CLASHINDARROCH II WIND FARM

Peat Assessment

Prepared for: Vattenfall Wind Power Ltd

Technical Appendix 11.1

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1.0 Introduction

1 SLR Consulting Ltd (SLR) was commissioned by Vattenfall Wind Power Ltd (Vattenfall) to undertake a peat assessment for the proposed Clashindarroch II Wind Farm (the proposed development), which would be located approximately 6km to the south west of Huntly, Aberdeenshire, to the north east of the existing Clashindarroch Wind Farm. The Site location is shown in Figure (the Site).

2 The proposed development is likely to comprise 14 turbines with associated infrastructure including borrow pit (and borrow pit search areas), substation and access tracks. The proposed development would be accessed via the existing track to the Clashindarroch Wind Farm.

3 The purpose of this report is to consider the extent of peat at the site and if present consider the potential impact to the proposed development, such that suitable controls and appropriate methodologies can be employed during the construction and commissioning of the wind farm to mitigate against associated risks. If significant peat is present, a peat landslide and hazard risk assessment will be required. This report presents the findings of the peat survey undertaken by SLR in May 2017, July 2017 and October 2018.

4 The methods adopted for the assessment follow the best practice guidance[1] issued by the Scottish Executive for investigation, assessment and reporting for wind farms in peat areas.

1.1 Background

5 The importance of assessing the stability of peat deposits in relation to wind farm developments came to the fore as a result of peat failures during the construction of Derrybrien[2] Wind Farm in Ireland in 2003. Although no fatalities were associated with these failures, there was a significant environmental impact. Wind farms tend to be constructed in high moorland areas which are primarily associated with significant peat deposits (typically blanket bogs). There is a potential for peat instability to occur, particularly where deposits are in excess of 1m deep. Peat instability is influenced by many factors, including, but not limited to, peat thickness, hill slope gradient, underlying geology and subsurface hydrology.

1.2 Objectives of the Report

6 This Peat Assessment has primarily been concerned with the influence of peat on the design and development of the proposed development and to identify any need for a Peat Land Hazard Risk Assessment (PLHRA).

7 The main objective was to identify any areas of peat on the site, not only to inform the design of the proposed development, but to also assess the potential peat stability (if any) at the site and identify any areas of potential concern. This would then enable the identification of mitigation measures to ensure the maintenance of peat stability before, during and after construction. All aspects of construction should be based on ensuring minimum disruption to the peat areas.

1.3 Site Location and Description

8 The proposed development would be located approximately 6km south west of Huntly to the north east of the Clashindarroch Wind Farm.

[1] Peat Landslide Hazard and Risk Assessments (Scottish Executive, April 2017)

[2] Lindsay, R.A. and Bragg, O., (2004), 'Windfarm and Blanket Peat, The Bog Slide of 16th October 2003 at Derrybrien, Co. Galway, Ireland'. University of East London

9 The site would be accessed from the A920 at Craighead, 3km south west of Huntly, Aberdeenshire, from the Clashindarroch Wind Farm access track. The site straddles several hills including Auchindinnie Hill (330m Above Ordnance Datum (AOD)), Raven Hill (421m AOD), Craigend Hill (492m AOD), Grumack Hill (517m AOD), Muckle Black Hill (522m AOD) and Red Hill (526m AOD). The site comprises upland forestry and open moorland. There are existing forestry tracks that serve much of the site, accessed from the Clashindarroch Wind Farm access track.

Photograph 1.1
General View of Ground Conditions near Turbine 10 (T10) (NGR 251290, 611747)

Photograph 1.2
General View of Ground Conditions Looking Towards Clashindarroch Wind Farm
(NGR 251290, 611747)

10 The proposed development would include the following:

- 14 turbines, of a maximum tip height of 180 m with external transformers;
- A hardstanding area for each turbine base (approx. 74.75 x 42m in extent ;
- A total of approximately 10.9 km of new access tracks with a typical 5m running width and associated drainage;
- 21 km of existing on-site access tracks not requiring upgrade and 1.95km of existing track requiring upgrade;
- Underground cabling along access tracks to connect the turbine locations, and electrical substation;
- 1 substation compound including a control building; and
- 1 permanent met mast 112m in height.

11 In addition, the following activities would be required during the construction phase of the proposed development:

- Temporary construction compound and storage area;
- A central laydown area with onsite concrete batching compound;

- Removal and management of material during foundation and track construction; and
- Up to three borrow pits (one formed by the extension to an existing borrow pit and two additional search areas, should they be necessary).

1.4 Scope of the Report

12 The scope of the report has been primarily concerned with the influence of peat on the design, construction and operation of the proposed development, and secondly to minimise the disturbance of peat, if it is present.

13 The principle objective was to assess the extent of organic peat (>0.5m) and peaty soils (<0.5m) on the site, with the purpose of identifying peat stability at the site, areas of potential concern and any mitigation measures required to ensure the maintenance of peat stability before, during and after construction.

14 All aspects of construction would be based on ensuring minimum disruption to peat areas, by avoidance of deeper peat in the first instance during the iterative layout design process for the proposed development, and secondly, if peat could not be avoided, minimising its disturbance through good construction practice.

15 The objectives were achieved by completion of the following:

- Review of geological, hydrological and topographical information;
- Geomorphological mapping of the site to identify the prevailing conditions influencing the potential for, or any evidence of, active, incipient or relict peat instability, including a photographic record and identification of their location and report on the potential risk of future instability, describing the likely causes and contributory factors;
- Identifying potential controls (if required) to be imposed on the construction contractor to minimise the risk of peat instability occurring at the proposed development; and
- Provide recommendations for further work or specific construction methodologies (if required) to suit the ground conditions at the proposed development to mitigate any unacceptable risk of potential peat instability.

16 An initial Reconnaissance Survey was undertaken in May 2017 by SLR to gain a preliminary understanding of the site and to establish peat coverage onsite and review areas of concern, such as watercourse crossings, deep peat where identified, borrow pit and substation locations.

17 A detailed probing survey was undertaken in May (Phase 1), July 2017 (Phase 2) and additional probing based on design freeze in October 2018, targeting key areas of infrastructure around tracks and turbine locations. The results have been used to produce a peat isopach map. Further details are given in subsequent sections of this report.

1.4.1 Peat Landslide Hazard and Risk Assessment

18 The purpose of a PLHRA is to identify those parts of the site that are naturally susceptible to a higher risk of instability, so that they can be avoided or accommodated. It should be noted that all peat slopes have a risk of instability and the vast majority of peat slope failures occur naturally.

19 Construction of a wind farm would only increase the risk of peat slope instability if good geotechnical construction practice is ignored and it is a requirement of all wind farm developments to follow a very

carefully worded and designed Construction and Environmental Management Plan (CEMP) which uses many of the recommendations of the peat landslide hazard and risk assessment[3].

20 Without the guidance contained in a Construction Method Statement or CEMP, the following factors would increase the risk of instability:

- Construction of access tracks;
- Excavation and stockpiling for foundations;
- Construction of hardstanding areas; and
- Blocking of natural drainage, inappropriate new drainage or drainage discharge.

21 It is important to note that peat instability and the impacts of any instability are not constrained by artificial site or ownership boundaries, but by topographic and geomorphologic boundaries. It is therefore important to ensure that the breadth of scope of any assessment adequately covers the areal extent of any possible impact.

22 The risk assessment has been based on ground models developed using a Geographical Information System (GIS) specifically for this site. A numerical analysis was undertaken in which coefficients were allocated for each of the factors influencing peat stability and their impact on possible receptors.

23 The conceptual layout of the turbines and access routes, the findings from the peat probing, sampling and analysis were used by the design team to optimise the turbine layout to avoid or mitigate areas of unacceptable peat slide risk. The layout presented in the Figures attached to this report, represents the final iteration of the turbine layout.

24 This system outlined above was developed in accordance with the guidelines on PLHRA by the Scottish Executive (SE) for the investigation, assessment, and reporting for wind farms in peat areas. The analysis and interpretation is based upon the results obtained from this process as well as previous professional experience and the results of case studies elsewhere.

[3] Peat Landslide Hazard and Risk Assessments (Scottish Executive, April 2017)

2.0 Peat Instability

25 This section reviews the nature of peat and how current and past activities can influence stability. The factors which are likely to influence the potential for peat instability are:

- Significant peat depths over impermeable bedrock or minimal soil;
- The presence of slope gradients greater than 4o (approximately) and general topography;
- Natural drainage paths;
- Evidence of past failures, including soil creep;
- Drainage features at the base of slopes which could lead to undercutting;
- Forestry plantations and artificial drainage; and
- Recent climate patterns.

