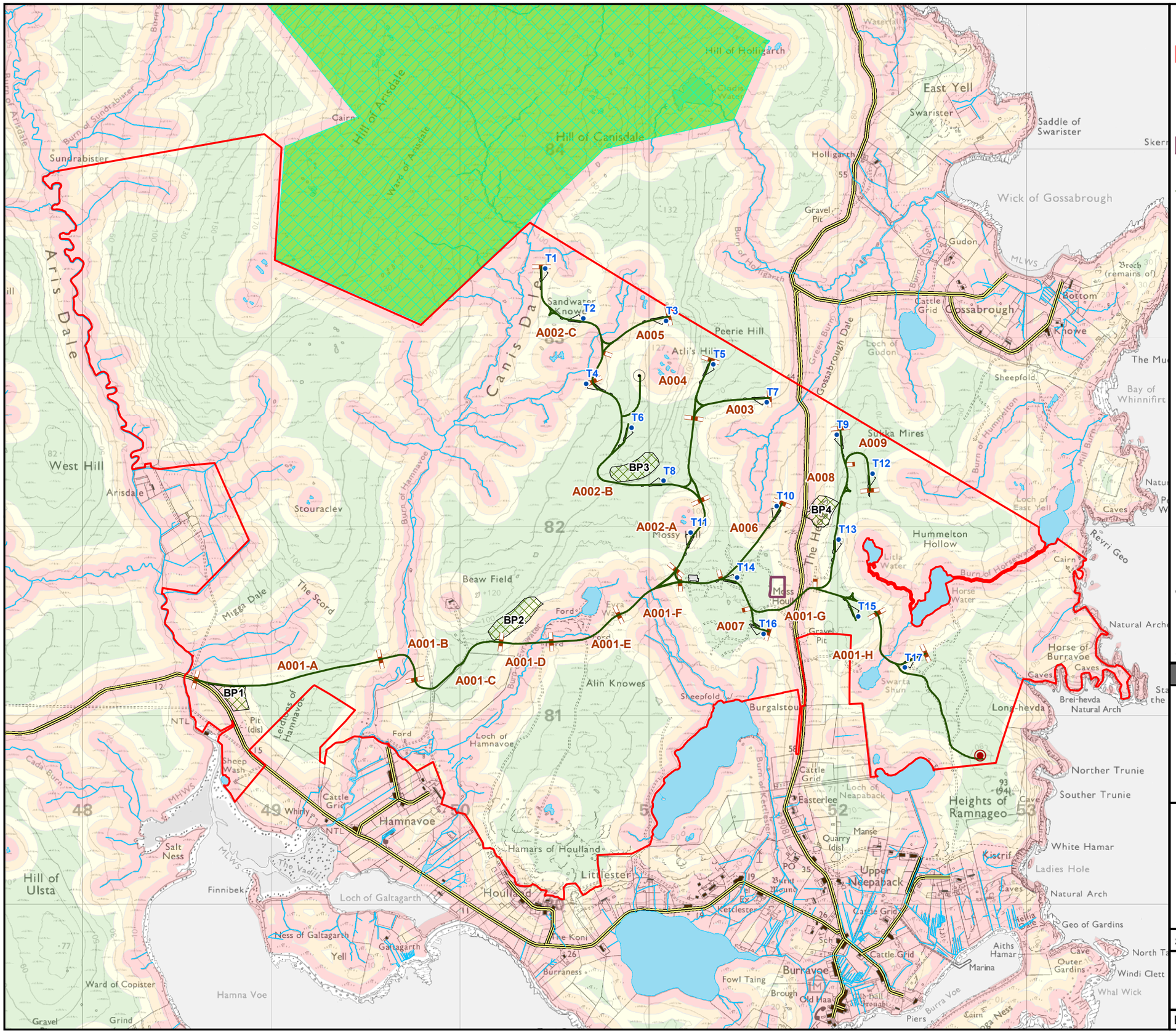
Qualitative Assessment of Peat Landslide Hazard
Figure A12.2.2

Scale: 1:20,000 @ A3

Date: 28/01/2016

Ordnance Survey Developer Partner

Ref:



Key

- Application Boundary
- Locations of Turbines T1 to T17
- Borrow Pits
- Hardstanding
- Compound during construction
- Substation
- Route of Access
- Anemometry Mast
- Radio Communications Tower
- Section Markers
- Otterswick and Graveland SPA
- Otterswick SSSI
- Waterbodies and watercourses
- Roads
- Buildings

Exposure

- 1 Very low (distance >150m)
- 2 Low (100m<distance≤150m)
- 3 Medium (50m<distance≤100m)
- 4 High (distance ≤50m)

Beaw Field Wind Farm

N

PEEL

TITLE:

