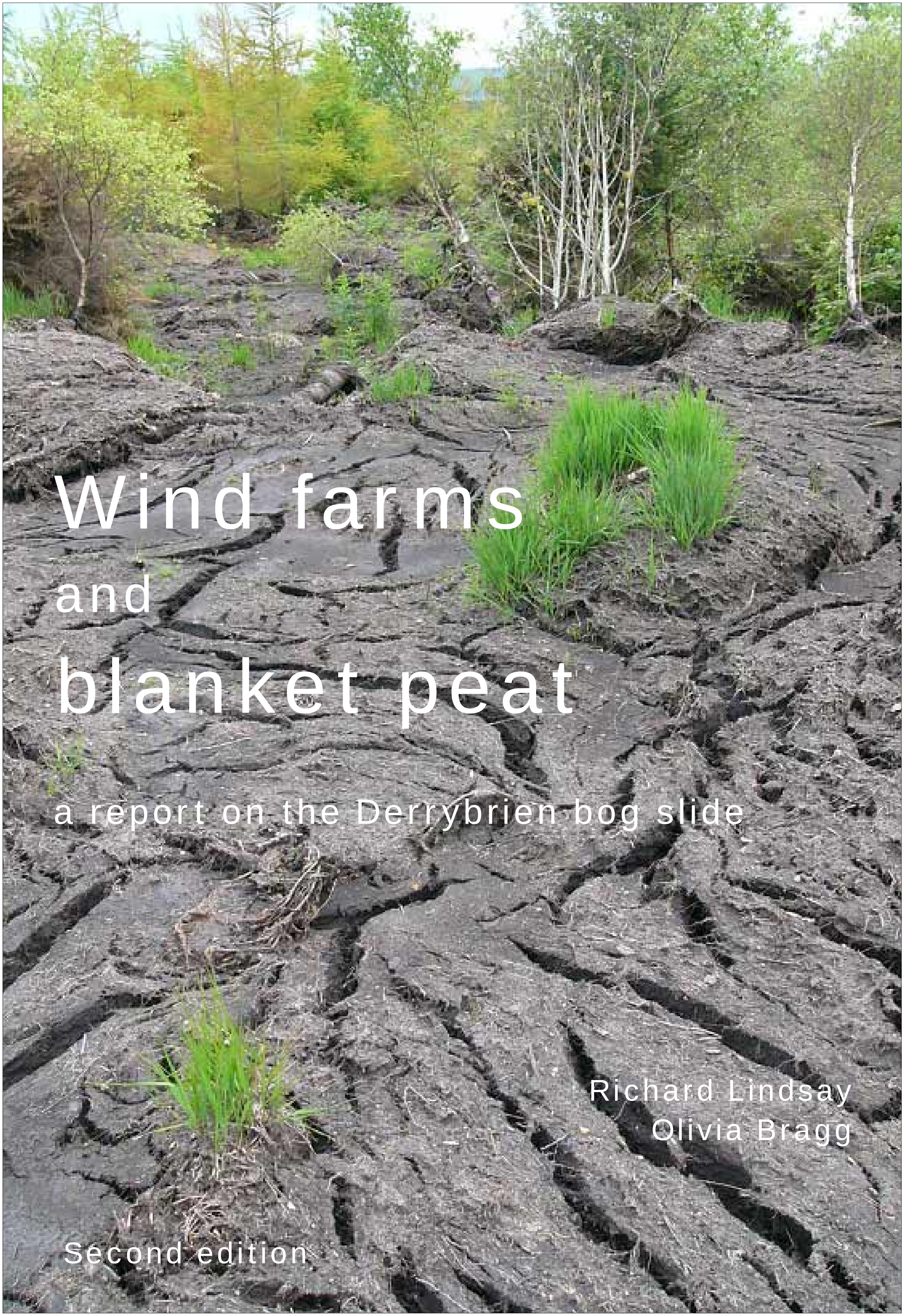

Wind farms and blanket peat

a report on the Derrybrien bog slide

Richard Lindsay
Olivia Bragg

Second edition

WIND FARMS AND BLANKET PEAT

The Bog Slide of 16th October 2003
at Derrybrien, Co. Galway, Ireland

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This is the second edition of a report first published in October 2004. While the opportunity was taken to correct minor errors of fact or attribution brought to the attention of the authors since publication of the first edition and slightly to edit the text for style, it is essentially unchanged.

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He was appointed National Peatland Specialist to the NCC's Chief Scientist Team in 1981 and remained in that post until transferring to Scottish Natural Heritage on the creation of the successor statutory agencies to the NCC. During this time he was involved in a number of high-profile conservation cases including the effect of forestry in the Flow Country of northern Scotland, the issue of peat-use in horticulture and with implementation of the EU Habitats Directive. In 1996 he spent 17 months undertaking international peatland conservation work in Australia, New Zealand, China, Japan, Latvia, France, Austria and Russia, before joining the University of East London in late 1997.

For 16 years he was Chairman of the International Mire Conservation Group (IMCG), which is the international network of peatland specialists who advise their respective governments about peatland conservation issues. He continues to be the IMCG's representative on the European Habitats Forum. He has written and broadcast extensively about peatland conservation issues both in the UK and abroad.

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She has undertaken a very large body of work examining the eco-hydrological condition of particular peatland sites throughout Britain, has worked on several sites in Russia and Indonesia and others in Canada, Ukraine and Belarus. She was responsible for a major Darwin Initiative programme involving knowledge-transfer of peatland conservation management skills through a number of Central European countries and was co-editor (with Richard Lindsay) of a Strategy for Peatland Conservation in Central Europe.

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WIND FARMS AND BLANKET PEAT

The Bog Slide of 16th October 2003 at Derrybrien, Co. Galway, Ireland

R.A. Lindsay and O.M. Bragg
University of East London, 2004

EXECUTIVE SUMMARY

Introduction

THE DERRYBRIEN BOG SLIDE of October 2003 occurred during construction of a 71-turbine wind farm. As well as examining some wider issues, this report examines key areas of the project, the bog slide event and issues arising from it, including :

- the nature of the area within the windfarm site; the likely environmental impact; the planning process; events leading up to, and possibly causing, the slide; an assessment of the geotechnical reports and some future scenarios.

Nature of the development area

Recommended procedures for Environmental Impact Assessment (EIA) involve an initial scoping stage in which the characteristics of a site are established and the area likely to be affected is determined. This is usually an iterative process because many issues have wider effects, e.g. local erosion leads to sedimentation at a distance from the site.

The Derrybrien development straddles the summit of Cashlaundrumlahan, an area dominated by extensive blanket mire generally over 1.5 metres thick and, in many places, over five metres thick. This raises significant engineering problems because peat is a matrix typically of two per cent dead plant material and 98 per cent water (by weight). If peat soils are drained, they tend steadily to oxidise and release CO_2 into the atmosphere. If they are de-stabilised by engineering works, they can erode, washing quantities of material into downstream watercourses.

The blanket peat on Cashlaundrumlahan has already been substantially changed by mature forestry. Particularly on deep peat, this causes it to lose water through evapo-transpiration from the tree roots and reduced rainfall because the canopy cuts off much of the rain. Especially where the forest species is lodgepole pine (*Pinus contorta*), as it is at Cashlaundrumlahan, this causes the peat to crack along the lines of the forestry ploughing furrows. These cracks may be over half a metre deep and many metres long. Following canopy closure after 20 to 30 years, they will extend for considerable distances even though they may be hidden by leaf litter and surface roots. The whole area becomes heavily fissured and, in effect, divided into long ribbons of peat running between the ploughing furrows. The blanket peat is altered from a continuous cohesive mass into a discontinuous series of blocks which are no longer cohesive and may be unstable. This was the situation at Derrybrien prior to development.

Stability of blanket peat

There is substantial evidence from all over the world and from as far back as the Middle Ages, both in the literature and from experience, to show that peat bogs, and blanket peat in particular, can undergo catastrophic collapse. Substantial areas of blanket peat can suddenly begin sliding down hillsides, either as a single slab or as a liquified mass. Sometimes the peat travels many kilometres and there has been loss of life. Almost invariably, the incidents can be linked to human disturbance. Various mechanisms have been proposed for bog or peat slides but there is, as yet, no clear understanding of where or how they occur. This should have led to very careful assessment at Derrybrien before engineering work was undertaken.

Likely impact of the wind farm development

The three main elements of wind farm construction are the building of access roads, the excavation of turbine bases and the erection of the towers.

The developers proposed that the access roads be 'floated' on the peat partly because it was so deep and partly to avoid the need for drainage. However, these 'floating' roads cut across the natural drainage lines of the peatland system so that water tends to become ponded on their upslope while downslope areas become drier. Over time, the roads tend to sink below the peat surface, becoming awash and thus unusable. 'Floating road' technology cannot by its nature be sustained for more than short periods in localised areas. On wind farms, however, the roads have to be maintained for the life of the project (including decommissioning) and they need to be drained to remain usable.

This leads to the constant oxidation of the peat forming the ditch walls. Many 'floating' roads or railways now lie several metres below the peat and are themselves now draining the bog.

The development proposals also claim that excavation of turbine bases will not cause drainage of the peat. These excavations require a hole through the peat and underlying glacial deposits to reach competent bedrock. It is stated that they will not be connected to a drainage system and will not cause drainage of the surrounding area either because they will fill with water or because they will be back-filled with material.

The area excavated for a turbine base is suggested as about 10 x 10 metres. In practice, it is much larger, partly because the stable angle of repose for the cut peat faces means that they cannot be vertical. A turbine also requires hard-standing for heavy construction and maintenance vehicles. Most turbines are sited on sloping ground and, even if they are allowed to fill with water, the upslope faces of the excavation will drain. This is true even if they are back-filled because hard-core is much more porous than peat. Normal construction practices for turbine bases involve explicit drainage of the area around the base, partly to ensure that hard-standing does not become waterlogged. It is likely that the blanket peat will undergo significant hydrological disturbance as a result. There are also issues of load-bearing capacity in relation to expected usage and of how this combined impact will interact with the fissured peat beneath the forest plantation.

There are major concerns about impacts because, if the peat should display instability, either as surface erosion or actual collapse, the effects will be felt primarily in downstream streamcourses. Cashlaundrumlahan is a major watershed and the source of river systems leading into important karst or lake systems, some of which are designated as candidate Special Areas for Conservation (cSAC) under EU legislation. There is a danger that sites of significant commercial or nature conservation interest will be adversely affected if development renders the peat cover unstable. This danger persists for the duration of the development and beyond, not just during construction.

The potential for turbines to pose a hazard to important bird populations is also relevant. The Slieve Aughty Mountains have, for example, been identified as supporting important concentrations of hen harrier in Ireland. These have long breeding cycles, relatively low population densities and low absolute numbers. Loss of only one of two individuals can represent a significant impact. Blade strikes are most likely during periods of adverse visibility such as low cloud cover, conditions that regularly prevail around Cashlaundrumlahan.

The planning process for the Derrybrien development

The planning process for Derrybrien comprised three separate applications. The first two were submitted in 1997, prior to S.I. No. 93/1999, which made even modest wind-farm developments subject to statutory EIA. While an EIA was produced on a voluntary basis for the first proposal, there was no explicit assessment, voluntary or otherwise, for the second. The final application (25 turbines) was subject to statutory EIA because it was submitted after S.I. No. 93/1999.

Being put forward in stages (the EU calls it 'salami-slicing') means that the project has been considered piecemeal: it has not been evaluated as a whole, only a third has been subject to statutory EIA and much of one of Europe's largest wind farms has not been subject to direct assessment at all.

The assessments present a 'best-case' for the development instead of objectively and comprehensively assessing the full scale of potential impacts. Although they recognise that peat is present across most of the site, there is no discussion of the ecology, hydrology or physical stability of peat soils although most of its potential environmental impacts arise as a result of the characteristics of peatland ecosystem.

Detailed analysis is restricted to noise and visual impacts whereas the most important ecological factors (soils, water and drainage patterns) are considered only to the extent of acknowledging that there might be some mineral sediment release but that this would be prevented. Despite a statutory requirement to consider indirect and cumulative impacts and impact interactions, both EIAs state that there would be no significant impacts. Most important, they do not consider peat stability, although they do recognise that the peat has been severely disrupted by forestry. There is no attempt at stability analysis, despite readily availabile and detailed guidance such as PPG14 for England & Wales. Instead, the plantation forestry is described as an advantage because it means that the wind farm will have minimal environmental impact.

Wildlife assessment, particularly of avifauna, is superficial and does not make use of available information. Its conclusions do not reflect the information presented about birds and, again, give a best-case scenario.

Claims are made concerning carbon emissions which are incorrect and present only part of the story. It is suggested that there are no emissions from wind farms and that all carbon-balance issues are favourable. This is not so because vehicles are used to construct and maintain the wind farm and there are emissions associated with construction. While these should form part of the environmental audit, the most important issue at Derrybrien is the release of CO_2 from the peat soil as it oxidises during construction and as a result of catastrophic failures. The losses from the October 2003 event alone are equivalent to the energy production of three or four turbines for the lifetime of the project.

Events surrounding the bog slide of October 2003

The bog slide of October 2003 occurred after a period of dry weather, during construction of two turbine bases on a south-facing slope. The uppermost point was at Turbine 68 and Turbine 70 was swept away as a mass of peat slid for some 2.5 km. Failure appears to have occurred within the peat rather than at the peat-mineral interface. It is difficult to say exactly what happened, partly because evidence was washed away, but it seems that excavations were taking place for T68 while, immediately downslope, ponded water was being released beneath or over the road at T70.

The peat came to rest for some days but was re-activated by heavy rains in late October. It then became extremely fluid and flowed over 20 km down the Owendalulleegh River into Lough Cutra.

The evidence suggests that the failure may have resulted either from loading by excavation machinery or from the release of water into heavily-fissured peat or both. The initial failure led to a series of peat 'ribbons' separating from each other like zips and flowing off downslope, each supporting a line of plantation trees. The fault-lines corresponded to cracks from the forestry.

Unusually, the bog slide occurred during a spell of dry weather. The area had experienced an exceptionally dry summer in a run of dry summers which probably exacerbated cracking within the peat. If too much water entered the heavily-fissured peat either as rainfall or through pumping and drainage, this, combined with heavy machinery, may well have caused the failure.

Assessment of the geotechnical reports

Two geotechnical reports were produced after the slide, one by BMA, the other by AGEC. Both catalogue several factors to investigate but only one is used to calculate Factor of Safety (FoS) values. Both consider only static loading, not the impacts of vehicle movements or temporary loading.

The FoS values obtained indicate that 10 to 25 per cent of turbine locations showed a potential for instability. However, locations with high FoS values (i.e. stable) actually showed signs of instability while some locations with low FoS values showed no such signs, suggesting that the measurements gave only a crude picture of stability. This may be partly because the calculations assume fixed values for shear strength, do not consider the fissured nature of the peat and make no allowance for localised temporary ponding or unsupported peat faces.

Both reports recommend ‘robust’ site drainage to stabilise the site sufficiently for work to continue. Given the tendency of drainage to concentrate water flows and the attendant dangers should the drainage system fail, it is not clear that it will produce the desired result in, say, storm conditions. As reported, the slide involved drained peat and occurred during dry weather.

Intensive drainage will result in the continued release of CO_2. If it causes major degradation of the peat through, for example, erosion, then the CO_2 release could continue long after the site has been decommissioned. It is also likely to result in increased sedimentation in the freshwater systems that arise in, or are fed by, the watershed. This is likely to have a significant impact on the quality of these systems, some of which are candidate SAC sites under EU legislation.

Assessment of scenarios

By integrating a range of spatial, topographic and habitat information into a drainage-pattern model for the whole of Cashlaundrumlahan, it is possible to view areas of significant peat cover in the context of a landform model. It is then possible to identify possible routes of movement should the peat fail again. These are akin to the avalanche corridors used in safety planning in the Alps.

From this, it is clear that the main bog slide arose in an area of moderate peat depth. The deepest peat is on the western limit of the summit on a slope that points towards Derrybrien and where there are three closely-spaced watercourses, any one of which might form a potential avalanche route. One of them flows into the village, past its school.

If the model examines the areas that show evidence of instability, it is clear that several of the corridors are linked to instability, including the deep peat on the western slopes. This significantly increases the threat posed by avalanche corridors directed towards Derrybrien.

The bog slide was not a single, freakish incident but part of a general pattern of instability within the area. There is evidence of other bog slides and of peat movement on the site and a bog slide was associated with another wind farm only four km to the north. It is reasonable to believe that another slide – perhaps small, perhaps as big as the last one – could occur.

The problem is that not enough is known about bog slides to predict where such an event might occur or what might trigger it. It is clear from the recent rainfall record that the region is in an extended period of weather drier than anything envountered over the last 15 years. The bog slide was associated with a prolonged dry period and there must be concerns that continued working on the site, either construction work or ongoing maintenance, may trigger a repeat event.

The general issue of wind farms, peatlands and renewable energy

The rationale for wind farms is that they reduce CO_2 emissions compared to fossil fuels. In most places, emissions from wind farms are associated only with the construction of the components and vehicular emissions linked to the site’s development and maintenance. However, on peatlands, construction results in significant ongoing CO_2 release because they are substantial long-term carbon stores and this carbon is released when they are disturbed.

The Ramsar Convention recognises that peatlands are a habitat that is overlooked, misunderstood and under-recorded but which represent more than 50 per cent of the world’s terrestrial wetland and which hold around 25 per cent of its soil carbon. They contain three times more carbon than the tropical rainforests and it is stored for thousands of years rather than the hundreds associated with most natural forests.

It is difficult to understand the logic of damaging long-term carbon stores to install devices whose purpose is to reduce emissions.

Introduction and objectives

IRELAND'S LARGEST WIND FARM proposal was consented through a series of planning permissions between December 1997 and July 2003, initially by Saorgus Energy and latterly by Hibernian Wind Power Ltd / Gort Windfarms Ltd. The site is on the summit of Cashlaundrumlahan Mountain[1] in the Slieve Aughty range, about 14 km east of Gort, County Galway and three km north of Derrybrien (fig 1). It is blanketed by up to 5.5 metres of peat and is now mostly covered by mature plantation forestry.

Construction of access roads and the first of 71 turbine bases started on 2 July 2003. On Thursday 16 October 2003, an estimated 450,000 cubic metres of peat slid down the southern side of the mountain. The slide initially stopped moving on 19 October, about 2.45 km downstream at an elevation of about 195 m and immediately upslope of a minor road known as the Black Road. At that time, most of the failed material lay on forestry land but it had surrounded an unoccupied house.

On 28 October, the peat began to move again following heavy rain. It crossed the Black Road and continued for 1.5 km to the Owendalulleegh River, whence it 'coursed along the Derrywee River and meandered for 20 miles to Lough Cutra, the source of Gort's domestic water supply'.[2] At a Derrybrien Co-ordination Meeting held on 17 November 2003 to discuss the impact of the bog slide, initial estimates of the impact on Lough Cutra indicated that more than 50 per cent of fish in the lake had been killed, about 50,000 fish of all species and age groups.[3]

Hibernian Wind Power halted construction and two geotechnical investigations were commissioned. On the basis of the results, the company acknowledged that the landslide was caused by its activities but contended that the risk of such an outcome could not have been foreseen. Its intention is to resume construction, adopting modifications to working practices recommended by the reports.

The University of East London was engaged in June 2004 by V.P. Shields & Son, on behalf of the Derrybrien Development Cooperative Society Ltd and individual landowners whose lands were affected by the bog slide[4] to provide an independent assessment of the development. The authors visited the site on 8 June 2004 and were shown around by Hibernian Wind Power staff. The objectives of their report are:

- to assess the adequacy of the Environmental Impact Statement and the Environmental Assessment compiled to support the planning applications submitted for the wind farm development;
- to highlight and consider any issues relevant to the development but not considered in these Environmental Impact Assessment reports;
- to assess in similar terms the two geotechnical investigations undertaken after the peat slide.

It is in two sections. Part 1 deals with issues prior to the slide, including the pre-development state of the site, the issues to be considered in an EIA and the EIA reports actually produced for the development. Part 2 deals with the slide, its possible causes, the analyses of the event carried out to date and some scenarios for the future.

1 Irish National Grid Reference M 589 049, summit altitude 365m above mean sea level at Malin Head (Malin datum).
2 Ronnie O'Gorman, Galway Advertiser. The river has variant names and spellings: the Derrywee, the Owendalulleegh and the Abhainn Da Loilioch River. (The distance the slide travelled was more like 20 km.)
3 The Shannon Regional Fisheries Board confirmed the estimate in a press release of 18 November 2003.
4 Mary Curley, Michael Mahony, Joe Slattery, Frances Broderick and James Kelly.

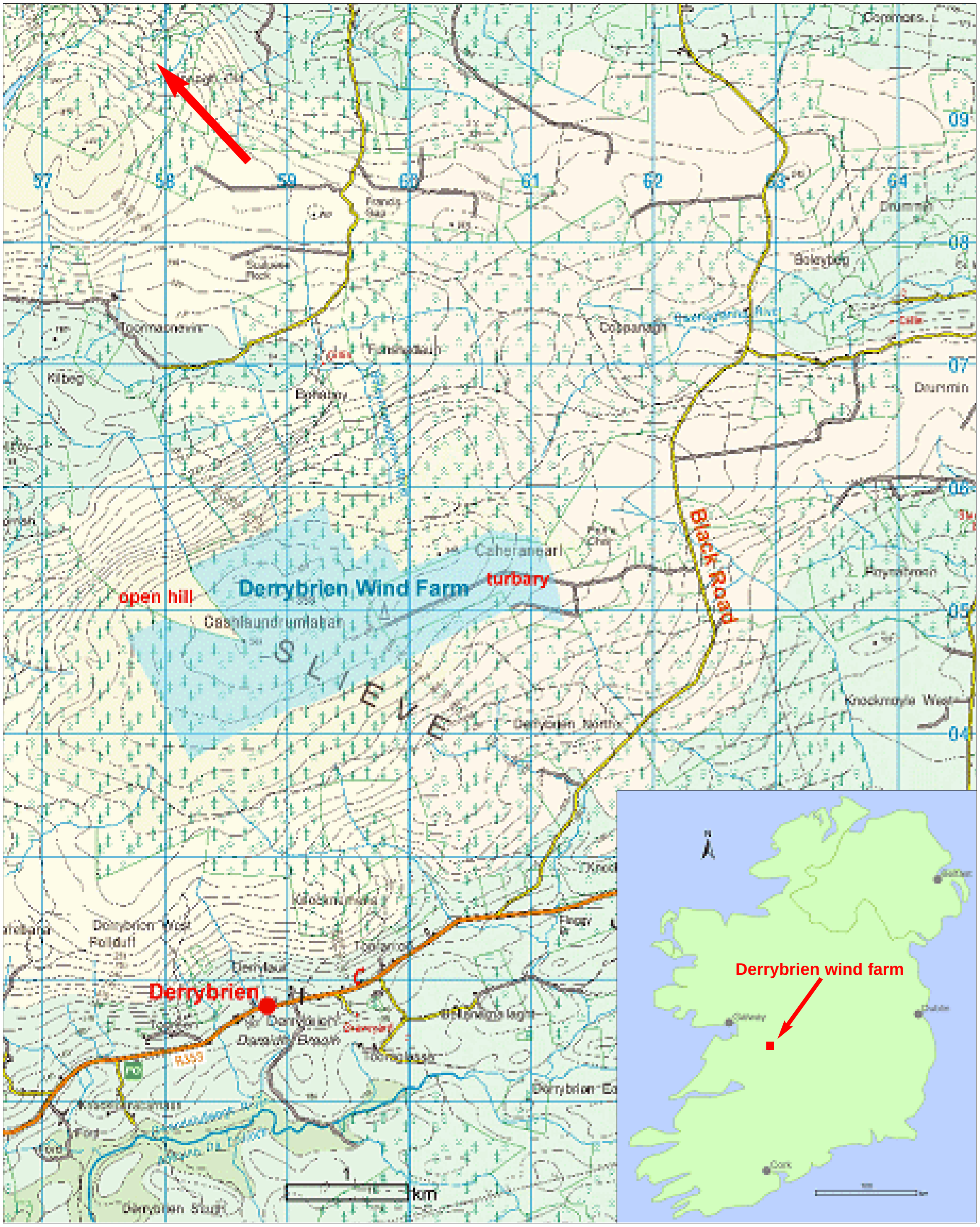


Figure 1: The location of Derrybrien wind farm (shaded pale blue), based on Ordnance Survey Ireland 1:50,000 Discovery Series, Sheet 52. (The arrow in the upper left corner points to the Sonnagh Old wind farm – see page 120.)

PART 1

Issues prior to 16 October 2003

Chapter 1
Development and Environmental Impact Assessment

FOR THE PERIOD LEADING up to the bog slide, the report is concerned with:

- an assessment of the area prior to the development;
- an assessment of the proposed development;
- identification of factors relevant to an assessment of its impact;
- observations about the impact assessment the developers actually carried out.

The process of Environmental Impact Assessment (EIA) is central to Part 1 of the report. The legislative background to EIA and the available guidance are therefore reviewed below and set in the context of the Derrybrien wind farm proposals.

1.1 *General background to Environmental Impact Assessment*

The European Communities Directive 85/337/EEC first established a legislative requirement within the European Union for Environmental Impact Assessment (EIA) in 1985 and identified a number of activities for which an EIA would be required. These were later transposed into Irish legislation through various planning and development consent systems (EPA 2002). In 1997, the original Directive was amended by Directive 97/11/EC to encompass a wider range of more clearly specified developments for which EIA would be a legal requirement. Member states had to implement this amending legislation by 14 March 1999 (Bond, undated).

A considerable body of literature concerning EIA, EIS and EA is freely available. Much of this provides detailed and helpful guidance about the assessment process, how it should be approached, what sorts of factors should be considered for a given development type and even where information can be obtained (e.g. Essex Planning Officers' Association 1994, Morris and Therivel 1995, Gilpin 1995, Weston 1997, Petts 1999, European Commission 1999).

Guidance about the details required for EIA varies to a degree from author to author and from country to country but there is a remarkable degree of consistency in general structure. This is perhaps not so remarkable given that the approach established by the US Environment Protection Agency forms the model for many systems around the world. The key elements generally recognised as forming part of an EIA and explicitly set out for EU Member States in Article 5(1) of Directive 97/11/EC, consist of:

- Description of the physical nature of the project and its processes;
- Outline of the various alternatives considered and the reasons for the final choice;

- Description of those parts of the environment likely to be significantly affected by the project;
- Description of the the project's likely effects on the components described above;
- Description of the measures to be taken to minimise or mitigate these effects.

These form the essential components of an EIA but they must then be incorporated into the planning process which has its own clearly-defined stages. Within the European Union, these stages are recognised as:

- Project Preparation – the developer prepares the proposals;
- Notification to Competent Authority – some Member States require prior warning of a development proposal;
- Screening – the Competent Authority considers whether a project requires an EIA;
- Scoping – the developer determines the range of environmental issues that must be addressed by the EIA;
- Environmental Studies – the developer gathers environmental information;
- Submission of EIS – the report is presented to the Competent Authority;
- EIS Review – the Competent Authority considers whether the EIS is adequate;
- Consultation – the EIS is subject to a consultation process involving statutory bodies and interested parties;
- Consideration of the Environmental Information – the Competent Authority considers the EIS and consultation comments prior to making a decision about the application;
- Announcement of Decision – the decision is made public, along with reasons and mitigation measures to be adopted;
- Post-Decision Monitoring – if the project is approved, there may be a requirement to monitor subsequent project effects.

Not all these steps are legal requirements under Directives 85/337/EC and 97/11/EC but all are recommended to Member States as good practice and have been formalised by some into national law. However, as far as the wind farm development at Derrybrien is concerned, all the steps except the last fell within the period prior to the bog slide and can be considered in Part 1 of the report.

1.2 *Project Preparation*

Strictly speaking, the project is not one development but three because three separate planning applications were made to Galway County Council. The details are dealt with in section 7.1 and it is sufficient to note here that the composite application involved the construction of 71 wind turbines within an area of some 345 hectares across the summit of Cashlaundrumlahan. In contrast with the developer's approach, in which two separate Environmental Statements were produced (they are considered in section 7.5), the scheme will be considered here as a single development proposal.

1.3 *Notification to Competent Authority*

There is no requirement in Irish legislation for a developer to notify the planning authority of an intention to submit a planning application.

1.4 *Screening*

Directive 85/337/EC specifies a range of development proposals for which EIA is mandatory but wind farms are not included. Consequently, the first EIA Directive is not relevant to the wind farm proposal at Derrybrien. The amending Directive 97/11/EC extended the list of developments for which EIA is required and wind farms are explicitly listed in Annex II of the Directive. Member

States have a certain flexibility in relation to Annex II developments in that they can decide if an EIA is required on a case-by-case basis or they can specify national thresholds to determine what developments require assessment. Ireland chose the threshold approach and Statutory Instrument No. 93/1999 states that all wind farms with more than five turbines or whose capacity is over five MW are subject to EIA. A development the size for Derrybrien would thus be legally required to undertake an EIA as part of the planning process. In practice, the final phase of the scheme, involving 25 turbines, required EIA because it was submitted after S.I. No. 93/1999 came into force. The planning sequence is discussed in detail in section 7.3.1.

1.5 *Scoping*

Although detailed guidance on scoping was not published by the European Commission until 2001 (European Commission 2001), the subject has been covered extensively in the literature and the Commission's guidance in relation to environmental impact assessment and cumulative impacts (European Commission 1999) gives a valuable and informative treatment of the subject. Scoping is defined by the 2001 Guidance:

> Scoping is the process of determining the content and extent of the matters which should be covered in the environmental information to be submitted to a competent authority for projects which are subject to EIA.

More particularly, the guidance provided for the assessment of cumulative impacts has the following to say about the importance of scoping:

> Scoping is a well established principle in EIA and much guidance has already been produced on the subject . . . The objective of undertaking scoping is to identify issues that are to be addressed in the EIA and to focus the assessment on the most potentially significant impacts . . . Scoping is generally accepted to be one of the main factors in a successful EIA . . . Decisions made at the scoping stage of the EIA are of fundamental importance to the project as they determine, in the most part, what will follow.

What follows in Part 1, sections 2 to 6 is largely a scoping exercise for the Derrybrien development based on the guidelines set out by the European Commission. This is then compared (in section 7) with the EIA reports that accompanied the planning applications. This provides a means of judging to what extent these adequately addressed the issues relevant to, and the potential impacts of, the project.

Chapter 2
Scoping – the ecological framework

2.1 *Establishing geographical (and temporal) limits for the EIA*

One of the key steps in the EIA process is determination of the geographical boundary over which assessment will be undertaken. This in turn determines the environmental issues that the EIA must address. Although providing an obvious limit, the area encompassed by the planning applications rarely proves to be an adequate boundary for an EIA. Consider factors such as visual impacts or noise and it soon becomes evident that impacts may involve areas some distance beyond the bounds of the development. Other factors may have a seasonal aspect or a cumulative geographical effect – it is important to consider limits over time as well as space.

The geographical area embracing all possible impacts will rarely be clear at the outset of the exercise because, as more factors are considered, so they bring with them their own geographical boundaries of possible impact. It is important to return to the boundary question repeatedly during the scoping process as additional factors are introduced because each may have an influence on the final boundary. This iterative approach is fundamental to the scoping process and is particularly important in ensuring that indirect and cumulative impacts as well as impact interactions are fully addressed. As the guidelines for this process observe (European Commission 1999):

> Indirect and cumulative impacts and impact interactions may well extend beyond the geographical site boundaries of the project. Determining the geographical boundaries will therefore be a key factor in ensuring the impacts associated with a project are assessed comprehensively wherever possible ... Additional data may need to be gathered to cover wider spatial boundaries, taking into account the potential for impacts to affect areas further away from the site than if just direct impacts were considered. Consideration should be given to the distance that an impact can travel and any interaction networks.

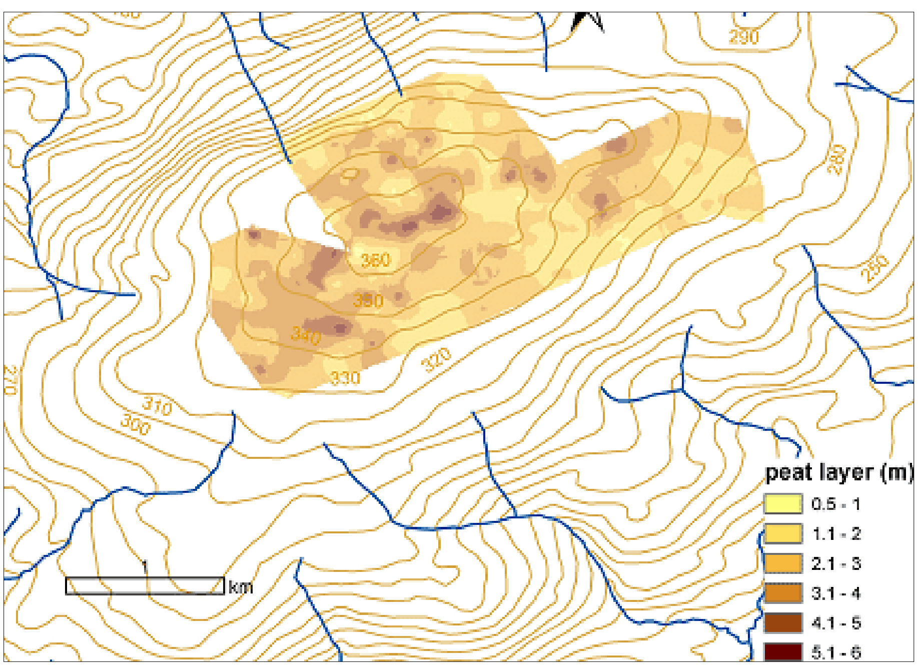


Figure 2.1: The depth of peat recorded for Cashlaundrumlahan within the area of development.
Surface contours give some indication of slope, while the streamlines indicate patterns of drainage.

Original peat depth data recorded by Malone O'Regan McGillicuddy, Consulting Engineers, Cork.

2.2 *Characteristics of the Cashlaundrumlahan summit*

The limits of the Derrybrien wind farm development embrace most of the broad summit of Cashlaundrumlahan, one of the northernmost peaks of the Slieve Aughty Mountains which lie towards the western seaboard of Ireland (inset, fig 1). The mountain range appears on the simplified geological map of Ireland (GSI 2004) as a massif of Devonian Old Red Sandstone[1] rising from lowlands of Burren (karst) limestone. The west of Ireland is a classic location for the extensive development of peat soils and the Cashlaundrumlahan summit is covered by these to a thickness of between 0.4 and 5.5 metres (average 2.5 m). The distribution of this within the area of the development can be seen in fig 2.1.

The environmental assessment should recognise that a large proportion of the issues to be addressed arise from the fact that peat is the dominant soil type. The first stages of information-gathering to establish its ecological baseline should involve a detailed review of peat and its ecological characteristics in order to begin identifying the key factors that may be relevanct to the assessment.

2.3 *Peat*

Peat has been defined as 'partly decomposed plant material that has accumulated in situ (rather than being deposited as a sediment) as a result of waterlogging' (Bragg and Lindsay 2003). When peat-forming plants die, they do not decay completely because their remains become waterlogged as a result of constant, regular rainfall. This constant waterlogging excludes air and limits the range of active decomposer organisms. Instead of decomposing entirely to carbon dioxide and water when they die, some of the plant remains from the surface vegetation become incorporated into a layer of partly-decomposed vegetation beneath the surface. This 'soil' has been accumulating for thousands of years to become, in places, several metres thick. Its only water supply is rainfall and the low permeability of peat means that the water drains away very slowly. The peat remains saturated almost up to the surface, maintaining the anaerobic conditions necessary for its own preservation. Such persistently wet, nutrient-poor conditions favour the growth of the bog-moss Sphagnum, which carpets much of the ground and provides the majority of the plant material that eventually becomes peat. Sedges, dwarf shrubs and other specialist vascular plants grow rooted in this carpet as though it were the surface of the soil.

The peat may be little decomposed and retain recognisable fragments of Sphagnum and other living plants that formed it or it may be more strongly humified and amorphous. The degree of decomposition (humification) can be estimated in the field by applying the 'squeezing test' of von Post and Granlund (1926). This yields a humification value ranging from H1 (completely undecomposed) to H10 (highly decomposed). As material passes down through the living surface layers (or, more accurately, is increasingly buried by fresh growth at the surface), its degree of decomposition increases as long as it continues to be exposed to oxygen by fluctuations in the water table. However, once it enters the lower layers of permanently waterlogged peat and remains bathed by the nutrient-poor, acidic water of these layers, most of the decomposing organisms become inactive and further breakdown occurs only by slow anaerobic fermentation, which produces methane.

Although regarded by geologists as a drift deposit and by pedologists as a soil, many types of peat contain negligible quantities of mineral material. A silt-laden river contains more mineral matter by volume than does the same volume of bog peat. Bog peat accumulates under conditions where mineral inputs are extremely low and the dry mass content of peat is almost entirely organic. This is because peat bogs receive practically all their water and mineral nutrients directly from the

1 Bedrock within the wind farm boundary varies from 'medium-grained pale brown thinly to massively bedded sandstones' towards the north and east to 'fine-grained pale pink thinly to medium bedded silty sandstones' towards the south and west and 'medium bedded conglomerates interbedded with sandstones' in the north. In some places, it is overlain by glacial till (AGEC 2004). One of the planning documents (Saorgus Energy Ltd. 2000, page 38) indicates that 'shale bedrock' will be quarried for road construction.

atmosphere as rain, snow, fog or other forms of atmospheric deposition. Inputs of water are high in the high rainfall areas where peat bogs are relatively frequent or even abundant but the input of minerals is generally extremely low.

Peat bog soil may be largely organic matter but, when calculated by volume, in undrained peat the quantity of even this organic material is typically only three to six per cent: the principal constituent of peat is water. Hobbs (1986) illustrates the point with the example that five metres of fibrous peat may contain 4.7 metres of water but only 0.3 metres of plant matter. The figures are even more dramatic by weight, yielding only two per cent solid matter and 98 per cent water. Hobbs concludes that some powerful agency must give the peat its demonstrably solid properties.

The secret lies in the colloidal nature of peat, which relates to the unusually high cation exchange ability (CEA) of Sphagnum bog moss. This CEA enables Sphagnum to utilize the minute quantities of plant nutrients offered by rainwater to survive in the bog habitat (Clymo 1983). Essentially, the process works through electrostatic binding of positively charged metal cations to negatively charged exchange sites on the Sphagnum cell walls. Exchange sites that are not occupied by metal cations can bind water instead, which is adsorbed tightly onto the surface of the plant tissues. Water in peat exists in three interchangeable states:

- State 1 water held loosely (at suctions <10 kPa) in large spaces ranging from pipes, cracks and other large voids which can be drained under gravity;
- State 2 water held by capillary forces (>10 kPa) in narrower cavities and some cell structures;
- State 3 water that is bound tightly to the surfaces of organic matter, being held by forces much stronger than the two previous states (at suctions up to 20 MPa).

When peat is drained or otherwise dried, water in voids or held by capillary action (states 1 and 2) is withdrawn but it is replaced by air and there is no change in volume but, when adsorbed (state 3) water is lost, it is not replaced by air.

Instead, the particles are drawn closer together, reducing the size of the water-filled spaces between them (Ward 1975). The peat shrinks, undergoes a permanent material change and cannot be re-hydrated. This occurs to such a degree that peat bales and turfs which have been dried sufficiently to remove at least some of the adsorbed water can be used as a lightweight, underwater engineering fill, remaining strong and stable so long as the bales are permanently submerged and never re-exposed to oxygen.

The proportions of water held in each of states 1 to 3 can be expected to change with the degree of decomposition (humification). For example, as the large storage cells of Sphagnum plants are broken open and plant fragments generally become more tightly pressed together, the proportion of capillary (state 2) water to loosely-held (state 1) water increases. Since the adsorption complexes on the cell walls are weakened as decomposition proceeds, we can anticipate changes in both the total and relative quantities of state 3 water. As this acts as the real 'glue' of a peatland, giving it the properties of a solid remarked upon by Hobbs (1986), progressive water removal will have important implications for these properties. For example, the liquid limit of peat (the water content at which it begins to flow like a fluid) is high compared with that of other soils (including clay which has a similar CEA). In other words, peat can hold much more liquid than other soils before it starts to flow like a liquid because the peat particles are less dense than mineral material and can be held together more firmly by the adsorption complex. However, this liquid limit declines with increasing humification because, as the plant tissues break down, so the strength of the adsorbtion complex steadily weakens.

The physics and chemistry of the peat, the water in the peat and the nature of the organic matrix exert important influences on the engineering properties of peat soils. For a development proposal involving possible drainage effects on a peatland ecosystem, these are pertinent factors and must be addressed by the EIA process.

Peat soils occur from the equator to the arctic in a wide variety of forms and are associated with a wide variety of habitats. It is important to be clear precisely which type or types of peat are involved with the proposal. At Cashlaundrumlahan, it forms a habitat known as 'blanket bog' or 'blanket mire',[2] which is one of the major peat-forming systems found on the Atlantic seaboard of Europe (Tansley 1939). The properties of the blanket peat soil are intimately bound up with the characteristics of the blanket mire habitat that it supports.

The next stage in this scoping exercise involves a review of the blanket mire habitat.

Plate 2.1: Typical Derrybrien bog vegetation, with heath milkwort (*Polygala serpyllifolia*) and purple moor grass (*Molinia caerulea*) as characteristic oceanic species within a bog moss (*Sphagnum capillifolium*) hummock [nanotope] capped by heather (*Calluna vulgaris*).

2.4 *Blanket mire*

2.4.1 *General characteristics*

The global distribution of blanket mire is quite limited although it occurs widely in the UK and Ireland. It is found less extensively along the western seaboards of Scandinavia and Canada and in a few locations within similar southern-hemisphere latitudes, including the Falkland Islands, where it dominates the landscape (Lindsay et al. 1988). It is generally associated with temperate climates characterised by frequent rainfall. For example, blanket mire in northern Scotland experiences some precipitation on at least 180 days each year (Lindsay et al. 1988). Cloud cover and rainfall tend to be greatest on hill summits and peat formation is often vigorous on high-level plateaux and gently-rounded hill tops.

In locations where blanket mires have formed, the water supply from precipitation is sufficient to maintain the peat layer in a saturated state on level areas and even on moderate hill slopes. As the name implies, in areas with a suitable climate the peat deposit may come to blanket the hills and valleys of an entire landscape provided the hill slopes are not too steep. The peat is thickest where it overlies basins, plains, broad ridges and level plateaux in the substratum and here it is possible for lakes and pools of open water to form in the mire surface. Since bog pools tend to form on areas of deep peat and the deepest peat is often found on hill summits, the result gives the rather curious impression that 'all the water sits at the top of the hills' – a widely-quoted saying from the Falkland Islands. Fig 2.2 gives a schematic view for part of a blanket mire.

Blanket mires generally consist of several peat-forming units interlinked by their hydrology into a complex mosaic. The term for this is a 'macrotope' while the individual peatland units which together make up the interconnected blanket mire complex are termed 'mesotopes' (Ivanov 1981). These may be distinguished from each other most readily by their differing and distinct regions of surface pattern, which arises because some areas of the bog surface hold water as shallow pools or hollows while other areas between the pools form hummocks and ridges. The pattern formed by this hummock-hollow arrangement results from growth of differing Sphagnum species which create these alternating structures. The pattern itself is termed a 'microtope'. The microtope is thus made up from individual structural elements such as hummocks or shallow hollows. These are termed 'nanotopes'. They are created, and characterised, by differing types of bog vegetation.

The whole assemblage, from individual hummock to large peatland mosaic, is created from a hierarchy of interlinked structures interconnected by their hydrology (fig 2.3).

[2] 'mire' is the technical term for any peat-forming system.

2.4.2 Blanket mire at Cashlaundrumlahan

The site retains many characteristics of a typical blanket mire ecosystem despite extensive disturbance from a range of human activities including peat cutting and afforestation. In some parts, the open blanket bog, with its characteristic vegetation of Sphagnum bog mosses, can still be found while even in such disturbed areas as the forestry plantations it is possible to find a range of bog plants growing within scattered Sphagnum bog moss carpets.

In the case of Cashlaundrumlahan, the blanket mire complex (macrotope) represents the whole assemblage of peatland units that interlink to form the continuous peat landscape centred around, and dominating, the Cashlaundrumlahan massif. These individual peat systems are now quite difficult to see because extensive forestry has obscured much of the blanket mire structure. Nevertheless, a small portion of characteristic watershed mire can be seen on the summit ridge, where an area of bog pools has not been ploughed for forestry. Here, the bog surface shows a repeated pattern (microtope) of pools and intervening ridges on which there are both high and low hummocks. Some of the blanket mire features still to be found are illustrated in plates 2.1 to 2.3.

Plates 2.2: Typical view across the northern slopes of the watershed blanket mire (mesotope) that dominates the summit of Cashlaundrumlahan. In the upper photograph a series of hummocks (nanotopes) can be seen as a repeated structural motif (microtope) scattered across the slope but, in this case, there are no pools, only terrestrial elements forming the microtope pattern.

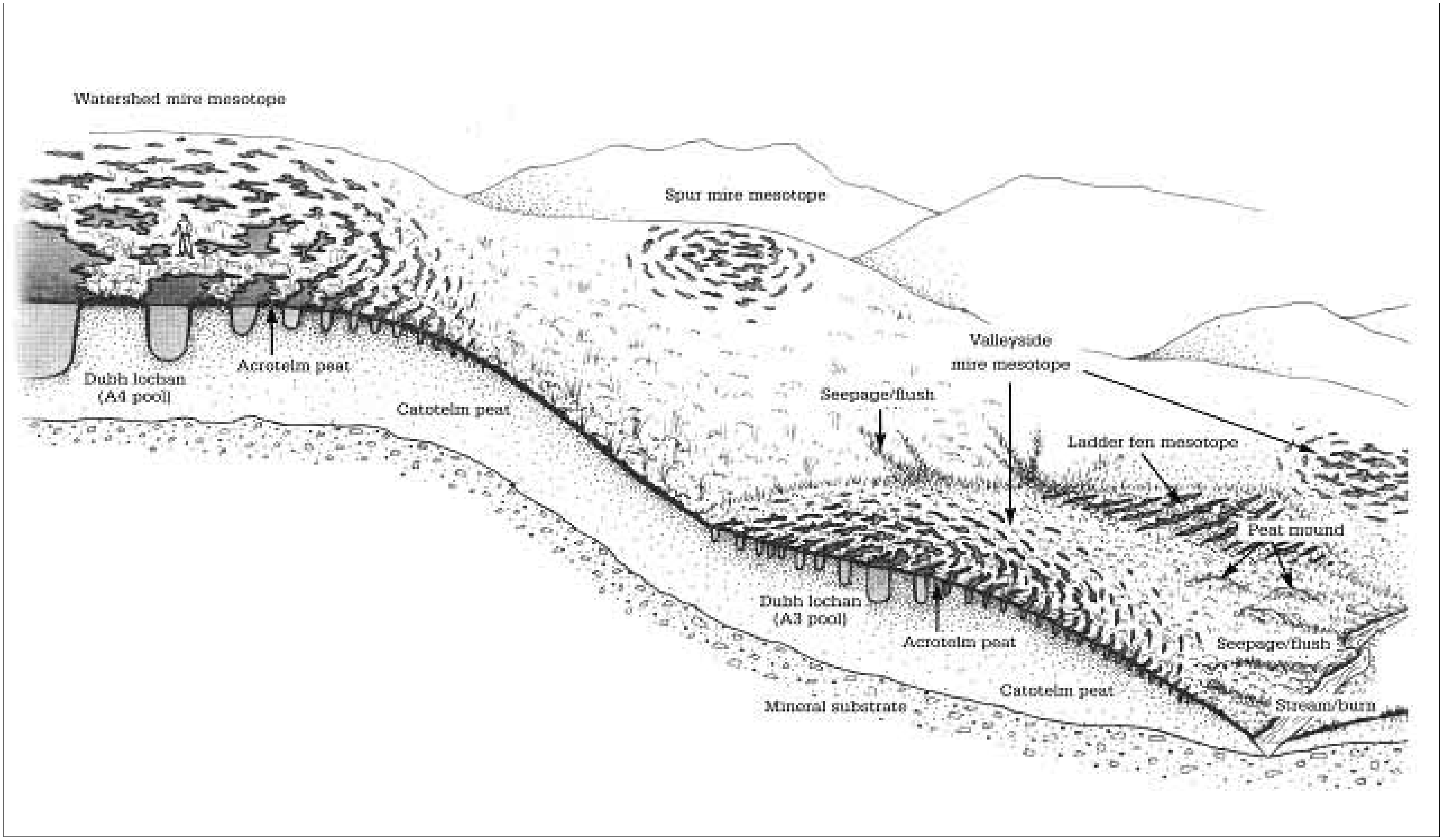


Figure 2.2: Schematic representation of blanket mire, adapted from Lindsay et al. (1988), showing the relationship between peat depth and slope of the underlying mineral substrate as well as the physical (and associated hydrological) inter-relationships between the various structural components of a blanket bog complex [or macrotope]. Terms are explained in sections 2.4.1 and 2.4.2. (Depth of peat exaggerated compared to horizontal scale).

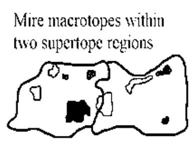
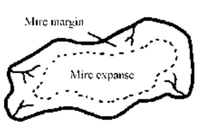
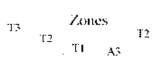
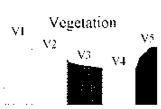
Feature	Hierarchical level	Description	Hydrological relationship	Utility for classification and evaluation
	Supertope	Position of linked mire units within the regional landscape	Overall climate and regional water-table	Regional overview
	Macrotope	Assemblage of hydrologically linked mire units	Individual bog units hydrologically linked via intervening fens and stream-courses	Identification of boundary for minimum, hydro-logically sound, conservation unit
	Mesotope	Distinct, recog-nisable hydro-topographic unit.	Inputs of rainfall, outputs of seepage, drainage and evapo-transpiration	Identification of individual, recognisable units for comparison
	Mesotope	Distinction between mire-margin and mire expanse.	Broad patterns of water movement within the mesotope, from high ground to low ground	Recognition of 'core' and 'marginal' zones; in Europe, the margin often partly removed
	Microtope	Repeated surface pattern - *e.g.* pool system.	Surface pattern reflects hydrology of acrotelm layer and overall mire gradient	Identification of naturalness; source of comparative diversity
	Nanotope	Individual surface features (*e.g.* hummock, pool)	Small-scale water movements within the acrotelm	Source of niches for individual species; com-parison of diver-sity and damage
	Vegetation	Distribution of vegetation within surface structures.	Ultimate control of acrotelm and surface water movement	Source of comparative diversity; indicator of 'naturalness'

Figure 2.3: Hierarchical relationship between the various functional levels of peat bog systems, from the large-scale concept of mire landscapes [supertopes], to the smallest structural level of hummock or hollow [nanotope], and the hydrological relationships that operate at each of these levels (adapted from Lindsay et al. 1988).

2.5 *Soil structure*

The hierarchy of hydrological structures that contribute to the orderly functioning of a bog does not end at the soil surface. The soil profile of an intact bog has a distinctive two-layered structure (Ingram 1978) which differs fundamentally from that of mineral soils and is intimately linked to the processes that maintain the peatland system.

Plate 2.3: Example of the only bog pool complex surviving on Cashlaundrumlahan. As might be expected, this indicates an area of deep peat on the summit ridge and represents a watershed mire mesotope with a typical microtope pattern of pools.

The upper layer, known as the acrotelm, is a fibrous surface skin, typically around 0.5 m thick, that occupies the layer of the bog between the mire surface and the lowest position of the water table in dry summers. Its uppermost part acts as the soil surface for vascular plants and a vertical profile through the acrotelm displays the series of changes that the vegetation undergoes as it is progressively assimilated into the body of peat. It is first buried by fresh growth at the surface, then dies and partially decomposes into what is commonly known as peat. The acrotelm is the equivalent for a peat soil of the parent material (usually rock) of a mineral soil although it lies at the top of the soil profile rather than at the base.

The acrotelm consists essentially of a matrix of plant material bound together by live roots. It has considerable tensile strength and forms a coherent surface that can bear weight. Perhaps most important, however, it plays a key part in maintaining the hydrological stability of a peat bog. Near the mire surface, structures in the acrotelm consist largely of vertical moss stems with many cross-links formed by branches. Spaces between these structures are frequent and relatively large and the bog water table is thus able to move up and down through this part of the acrotelm with ease while excess water following heavy rain can flow laterally through these large spaces in a more controlled way, as it would through a sponge, rather than as dangerous sheet flow across the bog surface. Lower in the profile, the stems weaken and break and branches are pressed more tightly together. Spaces are smaller and less oriented and vertical water-table movement thus becomes progressively more difficult, as does lateral seepage. Towards the base of the acrotelm, stems and branches are fragmented and pressed together, leaving few spaces and and with little orientation. Water movement, either vertically or laterally, is extremely slow in this zone.

During periods of rainfall, the water table rises so that the large spaces in the upper part of the acrotelm become water-filled. The coarse structure offers little resistance to water movement – in other words, it is highly permeable – so that the water can drain downslope quite easily. During dry weather, on the other hand, drainage is progressively impeded as the water table falls deeper into the acrotelm. It could be said that the bog allows water to flow easily during wet weather but, once the rain stops and the acrotelm begins progressively to empty, it holds on increasingly tightly to the water that remains. This mechanism is important for mire vegetation in that during heavy rain it permits rapid surface runoff in a way that might otherwise wash away the rootless Sphagnum carpet but it does not allow the water table to fall below the minimum level required to support ‘water-loving’ (hydrophytic) mire plants at the bog surface (Ingram and Bragg 1984).

Beneath the acrotelm is the bulk of the peat deposit which, on Cashlaundrumlahan, is more than five metres deep in places. This lower deposit, known as the catotelm, remains completely saturated at all times under natural conditions, losing water slowly through gravity-driven seepage but being constantly re-supplied from the acrotelm. It may also be drained by systems of underground (soil) pipes which may or may not communicate with the surface. The catotelm provides an undisturbed peatland with its overall shape and, because catotelm peat can be preserved only if it is waterlogged, this shape is an expression of the peatland’s hydrology (Ingram 1982).

2.5 *The blanket mire environment – an integrated system*

These various levels of soil structure and ecosystem organisation are linked through hydrological processes. Damage to the acrotelm, for example, may lead to hydrological changes to the bog unit as a whole which in turn may bring about changes in the small-scale surface pattern. In hydrological terms, the peat blanket is an integrated system that absorbs all the rain that falls on its surface and transmits it to the lower slopes of the mountain in as controlled a way as possible through a variety of interconnecting processes that operate at different scales and speeds.

Once below the mire surface, water moves much more slowly downslope than it would if the bog were not present because it has to find its way through small spaces in the peat matrix in a process known as seepage. Seepage is driven by gravity and so is always directed along flow-lines that cut directly across (perpendicular to) the surface contours. As the slope steepens towards the edge of the peat blanket, the flow-lines converge into shallow valleys which focus the seepage into flushes which eventually form streams that emerge from the edge of the peat.

The bog peat forms a protective layer over the bare rock and mineral soils beneath, shielding them from the erosion that would otherwise result in such high-rainfall areas. The quality of the water that is discharged into streams fed by blanket mire run-off, and thence into rivers, is quite different from the runoff that would be derived from a similar mountain with no peat cover in its chemical composition, in the quantity of sediment that it carries and in the pattern of water flow. The presence of blanket bog in the headwaters of a catchment exerts a strong influence on the ecology of streams, rivers and lakes within the catchment.

The structure and functioning of mires is described in a number of substantial texts (e.g. Osvald 1949, Moore and Bellamy 1974, Gore 1983, Lindsay et al. 1988, Lindsay 1995, Feehan and O'Donovan 1996) and the interested reader is referred to these sources for more information about these ecosystems.

Summary of Chapter 2

1 The definition of the boundary required for scoping and assessment is an iterative process that develops from the range of information found to be required.

2 The development site is almost entirely covered by blanket bog ranging from less than 0.5 metres to more than 5.5 metres in depth.

3 Peat is an unusual 'soil' in being mostly water but with a small amount of organic matter created by Sphagnum bog mosses that grow, but only partially decompose, in waterlogged conditions. There is very little mineral matter in a peat soil.

4 The peat matrix is held together by hydrostatic forces arising from strong surface charges present on the Sphagnum fragments. Some of the water in peat can be removed by gravity drainage but this tightly-bound water is difficult to remove except by slow drying and decomposition of the peat.

5 Peat has a high liquid limit, meaning that it can hold much more water than most soils before acting as a liquid but this limit is reduced by oxidative decomposition.

6 Blanket mire is a form of peat that typically develops in oceanic climates and occurs as a blanket of peat that covers all but the most steeply-sloping parts of the landscape.

7 The bog soil consists of two distinct layers – a thin upper acrotelm which is fibrous and contains the living vegetation and the fluctuating water table, and a deeper catotelm which represents the main mass of accumulated peat and which remains waterlogged and sealed from the atmosphere by the acrotelm under natural conditions.

8 Although individual structural components can be identified within a blanket mire landscape, many of these are hydrologically linked into complexes or as part of a hierarchical hydrological series. Damage to one of these features, or to one of the peat-soil layers, is likely to cause harm to other parts of the blanket bog system.

Chapter 3
Scoping – pre-development conditions at Derrybrien

HUMAN IMPACT CAN RESULT in significant changes to different elements of a mire ecosystem which then influence the way in which the mire functions. Some of these are reversible to a greater or lesser degree whereas others are irreversible and can lead in some cases to complete disintegration of the ecosystem. Some effects of human impact are considered in this section first in a general sense and then with specific reference to identifiable instances within the area of the Derrybrien wind farm.[1]

A key step in EIA scoping involves the identification of existing conditions on the development site and associated ground. The land-use activities hitherto associated with a site and their impact on it should be catalogued with some care. Not all forms of land-use are necessarily damaging nor are all aspects of pre-development conditions on a site associated with harmful intervention or negative site characteristics. Nature conservation is often considered to be a form of land use, for example.

Statutory designations associated with the site are certainly relevant to scoping partly because they may lead to changes to the boundary considered necessary to complete a comprehensive EIA but also because they are likely to impose particular constraints on development proposals. Although these issues form part of the iterative evaluation sequence and are an important part of the scoping process, clarity of presentation is best served in practice by leaving the listing of designations and features of interest until the geographical scope of the EIA has been determined.

A detailed description of statutory designations and features of conservation value can be found in section 6.3.

3.1 *Agriculture*

3.1.1 *General context*

Most upland blanket mire is, or has at some time been, grazed by large wild herbivores such as deer and, more intensively, by domesticated sheep and/or cattle. In this context, grazing involves the direct removal of vegetation and the addition of nutrients in excreta. There are potential effects on the species composition of vegetation as a result of selective feeding and nutrient enrichment and on peat formation processes in the acrotelm through alteration of the supply of raw plant material and increased activity of the decomposer microflora. Associated trampling compresses the acrotelm and alters its water transmission characteristics so that the frequency of surface runoff increases. If trampling becomes more intense, it can break up the Sphagnum carpet to leave areas of bare peat exposed to the actions of rain and frost. This in turn can lead to erosion of the peat. Acute degradation of blanket mire through overgrazing by sheep has been reported from west Galway (Douglas 1998) whilst Lindsay et al. (1988) report Dr M.W. Holdgate's observation that 'the only areas of significant peatland erosion in the islands of Tierra del Fuego were associated with the world's most southerly sheep farm'.

Blanket mire is often burnt as part of a systematic programme intended to improve the quality of grazing. A light, controlled fire removes only the taller vegetation and old dead leaf-litter, encouraging fresh new growth. However, few fires on blanket bog are controlled in such a way. Most burn off all the surface vegetation including the moss layer. Even the peat can catch fire. This leaves a bare peat surface through which – in the most oceanic parts of Europe – purple moor grass (Molinia

[1] For a more wide-ranging review of human impacts on blanket mire systems, see chap 5 & 6 of Lindsay et al. (1988).

caerulea) and deer grass (Trichophorum cespitosum) emerge to form a green sward which is palatable to animals for a month or two. The surface beneath this sward is largely bare and unprotected from rain and frost and, once again, this can lead to peat erosion.

Drainage is also believed to improve the quality of grazing and to make blanket mires safer for grazing animals. Moor gripping involves the digging of ditches some 10 to 20 metres apart to promote the growth of heather (Calluna vulgaris) and to drain particularly wet areas where sheep may become bogged down and drown. In the immediate vicinity of each ditch, the water table is drawn down into the catotelm, allowing air to enter the peat so that oxidative decomposition begins. For moor grips, the marked effect is restricted to a narrow strip of ground either side of each ditch (Stewart and Lance 1983). There is little widespread drainage of the catotelm because its low permeability resists dramatic water loss. The main function of the grip is to collect water seeping through the acrotelm and direct it to the edges of the bog system. The supply of seepage water to the surface of peat blanket downslope is thus reduced. This affects the vegetation since some bog species are sensitive to water table changes of only a few centimetres (Ivanov 1981). It also deepens the acrotelm, again promoting decomposition. The intensity of these effects increases with the intensity of drainage.

The eventual outcome of peat drainage is most dramatically illustrated by the results of past agricultural drainage projects on lowland peat:

> Dewatering of wetlands for agricultural purposes in the western Netherlands began as early as the 9th century. By the 16th Century, serious subsidence had occurred to the extent that dikes, canals and windmills were built to avoid inundation. In the Sacramento-San Joaquin Delta of California and the Florida Everglades, organic soil-related subsidence occurs at a rate of one to three inches per year. One of the contributing factors to this subsidence is microbial decomposition of organic matter that occurs when oxygen becomes available upon dewatering. This process converts organic carbon to carbon-dioxide gas and water when oxygen becomes available upon lowering of the ground water and results in large volume change and regional subsidence. (Levine-Frick 2001).

On blanket mire, the orientation of ditches relative to the slope is also significant. Traditional moor grips usually run across the slope at a shallow angle to the surface contours so that they intercept many flow-lines but water movement in the ditch itself is relatively slow. Ditches running perpendicular to the contours (i.e. straight down the slope), on the other hand, cross few natural flow-lines but the water they do collect can move along them at scouring velocities, especially in wet weather. Grieve (2001) points out that the incidence of soil erosion in Scotland can be related to the presence of such ditches.

There is a plentiful literature on peat erosion (e.g. Bower 1962a, b, Tallis 1964, 1985, Taylor 1983), much of it demonstrating that it generally occurs where the vegetation has been degraded to the extent that bare peat is exposed. This can result from overgrazing or because the vegetation has died as a result of drainage or fire.

In the absence of a functional acrotelm, excess water must often be discharged as so-called ‘overland flow’. This sheet flow of water across a bog surface that lacks vegetation is physically dangerous because it can directly erode the peat. The low density of peat, particularly if it is dry, means that it can be readily lifted and transported downslope by concentrated water flow. Hulme and Blythe (1985) describe a particularly dramatic peat erosion event they witnessed during a thunderstorm in Shetland. Within a few minutes, the rainstorm caused such rapid flow of water through a series of erosion gullies that dried-out peat was lifted from the bottoms of the gullies. The peat became detached in large flat plates more than 25 cm across and several centimetres thick and was transported downslope by the rainwater torrent through the network of erosion gullies.

3.1.2 *Agriculture and Cashlaundrumlahan*

Grazing is not the dominant current land use on Cashlaundrumlahan but it is likely that it has been grazed in the past and that unafforested areas may still be used in this way. The open ground to the north west of the summit shows no direct evidence of fire damage. A vegetation dominated by purple moor grass (*Molinia caerulea*) is often indicative of past burning but it is equally characteristic of highly oceanic western blanket mires. Coupled with the fact that the ground layer in this area has a reasonably continuous and vigorous Sphagnum bog moss carpet, the evidence seems to point to a lack of any serious direct damage by fire or trampling by grazing animals, at least in the recent past.

The fact that a reasonably intact pool system continued to survive on the hill summit until the coming of the forest plantations, and even now survives in somewhat modified form, would suggest that the blanket mire of Cashlaundrumlahan was in a reasonably natural state prior to afforestation. If it had been subject to significant burning and grazing, this pool system would almost certainly have degenerated into the type of erosion complex found on so many damaged blanket mires in northern Scotland (Lindsay et al. 1988).

3.2 *Forestry*

3.2.1 *General context*

Large-scale afforestation of peatlands was first made possible by the development of the Cuthbertson plough in the 1930s followed by the ‘humpy’ plough in the 1960s. Plantation forests expanded rapidly on blanket mire in Britain and Ireland during the 1970s.

The first stage of afforestation involves the construction of access roads so that the machinery for ploughing and other operations can be moved easily into the site. They must be capable of carrying the traffic required at all stages of the rotation, including the lorries used to transport harvested wood off the site. In the UK, forestry roads crossing peatland are usually laid on the mineral substratum after excavation of the full depth of both the acrotelm and the catotelm and are flanked by ditches that intercept and conduct away water draining from the cut peat faces so that it does not flood onto the road. The situation in Ireland is different in that most of the country’s forestry is on bogland and techniques have been developed for constructing forestry roads without first removing the peat.

Where roads are laid directly onto peat (i.e. they have a peat subgrade), a range of engineering issues must be addressed, including subgrade drainage, materials consolidation, potential failure due to hydraulic pressure and bearing capacity.[2] Since peat deforms easily under mechanical pressure, roads with peat subgrades are inherently weak.[3] This means that they are vulnerable to excessive wear as a result of the flexing or deformation of the road that occurs as vehicle pass over it. The effect can be reduced by making the road thicker than it would need to be on a strong subgrade so that the weight of the vehicle is spread over a greater area. However, the design of these roads is complicated by the singular engineering properties of peat[4] which mean that both the bearing capacity and the stability of a peat road will vary with weather conditions and between time frames.

An investigation carried out in County Mayo in 1996 showed that a vehicle moving along a peat road caused it to flex by different amounts in winter and summer and that the amount of deformation also varied with the thickness of the peat substratum. This means that peat forestry roads in Ireland may generally be under-designed for the loads involved in all-season timber transportation and that certain measures to ensure their safe operational use are advisable. These include the imposition of limits on axle loadings, the use of low- or variable-pressure tyres and the introduction of vehicle routing restrictions that take into account seasonal variations in road strength. In particular, because deflection increases under warm, wet conditions, the summer is the most dangerous time for heavy traffic in terms of the degree of peat deformation (O’Mahony et al. 2000).

Once access for the machinery has been established, a widely-spaced series of 1.5 m deep drains is

2 The California Bearing Ratio (CBR) for peat is two to four per cent, compared to a CBR value of 15 to 30 per cent for strong subgrades.

3 See www.highwaymaintenance.com.

4 In particular, the deformation modulus of peat decreases with water content and increases with the degree of decomposition.

established across the whole of the area to be afforested. Between these drains, fertilizer is applied and a double-mouldboard plough is used to turn up continuous ridges of peat at between two and ten metres spacing from shallow (40 to 60 cm deep) furrows at a four metre spacing. In effect, the acrotelm is dissected into four metre strips, fertilized and buried. The plough furrows usually run perpendicular to the surface contours to promote drainage. The trees are planted on the upturned ridges between furrows so that their roots initially tend to develop preferentially along the length of the ridges rather than towards the furrows. As they grow, weed control and thinning are carried out and a second dose of fertiliser may be applied from the air at ten to fifteen years. The trees are harvested at around 40 years (Coillte 2004).

Forest planting is a surface impact whose initial effect is largely restricted to the acrotelm. If some of the trees fail to grow, it is quite common to see vigorous recovery of bog vegetation (and thus regeneration of the acrotelm) beneath the dying trees because the catotelm still provides the underlying hydrological conditions necessary to support the bog ecosystem. Lodgepole pine (*Pinus contorta*) appears to be more tolerant of these conditions than the other species commonly used in commercial conifer plantations (e.g. Sitka spruce, *Picea sitchensis*) because it requires less root aeration and so is able to root and grow in saturated peat. It is often used as a 'nurse' crop, its main function being to convert deep, wet peats into dry, mineralised peat soils and thus enable more commercially attractive timber species to be grown (Pyatt 1987).

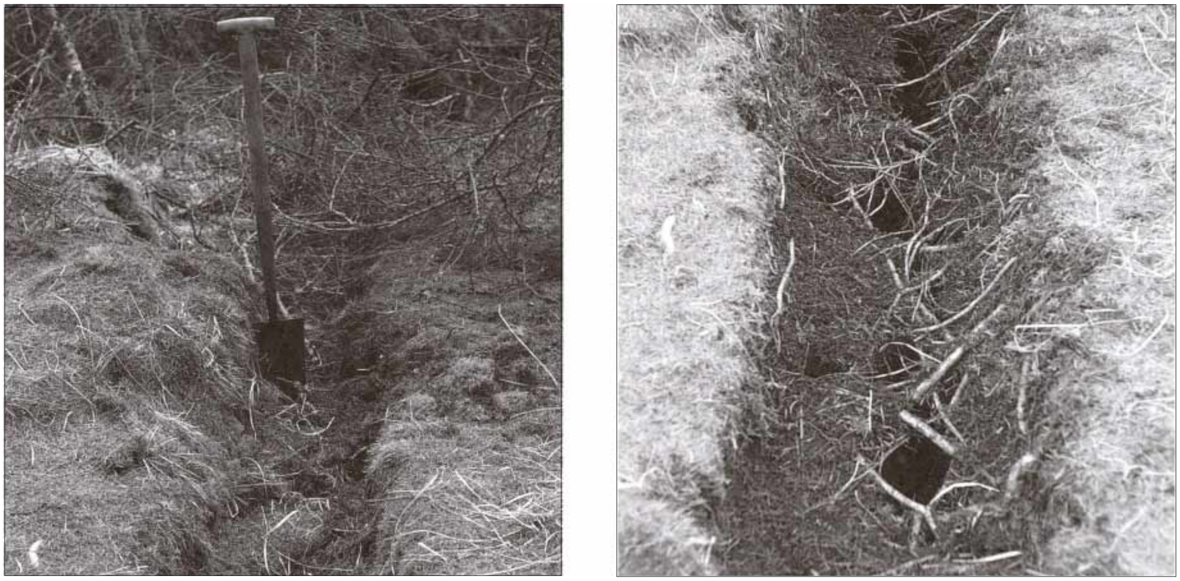
If lodgepole pine grows reasonably successfully, the trees start to bring about change on their own account and the effects of afforestation extend beyond the acrotelm into the catotelm, causing significant changes in the structure and hydrological functioning of the peat blanket. These changes have been researched in northern Scotland and the results widely reported in scientific and forestry journals since the late 1970s (e.g. Pyatt & Craven 1979, Pyatt 1987, 1990, 1993; Anderson et al. 1995; Anderson 2001).

The critical stage of the rotation is canopy closure which, for *P. contorta*, occurs ten to twenty years after planting. At this time, the ditches are already appreciably wider than they were at planting due to water loss and the consequent shrinkage of the adjacent peat. Now, shade-intolerant bog vegetation is replaced over a period of two to three years by forest floor communities and a litter layer consisting of dead needles develops. This enables fine tree roots to form mats across furrows and ditches, although these roots remain small and do not contribute appreciably to tree stability.

Canopy closure is accompanied by an increase in the capacity of the trees to intercept rainfall before it reaches the ground and in the rate at which they lose water by evapotranspiration. Consequently, in dry summer weather, water uptake by the trees replaces drainage as the main cause of peat drying and the water table falls well below the level of the furrow bottoms. As drying proceeds, peat shrinkage (section 2.3) leads to subsidence of the ground surface. Differences in ground level of up to 55 cm have been measured between plots of 20-year-old trees and the surrounding unplanted ground, most of the subsidence resulting from loss of water from the peat matrix.

Eventually, a point is reached where the peat's resistance to tearing is less than its resistance to subsidence, so it cracks. The ditches and furrows act as lines of weakness to the tensile stress produced by shrinkage of the intervening peat mass. The first cracks appear in summer along deep ditches, where the fibrous acrotelm has been removed and are followed a year or two later by similar cracks in furrows (plate 3.1). These early cracks can appear in very wet soft peat and are usually hidden by the litter and root mat.

Shrinkage cracks are commonly up to 15 cm wide and extend to a depth of 70 cm. Although they form in summer, they persist from year to year because peat shrinkage is irreversible. They do not, however, extend across the forestry rides. The water table lies below the cracked layer during the summer but rises into the cracks in winter. The ditches draining these cracks can lose half their depth within 15 to 20 years and, if they become blocked, the water stands in the cracks. However, once the reticulate network has developed, this can act as a drainage system. Dried peat has a limited ability



From Anderson (2001), reproduced courtesy of the Forestry Commission

Plate 3.1: Longitudinal crack in a plough furrow under mature forestry on deep peat in the north of Scotland, after removal of the litter layer.

to absorb moisture (section 2.3) and the cracks provide a bypass route so that eventually the water table beneath the trees is controlled principally by the cracks. At Braehour Forest, Caithness, plough furrows in peat less than one metre thick on a slope of five degrees cannot be effectively dammed with plastic piling because drainage continues to occur through the surrounding network of cracks.

Some years later, reticulate networks of cracks develop on the plough ridges directly beneath the trees. These develop fully within 20 years of planting on shallow and moderately deep peats and can penetrate to the substratum if the peat layer is less than one metre thick. These cracks are confined to the catotelm peat which has by now lost a great deal of water and is fairly dense. They do not open on the surface because the acrotelm is reinforced by strong structural tree roots but are invariably found when the surface 30 cm fibrous layer is removed (plate 3.2). However, the ditch and furrow cracks now become visible because they have grown so wide that the root and litter mat tears (fig 3.1).

A tree growing in wet, unstable peat will normally send out a wide mat of roots, partly to provide stability in the soft medium but also to maximise the root-surface area within the thin oxygenated surface zone of peat. However, small roots cannot grow across cracks. As the cracks steadily widen, only the roots that had already extended across them can continue to grow laterally. Most other roots are confined to the lines of the original planting ridges. The trees are therefore incapable of forming a wide stable fan that provides stability in all directions; the root systems of individual trees instead generally extend in the direction of the planting ridges but are extremely limited in the direction of the flanking furrows. This has been identified as a sylvicultural problem because the trees are stable in the direction of the plough lines but are markedly unstable to forces, such as wind, operating at right angles to the plough

Reproduced courtesy of John Hawell

Plate 3.2: Reticulate cracking in a plough ridge under mature forestry on deep peat in the north of Scotland, revealed by removing the surface fibrous layer.

lines. Peat cracking thus tends to make plantations prone to windthrow from certain directions. Indeed, windthrow is one of the principal risks to Irish forests, particularly after thinning.

3.2.2 *Forestry and Cashlaundrumlahan*

Cashlaundrumlahan was planted by the Irish forestry board, Coillte Teoranta (Coillte) during the 1970s. A large proportion of the hill was planted although some substantial areas remain between the various forest blocks (fig 3.2). The most frequent species is lodgepole pine but some Sitka spruce (*Picea sitchensis*) have also been planted, particularly as a second rotation crop after fire destroyed the first crop on the south-western slopes of the mountain (plate 3.3).

The network of existing, unmade forestry rides that connect with the access road for the turbary and the Cashlaundrumlahan radio mast (fig 3.3) was mapped in June 2002. These are not constructed roads but merely open corridors between the plantations for use as fire-breaks and access routes.

A number of areas across the site were examined for evidence of cracking in June 2004 and cracks were found in many places beneath 20 to 30 year old forest stands although, in most cases, their

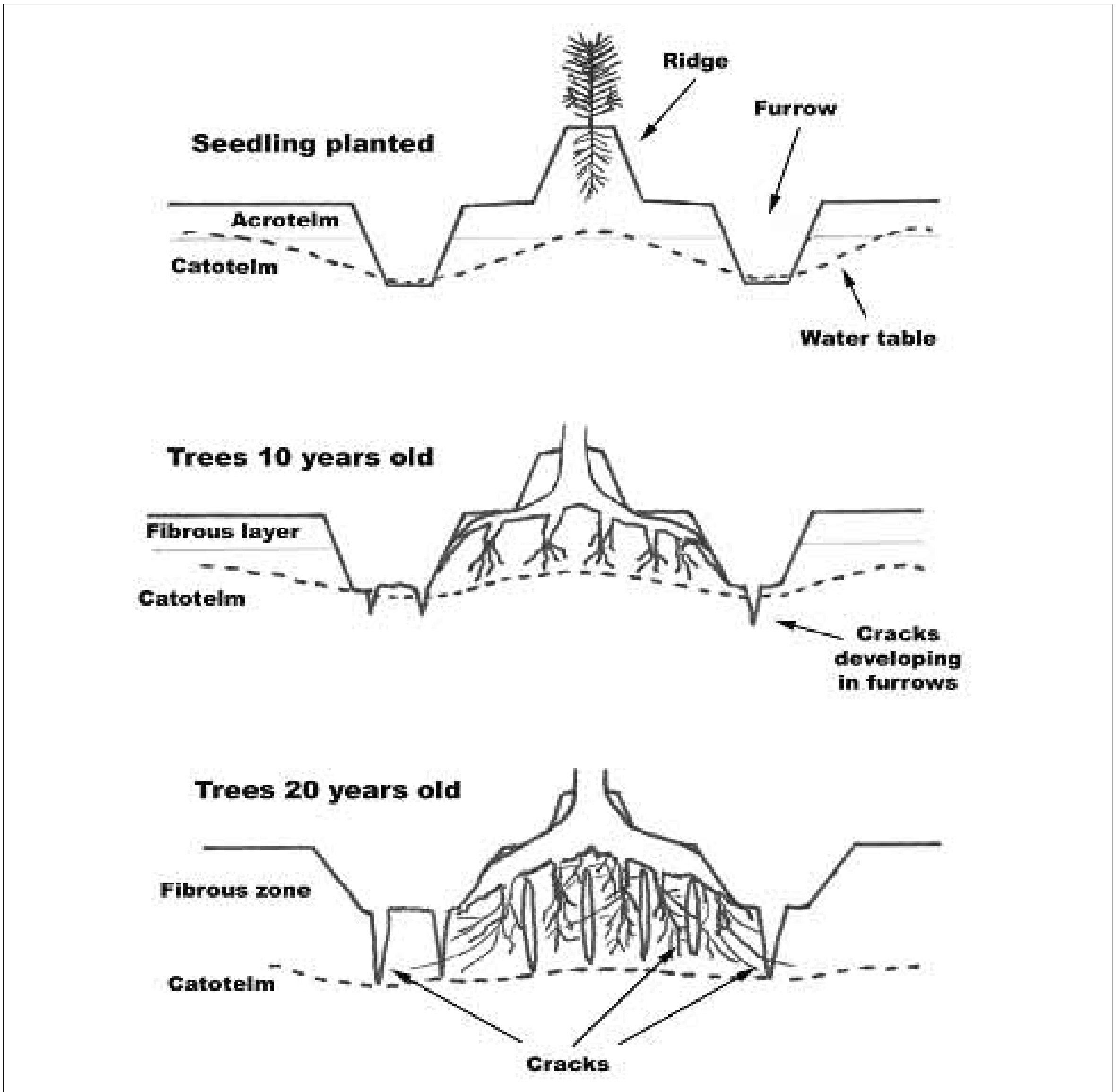


Figure 3.1: The sequence of drying and cracking that occurs in peat over a 20-year period beneath plantation forestry, particularly when the crop is lodgepole pine, *Pinus contorta* (adapted from Pyatt 1987).

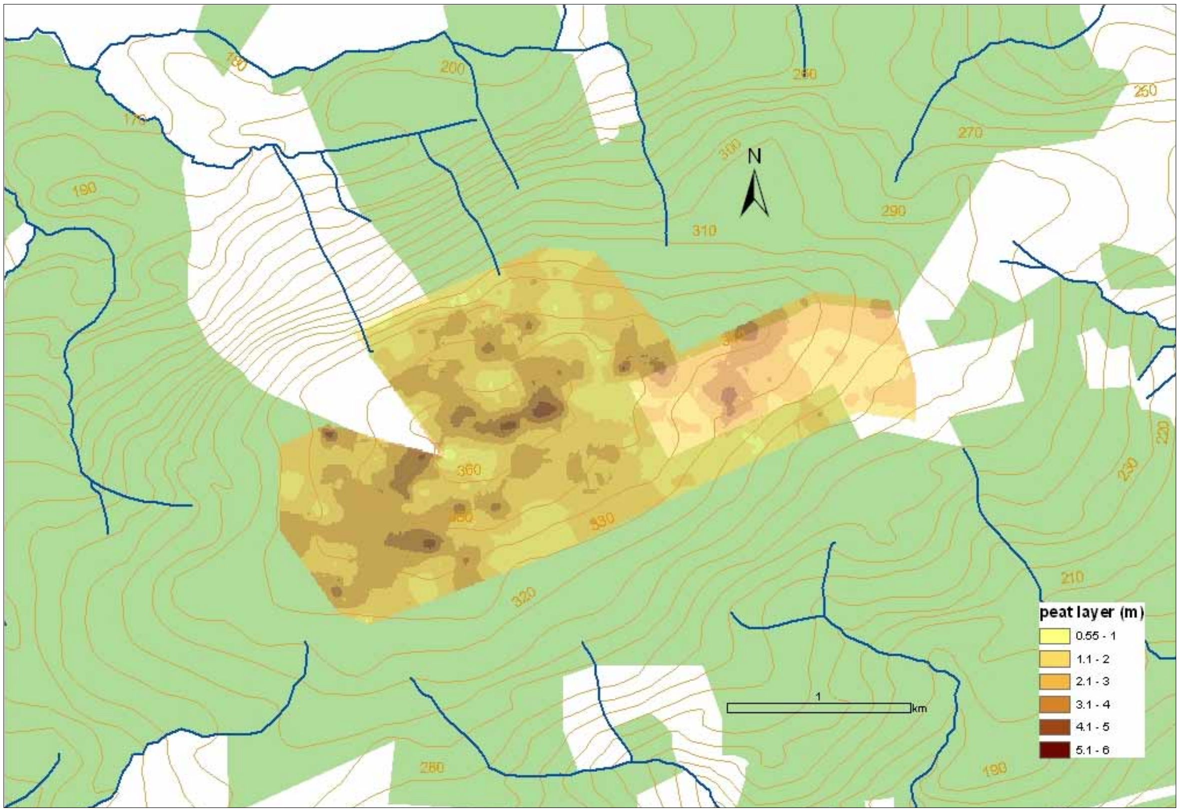


Figure 3.2: The extent of forestry on Cashlaundrumlahan, indicated by green shading. The wind-farm boundary is indicated by the area for which peat thicknesses are given.

extent was not immediately obvious because they were covered by a surface layer of needles and small roots (plate 3.4). On removing this thin surface layer by hand, however, it was obvious that many of the ploughing furrows contained deep cracks running parallel with the furrows, which were generally oriented downslope. It was not possible in the time and with the resources available to determine whether a reticulate pattern of cracks had formed across the ridges but the deep and extensive nature of the plough-furrow cracks suggests that reticulate cracking may also be reasonably widespread if the sequence follows that set out by Pyatt (1987).

Almost the whole of a forestry rotation involves progressive loading of the peat surface. Peat solids in the catotelm of an undrained bog are close to being neutrally buoyant – they tend neither to sink nor to float up to the surface. As the bog is drained, the water table falls and the dewatered layers of

Plate 3.3: Spruce planted after the south-west part of the forest was destroyed by fire about 10 years ago. The ground here has thus been drained and planted twice: part of this area was involved in the October 2003 bog slide.

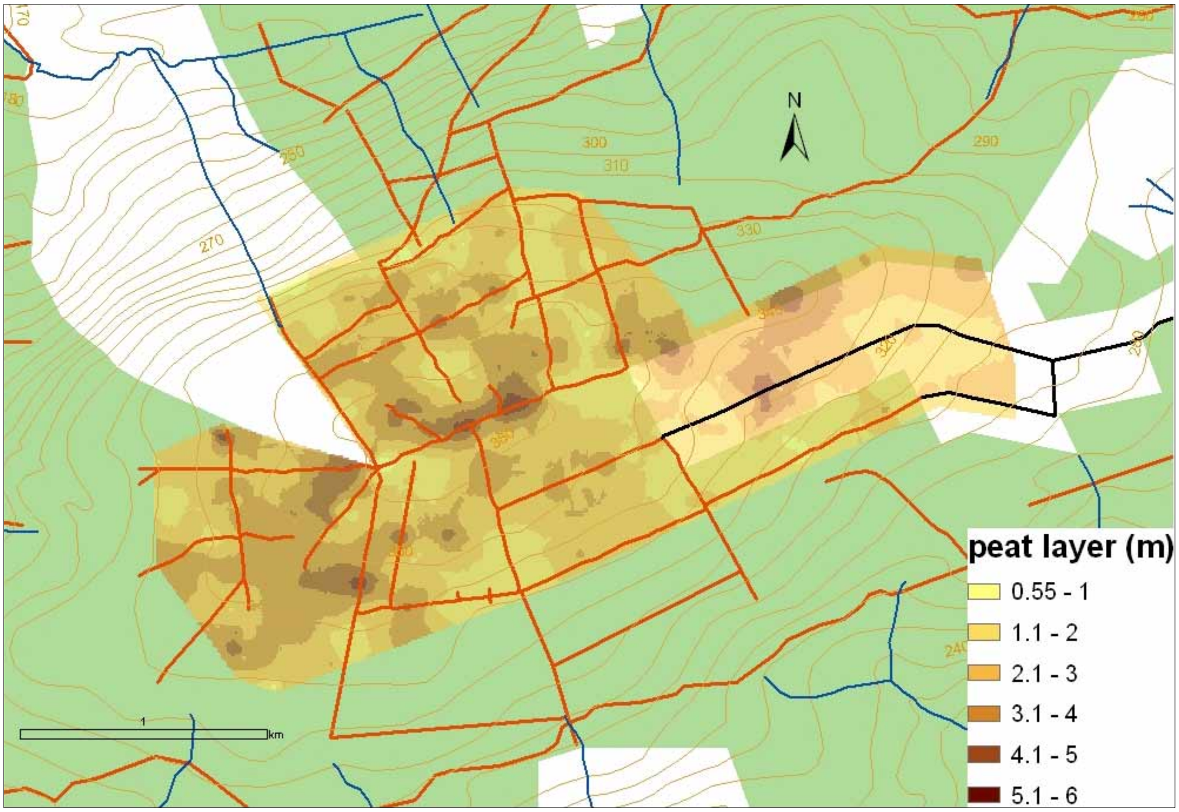


Figure 3.3: The turbary road (black) and forestry rides (orange) on the site. Forestry areas are shaded green. The wind-farm boundary is indicated by the area for which peat thicknesses are shown, streams are shown in blue.

peat gain weight because buoyant uplift is lost. Further loading of the surface occurs as the trees grow to maturity and their increasing weight is added to the existing overburden of drained peat. The final phase of the rotation is harvest, entailing the removal of the timber crop – and thereby also removing a substantial part of the load that has been accumulating on the peat. The water table may now rise because water is no longer being intercepted by, or removed through evapotranspiration from, the forest canopy. Some of the load resulting from the weight of drained peat may also thus be relieved as this peat is re-submerged and so re-gains buoyant support. Further physical and hydrological changes in the peat can thus be anticipated.

One possible effect is that the peat surface will rise or 'rebound' on unloading (Hobbs 1986). However, Schneebeli (1989) indicates that at least some of the reduction in peat permeability imposed by compression under the growing trees will persist after harvest, suggesting that rebound is incomplete. These are effects that have not yet been studied and recorded systematically because most first rotations of forestry on peat are only now approaching harvestable age.

Plate 3.4: A crack in the peat surface beneath forestry which is just visible despite the thick litter layer.

However, the potential for effects on the peat indicates a need for particular vigilance when the forestry on Cashlaundrumlahan is harvested. Only those trees that were directly obstructing wind farm development work, such as road-building and turbine site excavation, have been felled so far (plate 3.5) and it seems possible that this patchy unloading could introduce significant local variations in peat condition across the site.

3.3 *Peat removal – turbary*

3.3.1 *General context*

The immediate effects of agriculture and forestry are felt by the surface layer, or acrotelm, of a bog. Longer-term effects on the catotelm may also be observed but direct physical disruption of the catotelm peat is relatively limited. This is not the case where peat is removed from the bog by peat or 'turf' cutting. This may involve only a small amount of peat removal from an individual 'peat bank'

Plates 3.5: Areas on Cashlaundrumlahan where forestry has been felled to make way for construction work.

but, where a community works collectively within a defined area, the result is an area of more extensive peat removal, generally referred to as a turbary. It involves cutting slabs of peat from the deeper part of the peat body then drying these slabs or 'turves' to use as domestic fuel. This exposes the catotelm directly to the atmosphere and also creates a sharp hydrological gradient in the peat because the shape of the catotelm has been radically altered.

Before the peat is cut, the surface layer of vegetation is removed. This is known in Shetland, for example, as 'flaying the peats'. After this, the remaining, lower part of the acrotelm is cut to produce quick-burning 'mossy peat', then the upper part of the catotelm (being of much more value as fuel and often termed 'black' or even 'blue' peat) is progressively cut away in turves from the face of a vertical peat face or bank. A drain may be cut to prevent water from ponding excessively at the base of the peat bank. When each year's crop of turves has been collected, a face of catotelm peat is left exposed directly to the atmosphere. What occurs next happens in four phases, described by Hobbs (1986) as:

- primary consolidation, in which water is squeezed from the large spaces in the peat matrix;
- shrinkage, where formerly wet material shrinks on exposure to air;
- secondary compression, caused by a slow rearrangement of fragments that permits micropore water to be squeezed out and which Hobbs describes as a major process in peat but one that is often overlooked;
- oxidative wastage, which Hobbs describes as almost unique to peat soils, resulting in conversion of the peat material to CO_2 and water.

The first three processes reduce the permeability of the peat along the face which tends to slow down further water losses from parts of the system that remain intact.

The process of peat extraction inevitably lowers the bog surface substantially and the new, lowered surface is generally (though not always) wetter than the uncut surface. Traditional practice also involves placing the 'flayed' turves of vegetation back down onto the new lowered surface, thereby encouraging it to knit together over time into something resembling bog vegetation. In this way, turbary operations tend not to generate significant areas of bare unprotected peat and are thus not normally associated with significant erosion. The immediate effect of a turbary is in the region of the raised cut face which undergoes slow but steady oxidative wastage. However, domestic turbaries are often poorly drained and minimally maintained so that water ponds in the cut areas and in adjacent drains, with the result that there is significant regeneration of peat-forming vegetation.

3.3.2 *Peat cutting and Cashlaundrumlahan*

A significant portion of the eastern end of the site consists of a large turbary containing several individual peat banks (fig 3.4). Many of these banks have not been cut for many years while some have evidently been used quite recently.

The pattern of cutting, enclosed within this one large turbary, differs in its impact from the more haphazard domestic peat banks found throughout much of Scotland. Typically, the Scottish banks are cut into a sloping hillside of peat to create an open-faced step that faces downhill. Although the flayed vegetation is then replaced on the lowered surface, the surface is generally able to drain freely downslope.

The enclosed and regularly-arranged turbary at Derrybrien consists of a series of parallel peat faces, each with a drain at the foot leading off downslope (because the turbary as a whole lies to the south of the summit ridge and thus slopes gently to the south). These drains then feed into a collecting drain at the foot of the turbary. However, because many peat faces have not been cut for several years and because the drains have not been renewed, drainage across a large proportion of the turbary is increasingly impeded and there are signs that a bog vegetation is regenerating (plate 3.6). Cracking, slumping and oxidative wastage can be expected within and around the margin of the turbary. In the absence of the forestry, the turbary may have given rise to drainage effects and erosion within the wet

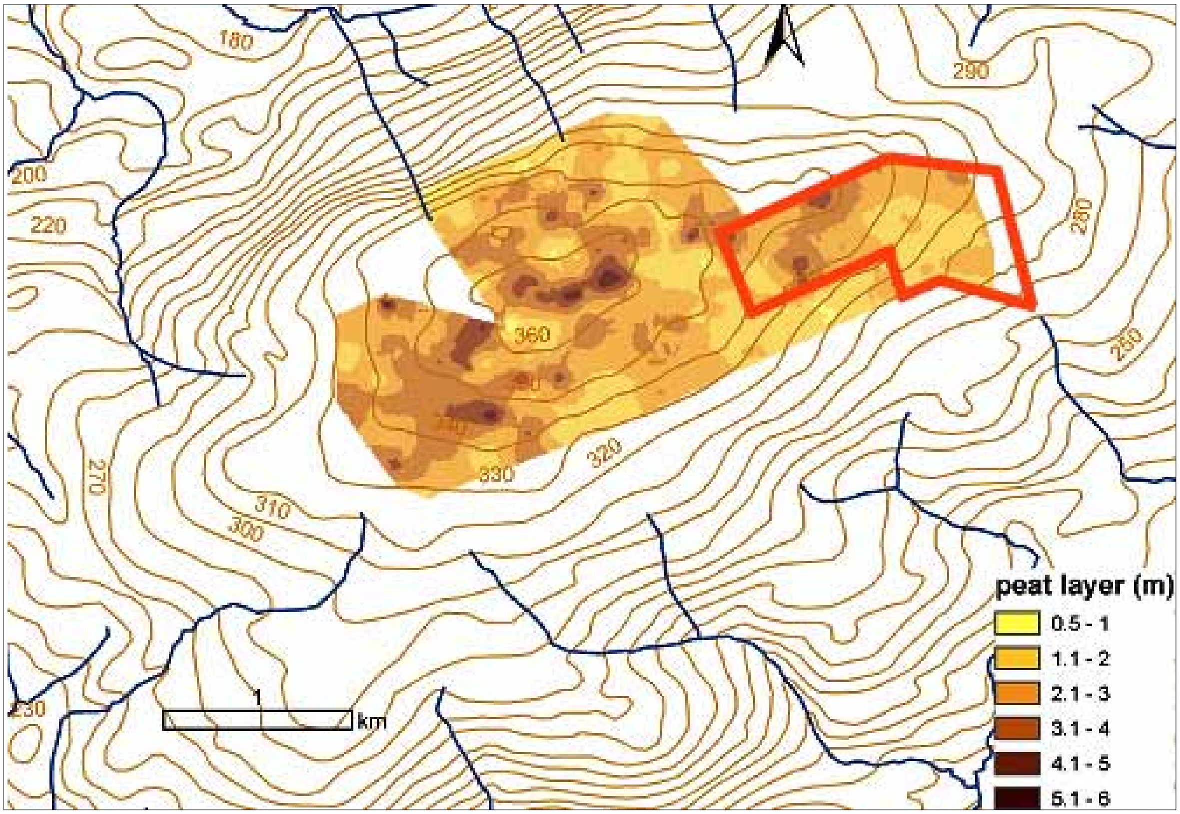


Figure 3.4: The extent of the turbary (indicated by the red boundary) on the Cashlaundrumlahan summit. The wind farm boundary is indicated by the area for which peat thicknesses are given.

blanket mire of the summit but, now the forestry has a much more profound impact, it masks the effect of the turbary.

3.4 *Slope stability*

One of the more spectacular results of human impact on a peatland is termed a bog burst or bog slide. This represents erosion of a spectacular type (which sometimes occurs on a dramatic scale) which occurs when large sections become detached from the main body of peat and collapse downslope like a snow avalanche, a mud-flow, or a volcanic lahar.

Slope stability is recognised as such a significant issue for certain types of development that the UK government has provided detailed policy planning guidance on the topic. This is discussed in more detail in section 7.6. For the moment, it is sufficient to observe that the guidance makes it clear that slope stability should form part of the initial assessment and the review of relevant factors that are part of the scoping stage.

In particular, scoping for stability should look at the predisposition to instability of the particular geology, slope, soil type, or any combination of these.

The published literature shows that blanket mire systems can be made less stable and more prone to slope instability as a result of various types of impact. The record shows that bog bursts have been associated with drainage, peat cracking, peat cutting and peat excavation and points to the need for both the scoping and impact assessment phases to consider very carefully the inherent potential of the Cashlaundrumlahan blanket mire for instability , given its existing pattern of impacts.

The possibility that further development of the type envisaged for Derrybrien might initiate such instability should be carefully examined. Section 4 is therefore devoted to the phenomenon of bog slides, bog bursts and instability in peat.

Plate 3.6: Turbary fields on the summit if the site showing (above) an old peat bank and (right) the downslope catchwater drainage system, re-excavated after peat slide in 2003).

Summary of Chapter 3

1 Agriculture on blanket bogs tends to lead to damage caused by trampling grazing stock, by burning to improve grazing and by drainage to improve grazing and remove hazards to stock.

2 These all tend to disrupt and destroy the living surface of Sphagnum bog moss that maintains the bog system as a biologically-active, self-sustaining ecosystem. Loss of this surface layer (and the protective acrotelm) tends to lead to peat loss through oxidation to CO_2 (oxidative wastage) and through the powerful forces of rainfall-induced erosion. There is little evidence of such damage on Cashlaundrumlahan.

3 Forestry causes major changes to the upper layers of peat. The living bog surface is lost through a combination of surface drainage and the interception of rain and light by the forest canopy. The trees dry out the surface layers of peat and cause increasingly deep cracking down into the catotelm. After 20 years the peat is deeply fissured. There is extensive forest plantation at Derrybrien and clear evidence of fissuring in the peat beneath the forest cover.

4 Peat cutting for fuel (turbary) leads to loss of both acrotelm and catotelm. The area from which peat is removed may become wetter because it becomes an area of water collection but the cut peat face is now subject to oxidative wastage. The turbary area at Cashlaundrumlahan forms an inclined but also enclosed basin. Many of the peat banks have not been used for some time and are now re-wetting. The major impacts of the turbary are enclosed within the turbary bounds.

5 There is potential for slope instability to develop on certain types of ground, particularly blanket peat, in association with impacts such as those described above.

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

4.1 *Historical and geographical occurrence*

CATASTROPHIC MASS MOVEMENTS of peat have been recorded since the Middle Ages (Smith 1910). Some early accounts are tinged with fascination. Praeger, for example, (1897a) quotes one early source as follows:

> On the 7th day of June 1697, near Charleville, in the County of Limerick, in Ireland, a great Rumbling, or faint Noise was heard in the Earth, much like unto a Sound of Thunder near spent; for a little Space the Air was somewhat troubled with little Whisking Winds, seeming to meet contrary Ways: and soon after that, to the greater Terror and Affrightment of a great Number of Spectators, a more wonderful thing happened; for in a Bog stretching North and South, the Earth began to move . . . Leaving great Breaches behind it and spewings of Water that cast up noisome Vapours: And so it continues at present, to the great Wonderment of those that pass by, or come many miles to be Eye-witnesses of so strange a thing.

Sutcliffe (1899) gives a rather different description of a peat flow:

> Its solid, oncoming front was black and sticky: a man had time to count his sins thrice whilst the monster crept stealthily towards him. There are those about the moorside who remember seeing the spectacle; and they say that it seemed as if the whole moor top were turning over on its side and rolling downward.

The accompanying threat to life and property is clearly conveyed by accounts of the two nights in the late 19th Century when peat workings on the hill immediately behind the town of Stanley in the Falkland Islands gave way:

> Just after midnight on Friday the 29th November 1878, one of the inhabitants was awakened by the continuous barking of his dog and, on going out to investigate, discovered to his alarm that his house was surrounded by a moving mass of semi-liquid peat. The mass, which was several feet deep, was moving slowly down the hill at about four to five miles an hour . . . those houses affected were completely cut off from communication with the rest of the town until they had cut their way through the black mass. All communications between the east and west ends of the town were cut off except by boats.
>
> Despite attempts to stabilise the peat on the hill above the town, drainage remained a problem and on the night of 2nd June 1886 . . . A stream of half liquefied peat over a hundred yards in width and four or five feet deep flowed suddenly through the town into the harbour . . . The story is best told in the words of an eye witness, Mr Frederick E. Cobb, Manager of the Falkland Islands Company, in the report he sent home to his office in London:
>
> 'A horrible calamity occurred here last night, by which one life has been lost and great damage done to property. About 9 p.m. another peat slip took place similar to that of 1878 but more disastrous in its results. It started from the top of the hill and descended with immense force to the harbour and moved one house several yards and nearly overturned it, smashing all fences and walls that stood in its path, carried all outbuildings down to the water and found its way into the back premises of many buildings. The Church is half buried and the back wall cracked and bulged in, so as to be unsafe. A lad named Ratcliffe in trying to escape when the first rush came, was caught in some wire fencing and although several people had hold of him and nearly lost their lives in trying to rescue him, was horribly smothered and his body only recovered after daybreak this morning. There is a report that a man is missing supposed to be dead in a house that is nearly buried and a search is being made for him. Our

> store next the Church has suffered severely and I have at present as many men as I can gather trying to clear it but it is an impossible task. The liquid peat is nearly up to the ceiling in the kitchen and as fast as any is moved, more slides down from the hill. The inmates escaped just in time and took refuge in my house last night. In short Stanley is in a horrible plight and upside down and how it is to recover this winter I don't know.'.[1]

Similar catastrophes were occurring in Ireland at around the same time. In 1867, a whole townland in the Glancastle Hills in Erris slipped into the sea (Feehan and O'Donovan 1996) and a family of eight, their home and their livestock were carried away and buried by an extensive bog-burst in northeast Killarney on 28 December 1896 (Praeger 1937).

A century later, in 1983, three peat slips were recorded in northern England and southern Scotland within the space of eight days; two in the Pennines on 17 July (Carling 1984) and one in Roxburghshire on 25 July (Acreman 1991).

Peat slides were again in the news in 2003. On the morning of 19 September, the southern part of the Shetland mainland was cut off when the A970 road was blocked by peat sliding down the mountainside after a torrential downpour. In Ireland on the same night, intense localised rainfall triggered a series of forty slides on the Dooncarton and Barnachiulle Mountains near Pollothomas in County Mayo, damaging roads, private property and two graveyards (Tobin 2003, Trodd 2003).

An examination of available literature indicates that peat mass movements have been widely reported and have formed the subject of several scientific investigations. They appear to be particularly frequent in Ireland. Feldmeyer-Christie and Mulhauser (1994) comment that such events are very unusual in Switzerland but they occur comparatively frequently in Ireland and Scotland and Carling (1986) calculates an average recurrence interval of 6.3 years for peat mass movements in Northern Ireland as compared with 36 years for the English Pennines. Tables 4.1 and 4.2 summarise the locations and dates of peat mass movement events reported in the sources identified. Most of the records are from Britain and Ireland and more than 50 per cent are from Ireland or Northern Ireland.

Specifically for the Slieve Aughty Mountains, a sudden thaw precipitated mass movement of peat from Loughatorick North[2] into Ballinlough Lake, covering 100 acres of lowland with peat to a depth of one to seven feet on January 27 1890. The upper part of the bog is reported to have subsided by 10 to 15 feet (c. 3 to 5 m). A second event occurred in the southern part of the range (County Clare) in October 1934 and has been associated with high antecedent rainfall.

4.2 *Causes and mechanisms*

At least three types of catastrophic peat failure can be recognised. Classic bog bursts or bog flows involve 'rapid dewatering' – the emergence of well-humified amorphous peat as a fluid from a break in the bog surface, followed by settling of the residual peat in situ. Peat slides, on the other hand, involve failure at or below the peat/substratum interface leading to the translational sliding of detached rafts of surface vegetation together with the whole underlying peat profile. An intermediate type appears to result from failure within the peat layer itself, with detached rafts of surface vegetation being carried by the movement of a mass of liquid peat. The event at Slievenakilla (Ireland) described by Large (1991) appears to be one example of the latter (Kirkpatrick 1999). Dykes and Kirk (1991) propose the term bog slide to denote this intermediate category.

Substantial detail of the 1824 bog burst on Crow Hill (table 4.2) near Keighley in Yorkshire is available from records made by and associated with the Reverend Patrick Bronte (Tallis and Seaward 1999). The peat flow was 30 to 60 metres wide and five to six metres deep and continued for 10 to 15 miles. Substantial fish kills (1,270 kilograms of perch and trout taken from the River Aire at Horsforth) and disruption to the woollen industry were reported. Its point of origin was an almost-level bog which had become 'soft and swampy' over the preceding years, approximately 500m from the top of a steep gorge carrying a stream rising from the peat eastwards into the River Worth. The

1 Falkland Islands Journal, 1974

2 Loughatorick North is situated approximately eight km south east of Cashlaundrumlahan.

County	Location and date	References
IRELAND		
Clare	Slieve Aughty Mountains 1934	Mitchell (1935), AGEC (2004)
Cork	Bog of Farrtindoyle 1840	Lyons (undated)
Donegal	Meenacharvy Townland	Bishopp and Mitchell (1946)
Galway	Bog of Addergoole 1745	Lyons (undated)
	Joyce Country 1821	Lyons (undated)
	Dunmore 1873	Lyons (undated)
	Loughatorick North 1890	Lyons (undated)
	Slieve Aughty Mountains (Derrybrien) 2003	
Kerry	Knocknageeha / Gneevegullia, Killarney 1896	Cole (1897); Praeger (1937); Praeger (1897a); Sollas *et al*. (1897)
Leitrim	Slievenakilla 1980s	Alexander *et al*. (1985); Large (1991)
Limerick	Charleville 1697	Praeger (1897a)
	Castlegarde Bog 1708	Lyons (undated)
Longford	Bog of Rine 1809	Lyons (undated)
	Newtownforbes 1883	Feehan and O'Donovan (1996)
Mayo	Glancastle Hills, Erris 1867	Feehan and O'Donovan (1996)
	Glencullin	Delap *et al.* (1932)
	Owenmore River 1980s	Byrne (undated)
	Bellacorrick Forest	Hendrick (1990)
	Dooncarton Mountain 2003	Trodd (2003)
Offaly	Bog of Kilmaleady	Lyons (undated)
Roscommon	Castlereagh 1870	Lyons (undated)
	Castlereagh 1883	Kirkpatrick (1999); Feehan and O'Donovan (1996)
Sligo	Geevagh 1831	Lyons (undated)
	Straduff Townland	Alexander *et al*. (1985, 1986)
Tipperary	Dundrum 1788	Lyons (undated)
Wicklow	Powerscourt Mountain	Mitchell (1938); Delap and Mitchell (1939)
NORTHERN IRELAND		
Antrim	Fairloch Moss 1835	Lyons (undated)
	Slieve-An-Orra Hills	Tomlinson and Gardiner (1982)
	Skerry Hill	Wilson and Hegarty (1993)
Fermanagh	Carrowmaculla	Tomlinson (1981)
	Cuilcagh Mountain	Kirk (1999)

Table 4.1: Summary of the dates and locations of catastrophic peat failure events in Ireland and Northern Ireland as reported in the literature.

burst occurred at 18:00 hrs on 2 September 1824 during a violent localised thunderstorm. Two areas, the larger 200 to 300 metres across, slumped by four to six metres, their contents forming rivers of peat that united 100 metres downslope into a channel 12 metres wide and seven to eight metres deep which in turn discharged into the gorge. The event was accompanied by 'a deep, distant explosion' and 'a very considerable tremor of the neighbouring parts'. There was a second discharge of peat the following morning and four further 'eruptions' two days later, apparently in dry weather since there is an eye-witness account. This describes a new front of peat moving slowly down the channel, sometimes stopping, until it was discharged noisily into the gorge.

The peat failure at the Hermitage Valley in southern Scotland on 25 July 1983 (Acreman 1991)

Area	Location and date	References
Scotland		
Shetland		Kirkpatrick (1999); Marter (2003)
Isle of Lewis		Bowes (1960)
Borders	Hermitage Valley	Acreman (1991)
Central	Blantyre Muir	Bragg *et al*. (1991)
England		
North York Moors	1938	Hemingway and Sledge (1943); Carling (1986)
Pennines	Crow Hill 1824	Bronte (1824a,b); Turner (1898); Sutcliffe (1899); Turner (1913); Barker (1994); Lock and Dixon (1965); Tallis and Seaward (1999)
	Meldon Hill 1870	Crisp *et al*. (1964)
	southern	Bower (1960)
	Langdon Beck 1961	Carling (1986)
	Teesdale 1963	Carling (1986)
	southern	Tallis (1985)
	no information	McCahon *et al*. (1987)
	Teesdale/Weardale 1983	Carling (1986)
CONTINENTAL EUROPE		
Germany	Schšnberg, Oberbayern	Vidal (1966)
Switzerland	La Vraconnaz 1987	Feldmeyer-Christie and Mulhauser (1994); Feldmeyer-Christie (1995)
CANADA		
British Columbia	Prince Rupert	Hungr and Evans (1985)
SOUTHERN HEMISPHERE		
Australia (Sydney)	Wingecarribee Swamp 1998	Proctor (1998)
sub-Antarctic	Maquarie Island	Selkirk (1996)
Falkland Islands	Stanley 1878 and 1886 Cape Meredith Hill (recent)	Anonymous (1974); Falkland Islands Journal (1974); Hungr and Evans (1985) Un-referenced newspaper article (A. Douse)

Table 4.2: Summary of dates and locations of catastrophic peat failure events other than in Ireland and Northern Ireland as reported in the literature.

involved the movement of sections of peat and vegetation that, during an intense localised storm at the end of a dry summer, parted intact from the edge of the peat blanket and slid towards the river below. Soil pipes were visible near the bases of failed peat faces and the failure plane appeared to be associated with an iron pan 20 cm below the peat/soil interface. The configuration of the edge of the peat suggested that such events occurred fairly regularly, effectively limiting the downslope development of peat cover. The mechanism invoked for this event is that stormwater was fed into the regolith beneath the peat via soil pipes above the slides and through cracks in the peat. Here, the water could infiltrate no further due to the presence of the iron pan and the resultant increase in pore-water pressures led to failure of the regolith. Carling (1986) reached a broadly similar conclusion from detailed investigation of the mechanisms of five translational peat slides that occurred on the flanks of Noon Hill at the Teesdale/Weardale watershed (northern England) in the afternoon of 17 July 1983. Once again, these occurred after thunderstorm rainfall of a very rare intensity (42-84 mm hr^{-1}) and return period (400-2500 years) following two dry months during which cracking of the surface peat had occurred. The mechanism proposed involves penetration of water to the base of the peat via cracks in association with overland flow, giving rise to super-charging of the pipe system and development of artesian pressure. Specifically, the cause of these slides was the crossing of an intrinsic stability threshold in the clay beneath the peat overburden which failed at the lower surface of the rooting zone, some 20 cm below the peat/clay interface. Under these circumstances, the peat overburden may be locally unstable on slopes as low as seven degrees. Similar failure mechanisms are indicated by the accounts of Crisp et al. (1964) and Tomlinson and Gardiner (1982).

The literature also indicates a number of associations with prior disturbance of the peatland:

- The two peat slips that engulfed Stanley in the Falkland Islands on 29 November 1878[3] and 2 June 1886 were attributed to the accumulation of water in old peat workings during unusually wet weather. The water eventually broke through uncut sections of bog on the brow of the hill behind the town (Anonymous 1974).
- Praeger (1897a) reports a number of bog bursts where the bog had given way along the face of a peat bank.
- Feehan and O' Donovan (1996) conclude that the probability of a failure event occurring is increased by the extent to which the surface has been damaged by burning or peat cutting.
- In 1987, a 15 ha section of the sloping bog of la Vraconnaz in the Swiss Jura Mountains which had been cut for fuel from the 18th Century until around 1945 slid downslope for at least 300 metres, breaking into rafts but leaving most of the trees standing upright (Feldmeyer-Christie and Mulhauser 1994). Although the immediate cause of this translational slide appears to have been the swelling of a spring at the upslope edge of the bog during two days of heavy rainfall following three weeks of drought, it seems likely that the area involved had been pre-disposed to sliding by the disturbance.
- Byrne (undated) includes in her account of Irish bog bursts a photograph of failure of peat by the Owenmore River in County Mayo that had been pre-drained for forestry (plate 4.1).

Some insight into possible mechanisms for these associations is also available. Carling (1986)

3 'The proximity of the settlers' peat banks (from where they obtained peat as a fuel for domestic stoves) to Stanley gave rise to large amounts of surface water runoff, which ran directly down the hill through central Stanley. This was not paid attention to and in late November 1878 the whole bank to the south of Stanley collapsed, running down in a three feet deep flow of liquid peat. This swamped the town, surrounding houses and actually cut off communication between east and west Stanley, apart from by boat. The next day a trench was cut at the back of the banks to cut the flow of water and it took a full week to clear the town of the residue' (Falklands Museum, undated).

Plate 4.1: A bog burst in pre-drained forestry area in Co. Mayo blanket bog. Liquefied peat was discharged into the Owenmore River. Late 1980s.

Failure mechanism	Description	Hydrological control
Shear failure by loading	Hydrological loading – weight of absorbed water (rainfall, snowmelt) or snow	Absorption of water into the peat mass
	Increase in shear stress – hydrostatic pressure generated by water-filled cracks, ponds and lochs	Development of standing bodies of water in the peat
	Catastrophic loading – rapid increase in peat mass exceedance of shear strength	'Hydraulic mining' by heavy localised cloudbursts
Buoyancy effect	Generation of artesian pressures	Routing of water to base of peat (pipes, drains)
	Increase in interstitial pore-water pressure and reduction in cohesion	Transfer of surface water to base of peat through peat matrix
Liquefaction	Basal peat slurried by increased water content (exceedance of liquid limit)	Routing of water to base via watercourses, infiltration, surface routing
	Basal clay slurried by organic acid dispersal (passing of liquid limit)	Long-term peat/clay interface chemical interaction
	General increase in basal moisture content by routing of artificial drainage	Downslope drainage impedance by blocked drains; enhanced upslope drainage by open drains and cuts
Surface rupture	Swelling of basal peat leading to rupture of the drier surface	Increase in water availability to basal peat
	Relative swelling of basal peat by contraction of surface during drought	Reduction in surface water content
	Long-term depth creep inducing surface rupture or shear failure	Development of seepage pressures
Margin rupture	Removal of underlying support by stream action – release of basal peat	External hydrological processes
	Removal of underlying support by peat cutting	Anthropogenic cause

Table 4.3: Some possible failure mechanisms triggering peat slides

observed the capture of artificial drains by perennial peat pipes, whose catchment areas are thus substantially increased, and suggested that this phenomenon might substantially reduce peat stability where drains run transverse to the slope and where they cross natural drainage lines or flushes. Kirk (1999) suggests that re-establishment of a high water table in cutover blanket bog on Cuilcagh Mountain in County Fermanagh (Northern Ireland) may lead to a rise in pore water pressure and changes in a variety of other stability factors, reducing the shear strength of the peat and increasing the risk of slope failure. Morphological evidence at one failure location with only 0.7 metres of peat indicated a distinct sequence of events, beginning with the failure of a small segment of slope above a degraded transverse drainage ditch which had been cut less than 10 years previously. The failure surface was not in the peat but at or near the base of an underlying 0.5 metre clay layer which contained small soil pipes. Modelling indicated that both the soil pipes and the drain were required to reduce stability sufficiently to initiate failure, leading to the conclusion that the cutting of the drain and the hydrological impacts of its subsequent degradation were the ultimate cause of the peat slide (Dykes and Kirk 2001).

Two accounts of other similar incidents associate peat failures with specific drainage activities. At Blantyre Muir in central Scotland, the collapse of a section of mire above a truncated bog edge left by adjacent open-cast mining operations appeared to be centred on a drain running perpendicular to the cut peat face (Bragg et al. 1991) and it is possible that a water pump was being used in the vicinity. Wingecarribee Swamp, a spring-fed fen largely dominated by Restionaceae near Sydney, Australia, suffered spectacular failure following heavy rainfall in August 1998. It originated on a slope of 0.15 per cent at the upstream edge of a peat-mining operation in which peat slurry was being pumped out of a dredge pool some 30 ha in area. The unsupported peat face at the head of the dredge pool sheared and gave way and some four million cubic metres of peat collapsed progressively 'like a pile of dominoes or unzipping a zip fastener'. This appears to fall into the intermediate 'bog slide' category, with the middle part of the peat column behaving as a semi-fluid material (Proctor 1998).

In a current review, Warburton et al. (2004) report associations of peat mass movements in the north Pennines with summer thunderstorms and pre-existing drainage features and identify four common characteristics of peat mass-movement sites:

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

However, they consider that the exact mechanisms of failure are not fully understood and that key hydrological questions remain unanswered. They suggest five possible failure mechanisms, summarised in table 4.3.

Whatever the particular mechanisms in any given case, one of the common threads that runs through most of the literature concerned with bog bursts and bog slides is that the incidents are generally associated with some form of human disturbance, particularly disturbance that has disrupted the integrity of the acrotelm in some way. The mechanics of a slip may involve collapse or rupture within the acrotelm or even in the mineral base beneath the peat but the weak spot which acts as the trigger for the event is more often than not to be found in damage to the thin surface layer. It may be thin but the acrotelm plays a much more important role in maintaining peatland stability than is perhaps generally realised.

Summary of Chapter 4

1 When peatland ecosystems undergo catastrophic collapse, releasing much of the liquid core of the catotelm in a dramatic flow, this is known as a bog burst.

2 When a mass of peat slides dramatically down a slope in the style of an avalanche, it is referred to as a peat slide if the failure occurs in the underlying mineral soil and a bog slide if the failure occurs within the body of the peat.

3 Bog bursts, peat slides and bog slides are widespread and well-documented phenomena. There are records of such occurrences from as far back as the Middle Ages and they have been recorded from as far away as the Falkland Islands There are many documented cases for Ireland and the UK.

4 Heavy and prolonged rainfall is often associated with such events. In other cases there may be a link to ponding and surface-water movement through the use of pumps. In either case, localised ponding and rapid surface water movement appear to be common factors.

5 In most cases, the origination point of the bog burst/slide is found to be a feature resulting from human impact.

6 The peat may travel several kilometres, particularly if it enters a watercourse.

7 Several different types of failure have been recognised – shear failure through loading, buoyancy effect, liquefaction, surface rupture and margin rupture.

Chapter 5
Assessing potential impacts

UNDER NORMAL CIRCUMSTANCES an EIA is concerned only with impacts that may occur at some time in the future as a result of a proposed development. In the case of Derrybrien, circumstances are different because some work had already been undertaken prior to the authors' site visit in June 2004 and, although this section is nominally about proposed and potential effects, it is possible to say something about the methods actually used.

This provides the rather unusual benefit (for an EIA) of 20:20 hindsight and brings with it the suggestion that the present authors have an unfair advantage over the authors of the original EIA because factors which are now plainly evident could not have been foreseen before work started. However, while that is valid as a point of general principle, the issues discussed in this section arise from the first principles of understanding of peatland ecosystems and the existing evidence of associated impacts obtained for a wide range of peatland sites in Ireland and elsewhere.

The scoping section of the present report does not therefore differ significantly from what would have been said had it been written prior to any development. The issues raised here about on-site practices would have been raised in any case on the basis of practices on sites elsewhere in Europe.

The final outcome of the three-year planning process that preceded the start of construction (section 7.1) was that there would be 71 turbines arranged at approximately 200-metre centres across the summit of Cashlaundrumlahan. The layout of the turbines is shown in fig 5.1.

Construction began on 2 July 2003 but was halted after four months due to the landslide of 16 October. Thereafter, only maintenance and safety operations had been carried out by the time of the authors' site visit on 8 June 2004, when most of the site photographs in this report were taken.

5.1 *Road construction*

5.1.1 *Road proposals*

The need for vehicular access for installation of turbines and subsequent maintenance means that a network of roads was needed. Since the existing forest rides are merely unplanted corridors between the plantations and are not surfaced, vehicular access needed be upgraded to something capable of carrying wind farm traffic. The developers therefore proposed to construct a number of new road sections. Their relationship with the existing turbary road and the various forest rides is shown in fig 5.2. Unlike the turbary road, these new roads were intended to float on the surface of the peat. Each 'floating' roadway consists of a base raft of brushwood and felled trees, covered by a layer of geotextile and surfaced with aggregate to a total thickness of c. 1.5 metres (AGEC 2004. See also plate 5.1). The aggregate would be obtained from a 'borrow pit' on site. The perceived advantages of the floating design were cost and the fact that no drainage of the peat was necessary (Saorgus Energy Ltd. 1997, 2000). The possible disadvantage of the method was that it is largely untried on this site.

5.1.2 *Floating 'undrained' roads on peat*

Roads supported by geotextile matting have been used in recent years at a variety of locations within

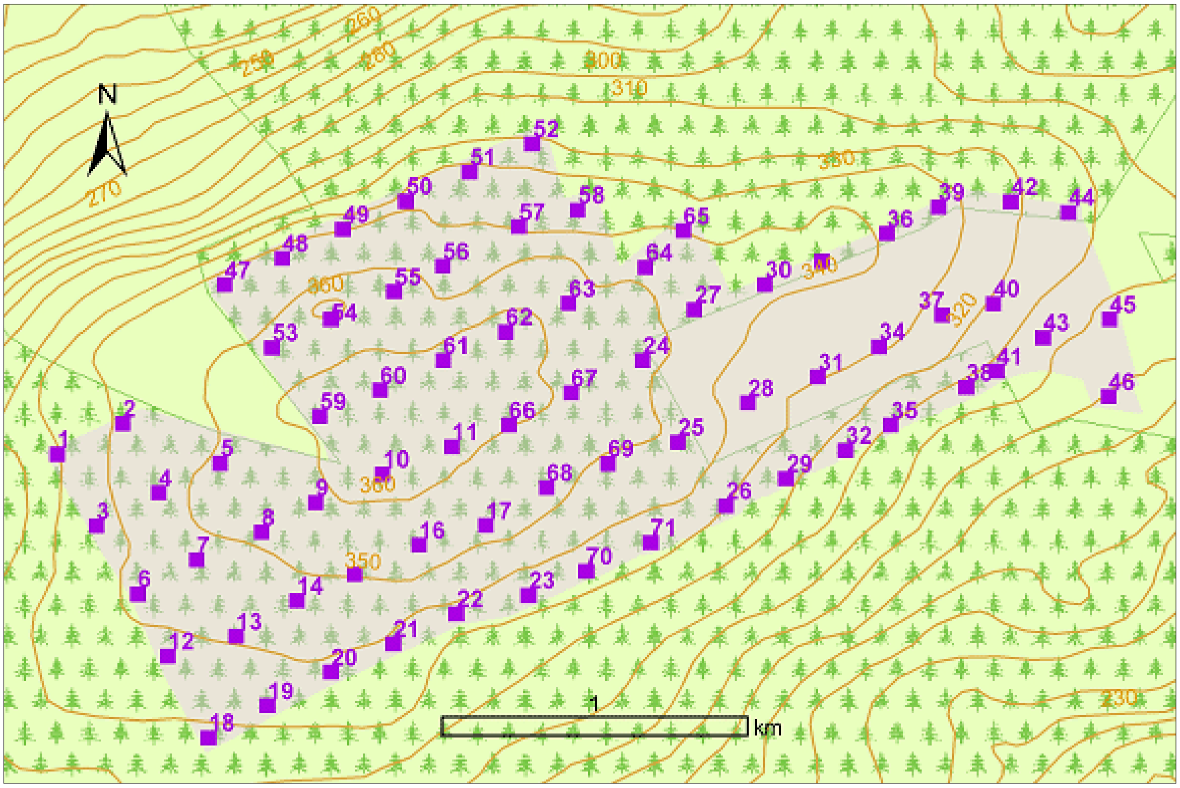


Figure 5.1: Proposed layout of turbines (violet squares) at the Derrybrien Wind Farm site (shaded pale purple). The numbering of the turbines reflects the three planning phases: Phase 1 (turbines 1-23 at the western side of the site), Phase 2 (turbines 24-46 to the east) and Phase 3 (turbines 47-71 in the centre).