26 It should be noted that peat instability is not a recent phenomenon and there is documentary evidence of peat landslides dating back over 500 years[4]. Many landslides that involve peat have no human interference that could be considered as a trigger and this should be borne in mind when considering the susceptibility of a site to potential instability.

2.1 Background Information Regarding Peat

27 Peat is found in extensive areas in the upland and lowland regions of the UK and is defined as the partly decomposed plant remains that have accumulated in situ, rather than being deposited by sedimentation. When peat forming plants die, they do not decay completely as their remains become water logged due to regular rainfall. The effect of water logging is to exclude air and hence limit the degree of decomposition. Consequently, instead of decaying to carbon dioxide and water, the partially decomposed material is incorporated into the underlying material and the peat 'grows' in situ.

28 Peat is characterised by low density, high moisture content, high compressibility and low shear strength, all of which are related to the degree of decomposition and hence residual plant fabric and structure. To some extent, it is this structure that affects the retention or expulsion of water in the system and differentiates one peat from another.

29 Lindsay[5] defined two main types of peat bog, raised bog and blanket bog, which are prevalent on the west coast of Europe along the Atlantic seaboard. In Britain, the dominant peat land is blanket bog which occurs on the gentle slopes of upland plateaux, ridges and benches and is predominantly supplied with water and nutrients in the form of precipitation. Blanket peat is usually considered to be hydrologically disconnected from the underlying mineral layer.

30 There are two distinct layers within a peat bog, the upper acrotelm and the lower catotelm. The acrotelm is the fibrous surface to the peat bog6, typically less than 0.5m thick; which exists between the growing bog surface and the lowest position of the water table in dry summers. Below this the catotelm exhibits various stages of decomposition of the vegetation as it slowly becomes assimilated into the body of the peat.

[4] Smith, L.T., (Ed) (1910), 'The literary of John Leland in or about the years 1535-1543.' Vol.5, Part IX. London: AF Bell and Sons.
[5] Lindsay, R.A., (1995), 'Bogs: The ecology, classification and conservation of Ombrotrophic Mires.' Scottish Natural Heritage, Perth
[6] Ingram, H.A.P., (1978), 'Soil layers in mires: function and terminology'. Journal of Soil Science, 29, 224-227.

31 For geotechnical purposes the degree of decomposition (humification) can be estimated in the field by applying the 'squeezing test' proposed by von Post and Grunland[7] (1926). The humification value ranges from H1 (no decomposition) to H10 (highly decomposed). The extended system set out by Hobbs[8] provides a means of correlating the types of peat with their physical, chemical and structural properties.

32 The relative position of the water table within the peat controls the balance between accumulation and decomposition (acrotelm and catotelm) and therefore its stability, hence artificial adjustment of the water table by drainage requires careful consideration.

2.1.1 Peat Shear Strength

33 In geotechnical terms, the shear strength of a soil is the physical characteristic that provides stability and coherence to a body of soil. For mineral soils such as clays or sands, such strength is variously given by an inter-particle friction value and cohesion. Depending whether the mineral soil is predominantly cohesive (clay) or non-cohesive (sand) governs which of the components of strength control the behaviour of the soil.

34 For peat soils, where the major constituent is organic and there is likely to be little or no mineral component, the geotechnical definition of shear strength does not strictly apply. At present there is no real alternative method for defining the shear strength of peat, therefore the geotechnical definition is generally adopted, in the knowledge that it should be used with great caution.

35 As noted before, the acrotelm or near surface peat comprises a tangle of fresh and slightly rotted roots and vegetable fibres. These roots and fibres impart a significant tensile shear strength capacity to the material which provides it with a significant load carrying capacity. The acrotelm is, in effect, a fibre reinforced soil.

36 In the more decomposed catotelm, the tensile shear strength is reduced as the roots and fibres become more rotted. However, the loss in strength due to decomposition is off-set to a limited degree, by a gain in strength due to the overburden pressure. In geotechnical engineering there is an established relationship for recently deposited soils, between the shear strength of a sample and the thickness of overburden above it.

37 Consequently it is almost impossible to predict a shear strength profile in peat and attempts to measure the shear strength using normal geotechnical methods can be misleading. Typical values of shear strength from hand shear vanes would be in the range 20-60 kilopascal (kPa) although values over 100kPa have been recorded in peat elsewhere. The higher strengths are almost certainly the influence of roots or other non-decomposed material. It is believed that the strength of peat should be quoted as a cohesion value as there are few, if any, discrete particles to give the material a significant frictional resistance. It should be noted, however, that any quotation of shear strength for peat should be treated with extreme caution.

2.1.2 Peat Stability – Factors to be Considered

38 There is considerable observational information relating to debris and peat flows although the actual mechanisms involved in peat instability are not fully understood. The main influences on slope stability are geological, geotechnical, geomorphic, hydrological, topographic, climatic, agricultural and human influences such as drainage and construction activity. Peat is affected to a degree by changes in any of the

[7] Von Post, L. and Grunland, E., (1926), 'Sodra Sveriges torvillganger 1' Sverges Geol. Unders. Avh., C335, 1-127.

[8] Hobbs, N.B., (1986), 'Mire morphology and the properties and behaviour of some British and foreign peats.' Quarterly Journal of Engineering Geology, London, 19, 7-80.

above list and it is vital to appreciate that changes to the existing equilibrium would affect the level of slope stability during construction and operation of the proposed development.

39 Some of the contributory factors to peat instability are summarised below:

- The geographical limits – areas which could be affected by potential instability are not confined to the artificial boundaries imposed by land ownership; landslip occurring above a site could affect the site and property down slope or downstream of the site for several kilometres;
- Agriculture and grazing – this has a substantial effect on peat areas and this can be compounded in areas that have been managed to improve grazing. Grazing compacts the peat surface reducing the rainwater infiltration and the additional nutrients change the ecological balance of the original peat bog. Agricultural management can include surface drainage and periodic burning, both of which can leave the surface of the peat bare for a period of time resulting in temporary desiccation of the surface. Subsequent wetting of the peat and resumption of peat accumulation results in the former desiccated and possibly ash covered surface being incorporated into the body of the peat which introduces a weak discontinuity in the profile; this in turn becomes another unknown factor in the stability assessment.
- Forestry – this has a substantial effect on slope stability particularly in the early stages as the creation of a forest involves disruption of the natural equilibrium and drainage of the slopes and the installation of artificial drains by deep ploughing. The construction of access tracks further disrupts the drainage and concentrates groundwater flow into narrow, fast flowing erosive streams. The work by Winter *et al* [9] noted that forest tracks can act to retard or concentrate the down slope flow of water and thus aid its penetration into the slope below. Such a mechanism has been observed at a number of recent landslips that have affected the road network in Scotland.
- Natural Drainage – some of the precipitation falling onto a natural upland peat bog would be absorbed into the low permeability catotelm peat. However, most of the water would run-off as sheet flow through the upper, high permeability acrotelm. Thus the water is transmitted to the lower slopes in a reasonably controlled manner through a range of interconnections that operate at different scales and speed[2]. Failure to understand this and to disrupt the transmission process for the groundwater could result in instability.
- Artificial Drainage - where agricultural drainage has been used to improve the quality of the grazing or to promote forestry it reduces the overall volume of water entering the bog and transfers this water to the edges more rapidly. This can result in ditches and streams becoming enlarged, causing increased erosion and a greater silt burden in the stream water.

2.2 Peat Mass Stability

40 The principal surface indicator of peat slide potential is cracking of the peat land surface and it is the identification of crack patterns in the field and the attendant causes of the cracking that is fundamental to a peat stability assessment.

41 Sites that have exhibited natural instability in the past are likely to be more susceptible to future instability during and following construction of a wind farm, therefore it is important to identify such instability as part of the Peat Assessment.

[9] Winter, M.R., Macgregor, F. and Shackman, L. (2005a), 'Scottish tracks networks landslide study' Trunk tracks: network management division, published report series. The Scottish Executive.

2.2.1 Types of Failure

42 The result of instability in peat is the down-slope mass movement of the material. There are a number of definitions of peat instability which are used to characterise the type of failure. A brief description is given below:

- Bog Bursts or Bog Flows – the emergence of a fluid form of well humified, amorphous peat from the surface of a bog, followed by the settling of the residual peat, *in situ* [10];
- Peat Slides – the failure of the peat at or below the peat/substratum interface leading to translational sliding of detached blocks of surface vegetation together with the whole underlying peat stratum[10]; and
- Bog slide – an intermediate form of instability where failure occurs on a surface within the peat mass with rafts of surface vegetation being carried by the movement of a mass of liquid peat.

2.2.2 Bog Bursts

43 Accounts of bog bursts are generally associated with very wet climates or areas which have received storm rainfall events. Bog bursts can be associated with particularly wet peat landscapes; therefore it is possible to identify broad regions of a higher susceptibility to these failures. The constraints used to identify the areas of higher susceptibility to bog burst failure are given below:

- Peat thickness in excess of 1.5m with no upper limit[1];
- Shallow gradients from 2^o to 10^o (peat thicker than 1.5m is generally not observed on slopes steeper than 10^o, also moisture content is generally reduced on steeper slopes due to drainage)[1];
- Ground which is annually waterlogged to within the upper 1m below ground level, (the groundwater level may rise above this but rarely falls below) [11];
- Greater humification of the lower catotelm within the waterlogged ground; and
- Lower surface tensile strength of the fibrous peat and vegetation.

44 The humified mass can be considered as analogous to a heavy liquid and the stability of this mass is maintained by the strength of the surface or acrotelm peat. Should the surface become weakened through erosion or desiccation, or the construction of a surface drainage ditch for agricultural or forestry reasons or through turbary (peat cutting), failure is made more likely.

2.2.3 Peat Slides

45 Peat slides tend to be translational failures with a defined shear surface at or close to the interface with the substrate.

46 The factors generally considered to influence susceptibility to peat slide failures are listed below:

- Peat depth up to 2m;
- Slope gradients between 5^o and 15^o;

[10] Dykes, A.P and Kirk, K.J., (2001), 'Initiation of a multiple peat slide on Cuilcagh Mountain, Northern Ireland.' Earth Surface Processes and Landforms, 26, 395-408.

[11] Crisp, D.T., Dawes, M. & Welch, D. (1964), 'A Pennine Peat Slide', The Geographical Journal, Vol 130, No4, pp519-524.

- Natural or artificial drainage cut into the surrounding peat landscape;
- Greater humification of the lower catotelm within the waterlogged ground; and
- Lower surface tensile strength of the fibrous peat and vegetation.

47 It will be noted that some of the factors causing instability are common to both bog bursts and peat slides.

48 The peat–substrate interface is the primary zone of failure and is enhanced by elevated water content at this boundary and softening or weathering of the lower mineral surface. For this reason, any investigation or probing should try to distinguish the nature of the lower mineral substrate.

2.2.4 Bog Slides

49 A variation on a peat slide where part of the peat mass is subject to movement, usually on an internal layer of material, which may be more prone to movement, such as an interface between the acrotelmic and catotelmic layer.

2.2.5 Natural Instability

50 The stability of a peat mass is maintained by a complex interrelationship of many factors, some of which may not be immediately obvious. Key factors include sloping rock head and proximity to a water body. Rainfall often acts as the trigger after the slope has already been conditioned to fail by natural processes.

51 It should also be remembered that peat bogs are growing environments and that there would come a time, on sloping ground, where the forces causing instability, i.e. the weight of the bog, can no longer be resisted by the internal strength of the peat and its interface with the underlying mineral surface. At this point, failure would occur.

52 The weight of the peat bog or any soils mantling steep hill slopes would be increased during periods of very heavy rain and it is common to see landslips occurring following extreme rain events. This may be a concern for future developments where one of the predicted effects of global warming will be a greater frequency of extreme weather, intense storms being one element.

3.0 Detailed Site Assessment – Desk Based

3.1 Desk Study

53 The assessment of the character of the peatland within the site boundary has included a desk based assessment, integrating this information as well as determining the extent of the peat in its current geomorphological setting. As part of this SLR have reviewed historical plans, aerial photographs, geological plans and created site specific plans, including slope and extent of peat.

3.1.1 Sources of Site Information

54 The following sources of information have been utilised:

a) The Clashindarroch Wind Farm Environmental Statement (ES; dated 2009) have been reviewed, as well as anecdotal information from site based staff;
b) Soil Surveys;
c) Geological and Hydrogeological Setting;
d) Aerial Photography;
e) Digital Terrain Data (DTM) (e.g. slope); and
f) Local Knowledge.

3.2 Previous Reports

55 Background on site conditions was reviewed from previous Environmental Statement for Clashindarroch Wind Farm, to determine likely conditions at site and along existing tracks. This highlighted where areas of peat were likely to occur and the possibility that there may be limited extent of peat on the actual area to be developed as a wind farm.

3.3 Soil Surveys

56 Soils plan from (http://map.environment.gov.scot/Soil_maps), indicate that the site is dominated by mineral podzols to east of the Burn of Bedlaithen, with predominantly peaty podzols to the west. One area of peat is indicated between Red Hill and Muckle Black Hill to west of the development site and not impacting the site, along the top of the catchment on a flat lying plateau area. There is no evidence of any significant peat underlying the areas where potential turbines or infrastructure could be located within the Site boundary.

3.4 Geological and Hydrogeological Setting

3.4.1 Superficial Geology

57 The superficial geology of the site is detailed in **Error! Reference source not found.** – Superficial Geology[12].

58 The superficial geology on the site is largely absent, with bedrock found at or close to the surface across much of the site. Glacial Till is mapped across the site, generally confined to the valleys between the

[12] http://www.bgs.ac.uk/opengeoscience/home.html

summits of hills. There is no peat mapped on the site, however this is not definitive and there may be peat which has not been mapped.

3.4.2 Bedrock Geology

59 The solid geology of the site is shown in **Error! Reference source not found.** – Bedrock Geology[13]. The geology of the site comprises predominately Neoproterozoic age Dalradian metasediments and meta-igneous rocks.

60 The existing access track generally lies on the boundary between the Corininacy Pelite Member to the west and the younger Clashindarroch Formation to the east. The existing and proposed borrow pit locations are sited predominately on the Clashindarroch Formation comprising semipelite, pelite, gritty psammite and quartzite. The remainder of the access track and proposed turbine locations are sited on the Clashindarroch Formation. The area to the north of the site generally comprises Ordovician age igneous and meta-igneous rocks. There are no major faults within the site boundary, however the area to the north of the site is heavily faulted (see **Error! Reference source not found.**).

61 Details of the geological units present on sand immediately adjacent to site are detailed in Table 3-1.

Table 3-1
Solid Geology Summary

Age	Supergroup	Group	Formation	Member	Description
Ordovician (488-433 Ma)	Caledonian Supersuite (CIGSS)	North-East Grampian Basic Suite (NEBAS)	Succoth-Brown Hill Intrusion (SUBH)		Meta-gabbroic-rock and serpentine.
NEOPROETOZOIC (1000 – 542Ma)	**DALRADIAN SUPERGROUP (DALN)**	**SOUTHERN HIGHLAND GROUP (SOHI)**	MacDuff Formation (MCD)		Metagreywacke: interbedded psammite and semipelite with subsidiary pelite.
			Clashindarroch Formation (CLAS)		Phyllitic semipelite and pelite, represented by andalusite-cordierite schist in parts with rare quartzite and psammite.
				Garnel Burn Pelite Member (GBPE)	Pelite, magnetic.
		ARGYLL GROUP (ARGY)	Blackwater Formation (BLWR)	Grumack Hill Quartzite Member (GHQU)	Quartzite and gritty psammite.

[13] http://www.bgs.ac.uk/opengeoscience/home.html

Age	Supergroup	Group	Formation	Member	Description
				Corninacy Pelite Member (COPE)	Gritty psammite and Pelites, dark-grey, graphitic in parts, commonly andalusite-bearing, phyllitic to slaty with bands of metabasalt and ultramafic rock.

3.4.3 Mining and Quarrying

62 Following review of publicly available records[14], there is no evidence of mining or quarrying within the site boundary or its immediate surrounding. A borrow pit was developed for the original Clashindarroch Wind farm and it is proposed this will be extended, to supply rock for the new project .

3.4.4 Hydrogeological Setting

63 The solid geology underlying the site is classified as concealed, of limited potential or without significant groundwater, with the site underlain by impermeable Precambrian and intrusive rocks[15].

3.5 Aerial Photography

64 A review of the aerial photography[16] indicates changes in vegetation on the ground, and it is also possible to identify stream courses, ditches, and roads/tracks. The aerial photographs were used in conjunction with the site DTM data to identify the major geomorphological features such as the breaks of slope and landslips. These were inspected where identified during site visits when more detailed assessment of the site was undertaken.

65 Interpretation of available aerial photographs was undertaken to assess and identify evidence of historic peat instability. The photographs were examined to highlight features of interest, including:

- possible extension and/or compression features;
- areas of historic failure scars and debris;
- evidence of peat creep;
- areas with apparently poor drainage;
- areas with concentrations of surface drainage networks; and
- steeply incised stream cuttings within peat deposits.

66 From interpretation of the aerial photographs and topographic survey information, no significant features or obvious evidence for areas of concern were identified that could indicate evidence of peat instability, and that might warrant further attention. However only limited aerial photography was available, dating back to 1984.

14 http://www.bgs.ac.uk/opengeoscience/home.html

15 BGS Hydrogeological Sheet 18 (1:625,000)

16 Google Earth Pro.

67 The Reconnaissance Survey and peat probing survey (Phase 1 and 2) also confirmed that there were no significant features of this nature in the vicinity of the proposed development (see Section 4 below).

3.6 DTM (Slope Plan)

68 The slope gradients were assessed by reference to the mapping and particularly DTM which was used to generate a gradient map for the site, from which the gradient could be determined (see Figure 6). The gradient quoted at each probe location was based on the average gradient over a 5m grid. The design process for the proposed development has sought to reduce slopes along access tracks and at turbine bases and to position infrastructure on flatter areas where possible. As shown on Figure 6 the majority of the access tracks and turbine locations have been located on areas with flatter gradients (2-8°) where ever possible.

3.7 Local Knowledge

69 Evidence from work undertaken during construction of the Clashindarroch Wind Farm suggested a lack of peat presence within the area likely to contain proposed turbines and infrastructure and confirmed that peat was very locally developed at Red Hill and limited to an area along the catchment between the River Bogie and River Deveron. From this site knowledge it is likely that peat does not underlie the site.

4.0 Detailed Site Assessment – Site Based

4.1 Site Reconnaissance Survey

70 A site Reconnaissance Survey was undertaken in early May 2017, when an experienced hydrogeologist and a geologist visited the site to consider the site setting and determine where areas of concern might be present. An early assessment of the extent of peat and the hydrogeological setting was also undertaken. Following this Site Reconnaissance Survey, an initial peat survey (Phase 1) was undertaken during May 2017 to determine the extent of peat around the proposed development area (i.e. the area identified during constraints mapping that would be most suitable for the location of turbines and ancillary infrastructure)

4.2 Ground Conditions Assessment

4.2.1 Peat Depth Survey

71 The peat depth survey (Phase 1) was undertaken by SLR in May 2017 within the proposed development area. Probing was completed across the site to address potential infrastructure locations, along existing and proposed track routes, but not in the final locations. This aspect of the assessment was undertaken to determine any potential development constraints due to the presence of peat, the potential for peat slides and any areas of thick peat which might need to be avoided.

4.2.2 Methodology

72 The thickness of the peat was assessed using a graduated fibre glass peat probe, which can be extended to over 10m in depth. This was pushed vertically into the peat to the point of refusal and the depth was recorded, together with a unique location number and the coordinates from a handheld Global Positioning System instrument (GPS). The accuracy of the GPS was quoted as ±4m, which was considered sufficiently accurate for this assessment. All data was uploaded to a PC for subsequent incorporation into various figures and to allow analysis and assessment. Where the peat probing met refusal on a hard substrate, the ‘feel’ of the refusal was used to provide an insight into the nature of the substrate. The following criteria were used to assess the likely basal material:

- Solid and abrupt refusal – rock;
- Solid but less abrupt refusal with grinding or crunching sound – sand or gravel;
- Rapid and firm refusal – clay; and
- Gradual refusal – dense peat or soft clay.

73 The peat depth data was used to create various figures and enable the analysis and assessments included within this report.

4.2.3 Phase 1 Peat Probing Survey

74 The Phase 1 Peat Probing Site Survey was designed and undertaken in May 2017 by experienced geotechnical engineers, following the Site Reconnaissance in early May 2017. During this Phase 1 visit a total of 490 probes were undertaken across the likely development area on a 100m spacing, a further 112 probes were undertaken as part of the Phase 2 Peat Probing Site Survey on an approximate 50m spacing, with an additional 95 probes undertaken in October 2018 to update final design modifications.

75 It was impossible to undertake a 100m x 100m grid of peat depth recording in this setting, due to the presence of dense forestry. Essentially it was unsafe to probe in some of the dense areas with windblown trees and virtually impossible to position the probeholes accurately, so probing was targeted along forest tracks and rides and where possible among the trees.

76 The main survey areas of the Phase 1 Peat Survey were located primarily around, Craigie Beg (T6 & T9), lower slopes of Red Hill (T1), Corrydown (T7), The Lumps (T8), Raven Hill (T2, T3, & T11), Hill of Finglenny (T10) and Shank of Baditimmer (T13) and The Shank (T12) where the proposed turbines and infrastructure would be located.

77 The extent of the Phase 1 Peat Probing Survey is illustrated on Figure 4 Peat Depth Plan. The areas extend over the proposed development area of the site. A combination of exposed shallow bedrock, steep slopes defined the extent of the site survey at this stage. Where outcrop or significant exposure was present this was noted as part of the survey. The data was recorded on Trimble GPS hand held equipment, with peat depth, substrate type and composition of superficial deposits was all recorded. Any significant features such as watercourses, drainage, outcrop etc. were recorded in the notes section.

4.2.4 Phase 2 Peat Probing Survey

78 The Phase 2 Peat Probing Survey visit in July 2017 was undertaken to determine the nature of superficial deposits present and to determine that there was no localised peat at any of the proposed infrastructure locations. Particular reference was paid to establishing the extent of superficial cover at any locations that could be occupied by turbines, borrow pits and associated infrastructure including compounds, substation compound and along tracks. The peat probe positions were verified onsite by the use of GPS and downloaded directly into ArcGIS for modelling. The result of the peat probing is illustrated in Figure 5.

79 During this Phase 2 visit a total of 207 probes were undertaken across the site at approximately 50m intervals along the proposed access routes and around the proposed infrastructure, turbines and crane hardstanding areas on an approximate 50m x 50m grid (in line with SEPA Guidance).

80 A further 95 probes were undertaken following design freeze in October 2018.

81 The majority of the site was found to have a thin (<0.5m) peaty soil cover over glacial till as shown in Figure 5.

4.3 Results of the Peat Surveys

82 As part of the peat surveys, an assessment of the depth of soils/peat at the site was undertaken. The ground conditions were assessed from the peat probing exercise, and descriptions of in situ peat observed in streams and drainage ditches across the site. The original data collected during the Reconnaissance Survey and Phase 1 Survey was collected across the proposed development area, whereas the Phase 2 Survey was targeted primarily at infrastructure and along tracks. The two sets of data are presented on Figure 5 and shows the concentration of data from the Phase 2 Survey around the infrastructure locations.

83 The Phase 1 Survey data was used to determine the characteristic of the peat across the site, over a wider general area. As a consequence this survey was used to contour the extent of peat across the site and highlight areas where peat was not present or to identify areas of thicker peat (limited in extent to the extreme west part of site beyond Red Hill). From this Phase 1 Survey, a contour plot of the site was developed and was used to advise the overall wind farm design process, depicting areas where peat should be avoided.

4.3.1 Extent of Peat

84 The peat surveys were undertaken to address presence of peaty soils and/or peat. Peat is generally defined as an organic soil in excess of 0.50m, if the soil is less than 0.50m, then it is considered peaty soil. Both are organic soils and effectively and would be excavated during the construction process. The peat and/or peaty soils were found to be limited across the site in terms of thickness and coverage. The ground conditions were assessed by using peat depths recorded during the peat probing survey. Thin peat was classed as being 0.5m to 1.5m thick, with deposits in excess of this being classed as thick peat. The thickness ranges used are intended to reflect the risk of instability associated with both peat slides (in thin peat) and bog slides. Where the probing recorded peat less than 0.5m thick, this has been considered to be an organic peaty soil rather than peat.

4.3.2 Summary of Results

85 The results of the probing survey are detailed within Figure 4 – Peat Depth Plan, with a summary of peat depths included within Table 4-1 below.

86 The peat was found to be very limited across the site in terms of thickness and coverage. The majority of probes (approximately 95%) identified peaty soils (<0.5m). Peat deposits are present to the western edge of the site boundary extending across a flat expanse, northwards from the summit of Red Hill, reaching thicknesses of 1.9m. This area of peat comprises haggy deposits, shown in Photograph 4.3. This area is very localised and outside of the proposed development area, and as such it has been discounted from the assessment as it is not in the development footprint and could not impact upon the proposed development.

Photograph 4.3
Haggy Peat Deposits (NGR 251636, 611971)

87 Peat/soil probing in the proposed development area was undertaken primarily along existing tracks and forest rides, due to the intensity of forest growth. The survey data immediately established that the proposed development area was not underlain by peat and that there was little or no evidence of peat development within the proposed development e.g. the turbine layout or areas for associated infrastructure.

88 A total of 602 peat/soil probe holes were undertaken across the peat probing surveys (Phase 1 and 2), with the results summarised in Table 4-1.

Table 4-1
Peat Probing Data

Peat Thickness (m)	Percentage (of total probes undertaken on site)
0 (no peat)	<1
0 – 0.5 (peaty soil)	~ 95
0.5 – 1.0 (thin peat)	~ 3

Peat Thickness (m)	Percentage (of total probes undertaken on site)
1.0 – 2.0 (peat)	~ 2

89 In summary the peat depth probing has shown that:

- Peat is generally limited to one area, outside the proposed turbine/infrastructure locations, to the west of Red Hill;
- Approximately 95% of peat probes undertaken across the entire site found no peat or peaty soils; and
- Probing intersected peaty/glacial soils at all proposed infrastructure locations.

90 The underlying soil/peat thickness at each location was recorded and the data used to draw the interpreted peat thickness map, presented as Figure 4 – Peat Depth Plan. The slopes on site are detailed in Figure 6 – Slope Plan.

4.3.3 Substrate

91 The assessment of the underlying substrate from the probing data was interpreted as predominately glacial soils and weathered bedrock. A typical stratigraphic section is shown in Photograph 1.4.

Photograph 4.4
Peat Overlying Glacial Soils (NGR 251607, 612845)

4.4 Peat Stability Risk Assessment

92 The best practice guidance[17] issued by the Scottish Executive for investigation, assessment and reporting for wind farms in peat areas was referenced and following the results of the peat assessment, it was considered that no peat landslide and hazard risk assessment was required for the site.

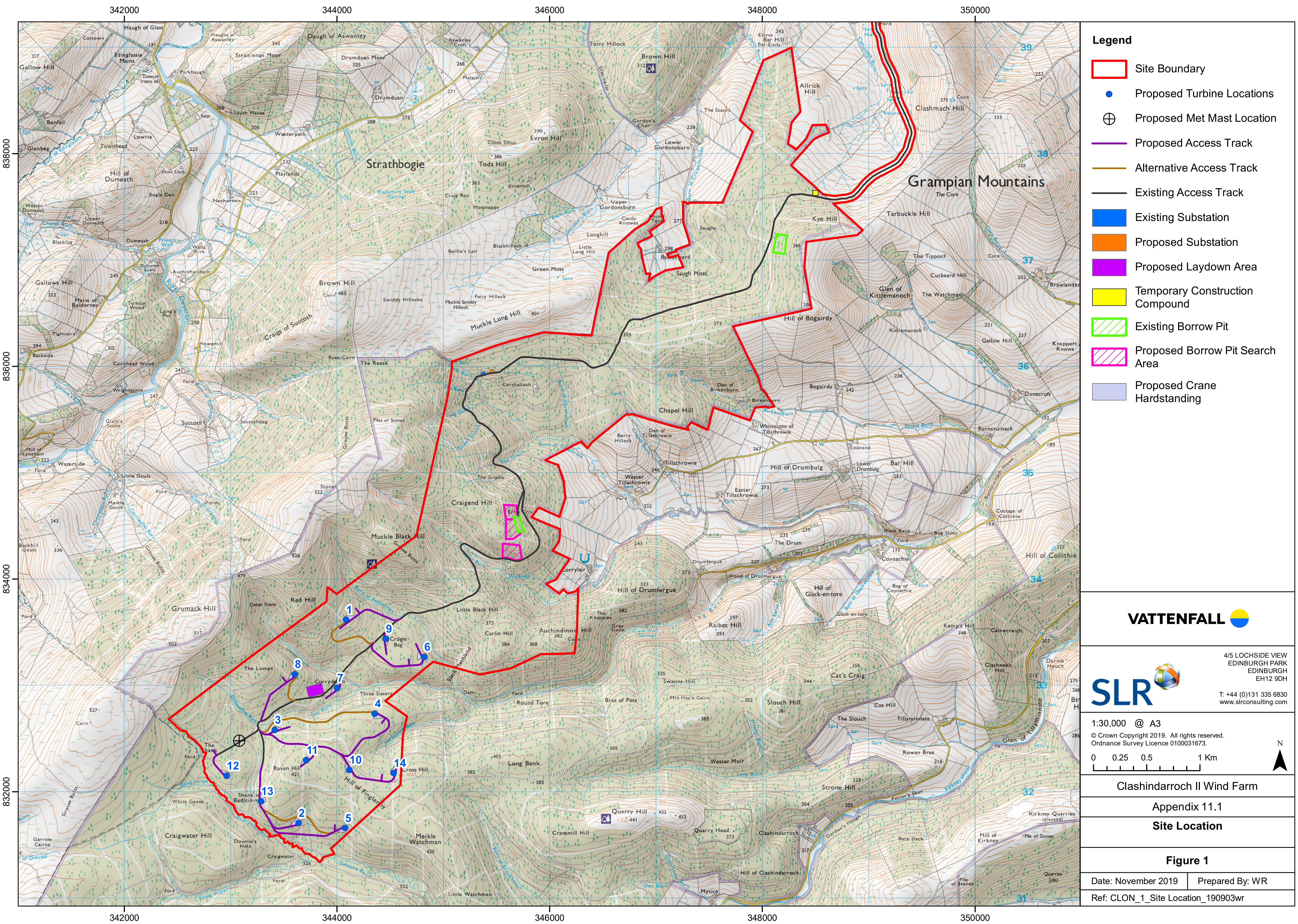
93 Following review of geological maps and records, followed up by a detailed peat probing survey, the results show that there are no significant areas of peat within influencing distance of any infrastructure or turbines for the proposed development. For this reason a detailed peat landslide hazard and risk assessment has not been undertaken for the site.

[17] Peat Landslide Hazard and Risk Assessments (Scottish Executive, April 2017)

5.0 Conclusion

94 Following review of Scottish Government Guidance on developments on peatlands[17] it was concluded that there was no risk of peat landslide on the site and that a detailed peat landslide and hazard risk assessment was not required. This decision was based on there being no peat identified on site on any of the proposed access tracks, turbine locations or ancillary infrastructure locations and no evidence of historic peat instability.

FIGURES


Legend
Site Boundary
Proposed Turbine Locations
Proposed Met Mast Location
Proposed Access Track
Alternative Access Track
Existing Access Track
Existing Substation
Proposed Substation
Proposed Laydown Area
Temporary Construction Compound
Existing Borrow Pit
Proposed Borrow Pit Search Area
Proposed Crane Hardstanding
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0 0.25 0.5 1 Km
N
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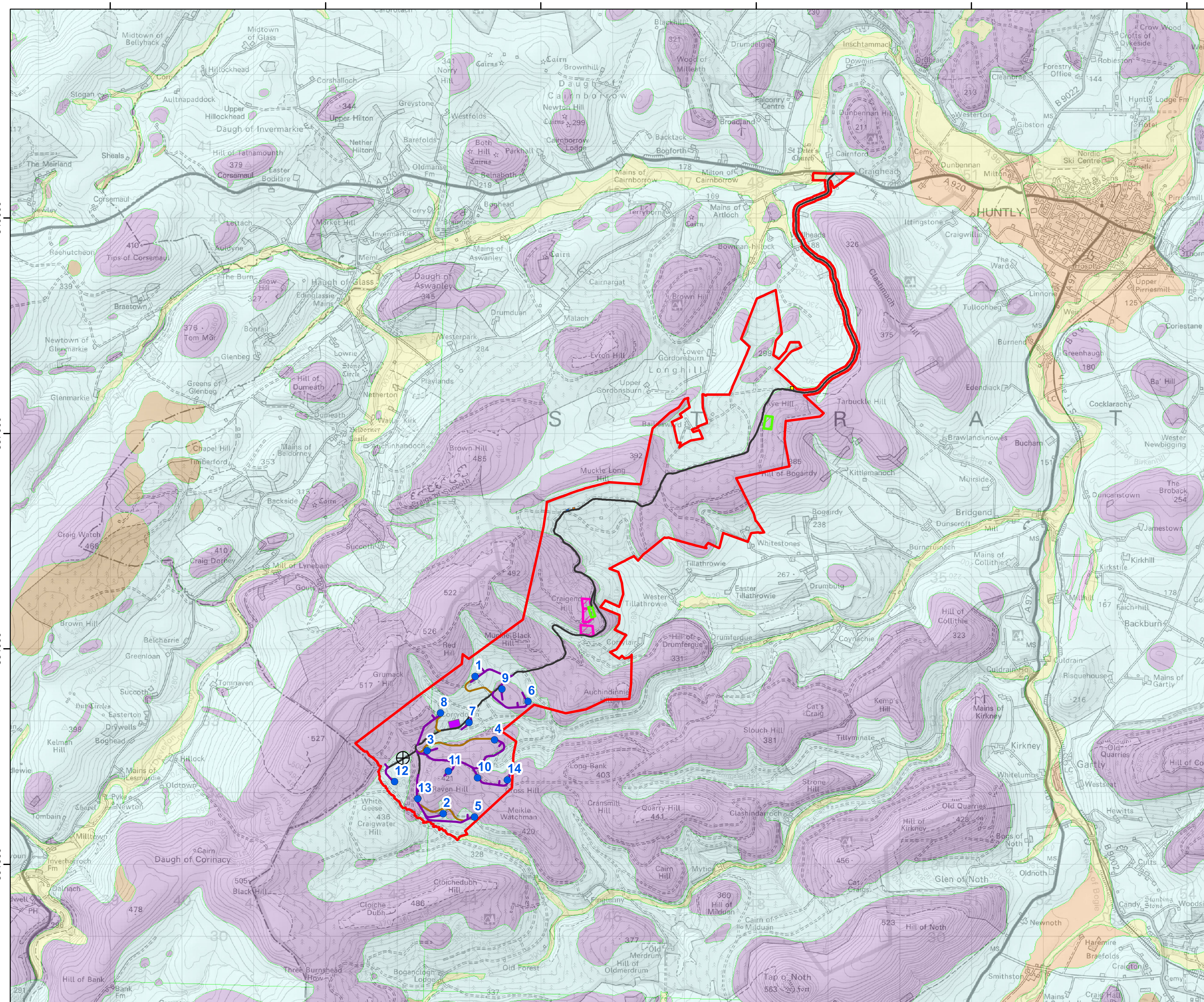
Appendix 11.1
Site Location
Figure 1
Date: November 2019
Prepared By: WR
Ref: CLON_1_Site Location_190903wr
342000
344000
346000
348000
350000
838000
836000
834000
832000
Strathbogie
Grampian Mountains



Legend

- Site Boundary
- Proposed Turbine Locations
- Proposed Met Mast Location
- Proposed Access Track
- Alternative Access Track
- Existing Access Track
- Existing Substation
- Proposed Substation
- Proposed Laydown Area
- Temporary Construction Compound
- Existing Borrow Pit
- Proposed Borrow Pit Search Area
- Proposed Crane Hardstanding

Superficial Geology

- Peat
- Alluvium - clay, silt and gravel
- Alluvium and river terrace deposits
- River terrace deposits
- Till, Devensian
- Bedrock at or near surface

Notes
1. Superficial geology data obtained via BGS wms. British Geological Survey ©NERC. All rights Reserved.

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0 0.5 1 2 Km

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Appendix 11.1

Superficial Geology

Figure 2

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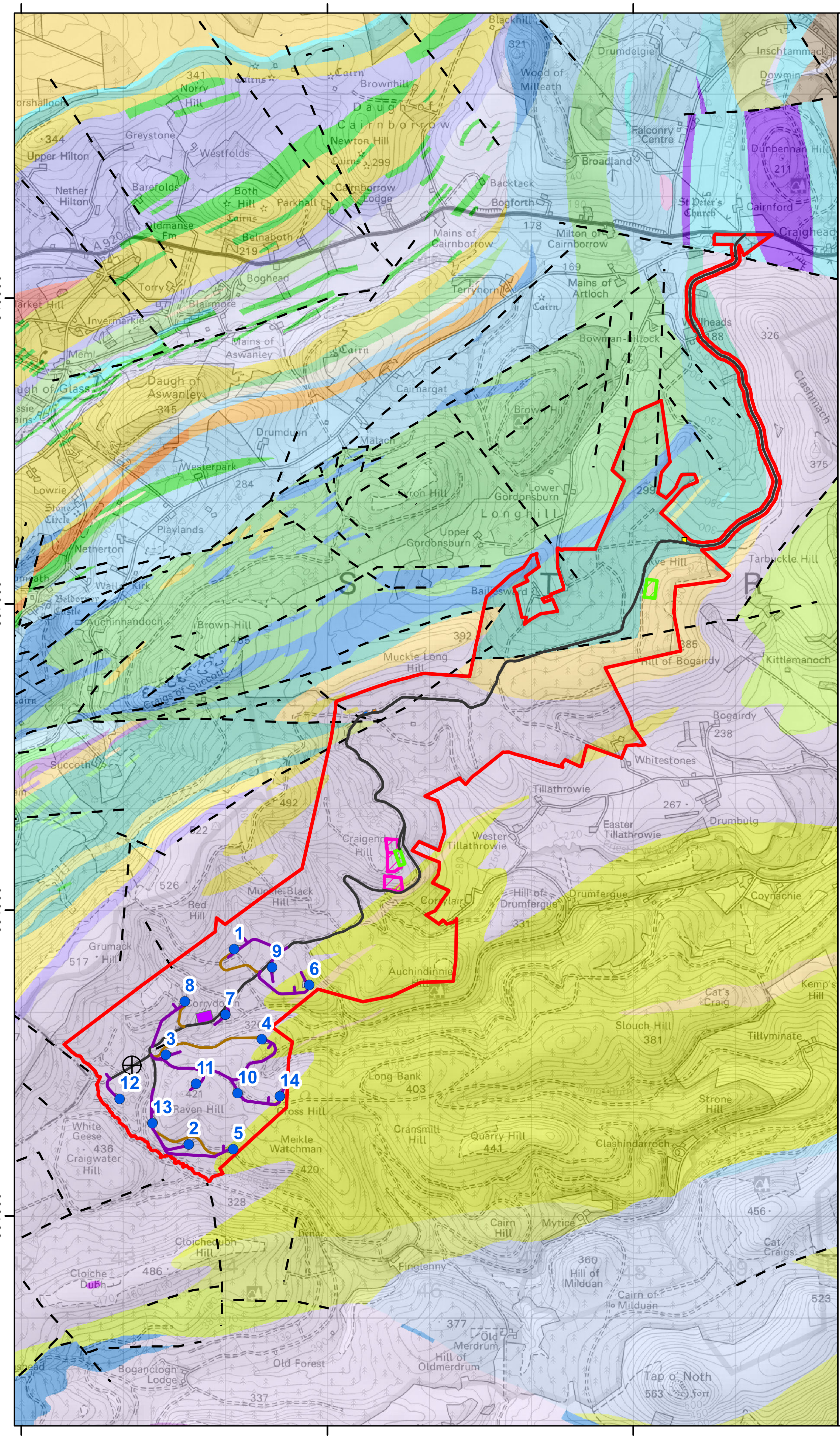
Ref: CLON_2_Superficial_Geology_190903wr



Bedrock Geology

- Macduff Formation - Metaconglomerate
- Macduff Formation - Micaceous Psammite, Semipelite and Pelite
- Macduff Formation - Hornfelsed - Micaceous Psammite, Hornfelsed Semipelite and Harnfelsed Pelite
- Macduff Formation - Hill of Foudland Pelite Member - Hornfelsed Pelite and Hornfelsed Semipelite
- Macduff Formation - Hill of Foudland Pelite Member - Pelite and Semipelite
- Whitehills Grit Formation - Psammite and Pelite
- Clashindarroch formation - Semipelite
- Clashindarroch formation - Psammite, Gritty
- Clashindarroch formation - Hornfels
- Argyll Group - Pelite and Semipelite
- Blackwater Formation - Grumack Hill Quartzite Member- Quartzite and Psammite
- Blackwater Formation - Corinacy Pelite Member - Pelite, Graphitic
- Beldorney Pelite Formation - Pelite and Semipelite
- Beldorney Pelite Formation - Pelite and Semipelite
- Kymah Quartzite Formation - Quartzte
- Blair Atholl Subgroup - Semipelite
- Ailnack Phyllite and Limestone Formation - Semipelite and Psammite
- Corryhabbie Quartzte Formation - Quartzte
- Mortlach Graphitic Schist Formation - Pelite, Graphitic
- Pitlurg Calcareous Flag Formation - Calcareous Psammite and Calcareou Semipelite

Southern Highland Group
Argyll Group
Appin Group
Ballachulish Subgroup
Lochaber Subgroup
Dalradian Supergroup

Extrusive Rocks

- Tillybrachty Sandstone Formation - Basaltic Andesite (TAS)

Devonian

Intrusive Rocks

- Carvichen Pluton - Granite, Biotite
- Corinacy Pelite Member - Pelite, Graphitic
- Ernan-Glass Metabasic Swarm - Metamicrogabbro, Feldspar-Phyric
- Huntly-Knock Pluton - Orthopyroxene - Gabbro and Clinopyroxene - Norite
- Huntly-Knock pluton - Gabbroic-Rock, contaminated
- Huntly-Knock Pluton - Olivine - Gabbro and Orthopyroxene - Gabbro
- Huntly-Knock pluton - Olivine - Gabbro
- Huntly-Knock pluton - Ultramafic rock
- Insch Pluton (Boganclogh sector lower zone) - Metaharzburgite
- Insch Pluton (Boganclogh sector upper zone) - Olivine, Gabbro, Ferich
- Kennethmont Intrusion - Quartz-Diorite
- Kymah Quartzte Formation - Quartzte
- North-East Grampian Granitic Suite (ordovician) - Granite
- Scottish Highland Ordovician Minor Intrusion Suite - Microgranite, Shreared
- Succoth - Brown hill intrusion - metagabbroic rock
- Succoth - Brown hill intrusion - Serpentinite
- Succoth - Brown hill type ultramafic intrusion

Ordovician

Legend

- Site Boundary
- Proposed Turbine Locations
- Proposed Met Mast Location
- Proposed Access Track
- Alternative Access Track
- Existing Access Track
- Existing Substation
- Proposed Substation
- Proposed Laydown Area
- Temporary Construction Compound
- Existing Borrow Pit
- Proposed Borrow Pit Search Area
- Proposed Crane Hardstanding
- Fault, Inferred, Displacement Unknown

Notes

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Appendix 11.1

Bedrock Geology

Figure 3

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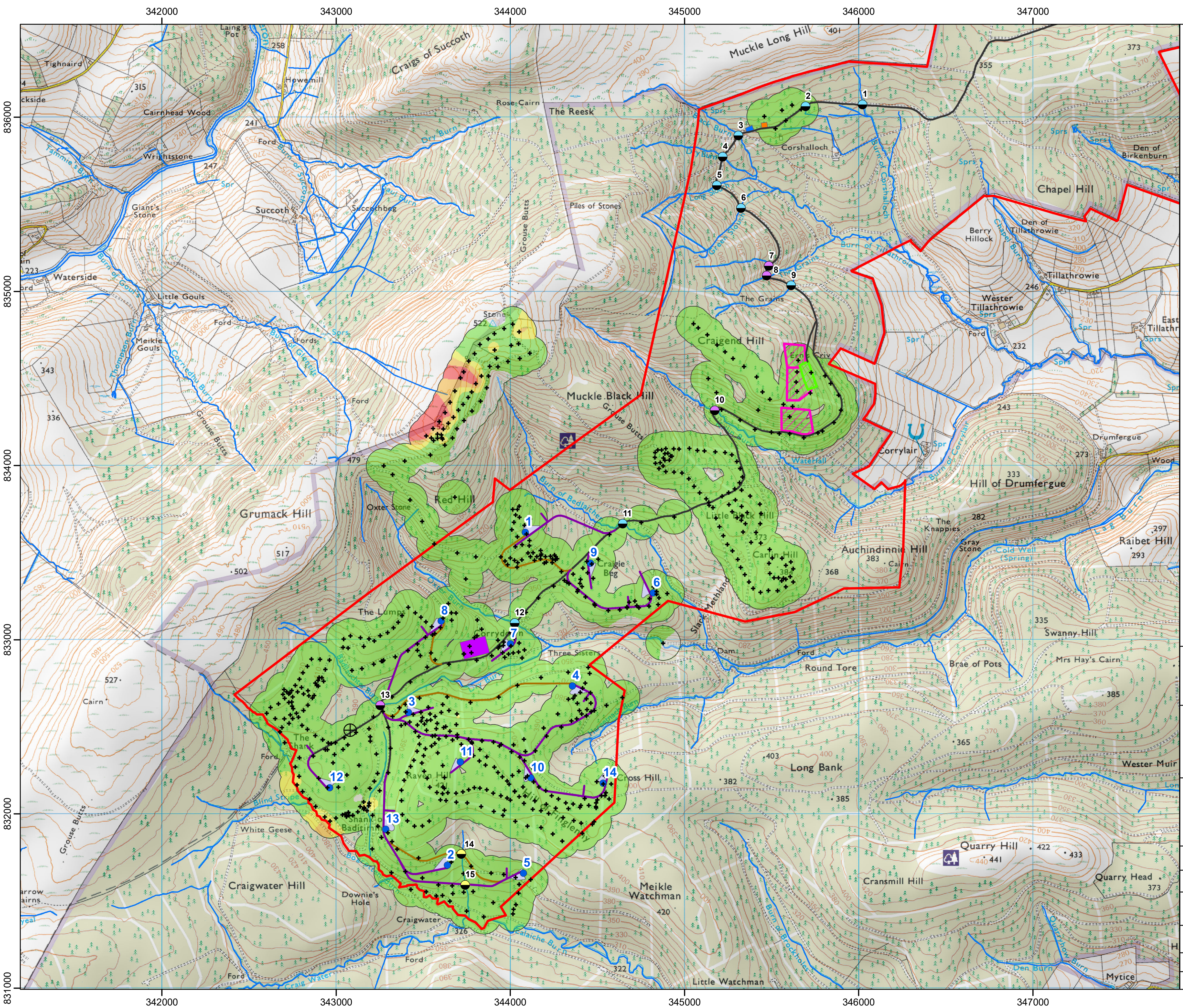
Ref: CLON_3_Bedrock_Geology_190903wr



Legend

- Site Boundary
- Proposed Turbine Locations
- Proposed Met Mast Location
- Proposed Access Track
- Alternative Access Track
- Existing Access Track
- Existing Substation
- Proposed Substation
- Proposed Laydown Area
- Temporary Construction Compound
- Existing Borrow Pit
- Proposed Borrow Pit Search Area
- Proposed Crane Hardstanding
- Existing Water Crossing
- Existing Water Crossing with Additional Works
- New Water Crossing
- Watercourse
- Peat Probe Location

Peat Depth (m)