Exposure of Sensitive Receptors to Potential Peat Landslide
Figure A12.2.3

Scale: 1:20,000 @ A3

Date: 28/01/2016

Ordnance Survey Developer Partner

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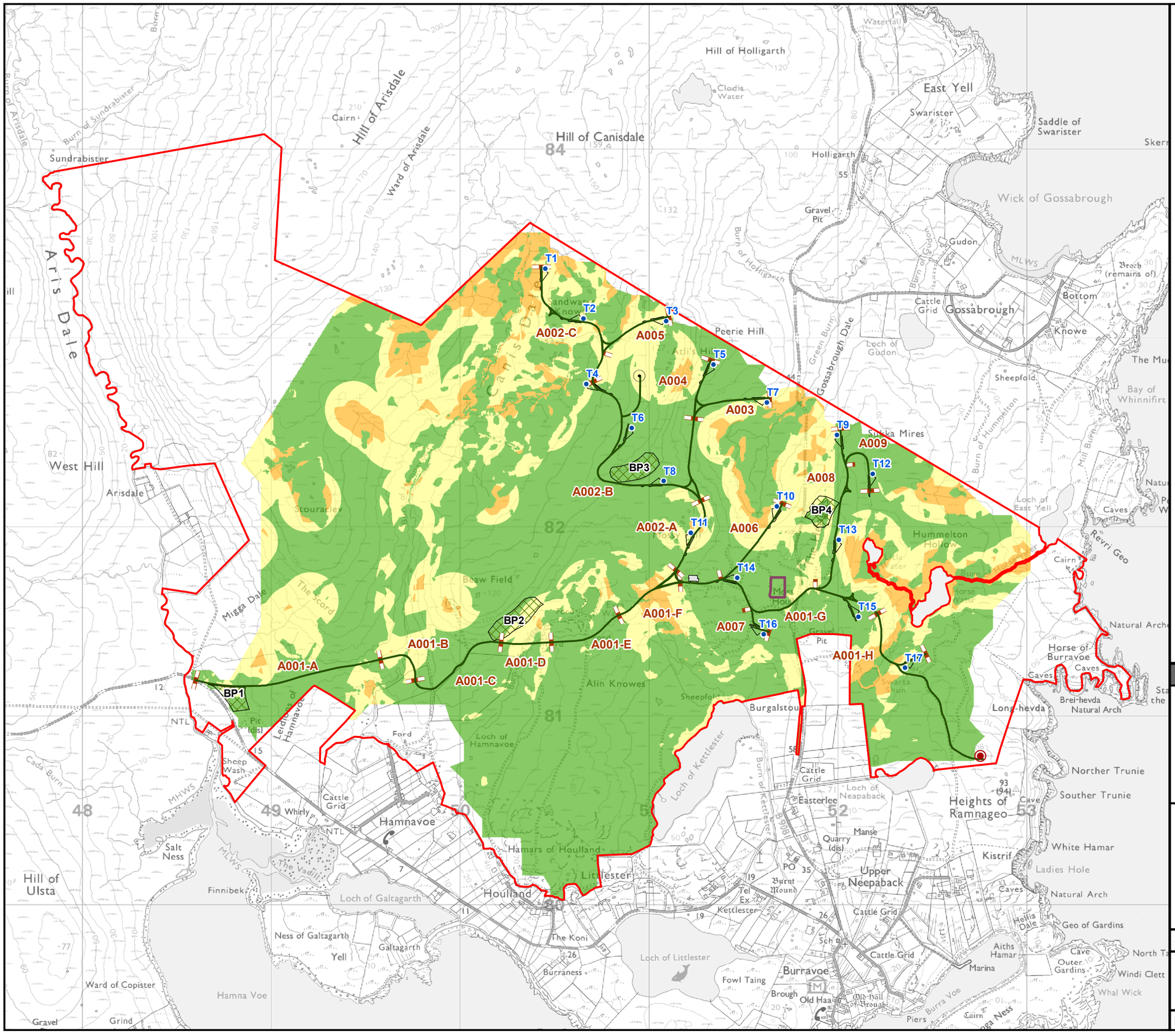
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
T13
T14
T15
T16
T17
A002-C
A005
A004
A003
A009
A008
A002-B
A002-A
A006
A001-F
A007
A001-G
A001-H
A001-B
A001-E
A001-A
A001-D
A001-C
BP1
BP2
BP3
BP4
Hill of Canisdale
84
Hill of Holligarth
East Yell
Swarister
Saddle of Swarister
Wick of Gossabrough
Gossabrough
Peerie Hill
Sundrabister
West Hill
Arisdale
Stourarley
Beaw Field
Alin Knowes
Loch of Hamnavoe
Hamnavoe
Houlland
Littlester
Loch of Littlester
Burgalstou
Heights of Ramnageo
Upper Neepaback
Burravoe
Hummelton Hollow
Hill of Ulsta
Loch of Galtagarth
Hamna Voe
Aris Dale
Key
Application Boundary
Locations of Turbines T1 to T17
Borrow Pits
Hardstanding
Compound during construciton
Substation
Route of Access
Anemometry Mast
Radio Communications Tower
Section Markers
Hazard Ranking
1–4 Insignificant
5–10 Significant
11–16 Substantial
17–20 Serious (not present within the Study Area)
Beaw Field Wind Farm
N
PEEL
TITLE:
Qualitative Peat Landslide Hazard Ranking
Figure A12.2.4
Scale: 1:20,000 @ A3
Date: 28/01/2016
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