Europe to limit surface damage when temporary access has been required for tracked machinery across peatlands. However, these roads have been required for only a few weeks and have been rolled up and removed from the site after use. The wind farm roads would not be temporary since, once the turbines have been installed, it is necessary to maintain the roads in such a condition that heavy lifting gear can be brought in at any time. It cannot be predicted when a rotor blade might break or a new component might be required in a nacelle. Maintenance cannot wait while the road is re-instated.

At first sight this approach to road-building might appear to be compatible with the eco-hydrology of the bog since the timber raft is designed to float within the acrotelm, the spaces between the piled tree trunks and branches providing a series of large interconnected spaces that would allow water to move freely beneath the road.

Even though many of the roads would cross natural seepage flow-lines, the intention was that the hydrological functioning of the peat blanket described in section 2 would not be disrupted.

As far back as Neolithic times, trackways were being ‘floated’ across peat bogs (Cox, Straker and Taylor 1995) and the principle was used by Stephenson when taking the Liverpool-Manchester railway across the great

Plate 5.1: Floating road at Derrybrien Wind Farm.

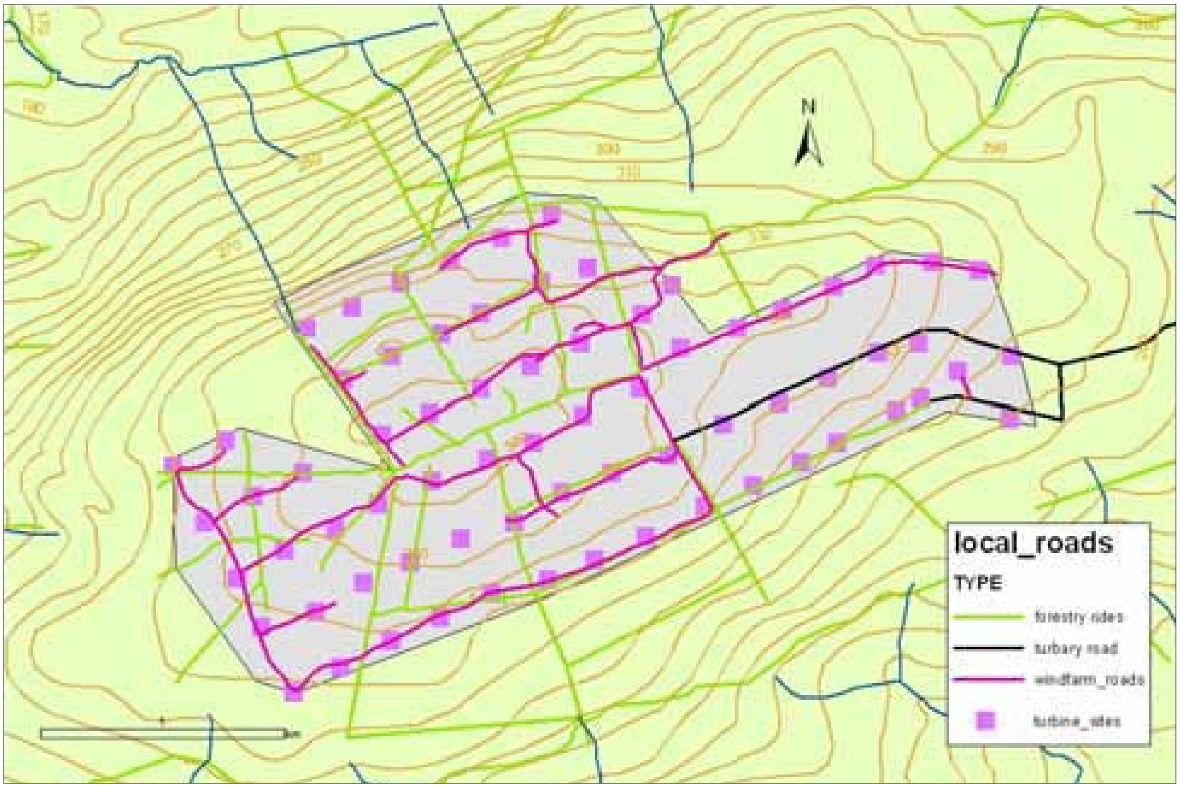


Figure 5.2: Arrangement of existing turbary road (black) and forest rides (green) on the Derrybrien site together with the new floating roads (purple) built before October 2003. (New roads according to AGEC 2004.) Some of the turbine sites (lilac squares) are not yet served by access roads so that a need for further road construction can be anticipated. Stream-courses are shown in blue, contours in pale brown.

Chat Moss (Simmons 1995). However, in the practical installation of these modern-era roads, it has proved necessary to add a vital factor to the construction method – drainage – for reasons explained below.

There are many examples of 'floating' roads or railways from Britain and Ireland and plate 5.2 shows one on Lenzie Moss in Scotland. Here, a railway line that was floated across the bog in the 19th century now lies at the base of a three-metre cutting. It is evident that, in practice, even when a road or railway is constructed using the floating principle, it very rarely truly floats on the mire surface but tends instead to sink deeper and deeper into the peat, in some cases very obviously so, as at Lenzie Moss. Here it has sunk to a much greater depth than can be explained by simple waterlogging of the underlying raft.

This may at first seem surprising, since peat is essentially a liquid (section 2.3) and the roadway should continue to float provided sufficient buoyancy has been provided. After all, a soundly-made

Plate 5.2: Railway line 'floated' across Lenzie Moss during the 19th Century. The track has now sunk by about three metres and the bog is clearly divided into two sections. Note also the lines of taller trees flanking the track, reflecting the associated drainage.

wooden boat does not sink simply because it has been floating on the water for some time. The floating-road design becomes less attractive, however, when we realise that a timber raft will eventually become waterlogged and that wet wood is negatively buoyant. Even a soundly-made boat requires constant maintenance if the timbers are not to become waterlogged. If they do, the boat will sink just like any other waterlogged timber. A road built to a design based on floating timber cannot be expected to float for very long. Once it ceases to float, the wood and the aggregate on top of it will begin to sink into and/or compress the peat beneath.

In fact a road (and its flotation layer) laid across a mire surface does not lie on the surface of the liquid but on the surface of the acrotelm, which is not continuously saturated. Such a road therefore tends progressively to crush the surface of the acrotelm beneath it when the water table falls. Eventually it comes to settle at the base of the acrotelm, beneath the range of water table fluctuation. The timber becomes progressively waterlogged, sinking further into the upper layers of the catotelm. In times of high rainfall, water from the acrotelm begins to drain onto the road surface because the surface is lower than that of the bog surface around it. The road (or railway) thus becomes more liable to surface flooding and in turn becomes increasingly unusable.

5.1.3 *Floating roads and slopes*

There are additional complications associated with floating roads wherever the road lies on a slope. Where they run parallel with the contours or at gentle angles to them, they tend to pond water along their upslope side while, at the same time, preventing this water from reaching parts of the bog downslope from the road. This ponded water poses a threat because it brings a significant weight to bear on the upslope side of the road and creates a pressure differential tending to push the road out of alignment. In wet weather, it may also overflow across the road surface, especially if this has sunk into the peat to any degree, leading to further disruption of the roadway surface and making it even les suitable for traffic.

The supply of water to the bog downslope is also modified. Instead of receiving natural seepage from upslope, this part of the system is now generally deprived of water in the same way as peatland that lies downslope of a ditch but there will be occasions when it is suddenly inundated by ponded water spilling over the road, creating the type of flow conditions that induce erosion (section 3.1.1).

5.1.4 *The need for drainage*

To avoid problems of localised ponding, it is almost invariably necessary to dig ditches running parallel to the road on one or both sides, with the road surface cambered to shed water towards these ditches. This introduces problems of drying, shrinkage and wastage associated with the drainage of peat adjacent to ditches (sections 2, 3). The oxidative wastage caused by continual cleaning out and re-cutting of the ditches (thereby continually exposing catotelm peat to the atmosphere) is the principal reason that many formerly-floating routes across bogs now lie firmly on the underlying substratum.

The need to maintain the turbines means that there is also a need to maintain the drainage for the lifetime of the wind farm and the de-commissioning process. No detailed design criteria have been provided for the peat roads at Derrybrien. However, experience with wind farms in Britain leads the present authors to conclude that floating roads cannot provide the environmentally-friendly solution proposed in the EIA for Derrybrien.

5.1.5 *Roads and water management*

Establishing a drainage system may provide an operational (though not an environmental) solution to localised ponding but it must be designed and set out appropriately in relation both to the natural pattern of drainage and to the arrangement of roads across the site. Where the natural drainage pattern crosses roadways, culverts can be placed at appropriate locations beneath the road but the water flowing from these culverts must be fed into an effective drainage system capable of carrying the water away safely. If instead the water is allowed to flow unchecked and uncontrolled onto the peat surface, it will cause significant peatland erosion from the mouth of the culvert downslope in an ever-expanding fan. It also has the potential to cause more dramatic effects if the peat is already somewhat destabilised.

Once the need for drainage is identified, it must also be acknowledged that it is only as good as its weakest point. A system that moves water from one part of the site simply to collect in another merely transfers the problem rather than solves it. To minimise the possibility of instability due to from localised ponding, the developer is faced with a substantial integrated drainage programme. However, such a programme may give rise to other forms of hydrological instability, particularly if the site is already predisposed to instability.

There are significant dangers in attempting instead to disperse water over the surface of the peat. Water emerging from a drain or culvert during heavy rain does so with a force quite unlike that normally experienced on a bog with an intact acrotelm. A living bog surface cannot withstand such shearing forces and the protective plant cover is quickly destroyed. Once this acrotelm layer has been removed, or if the site was already damaged and lacked a protective vegetation cover, the unprotected catotelm becomes subject to strong scouring and erosive forces, much as is seen in the extensive eroding blanket mires of the Peak District in England (Tallis 1964, 1985, 1987). Such erosion complexes can begin from a single location but in time can spread across an entire bogland system.

Such release of water may also trigger a more dramatic set of events if it is channelled onto areas of peat already predisposed to instability – with, say, extensive cracking as a result of drainage, for example. In such cases, there is a danger that bog slides may be initiated.

The developer is faced with having to weigh up several sometimes sharply opposing factors, including:

- landform and natural drainage patterns;
- road layout;
- required drainage layout;
- oxidation of drained peat;
- current stability of peat cover;
- possible subsequent stability of peat cover;
- influences on downstream water quality;
- changes in streamflow regime;
- influence on downstream ecology.

5.2 *Excavation of turbine bases*

5.2.1 *Size of turbine bases*

Once access to a turbine site is established, its foundation, whose purpose is to support the turbine in a vertical position, can be installed. It must be sufficiently massive to make the structure 'bottom-heavy', so that it remains vertical even when the wind is pushing it sideways, and it must spread the weight so that the turbine does not sink into the ground. At Derrybrien, the method proposed is that peat is excavated down to 'competent' (solid) bedrock and a fifteen-metre square concrete pad or foundation block is constructed on this. A tubular steel can cast into the concrete forms the lowermost section of the tower.

The thickness of peat varies widely across the site so that, whilst some of the turbine excavations need to be barely one metre deep, others are associated with considerable thicknesses of peat and need to be much deeper. The surface area required for each excavation represents the area of the concrete base pad plus a volume of rock overburden introduced once the concrete of the base-pad has set. This backfill is piled over and around the pad to provide sufficient weight to ensure that it remains anchored to the ground when the turbine is in place and subject to its maximum wind load.

The backfilled area also provides a permanent hard-standing for construction vehicles, particularly in areas of deep peat. A heavy crane is required to erect the tower and attach the nacelle and rotor. The excavation must be big enough to provide adequate hard-standing for this and for maintenance.

5.2.2 *Turbine bases and drainage*

Turbine excavations raise a number of drainage-related issues. A hole dug through peat down to bedrock represents an area of drainage as long as the cut peat face remains exposed to the atmosphere. An enclosed hole without an outflow will tend slowly to fill with water seeping from both the acrotelm and the catotelm (and from direct rainfall) until the water in the hole is level with that in the surrounding peat.

Construction of the turbines is hampered by this ponded water, particularly if it accumulates to any depth. Wherever ponding is a problem, there is an associated requirement for drainage. This is achieved either through digging outflows from the excavation or by using a pump. Both techniques come with all the hazards already discussed in relation to road construction and an impact assessment would need to consider this carefully.

If the hole is in flat ground and it is not drained, once it is full of water it will largely cease to act as a drain on the surrounding peat (fig 5.3a). If, on the other hand, the hole is dug in sloping ground, the water table in the hole can only rise to the level of the lower lip of the hole and the upslope face of the hole, remaining above the water level, continues to suffer drainage (fig 5.3b). The larger the surface area of the hole for a given gradient, the larger will be the difference in height between the lower and upper lip of the excavation. As discussed above, the area of each excavation is quite substantial because it must include hard-standing for construction and maintenance. It is likely that at least the upslope face of the excavated peat will in such cases remain dry and exposed even if the excavation is permitted to fill completely with water.

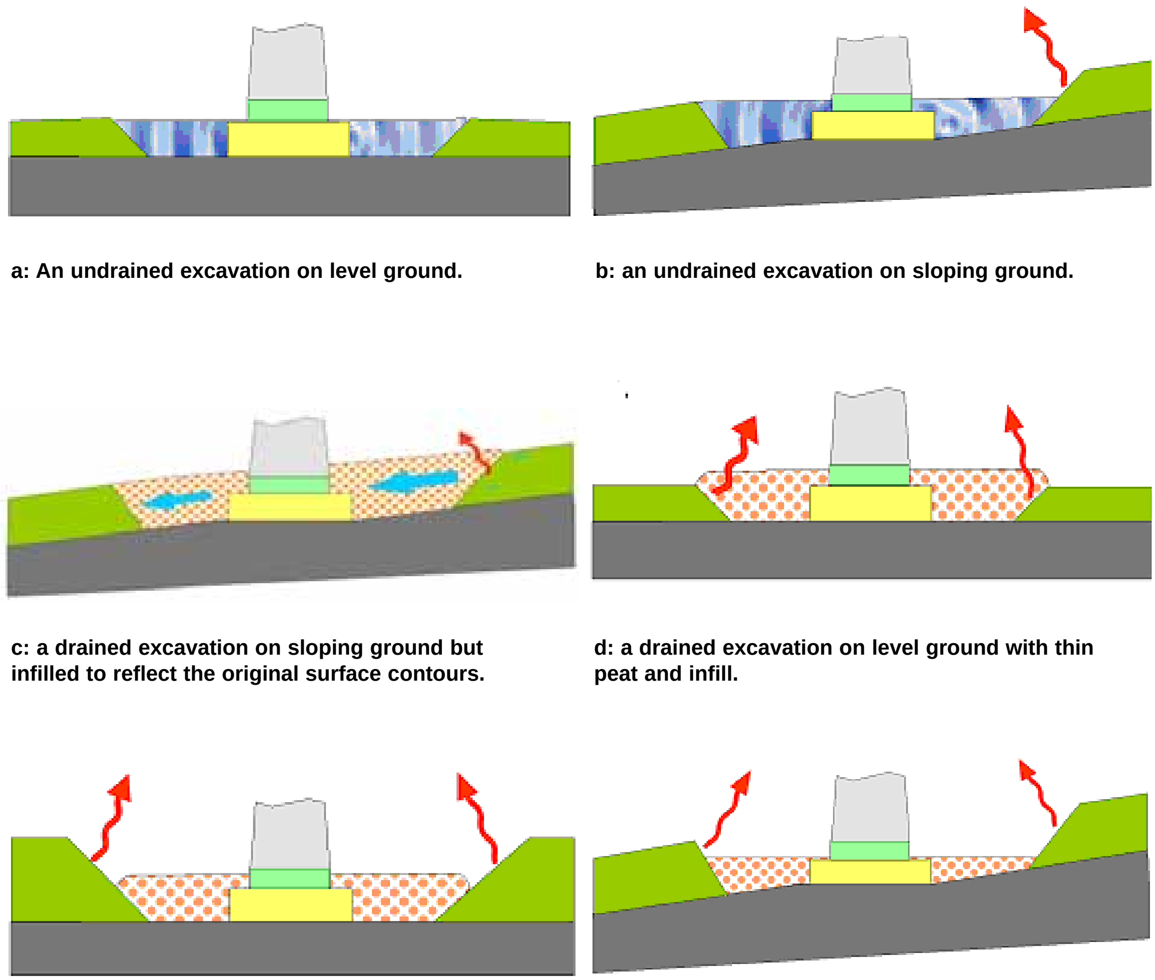
A partial solution involves backfilling the excavation to the former surface contours with original sub-soil and covering this with a layer of peat that reflects as far as possible the original peat thickness. This is not as simple as it might seem. Neither the replacement subsoil nor the peat will possess their original structural integrity and, without a well-knit mat of bog vegetation covering everything, the peat tends to be eroded by rain. Infilling an excavation with anything other than the original type of sub-soil and peat will not produce the same hydrological characteristics as before. It does not provide a replacement for the peat and sub-soil because the overburden contains relatively large spaces between the rock fragments through which water can flow much more easily than it can through peat.

If the partially or wholly-infilled excavation also has a drainage system to prevent this infill (and the turbine base) from becoming inundated, then the whole mass of overburden will remain freely-draining and the peat faces of the excavation margins will continue to suffer water loss even though they may not be so obviously exposed to the atmosphere (fig 5.3c).

In practice, such comprehensive, contoured backfilling is most unlikely because the site managers require hard-standing for construction and maintenance vehicles. A turbine base is likely to be a reasonably wide hole with drainage and rock infill brought from the borrow pit to give added weight and form a flat surface around the tower. If the ground is level and the peat shallow, the infill may indeed cover the cut peat face but even this will not prevent drying of the peat if the excavation is drained (fig 5.3d). If the basin is flat but surrounded by deep peat and is also drained, then the exposed peat faces will be extensive (fig 5.3e). The most likely scenario is fig 5.3f, where the ground surface slopes, the excavation is drained and the backfill covers only a small proportion of the exposed peat faces.

5.2.3 *Turbine bases and the water table – buoyancy*

The design of the foundation for the turbine base is crucial and may vary from turbine to turbine across a single wind farm if, for example, there are local differences in ground strength. Of particular significance, given that most bases are set into ground formerly covered with peat, is the relationship



a: An undrained excavation on level ground.

b: an undrained excavation on sloping ground.

c: a drained excavation on sloping ground but infilled to reflect the original surface contours.

d: a drained excavation on level ground with thin peat and infill.

e: a drained excavation on level ground with deep peat and infill.

f: a drained excavation on sloping ground with infill.

Figure 5.3: Turbine-base construction. The illustrations represent a cross-section of an excavation and construction for a wind-turbine tower. The bedrock is dark grey, the peat thickness is green, water is blue and rock infill is red spots. The yellow is the concrete base for the turbine, the turquoise is the turbine base 'can' and the light grey is the turbine tower. The red wavy arrows represent loss of CO_2 and water from the peat, the blue arrows represent water movement.

between the base and the water table. If the base is installed below the water table and is thus submerged in use, its effective mass will be reduced by a buoyancy effect. This will tend to reduce the effective downward anchoring force, adding a potential instability into the construction. This explains in part why developers normally ensure that there is adequate drainage around turbine bases.

5.2.4 *Turbine bases and the water table – leaching*

Another consequence of submersion is that the foundation pad is subjected to hydrostatic pressure. Even though care is taken to ensure that the concrete is dense, homogeneous and free of cracks so that it has low permeability, water can seep through it under pressure. This is dangerous because concrete contains calcium hydroxide which can be leached out in seepage water, reducing the strength of the concrete, especially if the water contains carbon dioxide. Acid waters with a pH of less than 6.5 are known slowly to degrade concrete while humic acids (the main acids in peat) cause much more rapid degradation.[1]

1 Cement & Concrete Association of New Zealand – www.cca.org.nz

5.3 *Turbine towers and blades – bird strikes*

There is considerable concern within the ornithological world about the possible impacts of wind turbines on bird populations. The uplands, being relatively free from regular human disturbance, tend to form the main refuges for a number of rarer bird species, especially raptors. A number of species protected under the EU Birds Directive and the EU Habitats & Species Directive are characteristic of the kind of blanket mire landscape found in the Slieve Aughty Mountains, including hen harrier, merlin, peregrine falcon and golden plover.

The level of concern has stimulated the Irish government to undertake a research programme into the impacts of wind farms on hen harriers in Ireland (Parliamentary Answer: Mr Cullen 2003). The new research will focus only on the hen harrier; questions about (for example) merlin, peregrine falcon or grouse will remain unanswered. The RSPB in its latest advice about wind farms and birds (RSPB 2004) states that the RSPB will object to wind farm proposals where:

- there is an inadequate assessment of the impacts on birds or their habitats;
- the assessment reveals potentially serious problems for birds or their habitats that cannot be controlled or avoided;
- there is insufficient information about the risks to birds and their habitats to conclude that there will not be a problem.

The most recent evidence about wind farms and bird collisions (Langston 2004) highlights the fact that high bird mortalities due to collisions have been recorded in particular for weather conditions involving poor visibility or that create flying conditions where manoeuvrability is difficult. The summit of Cashlaundrumlahan can be expected to have cloud cover fairly frequently, while strong westerly winds from the Atlantic must also be common. Both conditions render the summit area of the wind farm more hazardous than a similar wind farm at lower altitude. The report highlights in particular the danger to large, long-lived rare bird species with low reproductive rates, where a small increase in mortality can have a disproportionate impact on the population. Such concerns would thus apply equally to hen harrier, peregrine falcon and to merlin and would suggest that for such a large wind-farm development it would be important to determine usage of the area by such species.

Summary of Chapter 5

1 An assessment of the proposed construction methods is made initially on the basis of first principles of ecological science. Following this, the methods actually employed by the developer are considered.

2 Floating roads have been widely used on peat but in current usage they are truly floating only when used as temporary structures. For longer-term use, ‘floating’ roads are supplied with marginal drains along their length in order to prevent flooding of the roadway.

3 The method of ‘floating’ roads is not generally associated with extended heavy traffic and is an untried method at Cashlaundrumlahan.

4 Flooding tends to occur because the roadway sinks into the acrotelm and also because the line of the road rarely follows the natural drainage lines of the bog surface; consequently the road tends to pond water immediately upslope and cause drying out of the peat downslope.

5 Ponded water is a hazard because it causes pressure on the roadway; if it overtops the roadway it can erode the surface of the road.

6 Removal of ponded water can be a hazard if it is suddenly released onto the bog surface by a pump or temporary culvert because the peat surface cannot withstand such powerfully erosive forces.

7 The only effective way to prevent ponding of water is to ensure that roadways are adequately drained – a fact acknowledged by the developers, although the planning proposal emphasises that there will be no drainage.

8 Excavation of turbine bases generally creates a pond of water that must be safely removed (see Point 6).

9 Excavation of turbine bases leaves peat faces at the margins of the excavation permanently exposed to the atmosphere, especially in deep peat or on sloping ground. These faces are subject to long-term drainage and cracking, even if backfilled with aggregate because aggregate is more porous than peat.

10 In most cases the excavations are not completely filled either with aggregate or water, because the volume of aggregate would be too great and infilling with water would cause buoyancy and leaching problems. Drainage is therefore usually an important part of base excavation.

11 Concerns about bird strikes against turbine towers and blades suggest that good bird data are needed for Derrybrien, given that it will be one of the largest such windfarms in Europe but often suffers from low-visibility conditions.

Chapter 6
Impact interactions

GUIDANCE PROVIDED BY the European Commission (1999) emphasises that there is a legal requirement for an EIA to consider impacts which are of an indirect or cumulative nature or which occur as a result of interactions between factors. This applies to all aspects of an EIA but particularly to ecological issues. In the century or more since Ernst Haekel first coined the term ‘ecology’ and in the 70-odd years since Tansley (1935) first defined the concept of ‘ecosystem’, our appreciation of the complexity that underlies ecological systems has increased in equal measure with our increased knowledge.

Ecology certainly has direct linkages and impacts but, for any given ecosystem, there are many, many more links that are either indirect or cumulative or which result from a variety of interactions. It is reasonable to assume that an accurate view of the likely ecological impacts of a development can only be obtained by addressing these linkages and interactions. It is an issue that can (and should) be explored in some depth within an EIA. However, for the present exercise it is sufficient to provide some examples of ways in which such issues might be addressed.

6.1 *Indirect and Cumulative Impacts and Impact Interactions*

The European Commission has identified a range of approaches that can be adopted when considering indirect and cumulative impacts and impact interactions. They are provided for Member States as published guidance (European Commission 1999). The differing approaches are intended to be seen as complementary rather than as mutually exclusive options. The application of each is considered below.

6.1.1 *Expert opinion*

The authors of the present report are both internationally-recognised specialists in peatland ecology and conservation. Between them they have expertise in peatland biodiversity, peatland biogeography, peatland hydrology, peatland vegetation, blanket mire ecology, human impacts on peatland systems and international environmental legislation. For a fuller summary of their range of expertise and experience, the reader is directed to the biographies at the front of this report. For expert opinion about engineering and soils, Dr Trevor Orr from Trinity College Dublin has been engaged to produce a separate report. Full consultation has been maintained between the authors of these two reports in order to avoid one of the commoner problems of using expert opinion, as identified by the European Commission (1999) guidance:

> There may be a tendency for experts to complete their own chapters of an Environmental Statement in isolation from other experts. This runs against the nature of many cumulative and indirect impacts and impact interactions, because they often involve more than one scientific discipline or environmental receptor. Care should be taken to ensure that when producing the Environmental Statement, that effective communication is translated into the report.

6.1.2 *Consultation*

The authors consulted with a wide range of specialists and information sources during the production of this report. There has been communication with localities as geographically scattered as England, Ireland, Scotland, Wales, Switzerland, Denmark, New Zealand and the Falkland Islands. Bodies consulted include, in the UK, the Forestry Commission, Scottish Natural Heritage, English Nature and the Countryside Council for Wales; in Ireland, Dúchas, Ordnance Survey Ireland, Derrybrien Citizens' Action Group and the Irish Peatland Conservation Council; in Switzerland, the Institute for Forest, Snow and Landscape Research; in New Zealand, Landcare Research and, in the Falklands, the Falkland Islands Council.

This range of consultations provided valuable information about land instability, bog bursts and bog slides under a variety of conditions and in a variety of locations. It also helped clarify the relationship between these events and human impacts, opportunities for modelling the relationship between peat depths and landforms, the impact of forestry on peat soils and details of the widespread nature of the ecological impacts resulting from the Derrybrien bog slide.

6.1.3 *Checklists*

A simple checklist (as opposed to a weighted matrix – see below) can be produced for the Derrybrien case, listing the key elements in the case based on the range of environmental factors to be considered and the types of activities anticipated for the development. An example for Derrybrien is presented in table 6.1. It should be noted that development activities have been modified from those given in the original proposal (for example, road drainage is included) in order to give a fuller picture of the likely impacts based on a realistic view of the necessary on-site actions.

6.1.4 *Spatial analysis*

Examples of spatial analysis using GIS have already been provided in this report. For example the relationship between peat depth and forest cover was discussed in section 3.2.2 while the pattern of turbine sites in relation to existing and new roads was described in section 5.1.1. Further examples of spatial analysis will be found later, relating factors such as peat depth, forest cover, stream-courses, surface gradients, residential areas and impact boundaries.

This is one of the most powerful tools for identifying potential relationships between impacts and for then integrating these relationships to assess the combined result. A considerable amount of analysis could be undertaken using just the datasets listed above and, with the addition of a limited amount of additional information such as hen harrier sightings, brook lamprey distribution, sub-soil geology or catchment boundaries, a series of reasonably sophisticated environmental analyses could be undertaken. It is not the task of this report to undertake such analyses but rather to identify the fact that detailed spatial analyses are eminently possible and worthwhile. Section 10 provides an example of how they might be employed.

6.1.5 *Network and systems analysis*

Two forms of network analysis are presented in the European Commission (1999) guidance for indirect impacts and impact interactions. The first gives an example of a network chain that could have been written (albeit in a much simplified form) with Derrybrien in mind:

The second is more like an ecosystem map or a mind map. Such a diagram was generated before beginning this report to clarify potential linkages, indirect impacts and impact interactions. Fig 6.2 may appear rather crude or rough-and-ready but this is precisely the stage when such diagrams are at their most useful. Once something has been neatly typed and formatted, it becomes much less easy psychologically to make radical changes whereas something that has the look of a 'work in progress' positively invites more input. It performed a valuable service in identifying, at a very early stage in the process, linkages that might otherwise have been overlooked and the broad interconnected topics that should make up the present review.

6.1.6 *Matrices*

A matrix is a more refined version of a checklist in that it approaches the subject matter from a more complex perspective and generally includes some judgement values. The two illustrations of 'stepped matrices' provided in the European Commission (1999) guidance could readily be applied to the

Potential impact from key construction activities												
	Road Construction				Turbine bases				Turbine operation			
Environmental Resourse	**Drainage**	**Vehicle weight**	**Quarrying (blasting)**	**Laying ballast**	**Peat removal**	**Ponding & drainage**	**Vehicle weight**	**Quarrying (blasting)**	**Hard-standing**	**Roads***	**Drainage**	**Turbine blades**
Peat soil	Y		Y		Y			Y		Y	Y	
Peatland hydrology	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Peatland vegetation	Y			Y	Y	Y			Y		Y	
Carbon emissions	Y				Y	Y					Y	
Peat stability	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Water flows	Y		Y	Y	Y	Y		Y	Y	Y	Y	
Water quality	Y		Y	Y	Y	Y		Y	Y	Y	Y	
Hen harrier			Y					Y				Y
Brook lamprey	Y					Y					Y	
WFD reference waters**	Y		Y	Y	Y	Y		Y	Y	Y	Y	

** i.e. Road maintenance
** WFD = Water Framework Directive

Table 6.1: An example of the kind of checklist table that can be drawn up to consider the wind farm proposals at Derrybrien.

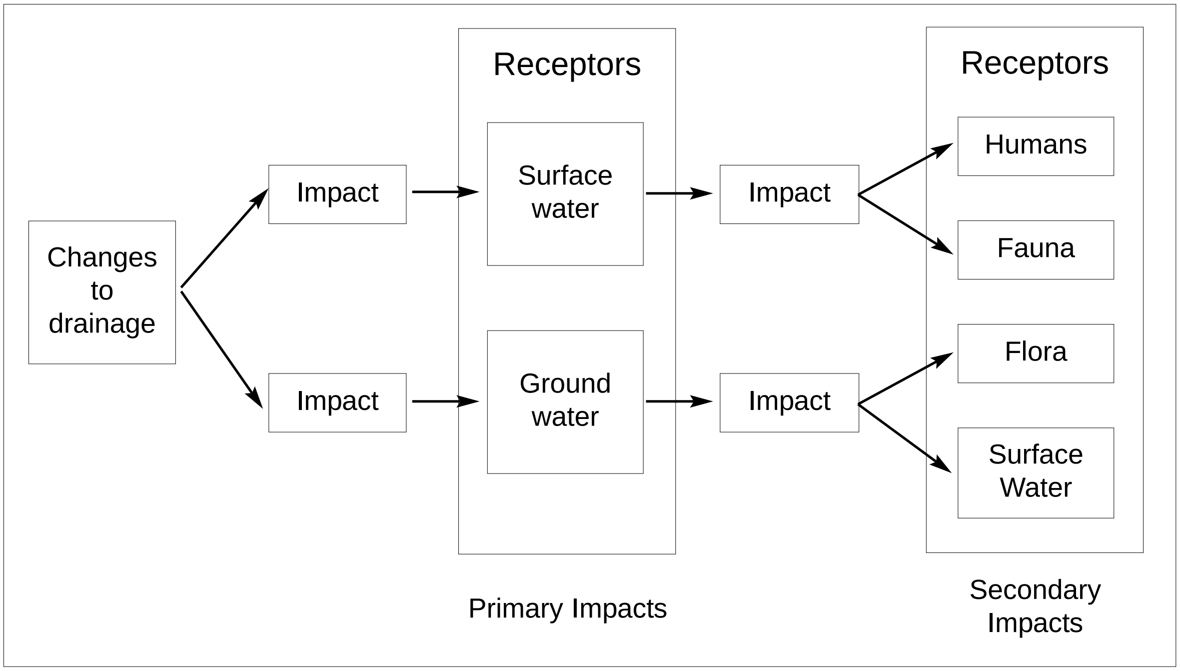


Figure 6.1: An example of a simple network analysis (taken from European Commission 1999).

Derrybrien case. In doing so, they would undoubtedly have the potential to add a significant level of detailed understanding to the EIA and highlight a number of critical issues.

6.1.7 *Carrying capacity or threshold analysis*

Analysis of carrying capacity is directed towards identification of the extent to which the ecosystem, or parts of it, are able to withstand given levels of impact. In the case of Derrybrien it might be argued that detailed survey of the hen harrier population could clarify both the size of the population (if any) and the type of territory used by the birds. This could be matched with evidence of any avoidance behaviour in relation to wind turbines to determine the overall pressure that the wind farm may place on the hen harrier population.

Alternatively (or rather, in addition), analysis of carrying capacity could be directed towards the engineering impacts of the wind farm on the mechanical properties of the peat soil to determine areas of low stability and thus with low potential impact thresholds. This is precisely what was carried out following the large bog burst of October 2003 in an effort to assess whether the situation was now stable and whether work could continue.

6.1.8 *Modelling*

Modelling can take many forms and at Derrybrien the developers undertook modelling of both noise and visual impact using spatial information consisting of a digital terrain model (DTM), the turbine locations and models of sound transfer. Assessments were made about the likely visual impact of the turbines from various localities together with quantitative figures for noise levels at various distances from the site. In cases like this, modelling involves the addition of a known behaviour or property of a feature and then relating it to a set of spatial information to make judgements about likely impacts.

Much of the early part of the present report is concerned with the properties and behaviour of peat and blanket peat systems. Towards the end of the report, such understanding is used in conjunction with a range of spatial data (e.g. peat depth, slope angle, presence of forestry) to make predictions about possible impacts resulting from wind farm activities.

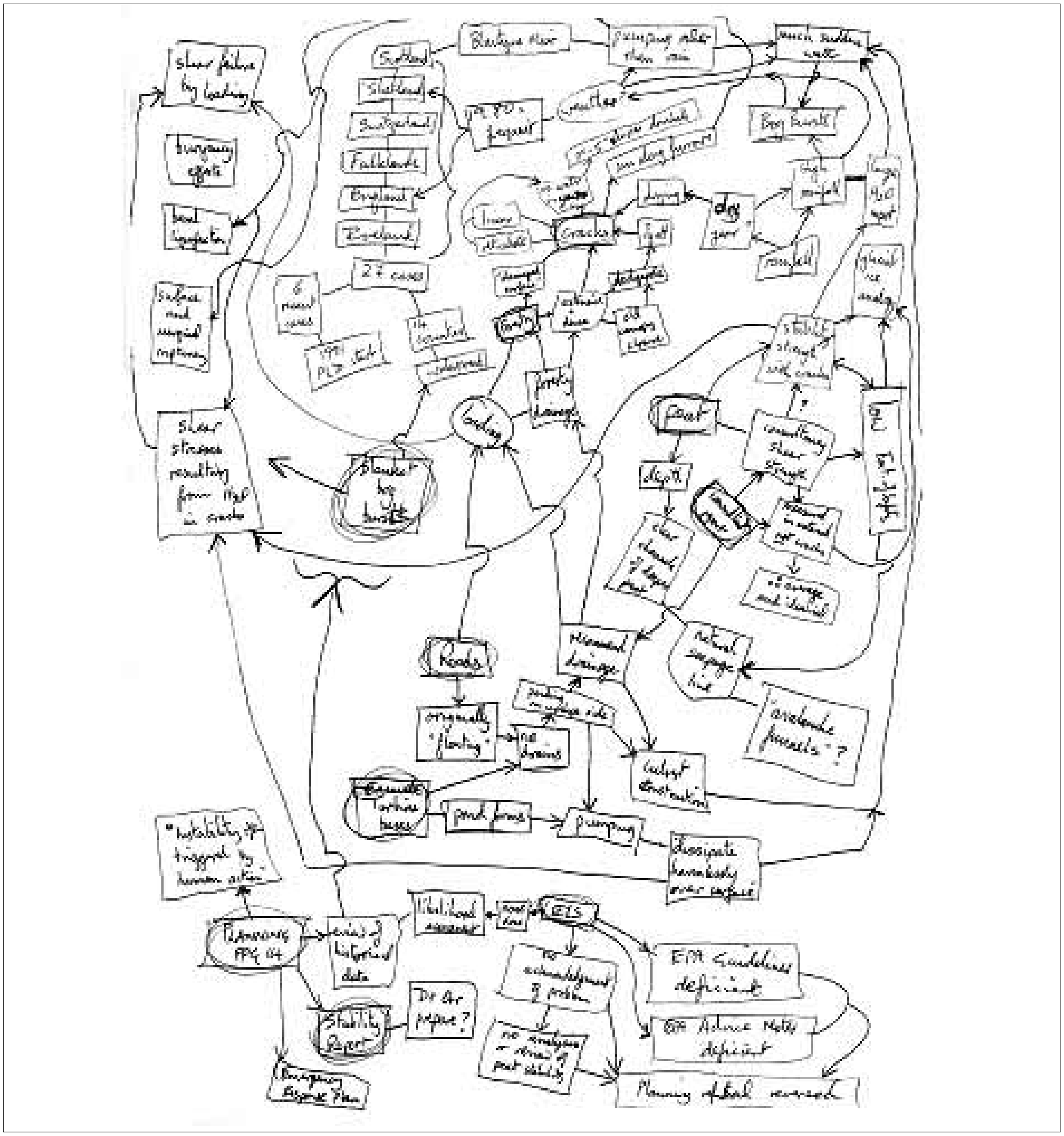


Figure 6.2: Initial matrix analysis ('mind map') of the Derrybrien incident produced as the first stage in preparing the present report. The informal appearance of the diagram invites further input and cross-referencing that might otherwise be constrained by a more formal printing of the diagram.

6.2 *Geographical boundary for the EIA – integrated assessment*

Reference has already been made (section 2.1) to the fact that determination of the geographic boundary for the EIA process in any given case must be an iterative process. Information is gathered; this reveals factors that were perhaps not originally anticipated; these factors involve potential impacts beyond the originally-defined impact boundary; the EIA boundary is re-drawn, embracing new areas; these areas contain factors that must now be considered; these may connect with other factors that involve additional areas; the boundary is re-drawn and so the process continues until a boundary has been defined that embraces all reasonable issues.

At the start of this report, the defined area for impact assessment was taken to be defined by the wind farm boundary. Much of what has been considered since indicates a clear need to enlarge this. Questions of peat stability are evidently a major issue, particularly given the identified disruption to the peat caused by forestry operations and the developers' acknowledged problems with drainage.

The definition of peatland ecosystem for conservation purposes involves identification of all the ground necessary to maintain the hydrological integrity of the system. In the case of blanket mire systems, this generally means that whole mire complexes (macrotopes, section 2.4.1) be identified as the conservation unit because each individual peat unit is linked to its neighbours by a hydrological connection within the peat – damage one unit and this may lead to knock-on effects in adjacent units. The issue is explored in some depth by Lindsay et al. (1988) in relation to the Flow Country of Caithness and Sutherland. By extension, this principle also applies to EIA of blanket mire systems because EU legislation requires that such connections are included within the assessment process.

The first iterative stage in considering the EIA boundary should therefore involve a review of the blanket mire complex at Cashlaundrumlahan to determine the extent of the hydrological connections resulting from the interconnected deep peat that dominates the site. Areas of deep peat outside the development boundary but contiguous with the peat on the summit should be considered for inclusion because they are directly linked through their hydrological connections.

It is possible to define an approximate boundary of the Cashlaundrumlahan summit blanket mire complex on this basis. However, this does not necessarily embrace issues relevant to conservation of hen harrier and other moorland birds nor does it address the very significant issues of stability raised in this report. It is clear that the loss of peat stability could have far-reaching consequences because the summit area forms the headwaters for several catchment systems. Problems on the mountain summit may be felt throughout parts of any or all of these catchments. It is, of course, possible to point to effects that are already evident at Derrybrien and draw conclusions about the potential area of impact should there be further instances of instability.

