Natural England Commissioned Report NECR032

Investigating the impacts of windfarm development on peatlands in England: Part 1 Final Report

First published 08 January 2010

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NATURAL ENGLAND

Introduction

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

Blanket Bog is a Biodiversity Action Plan (BAP) habitat. The peat it forms represents the largest terrestrial carbon store in the UK. Blanket Bog development is dependent on a number of very specific conditions including sufficient rainfall, suitable temperature, topography and landuse.

Areas of upland blanket bog without any nature conservation or landscape designation are often targeted by wind farm developers. They are high, exposed, windy places often sparsely populated and relatively unprotected by statutory regulations.

The development of wind farms on peat raises a number of issues, some of which are not easy to resolve.

Natural England commissioned this work to:

- Understand and collate evidence of the impact of wind farm developments on Blanket Peatland in England bogs.
- Develop a set of assessment criteria against which a development proposal can be tested to determine the scale of impact and enable an appropriate response to the Environmental Impact Assessment.

Natural England will use the findings to:

- Help assess windfarm applications.
- Develop guidance for staff, developers and local authorities.

This report (Part 1) details the work and the main findings. Part 2 of the report contains the appendices and references including:

- Appendix A - a literature review and comparative case studies for existing wind farms on peat and non-peat areas in northern England.
- Appendix B - a set of assessment criteria to enable an appropriate response to the Environmental Impact Assessment and recommendations for good practice for developers and local authorities.

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Keywords - peat project, peatlands, wind farms, blanket bog

Further information
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ISSN 2040-5545

Natural England

Assessing Impacts of Wind Farm Development on Blanket Peatland in England

Project Report and Guidance

April 2009

FINAL REPORT

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REVISION HISTORY

Revision Ref./ Date Issued	Amendments	Issued to
Report Stage: Initial Draft Date of Report: 20 March 2009		Client Contact: R. Dhillon-Downey Number of copies: 1 digital
Report Stage: Draft Date of Report: 9 April 2009	Update of report including addressing NE comments and some case study reporting.	Client Contact: R. Dhillon-Downey Number of copies: 1 digital
Report Stage: Final Date of Report: 30 April 2009	Finalisation of report.	Client Contact: R. Dhillon-Downey Number of copies: 1 digital, hard copy.

CONTRACT

This report describes work commissioned by Natural England under Order 2-9275-04-2 of 30-01-09. Natural England's representative for the contract was Mrs R Dhillon-Downey. Alex Jones, David Gooch, Judith Stunell, