Chapter 9

The geotechnical reports

9.1 *Digest of Galway County Council report*

THIS IS A COMPILATION of three reports apparently commissioned by Galway Council. It includes an executive summary giving details of the Council's actions and conclusions in response to the landslide of 16 October 2003, a geotechnical assessment of the wind farm site by BMA Geoservices Ltd, a single-page report by Michael Rogers, Senior Lecturer in Civil Engineering at the National University of Ireland, Galway and an assessment of the environmental impact of the 16 October landslide by Máire Ní Chionna (affiliation not stated).

After preliminary inspections of the site by Galway Council and the National University of Ireland (NUI), BMA Geoservices Ltd were commissioned to carry out an assessment of landslides at the site. They started on site on 25 October 2003 and the work was carried out over the following three months. The report includes failure analyses for two turbine locations, a more general site assessment and a conclusion. This includes recommendations for the conduct of any future construction.

The failure analyses focus on the landslides near Turbines 17 and 68 and are based on the assumption that, for each location, stockpiling of excavated material resulted in a rotational slip failure which in turn mobilised a translational failure of the entire 250m slope between the turbine base in question and the next access road downslope. Factors of Safety (FoS) are calculated using the method of variably inclined inter-slice forces (Bishop 1955) and translational slope stability analysis (Janbu 1957).

The FoS (Carling 1986) can be expressed as:

$$F = \frac{\text{the sum of the resisting forces}}{\text{the sum of the driving/disturbing forces}}$$

Values of F much greater than unity indicate a stable slope, with the degree of confidence in stability declining as the ratio approaches unity. Values of $F < 1$ indicate slope failure.[1]

Data for surface slope and peat thickness were derived from existing maps[2] and peat strength values for the upper, middle and bottom peat layers at each turbine site were estimated on the basis of 'a reasonable assessment of the available data' as:

	Peat strength (kPa)	
Site	T68	T17
Top 0.5m	12	8
Middle 2.5m	6	6
Bottom 0.5m	2.5	

The loading condition investigated was the placement of a 20 kPa load (equivalent to two metres of peat or one metre of peat plus 0.5 metre of glacial till) on the downslope side of each turbine base and the stability threshold was set in accordance with BS 6031 (1981), at FoS = 1.4.

1 Carling (1986) calculated *F* values for Pennine blanket peat which were in the range two to six except at the toe of one failure ($F = 0.93$).

2 One metre contour maps and Malone, O'Reagan McGillicudy Drawing Ni 20206-01, dated 5/06/02.

The results indicated that the placement of a 20 kPa load of excavated material on the peat surface downslope of each of the two turbine sites would reduce FoS against initial rotational failure from a value 'significantly greater than' 1.4 to 0.98 at T68 and 0.99 at T17 and thus could account for the failures that had occurred.

Elsewhere (e.g. Section 5) in the Galway Council report, other possible causal factors are listed but no detailed analyses of their effects are performed. These are:

- the uncontrolled discharge of water from over-pumping of the excavated turbine bases above and around the area of the failed slope (which) may well have resulted in a reduction in the natural peat strengths at the failure locations;
- the blocking or removal of pre-existing drainage paths throughout the site (which, again) may well have resulted in a reduction in the natural peat strengths at the failure locations; and
- vibrations from site activity.

The significance of weather conditions is briefly recognised in two places but they are somewhat contradictory and there is no evidence of a detailed analysis. Specifically, the slides are stated to have occurred during 'a period of abnormally low rainfall' (Section 2) and 'a period of relatively dry weather' (Section 6).

Attention is paid to the condition and future management of the material that slipped at T68. This is considered now to have no effective strength. Although the peat flow had been eventually contained by the creation of new up-slope drainage channels to divert runoff away from the slip area and the construction of bunds to retain the slipped peat, it was still considered necessary to apply permanent remedial measures to prevent further movement of both detached peat rafts and of material from the sides of the slip scar.

Some assessment of the stability of other excavated turbine sites was also undertaken. Evidence of minor bearing failures (areas that appeared to be in the initial stages of rotational failure) at T23, T29, T66 and T69 are noted, along with evidence of minor ground (peat) instability associated with the removal of lateral support at a significant number of turbine base excavations. The possibility that further instability may result from continued construction activity at the site is underlined but the authors consider that 'this risk can be reduced by the adoption of appropriate construction techniques and on-site practices'. In conclusion, the authors state that:

> . . . it would appear that evidence of instability prior to the main failure on the 16th October was not adequately taken into account in the continued construction at the site, nor were lessons learnt and/or immediate preventative/remedial measures adopted,

and advise that 'any future development at the site should take cognisance of the probable major causes of the failure'. Specific advice on future working practices includes:

- prohibition of the placing of any material on the peat – ideally all such material should be taken off site and/or disposed of in a suitable, non-sensitive location;
- maintenance of the natural and engineered drainage of all portions of the slope and the turbine bases be; if blocked it should be reinstated on an on-going basis;
- a comprehensive individual stability analysis, exploring a variety of potential failure mechanisms prior to starting construction of any new road or turbine base – incorporating the option of moving or abandoning turbine sites where excessive slope angle, substantial peat thickness or low-strength peat may give rise to lower-than-acceptable FoS for construction;
- giving careful consideration to de-watering and wall support in excavations; to the standings for heavy construction plant; and to the construction and drainage (lateral and transverse) of access roadways;

- minimising vibrations through careful monitoring of blasting and prudent traffic management;
- giving attention to the possibility that the felling of trees may influence ground conditions and help promote instability;
- development of a programme for stabilising existing failures and monitoring for further ground movements, with comprehensive documentation; also development of detailed plans for permanent remediation of failures throughout the site;
- monitoring and reporting of all site activities.

The Michael Rodgers report begins by endorsing the conclusion that the landslides at T17 and T68 were caused by construction operations as stated in the developer's own report (AGEC 2004) and then lists 13 points the developer must address 'for the safe and successful completion of the Derrybrien wind farm project'. Many of these are similar to those listed by BMAG and cover the stabilisation of existing failures and flows, the effects of rock blasting and the immediate removal of excavated material to safe repository locations although, for this, attention is also drawn to the method of deposition at the repositories. For each turbine base, access road and repository location, the developer should arrange:

- detailed geotechnical investigation including piezometric measurements;
- stability analyses for construction, long-term loads and excavated material loadings;
- construction methods to safely bear all potential loadings including those introduced during construction work, as well as by cranes, wind turbines and wind loads;
- drainage, provision for settlement of suspended matter and monitoring (physical movement, pore water pressures, environmental parameters) throughout the construction and life of the wind farm project and thereafter.

The environmental impact assessment reports on ecological damage to the Owendalulleegh River, Lough Cutra and downstream water bodies arising from the 16 October 2003 landslide and sets out the following requirements for mitigation and avoidance of further pollution:

- continued water quality monitoring and ecological assessment;
- river rehabilitation plan;
- study of effects of peat loading on Lough Cutra;
- prevention of remobilisation of slipped material into streams;
- any further drainage, movement of excavated material and works that may be undertaken to complete the wind farm project in the future must be undertaken in a manner that eliminates risk to the water quality and ecology of downstream areas.

9.2 *Digest of AGEC report*

The report prepared by Applied Ground Engineering Consultants Ltd (AGEC) is presented in two parts, the first describing their initial inspection of the landslide of October 2003 and the second their post-landslide appraisal of the whole site.

AGEC was first engaged on 17 October 2003 by Electricity Supply Board International (ESBI) to provide an opinion on the cause(s) of the T68 failure on the basis of a walkover site inspection. This was carried out on 18 October, two days after the initial failure, so that the report includes observations made soon after the failure and before any rainfall. A number of these observations have been noted elsewhere in the present report. Factors likely to have contributed to the failure were identified as:

- Location in a natural drainage line which concentrates both surface and sub-surface water flow;

- Zone of weaker peat at the centre of the drainage line (identified by in situ strength testing;
- Loading of the peat surface by a floating access track at the head of the failure.
- Loading of the peat surface by placement of 'arisings' (excavated material) from the excavation at T68 on the slope at the head of the failure;
- Water-filled excavation giving rise to transmission of water along the base of the peat leading to a build-up of water pressure at this level, reducing effective stresses;
- Drainage works at the road some 300 metres directly downslope, involving severing of the road to install a drainage pipe, which locally removed lateral support in an area of wet peat;
- Previous creep instability, as suggested by knee-bends oriented into the drainage line on some trees which, over time, might have reduced shear resistance within the peat;
- Forestry plough and drain channels which dissected the vegetative upper layers of the peat creating lines of potential surface weakness; once failure was initiated, the peat rafts generally detached themselves along these.

Over-pumping of water from the excavation onto the downslope was considered but dismissed, since 'site representatives . . . indicated that they (were) unaware of any over-pumping at this location'.

Even at that time, it was not possible for the surveyors to say with certainty that failure was initiated immediately south of T68. However, they did classify the failure as a translational slide of peat whose basal failure surface was in the lower part of the peat layer, typically 200 to 400 mm above mineral soil. After consideration of possible mechanisms, they conclude that construction activity within the head of a shallow valley (flush), which they regard as an area of 'poorer' ground, triggered a localised failure of in situ peat which, in turn, led to progressive and then runaway failure.

The subsequent stability assessment of the whole of the Derrybrien wind farm area was conducted during the remainder of October and the first half of November and involved:

1. in-situ shear vane testing;
2. cone penetration testing;[3]
3. resistivity survey (APEX Ltd) to locate base of peat and rockhead;
4. driven-in piezometers (AGL Consulting Engineers);[4]
5. walkover survey examining 200 x 200m cells for peat thickness, slope, drainage and evidence of failures.

The walkover survey indicated several clear signs of previous ground instability including:

1. slumping of recently excavated 1.5m deep V-ditches at T14, T53 and T54;
2. localised tension cracking, bulging and slumping of excavated faces at 10 turbine base sites;
3. heaving, cracking and distortion of the peatland surface (identified as incipient non-circular shear failure) at T66 and T29 associated with arisings from turbine base excavations being dumped on the adjacent peat surface;
4. that the volume of peat involved in the slide at T17 (adjacent to T68) was 2,000 m^3, that this slide had occurred on 02 October 2003 and that it had left a 140m scar.

Signs of instability were recorded at sites with surface slopes ranging from 0 to 8 degrees and with peat thickness from 1.5 m to 3.5 m. Fig 9.1 shows peat thickness, the stage of excavation reached and whether any signs of instability were recorded, for all 71 turbine sites. No excavation had been carried out at 28 sites. Of the 43 sites where work had been carried out, 15 showed signs of local instability

3 This was abandoned early due to equipment breakdown and no results are reported.

4 Piezometers are used to assess hydraulic pressure below the ground surface. However, their specific purpose in this study is not stated and no results are reported. They appear to consist of 19mm internal diameter standpipes with ceramic tips inserted to the base of the peat and periodic reading is requested on behalf of Ascon Ltd.

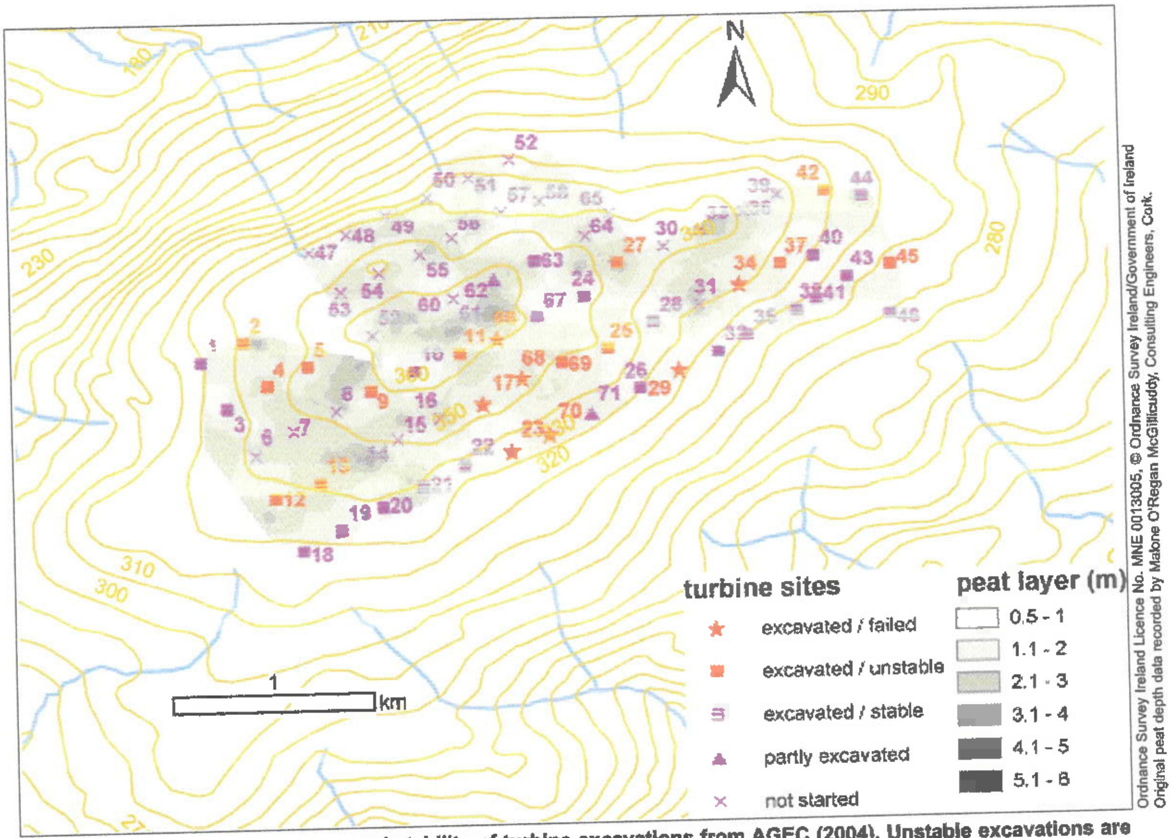

Figure 9.1: Summary of the stage and stability of turbine excavations from AGEC (2004). Unstable excavations are those where localised cracking or slumping has occurred. Sites marked as failed are those where downslope movement of peat has occurred or where incipient rotational failures were recorded.

and downslope peat movement had occurred at a further five (table 9.1): 47 per cent of the sites excavated show some evidence of instability.

Additional evidence of instability, in the form of possible old peat slides, was recorded at four sites (47 to 50 inclusive) that had not yet been excavated. These are located above a scarp slope to the north, with surface gradients ranging from 1 to 18 degrees. Water is channelled into this area by forestry furrows and drains and there are numerous springs along the scarp line.

It was also noted that a significant number of the excavated turbine bases were water-filled, that they had no apparent drainage and that there did not appear to be a formalised drainage network on the site. This situation was considered likely to give rise to instability.

The peat was found to lie directly on bedrock (24% of probes) or a thin layer of weathered rock/glacial till (59% of probes). Whilst the uppermost c. 1m was fibrous, possibly desiccated and so relatively strong and stiff, the basal peat was soft and amorphous (BS:5930/H6-H8). Thus, factor of safety (FoS) was calculated for the (weaker) lower peat layer using the infinite slope analysis approach of Skempton and DeLory (1957),[5] which apparently originates from the same conference proceedings volume as the Janbu approach employed by BMA Geoservices but assumes translational sliding. Relevant field measurements were slope, peat thickness and shear strength; the disturbing forces were the weight of the ground, water and construction loading while the resisting force was the shear strength of the ground along an assumed failure surface, measured using hand-held and/or mechanical shear vane apparatus. As in the BMA analysis, the minimum FoS required for stability was 1.4.

The stability analysis was carried out at two resolutions:

5 Apparently, the assessment was 'verified by more rigorous stability techniques in Talren compter program' but no further details are given.

Turbine site #	Slope (degrees)	Peat depth (metres)	Evidence of instability
2	2 to 6	>2	Tension cracks upslope of excavation.
4	2.5	>2	Tension crack upslope of excavation; upslope face of excavation reinforced with large boulders.
5	2.5 to 5	>2	Upslope face of excavation reinforced with boulders and stone-fill.
9	0	>2	Slumping of peat in sides of excavation.
11	1	>2	Localised failure at northeast of excavation.
12	3	?	Tension crack around north and east side of excavation.
13	3	?	Tension crack around north and east side of excavation
17	2 to 4	3	Tension crack to east; peat slide origin 10m east of excavation; downslope movement of 200m^3 of peat.
23	2 to 4	>1.5	Heaving (2m) downslope of arisings.
25	3	1.8	Slumping of peat in northeast corner of excavation; tension cracks in access road adjacent to arisings piled downslope of excavation.
27	2 to 3	>2	East-west tension cracks (along ridge) to north of excavation.
29	2 to 4	>2	Cracking and heaving of peat (in forestry) downslope of slumped arisings.
34	3 to 6	>2.4	Flow of excavated material for 80-130m downslope.
37	2 to 3.5	1.5 to 2	Localised failure at southwest corner of excavation.
42	4	2.1	Tension crack upslope; slumping of northern face of excavation and arisings.
45	2 to 4	>2	Localised failure at southwest corner of excavation.
66	3 to 5	>2	Tension cracks upslope; bulging of upslope wall of excavation (including repaired slip); road subsidence; heaving (1m) of peat (in forestry) downslope of arisings; downslope peat movement of 1-3m.
68	2 to 6	3.5	Tension cracks downslope; road subsidence; downslope peat movement of 1.3 km.
69	8	>2	Base only partially constructed but there were localised 5-6m tension cracks around the excavation and slumping of arisings. Ponding of water from over-pumping was also observed.
70	5 to 8	2.5	Tension cracks to east and west; downslope movement of peat and road by 30-40 m.

Table 9.1: Summary of indications of peat instability associated with individual turbine base excavations, derived from Geotechnical Mapping Sheets appended to the AGEC report.

1 for (typically) 200m x 200m cells centred on the turbine base locations and covering the whole site;

2 for 50m x 50m cells, again centred on turbine bases.

For each cell, the analysis was based on average slope and peat thickness and the lowest shear strength measured within the cell.

Two loading conditions were considered:

1 no loading and

2 construction loading of 10kPa, equivalent to 1.0m of peat arisings or half the loading considered in the AGEC analyses.

For the scenarios considered, FoS fell below the threshold of 1.4 without surface loading for four 200m cells (T2, T5, T34 and T69). These four cells and one other (T18) were deemed susceptible to failure if subjected to construction loading equivalent to 1.0m of peat arisings. Adding the three

already-failed cells (T17, T68 and T70), the risk of failure under loading for the area as a whole[6] appears to be 8/71 or just over 11%. Eleven (15.5%) of the 50m cells[7] had already failed or were likely to fail under load.

The report concluded that construction of the wind farm could be completed safely provided that 17 revisions to construction work practice are adopted. The key recommendations given in the executive summary are:

1. The placement of concentrated loads on marginally stable ground and concentrated water flow onto peat slopes and unstable excavations to be avoided;
2. A geotechnical expert to be on site full-time during construction;
3. Ground investigation and movement monitoring to be ongoing;
4. Modified construction practices to be adopted that do not adversely affect stability;
5. A robust drainage plan to be developed and implemented;
6. Periodic geotechnical inspections throughout the lifetime of the site.

The detailed recommendations prescribe support of excavations and piping/filling of ditches to prevent the development of tension cracks and subsequent collapse of the peat. They draw attention to the particularly steep local scarp slopes at the northern side of the site and to the vulnerability to failure of peat in natural flushes ('shallow valleys') and prescribe cautious working in all cells where their FoS calculations give values of less than 1.4. They recommend the development of method statements for working practices, contingency plans for dealing with 'poor' ground and formalised reporting procedures. They also indicate a requirement for 'details of the effectiveness of measures (adopted for stabilisation of the T68 failure scar) for long-term stability'.

9.3 *Overall opinion on the BMA/AGEC geotechnical investigations*

The AGEC and the BMA Geoservices reports are similar in that both recognise that a number of factors may contribute to the loss of stability of peat but explore in detail only failures initiated by loading of the peat surface with excavated material. To do this, they apply theoretical approaches based on methods developed in the 1950s for mineral soils. They differ in the assumed slip mechanism, BMA exploring a scenario where the slides at T17 and T68 were initiated by rotational failures whilst the AGEC analysis employs a translational slip model. Nonetheless, the FoS values derived for T17 and T68 by BMA Geoservices coincide exactly with those calculated for 50 metre cells under load by AGEC.

The BMA work employed data collected during the pre-development site survey and was essentially desk-based. It is rather puzzling that a study of this type was not considered relevant or practical in the early stages of planning. In view of the outcome of the more extensive field-based AGEC survey, it seems likely that such an exercise would have been sufficient to indicate potential instability of the peat cover on at least 10 to 15 per cent of the area to be developed.

In addition to field-based FoS calculations, AGEC collected detailed evidence of instability throughout the wind farm site but did not attempt to relate these two types of data. Appendix 1 lists the data presented for slope, peat thickness, shear strength and FoS, together with any direct evidence of instability observed, for each turbine site and a summary is given in table 9.2. It should be noted that 28 turbine sites have not yet been excavated. There are signs of instability, in the form of old peat slips, at five of these and settlement has occurred as a result of installation of wind farm infrastructure (roads and drains) at another six. However, the sites for which the lowest FoS values were calculated are amongst those for which no evidence of instability was recorded. The highest FoS value (121.26 without loading, 79.30 with loading) was derived for the 200 m cell centred on the proposed site for T61, where a tension crack has appeared due settlement of the access road. FoS

6 Cells T2, T5, T17, T34, T58, T69 and T70.

7 Cells t2, t17, t18, t34, t47, t51, t66, t68, t69, t70 and t71.

already-failed cells (T17, T68 and T70), the risk of failure under loading for the area as a whole[6] appears to be 8/71 or just over 11%. Eleven (15.5%) of the 50m cells[7] had already failed or were likely to fail under load.

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7 Cells t2, t17, t18, t34, t47, t51, t66, t68, t69, t70 and t71.

	Turbine No	Slope (deg)	Depth (m)	Shear strength (kPa)	FoS without load	FoS with load
Sites that have not yet been excavated						
No evidence of instability	6,7,8,15,16,30, 31, 36, 39, 51, 52, 56, 57, 58, 59, 64, 65	1.5 to 4	0.85 to >2.4	5.7 to 13.2	1.37 to 9.34	1.11 to 6.82
Signs of previous instability (old peat slips)	47, 48, 49, 50, 54	1.5 to 3.5	2+	5.7	1.65 to 7.6	1.21 to 5.69
Signs of road settlement and / or collapsed ditches	14, 33, 53, 55, 60, 61	0.1 to 4	>2 to 3.1	4.5 to 6.6	2.03 to 121.26	1.5 to 79.3
Excavated sites						
Cracks around excavation and/or wall instability	2, 4, 5, 9, 11, 12 , 13, 17, 25, 27, 37, 42, 45, 66, 69, 70	1 to 8	1.75 to 3	3.8 to 9.4	0.83 to 9.9	0.64 to 7.6
Bearing failure (associated with surface loading by arisings)	17, 23, 25, 29, 66, 68	3 to 5	1.8 to 3.5	3.8 to 9.65	1.27 to 4.11	0.98 to 2.62
Excavated without failure of *in situ* peat (including sites with unstable arisings)	1, 3, 10, 18, 19, 20, 21, 22, 24, 26, 28, 32, 34, 35, 38, 40, 41, 43, 44, 46, 62, 63, 67, 71	0.1 to 6	1 to (>)2.5	2.8 to 11.6	0.96 to 88,83	0.71 to 64.02

Table 9.2: Evidence of instability at turbine-base excavations as recorded by AGEC (2004). (The figures in red are below the FoS threshold of 1.4.)

values for sites that have been excavated without failure cover a wide range, whose lower end overlaps the ranges of FoS calculated for sites that have failed.

Thus, the FoS calculations that have been completed so far do not appear to provide a totally realistic representation of the site's response to wind farm construction work. This is not entirely surprising since the models employed to represent surface loading, the shear strength of the peat and the failure mechanism represent only parts of the 'real-life' situation.

First, both reports consider only scenarios involving static loading of the peat surface with material (arisings) excavated from the turbine sites. The effects of other types of loading are not taken into account; at Derrybrien these include:

- Temporary loading by construction and maintenance machinery. Once the excavators required for installation of the turbine bases have finished working, heavy craneage will be brought in to erect the turbine masts. It would seem prudent to perform some preliminary theoretical assessment of the ability of roads and hard-stand areas to support these machines;
- Moving loads. These include forestry trucks, excavators and cranes using the floating access roads;
- Sudden loading associated with blasting at borrow pits;
- The standing crop of trees. It would seem advisable to explore not only the influence of the existing forestry overburden on the outcome of the stability calculations but also to take into account the prospect that the trees will be felled in the near future (section 8.4). At present, the piecemeal felling that has taken place to make way for turbine sites and access roads, in

addition to the location of some of the turbine bases in forestry rides, introduces local variations in surface loading that could also be significant for site stability.

Secondly, both reports assume fixed values for the shear strength of peat. BMA Geoservices incorporate in their analysis allowance for the significant difference in strength between the acrotelm and the catotelm, without consideration of the fact that the acrotelm at Derrybrien has been fragmented by ploughing for forestry. For this reason, the 'worst-case' approach taken by AGEC, which bases FoS calculations on the lowest strength measured in the profile and within the cell under consideration, is preferable. However, no account is taken of temporal variations in strength, which can be anticipated in both the short and the long term:

- Peat is known to exhibit highly erratic strength properties and these appear to be linked to water content. Undrained bog peats generally have water contents in excess of their liquid limits, which lie in the range 800-1500% (Hobbs 1986) and shear strength increases as water is removed (Sharma and Bora 2002). At many locations at Derrybrien, the water content of the peat on any particular day will depend upon the degree to which it is influenced by artificial drainage as well as by weather conditions. Thus, shear strength at any location may well change from day to day. A rigorous stability assessment should, therefore, interpret 'one-off' shear vane measurements in conjunction with water content data, using these two measurements to predict the lowest shear strength that the peat is likely to exhibit under 'worst-scenario' weather conditions.
- Hobbs (1986) pays considerable attention to consolidation processes in peat which, in contrast to those in mineral soils, are dominated by secondary compression. In consequence, he concludes that the shear strength of peat under a maintained load (e.g. due to drainage or the presence of a road or other structures, as well as forestry) can be expected to vary not only with the degree of loading but also with time.
- Strength can also be expected to decline as humification of the drained peat proceeds, due to the breakdown of both plant structures and the adsorption complex (section 2.3).

BMA Geoservices recommend further stability analyses, 'exploring a variety of potential failure mechanisms'. Several alternative mechanisms can be suggested (sections 4.2 and 5.2 and Warburton 2004) but none have been considered in the stability assessments that have been carried out so far. Factors that require further investigation include:

- The influence of ponded water on shear strength;
- The role of cracks, due to both forestry and turbine/road construction, in promoting build-up of subsurface pressure during sudden intense surface irrigation. Even if wind farm construction methods are modified to prohibit indiscriminate manipulation of drainage patterns and over-pumping of water from inundated turbine bases, such conditions could still arise during a severe thunderstorm centred on Cashlaundrumlahan;
- The stability of unsupported peat faces on slopes.

There is a notable difference in the degree of confidence that each report places in the prospects for safe completion of the project. Whilst the contractors engaged by the developer (AGEC) indicate that 'construction of the Derrybrien Wind Farm can be completed safely' and Michael Rogers submits recommendations 'for the safe and successful completion of the Derrybrien wind farm project', BMA Geoservices are much more cautious in their conclusion that:

> . . . the risk (of further instability) can be reduced by the adoption of appropriate construction techniques and on-site practices.

This seems to be very much in line with the advice published by Levine-Frick (2001) on the use of organic soils for structural engineering purposes. These are regarded as highly variable materials,

with shear strength and consolidation characteristics that are hard to predict. They undergo reversible shrinkage and swelling so that their use can result in large differential settlement and ground cracking. Most also exhibit secondary compression settlement behaviour which can continue for over 20 years. Materials containing more than two percent by weight of organic matter are regarded as unsuitable for structural engineering purposes and geotechnical earthwork specifications generally require that material used for structural fills should be free of organic matter and other 'deleterious' materials. Where organic soils are unavoidably involved, a thorough investigation of their engineering characteristics and proper site treatment is essential to the success of any civil engineering project. Evaluation of the engineering characteristics of organic soils typically involves geotechnical tests such as Atterberg limits,[8] moisture content and compressibility in addition to shear strength measurements.

Peat, the most organic of organic soils, is generally characterized by high moisture content, high plasticity, high compressibility even under relatively light loads, high shrinkage, low permeability, low density and low shear strength. These characteristics have been explored in more detail by Hobbs (1986), who points out that the critical pressure (at which shear failure occurs) for peat depends upon past morphological, climatic, biological and human influences and also on age. It is also unpredictable, most peats exhibiting a critical pressure which cannot be entirely accounted for by past loading.

Both reports recommend that geotechnical expertise should be permanently available on site during any further construction work. It is not clear, however, that an expert can be expected to foresee all the potential repercussions of on-site practice when the material he or she will be dealing with is acknowledged as unpredictable in engineering terms nor that it will be possible to prevent progression of an incipient failure even if its presence can be identified. Moreover, since the properties of the peat change with time, it seems likely that some disastrous consequences could arise long after the activities that give rise to them.

Neither of the geotechnical reports expresses complete confidence in the possibility that the peat that has already slipped can be permanently stabilised and thus prevented from entering the Owendalulleegh River at some time in the future. This is underlined by the request from AGEC for information on the long-term effectiveness of the stabilisation techniques employed. If it is not certain that the existing slide has been, or can be, made permanently safe, it would seem highly inadvisable to proceed with any work that carries even a small risk of destabilising it. Presumably the same problem would arise in respect of any new failures that might occur in the future.

Thus, for the long-term security of Derrybrien, it would seem essential that there should be a more exhaustive stability assessment taking into account all possible alternative failure mechanisms with long-term projections covering the lifetime of the project and the situation beyond decommissioning, before any further work on construction of a wind farm there is considered.

Whatever degree of confidence they place in their conclusions, the reports are unanimous in recommending formalised drainage as a means of improving the stability of the site. It would aim to provide water control throughout the site during the lifetime of the development and would mean that surface water flow will be concentrated in ditch-lines. It would also result in more intense overland flow if water volumes ever exceed ditch capacity or if a ditch became blocked. It is not clear that drainage will necessarily ensure the stability of peat under all conditions. For example, the slide at Derrybrien occurred during dry weather and involved an area of peat with many drain lines. These would also cut through the acrotelm, constantly dewatering it while also causing localised oxdation.

Whilst Warburton (2004) lists shear failure, buoyancy effects and liquefaction as contributing to some failure events, he links others with contraction and rupture of the surface due to drying out (section 4.2). The role of cracked peat in initiating some failures and the association of cracking with

8 Depending on the amount of water present, cohesive soils such as peat can exist in three states: as a liquid slurry, a plastic substance or a solid. These states are distinguished empirically by identifying the so-called Atterberg limits. The 'liquid limit' is the relatively high water content at which the soil changes from a plastic to a liquid state, losing its load-bearing ability (Endurazyme 2000/4).

Plate 9.1: The excavation at T17 lies on the line of an already-existing double ditch and so is well drained. Nonetheless, it was the site of the first substantial bog slide.

drying of peat under forestry casts further doubt on the premise that drainage is necessarily the effective solution in this case. Alarm bells really begin to ring when we realise that the T17 site is extremely well drained because it lies between, and connects with, two ditches that run almost directly downslope (plate 9.1) but that a 2,000 m^3 slide originated here just two weeks before the T68 failure (see next section).

Michael Rodgers' proposal of 'drainage for each access road, all turbine bases and each repository site . . . continuously for the life of the windfarm project and thereafter' directly contradicts the statements made in the Environmental Impact Assessment documents (section 7.5.3) to the effect that, 'construction of turbine bases does not result in long-term drainage of the surrounding peat.'

We now have the prospect that the whole of the summit peat blanket of Cashlaundrumlahan will be comprehensively and permanently drained. This scenario was not considered by the EIA reports (section 7) and introduces a whole set of new factors. For example, it is pointed out (sections 2 and 3.3.1) that drainage results in the resumption of aerobic decomposition so that the peat is progressively converted to carbon dioxide and water and, if it does not fail and slide first, disappears *in situ*. Many of the turbine bases and their anchoring overburden would thus be left standing proud of the ground surface and, apart from the loss of habitat and after-use potential for Cashlaundrumlahan, there would be associated changes in the quantity and quality of runoff feeding the surrounding streams and rivers.

Moreover (section 7.5.8), the release of carbon dioxide tends to cancel out the principal perceived advantage of wind power over energy derived from fossil fuels in reducing greenhouse gas emissions.

The volume of peat within the wind farm boundary is estimated, on the basis of AGEC data,[9] at 7,100,000 cubic metres. Oxidation of this quantity of peat would almost totally cancel out the projected saving in emissions from 10 years of operation of the entire wind farm – provided the CO_2

9 71 turbines, each occupying an area of 4 ha (200 x 200 m) and average peat thickness 2.5 m.

savings quoted by the developers for the Kilronan facility can be matched at Derrybrien (tables 7.1 and 7.2). If the more conservative UK emission savings figures are used, peat oxidation would cancel the CO_2 saving anticipated from just under 20 years of wind farm operation. This is in addition to the non-peat CO_2 emissions incurred in the manufacture, transport, installation, maintenance and decommissioning of the turbines. It is understood that the projected life of the wind farm is 20 years. It would seem that it will, in practice, have an approximately neutral effect on CO_2 loading of the atmosphere and that, contrary to the claims made in the non-technical summary of the EA, the 'do-nothing' option of no development could be just as effective.

The story that has unfolded in this report seems to cast doubt on the wisdom of wind farm development on any area of deep blanket peat. Whilst the prospect of a few 15 x 15m undrained holes accommodating turbine bases does not at first sight seem incompatible with the processes that maintain the peat blanket, the reality of wind farm construction and maintenance requires comprehensive disruption of a site's hydrology through drainage and thus of the peat itself – either relatively safely through wastage or, as the residents of Derrybrien have discovered, through catastrophic failure.

Summary of Chapter 9

1 Both geotechnical reports recognise that a number of factors may have contributed to loss of stability at Derrybrien. However, both reports then only investigate a single factor, and calculate Factor of Safety (FoS) values on this limited basis.

2 Both consider only static loading, whereas other types of loading include temporary loading by machinery, moving loads, possible sudden loads caused by blasting in the quarries, and the standing crop of plantation forest.

3 The BMA analysis used pre-development data that could have formed a geotechnical analysis to accompany the EIS. It is not clear why such a report did not accompany the planning application.

4 The AGEC analysis used additional field-based data. Their analysis indicated potential stability over at least 10%-15% of the development area. However, they did not attempt to integrate information about stability with their field-based data.

5 Some turbine sites with very low calculated FoS values show no signs of instability whereas sites with higher FoS values do show such signs, suggesting that FoS values do not give a wholly realistic picture of stability in response to the construction and maintenance work.

6 Both reports assume fixed values (spatially and temporarily) for shear strength of the peat. This is not a valid assumption, particularly given that the peat is highly fissured beneath the plantation forest, that localised ponding clearly occurs from time to time, and that some unsupported faces are created.

7 As the properties of peat change with time, some significant consequences may arise long after the activities that give rise to them.

8 Hobbs (1986) observes that the critical pressure leading to shear failure in peat depends on a wide range of factors, not all of them quantifiable. The geotechnical reports recommend constant on-site geotechnical expertise, but it is not clear that such an expert could predict how, when or where particular operations might cause failure.

9 Neither report is completely confident that the peat already subject to failure can be permanently stabilised.

10 Both reports recommend formalised 'robust' site drainage as the means of stabilising the site sufficiently for work to continue. Given the tendency of such drainage to concentrate water flows, with the attendant resulting dangers should the drainage system fail, it is not at all clear that it would produce the desired result in, for example, conditions of extreme storm intensity. Indeed, the T68 slide involved drained peat and occurred during dry weather.

11 Intensive drainage of the site was not envisaged in the planning proposals nor considered in the decision process and introduces a whole new range of unconsidered factors.

12 Extensive, maintained drainage (even if it does not cause slope failure) will result in increased sedimentation and water quality within watercourses receiving water from the site. This will take the form of increased organic matter, mineral sediment, and increased water colour.

13 Drainage will also result in a substantial amount of carbon release from the oxidised peat. If the whole amount of peat within the Derrybrien site were to be so oxidised, it would equal the amount of CO_2 emissions likely to be avoided by 20 years of energy generation from wind power at Derrybrien, thereby cancelling out this benefit. The whole peat volume is unlikely to be lost in 20 years, but if the CO_2 emissions involved in construction, maintenance and decommissioning of the site are included, the figures look increasingly unattractive.

14 It would seem essential that an exhaustive stability assessment is made of the site, taking into account all possible failure mechanisms, with long-term projections covering the lifetime of the project and the situation beyond commissioning.

15 In the meantime, it would seem highly inadvisable to proceed with any work, including any form of drainage programme, that carries even a small risk of triggering further slope failure.

Chapter 10

A review of scenarios

THIS REPORT HAS CONSIDERED a number of issues relevant to the assessment of the environment at Cashlaundrumlahan but the question of slope stability is paramount. Issues such as noise or use of the hill by merlin pale into insignificance against the spectacular impact associated with the October 2003 bog slide. The key question, for which everyone is seeking an answer, is whether there is a possibility of further peat movement.

Two engineering reports have been produced, both recommending that work can continue on the wind farm provided certain actions are taken. This report has raised questions about both of these and highlighted a number of important issues yet to be addressed. In particular, it has made clear:

- the degree to which the peat surface has probably fractured and become potentially unstable beneath the extensive forest cover;
- the degree to which instability is evident elsewhere on the site;
- the considerable peat depths that remain on the hill summit.

10.1 *An integrated spatial analysis of potential instability*

By combining information about peat depths with data for surface elevation across the site and with the drainage patterns associated with watercourses, it is possible to begin to build up a picture of where there might be a high probability of instability on Cashlaundrumlahan.

Examining first the relatively simple combination of peat depth, slope and watercourses, peat depths are displayed in fig 10.1 in three categories:

- relatively shallow peat (0 to 2.2 metres),
- deep peat (2.2 to 3.2 metres)
- very deep peat (> 3.2 metres).

The two deeper categories together give a good picture of the main deep-peat areas on the site and it can be see that some of these areas 'point' (as it were) to the headwaters of streams that arise on the slopes of the hill, as indicated by arrows. These represent a form of 'avalanche corridor', a notion used in Alpine regions to identify areas at risk from snow avalanches. It does not follow that, if an area lies in such a corridor, there is a likelihood of an avalanche but it does highligh the areas that need to be monitored.

The central (wider) arrow represents the approximate path of the October peat slide (cf fig 8.1). It is evident that it was neither linked to the deepest peat deposits found on the site nor did it occur on a markedly steeper slope than is typical for other parts of the peat blanket.

The arrows represent possible pathways for peat movement, given the depth of peat and general landform at these points: one might say that there is a hypothetical predisposition towards peat movement in these areas. As with avalanche corridors, it does not necessarily mean that peat movement will occur, merely that the situation should be monitored. To turn this hypothetical predisposition into something more tangible, it is necessary to look at the behaviour of the peat in these areas.

The graphic also displays the locations of the turbine bases and assessments of their stability as

reported in AGEC's paper and categorised following the field visit made by the authors of this paper. It is apparent there are regions on the site where there is a combination of deep or even very deep peat and individual or clustered turbine bases displaying evidence of instability. (Note that the bases for the northernmost lines have not yet been excavated and it is not possible to say how many turbines between 47 and 58 might display signs of instability.)

The cluster of 'unstable' turbines round the main area of the bog slide (11, 17, 23, 66, 68, 69 & 70) is evident but so too is the small cluster (12 & 13) on much deeper peat in the south-west corner of the site and a group (2, 4 & 5) in the north-west corner, again associated with deep or very deep peat.

On the crest of the summit ridge, Turbine 27 clearly sits over a very great thickness of peat while the ridge runs to the east with a deep layer of peat all along it, ending, more or less, with the somewhat unstable Turbine 42.

To the south is another line of unstable turbines (25, 34, 37 & 35) that seems to form a gentle arc pointing to the headwaters of the stream that arises near Earl's Chair but the peat thickness is generally two metres or less. Large-scale instability seems unlikely in such relatively shallow peat, though the literature contains several instances of bog slides involving peat as shallow as this or even shallower.

The instability evidence discussed so far, however, generally concerns localised collapse or cracking in the immediate vicinity of a turbine base. One of the primary potential causes of more widespread instability which is stressed in this report is the effect of the forestry because of its tendency to cause extensive cracking in the surface layers of peat. It is therefore worth looking at the general pattern of forest cover at Cashlaundrumlahan in relation to the peat depths.

It is evident that a large proportion of deep and very deep peat lies beneath the forest and may be deeply fissured. Perhaps a third of the unafforested land – essentially the turbary area in the eastern part of the site – is on relatively thin peat but, even here, there are still some deep deposits. The pattern of instability is, of course, as before but it is interesting to note that there are three turbine bases which show signs of instability despite never having been afforested.

This perhaps serves to emphasise that forestry is not the only potential source of peatland instability and that peat will react to any stimulus that sufficiently disrupts its hydro-mechanical properties.

10.2 *Modelling stability in 3-D*

It is one thing to see the contours, drainage lines and peat cover on a flat plan view but it is quite another to see it as a three-dimensional model because it becomes easier to visualise the type of gradient being faced by the peat surrounding a turbine base or the possible routes for an unstable mass of peat, should it start to move.

The elevation data for Cashlaundrumlahan have therefore been transformed into a 3D representation of the landscape (much as the developers used to model visual impact in their Environmental Assessment). The basic model can be seen in fig 10.2a, while peat depth data, possible routes for peat movement and the position of local buildings can be seen in10.2b.

Figs10.2c to10.2g provide a 360° 'tour' around Cashlaundrumlahan, beginning with a view from the south. Vertical scale has been exaggerated to make more evident the individual catchment regions of the stream-courses and the relative differences in slope across different parts of the site. It can be seen that the angle of slope associated with the bog slide is not markedly different from many of the other slopes on the south side of the summit though it is much less steep than the slopes encountered on the north flanks. Areas on the south side can be expected to react with much the same force of movement as the slide, though perhaps with somewhat more force simply because there may be a greater volume of peat involved. The northern flanks, on the other hand, may produce more dramatic movement, should the peat become unstable, because of the markedly steeper slopes.

Perhaps the most striking thing to emerge from the 'tour' is that the most extensive area of the deepest peat sits on the western flanks of the summit, on a slope that points towards the main area

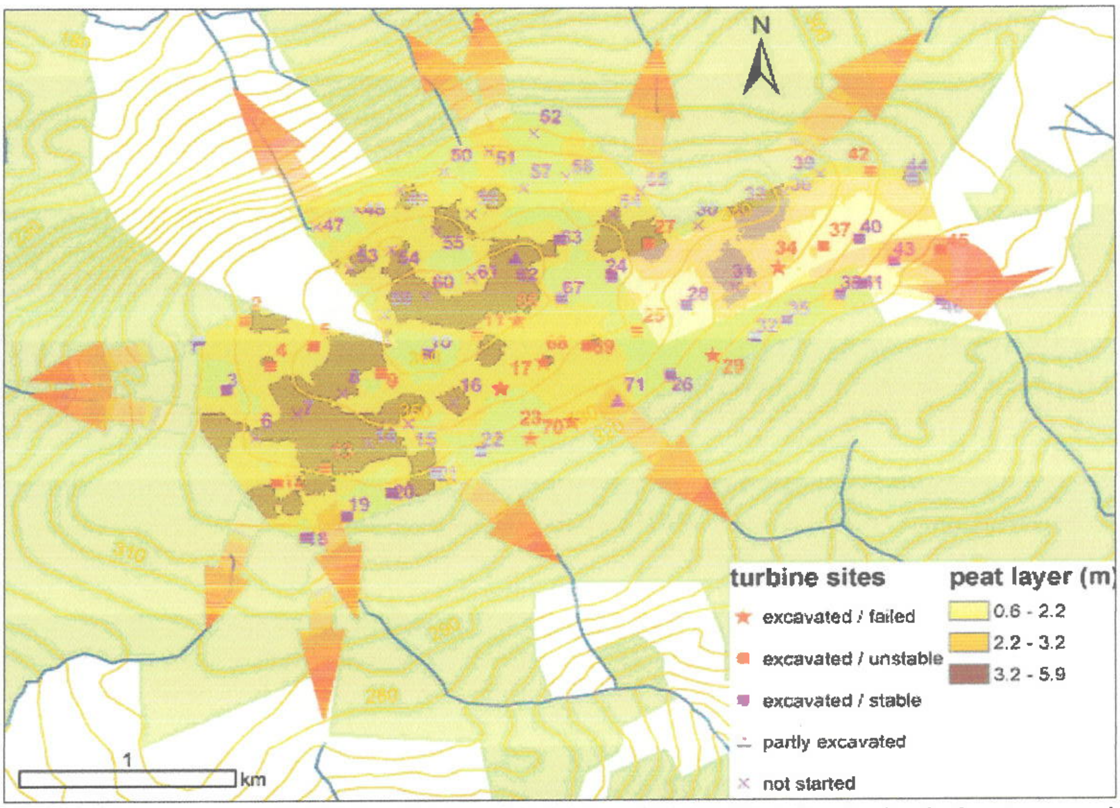


Figure 10.1: Distribution of differing peat depths within the area of the wind farm also showing the forest cover and locations of the turbine bases. These are coded according to their state of development and their assessed condition of stability. The red arrows highlight the likely direction of any peat movement towards stream

of habitation – Derrybrien – and that the two turbines constructed in the deepest part of this sloping peat have shown signs of instability (see fig 10.1). However, the picture is complex on this part of the hill as three watercourses have their origins in fairly close proximity and it is not clear quite which direction a mass of unstable peat might take were it to begin sliding from this south-west facing slope.

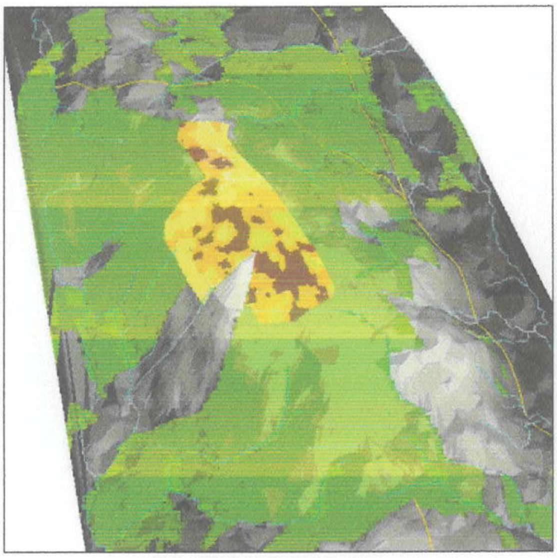
10.3 *Stability prediction*

To an extent, the question of whether or where another bog slide might occur can only be based on informed speculation because there are several significant unknowns. The understanding of how and why bog slides occur is still limited compared to, for example, snow avalanches, though even here there is much that is unexpected and tragedies continue to occur.

The nature of the peat beneath the forest cover has not been adequately assessed and, if it were to be (perhaps following tree removal), it would be a huge task to identify, map and measure all the cracks in the peat, even assuming it were possible without causing yet more disturbance.

The methods employed during construction have already been shown to be at variance with the methods described in the planning application. This problem is common to all construction work in that operational constraints require the on-site managers to make adjustments to the original plans which are inevitably impossible to predict in advance. Their decisions can seem of little consequence at the time in that they may involve simply directing an outflow of water in one direction rather than another or temporarily moving a heavy vehicle onto a particular area of ground but they may have significant consequences for stability of the peat: both of these actions have been identified as potential contributory factors to the peat slide of October 2003.

On ground predisposed to instability, small actions can have large consequences.



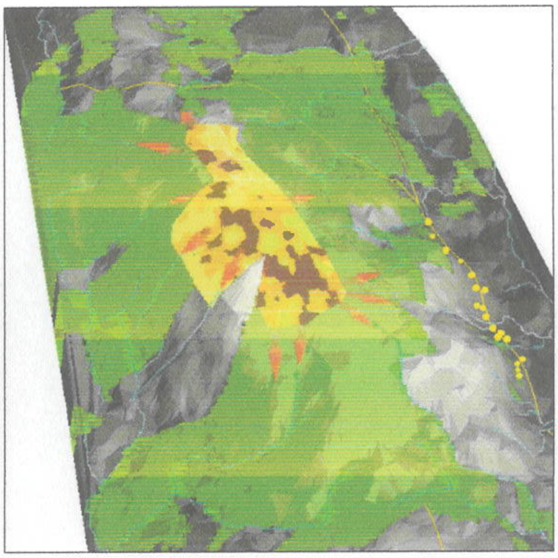


Figure 10.2a, above left: Three-dimensional view of the Cashlaundrumlahan summit from the WNW. It shows showing the extent of forestry (green shading), stream-courses (blue), roads (brown) and the depth of peat in the wind farm

Figure 10.2b, above right: As 10.2a but with arrows indicating potential 'avalanche corridors' and dots representing the main buildings in the landscape.

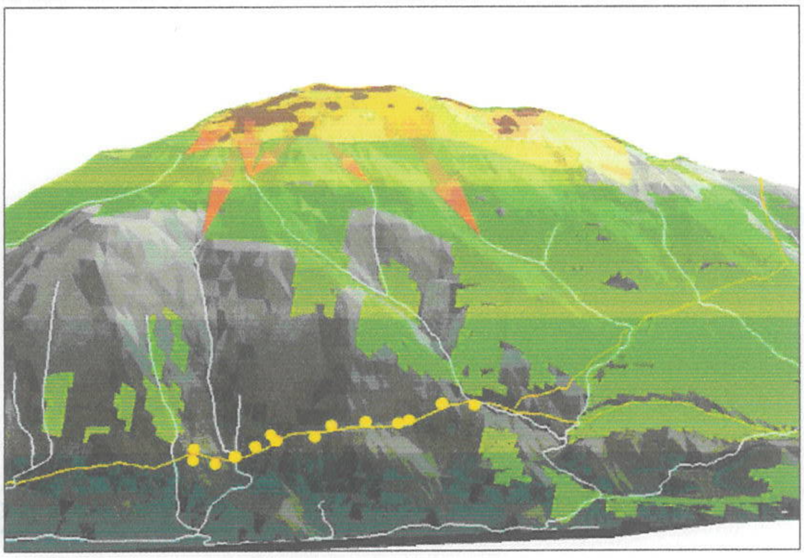


Figure 10.2:c As b but viewed from the SSW,

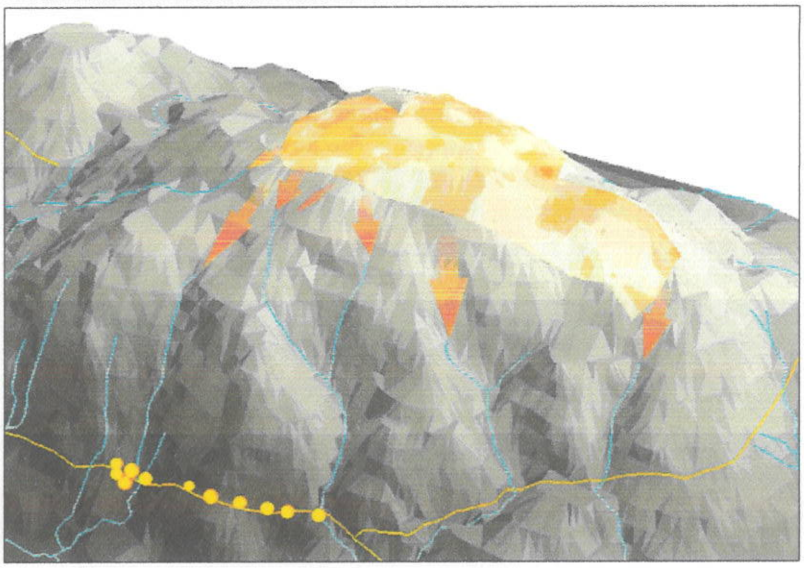


Figure 10.2d: As b but viewed from the SSE and without the forestry cover.

The graphics on these pages are based on data provided by the Ordnance Survey Ireland under Licence No. MNE 0013005; © Ordnance Survey Ireland/Government of Ireland. Original peat depth data recorded by Malone O'Regan McGillicuddy, Consulting Engineers, Cork.

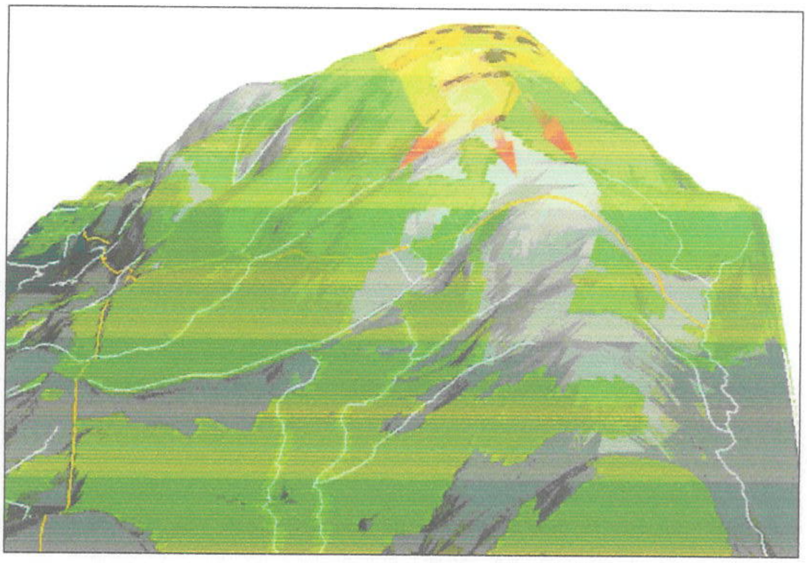


Figure 10.2e: As a but viewed from the east.

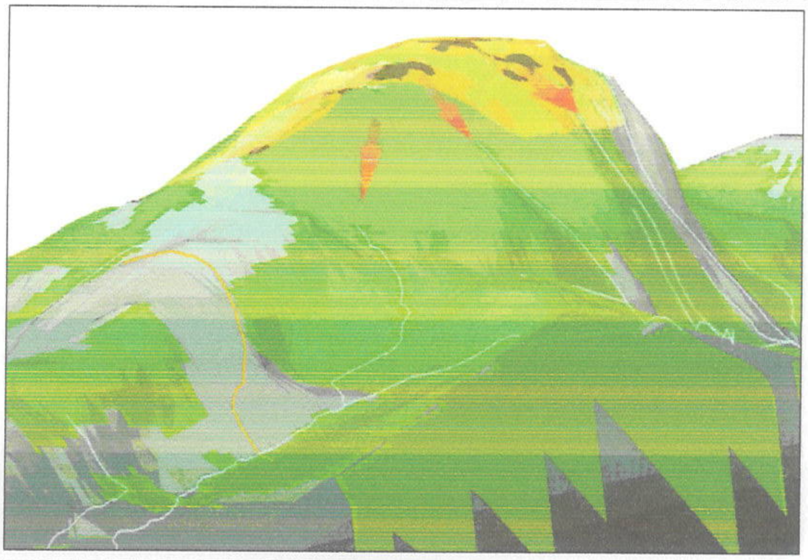


Figure 10.2f: As a but viewed from the north east.

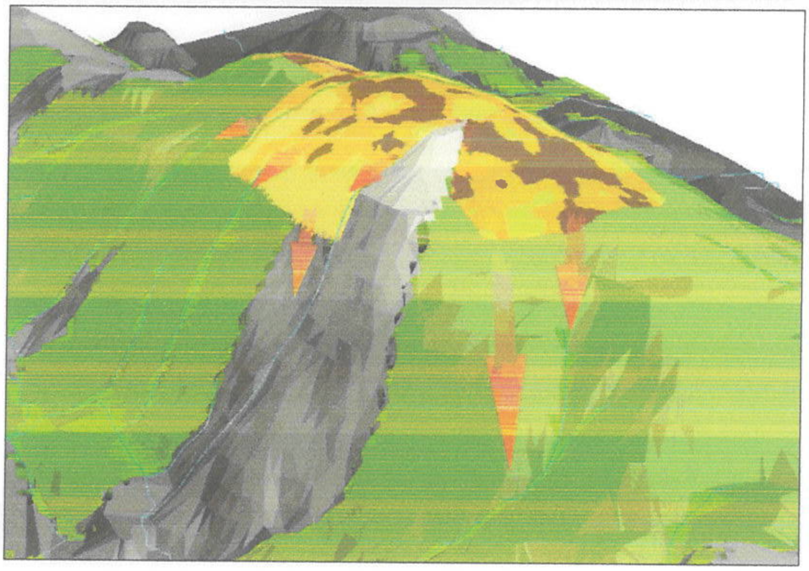


Figure 10.2g: As a but viewed from the north west.

10.4 *The bog burst of October 16 2003 – part of a pattern?*

Had the bog slide of October 2003 occurred in complete isolation with no similar instances either before or afterwards, it might reasonably be regarded as something quite extraordinary that arose from a unique set of circumstances and that a recurrence is most unlikely. This is not the case, however.

10.4.1 *Peat movement within the site*

Within the site, there are several examples of peat instability (section 9) associated with construction work. The most striking of these is the bog slide that occurred at Turbine 17, two weeks prior to 16 October. This involved collapse of the peat downslope for a distance of almost 150 metres and across a width of something over 20 metres (plate 10.1). It is reported to have happened with the same abruptness as the major bog slide and was also associated with construction work around a turbine base and road.

A remarkable fact about this failure is that, despite its substantial and dramatic nature, the event was not seen as an urgent reason to suspend work while the causes were determined. It seems to have been looked on as something curious and quite out of the ordinary – an exceptional event with little or no relevance to the rest of the operation. Had the original EIA reports highlighted the potential dangers of peat instability and bog slides, it is possible that the event at T17 would have been taken much more seriously.

There is evidence of peat movement in a great many places at Derrybrien, not all directly linked to construction work but revealed, for example, by drainage carried out as part of road building and maintenance. Plate 10.2 shows how a ditch alongside a new road has now partially closed and bent significantly out of true, evidently as a result of peat movement. The ditch is associated with some of the deepest peat to the north of the summit and lies on a steeper slope than is typical for the southern flanks. This movement may or may not be a natural process but it is clear that there is a predisposition for peat movement in this area. Further disruption (over and above that caused by the forestry) may lead to more dramaticmovement.

10.4.2 *Weather patterns*

Changing rainfall patterns on the stability of peat at Derrybrien has been discussed (section 8.2), particularly the possibility that prolonged dry periods may exacerbate fissures beneath the forest.

From a rainfall record maintained for the Derrybrien area over a number of years, it is evident that the 12-months prior to the 2003 bog slide was the driest since the record began 14 years ago.

The record since the slide also exhibits an unexpected and perhaps significant pattern. Fig 10.4 shows, for 2004, the difference from the 14-year mean monthly rainfall while fig 10.5 shows the 12-

Plate 10.1: The scene of the bog slide that occurred at T17 only two weeks before the main slide. As can be seen from the small size of the trees in this vicinity, it includes areas that have already been drained for forestry, then suffered fire damage and were then drained again at replanting. So, although the area has been subject to considerable drainage, it has clearly not prevented peat failure.

Evidence of continued peat movement within the site

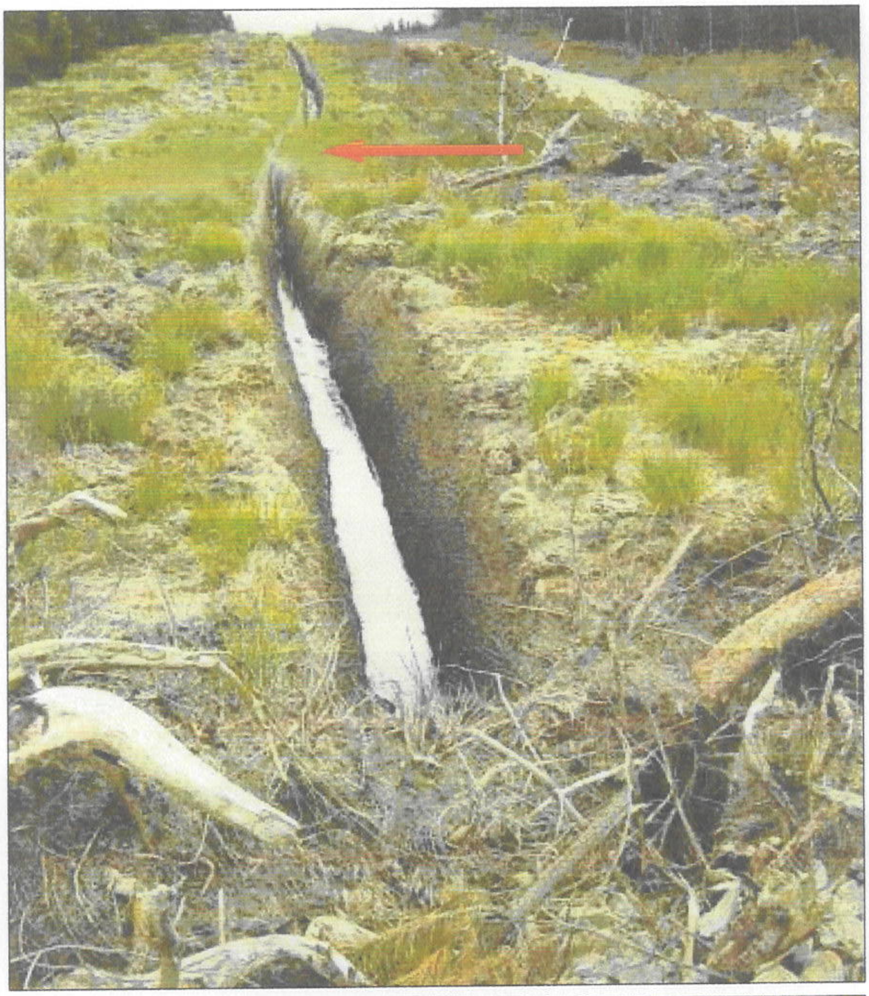
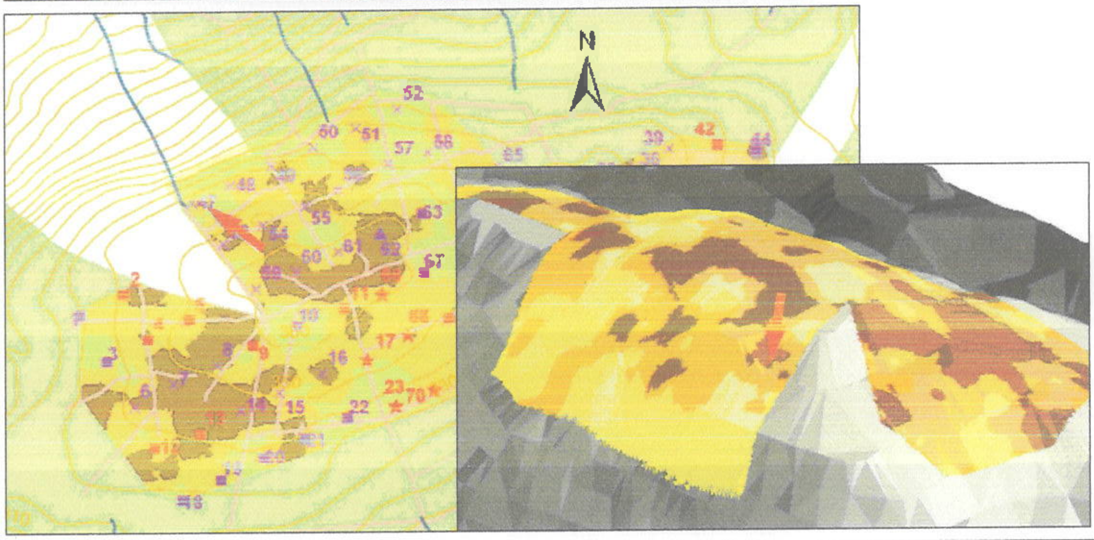


Plate 10.2: A ditch that runs ENE from T53 alongside a floating road across the northern slope of the mountain has obviously bowed and slumped downslope where it crosses deep peat. (It is assumed it orginally ran straight.)

Figure 10.3a, b: The arrows on the two diagrams show the direction in which the peat moved.

The graphics below are based on data provided by the Ordnance Survey Ireland under Licence No. MNE 0013005; © Ordnance Survey Ireland/Government of Ireland. Original peat depth data recorded by Malone O'Regan McGillicuddy, Consulting Engineers, Cork.



month, 6-month and 3-month moving averages of cumulative total monthly rainfall. They show that the rainfall at Derrybrien has reached new lows for a more extended period than at any time previously.

Does this mean that weather patterns are becoming more extreme, with long dry periods followed by extreme rainfall events? Only time will tell. The effect of even this single long dry spell on the condition of the fissured peat can only be guessed at as there is currently no form of monitoring of this aspect of the peat. The weather pattern, and the peat, on the summit of Cashlaundrumlahan have both entered a phase for which there is no precedent in the record.

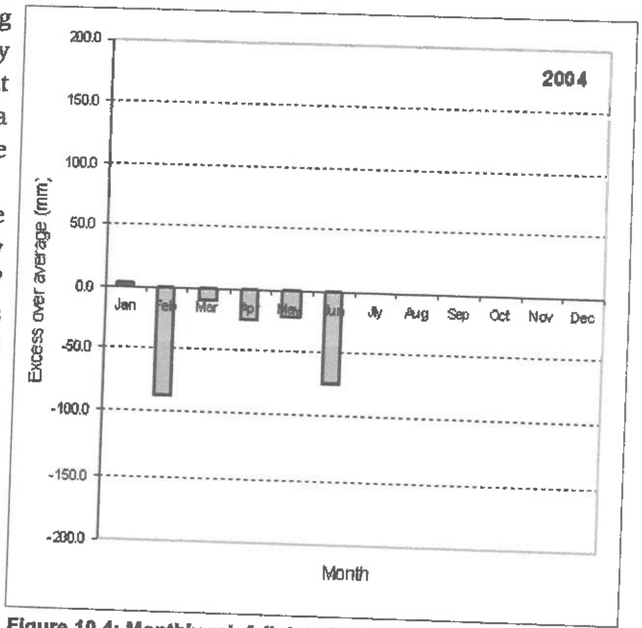


Figure 10.4: Monthly rainfall data for Derrybrien, 2004. Each bar indicates the deviation of the month's rainfall total from the appropriate 14-year monthly mean.

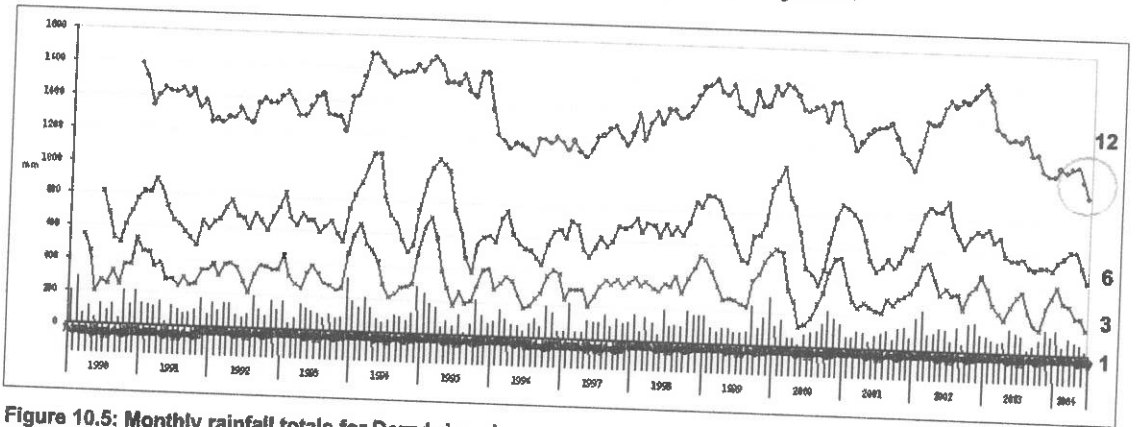


Figure 10.5: Monthly rainfall totals for Derrybrien, January 1990 to June 2004. The vertical bars at the bottom of the diagram (labelled 1) indicate monthly rainfall totals and the continuous lines indicate the accumulated rainfall for the three, six and twelve months preceding the last day of each month. The moving 12-month rainfall total for 2004 (circled in red) is the lowest in data series at 952mm.

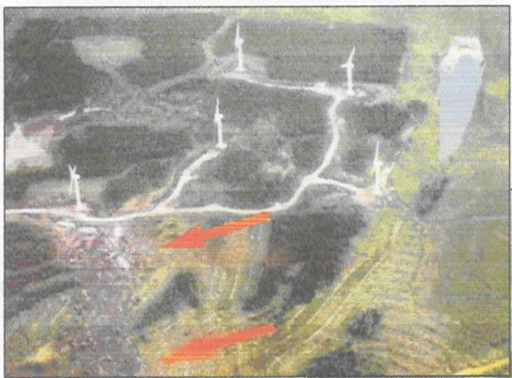


Plate 10.3a, above: The recently-erected 9-turbine wind farm at Sonnagh Old, four km to the north of the Derrybrien scheme from which this photograph was taken.

Reproduced courtesy of Martin Collins

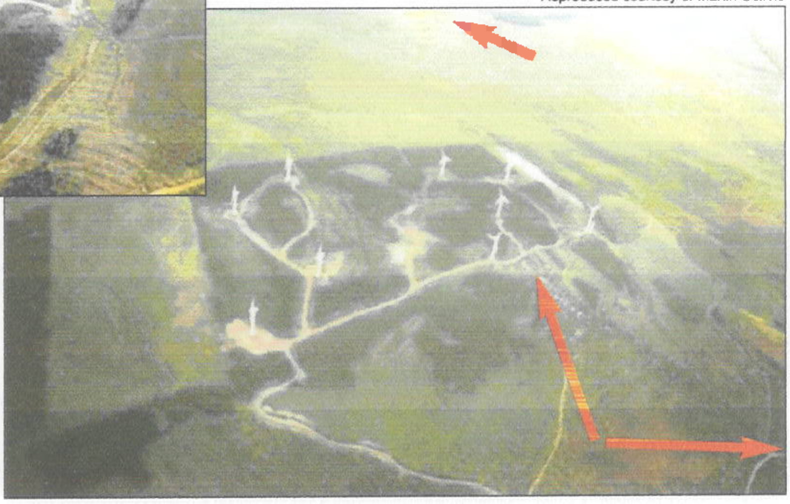


Plate 10.3b, above: The point of origin of the bog slide at Sonnagh Old, shown by the arrows. Plate 10.3c, right: The full extent of the slide at Sonnagh Old. The forestry associated with Cashlaundrumlahan can be seen in the distance (indicated by the arrow at the top of the photograph).

The bog slide at an adjacent wind farm

In October 2003, at much the same time as the Derrybrien incident, another slide occurred at Sonnagh Old, a recently installed 9-turbine wind farm on an adjacent summit four km to the north of Cashlaundrumlahan (grid reference M508093, fig 1). It involved 15,000 cubic metres of peat and appears to have originated at an access road.

The point of origin of the slide can be seen in plate 10.3a and the whole slide in 10.3b. The similarities with Derrybrien are striking: both are associated with a road, a turbine base and forestry. The relatively small size of Sonnagh Old compared to Cashlaundrumlahan suggests that a smaller volume of peat was involved but it still travelled a considerable distance.

It is clear from this and the other instances of peat movement described above that peat instability is a widespread feature of the area and that the slide of 16 October 2003 cannot be regarded as an aberration.

Any decent review both of the existing literature and of the site itself would have revealed that major instability was (and continues to be) a real possibility.

Summary of Chapter 10

1 Using spatial analysis, it is possible to build up a picture of where there may be a high probability of instability on Cashlaundrumlahan.

2 Combining peat depth, slope, landform and drainage pattern, it is possible to identify a number of possible routes for peat movement – potential 'avalanche corridors'.

3 An indication that movement along some of these avalanche corridors may be possible is provided by turbine bases which already display some signs of peat instability.

4 The distribution of forestry can then be added to the analysis, highlighting those areas of peat that are likely to be extensively fissured. This also reveals the fact that there is a possible line of non-forested weakness to the east of the site, surprisingly on rather thin peat.

5 Modelling of these various landforms and datasets in 3-D, especially with an enhanced vertical scale, gives a clearer picture of the possible avalanche corridors and direction.

6 Such modelling makes it evident that the most extensive areas of deep peat lie on the slopes above Derrybrien and one such corridor leads directly into Derrybrien, close to the school.

7 It is extremely difficult to make clear predictions about whether the likelihood of peat movement down any of these avalanche corridors because there are so many unknowns ranging from the detailed nature of the peat to the on-site practices of the site operators.

8 A major bog slide occurred at an adjoining turbine some weeks prior to the slide of 16 October 2003 but this does not appear to have altered working practices or initiated a period of investigation. Peat movement can be seen at various localities on Cashlaundrumlahan and this movement generally corresponds with one or other of the identified possible avalanche corridor routes.

9 Evidence of substantial 'avalanche'-type movement from similar wind farm developments can be found within four km of Cashlaundrumlahan. The nine-turbine wind farm at Sonnagh Old suffered a major peat slide at roughly the same time as the large slide at Derrybrien. It would appear that the slide had its origin at a combined locality of a turbine base and a roadway, just as with Derrybrien.

10 The weather at Cashlaundrumlahan since October 2003 has been drier than at any time in the 14-year rainfall record. The effect of this extraordinarily prolonged dry period on the peat fissures on the site may be considerable and are likely to render the site more sensitive to development impact.

Chapter 11

Summary

1 *Introduction*

THE REPORT WAS COMMISSIONED by V P Shields & Son on behalf of the Derrybrien Development Cooperative Society Ltd and individuals whose lands were affected by the bog slide. It has been prepared by Richard Lindsay and Dr Olivia Bragg of the University of East London to evaluate:

- the planning proposals for the wind farm at Derrybrien;
- the associated impact statements;
- the events leading up to, and possibly causing, the bog slide on 16 October 2003;
- the content and recommendations of the two geotechnical reports produced after the slide;
- impact assessment procedures.

It considers the legislation covering EIA and the guidance appropriate to reviewing what should be contained in an environmental assessment of the wind farm proposal. The key stages are identified as scoping and impact assessment and the report therefore undertakes a scoping and impact exercise for the development.

2 *Scoping – the ecological framework*

2.1 The development at Derrybrien is spread along the summit and upper flanks of Cashlaundrumlahan, part of the Slieve Aughty Mountains in Galway.

2.2 This summit is dominated by blanket peat, which is a characteristic habitat for such an oceanic region and which arises because the constantly humid climate maintains the living vegetation of Sphagnum bog moss in a waterlogged state, preventing complete decomposition of the dead plant material (known as peat) that slowly accumulates beneath the living carpet of moss.

2.3 Peat soils consist largely of water but are held together by the hydrostatic characteristics of the surprisingly small proportion of organic material that binds the water into a structure that is sufficiently solid to walk on. There is only a tiny amount of mineral matter in peat. Consequently, peat soils behave rather differently from many more typical soils.

2.4 For example, if the peat is allowed to dry, it turns into carbon dioxide and water and disappears into the atmosphere. If peat soils are continually drained, they can thus vanish completely over time but undergo shrinkage and cracking during the drying-out process.

2.5 Peat soils consist of two layers – the thin surface acrotelm, which protects the lower, deeper layers of peat known as the catotelm. The catotelm is never normally exposed to the atmosphere and remains constantly waterlogged under natural conditions because it is separated from the atmosphere by the acrotelm. Unprotected catotelm peat has few active defences against the external environment and tends to oxidise and erode.

3 *Scoping – pre-development conditions at Derrybrien*

3.1 The major land-use impact on Cashlaundrumlahan prior to the wind farm development was afforestation, involving intensive drainage and planting with exotic conifer species.

3.2 Plantation forestry on deep peat causes water loss from the peat especially after canopy closure after about 20 years, because the canopy intercepts rainfall and the trees draw water from the peat through evapotranspiration. Such drying conditions result in deep cracking and fissuring of the peat, first in the surface layers then progressively deeper as the plantation matures.

3.3 There is clear evidence of deep cracking within the forested peat at Cashlaundrumlahan.

3.4 The state of the peat, combined with experience of peatland sites elsewhere in the world, suggests that slope stability could be a major issue in relation to the development and the issue of bog bursts was identified as a key topic to explore.

4 *Scoping – bog bursts and peat slides, a review of evidence*

4.1 Bog bursts represent a dramatic collapse of peat across a landscape or down a hillside. They have been documented for over 500 years from a wide range of localities around the world with some described in detail. They can involve movement of peat over distances, as large as 10 to 20 km; sometimes they are slow-moving but sometimes they move as a fast-flowing stream.

4.2 Two fairly constant features of bog slides are:

- heavy rainfall immediately prior to (and sometimes during) the slide;
- some form of human disturbance to the peat surface.

4.3 A number of engineering mechanisms have been proposed to explain the causes of bog bursts and bog slides.

5 *Assessing potential impacts*

5.1 The developers propose to avoid drainage of the peat by building roads that float on the peat. Such roads do not, in fact, 'float' except when used briefly as temporary structures. Longer term use requires drainage to keep them operational but this causes oxidation of the peat. A cycle of sinking and drainage generally leads to the roads cutting their way down through the peat body.

5.2 Floating roads also cause problems of localised ponding because they cut across natural drainage lines. Such ponding is a problem for the developer, is a danger to peat stability and its sudden release can be even more of a risk to peat stability.

5.3 Excavation of turbine bases also involves the creation of ponded water which must be released somewhere. Again, the process by which it is released is critical because it can lead to instability of the peat. At the same time, the cut faces of the turbine excavations remain exposed to the atmosphere and suffer oxidation and cracking.

6 *Impact interactions*

6.1 A variety of approaches can be adopted when considering indirect and cumulative impacts and impact interactions. Extensive guidance is available and examples relevant to the proposals for Derrybrien are presented.

6.2 Consideration of all such impacts makes it possible to finalise the boundary required for the EIA and a boundary is presented for the Derrybrien proposal.

6.3 Having identified the boundary for impact assessment, it is possible to produce a comprehensive review of sites with statutory conservation status or conservation value that may need to be considered as part of the assessment process. Several SACs, SPAs and Ramsar sites are so identified.

7 *The EIA and the Derrybrien planning process*

7.1 There is immediate confusion about these documents because at least one of them should have been part of a statutory Environmental Impact Assessment but claimed to be produced on a voluntary basis. Part of the development appears not to have been formally assessed at all even though it was at the time one of the largest wind farm developments in Europe.

7.2 There are real concerns that the development has been enabled by the technique of 'salami slicing' whereby a large project is introduced in stages to make it seem smaller or to evade legal thresholds.

7.3 The EIA documents make it clear that they were produced to demonstrate the low environmental impact of wind warm developments. This is not consistent with the objective assessment of the facts.

7.4 There is no genuine scoping phase in the EIA reports and this is reflected in a superficial approach adopted towards many topics.

7.5 Only noise and visual impacts are addressed in any detail. All other topics touch on only a small proportion of the issues, are supported by very little data or information from the published literature and fail to address even some of the most basic impact questions. For example, there is no recognition anywhere that peat soils can be unstable and that plantation forestry can make them even more so.

7.6 A clear contrast is made between the type of information provided in the EIA reports and what would normally be required for a standard Slope Stability Report as required in the UK for potentially unstable ground.

8 *The bog slide at Derrybrien*

8.1 The failure appears to have occurred within the peat itself. Strips of peat appear to have 'delaminated' along lines of plantation trees and slid downhill in long narrow ribbons.

8.2 The weather prior to and during the event was dry and thus not typical of a bog slide. However, the general pattern of rainfall over the preceding 12 months had been exceptionally low with a long dry spell immediately prior to slope failure. Such weather conditions would probably have led to widening of the fissure systems in the forested peat. This may in turn have made the forested peat pre-disposed to failure, given a trigger.

8.3 This trigger may have been in the form of on-site operations where two areas seem to have been subject to drainage operations at the same time as excavations. Release of water across a deeply-fissured peat surface can generate buoyancy failure while loading by machinery can produce loading failure.

9 *The geotechnical reports*

9.1 Two geotechnical reports produced after the bog slide attempt to judge whether the site is sufficiently stable for work to continue in the light of the large area of slope failure.

9.2 Both list a number of possible contributing factors to instability but they then investigate only one of these in detail.

9.3 Several locations are identified as showing signs of instability but desk and field

investigations use idealised models of the peat matrix that assume constant properties in space and time. The issue of cracking beneath the forestry, for example, is not investigated.

9.4 Drainage is recommended as the way to stabilise the peat, despite the fact that drainage of peat soils does not produce the same effect as it does in minerals soils. There is also evidence of considerable instability (including a large peat slide) in areas of the site which have already been heavily drained.

9.5 Extensive drainage would lead to much greater sedimentation in streamcourses and result in a change in water colour, as well as potentially causing more instability rather than less.

9.6 It is important that a full-scale slope stability analysis is carried out before any other action is taken. This should investigate all possible alternative failure mechanisms and include long-term projections covering the lifetime of the project and beyond decommissioning.

9.7 In the meantime, no further work should be carried out on the site either in terms of additional drainage or resumption of wind farm operations.

10 *A review of scenarios*

10.1 Using spatial analysis that incorporates peat depth, slope, drainage patterns and forest cover, an assessment is made of possible routes that peat slides might take. These are described as 'avalanche corridors' in the same way that areas at potential risk from snow avalanches are highlighted and monitored.

10.2 A number of such corridors are identified and an assessment is made of the relationship between these and areas that already show signs of instability. Several are identified as showing such signs of instability and are at particular risk. The area of most extensive deep peat has at least two major areas described as 'at risk', one of which is a corridor that leads directly to Derrybrien.

10.3 It is possible to make predictions about instability on a theoretical basis but evidence of actual peat movement is provided that indicates that the bog slide of 16 October 2003 was part of a recognisable pattern of behaviour rather than a unique event.

10.4 A substantial bog slide occurred at the wind farm just two weeks prior to the main October slide. It was associated with a floating road and a well-drained turbine base, involved a large volume of peat and extended over a distance of around 150 metres. The event was regarded merely as curious, its causes were not investigated and working practices were not reviewed in the light of this clear sign of instability. Evidence is also presented for peat movement along the line of an avalanche corridor within the development site. At nearby wind farm, a large bog slide occurred around the same time as the Derrybrien collapse and the origins of this slide also seem to be linked to a turbine base and road.

10.5 The accumulated evidence for movement and instability points to the fact that the large bog slide of 16 October 2003 was by no means a unique event. It forms just one example within an obvious pattern of behaviour that involves greater or lesser instances of peat movement and instability.

10.6 Finally, rainfall patterns at Cashlaundrumlahan since October 2003 have produced the driest set of conditions recorded over the last 14 years. The impact of this on the peat fissures in the plantation forestry is likely to increase the sensitivity of the peat system to impacts. If the climate is shifting to more long dry spells and periods of intense rain, this too will heighten sensitivity to impacts.

Concluding thoughts

PEAT IS A SOIL consisting mainly of water. That such a system is able to remain stable at all while draped over a hillside is a remarkable phenomenon – but the same could be said for water smothering mountain slopes and summits as blankets of snow.

Sometimes, however, gravity re-asserts itself and both systems collapse downslope. Many people ski in perfect safety on snowy slopes but, despite the intensive research into and monitoring of, avalanche systems, every year there are still some tragedies. We know a great deal about the avalanche process in snow, we know much less about the process in peat.

Anyone who makes a genuine effort to understand blanket bog ecosystems will soon come to understand just how delicately-balanced, fragile and unpredictable they are.

References

AGEC (2004) *Reports on Derrybrien Windfarm – Final Report on Landslide of October 2003 – Final Report on Post-Landslide Site Appraisal.* Applied Ground Engineering Consultants Ltd. for Electricity Supply Board International, 04 February 2004.

Anderson, R. (2001) Deforesting and restoring peat bogs. Forestry Commission Technical Paper 32. Forestry Commission, Edinburgh.

Anderson, A.R., Pyatt, D.G. and White, I.M.S. (1995) Impacts of conifer plantations on blanket bogs and prospects of restoration. In: Wheeler, B.D., Shaw, S.C., Fojt, W.J. and Robertson, R.A. *Restoration of Temperate Wetlands.* Wiley.

Anonymous (1974) Peat, peat cutting, and the peat slip. *Falklands Islands Journal*, 23-27.

Acreman, M. (1991) The flood of July 25th 1983 on the Hermitage Water, Roxburghshire. Scottish Geographical Magazine, 107(3), 170-178.

Alexander, R.W., Coxon, P. and Thorn, R.H. (1986) A bog flow at Straduff Townland, County Sligo. *Proceedings of the Royal Irish Academy*, 86B, 107-119.

Alexander, R.W., Coxon, P. and Thorn, R.H. (1985) Bog flows in south-east Sligo and south-west Leitrim.In Thorn, R. (ed.) *Field Guide No. 8 for Sligo and West Leitrim*, 58-80. Irish Association for Quaternary Studies.

Barker, J. (1994) *The Brontes.* Weidenfeld & Nicholson, London.

Beven, K., Lawson, A. and McDonald, A. (1978) A landslip/debris flow in Bilsdale, North York Moors, September 1976. *Earth Surface Processes*, 3, 407-419.

Bishop (1955) The use of the slip circle in the stability analysis of earth slopes. *Geotechnique*, 5.

Bishopp, D.W. and Mitchell, G.F. (1946) On a recent bog flow in Meenacharvy Townland, Co. Donegal. *Scientific Proceedings of the Royal Dublin Society*, 24(17), 151-156.

BMA Geoservices (2004) *Landslide at Derrybrien Windfarm. Final Report.* In an unattributed collection of material originating from Galway Council, BMA Geoservices Limited and the National University of Ireland, Galway.

Bond, A. (undated) *Environmental impact assessment in the UK.* London: Chadwick House Group Limited.

BS 6031 (1981) British *Standards Code of Practice for Earthworks.*

Bower, M.M. (1960a) The erosion of blanket peat in the southern Pennines. *East Midlands Geographer*, 2, 22-33.

Bower, M.M. (1960b) Peat erosion in the Pennines. *Advancement of Science*, 24, 323-331.

Bower, M.M. (1961) The distribution of erosion in blanket peat bogs in the Pennines. *Trans. Inst. Brit. Geogr.*, 29, 17-30.

Bowes, D.R. (1960) A bog-burst in the Isle of Lewis. *Scottish Geographical Magazine*, 76, 21-23.

Bradshaw, R. and McGee, E. (1988) the extent and time-course of mountain blanket peat erosion in Ireland. *New Phytologist*, 108, 219-224.

Bragg, O.M. (1995) Towards an ecohydrological basis for raised mire restoration. In: Wheeler, B., Shaw, S., Fojt, W. & Robertson, R.A. (eds.) *Restoration of Temperate Wetlands.* John Wiley, Chichester.

Bragg, O.M., Brown, J.M.B. and Ingram, H.A.P. (1991) Modelling the ecohydrological consequences of peat extraction from a Scottish raised mire. In: Nachtnebel, H.P. and Kovar, K. (eds.) *Hydrological Basis of Ecologically Sound Management of Soil and Groundwater.* Publ. No. 202, IAHS, Wallingford.

Bragg, O. and Lindsay, R. (eds.) (2003) *Strategy and Action Plan for Mire and Peatland Conservation in Central Europe.* Wetlands International, Wageningen, The Netherlands.

Briggs, B. (1996) *Birds and Wind Farms - Can They Co-exist?* Policy Statement of the RSPB.

Bronte, P. (1824a) *The Phenomenon: or, An Account in Verse, of the Extraordinary Disruption of a Bog, which took place in the Moors of Haworth, on the 12th Day of September 1824: Intended as a Reward-Book for the Higher Classes in Sunday-Schools.* T. Inkersley, Bradford.

Bronte, P. (1824b) *A Sermon preached in the Church of Haworth, on Sunday, the 12th Day of September, 1824, in reference to an Earthquake, and extraordinary Eruption of Mud and Water, that had taken place ten days before, in the Moors of that Chapelry.* T. Inkersley, Bradford.

Byrne, J. (undated) Bog bursts. http://www.ipcc.ie/infobogburst.html
Carling, P.A. (1986) Peat slides in Teesdale and Weardale, Northern Pennines, July 1983: description and failure mechanisms. *Earth Surface Processes and Landforms*, 11, 193-206.
Charman, D.J. (2002) *Peatland systems and environmental change*. Chichester: John Wiley & Sons.
Clymo, R.S. (1983) Peat. In: Gore, A.J.P. (ed.) *Mires: Swamp, Bog, Fen and Moor. Ecosystems of the World 4A*. Elsevier, Oxford.
Coillte (2004) http://www.coillte.ie/
Cole, G.A.J. 1897. The bog-slide at Knocknageeha, in the County of Kerry. Nature 55 (1420), 254-256.
Colhoun, E.A. 1966. The debris flow at Glendalough, Co. Wicklow and the bog-flow at Slieve Rushen, Co. Cavan, January 1966. Irish Naturalists Journal 15, 199-206.
Colhoun, E.A., Common, R. and Cruickshank, M.M. (1965) Recent bog flows and debris slides in the north of Ireland. *Scientific Proceedings of the Royal Dublin Society*, 2A(10), 163-174.
Cox, M., Straker, V. & Taylor, D. (1995) *Wetlands: archaeology and conservation*. London: HMSO.
Crisp, D.T., Rawes, M. and Welch, D. (1964) A Pennine peat slide. *Geographical Journal*, 130, 519-524.
Delap, A.D., Farrington, A., Praeger R.L. and Smyth, L.B. (1932) report on the recent bog-flow at Glencullin, Co. Mayo. *Scientific Proceedings of the Royal Dublin Society*, 20(17), 181-192.
Delap, A.D. and Mitchell, G.F. (1939) On the recent bog flow in Powerscourt Mountain, Co. Wicklow. *Scientific Proceedings of the Royal Dublin Society*, 22(18), 195-198.
Department of the Environment (1990) *Planning Policy Guidance: Development on Unstable Land*. London: Department of the Environment
Douglas, C. (1998) Blanket bog conservation. In: O'Leary, G. and Gormley, F. (eds.) *Towards a Conservation Strategy for the Bogs of Ireland*, 205-222. Irish Peatland Conservation Council, Dublin.
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.
Endurazyme (2000/4) *Material attributes*, www.mite.com.au/manual/p6.html.
Environmental Protection Agency (1995) *Advice Notes on Current Practice in the Preparation of Environmental Impact Statements*. Johnstown Castle Estate, Ireland: Environmental Protection Agency.
Environmental Protection Agency (2002) *Guidelines on the information to be contained in Environmental Impact Statements*. Johnstown Castle Estate, Ireland: Environmental Protection Agency.
Essex Planning Officers' Association (1994) *The Essex Guide to Environmental Assessment*. (revised edn.) Chelmsford, England: Essex County Council.
European Commission (1999) *Guidelines for the Assessment of Indirect and Cumulative Impacts as well as Impact Interactions*. Luxembourg: Office for Official Publications of the European Communities.
European Commission (2001) *Guidance on EIA - Scoping*. Luxembourg: Office for the Official Publications of the European Communities.
Feehan, J. and O'Donovan, G. (1996) Bog bursts. In: *The Bogs of Ireland. An Introduction the and Natural, Cultural and Industrial Heritage of Irish Peatlands*. The Environmental Institute, University College Dublin, 388-419.
Feldmeyer-Christie, E. (1995) La Vraconnaz, une tourbière en movement (La Vraconnaz, a mire on the move) Dynamique de la végétation dans une tourbière soumise à une glissement de terrain. *Bot. Helv.*, 105, 55-73.
Feldmeyer-Christie, E. (2002) Onze ans de dynamique de la végétation dans une tourbière soumise à une glissement de terrain. *Bot. Helv.*, 112/2, 103-120.
Feldmeyer-Christie, E. (1999) Bogburst Bibliography. *Mires Research News*, 17.
Feldmeyer-Christie, E. and Mulhauser, G. (1994) A moving mire – the burst bog of la Vraconnaz. In: Grünig, A. (ed.) *Mires and Man. Mire Conservation in a Densely Populated country – the Swiss Experience*. Excursion Guide and Symposium Proceedings of the 5th Field Symposium of the International Mire Conservation Group (IMCG) to Switzerland 1992, 181-186. Birmensdorf, Swiss Federal Institute for Forest, Snow and Landscape Research.
Früh, J. (1897) Ueber Moorausbrüche (About Bog-bursts). *V'jahrschr, d. Naturforsch. Ges. Zürich*, 42, 202-237.
Früh, J. and Schröter, C. (1904) Die Moore der Schweiz – mit Berücksichtigung der gesamte Moorfrage (The Swiss Mires – considering the whole matter of mires). *Bietr. Z. Geol. D. Schweiz, Geotechn. Ser.* 751 pp.
Galway County Council (1997) *County Development Plan 1997-2002*. Galway: Galway County Council.
Government of Ireland (2002) *National Biodiversity Plan*. Dublin: Department for Arts, Heritage, Gaeltacht and the Islands.
Gilpin, A. (1995) *Environmental Impact Assessment (EIA): cutting edge for the twenty-first century*. Cambridge: Cambridge University Press.
Greig, I.C. (2001) Human impacts on soil properties and their implications for the sensitivity of soil systems in Scotland. *Catena*, 42, 361-374.
GSI (2004) Bedrock Geology of Ireland. Map simplified from the GSI 1:100,000 Bedrock Map Series (1993-2003) and the Geological Survey of Northern Ireland 1:250,000 scale Geological Map of Northern Ireland (1997). Geological Survey of Ireland.
Griffith, R. 1821. Report relative to the Moving Bog of Kilmaleady, in the King's County, made by order of

the Royal Dublin Society. *Journal of the Royal Dublin Society*, I, (1856-57), 141-44, with map.
Hemingway, J.E. and Sledge, W.A. (1943) A bog-burst near Danby-in-Cleveland. *Proc. Leeds Phil. Lit. Soc.*, 4, 276-284.
Hendrick, E. (1990) A bog flow at Bellacorrick Forest, Co. Mayo. *Irish Forestry*, 47(1), 32-44.
Hobbs, N.B. (1986) Mire morphology and the properties and behaviour of some Biritsh and foreign peats. Quarterly Journal of Engineering Geology, London, 19, 7-80.
Hulme, P.D. and Blyth, A.W. (1985) Observations on the erosion of blanket peat in Yell, Shetland. *Geographisca Annaler*, 67A, 119-122.
Hungr, O. and Evans, S.G. (1985) An example of peat flow near Prince Rupert, British Columbia. Canadian Geotechnical Journal, 22, 246-249.
Ingram, H.A.P. (1978) Soil layers in mires: function and terminology. *Journal of Soil Science*, 29, 224-227.
Ingram, H.A.P. (1982) Size and shape in raised mire ecosystems: a geophysical model. *Nature*, **297**: 300-303.
Ingram, H.A.P. (1983) Hydrology. In: Gore, A.J.P. (ed.*) Mires: Swamp, Bog, Fen and Moor. Ecosystems of the World 4A*, 67-158. Elsevier, Oxford.
Ingram, H.A.P. (1992) Introduction to the ecohydrology of mires in the context of cultural perturbation. In: Bragg, O.M., Hulme, P.D., Ingram, H.A.P. and Robertson, R.A. (eds.) *Peatland Ecosystems and Man: An Impact Assessment.* Department of Biological Sciences, University of Dundee, pp. 67-93.
Ingram, H.A.P. and Bragg, O.M. 1984. The diplotelmic mire: some hydrological consequences reviewed. In: *Proceedings of the 7th International Peat Congress, Dublin.* Irish National Peat Committee / International Peat Society, pp. 220-234.
Ivanov, K.E. (1981) *Water Movement in Mirelands.* London: Academic Press.
Janbu (1957) Earth pressures and bearing capacity calculations by generalised procedures of slices. *Proceedings of the 4th International Conference on Soil Mechanics and Foundation Engineering*, 2.
Joosten, H. and Clarke, D. (2002) *Wise Use of Mires and Peatlands – Background and Principles Including a Framework for Decision-making.* International Mire Conservation Group and International Peat Society. NHBS, Totnes, Devon.
Kelly, F.L. and King, J.J. (2001) A review of the ecology and distribution of three lamprey species, *Lampetra fluviatilis* (*L.*), *Lampetra planeri* (Bloch) and *Pteromyzon marinus* (*L.*): a context for conservation and biodiversity in Ireland. *Biology and Environment: proceedings of the Royal Irish Academy, 101B*(3), 165-185.
King, W. (1685) On the bogs and loughs in Ireland. *Philosophical Transactions, 15*, 948 *et seq.*
Kirk, K. (1999) Bog failures. *Mires Research News*, 17, 4-5.
Kirkpatrick, H. (1999) Bog-bursts in Ireland. *Mires Research News*, 18, 7-8.
Klinge, M.J. (1892) Ueber Moorausbrüche (About Bog-bursts). *Bot. Jahrbücher für Syst., Pflanzenges. u. Pflanzengeogr. Hrsg. von A. Engler*, 14, 426-461.
Langston, R. (2004) Windfarms and birds. *Naturopa*, No.101, p.29. Strasbourg: Council of Europe.
Large, A.R.G. (1991) The Slievenakilla bog burst: investigations into peat loss and recovery on an upland site. *Irish Naturalists' Journal*, 23(9), 354-359.
Latimer, J. 1897. Some notes on the recent bog slips in the Co. of Kerry. *Trans. Institution of Civil Engineers of* Ireland, 26, 94-97.
Levine-Frick (2001) *Geotechnical News Quarterly*, July 2001. http://www.lfr.com/ news/geotech-quarterly/July%202001Geotech%20%20Newsletter.htm.
Lindsay, R.A. (1995) *Bogs: the Ecology, Classification and Conservation of Ombrotrophic Mires.* Scottish Natural Heritage, Perth.
Lindsay, R.A., Charman, D.J., Everingham, F., O'Reilly, R.M., Palmer, M.A., Rowell, T.A. and Stroud, D.A. (1988) *The Flow Country: The Peatlands of Caithness and Sutherland.* Peterborough: Nature Conservancy Council.
Lock, J. and Dixon, W.T. (1965) *A Man of Sorrow.* Nelson, London.
Loebell, R. (1953) Moorbruchkatastrophen (Bog-burst catastrophes). *Wasser und Boden*, 5, 377-378.
Lyons, J. (undated) *From Ireland.* http://www.from-ireland.net/history/bogbursts.htm.
McCahon, C.P., Carling, P.A. and Pascoe, D. (1987) Chemical and ecological effects of a Pennine peat slide. *Environmental Pollution*, 45, 275-289.
Malone, O'Regan, McGillicuddy (2002) Derrybrien Windfarm – Site Survey. Drawing No. 20206-01 at 1:50,000.
Marter, H.J. (2003) Rain and mud devastate south. *The Shetland News*, 20 September 2003.
Mitchell, G.F. (1935) On a recent bog-flow in the county Clare. *Scientific Proceedings of the Royal Dublin Society*, 21(27), 247-251.
Mitchell, G.F. (1938) On a recent bog-flow in the county Wicklow. *Scientific Proceedings of the Royal Dublin Society*, 22(4), 49-55.
Moore, P.D. and Bellamy, J.D. (1974) *Peatlands.* London: Elek Science.
Morris, P. and Therivel, R. (Eds.) (1995) *Methods of Environmental Impact Assessment.* London: UCL Press Ltd.
Morrison, M. E. S. 1955. The water balance of the raised bog. *Irish Naturalists Journal*, 11, 303-308.
Norriss D., Marsh, J., McMahon, D. and Oliver, G.A. (2002) A national survey of breeding Hen Harriers *Circus cyaneus* in Ireland 1998-2000. Irish Birds, 7(1), 1-10.

O'Mahony, M.J., Ueberschaer, A., Owende, P.M.O. and Ward, S.M. (2000) Bearing capacity of forest access roads built on peat soils. *Journal of Terramechanics*, 37, 127-138.
Oswald, H. (1949) Notes on the vegetation of British and Irish mosses. *Acta Phytogeographica Suecica, 26*, 1-62.
Ousley, R. 1788. An account of the moving bog and the formation of a lake, in the county of Galway, Ireland. Trans. Royal Irish Academy B2, 3-6.
Page, S.E., Siegert, F., Rieley, J.O., Boehm, H-D.V., Jaya, A. and Limin, S. (2002) the amount of carbon released from peat and forest fires in Indonesia during 1997. *Nature*, 420, 61-65.
Parliamentary Answer (Mr Cullen: Minister for the Environment and Local Government) (2003) Wind Farms and Hen Harriers. (7.2.2003).
Petts, J. (Ed.) (1999) *Handbook of Environmental Impact Assessment.* (2 vols.) Oxford: Blackwell Science Ltd.
Praeger, R.L. (1897a) Bog-bursts, with special reference to the recent disaster on Co. Kerry. *The Irish Naturalist*, 6, 141-162.
Praeger, R.L. (1897b) A bog-burst seven years after. *The Irish Naturalist*, 6, 201-203.
Praeger, R. L. 1906. The Ballycumber bog-slide. *The Irish Naturalist*, 6, 201-203.
Praeger, R.L. (1937) *The Way That I Went*. Methuen.
Proctor, M. (1998) Travel Notes. *Mires Research News*, 16, 2.
Pyatt, D.G (1987) Afforestation of blanket peat – soil effects. *Forestry and British Timber*, March 1987, 15-16.
Pyatt, D.G. (1990) Long term prospects for forests on peatland. *Scottish Forestry*, 44(1), 19-20.
Pyatt, D.G. (1993) Multi-purpose forests on peatland. *Biodiversity and Conservation*, 2, 548-555.
Pyatt, D.G. & Craven, M.M. (1979) Soil changes under even-aged plantations. *In:* E.D. Ford, D.C.Malcolm and J. Atterson (Eds.) *The ecology of even-aged forest plantations.* pp. 369-386. Cambridge: Institute of Terrestrial Ecology.
Rafferty, B. (1990) *Trackways Through Time: Archaeological Investigations on Irish Bogs, 1985-1989.* Dublin: Headline Publishing.
RSPB (2004) *Wind Farms and Birds.* Information leaflet wpo\sc\5190.
Saorgus Energy Ltd. (1997) *Derrybrien Wind Farm: Environmental Impact Statement.* Tralee, Ireland.
Saorgus Energy Ltd. (2000) *Environmental Assessment: Derrybrien Wind Farm Extension.* Tralee, Ireland:
Schneebeli, M. (1989) Zusammenhänge zwischen Moorwachstum und hydraulischer Durchlässigkeit und ihre Anwendung auf den Regenerationsprozeß. *Telma*, 2, 257-264.
Selkirk, J.M. (1996) Peat slides on subantarctic Maquarie Island. *Zeitschrift für Geomorpholigie* 105, 62-72.
Shetland Islands Council (2003) *Information Bulletin: Sandwick Landslides*, 22 September 2003.
Sharma, B. and Bora, P.K. (2003) Plastic limit, liquid limit and undrained shear strength of soil – reappraisal. *Journal of Geotechnical and Geoenvironmental Engineering*, 129(8), 774-777.
Simmons, J. (1995) *The Victorian Railway*. London: Thames and Hudson.
Skempton, A.W. and DeLory, F.A. (1957) Stability of natural slopes in London clay. *Proceedings of the 4th International Conference on Soil Mechanics and Foundation Engineering*, Rotterdam, 2, 72-78.
Smith, L.T. (Ed.) (1910) *The Itinerary of John Leland in or about the Years 1535-1543.* Vol. 5 (Part IX). London: G. Bell and Sons.
Sollas, W.J., Praeger, R., Dixon, A.F. and Delap, A. (1897) Report of the Committee of Investigation on bog-flow in Kerry. *Scientific Proceedings of the Royal Dublin Society*, VIII(V), 475-510.
Standen, R. 1897. Bog bursts. *The Irish Naturalist*, 6, 224.
Stewart, A.J.A. and Lance, A.N. (1983) Moor draining: a review of impacts on land use. *Journal of Environmental Management*, *17*, 81-99.
Sutcliffe, H. (1899) *By Moor and Fell in West Yorkshire*. Fisher Unwin, London.
Tallis, J.H. (Studies on southern Pennine peats. II. The pattern of erosion. *Journal of Ecology*, *52*, 333-344.
Tallis, J.H. (1985) Mass movement and erosion of a southern Pennine blanket peat. *Journal of Ecology*, 73, 283-315.
Tallis, J.H. (1987) Fire and flood at Holme Moss: erosion processes in an upland blanket mire. *Journal of Ecology*, 75, 1099-1129.
Tallis, J. and Seaward, M. (1999) The extraordinary disruption of a bog, Haworth Moors, September 1824. *Mires Research News*, 18, 6-7.
Tansley, A.G. (1935) The use and abuse of vegetational concepts and terms. *Ecology*, *16*, No. 3, 284-307.
Tansley.A.G. (1939) *The British Islands and their Vegetation*. Cambridge: Cambridge University Press.
Taylor, J.H. (1983) The peatlands of Great Britain. *In:* A.J.P. Gore (Ed.) *Mires: Swamp, Bog, Fen and Moor. Regional Studies*, 1-46. Amsterdam: Elsevier Scientific (Ecosystems of the World 4B).
Tobin (2003) Report on the landslides at Dooncarton, Glengad, Barnachuille and Pollathomas, County Mayo: Executive Summary. Patrick J. Tobin & Co. Ltd. www.mayococo.ie/mcc3/DocumentArchive/2003_31_10_landslidefinal2.pdf
Tomlinson, R.W. (1981a) A preliminary note on the bog-burst at Carrowmaculla, County Fermanagh, November 1979. *Irish Naturalists' Journal*, 20(8), 313-316.
Tomlinson, R.W. (1981b) The erosion of peat in the uplands of Northern Ireland. *Irish Geography*, 14, 51-64.
Tomlinson, R.W. and Gardiner, T. (1982) Seven bog slides in the Slieve-An-Orra Hills, County Antrim. *Journal of Earth Sciences of the Royal Dublin Society*, 5, 1-9.

Trodd, V. (2003) Irish digest – bog slides, bog bodies and more. *Peatlands International*, 2/2003, 11-13.
Turner, J.H. (1898) *The Rev. Patrick Bronte, A.B., His Collected Works and Life.* Olicana Books, Bingley.
Turner, W. (1913) A spring-time saunter round and about Bronteland. *Courier*, Halifax.
Vidal, H. (1966) Die Moorbruchkatastrophe bei Schšnberg/Oberbayern am 13/14.6.1960 (The bog-burst catastrophe near Schšnberg, Upper Bavaria, on 13/14 June 1960). *Z. dt. Geol. Ges. Jahrgang 1963*, Band 115, 2 u. 3, 770-782.
Von Post, L. and Granlund, E. (1926) Södra Sveriges torvtillgångar I, *Sveriges Geol. Unders. Avh.*, C335, 1-127.
Warburton, J., Holden, J. and Mills, A.J. (2004) Hydrological controls of surficial mass movements in peat. *Earth Science Reviews* (in press).
Ward, R.C. (1975) *Principles of Hydrology*. McGraw-Hill, Maidenhead, England.
Wathern, P. (Ed.) (1988) *Environmental Impact Assessment: Theory and Practice.* London: Unwin Hyman.
Weston, J. (1997) *Planning & Environmental Impact Assessment in Practice.* Harlow, England: Addison Wesley Longman Ltd.
Wiggins, K. (2001) *Proposed wind turbine development at Derrybrien, Co. Galway: Archaeological Report.* Limerick: Michael Punch & Partners.
Wilson, P. and Hegarty, C. (1993) Morphology and causes of recent peat slides on Skerry Hill, County Antrim, Northern Ireland. *Earth Surface Processes and Landforms*, 18, 593-601.

Web references

Convention on Biological Diversity: www.biodiv.org/decisions/default.aspx

Dúchas The Heritage Service: www.duchas.ie/en/Conservationsites/

Falklands Museum: www.falklands-museum.com/timeline/data/1878b.htm

Hen harrier biodiversity action plan: www.coillte.ie/newsletters/www5/issue5-4.htm#harrier

Highway maintenance: www.highwaysmaintenance.com/drainage.htm

The Ramsar Convention: www.ramsar.org/index_key_docs.htm

Appendix 1. Summary of AGEC geotechnical data and field observations.

site	Mean slope	peat thickness (m)	Average strength	FoS 200/1	FoS 50/1	FoS 200/2	FoS 50/2	excavated?	Excavation drained	Previous instability	road settlement	Collapsed ditch	Cracks around excavation	Collapsed excavation	Bearing Failure (arisings)	Arisings unstable	Forestry cleared
6	1.5	>2	7.8	8.64	9.34	6.43	6.82	no	n/a								
7	2	>2	5.7	4.82	4.3	3.72	3.4	no	n/a								no
8	2	>2	5.7	4.68	3.63	3.64	2.97	no	n/a								no
15	3	>2		2.55	1.91	1.91	1.53	no	n/a								no
16	2	>2		4.25	2.73	3.1	2.21	no	n/a								partially
30	3	>2.4		3.56	4.5	2.43	2.83	no	n/a								partially
31	2	>2.4	13.2	3.51	2.29	2.69	1.91	no	n/a								
36	3	>2.4	6.6	3.56	4.21	2.78	3.16	no	n/a								
39	3	>2.4	5.7	4.96	4.54	3.41	3.21	no	n/a								
51	4	>2		2.43	1.37	1.71	1.11	no	n/a								no
52	3	2		4.11	4.03	2.68	2.64	no	n/a								no
56	4	2		1.88	1.92	1.42	1.44	no	n/a								no
57	3.5	0.85		3.85	4.79	2.56	2.61	no	n/a								yes
58	3	2		3.73	5.1	2.51	3.06	no	n/a								no
59	2	>2		4.59	4.1	3.28	3.02	no	n/a								no
64	2	>2		3.72	3.19	2.81	2.49	no	n/a								no
65	2	2.5		4.2	3.95	3.07	2.94	no	n/a								no
47	3.5	>2		5.91	1.65	3.9	1.21	no	n/a	yes							no
48	2	>2		5.57	4.99	3.75	3.48	no	n/a	yes							no
49	2	>2		4.28	3.58	3.12	2.73	no	n/a	yes							no
50	2	2		7.6	2.12	4.57	1.79	no	n/a	yes							no
54	1.5	2	5.7	7.57	5.11	5.69	3.89	no	n/a	yes							no
33	3	>2.4	4.7	2.1	2.73	1.65	2.01	no	n/a		yes						
60	0.1	>2		59.37	71.62	47.16	54.57	no	n/a		yes						no
61	1.55	>2		121.26	2.94	79.3	2.13	no	n/a		yes						no
53	2	2.35	4.5	3.97	3.82	2.95	2.87	no	n/a		yes	yes					no

site	Mean slope	peat thickness (m)	Average strength	FoS 200/1	FoS 50/1	FoS 200/2	FoS 50/2	excavated?	Excavation drained	Previous instability	road settlement	Collapsed ditch	Cracks around excavation	Collapsed excavation	Bearing Failure (arisings)	Arisings unstable	Forestry cleared
14	2	3.1	4.5	3.17	2.44	2.48	2.01	no	n/a			yes					partially
55	4	2.2	6.6	2.03	2.21	1.5	1.6	no	n/a			yes					no
2	6	> 2	7.3	1.19	1.1	0.91	0.86	yes	yes				yes				no
27	3	> 2		2.39	1.91	1.82	1.53	yes					yes				
12	3		6.6	2.35	2.55	1.8	1.91	Yes/b					yes			yes	yes
13	3		5.6	1.93	1.91	1.54	1.53	yes					yes			yes	yes
69	8	>2	6.8	0.97	0.83	0.73	0.64	Yes/bp					yes			yes	no
4	2.5	> 2	5.7	3.33	3.17	2.44	2.35	yes	yes				yes	yes			no
42	4	2.1	9.4	2.35	2.61	1.67	1.8	Yes/b	yes				yes	yes			
70	5		6.6	1.33	1.26	0.97	0.98	possibly					yes	yes			no
5	5	> 2	8.85	1.38	2.36	1.09	1.62	yes	yes					yes			no
9		> 2	8.25	4.83	3.08	3.34	2.4	yes	yes					yes			no
11	1	> 2	6.6	9.78	9.9	7.53	7.6	yes	yes					yes			no
37	3.5	1.75	5.7	4.75	4.25	3.15	2.92	yes						yes			
45	3	> 2	9.4	5.41	2.4	3.68	1.69	yes						yes			
25	3	1.8	3.8	4.11	3.64	2.62	2.42	yes						yes	yes		
17	4	3	5.6	1.44	1.34	1.03	0.99	Yes/b	yes					yes	yes	yes	no (burnt downslope)
66	4	>2	6.05	2.13	1.54	1.67	1.15	Yes/b						yes	yes	yes	no
29	4	> 2	7.25	3.94	4.11	2.34	2.4	Yes/b							yes	yes	
68	5	3.5	7.35	1.37	1.27	0.99	0.98	partially							yes	yes	no (ride)
23	4	> 1.5	9.65	3.62	3.598	2.22	2.21	yes							yes		no (burnt)
1	4	2	8.7	4.73	4.42	3.35	3.19	yes	yes								no
3	4	1.6	7	4.47	2.92	3.02	2.22	yes									no
10	0.5	>2	6.85	33.5	32.66	22.14	21.77	yes	no								No (burnt)
18	6	1.5	4	1.76	1.54	1.21	1.1	yes								yes	no
19	6	>2	9.85	2.21	2.49	1.58	1.71	yes								yes	no
20	4	>2	5.35	3.1	2.99	2.16	2.11	yes								yes	no
21	3	>2	8.3	4.42	6.01	3.27	4.07	yes								yes	no
22	3	2	11.25	9.24	6.26	5.89	4.52	yes								yes	no
24	4	1		3.59	4.11	2.21	2.4	Yes/b	yes								
26	6	2	7.05	3.19	3.17	2.12	2.12	yes									

Mean slope	peat thickness (m)	Average strength	FoS 200/1	FoS 50/1	FoS 200/2	FoS 50/2	excavated?	Excavation drained	Previous instability	road settlement	Collapsed ditch	Cracks around excavation	Collapsed excavation	Bearing Failure (arisings)	Arisings unstable	Forestry cleared
3	>2.4	5.7	4.73	4.19	3.08	3.03	yes									
5	>1	7.35	5.66	6.56	3.04	3.28	Yes/b									
6	> 2.4	2.8	1.1	0.96	0.78	0.71	yes								yes	
4	0.75	8.9	2.85	3.1	1.67	1.75	Yes/b									no
3	0.75	10	12.91	13.55	7.2	7.39	Yes/b									no
3	2	6.6	6.51	5.26	4.3	3.71	yes									
2	1.5	11.6	31.84	15.94	20.47	8.7	Yes/b								yes	
5	1.5	10	3.35	2.52	2.22	1.82	yes	yes								
3	2.3	5.7	5.31	6.52	3.88	4.48	yes									
3	1.65	8.9	3.3	2.91	2.27	2.08	yes									
1	2.5		88.83	3.1	64.02	2.44	yes									no
4	2.5	6.85	4.12	3.03	2.74	2.21	Yes/b									no
0.1			60.79	48.76	48.05	40.21	partially									no
6		7.5	4.31	1.55	3.08	1.21	partially									no

Appendix 4

Registered number: 367625

Gort Windfarms Limited

Annual Report and Financial Statements

For the Year Ended 31 December 2018

Gort Windfarms Limited

Company Information

Directors	C. Kinsman (appointed 14 January 2019) M.Sinnott (appointed 1 August 2019) A. Kelly (resigned 14 January 2019) J. Redmond (resigned 1 August 2019) J. Healy - Alternate Director (resigned 1 August 2019) J. Healy (appointed 1 August 2019)
Company secretary	J. Healy
Registered number	367625
Registered office	Two Gateway East Wall Road Dublin 3 Ireland D03 A995
Independent auditor	PricewaterhouseCoopers Chartered Accountants and Statutory Audit Firm One Spencer Dock North Wall Quay Dublin 1 Ireland

Gort Windfarms Limited

Contents

Gort Windfarms Limited

Directors' Report
For the Year Ended 31 December 2018

The directors present their annual report and the audited financial statements for the year ended 31 December 2018.

Principal activities

The company is engaged in the operation of a wind farm at Derrybrien, Co. Galway, Ireland.

Going concern

The directors have adopted the going concern basis in preparing the financial statements. Further details are set out in note 1.4 to the financial statements.

Results and dividends

The profit for the year, after taxation, amounted to €795 thousand (2017 - loss €10,136 thousand).

No dividend was declared by the directors (2017 - €Nil).

Directors, secretary and their interests

The directors who served during the year were:

A. Kelly (resigned 14 January 2019)
J. Redmond (resigned 1 August 2019)
J. Healy - Alternate Director (resigned 1 August 2019)

The directors and secretary had no disclosable interests in the shares of the company, or any other group company, as defined in section 329 of the Companies Act 2014, at 31 December 2018 or 31 December 2017.

Key performance indicators

The board has determined the following key performance indicators which cover operational performance:

1. Safety

There were 2 reportable incidents reported to the Health and Satefy Authority in 2018 (2017- Nil). Both were addressed at the time.

2. Environment

There were no reportable environmental incidents in 2018 (2017 - Nil).

3. Availability

Availability is the amount of time that a generator is able to produce electricity over a certain period, divided by ~~the amount of time in the period. The wind farm availability for Gort Windfarms Limited was 97.3% (2017 -~~ 97.1%).

4. Load factor

Full site capacity is the total possible electricity that a wind farm could produce if each turbine was producing electricity at full output. Load factor is a percentage of the full site capacity that was produced in a particular interval. The load factor for Gort Windfarms Limited for 2018 was 24.3% (2017 - 24%).

Gort Windfarms Limited

Directors' Report (continued)
For the Year Ended 31 December 2018

Small companies note

The company's financial statements have been prepared in accordance with the provisions applicable to entities subject to the small companies regime.

Political and charitable contributions

The company made no political or charitable contributions during the year (2017 - €Nil) and has complied with the Electoral Act 1997.

Events since the end of the financial year

There have been no significant events since the Balance Sheet date that the directors believe require adjustment to, or disclosure in the financial statements.

Accounting records

The measures taken by the directors to ensure compliance with the requirements of Sections 281 to 285 of the Companies Act 2014 with regard to the keeping of adequate accounting records, are the employment of appropriately qualified accounting personnel and the maintenance of computerised accounting systems. The company's accounting records are maintained at the company's registered office at Two Gateway, East Wall Road, Dublin 3, Ireland D03 A995.

Research and development

The company did not engage in any research and development activities in the current or preceding year.

Statement on relevant audit information

Each of the persons who are directors at the time when this Directors' Report is approved has confirmed that:

- so far as the director is aware, there is no relevant audit information of which the company's auditors are unaware, and
- the director has taken all the steps that ought to have been taken as a director in order to be aware of any relevant audit information and to establish that the company's auditors are aware of that information (within the meaning of section 330 of the Companies Act 2014).

Auditors

The auditors, PricewaterhouseCoopers, have indicated their willingness to continue in office in accordance with section 383(2) of the Companies Act 2014.

This report was approved by the board and signed on its behalf.

J. Healy
Director
Date: 15 October 2019

C. Kinsman
Director
Date: 15 October 2019

Gort Windfarms Limited

Statement of directors' responsibilities
For the Year Ended 31 December 2018

The directors are responsible for preparing the annual report and the financial statements in accordance with Irish law.

Irish law requires the directors to prepare financial statements for each financial year giving a true and fair view of the company's assets, liabilities and financial position at the end of the financial year and the profit or loss of the company for the financial year. Under that law the directors have prepared the financial statements in accordance with Irish Generally Accepted Accounting Practice (accounting standards issued by the UK Financial Reporting Council, including Financial Reporting Standard 101 'Reduced Disclosure Framework' and Irish law).

Under Irish law, the directors shall not approve the financial statements unless they are satisfied that they give a true and fair view of the company's assets, liabilities and financial position as at the end of the financial year and the profit or loss of the company for the financial year.

In preparing these financial statements, the directors are required to:

- select suitable accounting policies and then apply them consistently;
- make judgements and estimates that are reasonable and prudent;
- state whether the financial statements have been prepared in accordance with applicable accounting standards and identify the standards in question, subject to any material departures from those standards being disclosed and explained in the notes to the financial statements; and
- prepare the financial statements on the going concern basis unless it is inappropriate to presume that the company will continue in business.

The directors are responsible for keeping adequate accounting records that are sufficient to:

- correctly record and explain the transactions of the company;
- enable, at any time, the assets, liabilities, financial position and profit or loss of the company to be determined with reasonable accuracy; and
- enable the directors to ensure that the financial statements comply with the Companies Act 2014 and enable those financial statements to be audited.

The directors are also responsible for safeguarding the assets of the company and hence for taking reasonable steps for the prevention and detection of fraud and other irregularities.

On behalf of the board

J. Healy
Director
Date: 15 October 2019

C. Kinsman
Director
Date:15 October 2019

Independent Auditors' Report to the Members of Gort Windfarms Limited

Report on the audit of the financial statements

Opinion

In our opinion, Gort Windfarms Limited's financial statements:

- give a true and fair view of the company's assets, liabilities and financial position as at 31 December 2018 and of its profit for the year then ended;
- have been properly prepared in accordance with Generally Accepted Accounting Practice in Ireland (accounting standards issued by the Financial Reporting Council of the UK, including Financial Reporting Standard 101 "Reduced Disclosure Framework" and Irish law); and
- have been properly prepared in accordance with the requirements of the Companies Act 2014.

We have audited the financial statements, included within the Annual Report and Financial Statements, which comprise:

- the Balance Sheet as at 31 December 2018;
- the Profit and Loss Account for the year then ended;
- the Statement of Comprehensive Income for the year then ended;
- the Statement of Changes in Equity for the year then ended; and
- the notes to the financial statements, which include a description of the significant accounting policies.

Basis for opinion

We conducted our audit in accordance with International Standards on Auditing (Ireland) ("ISAs (Ireland)") and applicable law.

Our responsibilities under ISAs (Ireland) are further described in the Auditors' responsibilities for the audit of the financial statements section of our report. We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our opinion.

Independence

We remained independent of the company in accordance with the ethical requirements that are relevant to our audit of the financial statements in Ireland, which includes IAASA's Ethical Standard, and we have fulfilled our other ethical responsibilities in accordance with these requirements.

Conclusions relating to going concern

We have nothing to report in respect of the following matters in relation to which ISAs (Ireland) require us to report to you where:

- the directors' use of the going concern basis of accounting in the preparation of the financial statements is not appropriate; or
- the directors have not disclosed in the financial statements any identified material uncertainties that may cast significant doubt about the company's ability to continue to adopt the going concern basis of accounting for a period of at least twelve months from the date when the financial statements are authorised for issue.

However, because not all future events or conditions can be predicted, this statement is not a guarantee as to the company's ability to continue as a going concern.

Reporting on other information

The other information comprises all of the information in the Annual Report and Financial Statements other than the financial statements and our auditors' report thereon. The directors are responsible for the other information. Our opinion on the financial statements does not cover the other information and, accordingly, we do not express an audit opinion or, except to the extent otherwise explicitly stated in this report, any form of assurance thereon.

Independent Auditors' Report to the Members of Gort Windfarms Limited

In connection with our audit of the financial statements, our responsibility is to read the other information and, in doing so, consider whether the other information is materially inconsistent with the financial statements or our knowledge obtained in the audit, or otherwise appears to be materially misstated. If we identify an apparent material inconsistency or material misstatement, we are required to perform procedures to conclude whether there is a material misstatement of the financial statements or a material misstatement of the other information. If, based on the work we have performed, we conclude that there is a material misstatement of this other information, we are required to report that fact. We have nothing to report based on these responsibilities.

With respect to the Directors' Report, we also considered whether the disclosures required by the Companies Act 2014 have been included.

Based on the responsibilities described above and our work undertaken in the course of the audit, ISAs (Ireland) and the Companies Act 2014 require us to also report certain opinions and matters as described below:

- In our opinion, based on the work undertaken in the course of the audit, the information given in the Directors' Report for the year ended 31 December 2018 is consistent with the financial statements and has been prepared in accordance with applicable legal requirements.
- Based on our knowledge and understanding of the company and its environment obtained in the course of the audit, we have not identified any material misstatements in the Directors' Report.

Responsibilities for the financial statements and the audit

Responsibilities of the directors for the financial statements

As explained more fully in the Statement of directors' responsibilities set out on page 3, the directors are responsible for the preparation of the financial statements in accordance with the applicable framework and for being satisfied that they give a true and fair view.

The directors are also responsible for such internal control as they determine is necessary to enable the preparation of financial statements that are free from material misstatement, whether due to fraud or error.

In preparing the financial statements, the directors are responsible for assessing the company's ability to continue as a going concern, disclosing as applicable, matters related to going concern and using the going concern basis of accounting unless the directors either intend to liquidate the company or to cease operations, or have no realistic alternative but to do so.

Auditors' responsibilities for the audit of the financial statements

Our objectives are to obtain reasonable assurance about whether the financial statements as a whole are free from material misstatement, whether due to fraud or error, and to issue an auditors' report that includes our opinion. Reasonable assurance is a high level of assurance, but is not a guarantee that an audit conducted in accordance with ISAs (Ireland) will always detect a material misstatement when it exists. Misstatements can arise from fraud or error and are considered material if, individually or in the aggregate, they could reasonably be expected to influence the economic decisions of users taken on the basis of these financial statements.

A further description of our responsibilities for the audit of the financial statements is located on the IAASA website at:

https://www.iaasa.ie/getmedia/b2389013-1cf6-458b-9b8f-a98202dc9c3a/Description_of_auditors_ responsibilities_ for_audit.pdf

This description forms part of our auditors' report.

Use of this report

This report, including the opinions, has been prepared for and only for the company's members as a body in accordance with section 391 of the Companies Act 2014 and for no other purpose. We do not, in giving these opinions, accept or assume responsibility for any other purpose or to any other person to whom this report is shown or into whose hands it may come save where expressly agreed by our prior consent in writing.

Gort Windfarms Limited

Independent Auditors' Report to the Members of Gort Windfarms Limited

Other required reporting

Companies Act 2014 opinions on other matters

- We have obtained all the information and explanations which we consider necessary for the purposes of our audit.
- In our opinion the accounting records of the company were sufficient to permit the financial statements to be readily and properly audited.
- The financial statements are in agreement with the accounting records.

Companies Act 2014 exception reporting

Directors' remuneration and transactions

Under the Companies Act 2014 we are required to report to you if, in our opinion, the disclosures of directors' remuneration and transactions specified by sections 305 to 312 of that Act have not been made. We have no exceptions to report arising from this responsibility.

Mary Cleary

Mary Cleary (Senior Statutory Auditor)

for and on behalf of
PricewaterhouseCoopers

Chartered Accountants and Statutory Audit Firm

One Spencer Dock
North Wall Quay
Dublin 1
Ireland

Date: 15 October 2019

Gort Windfarms Limited

Profit and Loss Account
For the Year Ended 31 December 2018

	Note	2018 €000	2017 €000
Turnover	3	7,292	5,506
Cost of sales		(5,418)	(5,863)
Gross profit/(loss)		1,874	(357)
Administrative expenses		(809)	(883)
Impairment charge	9	-	(10,172)
Operating profit/(loss)	4	1,065	(11,412)
Interest payable and similar charges	6	(70)	(112)
Profit/(Loss) on ordinary activities before taxation		995	(11,524)
Taxation on profit/(loss) on ordinary activities	7	(200)	1,388
Profit/(Loss) for the financial year		795	(10,136)

The notes on pages 11 to 22 form part of these financial statements.

Statement of Comprehensive Income
For the Year Ended 31 December 2018

	2018 €000	2017 €000
Profit/(loss) for the financial year	795	(10,136)
Total comprehensive income/(loss) for the year	795	(10,136)

The notes on pages 11 to 22 form part of these financial statements.

Gort Windfarms Limited

Statement of Comprehensive Income
For the Year Ended 31 December 2018

	2018 €000	2017 €000
Profit/(loss) for the financial year	795	(10,136)
Total comprehensive income/(loss) for the year	795	(10,136)

The notes on pages 11 to 22 form part of these financial statements

Gort Windfarms Limited

Balance Sheet
As at 31 December 2018

	Note		2018 €000		2017 €000
Non-current assets					
Property, plant and equipment	8		20,141		19,641
			20,141		19,641
Current assets					
Trade and other receivables	10	2,280		1,239	
Cash at bank and in hand	11	9,649		9,135	
		11,929		10,374	
Trade and other payables falling due within one year	12	(21,013)		(21,591)	
Net current liabilities			(9,084)		(11,217)
Total assets less current liabilities			11,057		8,424
Trade and other payables falling due after more than one year	13		-		(1,158)
			11,057		7,266
Provisions for liabilities					
Deferred taxation	14	(1,655)		(1,925)	
Other provisions	15	(6,998)		(3,732)	
			(8,653)		(5,657)
Net assets			2,404		1,609
Capital and reserves					
Called up share capital	16		-		-
Profit and loss account			2,404		1,609
Shareholders' funds			2,404		1,609

The financial statements were approved and authorised for issue by the board:

J. Healy
Director
Date: 15 October 2019

C. Kinsman
Director
Date: 15 October 2019

The notes on pages 11 to 22 form part of these financial statements.

Statement of Changes in Equity
For the Year Ended 31 December 2018

	Share capital	Profit and loss account	Total equity
	€000	€000	€000
At 1 January 2018	-	1,609	1,609
Comprehensive income for the year			
Profit for the financial year	-	795	795
At 31 December 2018	-	2,404	2,404

Statement of Changes in Equity
For the Year Ended 31 December 2017

	Share capital	Profit and loss account	Total equity
	€000	€000	€000
At 1 January 2017	-	11,745	11,745
Comprehensive loss for the year			
Loss for the financial year	-	(10,136)	(10,136)
At 31 December 2017	-	1,609	1,609

The notes on pages 11 to 22 form part of these financial statements.

Notes to the Financial Statements
For the Year Ended 31 December 2018

1. Accounting policies

Gort Windfarms Limited is a limited company incorporated and operating in Ireland. The principal activity of the company is the operation of a wind farm at Derrybrien, Co. Galway, Ireland. The accounting policies set out below have, unless otherwise stated, been applied consistently to all periods presented in these financial statements.

The financial statements are presented in Euro, which is the functional currency of the company, rounded to the nearest thousand.

1.1 Basis of preparation of financial statements

The financial statements of Gort Windfarms Limited have been prepared in accordance with Irish GAAP (accounting standards issued by the Financial Reporting Council of the UK and the Companies Act 2014). The financial statements comply with Financial Reporting Standard 101, 'Reduced Disclosure Framework' (FRS 101), and the Companies Act 2014.

The financial statements have been prepared under the historical cost convention, except for derivative financial instruments which are valued at fair value.

1.2 Financial Reporting Standard 101 - reduced disclosure exemptions

In these financial statements, the company has applied the exemptions available under FRS 101 in respect of the following disclosures:

- IAS 1: Presentation of Financial Statements: Certain disclosures including comparative information
- IAS 7: Statement of Cash Flows: A Cash Flow Statement and related notes
- IAS 8: Accounting Policies, Changes in Accounting Estimates and Errors
- IAS 24: Related Party Disclosures: Disclosures in respect of transactions entered into between two or more members of the ESB Group, provided that any subsidiary which is a party to the transaction is a wholly owned subsidiary
- IAS 24: Related Party Disclosures: Disclosures in respect of the compensation of key management personnel
- IFRS 15: Revenue from Contracts with Customers: Disclosure requirements of paragraphs 110, 113(a), 114, 115, 118, 119(a) to (c), 120 to 127 and 129

As the consolidated financial statements of Electricity Supply Board (ESB), the company's parent undertaking, include the equivalent disclosures, the company has also taken the exemptions under FRS 101 available in respect of the following disclosures:

- IFRS 7: Financial Instrument Disclosures: Disclosures relating to financial instruments
- IFRS 13: Fair Value Measurement
- IAS 36: Impairment of Assets

1.3 New standards, amendments and IFRIC interpretations

IFRS 9 Financial Instruments
IFRS 9 replaces the provisions of IAS 39 that relate to the recognition, classification and measurement of financial assets and financial liabilities, derecognition of financial instruments, impairment of financial assets and hedge accounting. IFRS 9 replaces the incurred loss model in IAS 39 with an expected credit loss (ECL) model. The application of IFRS 9 from 1 January 2018 has had no impact on the amounts recognised in the company's Balance Sheet as at 1 January 2018 or its Statement of Comprehensive Income.

1. Accounting policies (continued)

IFRS 15 Revenue from Contracts with Customers

IFRS 15 establishes a comprehensive framework for determining whether, how much and when revenue is recognised. It replaced IAS 18 Revenue, IAS 11 Construction Contracts, IFRIC 18 Transfer of Assets from Customers, IFRIC 13 Customer Loyalty Programmes and related interpretations. The application of IFRS 15 from 1 January 2018 has had no impact on revenue recognised in the company's Profit and Loss Account.

1.4 Going concern

The financial statements have been prepared on a going concern basis, which assumes that the company has adequate financial resources to continue in operational existence for at least 12 months from the date of approval of these financial statements.

At 31 December 2018 the company had net current liabilities of €9.1m (31 December 2017: €11.2m).

The directors, having regard to the continued support of its shareholder, ESB, have a reasonable expectation that the company will have adequate financial resources to continue in operational existence for at least 12 months from the date of approval of these financial statements and consider that it is appropriate to adopt the going concern basis in preparing the financial statements.

1.5 Turnover

Turnover comprises income, exclusive of value added tax, derived from the sale of electricity generated by the company and is recognised in the Profit and Loss Account once the volume of energy sold under the terms of a power purchase agreement has been verified by both parties to the agreement. No turnover is recognised if there are significant uncertainties regarding the recovery of the consideration due, associated costs or the possible rejection of services by the client.

1.6 Interest payable and similar charges

Interest payable and similar charges comprises interest expense on borrowings.

1.7 Foreign currency translation

Transactions in foreign currencies are recorded at the rate ruling at the date of transactions. The resulting monetary assets and liabilities are translated at the rate ruling at the Balance Sheet date and the exchange differences are dealt with in the Profit and Loss Account. Non-monetary assets and liabilities measured at historical cost are translated using the exchange rate at the date of the transaction and non-monetary items measured at fair value are measured using the exchange rate when fair value was determined.

1.8 Property, plant and equipment

Property, plant and equipment is stated at cost less accumulated depreciation and provisions for impairment in value, except for land which is shown at cost less impairment. Property, plant and equipment includes capitalised employee, interest and other costs that are directly attributable to the asset.

The charge for depreciation is calculated to write down the cost of property, plant and equipment to its estimated residual value over its expected useful life using methods appropriate to the nature of the company's business and to the character and extent of its property, plant and equipment. The major asset classification and its allocated life span is:

Notes to the Financial Statements
For the Year Ended 31 December 2018

1. Accounting policies (continued)

IFRS 15 Revenue from Contracts with Customers
IFRS 15 establishes a comprehensive framework for determining whether, how much and when revenue is recognised. It replaced IAS 18 Revenue, IAS 11 Construction Contracts, IFRIC 18 Transfer of Assets from Customers, IFRIC 13 Customer Loyalty Programmes and related interpretations. The application of IFRS 15 from 1 January 2018 has had no impact on revenue recognised in the company's Profit and Loss Account.

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The directors, having regard to the continued support of its shareholder, ESB, have a reasonable expectation that the company will have adequate financial resources to continue in operational existence for at least 12 months from the date of approval of these financial statements and consider that it is appropriate to adopt the going concern basis in preparing the financial statements.

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The charge for depreciation is calculated to write down the cost of property, plant and equipment to its estimated residual value over its expected useful life using methods appropriate to the nature of the company's business and to the character and extent of its property, plant and equipment. The major asset classification and its allocated life span is:

1. **Accounting policies (continued)**

Plant and machinery	-	20 years

Depreciation is provided on a straight-line basis for all depreciable assets from the date of commissioning (date available for use).

Reviews of depreciation rates and residual values are conducted annually.

Subsequent expenditure on property, plant and equipment is included in the asset's carrying amount or recognised as a separate asset, as appropriate, only when it is probable that future economic benefits associated with the item will flow to the company and the cost of the item can be measured reliably. All other repairs and maintenance are charged in the Profit and Loss Account during the financial period in which they are incurred.

1.9 Impairment

Assets that have an indefinite useful life are not subject to amortisation and are tested annually for impairment. Assets that are subject to depreciation and amortisation are tested for impairment whenever events or changes in circumstance indicate that the carrying amount may not be recoverable. An impairment loss is recognised for the amount by which an asset's carrying amount exceeds its recoverable amount. The recoverable amount is the higher of an asset's fair value less costs to sell and its value in use. For the purposes of assessing impairment, assets are grouped at the lowest levels for which there are separately identifiable cash flows (CGU).

For power generation assets, value in use is based on the estimated cash flows expected to be generated by the asset and is based on estimates of forecast power generation, forecast power prices and the timing and extent of operating costs and capital expenditure. These cash flows are discounted to their present value using a pre-tax discount rate that reflects the current markets assessment of the time value of money and the risks specific to the asset.

1.10 Cash at bank and in hand

Cash at bank and in hand includes cash in hand, deposits repayable on demand and other short-term highly liquid investments with original maturities of three months or less.

1.11 Trade and other receivables

Trade and other receivables are initially recognised at fair value, which is usually the original invoiced amount and subsequently carried at amortised cost using the effective interest method less provision made for impairment.

1.12 Trade and other payables

Trade and other payables are initially recorded at fair value, which is usually the original invoiced amount, and subsequently carried at amortised cost using the effective interest rate method.

1.13 Amounts payable to and receivable from group companies

Intercompany receivables and payables, including loans, are non-derivative financial assets and liabilities which are not quoted in an active market. Those with maturities less than twelve months after the Balance Sheet date are included in current assets and current liabilities respectively. Those with maturities greater than twelve months after the Balance Sheet date are included in non-current assets or liabilities, as appropriate. The balances are initially recorded at fair value and thereafter at amortised cost.

1. Accounting policies (continued)

1.14 Impairment of financial assets

The loss allowances for financial assets are based on assumptions about risk of default and expected loss rates. The company uses judgement in making these assumptions and selecting the inputs to the expected credit loss calculations, based on the company's past history, existing market conditions and forward looking estimates at the end of each reporting period. For loans and balances with Group companies, the general approach permitted by IFRS 9 is applied, which requires 12 month expected credit losses to be recognised on initial recognition of these receivables. If a significant increase in credit risk occurs, this requires expected lifetime credit losses to be recognised on these receivables. The company applies the IFRS 9 simplified approach to measuring expected credit losses which uses a life time expected loss allowance for all trade and other receivables.

While cash and cash equivalents are also subject to the impairment requirements of IFRS 9, there is no impairment loss identified.

1.15 Current and deferred tax

Income tax on the profit or loss for the year comprises current and deferred tax. Income tax is recognised in the Profit and Loss Account, except to the extent that it relates to items recognised directly in other comprehensive income or equity.

Current tax

Current tax is provided at current rates and is calculated on the basis of results for the year.

Deferred tax

Deferred tax is provided using the Balance Sheet liability method, providing for temporary differences between the carrying amounts of assets and liabilities for financial reporting purposes and the amounts used for taxation purposes.

Deferred tax assets are recognised only to the extent that it is more likely than not that there will be suitable taxable profits from which the future reversal of the underlying temporary differences can be deducted.

Deferred tax is measured at the tax rates that are expected to apply in the periods in which temporary differences reverse, based on tax rates and laws enacted or substantively enacted at the Balance Sheet date.

1.16 Provisions

A provision is recognised if, as a result of a past event, the company has a present legal or constructive obligation that can be estimated reliably, and it is probable that an outflow of economic benefits will be required to settle the obligation. Provisions are determined by discounting the expected future cash flows at a pre-tax rate that reflects current market assessments of the time value of money and the risks specific to the liability. The unwinding of the discount is recognised in interest payable and similar charges.

Provision for asset retirement obligations

The provision for retirement and decommissioning of the wind farm represents the present value of the current estimate of the costs of closure of the wind farm at the end of its useful life. The estimated costs of retirement obligations are recognised in full at the outset of the asset life, but discounted to present values using a risk free rate. The costs are capitalised in property, plant and equipment and are depreciated over the useful economic life of the wind farm to which they relate.

Notes to the Financial Statements
For the Year Ended 31 December 2018

1. Accounting policies (continued)

1.14 Impairment of financial assets

The loss allowances for financial assets are based on assumptions about risk of default and expected loss rates. The company uses judgement in making these assumptions and selecting the inputs to the expected credit loss calculations, based on the company's past history, existing market conditions and forward looking estimates at the end of each reporting period. For loans and balances with Group companies, the general approach permitted by IFRS 9 is applied, which requires 12 month expected credit losses to be recognised on initial recognition of these receivables. If a significant increase in credit risk occurs, this requires expected lifetime credit losses to be recognised on these receivables. The company applies the IFRS 9 simplified approach to measuring expected credit losses which uses a life time expected loss allowance for all trade and other receivables.

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Current tax

Current tax is provided at current rates and is calculated on the basis of results for the year.

Deferred tax

Deferred tax is provided using the Balance Sheet liability method, providing for temporary differences between the carrying amounts of assets and liabilities for financial reporting purposes and the amounts used for taxation purposes.

Deferred tax assets are recognised only to the extent that it is more likely than not that there will be suitable taxable profits from which the future reversal of the underlying temporary differences can be deducted.

Deferred tax is measured at the tax rates that are expected to apply in the periods in which temporary differences reverse, based on tax rates and laws enacted or substantively enacted at the Balance Sheet date.

1.16 Provisions

A provision is recognised if, as a result of a past event, the company has a present legal or constructive obligation that can be estimated reliably, and it is probable that an outflow of economic benefits will be required to settle the obligation. Provisions are determined by discounting the expected future cash flows at a pre-tax rate that reflects current market assessments of the time value of money and the risks specific to the liability. The unwinding of the discount is recognised in interest payable and similar charges.

Provision for asset retirement obligations

The provision for retirement and decommissioning of the wind farm represents the present value of the current estimate of the costs of closure of the wind farm at the end of its useful life. The estimated costs of retirement obligations are recognised in full at the outset of the asset life, but discounted to present values using a risk free rate. The costs are capitalised in property, plant and equipment and are depreciated over the useful economic life of the wind farm to which they relate.

1. Accounting policies (continued)

The costs are reviewed each year and amended as appropriate. Amendments to the discounted estimated costs are capitalised into the relevant assets and depreciated over the remaining life of those assets.

1.17 Share capital

Financial instruments that have been issued are classified as equity where they meet the definition of equity and confer on the holder a residual interest in the assets of the company. Ordinary shares are classified as equity.

1.18 Operating leases: Lessee

Rentals paid under operating leases are charged to the Profit and Loss Account on a straight line basis over the period of the lease.

2. Judgements in applying accounting policies and key sources of estimation uncertainty

The preparation of financial statements in conformity with FRS 101 requires management to make judgements, estimates and assumptions that affect the application of policies and reported amounts of assets and liabilities, income and expenses. These estimates and associated assumptions are based on historical experience and various other factors that are believed to be reasonable under the circumstances.

The estimates and underlying assumptions are reviewed on an ongoing basis. Judgements made by management in the application of FRS 101 that have a significant effect on the financial statements and estimates with a significant risk of material adjustment are:

1. Carrying value of wind farm

The directors consider the appropriateness of the carrying value of the wind farm on an annual basis. Further details are set out in note 9.

2. Determining whether the company's turnover arrangements contain a lease

The directors have considered the company's turnover arrangements, having regard to IFRIC 4 "Determining whether an arrangement contains a lease" and have determined that the arrangement does not contain a lease.

3. Turnover

An analysis of turnover by class of business is as follows:

	2018 €000	2017 €000
Electricity sales	7,226	5,447
Other income	66	59
	7,292	5,506

3. Turnover (continued)

Analysis of turnover geographically:

	2018 €000	2017 €000
Island of Ireland	7,292	5,506
	7,292	5,506

4. Operating profit/(loss)

The operating profit/(loss) is stated after charging:

	2018 €000	2017 €000
Depreciation of property, plant and equipment	2,766	3,227
Impairment of property, plant and equipment	-	10,172
Operating lease payments	210	220

5. Employees and directors' remuneration

The company has no employees (2017 - Nil).

Directors of the company are employees of ESB and are remunerated by ESB for their services. During the year, no directors received any emoluments (2017 – Nil) in respect of acting as directors of the company.

6. Interest payable and similar charges

	2018 €000	2017 €000
Interest payable to group undertakings	70	112
	70	112

7. Taxation

	2018 €000	2017 €000
Corporation tax		
Current tax on profit/(loss) for the year	471	234
Total current tax	471	234
Deferred tax		
Origination and reversal of timing differences	(271)	(1,622)
Total deferred tax	(271)	(1,622)
Taxation on profit/(loss) on ordinary activities	200	(1,388)

Factors affecting tax charge for the year

The tax credit for the year is lower than (2017 - lower than) the standard rate of corporation tax in Ireland of 12.5% (2017 - 12.5%). The differences are explained below:

	2018 €000	2017 €000
Profit/(loss) on ordinary activities before tax	995	(11,524)
Profit/(loss) on ordinary activities multiplied by standard rate of corporation tax in Ireland of 12.5% (2017 - 12.5%)	124	(1,441)
Effects of:		
Fixed assets ineligible for depreciation	76	53
Total tax credit for the year	200	(1,388)

8. Property, plant and equipment

	Plant and machinery €000
Cost or valuation	
At 1 January 2018	68,154
Additions	3,266
At 31 December 2018	71,420
Depreciation	
At 1 January 2018	48,513
Charge for the year	2,766
At 31 December 2018	51,279
Net book value	
At 31 December 2018	20,141
At 31 December 2017	19,641

Included within additions in 2018 is the capitalisation of an increase in the asset retirement provision. Please see note 15 for more details.

9. Impairment

	2018 €000	2017 €000
Impairment charge	-	(10,172)
	-	(10,172)

An impairment review of property, plant and equipment was performed which resulted in no impairment charge being recognised in the Profit and Loss Account (2017 - €10.2 million).

8. Property, plant and equipment

	Plant and machinery €000
Cost or valuation	
At 1 January 2018	68,154
Additions	3,266
At 31 December 2018	71,420
Depreciation	
At 1 January 2018	48,513
Charge for the year	2,766
At 31 December 2018	51,279
Net book value	
At 31 December 2018	20,141
At 31 December 2017	19,641

Included within additions in 2018 is the capitalisation of an increase in the asset retirement provision. Please see note 15 for more details.

9. Impairment

	2018 €000	2017 €000
Impairment charge	-	(10,172)
	-	(10,172)

An impairment review of property, plant and equipment was performed which resulted in no impairment charge being recognised in the Profit and Loss Account (2017 - €10.2 million).

10. Trade and other receivables

	2018 €000	2017 €000
Amounts owed by group undertakings	1,824	766
Other receivables	437	458
VAT recoverable	19	15
	2,280	1,239

11. Cash at bank and in hand

	2018 €000	2017 €000
Cash at bank and in hand	9,649	9,135
	9,649	9,135

12. Trade and other payables falling due within one year

	2018 €000	2017 €000
Trade payables	-	4
Amounts owed to group undertakings	20,824	21,308
Accruals	189	279
	21,013	21,591

All amounts fall due within one year. Included in amounts owed to group undertakings within one year at 31 December 2018 is an interest bearing loan repayable within one year of €1.2 million (2017 - €1.3 million). See note 13 for further details.

13. Trade and other payables falling due after more than one year

	2018 €000	2017 €000
Amounts owed to group undertakings	-	1,158
	-	1,158

Amounts owed to group undertakings greater than one year are in relation to a loan provided by ESB on an arm's length basis. At 31 December 2018, the total loan balance repayable after more than one year is €Nil (2017 - €1.2 million). Interest on the interest bearing portion of the loan is charged at a fixed rate of 3.28% and is paid semi-annually in arrears up to 31 December 2019.

14. Deferred taxation

	2018 €000	2017 €000
At beginning of year	(1,926)	(3,548)
Credited to profit or loss	271	1,622
At end of year	(1,655)	(1,926)

The provision for deferred taxation is made up as follows:

	2018 €000	2017 €000
Accelerated capital allowances	(1,655)	(1,926)
	(1,655)	(1,926)

13. Trade and other payables falling due after more than one year

	2018 €000	2017 €000
Amounts owed to group undertakings	-	1,158
	-	1,158

Amounts owed to group undertakings greater than one year are in relation to a loan provided by ESB on an arm's length basis. At 31 December 2018, the total loan balance repayable after more than one year is €Nil (2017 - €1.2 million). Interest on the interest bearing portion of the loan is charged at a fixed rate of 3.28% and is paid semi-annually in arrears up to 31 December 2019.

14. Deferred taxation

	2018 €000	2017 €000
At beginning of year	(1,926)	(3,548)
Credited to profit or loss	271	1,622
At end of year	(1,655)	(1,926)

The provision for deferred taxation is made up as follows:

	2018 €000	2017 €000
Accelerated capital allowances	(1,655)	(1,926)
	(1,655)	(1,926)

15. Other provisions

	Asset retirement provision €000
At 1 January 2018	3,732
Additions during the year	3,266
At 31 December 2018	**6,998**

Analysed as follows	
Non-current liabilities	6,998
At 31 December 2018	**6,998**

The company has estimated environmental and decommissioning costs during the year ended 31 December 2018. The estimated value of future retirement costs at the Balance Sheet date include physical dismantling, site remediation and associated costs. Additions during the year relate to a revision of the estimated environmental and decommissioning costs.

16. Share capital

	2018 €000	2017 €000
Authorised		
1,000,000 (2017 - 1,000,000) Ordinary shares of €1.00 each	**1,000**	1,000
Allotted, called up and fully paid		
100 (2017 - 100) Ordinary shares of €1.00 each	-	-

The holders of ordinary shares are entitled to receive dividends as declared from time to time and are entitled to one vote per share at meetings of the company.

17. Contingent liabilities and guarantees

The company has, in the normal course of business, provided decommissioning and reinstatement cash bonds. The bonds may be drawn against in the event that the company fails to properly restore the site of any project on termination of the project's useful life. The total value of these bonds at 31 December 2018 is €386 thousand (2017 - €386 thousand).

The company is party to a bank guarantee facility for €40 million along with a number of its fellow Group companies.

15. Other provisions

	Asset retirement provision €000
At 1 January 2018	3,732
Additions during the year	3,266
At 31 December 2018	6,998

Analysed as follows	
Non-current liabilities	6,998
At 31 December 2018	6,998

The company has estimated environmental and decommissioning costs during the year ended 31 December 2018. The estimated value of future retirement costs at the Balance Sheet date include physical dismantling, site remediation and associated costs. Additions during the year relate to a revision of the estimated environmental and decommissioning costs.

16. Share capital

	2018 €000	2017 €000
Authorised		
1,000,000 (2017 - 1,000,000) Ordinary shares of €1.00 each	1,000	1,000
Allotted, called up and fully paid		
100 (2017 - 100) Ordinary shares of €1.00 each	-	-

The holders of ordinary shares are entitled to receive dividends as declared from time to time and are entitled to one vote per share at meetings of the company.

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The company has, in the normal course of business, provided decommissioning and reinstatement cash bonds. The bonds may be drawn against in the event that the company fails to properly restore the site of any project on termination of the project's useful life. The total value of these bonds at 31 December 2018 is €386 thousand (2017 - €386 thousand).

The company is party to a bank guarantee facility for €40 million along with a number of its fellow Group companies.

18. Commitments under operating leases

At 31 December 2018 the company had future minimum lease payments under non-cancellable operating leases as follows:

	2018 €000	2017 €000
Not later than 1 year	270	200
Later than 1 year and not later than 5 years	1,080	1,100
Later than 5 years	1,215	2,717
	2,565	4,017

The company has an operating lease arrangement in respect of land with 10 years remaining.

19. Events after the end of the reporting period

There are no events after the reporting period that the directors believe require adjustment to or disclosure in the financial statements.

20. Capital commitments

The company has no capital commitments at the Balance Sheet date (2017 - Nil).

21. Controlling party

The company is 100% owned by Hibernian Wind Power Limited, a company incorporated in Ireland. Hibernian Wind Power Limited is a wholly owned subsidiary of the Electricity Supply Board (ESB), established and operating in Ireland, which is the ultimate parent. The largest and smallest group into which the results of the company are consolidated is that headed by ESB and the consolidated financial statements of ESB are available to the public and may be obtained from Two Gateway, East Wall Road, Dublin 3, Ireland D03 A995.

22. Approval of financial statements

The board of directors approved these financial statements for issue on 15 October 2019

Appendix 5

4080778

Gort Windfarms Limited

Directors' report and financial statements

Year ended 31 December 2008

Registered no. 367625

Gort Windfarms Limited

Notes *(continued)*

17 Contingencies

The company has, in the normal course of business, provided commitment bonds, decommissioning and reinstatement bonds, and capacity bonds as required by the Transmission System Operator. These bonds have been provided in cash and are being held in trust by ESB National Grid. The commitment and capacity bonds may be drawn against should the company not proceed with projects which have secured grid connection agreements. The decommissioning and reinstatement bonds may be drawn against in the event that the company fails to properly restore the site of any project on termination of the projects useful life. The total value of these bonds is €823,000.

Legal cases affecting the company in the normal course of business are outstanding at year end, but none are expected to be material.

18 Commitments

The company has land lease commitments of €400,000 per annum, ending in 2028.

19 Group membership

The company is a wholly owned subsidiary of ESB Power Generations Holding Company Limited, a company incorporated and operating in Ireland, of which Electricity Supply Board (ESB), established and operating in Ireland, is the ultimate parent.

The consolidated financial statements of ESB are available to the public and may be obtained from 27 Lower Fitzwilliam Street, Dublin 2.

20 Approval of financial statements

The board of directors approved these financial statements on 17 June 2009.

Gort Windfarms Limited

Notes *(continued)*

17 Contingencies

The company has, in the normal course of business, provided commitment bonds, decommissioning and reinstatement bonds, and capacity bonds as required by the Transmission System Operator. These bonds have been provided in cash and are being held in trust by ESB National Grid. The commitment and capacity bonds may be drawn against should the company not proceed with projects which have secured grid connection agreements. The decommissioning and reinstatement bonds may be drawn against in the event that the company fails to properly restore the site of any project on termination of the projects useful life. The total value of these bonds is €823,000.

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