The area of the Cashlaundrumlahan summit mire macrotope has consequently been combined with the lines of watercourses that might be at similar risk to the type of impact already suffered by the Owendalulleegh River, Lough Cutra, possibly the Coole system and potentially even the Kinvarra outflow.[1] This revised boundary embraces the courses of the Boleyneendorrish River and its lower connections and the Duniry River as far as Lough Derg. Given the effect of the October 2003 bog slide on Lough Cutra, the northern part of Lough Derg is also included, at least as far south as the inflows of rivers near Gorteeny and Ballindery where their combined volumes would go some way to diluting any inputs from the Duniry River. This revised boundary can be seen in fig 6.3.

Although initially the EIA geographical limit was taken to be the area of the development and the immediate slopes of Cashlaundrumlahan, this boundary has changed substantially. The range of statutory environmental designations and features of conservation interest will now be considered in the context of this final boundary.

6.3 *Statutory designations and features of conservation value*

Having determined a boundary for the EIA, it is important to determine whether any statutory conservation sites lie within the boundary because these will impose some of the strongest constraints on development. In some cases, there will be no conflict and there may even be benefits to be gained for both the development and for the designated area. More often than not, however, a development gives rise to some form of potentially negative impact.

The listings and site descriptions given below are adapted from various official accounts to be found on the web-sites of Dúchas The Heritage Service, the Ramsar Convention and the Convention on Biological Diversity (see the web sites listed in the references).

6.3.1 *Habitats Directive – Special Areas for Conservation (SACs)*

A total of five SACs lie within or adjacent to the EIA boundary and have some potential, however small, to suffer impact from the development. These are Lough Cutra, Coole Garryland Complex, Lough Derg, Caherglassaun Turlough and the Galway Bay Complex. They are considered below.

1 Minutes of meeting, 4 November 2003, SHRB, Wildlife Service, GCC, ESB.

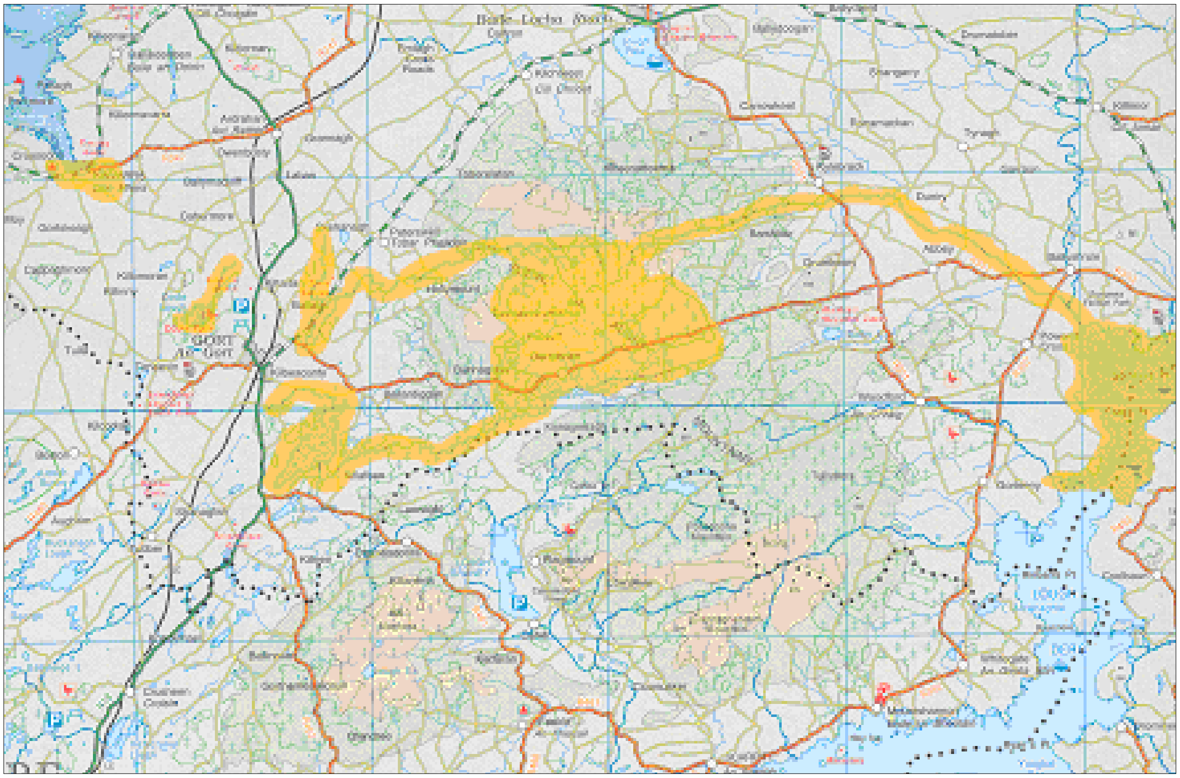


Figure 6.3: A map showing the total area (shaded orange) that might be affected by wind farm development on Cashlaundrumlahan and which should thus form part of the EIA process. Parts of the catchment drainage systems are connected through underground karst systems and are thus not easy to follow along their whole length.

Lough Cutra

This site is a candidate SAC on the basis of its Annex I alkaline fen and for the Annex II lesser horseshoe bat (*Rhinolophus hipposideros*). Both the Owendalulleagh River that feeds into Lough Cutra and the lake itself support a significant population of the brook lamprey (*Lampetra planeri*), another Annex II species.

Possible impacts on the alkaline fen depend largely on the main source of water for the fen. If this comes from alkaline springs, major changes to the main body of the lake water may not have a substantial effect but, if the alkaline water is largely derived from the lake itself, then a large influx of acidic and peat-laden water from a substantial bog-slide may give rise to significant changes in the fen vegetation.

Such changes would also undoubtedly markedly change the invertebrate population of the water body and they may have an effect on the lesser horseshoe bat (*Rhinlophus hipposideros*) population if significant feeding takes place over the lake.

Finally, the brook lamprey relies on two quite distinct habitats in its life-cycle (Kelly & King 2001). It requires clear water and a gravel bed for spawning then the larvae require soft organic-rich silt in which to bury themselves for the three to four years during which they mature to adults. The spawning grounds invariably lie upstream from the larval beds and, in the case of Lough Cutra, tend to be either towards the inflow of the Owendalulleagh River or in the river itself. They are therefore closer to the wind farm development than the silt beds of the larvae and would be seriously threatened by an influx of peat material washing from the site.

Coole Garryland Complex

This consists of a series of karstic turloughs, a type listed as a priority Annex I habitat. A characteristic feature of such turloughs is that they are fed by extremely clear alkaline waters, which in turn control the range of species associated with the turloughs.

An influx of acidic peat sediment (as a result of a bog-slide, for example), would substantially alter these conditions, leading to a decrease in the water's pH as well as potentially depositing quantities of highly acidic peat sediment onto the vegetation of the turlough, smothering the lower-growing species and causing harm to more sensitive plant tissues.

Lough Derg

Lough Derg is one of the largest bodies of freshwater in Ireland. The candidate SAC embraces only its northern shore, from the mouth of the Cappagh River in the north-west to just below Black Lough at the north-eastern shore, but it is the part of the lake into which the Duniry River flows.

It possesses two Annex I priority habitats that are associated with the water body itself, rather than habitats found in the associated hinterland – Cladium mariscus fen and alluvial woodland. In addition, Lough Derg supports important populations of lamprey species (listed under Annex II), including an apparently self-sustaining landlocked population of sea lamprey (Petromyzon marinus). This landlocked population, where the fish do not complete a seaward migration, is unique in an Irish context. The endangered fish species pollan (Coregonus autumnalis pollan) is also recorded in Lough Derg, one of only three sites in western Europe. Atlantic salmon (Salmo salar) is an Annex II species and spawns within the lake while otter (Lutra lutra) is known to use the lake and is protected by the Wildlife Act 1976 as well as being listed in the Irish Red Data Book.

As with Lough Cutra, an influx of peat sediment resulting from a bog slide could potentially impact significantly on the alkaline fen communities and the fish population of this part of the lake.

Caherglassaun Turlough

Caherglassaun is an Annex I turlough which, unusually, has a large permanent lake at its core. A bat roost associated with the site has both lesser horseshoe bat and Natterer's bat (Myotis nattereri), which is listed in the Irish Red Data Book. As with the Coole/Garryland Complex, this is likely to be adversely affected by an influx of acidic peat sediment while changes to the invertebrate fauna of the permanent lake may significantly alter the food supply for both bat species.

Galway Bay Complex

This site arguably has a tenuous connection to the EIA boundary because, as with the Coole/Garryland Complex and Caherglassaun Turlough, sections of the connection are underground within a karst cave system. It is therefore difficult to be sure of the extent to which a change in water quality in the upper reaches of directly-impacted river systems might be seen at the coastal outflow. At most, any effect is likely to be localised within such a large site but, if that part of the site contains particular features of interest, the effect may still be significant.

6.3.2 Birds Directive : Special Protection Areas (SPAs)

Four sites within the EIA boundary are listed as SPAs: Lough Cutra, the Coole/Garryland Complex, Lough Derg and the Galway Bay Complex.

In all four cases, the bird populations of interest comprise waterfowl species. Impacts on these would depend on changes in fish, aquatic invertebrates, or aquatic plant populations. All three are possible if the waters are affected by significant acidic peat sediment.

6.3.3 *Water Framework Directive*

The European Union (EU) Water Framework Directive (WFD) was introduced in October 2000. It focuses on the management of River Basin Districts and one of its stipulations is that European rivers and lakes[2] that are affected by human activity shall achieve good ecological status, or the highest level of ecological status that is possible given specifically justified human needs, before October 2015.

2 The minimum requirement is that rivers with catchment areas greater than 10 km^2 and lakes with areas greater than 0.5 km^2 shall be included but Member States may set lower thresholds if appropriate.

Ecological status is assessed on the basis of four biological quality elements, defined in terms of the taxonomic composition and abundance of phytoplankton, macrophytes and phytobenthos, benthic invertebrate fauna and fish, respectively. Good ecological status is achieved when the total effect of human pressures is insufficient to cause more than slight deviation in the biological quality elements from their natural condition.

In contrast to the simplicity of the objective, the prescribed mechanisms for compliance are complex. Reference standards are to be defined through establishment of typologies that characterise the natural biota (the condition of high ecological status) for individual biogeographical regions and river types, the latter being distinguished on the basis of physical attributes including altitude, geology and catchment area. Changes in the biological condition of each modified water body compared to the appropriate standard are then to be measured and classified on a scale of ecological status with divisions 'high', 'good', 'moderate', 'poor' and 'bad'. For watercourses falling into the latter three classes, all practical mitigation of physical and chemical impacts is to be applied, ideally restoring them to good ecological status, by the end of the Directive's implementation phase.

Article 4.1 requires, furthermore, that:

- Member States shall implement the necessary measures to prevent deterioration of the status of all bodies of surface water . . .
- Member States shall protect, enhance and restore all bodies of surface water . . . with the aim of achieving good surface water status at the latest 15 years after the date of entry into force of this Directive . . .

The Owendalulleagh River has been selected as a 'reference river' for Ireland under the Directive on the basis of its extremely high quality. There is thus a legal requirement to maintain this river in its (pre-October 2003) condition.

6.3.4 *The Ramsar Convention*

Two Ramsar sites are contained within, or adjoin, the EIA boundary: Coole Lough & Garryland Wood and Inner Galway Bay.

Coole Lough & Garryland Wood

This is described as the most important turlough complex in Ireland. It supports many rare species of flora and fauna and communities associated with the transition between turlough and woodland. Water levels fluctuate widely. The lakes are fringed by aquatic vegetation grading into grassland, tall grass and herb communities.

Inputs of water laden with acidic peat particles resulting from a bog slide could have a significant effect on this essentially alkaline system, as described above.

Inner Galway Bay

This area provides important habitat for marine life along Ireland's west coast. The site supports the richest seaweed flora on the Irish coast (500+ species) and 65 per cent of the Irish marine algal flora occur in the area. The site supports internationally and nationally important numbers of several waterbird species.

Though distant from the Cashlaundrumlahan drainage pattern and connected by a complex system of karstic drainage, the flow from the south face of Cashlaundrumlahan passes through Lough Cutra and eventually flows into Galway Bay. The impact potential is almost certainly very slight but it is not entirely absent.

In addition to the sites on the Ramsar List, a number of other Ramsar Convention Resolutions and Recommendations are relevant to the case:

- Resolution VI.5 – Inclusion of subterranean karst wetlands as a wetland type under the Ramsar Classification System

- Recommendation 6.1 – Conservation of peatlands
- Resolution VII.10 – Wetland Risk Assessment Framework
- Resolution VII.16 – The Ramsar Convention and impact assessment: strategic, environmental and social.

6.3.5 *Convention on Biological Diversity (CBD)*

The CBD provides a wide range of principles that now increasingly underpin national polices and legislation. Although there are no forms of protected site explicitly established through the CBD, the following Articles have relevance to the impact assessment process:

- Preamble
- Article 6 – General measures for conservation and sustainable use
- Article 7 – Identification and monitoring
- Article 8 – in-situ conservation
- Article 10 – Sustainable use of components of biological diversity
- Article 14 – Impact assessment and minimising adverse impacts.

The Preamble provides a fundamental concept of the CBD, namely the precautionary principle, which should be applied wherever appropriate:

> Noting also that where there is a threat of significant reduction or loss of biological diversity, lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimise such a threat.

Article 6 requires that the principles of the CBD apply through all policies, including planning.

Article 7 identifies the need for biodiversity action planning.

Article 8 identifies the objectives of biodiversity action planning which, in Ireland, has led to publication of the National Biodiversity Plan (Government of Ireland 2002). Within this NBP, there are at least two specific actions of relevance to wind farm development at Derrybrien:

> 47. Ireland will implement fully the CBD and relevant biodiversity-related conventions, etc. to which Ireland is already a Party (e.g. CBD, CITES, Ramsar, Bonn, Berne, Bats Agreement, International Convention for the Regulation of Whaling, World Heritage, Convention on Biological Diversity).
>
> 79. Maintain and expand the catchment-based national strategy for the protection and improvement of water quality in rivers and lakes by the establishment by Local Authorities of comprehensive projects for river basin management in relation to all inland and coastal waters and groundwaters. These projects will provide a major input, to be complemented by other appropriate measures by other public authorities, to the implementation of the EU Water Framework Directive and the achievement of at least ‘good status’ in relation to all waters.

Article 10 encourages support for activities that involve sustainable use of biological resources.

Article 14 requires that EIA is carried out as part of development control and in relation to this, at least three subsequent Decisions of the Conference of Parties have provided more detail about the necessary focus for such EIA:

- Decision V/6 – Ecosystem approach
- Decision V/18 – Impact assessment, liability and redress
- Decision VI/7 – Identification, monitoring, indicators and assessments.

6.3.6 *Scenic Amenity Areas*

The Slieve Aughty Mountains were classified within the Galway County Development Plan as being Category 2: High Scenic Amenity Areas (HSAAs). These scenic amenity areas are described as exhibiting a significant degree of visual and aesthetic interest. The development control objectives for such areas are:

> To restrict development which would detract from the amenity value of the zoned areas [indicated in the relevant maps] where such development would be visually inappropriate and out of character, or could not be satisfactorily blended into its surroundings (Galway County Council 1997).

This designation applies to the Slieve Aughty Mountains as a whole. It would therefore be important to consider the full scale of impacts likely to arise from the wind farm development and judge whether there is the potential for such impacts to detract from the amenity value of the designated areas. Given that the visual impact of a wind farm on a landscape is one of the most commonly-cited reasons for objection to such development, it might be expected that a detailed analysis of visual impacts and sighting lines would need to be undertaken to determine whether the development would be visually inappropriate.

Less obvious, however, is the potential for significant impacts on freshwater systems within the EIA study area, given the identified instability of the peat matrix at Cashlaundrumlahan. Release of significant amounts of peat into these watercourses and lakes may, for example, result in a reduced amenity value for fishing and other water-based activities.

Summary of Chapter 6

1. The assessment of possible impacts is based on a considerable range of expertise and experienced, drawn from a wide range of sources, including the UK, Switzerland, Denmark and the Falkland Islands.
2. Examples are given of various possible methods that can help in the assessment of indirect, cumulative and interactive impacts resulting from the development.
3. A geographical boundary for the EIA is defined, based on the various issues raised in the scoping and impact assessment process.
4. The EIA boundary contains or adjoins five SACs, four SPAs, two Ramsar Sites and a reference river for the Water Framework Directive.
5. The Convention on Biological Diversity (CBD) commits the Government of Ireland to the precautionary principle, as well as to biodiversity action planning that seeks to protect and improve water quality in rivers and lakes.
6. Galway County Council's Development Plan identifies the need to consider possible environmental impacts within the Slieve Aughty Mountains HSAA.

Chapter 7

EIA and the Derrybrien planning process

THE KEY STAGES IN CONDUCTING an EIA were discussed in section 1 and demonstrated for the Derrybrien development in sections 1 to 6. This chapter will examine how the EIA was actualy carried out by Saorgus Energy Ltd and what part this played in the planning process.

Two reports were produced – an Environmental Impact Statement (EIS) for the first planning application and an Environmental Assessment (EA) for the third. The reports are very similar, with large sections of identical text, and they are not worth dealing with separately – differences are highlighted as they arise.

> Note: In reviewing the reports, quotations from them are printed in a sans-serif font and indented (as here) to demarcate them from the commentary. The two reports taken together are refered to as 'the reports', the first alone is referred to as the EIS and the second alone as the EA.

7.1 *Project Preparation*

The Derrybrien project was not one development but three because three separate planning applications were made to Galway County Council (section 1.2). The first, for 23 turbines, and the second, also for 23 turbines, were submitted in December 1997 and form the eastern and western extremities of the development. Both were initially rejected because they did not include adequate site-location maps but were subsequently re-submitted – still as separate proposals – on 23 January 1998. The third application, which was for 25 turbines and was submitted on 2 October 2000, in-filled the space between the first two (fig. 5.1).

It is not clear whether the developers always anticipated the single large scheme that the development became or whether the three plots of land (and the finance) became available through fortunate circumstances. If the intention was always to expand from the first 23 turbines, as seems probable from the timescale of submission and the fact that the third proposal linked the first two into a single unit, there is a valid argument that the planning process should have identified whether there was such an intention at the outset and that the developers should have been asked to produce at least an outline proposal for the whole scheme at an early stage.

7.2 *Notification to Competent Authority*

There is no requirement in Irish legislation for a developer to notify the planning authority of an intention to submit a planning application (section 1.3). Nonetheless, the authorities cannot have been totally ignorant of how the scheme was emerging as one a single large development.

7.3 *Screening*

Given these observations, it seems strange that the screening process by the planning authority did not highlight, or at least identify, the high probability that the first two proposals were part of a larger scheme. Had it done so, the context in which planning decisions were taken would have been different and this might have had a bearing on the final outcome. As it is, there are anomalies in relation to the status under which the proposals were considered and the supporting documents provided. The screening process is designed to identify whether or not a proposal requires statutory EIA before it can be considered. The question is addressed in both reports.

7.3.1 *Mandatory EIA, 'salami-slicing' and the Planning Process*

> Planning and Environmental Policy, Statutory EA Requirements, Designations and Requirements
>
> In EPA Guidelines (1995), an EIS is not necessary for electrical generation projects of less than 300MW. This project clearly lies outside of these limits and an EIS is therefore not automatically required. However, Saorgus Energy has provided such a statement in the interests of public awareness of the low level of impact of this and similar wind energy projects.

Environmental Impact Statements were provided for the first of the three proposals and for the third. As discussed (section 1.4), there was no legal requirement to undertake EIA for the scale of wind farm development proposed at Derrybrien, either as individual proposals or as a single large development until the EU's Directive 97/11/EC was transposed into Irish law as Statutory Instrument No. 93/1999. The applications submitted in January 1998 were therefore correct in saying that there was no statutory requirement for EIA.

However, although it was submitted in October 2000, the Environmental Assessment for the application to construct the final 25 turbines also maintained that there is no legal requirement for EIA. This is wrong: S.I. No. 93/1999 came into force on 1 May 1999.

There is no reference in the Inspector's Report that finally awarded planning permission (on appeal – PL 07 122803, 25 October 2001) to this mistaken understanding about the EIA threshold although reference is made to the fact that supplementary environmental information had been requested.

The legal status of the EA produced for the final proposal is thus somewhat ambiguous and it remains the case that the second proposal was not supported by any explicit environmental statement at all and, except for a few rather generalised references in the EA for phase three, appears not to have been assessed at all.

This raises an important issue of planning procedure. Together, the three proposals represent, in the words of the developer, 'one of the largest wind farms in Europe'. It is difficult to reconcile good planning practice with such a substantial development not having been subject in its entirety to Environmental Impact Assesment or with parts of the development not having been subject to any form of assessment.

The European Commission's review of EIA implementation within Member States (European Commission 2003) identifies the tendency of developers to 'salami-slice' large developments by breaking them into several smaller proposals either to evade thresholds for mandatory EIA or to make the full impact of a large development appear much smaller by introducing it in stages.

The anomalous planning situation at Derrybrien would seem to be an example of the problems that result from not adequately controlling such 'salami slicing'.

7.3.2 EIA – objective assessment or public relations exercise?

Wathern (1988) describes EIA as 'a process for identifying the likely consequences, for the biogeophysical environment and for man's health and welfare, of implementing particular activities and for conveying this information at a stage when it can materially affect their decision, to those responsible for sanctioning the proposals'. The Essex Guide to Environmental Assessment (Essex Planning Officers' Association 1994) describes the primary purpose of an EIA with a clarity and robustness that leaves little room for misunderstanding. It must be:

> . . . an impartial objective assessment, not a best-case statement for the proposal – otherwise the integrity of the ES may be brought into question. Negative impacts should be given equal prominence with positive impacts and adverse impacts should not be disguised by euphemisms or platitudes.

The reports produced by Saorgus Energy have a very different objective – it is explicitly stated that there is no statutory requirement to produce either report (Saorgus Energy appears convinced that there was no requirement for it to produce an EIA for either application) but that the company chose to produce them in order to improve, 'public awareness of the low level of impacts of this and similar wind energy projects'.

A document produced with the explicit intention of promoting the low environmental impacts of a project is unlikely to be the same as an objectively assembled and tightly focused study that addresses the impacts of a particular project at the level of detail that might be expected from an EIA, especially one produced to a meet a statutory requirement.

Is, therefore, the 'Environmental Statement' produced by the developer in relation to Planning Application 00/4581 a public relations document or a formal submission under the terms of statutory EIA? The planning process did nothing to clarify this situation.

7.4 *Scoping*

A comprehensive scoping study should form the first (and in many ways the most important) stage of an EIA (Gilpin 1995, Weston 1997) because this determines what will be examined in terms of potential impacts (section 2.5). While an introductory paragraph (see below) within both of the reports can be regarded as a scoping statement, no evidence is provided to show that an integrated scoping exercise was carried out. At the very least, the first stage of scoping should involve a review of published scientific literature relevant to the site and the type of development proposed. Without it, assessment is undertaken in a vacuum: it is devoid of the experience of similar ventures elsewhere and in ignorance of the accumulated knowledge reflected in the literature. The lack of even a rudimentary literature review was a crucial omission from the reports.

> Structure of this Environmental Impact Statement
>
> This EIS has been structured according to guidelines published by the Environmental Protection Agency (1995). This document outlines both the subjects to be covered and the approach to be taken in dealing with them. These procedures have been followed in the preparation of this EIS. All likely impacts are considered in terms of:
>
> 1 Existing conditions
> 2 Potential or likely impacts
> 3 Proposals for mitigation of these impacts

As it says, this reflects the broad, general headings of the guidance provided by the EPA (1995) and, approached in the appropriate way, these can provide the key stages of an EIA with 'existing conditions' providing the opportunity for scoping, 'potential or likely impacts' covering the impact assessment phase and 'proposals for mitigation' being self-explanatory.

Unfortunately, the reports adopt a very literal interpretation of the stages and topics suggested by the guidelines. Each topic is taken as a discrete area of assessment in isolation from the others and is treated to a narrowly-focused 'background' review (essentially a highly constrained attempt at scoping for that particular topic) followed by an assessment of impacts and proposals for mitigation.

By making such a compartmentalised interpretation, the reports miss a key stage of scoping, which is the integration of impacts and effects *across* headings. The integration of indirect, cumulative and interactive impacts is an explicit part of EIA but it can only be achieved by bringing together the categories recommended by the EPA and using them as key components of a larger, integrated view of the development. Without this, an EIA cannot, as the saying goes, 'see the wood for the trees'. Unfortunately, the reports may see individual trees but there is no recognition that these trees can, and must, be considered as component parts of a larger system.

The brief scoping 'statement' is followed by a section not found in EPA guidlines whose purpose seems to be to promote the cause of the development rather than provide a dispassionate assessment of environmental pros and cons. It reflects an emphasis that is, yet again, inappropriate in an EIA.

<u>Site selection process</u>

Suitable characteristics of Derrybrien

The title is itself revealing – the focus is entirely on the 'suitability' of the site for wind farm development. There is nothing in EPA advice to encourage a site description based on 'suitability for wind farm development'. Such a description is inevitably biased towards factors tending to favour the development while minimising, or even omitting other, less favourable, factors that may nevertheless be significant. As noted above, this does not sit comfortably with a dispassionate and comprehensive attempt to describe the characteristics of a development site.

This emphasis on 'suitability' runs through much of the reports and gives rise to selective discussion about particular features in certain sections without reference to others. It is virtually impossible to obtain an overall picture of the site as a functioning whole. This gives rise to problems as the following extracts show:

> <u>Proximity to neighbours</u>
>
> Wind turbines need to be sited away from habitation. This is mainly because of the possibility of the turbines being audible at people's residences. The closest house is 2000 m from the nearest turbine and is shielded to a large extent by coniferous forestry . . .
>
> <u>Interference with other land uses</u>
>
> Forestry is at present the major land use in the area but changes in forestry practice mean that, when these trees are harvested, replanting will not occur due to low yields from forests planted on blanket bog. These trees are due to be harvested in the near future and therefore there will be no conflict with present land use.

These statements appear to contradict each another. On the one hand, the nearest neighbour is to be shielded from noise by extensive coniferous forestry while, on the other hand, there is no conflict with forestry because the plantations will soon be removed and not replaced. Again, there is a sense that positive aspects are emphasised without being balanced by potentially negative and conflicting aspects elsewhere. In short, there is little evidence of integrated thinking in either report – aspects are addressed in isolation in a way that favours the development.

7.5 *Impact assessment*

As noted, the bulk of the reports addresses environmental issues with a description of the existing environment, the expected impacts and, finally, the proposed mitigation measures. Within any single topic, there is some opportunity for scoping – but only in a limited way. The discussion of impacts is (with the exception of the visual impact and noise) constrained first by a lack of adequate information and second by the apparently limited understanding of ecological processes. As a result, the mitigation proposals are often inappropriate, impossible to comply with or just inadequate.

The compartmentalised approach is a major issue the problems of emphasis are illustrated by noting that 17 pages (26%) of the EIS and 11 pages (22%) of the EA are concerned with the visual impact of the wind farm while three pages (5%) of the EIS and four (8%) of the EA are devoted to noise impacts: the EIS devotes 32 per cent of its content to visual and noise impacts and the EA 29 per cent. This contrasts with the space devoted to habitat impacts (essentially confined to the section on flora) which amounts in total to only three per cent of the EIS and four of the EA.

Within an EIA, habitat can be addressed as a singular entity within the general review of flora and fauna. Alternatively, or additionally, it can be regarded as a complex entity arising from interactions between lithosphere, atmosphere, biosphere and hydrosphere and can be addressed in the light of impact interactions. What is not in doubt is that the habitat must be addressed at some stage because it generally represents an entity that is greater than the sum of its constituent parts.

Every habitat has unique properties that must be addressed if a true picture of possible impact is to be obtained. 'Ecological quality' should be measured by much more than just the presence or absence of particular plant or animal assemblages. However, the focus of ecological attention for both reports is directed almost entirely towards the two separate questions (with no attempt at integration) of whether any significant botanical interest remains on the site and whether particular bird species use it. This absence of an integrated habitat assessment is another key failure of the reports.

From this point on, this review of the reports follows the sequence and titles of their headings.

7.5.1 *Visual impact*

> <u>The existing environment</u>
>
> . . . These shale highlands occur through large parts of South Galway and Clare and are broad areas of gently rolling hills. There are few sharp [sic] or peaks or cliffs and poor drainage means that blanket bog is well developed . . .
>
> These hills are almost completely covered with blanket bog. In places this is several metres thick and is commonly harvested for turf. This bog gives the hills a bare and desolate aspect and contributes greatly to their character. Another factor is the relatively recent forestation of the blanket bogs. This has had a great effect on the landscape as the trees show great colour contrasts with the underlying bog. In addition, the planting of trees in blocks with abrupt boundaries and the monoculture nature of the plantations means that this effect is amplified . . .
>
> . . . The views from the site are very limited by both the very broad, almost flat nature of the hilltop and by the preponderance of forestry in the area.

It is clear that the developers recognise the presence of extensive blanket peat throughout the major part of the development area, that it is known to be at least two metres deep over most of the site and that there has been extensive afforestation on the peat.

The preponderance of blanket bog across this part of the Slieve Aughty Mountains is offered as an explanation for the open nature of the landscape. The forest blocks are described as providing sharp visual contrast with the blanket bog, particularly as these blocks have abrupt margins and consist of monocultures. It is therefore acknowledged that not only is forestry a feature of the site but that it reflects the typical practices of coniferous afforestation across deep blanket peat.

But there is no mention of the significance of the forestry for the condition and possible stability of these deep peat soils:

> <u>Measures to lessen adverse impacts</u>
>
> The visual impact of tracks and roadways will be slight. This is because the roads will be excavated in areas already cleared for drainage, because the site is surrounded by convex slopes and because most if not all new access tracks will be of the floating type, constructed on geotextile mats laid directly on the bog surface. These floating tracks will be used if the bog is more than 2m deep as is the case in almost all of this site.

7.5.2 *Other possible impacts on humans*

> <u>Use of access roads</u>
>
> The construction phase will involve the passage of equipment and materials for approximately six months. The operational phase thereafter will involve the weekly or monthly passage of a light van with the possibility of a truck or crane making very infrequent visits, perhaps once a year.
>
> During construction, access for heavy plant such as cranes and excavators will be required. Turbine components will also have to be transported to site by this route, necessitating the passage of some articulated trucks. The foundations for the turbines will require up to 345 [400][1] loads of readymix concrete in addition to other components such as reinforcing steel. The total number of truck loads is projected to be 443 [650] over the construction period of approximately 6 months. This heavy traffic would be spread over this construction time and would average approximately 3.5 [4.5] loads per day over this period. This traffic will peak when construction of foundations is at its maximum and will be correspondingly less than the average at other times during the six month construction period.

Despite acknowledging the depth of peat across the site and recognising the need for tracks that float on geotextile matting, no link is made either between the geo-mechanics of these roads and either the weight of machinery that will make use of them or the cumulative effect of frequent use. No

1 The numbers in square brackets [123] were presented in the EA, the others in the EIS.

comparison is made with the construction methods employed by the forest industry; no literature is cited concerning the load-bearing capacities of floating roads and neither report attempts to review the evidence of their soil stability, their load-bearing capacity or their long-term maintenance issues.

This report has pointed out key issues associated with floating roads (section 5.1) but it appears that no actual or even possible geophysical impact from road construction was anticipated by the authors of the reports because neither the one nor the other is described in either paper.

7.5.3 *Effects on ecological quality (flora)*

<u>Existing environment</u>

> The habitat throughout is upland blanket bog . . . On the site in question, most has been planted with commercial forestry. In the short term, at least, this has substantially degraded the ecological quality of these areas by the associated drainage and replacement of blanket bog species with coniferous species. Lodgepole pine or Shore Pine (*Pinus contorta*) is the principal tree planted, while Sitka Spruce (*Picea sitchensis*) is also common. The canopy cover can be quite dense, sometimes over 90%, with the canopy height of up to 40 ft. The understorey often shows little growth, with occasional moss and ferns. In more open areas amid the trees, Purple Moor Grass (*Molinia caerulea*) and Ling Heather (*Calluna vulgaris*) become quite common, indicating the blanket bog nature of the original habitat.
>
> . . . less than 5 of the total [is] reasonable quality blanket bog habitat. However, most has been disturbed by nearby forestry and associated drainage and this has resulted in a reduction of the ecological quality.
>
> Overall, the coniferous forestry which covers most of the site is of little botanical interest. The blanket bog plant species have mostly been destroyed and the integrity of the blanket bog itself has been badly affected by drainage channels.

This is further acknowledgement that the habitat over most of the site is upland blanket bog and further recognition that plantation forestry has substantially degraded it as a result of drainage which has badly affected 'the integrity of the blanket bog'. The general scarcity of continuous bog vegetation cover is also highlighted, with the ground surface beneath the trees in particular being described as largely devoid of vegetation.

As sections 4.2 and 5 suggest, these conditions should have triggered concern about a number of potential problems in such an environment.

The lack of a literature review has already been discussed but the most striking feature of this section is the lack of any reference to the literature about peat bogs in general and blanket bogs in particular. A few references about the birds of blanket bogs appear in the EA but neither report mentions any of the literature about the habitat that dominates the site.

The excuse cannot be made that there is no such literature. Peatlands are found on all the continents except Antarctica and, globally, are the most extensive and widespread terrestrial wetland: there is considerable literature about the peatland environment (section 3).[2] The dynamics of Irish bogs have been described for at least 300 years (King 1685). To find no reference to any of this in either report suggests that no serious attempt was made to assess the likely impacts of wind farm development on this habitat – yet it was precisely this habitat that was to suffer dramatic and spectacular collapse.

It is not necessary to emphasise the important part that the peatland habitat should have played within the assessment process as the habitat has amply demonstrated the point.

<u>The predicted impacts of the proposed development</u>

As discussed in section 3, a blanket bog consists of a layer of living vegetation, an associated peat deposit and a characteristic hydrology – the three are inextricably linked (Ivanov 1981, Ingram 1983, Lindsay 1995, Charman 2002). Nowhere in either report is this composite view of the habitat adopted, rendering it impossible to make an adequate assessment of potential impact.

Various statements in the reports do identify potentially critical issues for the peatland habitat,

2 See www.ramsar.org.

particularly the impact of forestry, but they fail to recognise their significance. It is even claimed that the use of afforested land for turbine construction would be a positive environmental gain although it should be evident (section 3.2) that forestry may well be a key factor in rendering such areas unsuitable for development.

7.5.4 *The critical nature of hydrology*

> The major botanical impact of the siting of a wind farm in this area is the loss of habitat in the vicinity of the turbines. Owing to the already highly disturbed nature of the forested area, this ecological impact would not be significant.

Again, the reports consider the site in a compartmentalised rather than an integrated way. Excavations for 71 turbine towers do certainly represent wholesale vegetation destruction (and catotelm removal) but it is not the only, or even the major, likely impact on the bog ecosystem. The excavations, the long-term effects of the forestry on the peat and the impact of the roads should each be considered in terms of their particular effects on ecology and hydrology. The cumulative effect of these should then be considered on the ecosystem as a whole. It is important to recognise that intimate hydrological linkages maintain a functioning habitat complex that extends beyond the boundary of the proposal.

> . . . The planting of forestry on site has already allowed significant drainage and this would not be significantly increased by the construction of a wind farm. Compared to current forestry, the construction of a wind farm would involve minimal impacts on botanical quality and with time the absence of forestry will allow the regeneration of a representative blanket bog flora.

While this recognises that the peatland system has been affected by long-established forest plantations, no consideration is given to the detailed nature of the changes or their implications. Once again, there is no evidence of a review of the literature describing the long-term effects of forestry on peat and no systematic attempt to establish the condition of the peat soils beneath the plantations. There is no recognition that the wind farm would compound the effect of afforestation and give rise to a cumulative impact. Instead, the implication is that, in some way, it replaces the impact of the forestry with something more environmentally benign. This is not so (section 4.2).

It is one of the ironies of this case that the site was chosen in part because it was assumed that afforested blanket bog would have little wildlife interest and that the ecological impact of the development would be limited. It is true that removal of forest from areas of deep peat can provide opportunities for peatland restoration – major EU LIFE projects have in recent years assisted in achieving just this in parts of the UK and Ireland – but there is a world of difference between removing trees and blocking drainage system to encourage Sphagnum-rich communities to re-develop and removing trees to introduce industrial-scale development with significant additional construction and drainage works. In the first case, removal is associated with a reversion to more natural conditions, in the second, the removal of trees is a precursor to a new pattern of disruption applied over an existing pattern of disturbance.

> The construction of this project would also impact on the quality of the blanket bog plants species present if it resulted in significantly increased drainage in the area. However, two features of wind farm construction have a bearing on this possibility:
>
> a) If peat is more than 2m deep it is more economical to construct a floating road over the surface of the bog than it is to excavate the peat down to bedrock. Floating roads tend to subside in time to the level of the surrounding peat. This means that no channels then exist to enhance the local drainage. Probing the peat at Derrybrien has revealed that this is economically the best option for new roads on site. Other roads will be located by pre-existing drains. Therefore road construction will not result in significantly enhanced drainage and consequent degradation of the ecological quality of the site.

Although the motivation for creating floating roads is clearly financial rather than ecological, it is presented as a solution to an acknowledged environmental problem. As discussed (section 2.3), peat can be regarded for many purposes as a liquid – which is why developers talk of 'floating' roads. It was made clear (section 5.1) that such roads (and railway lines) do not merely sink to the level of the surrounding peat but continue sinking for the simple reason that, for a floating road to be maintained in a functioning state, it requires as much drainage as an excavated road.

Discussion with site representatives made it clear that managers were already talking of the need for comprehensive drainage of the road network despite assurances in the reports that no additional drainage would be required. The developers now recognise that it is simply not realistic to propose undrained floating roads. The original assertion that 'road construction will not result in significantly enhanced drainage and consequent degradation of the ecological quality of the site' reveals a lack of understanding of peatland eco-hydrology and the necessary on-site practice.

Nor is there any reference to the extensive literature of road construction. There is also a significant body of literature on the physical properties of peat and its behaviour under differing forms of stress but none of it is cited in the reports either. Given what was to happen, this is a major failing. It is unfortunate that, while both reports acknowledge that 'the integrity of the blanket bog itself has been badly affected by drainage channels', no connection is made between this and a possible instability of the peat. The evidence was there but the reports failed to recognise its significance whereas even the briefest review of the published literature would have alerted the developers to potentially significant issues on the basis of what they themselves had already recorded.

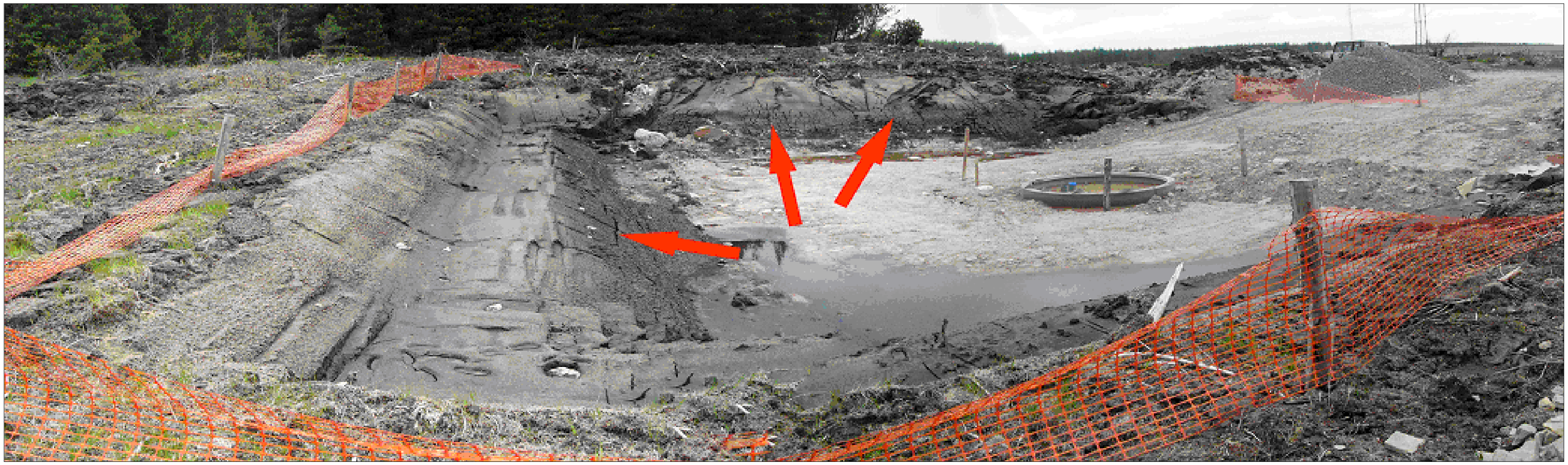
> b) Construction of turbine bases consists essentially of excavating a hole of approximately 15x15m down to competent bedrock and constructing the turbine base within this . . . The process does not result in long-term drainage of the surrounding peat.

Although acknowledging that habitat will be lost when turbine bases are constructed, the reports justify this by stating that it has already been damaged by forestry activities. Forestry has essentially a surface impact with much of the catotelm remaining undisturbed (section 3.2.1). With a turbine excavation, the entire acrotelm and catotelm are removed. If the peat is three metres deep, this will have taken around 3,000 years to accumulate and, as explained (section 5.2.2), it cannot be restored just by dumping new peat into the hole. Compared to forestry plantation, this is long-term damage.

Clearly of more concern is the possibility that the excavations might be thought to cause drainage from the surrounding peat and assurances are given that this will not happen – but they are not accompanied by any evidence. Given the issues associated with turbine-base construction, it is worth examining the reports more closely on this.

Their argument focuses on the relatively small footprint of the turbine bases and suggests that, although an area will suffer absolute loss, it only involves a hole 15 metres x 15 metres (i.e. 225 m^2) with the volume of material to be removed described as 175 m^3 of bedrock and overlying peat (equal to a concrete pad 15 metre square and approximately 0.8 metres thick. In reality, these figures give litle indication of the area required: they do not allow for the need for hard-standing for construction and maintenance machinery and they imply that a vertical-sided hole will be excavated whereas the side must be dug at or about the normal angle of repose for potentially unstable material. If the excavation is in deep peat, the margins of the excavation extend significantly further outwards (fig 5.3). In short, the total area of direct impact necessary for a securely installed turbine base with maintenance access is substantially larger is discussed in the reports. Plate 7.1 reveals the full extent of the impact of turbine-base.

Material removed from the excavations for the turbine bases (arisings) was reportedly heaped onto adjoining bog surface even when the excavation lay on a slope. In some cases, the peat mounds had failed and collapsed downslope (e.g. T34) while, in others, the underlying peat was showing signs of failure in the form of cracking, slumping or swelling. In the light of these, construction practices were altered and the arisings were spread out into much thinner layers across the surrounding bog surface, creating large areas of bare peat. As a result, the area of bog impacted by turbine installation is increased many times and these areas of sloping ground are now predisposed to erosion (section 4.1)



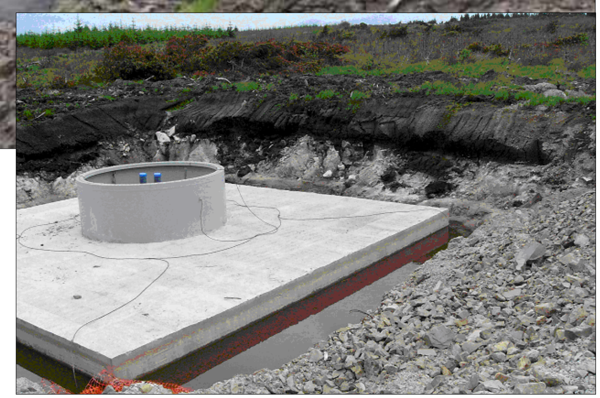


Plate 7.1. Top: T67, showing the base-can, the overburden burying its plinth and the exposed peat faces on the excavation sides. The area of peat removal is clearly much greater than the 15 metres x 15 metres claimed. Cracks in the catotelm peat are highlighted by arrows.

Above: T34. The excavation is the pale surface on the right surrounded by orange netting. The excavation area is slightly smaller than that for T67. The grey material spreading down to the forestry in the distance is peat that had been excavated and piled up on the bog surface. It had subsequently either collapsed and flowed or had been deliberately spread to avoid further possibilities of instability, depending on who was describing it.

Right: The foundation for T23 showing the concrete pad and steel base can before the addition of hardcore overburden. Sited in an area of shallow peat, the top of the pad lies below the peat-mineral interface.

because the vegetation has been smothered with little left to bind the loose matrix of the surface peat together. The substantial additional area directly affected by the need to do something with the material is illustrated in plate 7.1.

While this was all very largely predictable, at least in principle if not in total extent, the picture does not give a sense of the extent of semi-direct impacts if the extensive areas of bare peat were to initiate an erosion complex.

Not only is the area directly impacted by the excavations much larger than the reports suggest, there is also an issue of indirect impacts resulting from drainage – despite the statement that the ‘process does not result in long-term drainage of the surrounding peat’.

Under ‘Effects on water’ below, the reports recognise that turbine bases will fill with water and it is proposed that this be dealt with either by pumping it out or by displacing it with a backfill of hardcore and concrete. If it is pumped out, then the exposed peat faces will dry out – at several of the turbine excavations where pumping or drainage has been used, the resulting wall of catotelm peat has already become severely disrupted, is riven with cracks and is clearly undergoing oxidative change (plate 7.1).

The alternative solution, backfilling the excavation with hard core, is also inadequate as the picture shows. This backfill provides weight for the turbine base and hard-standing for machinery but it does not seem to be necessary to fill the excavation to the level of the cut peat faces.

Backfill, excavations on slopes and peat drainage have already been discussed (section 5.2.2) – the evidence of on-site practice confirms that the excavations will result in long-term drainage of the peat.

Not only do the approaches proposed for water management around turbine bases conflict with the practice at other (non-peat) wind farms, where adequate drainage is considered paramount to maintaining the functionality of the bases (sections 5.2.3 and 5.2.4) but the on-site practices are very different from their descriptions in the reports. Not only is it evident that substantial drainage has already been created to maintain a low water table in the excavations (plate 7.2) but geotechnical consultants have recommended that permanent drainage needs to be installed at all the excavations. This is being implemented through a series of ditches and culverts linked to a network of site drains. The claim that ‘the process does not result in long-term drainage of the surrounding peat’ is supported neither by any of the principles of peatland hydrology nor by evidence of on-site practice.

> <u>Measures to lessen impacts</u>
>
> Ecological impacts will be minimised by siting turbines predominantly in areas currently forested. Construction of roads will be carried out so as to minimise damage to undisturbed blanket bog habitat of which there is little in the site itself.

Plate 7.2: A drain dug to release water from the base of turbine T2. Note the rock reinforcement required to stabilise the sides of the excavation.

Blanket peat has a long history of instability, particularly when disrupted by human activity (section 5). Ironically, in an effort to reduce damage to upland blanket bog habitat, the development has been sited in an area where the bog is already highly disrupted and potentially unstable as a result of long-established forestry activities. It is, of course, correct that the reports should be concerned about, and propose ways of preventing, harm to undamaged blanket bog. However, just as with the administration of a dangerous medicine, if a proposal to minimise environmental impact poses its own significant risks, these should be acknowledged, measured, discussed and minimised. The adoption of solutions in a state of ignorance without following rigorous control procedures is likely to do more harm than good. Neither report acknowledges that the proposed 'measures to lessen impacts' pose any problems or dangers of their own.

7.5.5 *Effects on ecological quality (birds and other fauna)*

> Existing environment
>
> The bird species noted on the site visit include Meadow Pipet [sic], Skylark and Snipe. These are common on bogs and wetlands. Other species possibly frequenting the site include Merlin, Hen Harrier, Woodcock and Red Grouse. Merlin habituate open moorland and can nest in conifer plantations. Hen Harrier are found in similar habitats which have young forestry plantations. Woodcock can be found in forestry plantations and are not uncommon throughout country. Red Grouse, although currently scarce in the locality, can be found in open moorland with good Ling Heather growth.

It seems that assessment of the fauna of Derrybrien was based on a single site visit. Even if the wording is misleading and the evidence is based on more than one visit, it is of little value because no information is provided about the timing and duration of the visit(s) – i.e. dawn to dusk, morning, afternoon or some other period – or of the season in which the visit(s) took place, how many people were involved or what survey method was used – e.g. casual observation, timed transect, distance transect, fixed-point observations or repeated fixed-point counts. If more than one person was involved, how were the counts co-ordinated to avoid double counting? No numeric data are presented in either report, leaving the question open as to whether any counts were undertaken. Again, the reports present no data of possible relevance from the literature. The species list is most notable for its brevity: had the survey covered a full year, or even focused systematically on breeding and migration seasons only, it would surely have been substantially longer.

> One major limiting factor in the number of bird species found in the area is the extent of coniferous forestry plantation. This is such that the amount of open moorland is relatively small. The moorland is needed for hunting and food supply, while the forestry is mainly used for cover and nesting. Therefore, a dearth of open blanket bog would restrict the number of species frequenting the site.

The important question is whether there is, as implied, a 'dearth of open blanket bog'. If only the wind farm site is considered, then only a relatively small proportion of open blanket bog habitat still survives. However, even within the site, it is connected in a variety of directions with more extensive areas to the east, south west and north west. The point is made in the reports that a mosaic of habitats – forestry of various ages mixed with areas of open moorland – is required for successful feeding and nesting. No evidence is presented about the ratio of open ground to forestry that would either favour or discourage species such as hen harrier or merlin. It is implied that there is insufficient moorland for such species but no data are presented to support the implication.

It is worth noting that the first breeding survey of hen harriers in Ireland, carried out during 1998-2000, identified that a high proportion of the 102 hen harrier pairs recorded were found in young second-rotation conifer plantations (Norriss et al. 2002) whilst adult densities increase compared to open moorland in forests up to 10 years old. Following fire damage in the Derrybrien forest some years ago, a significant proportion of the forest on the southern slopes of Cashlaundrumlahan is now dominated by young plantations established after the fire (plate 3.3).

The survey by Norriss et al, undertaken between 1998-2000, raises another important planning issue. Its published results indicate that the Slieve Aughty Mountains represent the second most populated area for hen harriers in the country, with 15 to 23 pairs from a national population of 104 to 131 pairs. Awarding consent for the final 25 turbines on appeal, it appears that An Bord Pleanála did not request information from Norris's team about the survey (well-publicised through Dúchas, for example) but concluded instead that there were no data for the Slieve Aughty Mountains. The consent was subject to the developers undertaking a hen harrier survey concurrently with the development. Had An Bord Pleanála asked for summary results when considering the appeal, it is quite likely that at least provisional findings could have been supplied. The status of the hen harrier in the area would have been seen to be higher than the planning decision suggests.

It is difficult to reconcile good planning practice with the failure to embrace readily available information and even less so with the imposition of a planning condition that, in effect, postpones assessment of a potential impact until after the development. Such post-development assessment either gives a false impression of the impact because it occurred before the study begins or demonstrates impact when it may be too late to undo the harm identified.

To date, no detailed survey of Cashlaundrumlahan has been carried out for hen harriers though they are certainly present – a male was seen during our field visit. Furthermore, Coillte has established a Biodiversity Action Plan for the hen harrier under which forests will be managed to benefit the species (Coillte newsletter, www.coillte.ie). Harrier-friendly management of plantations seems to be feasible whether or not a wind farm is constructed.

All these factors raise questions, first about the suggestion that hen harriers are not significant components of the Derrybrien avifauna and, second, whether it is necessary to build a wind farm to create harrier-friendly conditions on the site. Would the biodiversity programmes now being established by Coillte have been better for hen harriers than the development of a wind farm, especially given concerns identified (section 6.3) about bird strike in poor visibility?

> <u>The predicted impacts of the proposed project</u>
>
> The impact of a wind farm on fauna present would not be major. The only species positively noted on site were Meadow Pipet [sic], Skylark, Snipe and Sika Deer. These species are quite robust and able to withstand some disturbance. With respect to other birds and mammals possibly present, the extent of coniferous forestry and relative dearth of good blanket bog habitat in the vicinity, would serve to restrict the numbers and variety of fauna present.
>
> <u>Measures to lessen impacts</u>
>
> If the wind turbines replaced some of the forestry, this may be in fact have a positive effect on the fauna present by increasing the diversity of habitats available and by an eventual improvement in the blanket bog habitat.

As research is only now being undertaken into the impacts of wind turbines on hen harriers in Ireland, it seems premature to state unambiguously that their impact on birds would not be significant. It would have been more correct to say that research was required. Notwithstanding the reports citing Briggs (1996), the RSPB's latest advice about wind farms and birds sets out guidance for developers wishing to be 'bird friendly'. The issues raised by the RSPB do not appear to have been considered in any depth by the reports.

7.5.6 *Effects on archaeological remains*

> <u>The existing environment</u>
>
> However, the coniferous plantation prevent archaeological investigation because the trees are planted close together and because the surface of the bog has been badly damaged in the process of forestation.

Here again is recognition that the bog surface is highly disrupted and has lost its structural integrity yet the implications again go unremarked and unrecognised.

7.5.7 *Effects on rocks and soil*

> The existing environment
>
> Derrybrien is underlain by shales and sandstones of Upper Coniferous age. This bedrock is covered by blanket bog of up to 6 metres thick. There are no significant amounts of mineral soils present in the area. The peat cover is largely intact under the trees.

This section contains nothing about the behaviour and characteristics of and the impacts on the major, or indeed any, soil type found on the site. In the absence of a section describing impacts on the habitat, this would have been an appropriate place to discuss the possible behaviour of the peat in relation to the proposals. It represents the major component of the development in terms of where direct impacts will be felt – excavation of turbine bases, floating of roads and dumping of arisings, etc. Wherever there is an effect on the ground, peat is involved yet the reports devote only two brief sentences to the nature of the peat.

The guidance provided by the Essex Planning Officers' Association (1994) on the topic says:

> [Soil investigations] can be a fundamental aspect of an ES, since soil affects agriculture, water movement and land drainage, vegetation growth, ease and time frame for traffic movement over land . . . excavation . . . landfill and pipeline proposals.

It is also worth noting that An Bord Pleanála's 2004 assessment on appeal of PL.12.205751 concerning wind farm development in County Leitrim (the proposal was rejected) identifies the need for detailed geotechnical survey of that blanket bog area:

> A detailed geotechnical survey does not yet appear to have been undertaken . . . The applicant has not demonstrated that a bogslide would be unlikely to occur.

The legislative requirements for EIA did not change between 1999 and 2004 yet An Bord Pleanála made no request for a survey of Derrybrien even though it expects detailed assessments elsewhere.

As early as 2001, the difficulty of working with machinery at Derrybrien was highlighted by a consultant archaeologist appointed to the development as a condition of planning consent. His report (Wiggins 2001) highlighted that only eight of the 23 turbine sites in the eastern part of the site could be investigated using excavating machinery because 'the jelly-like movement of the ground under the weight of the machine rendered further digging unsafe'. One might have expected that such obviously unstable ground would not only have been identified in the early stages of assessment but would have led to a clear demand for stability analysis as part of the planning process. Neither occurred.

As well as issues of geotechnical stability, another topic not adequately addressed by the reports was the quarries or 'borrow pits' from which aggregate would be obtained for backfill of excavations or to surface the roadways. There is no mention of the use of explosives in the quarrying process. The shockwave from these can fracture the rock beneath the peat even at a distance from the quarry and can lead to creation of new routes for seepage at the peat/rock interface, which is a possible source of instability in blanket bog (section 5.2).

Blasting can also disrupt the pattern of natural peat-pipes – natural underground tubes formed in the peat, often close to the mineral base and themselves apparently responsible for peat-slope failures. It is also likely to have an impact on birdlife but this was not mentioned in the review of impacts on fauna. These are serious omissions.

> The predicted impacts of the proposed project
>
> The only impacts on the soil and bedrock of the site will be in the construction stage. The foundations for each turbine will entail excavation of approximately 175 cubic metres of material comprising bedrock and overlying peat.

Not surprisingly, as there is no mention within the scoping paragraphs, no observations are provided about the potential impact of using explosives for quarrying nor is there recognition of the issues raised earlier concerning the excavation of the turbine bases, the pressure of floating roads, the need for drains, or the disruption of the hydrology by upslope ponding and downslope drying.

Measures to lessen adverse impacts

Few specific measures are proposed concerning impacts on the soils of the site. The one proposal for the peat is that it will be used for turf production, thereby ensuring that 'unsightly heaps of rubble do not have an adverse effect on the appearance of the site'. The extent to which reality contradicts this assurance can be seen in plate 7.1.

7.5.8 *Effects on water*

The existing environment

The surface drainage patterns at Derrybrien are largely natural despite drainage works associated with forestry. Apart from the acidifying effects of conifer leaf litter, ground and surface water are likely to be of high quality at Derrybrien. The high altitude location and a lack of development locally makes the likelihood of contamination of ground water from domestic, agricultural or industrial sources very unlikely.

Here, again, there is a chance to examine issues of peatland hydrology – drying, cracking, slumping, ponding – but these are not mentioned even though peatland erosion can give rise to substantial changes in water quality.

It was also an opportunity to consider wider questions relating to the geographical scope of the EIA because Cashlaundrumlahan forms the watershed summit for several river catchment systems. Impacts in the headwaters of these systems may have significant implications for conditions further downstream. It would have been reasonable to expect some acknowledgement of the watershed/catchment concept and its potential implications.

In addition, and clearly resulting from the lack of any proper scoping exercise, no review is provided of the potential for impact on a number of freshwater statutory conservation sites or sites of high conservation value. Had the literature concerning peatland stability been reviewed, it would have been obvious that there was a possibility of impacts to freshwater systems and that the potential effects of these impacts would need to be considered even if they were limited to increased sediment loading resulting directly from peatland drainage and erosion.

There are several SACs and SPAs and populations of several more Habitats Directive Annex I or Annex II species within the potential impact catchment (section 7.3). The SPA and Ramsar sites have been in place for some years and could have been so identified and SAC designation was ongoing during the planning phases of this development. Although the list of Habitats Directive sites for lamprey (all three recorded species are listed under Annex II of the Directive) was not identified until 2001 (Kelly & King 2001), the possibility that Lough Cutra, with its strong population of brook lamprey (Lampetra planeri), might well emerge as a candidate site was not identified.

The lower section of the Owendalulleegh River has been recognised as a reference site for high quality waters for the purposes of the Water Framework Directive, which came into force in December 2000. Some reference to the implications of this Directive could have been expected in the Environmental Assessment that accompanied the planning application submitted in October 2000, given that full implementation of the Directive would be completed within the lifetime of the development.

The potential impacts of the proposed project

The main potential impact to water from this project is during the construction phase if run-off from earth works brings large amounts of suspended solid matter into local streams. This risk is low as construction methods will not involve the large-scale movement of peat, soil or rock.

The construction of floating roads (see section on ecology above) means that the potential for excessive drainage and erosion along roads excavated to bedrock is eliminated. The excavation of turbine bases will result in water gathering in the resulting hole. This will be pumped out or displaced as the hole is back-filled with hardcore and concrete. This relatively small volume of water will be spread on the surface of the bog where it will be dissipated harmlessly.

After construction, the operation of the wind farm will have no significant effect on the site's water

> quality. The potential for spillage of turbine lubricants or vehicle fuel is low.

While the first sentence in this extract does make one accurate prediction of possible impacts, the second has, of course, been shown to be entirely incorrect. While there is a recognition that large-scale movement of peat is an issue, it is perceived only as physical transport of peat by construction machinery. No evidence is provided to demonstrate that the developer had investigated other forms, or causes, of peat movement or even of increases in sedimentation caused by construction activity.

Ponding associated with floating roads have been addressed (section 5.1) but the developers also identify that ponding may occur during the excavation of turbine bases. The hydrological and drainage issues associated with these excavations have also been discussed (section 5.2) but the explanation in the reports of how this water would be dealt with provides a revealing insight into the level of understanding that underpins them.

It is suggested that the water will either be displaced by infill or be pumped out. Any pumped water would then be 'spread on the surface of the bog where it will be dissipated harmlessly'.

Given the condition of the bog and observations about the dangers of pumping (section 6.1.5), it is difficult to think of a more dangerous proposal for this water. Such drainage cannot simply be achieved by 'over-pumping' the water onto the bog surface because concentrated discharge of water is one of the factors that triggers erosion and/or failure of the peat.

The other proposed solution is backfill, which was considered at some length (section 5.2.2). It has not been addressed by the developer; it is presented merely as the alternative solution but with no critical review of the implications in terms of the volumes involved, the need to obtain such quantities, the possible need for drainage or the potential for buoyancy effects if the excavation is not drained.

> <u>Measures to lessen adverse impacts</u>
>
> Earth-moving contractors will be required to ensure that their methods do not allow excessive soil run-off during the construction phase in the vicinity of streams (less than 50 metres). This may require temporarily blocking drains and watercourses feeding the stream so as to collect run off.

Having proposed pumping onto the peat as a solution to ponding within excavations, the mitigation measures for drainage of the site as a whole propose the ponding of drains and watercourses from time to time during construction to prevent excessive sediment release. This could cause significant volumes of water to be retained in drains followed by the release of the water on removal of temporary dams. Such sudden flows of water are just as likely to cause erosion as the pumping but the possible consequences are not considered.

7.5.9 *Effects on air and climate*

> <u>The predicted impacts of the proposed project</u>
>
> The project would also have a positive effect of global and local climate change. CO_2 and other greenhouse gas emissions emanating from fossil fuel power stations will tend to be reduced thereby lessening the effects of these gases on the enhanced greenhouse effect. There will be no impacts on local micro-climate.

The later of the two reports expands on this topic by presenting detailed information about the potential savings of greenhouse gas emissions:

> The following table shows the emissions saved by the Kilronan Wind Farm nearby during the year 1998. [Table of data provided.] The capacity of the Kilronan Wind Farm is 5MW and therefore approximately 10 times the shown environmental effects could be expected from the overall Derrybrien Wind Farm during the year 1998 had it existed. This shows the very significant avoidance of carbon emissions that can be achieved through the operation of large wind energy projects.
>
> The Derrybrien project would have positive effects on global and local climate change many times greater than those already taking place at Kilronan. CO_2 and other greenhouse gas emissions emanating from fossil fuel power stations will tend to be reduced thereby lessening the effects of

these gasses on the enhanced greenhouse effect. There will be no effects on local microclimate.

Even without the events of October 2003, it is too simplistic to talk of a 60 MW wind farm representing such a total saving of carbon emissions. If a true carbon balance is to be calculated, it should include the carbon released from peat excavated for the turbine bases or drainage activities, carbon released during the manufacture of raw materials and turbines components, in the hundreds of truck loads, regular maintenance journeys and in decommissioning the wind farm.

The claimed CO_2 savings at the Kilronan wind farm for 1998 and 1999[3] are summarised in table 7.1. The factor used is 0.89 kg CO_2 kWh^{-1} (presumably derived from Irish power generation data) whereas the UK national emissions factor for grid electricity is currently quoted[4] as 0.43 kgCO_2 kWh^{-1}.

Year	Month	Output (kWh)	CO_2 saved (kg)
1998	Jan	1,469,600	1,307,000
	Feb	1,658,360	1,474,000
	Mar	757,240	673,000
	Apr	1,113,200	990,000
	May	947,320	842,000
	Jun	817,080	726,000
	Jul	1,003,200	892,000
	Aug	1,141,694	1,015,000
	Sep	1,124,710	1,000,000
	Oct	1,410,650	1,254,000
	Nov	1,264,102	1,124,000
	Dec	1,531,633	1,362,000
1999	Jan	1,564,548	1,390,962
	Feb	1,401,578	1,246,073
	Mar	1,579,900	1,404,611
	Apr	1,575,646	1,400,829
	May	985,714	876,349
	Jun	685,560	609,497
	Jul	828,514	736,591
	Aug	685,658	609,584
	Sep	1,025,314	911,556
	Oct	1,474,326	1,310,750
	Nov	1,095,614	974,056
	Dec	1,504,970	1,337,994

Table 7.1: Summary of carbon dioxide savings claimed for wind power generation at Kilronan, 1998 and 1999.

Source: www.kilronanwindfarm.com.

The table indicates that the average power output of the Kilronan facility over two years was 1.635 MW, or around one-third of its full five MW capacity, presumably reflecting operational difficulties in addition to the availability of wind. Thus, the average power output to be anticipated from the 60.35 MW facility at Derrybrien is just under 20 MW. Table 7.2 shows annual carbon dioxide emission savings and equivalent peat volumes, calculated per turbine and for the whole Derrybrien facility, on the basis of both the Irish and the UK figures. On this basis, the CO_2 savings[5] associated with one year's operation of a single 850 kW turbine would be cancelled out by oxidation of 5,000 to 10,000 m^3 of peat and those achieved by operating the whole Derrybrien wind farm for one year by oxidation of 356,000-756,000 m^3 of peat.

The volume of peat estimated to have been released by the October 2003 bog slide is 450,000 m^3 (AGEC 2004). If completely oxidised, this is sufficient to cancel out the CO_2 savings from seven to 15 months of operation of the whole wind farm. If only half of this material were to oxidise, it would take the full projected lifetime (20 years) of one to two turbines to offset the associated release of CO_2 to the atmosphere. Thus, it seems that a 'do-nothing' option involving the omission of Turbine 68 would have given a more favourable outcome for atmospheric greenhouse gas loading.

7.5.10 *Interaction of impacts*

It is considered that there is little potential for special impacts caused by interaction of the environmental impacts described above or for significant exacerbation of these impacts.

Similarly, the other residual impacts are considered to be minor and show little potential for interactions leading to new negative impact. In addition it can be stressed that wind energy projects such as this do not pose worst-case scenario effects that lead to irreversible impacts of

3 www.kilronanwindfarm.com/kwh.htm.

4 www.dcarb-uk.org/pubs/phase1/udc/02.htm.

5 Based on peat bulk density 100 kg m^3 (0.1 g cm-3), carbon content 57 kg m^3 (57%) (Page et al 2002) and 1 kg of C equivalent to 3.664 kg CO_2.

	per 850 kW turbine		per 60,350 kW facility	
CO_2 saving/kWh of wind power (kg)	**0.43**	**0.89**	**0.43**	**0.89**
Anticipated annual generation (kWh)	**2,434,921**	**2,434,921**	**172,879,401**	**172,879,401**
Annual CO_2 saving (kg)	**1,047,016**	**2,164,767**	**74,338,142**	**153,698,487**
Equivalent peat volume (m^3)	**5,013**	**10,365**	**355,944**	**735,935**

Table 7.2: The potential annual CO_2 savings by wind generation at Derrybrien and equivalent peat volumes.

> an exceptionally severe nature such as contamination of an aquifer or destruction of a unique habitat.

These two paragraphs represent the sum total of assessment for impact interactions – arguably the most important phase in the EIA process. The conclusions expressed in the first paragraph reflect the selective and superficial nature of the information gathered. No attempt is made to examine potential interactions between different topic areas.

The second paragraph is an example of the belief that, if something is stated as being so, then it is so. No scientific argument is presented to justify the statements and actual events were later showed the degree to which they were both unfounded and unwise.

A genuine attempt to assess the indirect and cumulative impacts and potential impact interactions would have followed the detailed guidelines for such assessment produced by the European Commission (1999) and summarised above (section 6.1).

7.5.11 *Summary of likely overall positive and negative environmental impacts*

> <u>Positive Environmental Benefits</u>
>
> Wind power is one of the very cleanest ways of producing electricity. [There] are no emissions whatsoever.

This is misleading, indeed incorrect, for the reasons set out in the previous section.

7.5.12 *Non-technical summary*

> The site was chosen as the most suitable site for this venture owing to a number of factors.
>
> The ecological quality of a large proportion of the area has already been substantially damaged by the presence of monoculture forestry. The operation of the wind farm would not affect animals and plants and would tend instead to benefit the ecology of the area.

The claim that 'The operation of the wind farm would not affect animals and plants . . .' cannot be justified by the evidence presented in the reports, some of which even contradicts the statement. This is a case of 'hardening up' a statement into something more powerful than the evidence can support.

> The major impact of this development would be visual.

Clearly it was not.

> The effects on the ecological quality will be minor and mainly associated with road construction. These effects are primarily offset by the excavation of roads to bedrock where forestry work has already resulted in drainage and also by choice of floating roads in areas not already drained. These floating roads do to involve the excavation of peat in order to construct the road and so will not drain the bog.

The issues associated with floating roads have already been discussed.

> The potential impacts of the project on bird life are unknown but considered to be relatively minor due to the lack of known vulnerable bird species using or passing over the site.

It may be honest to admit that the potential impacts are unknown but it is difficult to see how the claim can be justified given the evidence that hen harriers (*Circus cyaneus*) and merlin (*Falco columbarius*), amongst other birds, possibly frequent the site. Evidence presented earlier is transformed into a 'lack of known vulnerable bird species using or passing over the site.' This does not accurately reflect the evidence presented in the main body of the reports.

> The 'do-nothing' effect of not proceeding with the project is a continued and increasing reliance on fossil fuels to generate the power that the wind farm would have produced. …. In addition, the fact that Ireland has already exceeded the Kyoto limits on CO_2 production, which should not have been reached until 2010, means that there is an urgent need in Ireland to generate power without emissions.'

The implication, once again, is that wind farms generate power without greenhouse emissions. Even if the wind farm were to be built on mineral ground rather than peat, it cannot be claimed that wind farms are entirely without carbon emissions but the fact that the Derrybrien wind farm is built on peat further increases the carbon emission total for the development. This is not acknowledged or, perhaps, even recognised.

To end this section, and in the light of what actually happenned at Derrybrien, it is perhaps sobering to consider the confident concluding statement of both reports:

> No impacts of an exceptionally severe nature (e.g. contamination of an aquifer, destruction of a unique habitat) are possible through the construction and operation of this project.

Given that Fate demonstrated otherwise in the form of a considerable landslide and that this has both contaminated important aquifers and seriously damaged valued habitats, the issue of slope stability clearly is a key factor in the evaluation process. This should already be obvious from this report but the topic is patently absent from the Derrybrien reports.

The next section considers best practice in relation to the whole issue of slope stability.

7.6 *Planning and development on unstable ground*

A common thread running through much of this report is the issue of stability – perhaps not surprisingly, given the turn of events in October 2003. It is, or should be, a primary issue of concern whenever engineering work is to be carried out on a peatland. The number, geographical extent, regularity and, in some cases, scale of incidents where peat has become unstable – a mere sample of which was discussed above (section 5) – is a strong indication that any EIA concerned with development on a peatland system should consult all available guidance about development on unstable ground.

The EIS cites Policy Planning Guidance (PPG) Note 22, published in 1993 by the UK's Department of the Environment (DoE) in discussing issues of landscape and planning policy as adopted for parts of the UK. It could usefully have cited an earlier note, produced by the DoE in 1990: PPG14 – Development on Unstable Land.

This begins by observing that there are three broad causes of ground instability – underground cavities, unstable slopes or the ground compression of unconsolidated deposits such as peat, alluvium or landfill. All three are relevant to Derrybrien because, as established above, the peat contains cavities, it lies on a slope and it is subject to compression either from roads and traffic or from coniferous timber.

While PPG14 is a UK policy document, it is freely available. It gives an informed view of issues that could have been incorporated into the Derrybrien reports but were not, even though significant portions are directly relevant. Some of the more pertinent (from Annex 1, Landslides and Planning) are set out below.

7.6.1 *PPG14 – Development on Unstable Land*

> 4 The effects of ground instability vary in their nature, scale and extent. At their most extreme, they may threaten life and health or cause damage to buildings and structures, so generating public alarm. Whilst such alarm may or may not be justified, public perception of the risk is such that it cannot be ignored.

7 Damage due to instability may necessitate an expensive remedial action, or in the worst cases result in loss of buildings, structures or more productive land. If not foreseen before the commencement of development, problems arising from the instability may result in delays and in increased costs. At worst they may result in a development being abandoned and investment being wasted.

The relevance of this to Derrybrien is sufficiently obvious to require no further comment.

14 While in all cases instability may arise whether or not there is any development on the surface, it is important to recognise that the development itself or the intensification of development may be the triggering factor which initiates instability problems.

17 Where there are reasons for suspecting instability, the developer should determine by appropriate site investigations and geotechnical appraisal whether:

– the land is capable of supporting the loads to be imposed;

– the development will be threatened by unstable slopes on or adjacent to the site;

– the development will initiate slope instability which may threaten its neighbours;

– the site could be affected by ground movements due to natural cavities.

18 If this investigation and appraisal indicates that the ground is unstable or may become unstable due to the development proposed or for any other reason, the developer and/or his consultants should then assess the suitability and sufficiency of the proposed precautions to overcome the actual or potential instability.

There is no evidence that the reports considered any of the above in their investigations.

22 Where development is proposed on land which the planning authority knows is unstable or potentially unstable, it should ensure that the following issues are properly addressed by the development proposed:

– the physical capability of the land to be developed;

– possible adverse effects of instability on the development;

– possible adverse effects of the development on the stability of adjoining land; and

– possible effects on local amenities and conservation interests of the development and of any remedial or precautionary measures proposed.

31 The handling of individual applications for development on land which is known or suspected to be unstable or potentially unstable will need to take account of the potential hazard that such instability could create both to the development itself and to the neighbouring area. Whilst there is scope for flexibility and each application must be treated on its merits, it is important that a local planning authority should be satisfied by the developer that any instability has been taken into account.

Nor is there clear evidence that the planning authority considered any of the above issues when granting planning permission (on appeal) either for the initial application or for the extension.

46 The assessment of the significance of ground instability and of the associated risks requires careful professional judgment. In line with his responsibility for the safe development of any site, the developer should ensure that he has available the appropriate expertise to design and interpret the necessary site investigations and to design and execute any necessary remedial, preventive or precautionary measures.

47 . . . With regard to specific development, however, it must be emphasised that responsibility for assessment, as well as investigation, of ground conditions and the design and execution of any necessary remedial or precautionary measures, rests with the developer and not the local planning authority.

There is no evidence that the developer involved appropriate expertise to assess slope instability issues when carrying out the EIA investigations.

50 A realistic appreciation of the problems of ground instability and of the need to seek expert advice requires sound information. The importance of good accessible records of past events due to ground movement cannot be over-emphasised and any future events due to instability should be adequately recorded for the wider benefit of the community.

The extent to which the developer has recorded the events of the landslip and consequent/subsequent changes is unclear. The content of the EIA reports would seem to indicate that the developer did not consider the evidence of previous bog slides, nor their implications for the development.

7.6.2 *PPG14, Appendix A*

<u>Causes of Instability</u>

A3 Whatever the ultimate cause of instability, the triggering factor which initiates instability problems is very often human activity.

A43 Both natural and man-made slopes may be subject to instability due to land sliding or soil creep. Landslides are mass movements of soil and/or rock under the influence of gravity.

A46 Landslide movement may be initiated by natural processes or by human activities. ... Slopes will only move if the forces contributing movement (e.g. gravity, water pressure, etc) exceed those resisting movement (e.g. strength of material, frictional resistance, etc). Movement can be initiated by changes in any of these factors individually or in combination. Loading of the top of slopes by natural deposition, tipping or by construction of buildings increases the weight (load) of the top of the slope, thus contributing to movement. Increases in water content due to heavy rainfall or alteration of drainage may increase water pressures and thus decreases the resistance to ground movement.

A48 Whilst present-day natural processes can cause or contribute to land sliding, it is fairly clear that, at the present time, the main cause of landslide movement, both in terms of first-time movements and re-activation of ancient landslides, is human activity.

A51 Ground compression occurs when all ground materials are loaded or drained but in certain situations the ground deformation may be sudden or of such magnitude as to cause or to be considered examples of instability. Some natural materials (e.g. peat, soft silts and clays) and landfills and quarry backfill may compress significantly under load or when drained and full consolidation may take many years. The variable nature of such materials and of the bedrocks surface on which they occur often leads to a particular problems of differential settlement.

A55 Rising groundwater has been identified as a significant factor in causing instability due to ground compression... Other activities which may cause ground water level to rise include impoundment of water behind a dam, construction of a deep basement [or] underground barrier for pollution control, blockage of underground drainage channels.

All these paragraphs clearly have relevance to the conditions at Derrybrien and the proposed development. Anyone reading this guidance would have been unambiguously alerted to the potential for instability at Derrybrien and thus the need for more detailed investigations.

7.6.3 *PPG14, Annex 1 – Landslides and Planning*

3 [The guidelines] are intended to help to ensure that:

- the occurrence of and potential for slope instability is recognised at the earliest possible stage;
- appropriate strategies are adopted for dealing with the problems arising thus preventing the un-necessary sterilisation of land;
- due account is taken of the constraints imposed by slope instability at all stages of the planning process;
- development does not proceed in certain areas of instability or where treatment proposed is ineffectual;
- development is suitable and will not be threatened by landslides or cause instability of surroundings slopes;
- expensive protection or remedial works, which may be publicly funded, are not needed after a site has been developed;
- any necessary protection or remedial works will not lead to significant adverse environmental effects at the site or elsewhere.

Use of guidelines such as these would certainly have made a considerable difference to the assessment and planning process at Derrybrien.

6 In most cases, the potential for landsliding can be identified by appropriate investigations. Many of these costs [associated with landslides] are, therefore, avoidable. Generally, the costs of investigation and precautionary or remedial measures are greatly offset by the savings in terms of construction costs, damage, disruption or destruction that would otherwise arise.

A valuable piece of guidance, the wisdom of which would probably not now be lost on Saorgus Energy Ltd.

7 Landslides occur when the gravitational forces acting on the material comprising a slope exceed the resisting strength of those materials. Movement may be initiated by natural or human-induced changes in either of these controls. Once movement has occurred, the slope and geometry may change to a more stable configuration but the resisting strength is reduced permanently. Further movement may be more likely if there is any adverse change in conditions. Water is particularly important since it increases the weight and therefore the forces tending towards failure. Since the strength which is effective in resisting the landsliding is reduced by water pressure, water is also important from this point of view. As might be expected, the rapidity of landsliding and the mobility of debris is increased by the presence of water.

The significance of water in landslips is made very clear in the above paragraph. Of greater concern for the future of the Derrybrien development is the emphasis that the condition of instability becomes a permanent feature of the site.

8 [Figure 1] shows the distribution of the 8835 landslides recorded in the national landslide database. [This] gives a broad general picture of the widespread nature of landsliding in Great Britain. The picture is not complete, however . . . There are undoubtedly many more landslides than are recorded in the database.

The above paragraph simply serves to emphasise the widespread nature of landslides and thus highlight the fact that the potential for slope instability should really have been seen at Derrybrien – especially given the relationship between instability, slope and water described in earlier paragraphs.

9 Landslides involve the movement of large volumes of material in a relatively short time. Once movement has occurred, the normal erosion processes are slow and ineffective in removing the evidence. As a result, landslides accumulate in the landscape. The survival time of landslide form and deposits and the shear surface on which movement took place is very long. They thus remain in the landscape as a hazard for perhaps thousands of years.

10 Even landslides which occurred a long time ago, when environmental conditions may have been different than now, are still present as a potential hazard to development. Over time, the surface form may have all but disappeared due to erosion but the shear surface remains beneath the surface as a weak zone which may be reactivated easily by both natural and human interference.

The above paragraphs serve to emphasise, once again, that a slope which has demonstrably become unstable for all practical purposes remains in an unstable state indefinitely.

12 . . . the range of activities which may contribute to slope instability includes:-

- the placing of fills and others superimposed loads for construction purposes or the disposal of wastes;
- excavation, especially into old landslides but also into slopes previously unaffected by landsliding;
- mineral extraction beneath slopes;
- uncontrolled disposal of water, including soakaways and the diversion of a natural drainage courses; and
- changes in land use, such as deforestation or ploughing of grassland.

The effects of changing the distribution of loading on a slope and, especially of changing the water regime, are evident.

This list could, in effect, be a catalogue of activities carried out at Derrybrien.

18 It is the responsibility of the developers to ensure that their developments will not initiate

> instability or will not be affected by instability originating outside the area of a development. Developers should therefore seek appropriate technical and environmental expert advice about the likely consequences of proposed developments on sites where landsliding is known or may be reasonably foreseen. They should also procure any necessary investigations to ascertain that their sites are and will remain stable or can be made so as part of the development works.
>
> 19 . . . for these reasons, at least a preliminary assessment of slope stability should be carried out at the earliest possible stage before a detailed design is prepared. Only on the basis of such a geomorphological and engineering geological assessment, comprising a desk study of available information, including aerial photographs and a ground inspection, can the need for further investigations to ascertain the true extent of the hazard and any necessity for precautionary or remedial measures be determined.

There is no evidence that the developer sought out appropriate expertise for the EIA investigations. Indeed the reports do not even contain a preliminary assessment of slope stability.

> 28 Where there are grounds for believing that there is active or potential landsliding which would affect a proposed development, reservations can be overcome in an environmentally acceptable manner. This may require the application to be accompanied by a slope stability report prepared by a competent person, which demonstrates that the site is stable or can be made so and will not be affected by or trigger landsliding beyond the boundaries of the site. Guidance on the preparation, content and format of slope stability reports is contained in [Appendix 1B].

There is no clear evidence that the planning authorities requested any form of slope stability report before granting permission for this development.

> 34 The considered assessment of landslides and their consideration when determining planning applications will help to reduce the impact of undesirable consequences such as risks to public safety, property damage, avoidable costs to development, personal distress to those affected, degradation of the physical environment and loss of environmental resources.
>
> 35 The investigation and evaluation of slope stability here recommended is consistent with current good practice. It will thus not lead to additional costs to responsible developers and is likely to enable savings in avoiding costs which might arise if investigation falls short of this standard.

7.6.4 *PPG14, Annex 1B – The Slope Stability Report*

Annex 1B of PPG14 provides a detailed account of what a Slope Stability Report should contain. It is also emphasised that such a report should be prepared by a competent person, that is:

> . . . someone who is a Corporate Member of a relevant professional institution such as the Institution of Civil Engineers or the Geological Society. In this context, a competent person would be a geotechnical specialist as defined by the Site Investigation Steering Group of the Institution of Civil Engineers.

The purpose of the Slope Stability Report is set out clearly in 1B2:

> In order to satisfy a local planning authority, slope stability reports should demonstrate:
>
> - an adequate appreciation of ground and groundwater conditions and any other relevant factors influencing stability based on desk studies, aerial photographic interpretation, geomorphological and engineering geological mapping of the site and appropriate subsurface investigation, laboratory testing and monitoring where necessary; this appreciation must include a statement on whether or not the site or surrounding areas are affected by earlier landsliding or periglacial deposits and, if so, a definition of their extent in plan and section;
> - that the site is stable and has an adequate margin of stability, or can be made so as part of the development works, for the foreseeable conditions that will operate at the site;

- that the site is not likely to be threatened or affected by reasonably foreseeable slope instability originating outside the boundaries and
- that the development is not likely to result in slope instability which will affect either the development or nearby property.99

The key elements of a Slope Stability Report can be summarised as desk and field investigations that provide information concerning:

- relevant published and available unpublished information;
- the morphology of the area; the geological sequence and structure; landslide features; seepage lines and wet areas; vegetation types indicative of high water table or changes in soil type; evidence of movement in existing structures and trees; evidence of past movement; evidence of movement due to mining or natural underground cavities; evidence of previous changes to the structure of site by human activity;

Other issues include:

- the location of any features indicative of slope instability in the site and surrounding area; the consequences of failure; understanding of ground water conditions; water pressures within the slope and likely fluctuations in adverse conditions; the engineering parameters of the materials in the slope for use in stability calculations; engineering interpretation of ground and ground water conditions; details of stability calculations.

It is clear that the level of investigation of stability issues described in the reports falls a long way short of the standard set by PPG14. Had suitable studies been undertaken or been insisted on by the planning authority, it is possible that the Derrybrien development could have avoided giving rise to:

> . . . undesirable consequences such as risks to public safety, property damage, avoidable costs to development, personal distress to those affected, degradation of the physical environment and loss of environmental resources.

Summary of Chapter 7

1 The project proposal for Derrybrien appears to have been prepared in the form of three smaller proposals that would form one large development – i.e. using the 'salami-slicing' approach to gain incremental approval for a single large development.

2 The developer claims not to need an EIA for the third development but this is incorrect. It is not clear that the screening process corrected this misapprehension.

3 The developer states that the two EIA documents have been produced on a voluntary basis to demonstrate the environmentally benign nature of wind farm development. The documents are not, therefore, dispassionate reviews of possible impacts.

4 Part of the development appears not to have been subject to specific EIA procedures, although the development as a whole represents one of the largest wind farms in Europe.

5 There is no real attempt at scoping in either of the documents.

6 There is no attempt to consider indirect or cumulative impacts, or impact interactions in either of the documents.

7 Detailed impact assessment is restricted to visual and noise impacts alone.

8 Little consideration given to blanket mire and its associated soils as an ecosystem or to the possible effect of forestry on these soils.

9 No credible assessment is made of avifauna using the site. Species are mentioned merely to be dismissed as significant factors. It appears that no request was made either by the developer or the planning authority for sight of recent survey data concerning hen harriers in the Slieve Aughty Mountains. The planning authority instead imposed a planning condition concerning survey of the hen harrier that can provide no safeguards for the population.

10 There is no mention of bog-slide potential within the consideration of either rocks and soil or water; there is no evidence that the developers have considered issues of stability at all nor did the planning authority require a stability assessment, despite the evidently unstable nature of the ground in many areas of the site.

11 Claims are made for the emission levels of wind energy that are quite simply not true and the fact that peat excavation and drainage causes CO_2 release does not seem to be recognised.

12 The authors of the present report point to PPG14 produced by the UK Government for development on unstable ground and in particular to the Slope Stability Report detailed in Appendix 1B. The level of detail required for such a report are in stark contrast to the details provided by the two Derrybrien EIA documents.

PART 2

The events of October 16 and subsequent issues

Chapter 8

The bogslide at Derrybrien

8.1 *Description*

MASS MOVEMENT OF PEAT commenced at about 16:00 hrs on Thursday 16 October 2003 and stopped around Saturday 18 October but was re-activated ten days later[1] following heavy, continuous rain.

The authors of this report visited the site eight months after these events, on 8 June 2004. By this time significant sections of the debris had been washed away and various works to stabilise the hillside had been completed. This account is necessarily based on records made by others within a few days of the initial slide as well as on our own observations. The principal sources are the account of a site inspection carried out on 17 October 2003 by consultants to the developer (AGEC 2004) and photographs provided by Martin Collins of Derrybrien. A video recording of an aerial inspection on 18 October (BMA 2004) by engineering staff at Galway County Council has also been viewed.

The route of the first slide can be traced on fig 8.1. Its upper limit lies close to the southern side of an excavation made by the developer to accommodate the base of Turbine 68 (T68). Its track passes through mature forestry, covering a second turbine site (T70) some 300 metres downslope. From here, it continued in a south-easterly direction along a natural drainage line to the stream-head and then followed the course of the stream, its toe initially coming to rest just north of the Black Road (M614036), 2,450 metres from T68. Failure of peat was apparently restricted to the upper 1,200 to 1,300 metres of this track, from the T68 site to the point where the stream turns eastwards into a narrow bedrock channel near M603038. The width of the failure scar on 18 October ranged from c. 45 metres at the head to a maximum of c. 270 metres some 750 metres downslope.

The later-re-activation of the bog slide led to a rapid flow of peat down into the Owendalulleegh River and then onwards for a further 20 km to enter Lough Cutra. The fate of the material after that is still the subject of environmental monitoring and investigation – the total geographical and ecological impact has yet to be established.

Observation on 18 October indicated that the original basal failure surface was within the lower part of the peat layer, typically 200 to 400 mm above mineral soil. The ground appeared initially to have separated into distinct rafts along forest plough/drainage channels, the rafts breaking down as they moved leading to flow-type movement of peat (AGEC 2004). This description suggests that the event should be termed a bog slide rather than a bog burst or peat slide (section 4.2).

Plates 8.2 to 8.5 give a photographic record of the section of the failure scar that lies within the wind farm boundary. The excavation at T68 was reported not to have failed and indeed appeared still to be more or less intact in June 2004 (plate 8.4a). The head of the failure was coincident with the upslope edge of a site access road a few metres downslope of the excavation. Photographs taken

1 Dates vary but Fire Services & Emergency Planning, Galway County Council reports it as Tuesday 28 October

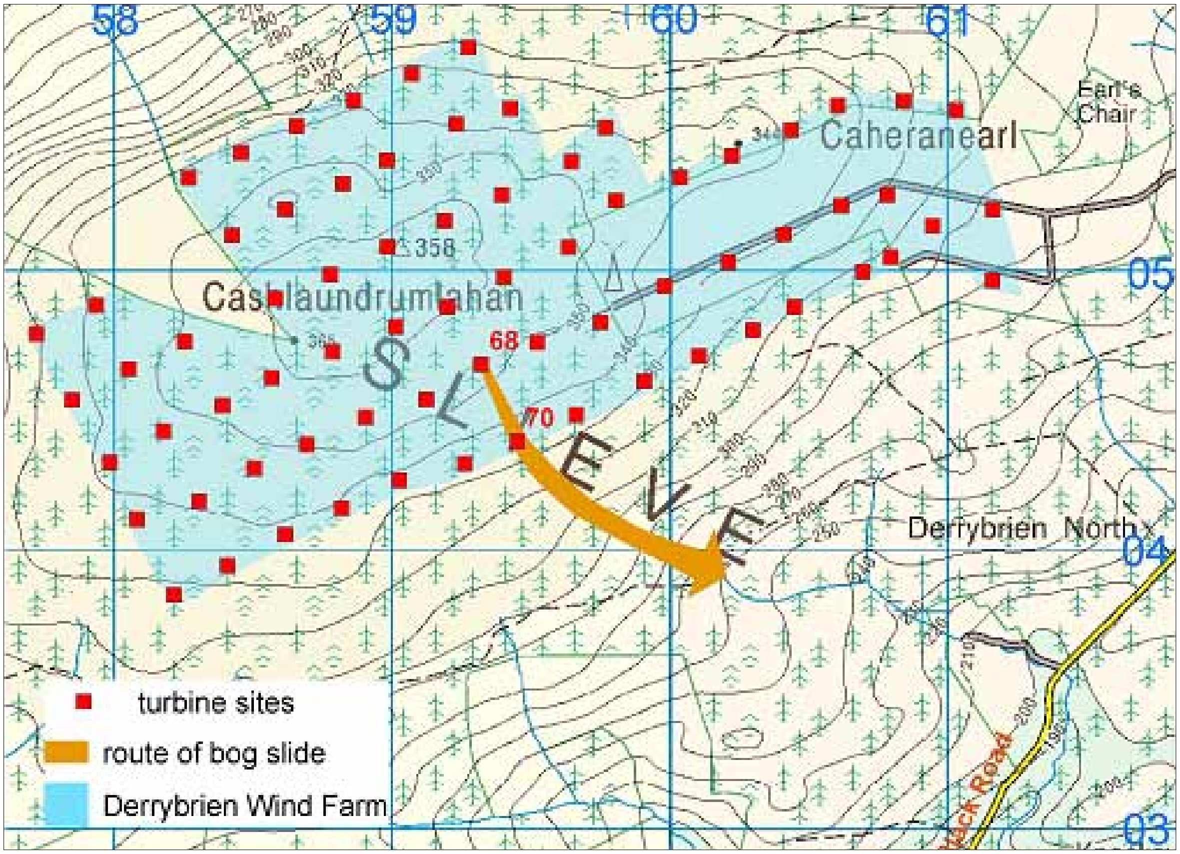


Figure 8.1: Route of the Derrybrien bog slide, indicated by the orange arrow.

within days of the slide indicate that the southern wall of the excavation remained in place, supporting a precariously perched excavator. The road had bowed southwards by 10-20 metres (plates 8.2b, c and d). Plate 8.3, taken in June 2004, gives two views looking southwards from the reconstructed road at T68. The pattern of detachment of rafts of vegetation along plough lines was still evident in mature lodgepole pine plantation at the eastern side of the scar. South of T70, a small exposure of bedrock was found at this time (plate 8.4c) but appeared to be the result of water erosion subsequent to the landslide. The trees in this area were smaller than those upslope and included some Sitka spruce understood to have been planted to repair fire damage (plate 8.4a). A crack in apparently intact surface was found at the eastern edge

Plate 8.1a & b: The view to the south of T70, 8 June 2004.

Reproduced courtesy Martin Collins

Plate 8.2: The head of the peat slide at T68. a: turbine base excavation in June 2004; b: deformation of floating road October 2003; c, d: an excavator after the bog slide.

of the scar (plate 8.1a). Probing indicated that the peat thickness here was 2.14 metres and the crack 0.7 metres deep.

8.2 *The contribution of the weather*

The weather is an important factor to consider because many bog slides are associated with heavy rainfall. In this case, there was no rainfall either on the day or on the days leading up to the incident.

Plate 8.3: The bog slide just below T68, 8 June 2004. Top, the pattern of detachment of rafts of surface vegetation along forestry plough lines at the west side of slide and, bottom, the centre of the slide, looking south.

Plate 8.4. Site T70 on 8 June 2004.
a: looking upslope from road towards T68;
b: looking upslope towards T70;
c: exposure of the bedrock.

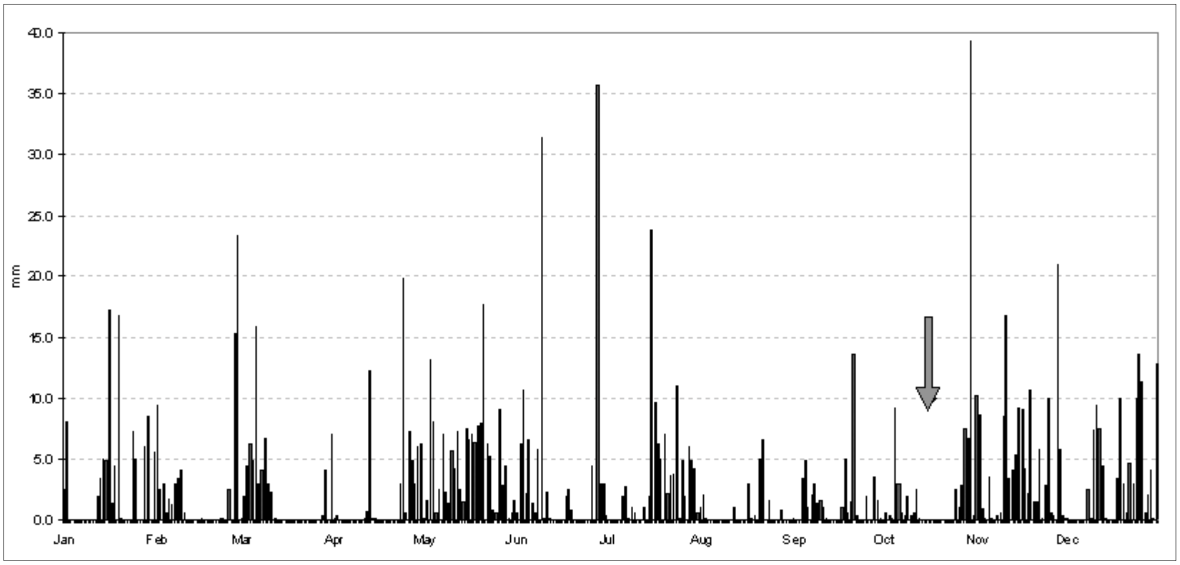


Figure 8.2: Daily rainfall for Derrybrien during 2003. The arrow indicates the date of the bog slide.

However, another factor may have played a key part in predisposing the site to what happened – the effect of prolonged dry spells on cracking in the peat. The usual examination of weather events immediately surrounding such incidents must replaced with a more extensive consideration of weather patterns extending over the whole year, and over previous years, to determine whether the weather pattern for the whole of 2003 provides to the causes of failure.

8.2.1 *The rainfall record*

Daily rainfall data for Derrybrien for period 17 January 1990 to 21 June 2004 were provided by the Irish Meteorological Service for a location three km to the south of and 220 metres below the summit of Cashlaundrumlahan.[2]

Many accounts associate mass movements of peat with heavy rainfall events (section 4) but the records in this case (fig 8.2 and table 8.1) indicates that there was no rainfall in Derrybrien during the period 14 to 24 October. Prior to this, the last three days with more than five mm rainfall were 5 October (9.1 mm), 21 September (13.6 mm) and 22 August (6.5 mm). The bog slide occurred after two dry days and the weather remained dry throughout the slide's initial advance towards the Black Road. The possibility of a localised storm on the mountain is ruled out by the accounts of people on site on the day of the slide,

Date	Rainfall (mm)	Progress of bog slide
1	0.0	
2	0.6	
3	0.4	
4	0.2	
5	9.1	
6	2.9	
7	0.5	
8	0.4	
9	1.8	
10	0.4	
11	0.6	
12	2.5	
13	0.1	
14	0.0	
15	0.0	
16	0.0	Bog slide initiated
17	0.0	
18	0.0	
19	0.0	Initial advance halted
20	0.0	
21	0.0	
22	0.0	
23	0.0	
24	0.0	
25	2.6	
26	1.0	
27	2.8	
28	7.5	
29	6.7	Slide re-mobilised
30	39.3	
31	0.3	

Table 8.1: The daily rainfall record for Derrybrien, in October 2003 and the progress of the bog slide.

[2] The data processing was carried out by Ms Hannah Stockwell and Ms Louise Francis. It is understood that the rain-gauge is located in Derrybrien near grid reference M598019 at an altitude of c. 140 metres above OSI datum, near the home of the observer, Mrs Sarah Slattery.

Year	Rainfall (mm)
1990	1587.2
1991	1252.0
1992	1412.5
1993	1422.7
1994	1587.8
1995	1374.8
1996	1194.9
1997	1258.8
1998	1551.4
1999	1569.7
2000	1348.7
2001	1083.9
2002	1620.4
2003	1075.4
Mean	1381.4

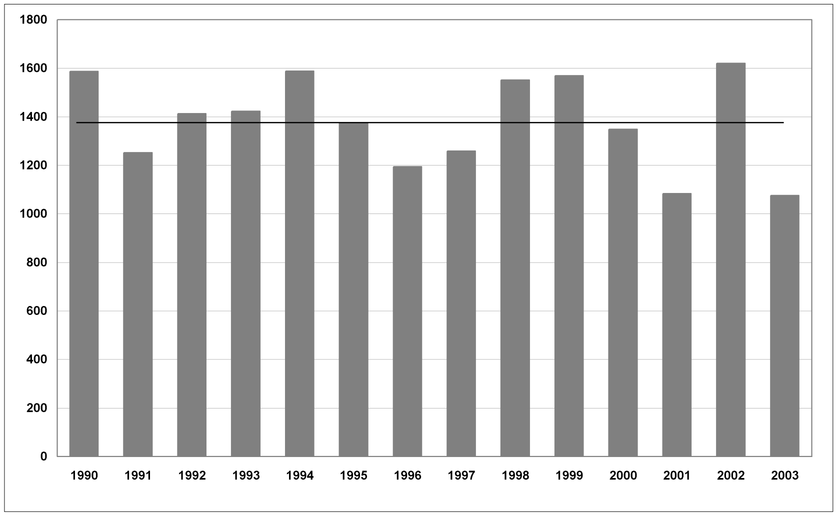


Figure 8.3: Annual (vertical bars) and 14-year annual mean (horizontal line) rainfall for Derrybrien, 1990 to 2003.

who report that the weather was fine. The displaced peat was re-mobilised only after four days of continuous rain, presumably accelerating during a storm on 30 October. Thus, although much of the downstream damage can be associated with a heavy rainfall event, the initial peat failure cannot.

8.2.2 *Rainfall averages: 1990 to 2003*

Annual rainfall totals for the 14-year period January 1990[2] to December 2003 are shown in fig 8.3. The record indicates that high-rainfall years were distributed fairly evenly throughout this period. The highest annual rainfall was recorded in 2002 (1620.4 mm) but annual totals for 1990, 1994, 1998 and 1999 were within 40 mm of the this value. Totals for 1992, 1993, 1995 and 2000 were close to average, whilst 1991, 1996 and 1997 were low-rainfall years. The two lowest rainfall totals occur near the end of the record, in 2001 and 2003.

2 The total for 1990 is slightly under-estimated as no correction was made for an absence of measurements for the first 16 days of January. This introduces a slight inaccuracy into the calculations.

		Month											
		Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec
year	1990	**202.2**	**286.5**	56.1	103.1	40.0	124.6	79.4	125.3	**38.4**	**206.2**	121.6	203.8
	1991	127.8	117.7	114.7	**148.1**	**17.6**	123.1	101	74.0	80.1	102.3	168.2	77.4
	1992	142.2	95.2	148.1	**147.8**	77.5	55.9	82.3	**189.2**	112.6	**77.4**	167.6	116.7
	1993	174.2	**34.5**	65.5	**151.8**	**132.5**	113.4	100.5	72.5	101.7	**73.5**	**82.4**	**320.2**
	1994	184.0	149.5	**203.4**	**149.6**	82.5	59.9	**70.4**	103.5	102.3	**76.3**	120.1	**286.3**
	1995	**244.1**	183.1	**156.6**	41.1	84.3	53.5	**124.8**	**13.2**	68.4	**216.1**	118.9	70.7
	1996	90.6	156.9	108.4	73.7	67.3	**35.6**	87.1	112.4	68.2	195.9	152.4	**46.4**
	1997	**41.0**	**214.9**	**44.8**	**42.5**	114.1	106	105	**153.7**	82.5	129.5	**110.1**	114.7
	1998	159.9	**60.2**	144.5	115.4	44.0	**196.1**	98.8	104.6	95.6	190.8	172.4	169.1
	1999	169.4	99.0	75.0	94.5	102.1	71.0	**71.7**	85.4	**238.4**	104.5	169.3	**289.4**
	2000	122.6	162.4	**54.3**	**53.3**	**12.8**	70.1	92.4	95.5	142.4	**219.5**	**175.1**	148.3
	2001	**66.7**	66.6	108.6	100.5	42.5	85.4	97.1	113.1	58.5	131.6	136.3	77.0
	2002	197.4	**235.3**	95.9	104.6	**138.6**	134.3	**63.7**	145.2	42.2	172.6	**178.7**	111.9
	2003	97.8	70.6	63.9	64.7	**149.3**	118.9	104.2	**21.6**	47.3	**79.7**	147.2	110.2
	Mean	144.3	138.0	102.8	99.3	78.9	96.3	91.3	100.7	91.3	141.1	144.3	153.0
	SD	56.8	73.8	46.9	40.1	44.3	42.7	16.6	47.4	51.5	56.9	29.8	89.1

Table 8.2: Monthly rainfall totals for Derrybrien, 1990 to 2003. Unusually wet months are shown in blue and unusually dry months in red. See also fig 8.4.

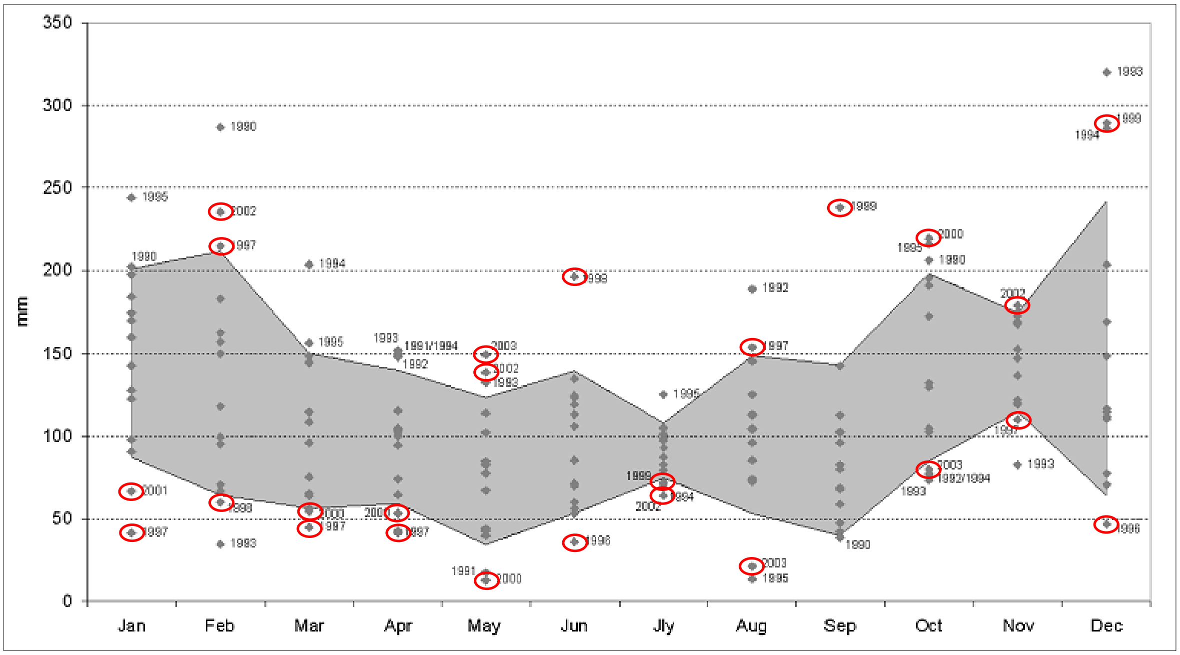


Figure 8.4: The range of monthly rainfall totals at Derrybrien, 1990 to 2003. The labelled values lie more than one standard deviation above or below the monthly mean (the shaded envelope) and are taken to indicate 'high-' and 'low-rainfall' months respectively. Values for 1996 to 2003 are circled in red and the full dataset is given in table 8.2.

Table 8.2 gives monthly rainfall totals for the same period. For each month, the 14-year mean and standard deviation is shown at the bottom of the table. Monthly totals that exceed the mean plus one standard deviation are shown in blue italics (high-rainfall months) and monthly totals that are less than the mean by more than one standard deviation (low-rainfall months) are shown in red italics.

These data are also plotted in fi 8.4. For each month, only the outlier values – those years when the rainfall total fell outside the boundaries defined by the monthly mean ± one standard deviation (i.e. years of relatively low or relatively high rainfall) are labelled. Outlier values occurred throughout the whole period of records and at least one high-rainfall and one low-rainfall month occurred during every year except 1996 (two high-rainfall months, no low-rainfall months) and 2001 (no high-rainfall months, one low-rainfall month). In the first six years (1990 – 1995), there were 16 high-rainfall and nine low-rainfall months. In the remaining seven years (1996 – 2003), nine high-rainfall and 15 low-rainfall months were recorded. The monthly data therefore indicate that low-rainfall months occurred far more frequently between 1996 and 2003 than in the period 1990 to 1995.

8.2.3 *Pattern of rainfall*

Clearly, slope failure is not directly linked to any particular high-rainfall incident and attention may be turned to the issue of dry conditions and exacerbation of peat cracking. The fact that there appears to have been a substantially higher number of dry months in the last eight years than in the six year period 1990 to 1995 suggests that steady exacerbation of drying out caused by the forest plantation is a possibility. However, of far greater significance is the possibility of long sequences of dry months, creating an extended period of relative drought. It is therefore important to look for such sequences.

Fig 8.5 compares monthly rainfall totals for 2003 with the 14-year monthly means. The May rainfall total was the highest during the period of records considered. Although only August and October qualify as low-rainfall months on the basis of the criterion adopted above, the record in fact consists of two sequences of relatively dry months (January to April and August to October) and two sequences of wetter-than-average months (May to July and November-December), giving a bimodal distribution of rainfall through the year.

Comparison with data for other years (figs 8.6 and 8.7) shows that this is an unusual pattern. Sequences of more than two wetter-than-average or drier-than-average months are rare throughout

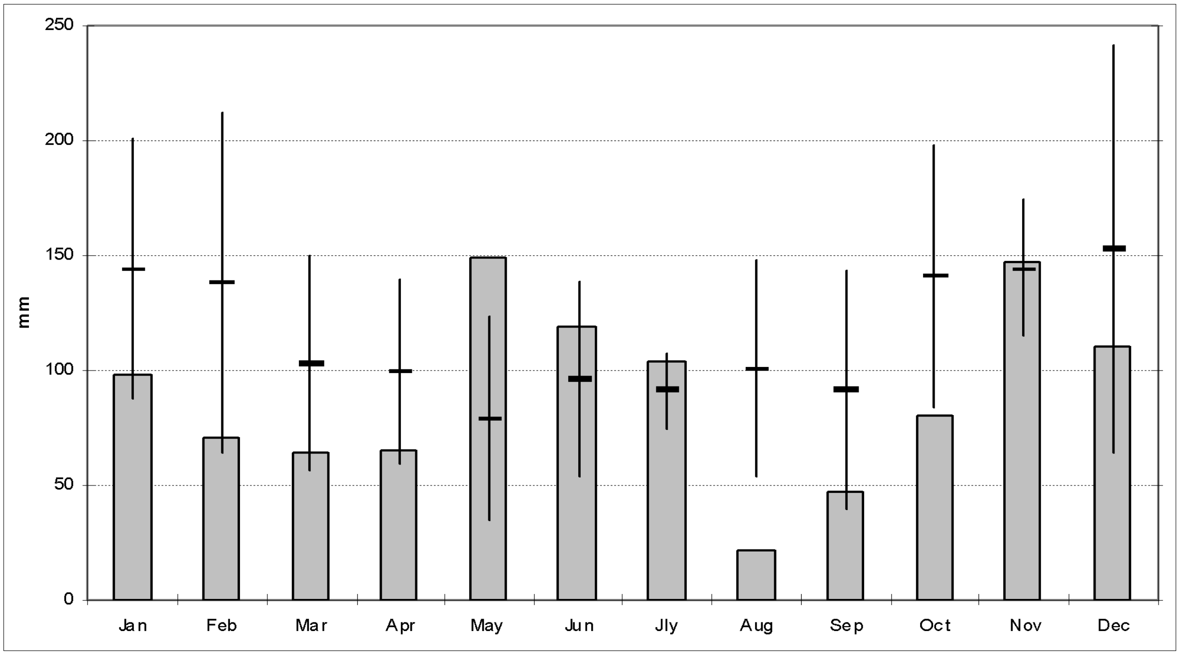


Figure 8.5: Comparison of Derrybrien monthly rainfall totals for 2003 (grey bars) with 14-year monthly means (black horizontal bars) and standard deviations (black vertical bars).

the 14-year record but a pattern involving sequences of four drier-than-average months (March to June), two close-to-average months (July and August) and three wetter-than-average months (September to November) did occur in 2000. Thus, the Derrybrien bog slide occurred during a low-rainfall year, towards the end of an apparently atypical weather sequence involving three low-rainfall months in late summer following three high-rainfall months in early summer and a dry spring.

The possibility that the cumulative effect of part or all of this sequence reflected a clear departure from the normal range of water availability at the time of the bog slide is explored in fig 8.8. The vertical bars at the bottom of the diagram represent rainfall totals for individual months throughout the 14-year period January 1990 to December 2003. The variation in antecedent rainfall is explored by calculating total accumulated rainfall during, respectively, the three, six and 12 months prior to the last day of each month. These values are indicated above each monthly rainfall total.

The graphic reveals that October 2003 came at the end of the second-driest three-month period in the 14 years of records. The average monthly rainfall for the preceding three months was 49.5 mm. The only drier three-month period ended in May 2000, for which the corresponding average was 40.1 mm. The wet weather in the early summer of 2003 meant that the rainfall total for the six-month period prior to the bog slide was within the range of figures obtained for several other years. On the other hand, the preceding 12-month period was again one of the driest on record (mean monthly rainfall November 2002 to October 2003 was 92.4 mm). A similar 12-month total was calculated for April 1997 and lower 12-month totals were obtained for July 1996 (average monthly rainfall 92.2 mm) and December 2001 (average monthly rainfall 90.3 mm).

A full assessment of the effect of dry weather on the moisture status of the peat blanket requires calculation of potential soil moisture deficit (the accumulated excess of potential evapotranspiration over rainfall). This would take into account the effect of any seasonal pattern in evapotranspiration, which would be expected to promote more intense drying of peat during low-rainfall periods in summer than during similar periods in winter. This calculation has not been performed because evapotranspiration data were not available. However, on the basis of the rainfall record alone, it appears that, although somewhat similar weather conditions had arisen on a few other occasions during the previous 14 years, the Derrybrien bog slide occurred at the end of a low-rainfall autumn in a low-rainfall year.

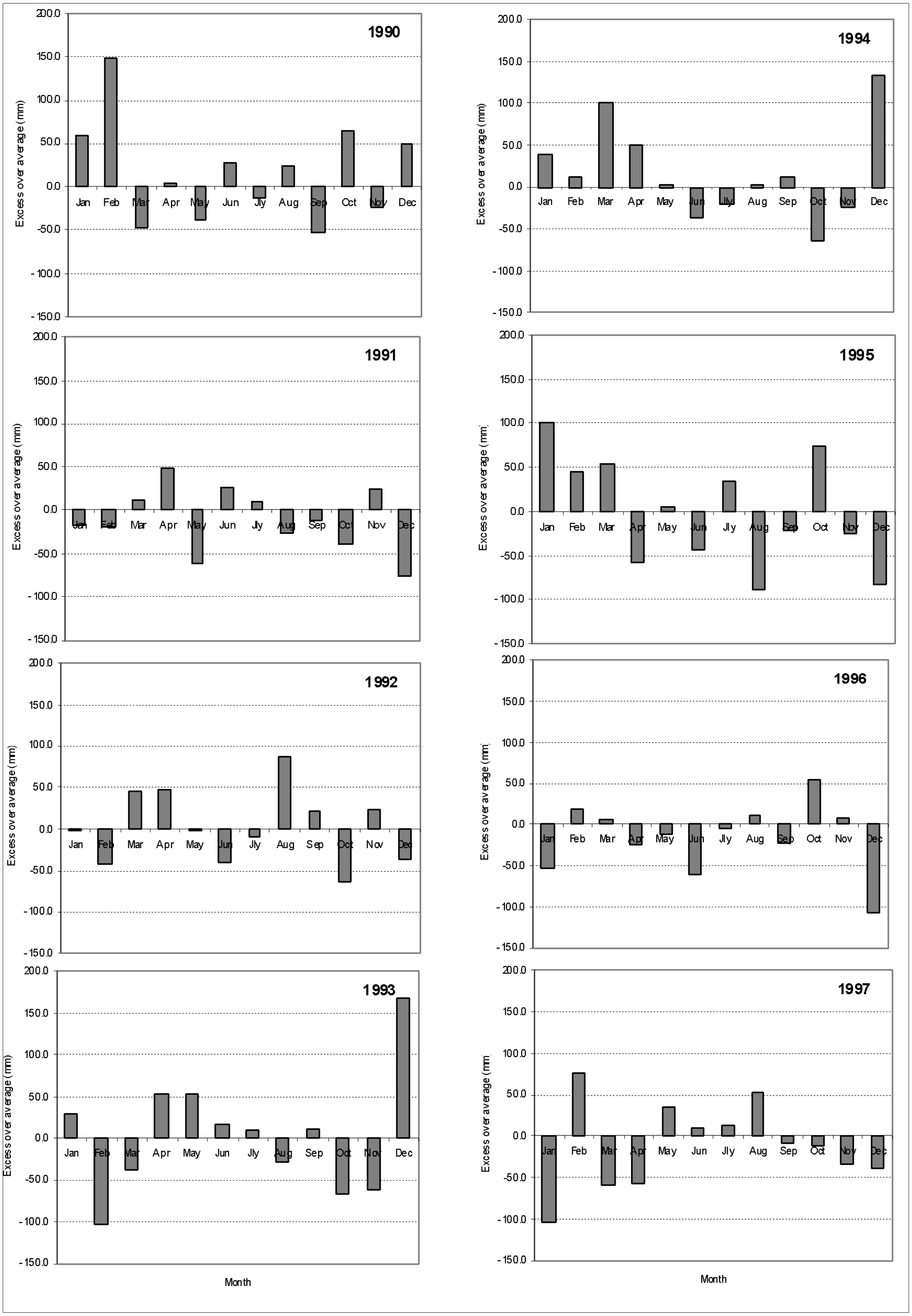


Figure 8.6: Monthly rainfall data for Derrybrien, 1990 to 1997. Each bar indicates the deviation of the month's rainfall total from the appropriate 14-year monthly mean.

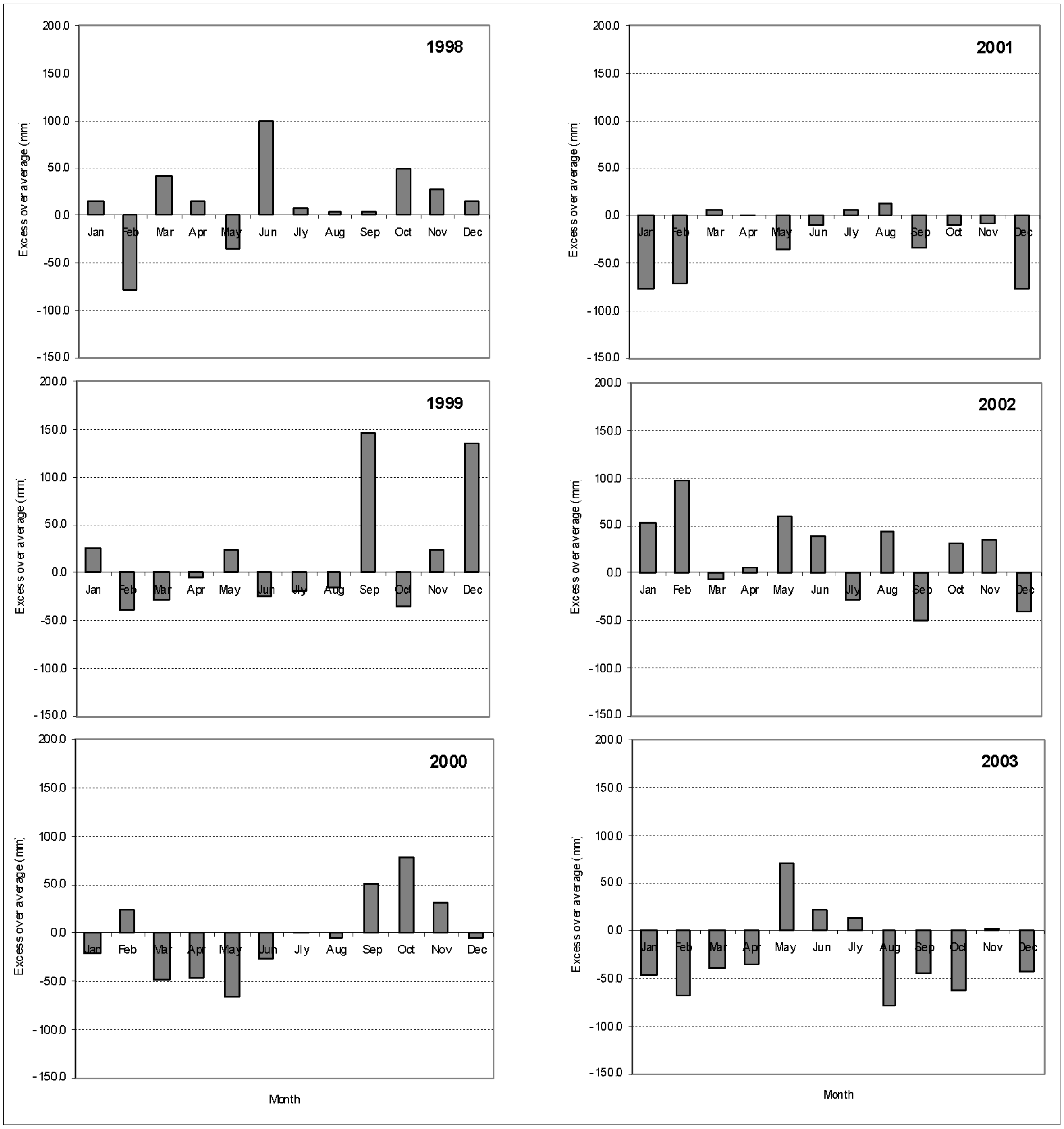


Figure 8.7: Monthly rainfall data for Derrybrien, 1998 to 2003. Each bar indicates the deviation of the month's rainfall total from the appropriate 14-year monthly mean.

8.3 *Influence of topography and hydrology*

The T68 bog slide occurred in a shallow valley or natural flush, where seepage flow lines in the peat begin to converge to form one of the streams that drain southwards from the peat blanket on Cashlaundrumlahan (fig 8.1). The catotelm in this area should be fairly resistant to drying out even in a drained site, because seepage is focused into it from a sector of bog stretching to the summit of the mountain. This is also the type of location where underground peat pipes develop, although they tend to be active in conducting water only during wet weather.

Nonetheless, we would expect that the surface layer of the bog in this area would be dry. The acrotelm was subdivided by forestry ploughing and drainage around 30 years ago and the living bog vegetation would have been lost at canopy closure some ten years ago. The area is also at the edge of a fire scar which may have further damaged the natural bog surface. The rate of evapotranspiration from mature trees is much higher than from natural bog vegetation. All these effects mean that the

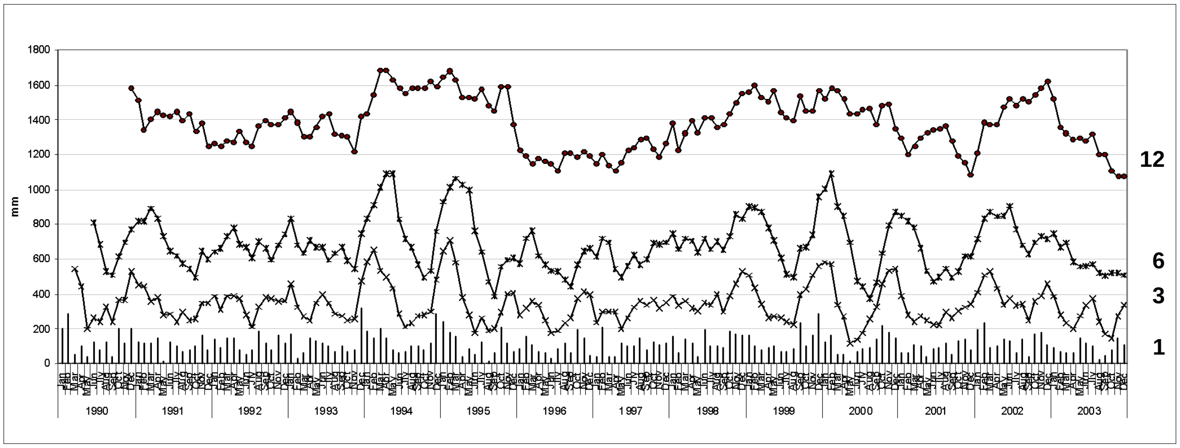


Figure 8.8: Monthly rainfall totals for Derrybrien, January 1990 to December 2003. The vertical bars at the bottom of the diagram (labelled 1) indicate monthly rainfall totals. The continuous lines indicate the total accumulated rainfall for the three, six and twelve months respectively preceding the last day of each month.

fibrous surface layer would dry out more rapidly than an intact mire surface during a spell of prolonged dry weather.

The conditions thus appear to be of a type that predispose the peat to slippage by one of the surface rupture mechanisms, described by Warburton et al. (2004),[3] involving the relative swelling of basal peat and the contraction of surface peat. Any water shed locally onto the mire surface in the vicinity would be focused into the centre of the flush and routed through surface cracks directly to the bases of cracks and any connecting peat pipes in the catotelm. This is capable of triggering the type of buoyancy failure where plates of dry peat were lifted from the ground (section 4.2).

8.4 *Predisposition by forestry*

Plates 8.3 to 8.5 clearly show that the area of the bog slide was afforested. T68 and T70 were located in a mature lodgepole pine (Pinus contorta) plantation and, below T70, there is mature lodgepole pine to the east and an area with sparse lodgepole pine scattered amongst Sitka spruce to the west. The Sitka spruce is a second-rotation crop planted after a fire destroyed part of the first.

A feature of the forestry worthy of note in this context is that the plough furrows run downhill, perpendicular to the contours. This is just the configuration of drains highlighted as being likely to allow water moving along them to attain scouring velocities that can initiate erosion (section 4).

A related and very striking feature of the bog slide is the way in which long ribbons of peat appear to have almost ‘delaminated’ from the rest of the peat body in successive layers, progressing outwards from the centre of the slide. Examples can be seen in plates 8.5 to 8.8. The ribbons, like the forest ploughing furrows, run straight down the slope. In fact they are sections of peat that have separated along the lines of the ploughing furrows so that they all tend to be the same width. It can be seen from plates 8.5 to 8.8 that each one supports a separate line of trees, reflecting the original planting lines with each successive line of trees now lying at a different angle and the different distances moved as the ribbons progressively peeled away from the lateral margins of the slip.

Closer examination of the delaminated ribbons reveals that the faces of the peat tend to be somewhere between 1-2m in height and generally display an upper pale fibrous layer while the lower parts are dark, amorphous and more obviously catotelm peat. Another striking feature of the ribbons, given that many support extensive tree growth, is their remarkably smooth faces. It is possible to see roots extending through this surface zone lengthways along the ribbon (plates 8.6 and 8.7) but there are few major roots extending sideways outwards from the ribbon as part of a circular root-mat. This is because (section 4.2), cracks in the furrows tend to inhibit sideways extension of new roots. The significance of this for Derrybrien is that the plough lines running down the hill are not bound together across the plough furrows by the sort of tight root mat that would be typical of a natural

3 See table 4.3.

forest formed on such a slope. Each planting ridge, with its load of timber, is bound reasonably tightly along its length by the tree roots but remains largely separate from its neighbours. The connecting material that joins two adjacent ribbons together is largely amorphous peat lacking coherence because of the extensive cracks that also run parallel with the planting furrows.

This separation into ribbons would be enhanced by the cracking along drain and plough lines. Since the plantation between T68 and T70 is around 30 years old and obviously mature, whilst that below T70 results from two plantings separated by a fire over the same period, we might well expect to find cracking in the vicinity of the slide. Plate 8.8 shows a peat ribbon just beginning to separate along what appears to be a plough-furrow crack just above the eastern side of the area that was most severely disturbed by the slide.

It appears that the dissection of the acrotelm caused by forestry ploughing, carried out around 30 years ago, at least predisposed it to fragmentation once the underlying peat had begun to fail. Furthermore, the plough furrows and forestry drains are arranged to run directly downslope, this pattern continuing uninterrupted across the natural drainage line that connects T68 and T70 before the slide. Such a pattern would encourage any water arriving at the surface in this vicinity to move rapidly downslope within the furrows and drains. The possibility that cracking has converted the shallow furrows into vertical slits penetrating from the surface to a depth of 70 cm or more provides a direct route into the catotelm for any such water. It is also possible that cracking could affect the strength of the peat matrix.

8.5 *Contribution of wind farm construction work*

The uppermost extent of the bog slide extended to just below turbine site 68 (T68) and obliterated site 70 (T70), approximately 300 metres downslope. At the time of the slide, the excavation for T68

Plate 8.5: Looking southwards from T68 on 8 June 2004, the peat appeared to have separated from the plantation along plough furrows to form long ribbons that were progressively drawn into the slide.

Plate 8.6: Face of delaminated ribbon of peat. Note the depth of delamination and the tendency of tree roots to run along the line of the ribbon with few roots extending laterally at right angles to the ribbon. This suggests that there is relatively limited root growth across lines of the cracks that form under plantation conditions.

was being dug. A ramp had been constructed at its western side and one excavator was positioned on this. There was a second excavator on the road edge at its southern side. Apparently, it was the job of the first excavator to dig peat (arisings) out of the site and that of the second to pile the arisings on the south side of the road.

According to the AGEC (2004) account, the excavation had reached mineral soil and had 'several drains feeding into it and appeared to have been water-filled . . . site representatives (have) indicated that they (were) unaware of any over-pumping at this location'. Photographs taken within days (plates 8.8 and 8.9) show the positions of the excavators. At that time there was a small quantity of water in the base of the excavation.

There was also a disconnected water pump at the southern edge of the road. It has not been possible to clarify whether this was being used on the day of the slide, or whether it had been brought in later. However, its position suggests that it could have been used at some time to pump water from the excavation to a point close to the centre of the failed area. The fact that it appears to have slid or been pushed off the edge of the surfaced part of the road onto the timber rafting may be consistent with its having been present when the road moved downslope.

Evidence that water does tend to pond in this location is provided by the fact that the T68 excavation was water-filled in June 2004 (plates 8.2 and 8.11). Such ponding would certainly render excavation more difficult and thus the presence of a pump at this location might not be unexpected. What is not clear, however, is whether this pump was in operation on the day of the peat failure. The T70 site was located to the north of a floating access road 300 metres downslope of T70. It is not clear whether or not the excavation for T70 had been completed at the time of the slide. All of the other sites planned for the southernmost row of turbines had been excavated except the one (T71) immediately to the east of T70, which had been partially excavated. The AGEC mapping sheet states that the T70 'base was not constructed'. Therefore it seems likely that T70 had been excavated but possible that it had not. If the former was the case, the excavation was certainly full of water (see below).

Plate 8.7: Delaminated ribbons of peat at the edge of the failed area near T70. The two-layered structure of the peat profile is obvious on the faces of the ribbons but there are few protruding tree roots. Some cracking of catotelm peat is evident in the upper picture.

Plate 8.8: A peat ribbon just beginning to separate along what appears to be a plough-furrow crack adjacent to the failed area.

On 16 October 2003, an excavator began working to release water that had become ponded at the northern side of the road. A channel had been cut through the road before a machinery fault developed and work was halted. The driver was still waiting for assistance to arrive when, some time later, the failure occurred.

In summary, the possible causes of, and contributory factors to, the slide appear to be the dry weather in combination with local factors at each of the turbine sites (fig 8.9), as follows:

at T68:

1 possible cracked peat south of the road due to forestry (the excavation being in a ride where cracks are reported not to propagate) giving direct access for surface water to the catotelm approximately 0.7 metres below the surface and to any underground pipe system;

2 possible standing water in T68 excavation with steep hydraulic gradient downslope due to the presence of the road, tending to push the road sideways;

3 loading of the peat surface by forestry, the road, the weight of machinery and piled arisings;

4 over-pumping of water from the flooded excavation onto cracked peat in an area where it will be focused into the centre of the natural seepage line after dry weather, raising the subsurface hydraulic pressure towards a point where either the peat mass begins to act like a liquid or dry peat is lifted in plates and transported downslope.

at T70:

1 possible cracked peat due to forestry, with additional disturbance due to fire and re-planting;

2 possible weight of machinery, although it is understood that this was some tens of metres

Reproduced courtesy of Martin Collins

Plate 8.9: T68 shortly after the bog slide. The head of the failure was marked by a tension crack which can be seen beneath the perched excavator and the access road bowed downslope (to the right of the lower picture, which was taken from the west side of the slide).

away from the centre of the drainage line at the time of the slide;

3 removal of support to the upslope wall of possible T70 excavation due to release of water through the line of the road;

4 discharge of water onto degraded peat downslope of T70, causing loss of strength as described for over-pumping at T68.

The cause of the failure could not be specifically identified even by the geotechnical experts who visited the site within days and so viewed all the evidence in a ‘fresh’ state. However, whilst the weather and condition of the site due to forestry could be predisposing factors, it seems probable that the slide was actually triggered at either T68 or at T70 or by a combination of the factors at both sites

Reproduced courtesy of Martin Collins

Plate 8.10: Photographs taken at T68 shortly after the bog slide. A disconnected water pump features prominently in these frames, which were taken from south and east of the slide.

simultaneously and acting on the slope as a whole. Possible triggers for the slide appear to be:

- a failure due to loading at T68 which was propagated downslope;
- this process possibly being promoted by over-pumping which reduced the strength of the peat below T68;
- the collapse of the northern face of the putative excavation at T70 due to removal of the water that had been supporting it, this failure being propagated upslope as described by Proctor for the event at Wingecarribee Swamp (section 4.2).

Thus it appears that the most likely triggers are various activities directed towards wind turbine installation.

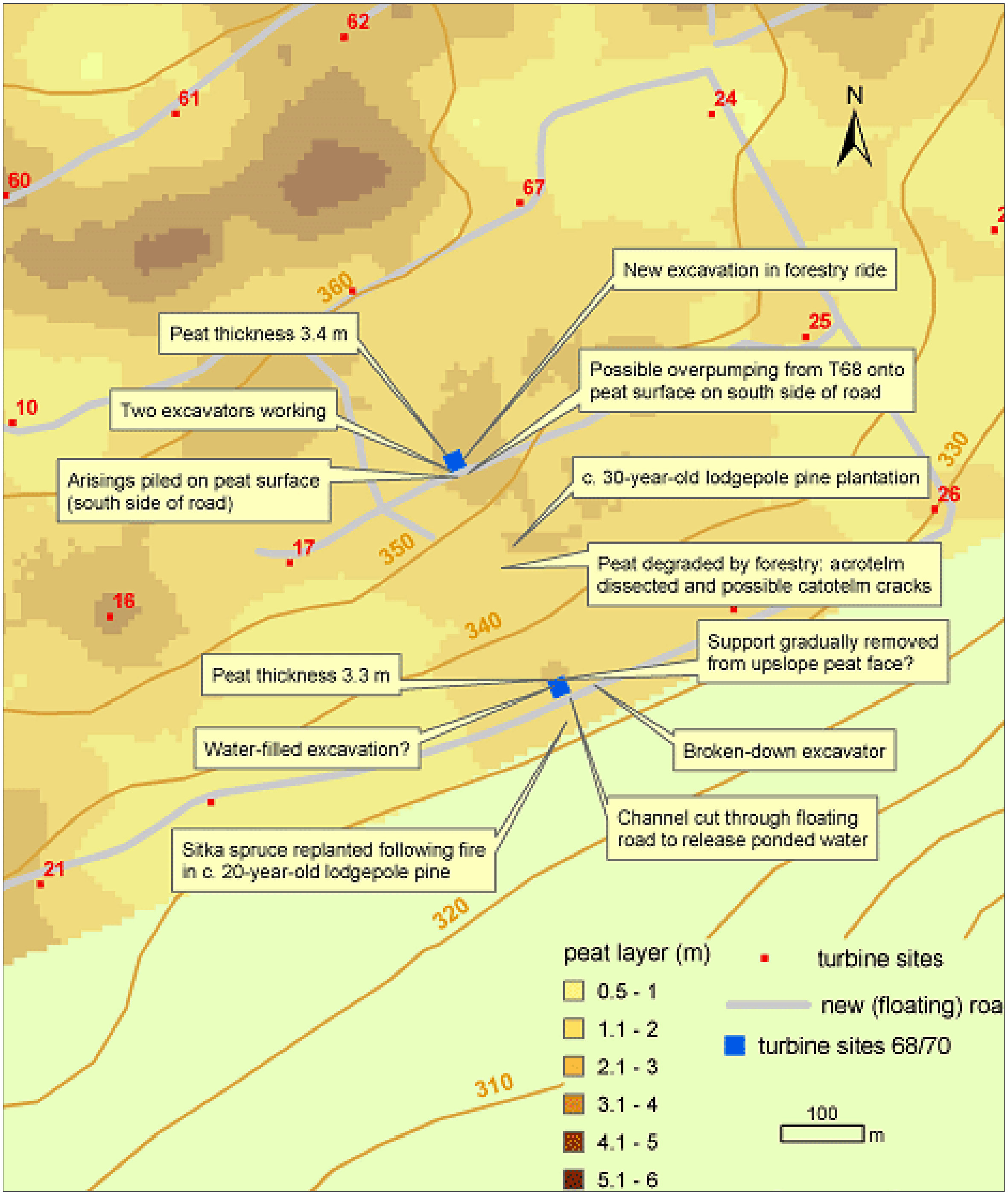


Figure 8.9: Factors that may have contributed to the bog slide at T68.

Plate 8.11: A damaged floating road just by T68. By June 2004, when this photograph was taken, it had been top-loaded with some decimetres of rock and aggregate, presumably rendering it rather less permeable to water than previously. A considerable depth of water had accumulated upslope, as the picture shows.

Summary of Chapter 8

1 The bog slide on 16 October 2003 involved failure of peat over an area 1.25 km long and 0.27 km wide, the uppermost point of which lay by the site of Turbine 68 (T68). The material travelled 1.25 km, affecting a total expanse stretching for some 2.5 km downslope. The peat flowed down a natural drainage line which led to a stream-course.

2 At the end of the month there was heavy continuous rain and the bog slide became re-activated, moving much faster in the form of a liquid stream and travelling a further 20 km along the Owendalulleegh River into Lough Cutra.

3 There was no rain at the time of the original event: the preceding few weeks had been exceptionally dry.

4 The failure appears to have been in the peat layer, thus pointing to issues affecting the peat rather than the sub-soil as the cause of the failure.

5 During the original event, the peat appears to have separated into long linear rafts each supporting a line of plantation trees. Even some eight months later, these rafts give the appearance of having delaminated from each other during the event.

6 The rainfall record for the 14 years up to and including the event give an annual average rainfall of almost 1,400 mm: 2002 was a very wet year compared to the 14-year average but both 2001 and 2003 were exceptionally dry years compared to the average.

7 Looking at the spread of rainfall throughout each year by comparing monthly rainfall with the 14-year average for each month, 2000 had very low rainfall for the first six months of the year, 2001 was generally below average for eight months scattered through the year and 2003 had prolonged periods of low rainfall in the spring and in the three months immediately before the bog slide. The 12 months preceding the bog slide produced one of the lowest cumulative rainfall totals in the record.

8 The rainfall record, rather than highlighting a high-rainfall incident as the trigger to failure, instead points to low rainfall conditions that exacerbated cracking of the peat initially caused by plantation forest cover.

9 The area of failure was covered with plantation forest and the surface of the peat was thus dry and extensively fissured, probably more so as a result of recent weather patterns. There was a considerable weight of timber sitting on the peat.

10 The bog slide occurred in a shallow valley forming a natural seepage line. The lower catotelm peat was probably thus fully saturated, whereas drainage and forest cover would have dried out the surface layers and caused extensive cracking. Peat slippage in these circumstances can be caused by swelling of the peat base and contraction of the surface, resulting in surface rupture.

11 Alternatively, if quantities of surface water are introduced to the system through pumping or by breaching structures holding ponded water, this flow of water can enter the cracked surface and cause buoyancy in the surface layers of peat, leading to buoyancy failure.

12 Loading failure from the weight of timber may have contributed further to both mechanisms described in Points 9 and 10.

13 Construction work at the time consisted of excavation for the base of T68 and drainage work on the road beside T70. The T68 excavation had filled with water and a pump was photographed close to the excavation a few days later. If there had been pumping out of released quantities of water onto the downslope surface, this may have initiated the slide.

14 If culvert construction at T70 involved the sudden release of ponded water onto the downslope surface, this may have initiated the slide.

15 The mechanisms in Points 12 and 13 would both be encouraged by extensive fissuring of the peat, the weight of construction machinery and the weight of plantation timber

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

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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.

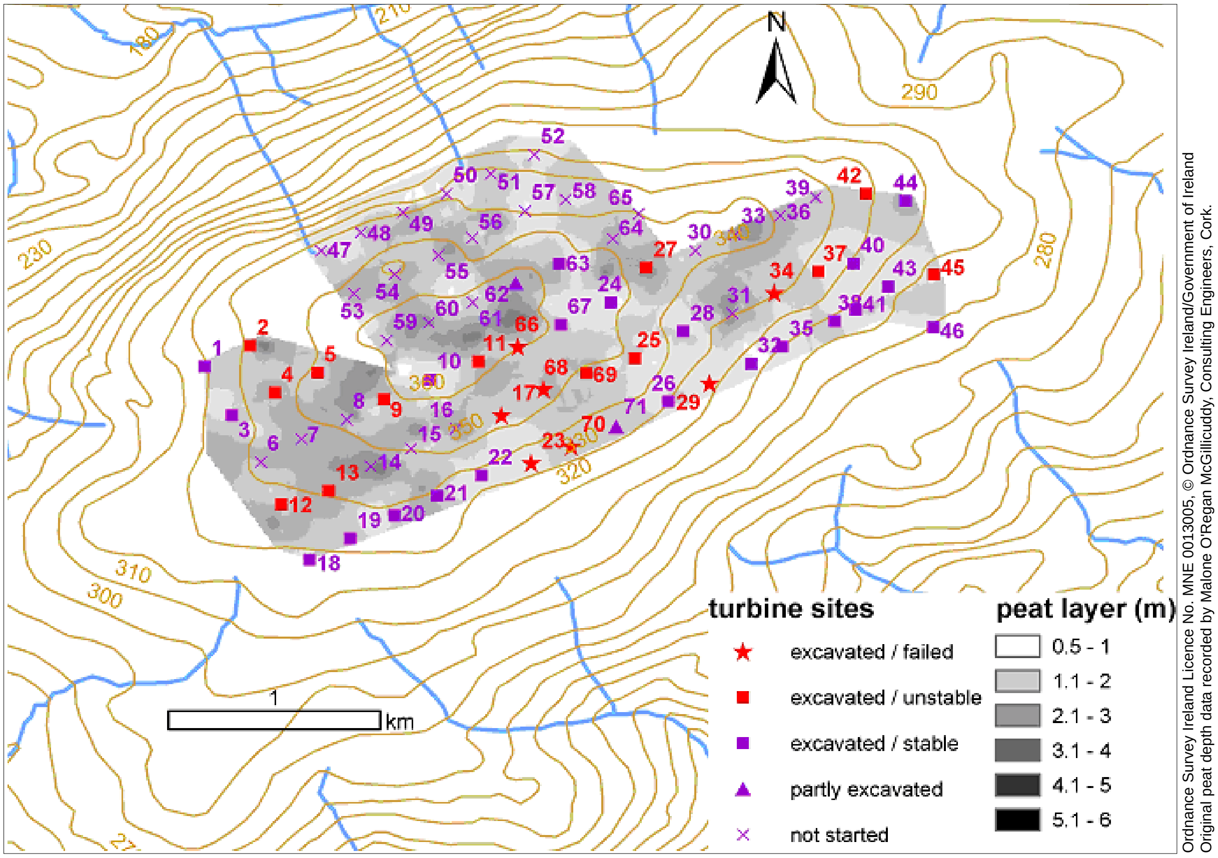


Figure 9.1: Summary of the stage and stability of turbine excavations from AGEC (2004). Unstable excavations are those where localised cracking or slumping has occurred. Sites marked as failed are those where downslope movement of peat has occurred or where incipient rotational failures were recorded.

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.

	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 360º '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

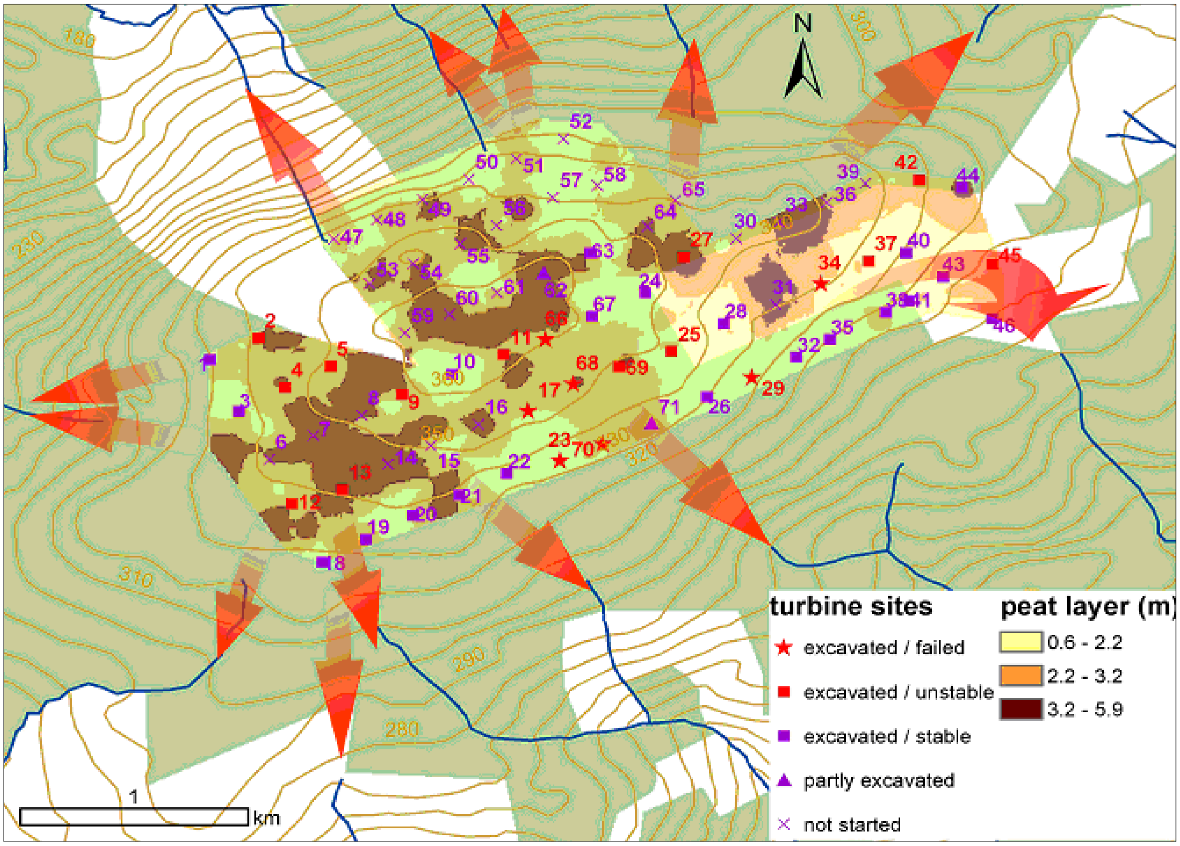


Figure 10.1: Distribution of differing peat depths within the area of the wind farm also showing the forest cover and locations of the turbine bases. These are coded according to their state of development and their assessed condition of stability. The red arrows highlight the likely direction of any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

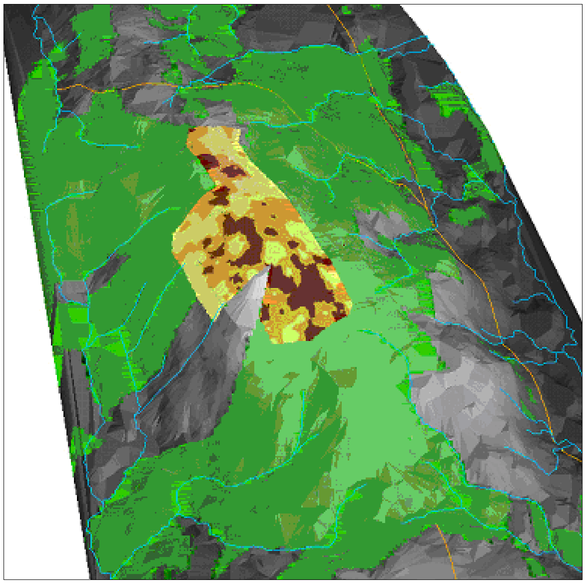
10.3 *Stability prediction*

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.



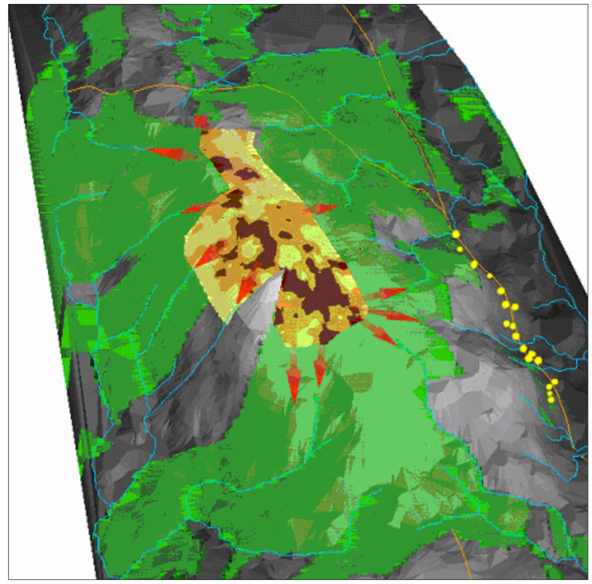


Figure 10.2a, above left: Three-dimensional view of the Cashlaundrumlahan summit from the WNW. It shows showing the extent of forestry (green shading), stream-courses (blue), roads (brown) and the depth of peat in the wind farm

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

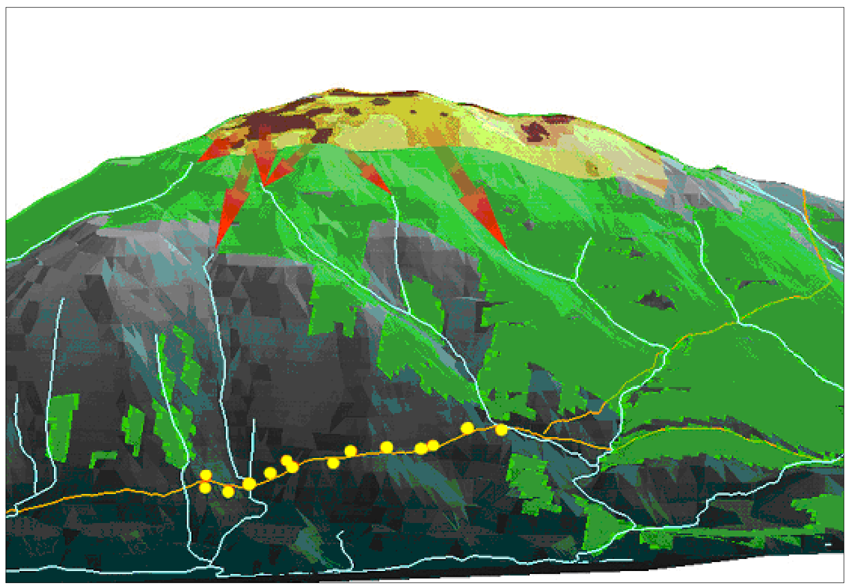


Figure 10.2:c As b but viewed from the SSW,

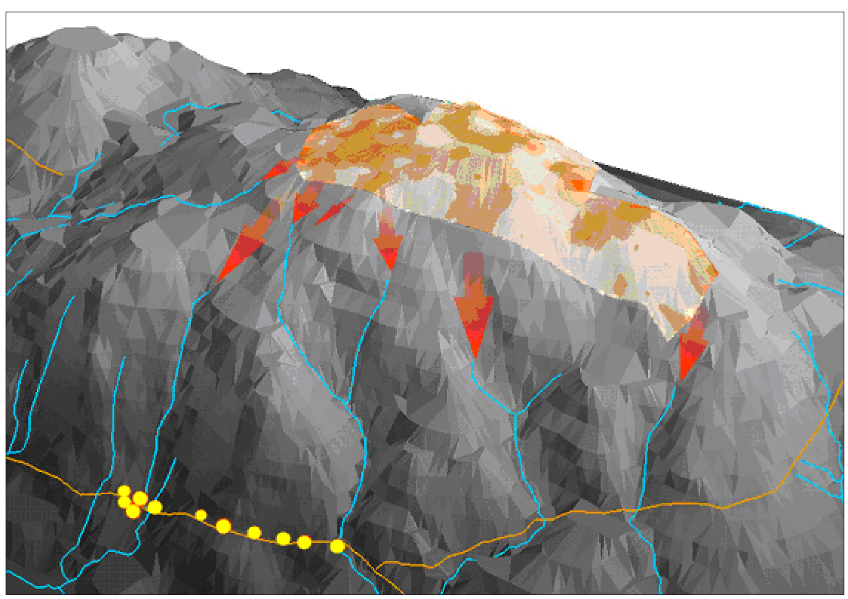


Figure 10.2d: As b but viewed from the SSE and without the forestry cover.

Original peat depth data recorded by Malone O'Regan McGillicuddy, Consulting Engineers, Cork.

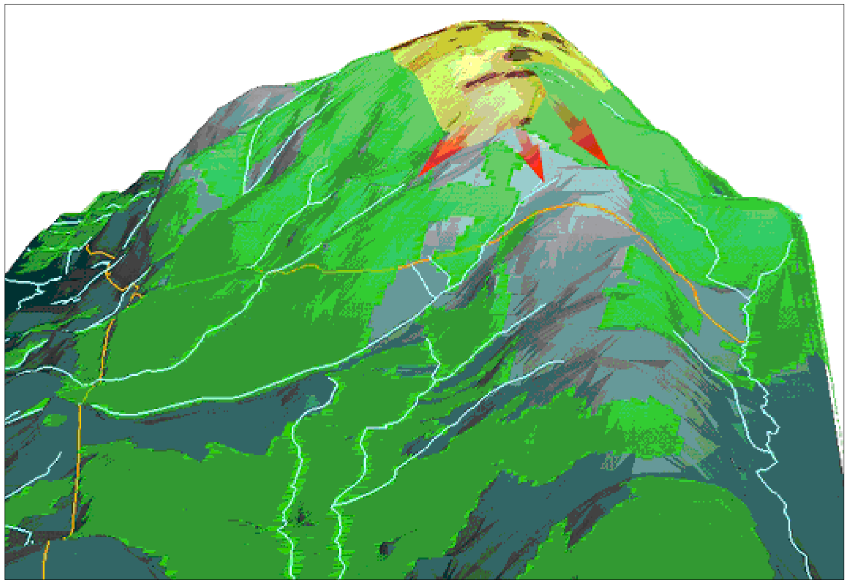


Figure 10.2e: As a but viewed from the east.

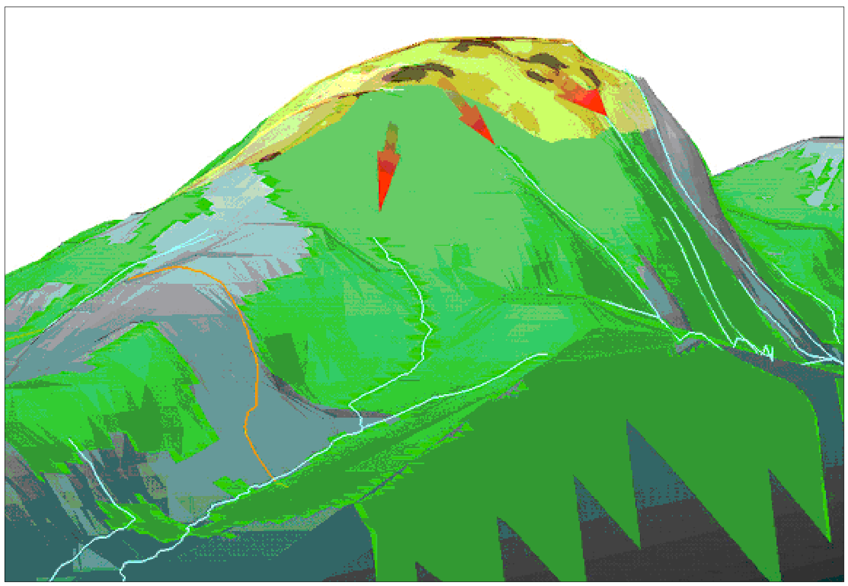


Figure 10.2f: As a but viewed from the north east.

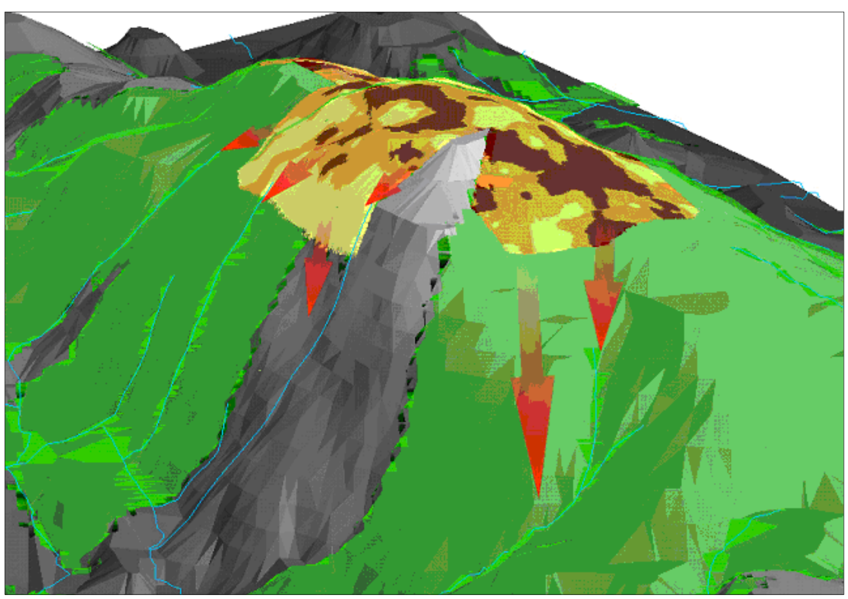


Figure 10.2g: As a but viewed from the north west.

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-

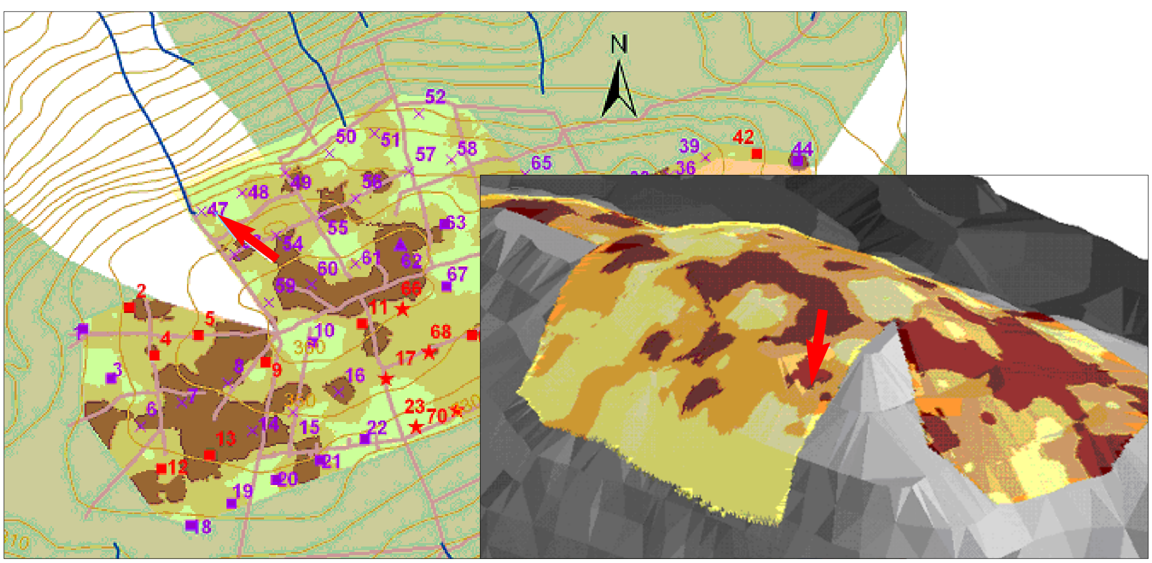
Plate 10.1: The scene of the bog slide that occurred at T17 only two weeks before the main slide. As can be seen from the small size of the trees in this vicinity, it includes areas that have already been drained for forestry, then suffered fire damage and were then drained again at replanting. So, although 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.

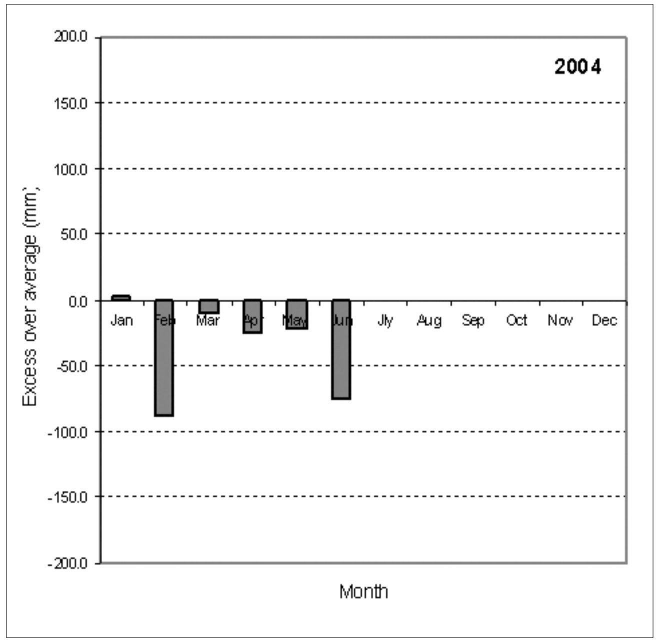


Figure 10.4: Monthly rainfall data for Derrybrien, 2004. Each bar indicates the deviation of the month's rainfall total from the appropriate 14-year monthly mean.

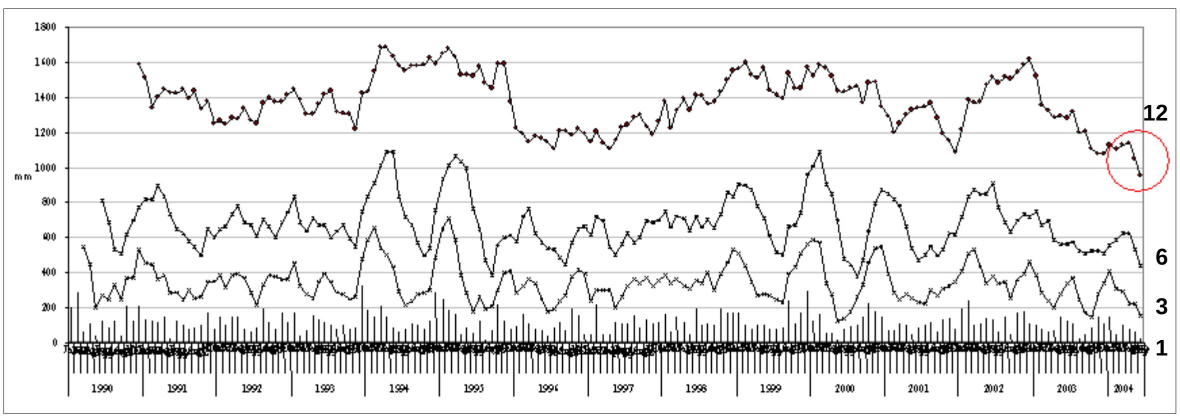


Figure 10.5: Monthly rainfall totals for Derrybrien, January 1990 to June 2004. The vertical bars at the bottom of the diagram (labelled 1) indicate monthly rainfall totals and the continuous lines indicate the accumulated rainfall for the three, six and twelve months preceding the last day of each month.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

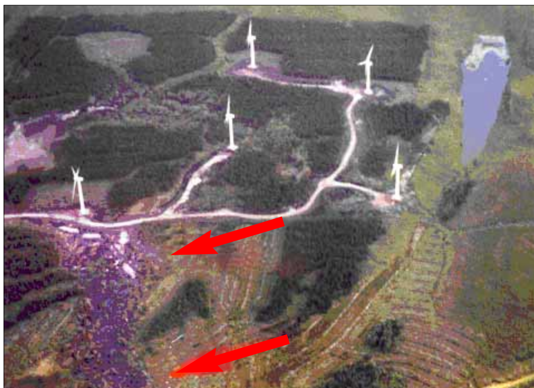


Plate 10.3a, above: The recently-erected 9-turbine wind farm at Sonnagh Old, four km to the north of the Derrybrien scheme from which this photograph was taken.

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.

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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								no
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								partially
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								
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