- 0
- 0 - 0.5
- 0.5 - 1
- 1 - 1.5
- >1.5

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0 0.25 0.5 1 Km

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Appendix 11.1

Peat Depth Plan

Figure 4

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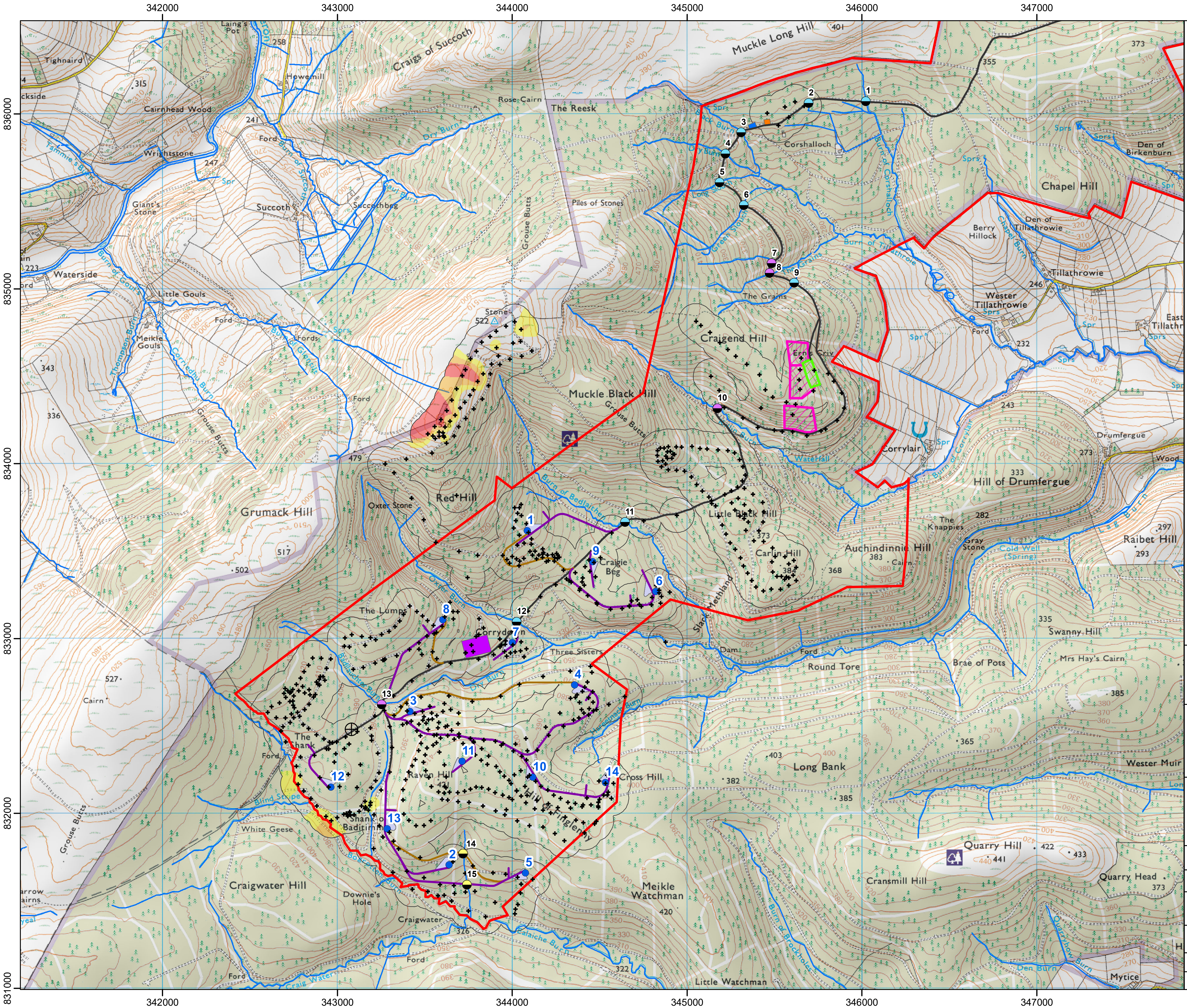
Ref: CLON_4_Peat_Depth_Plan_190903wr



Legend

- Proposed Turbine Locations
- Site Boundary
- Proposed Met Mast Location
- Proposed Access Track
- Alternative Access Track
- Existing Access Track
- Existing Substation
- Proposed Substation
- Proposed Laydown Area
- Temporary Construction Compound
- Existing Borrow Pit
- Proposed Borrow Pit Search Area
- Proposed Crane Hardstanding
- Existing Water Crossing
- Existing Water Crossing with Additional Works
- New Water Crossing
- Watercourse
- Peat Probe Location

Peat Depth (m)

- 0.5 - 1
- 1 - 1.5
- >1.5

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0 0.25 0.5 1 Km

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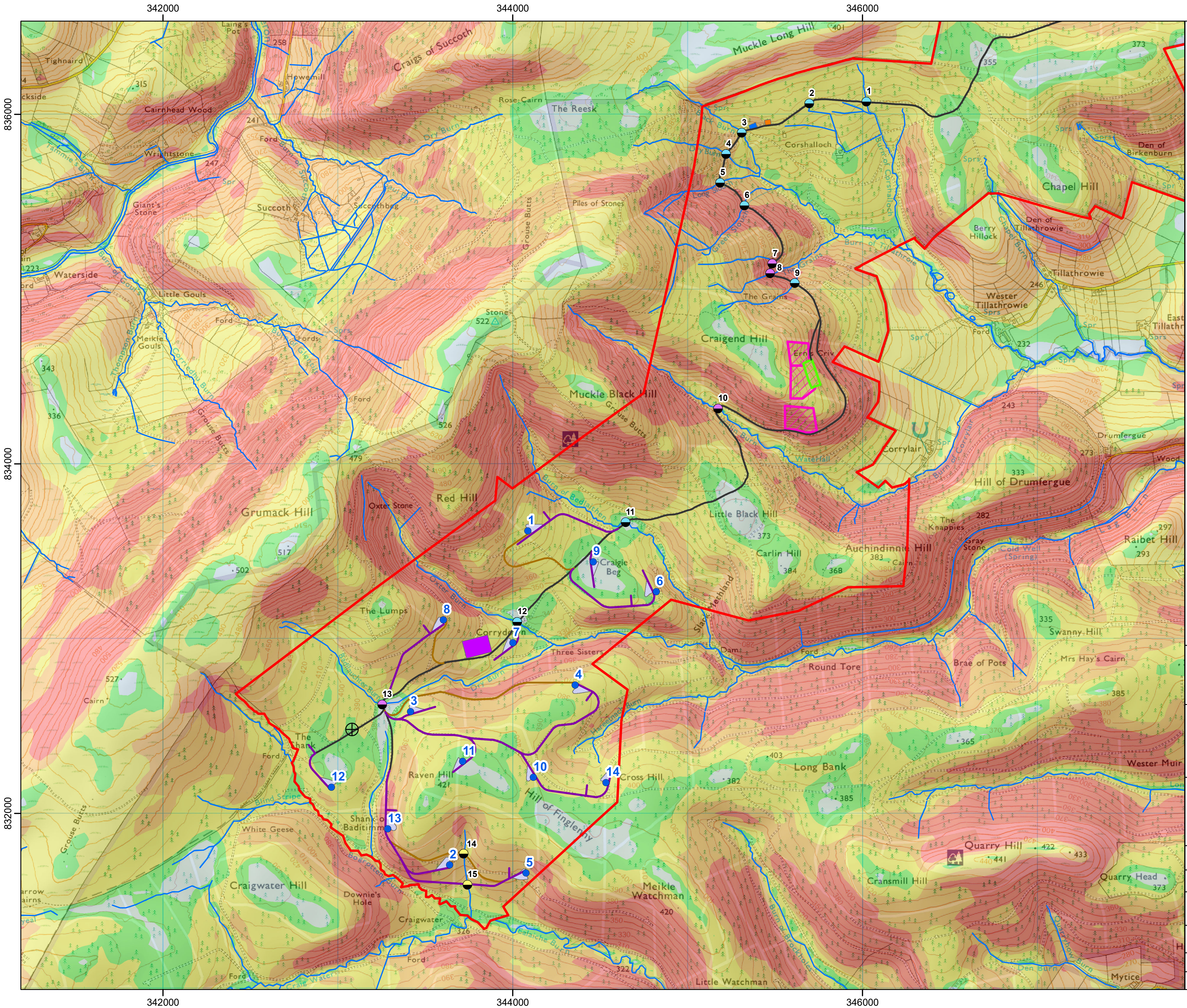
Appendix 11.1

Peat Depth Plan >0.5m

Figure 5

Date: November 2019 | Prepared By: WR

Ref: CLON_5_Peat_Depth_50cm_190903wr



Legend

- Site Boundary
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- Proposed Substation
- Proposed Laydown Area
- Temporary Construction Compound
- Existing Borrow Pit
- Proposed Borrow Pit Search Area
- Proposed Crane Hardstanding
- Existing Water Crossing
- Existing Water Crossing with Additional Works
- New Water Crossing
- Watercourse

Slope (Degrees)

- 0 - 2
- 2 - 4
- 4 - 8
- 8 - 12
- >12

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0 0.25 0.5 1 Km

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Appendix 11.1

Slope Plan

Figure 6

Date: November 2019 | Prepared By: WR

Ref: CLON_6_Slope_Plan_190903wr

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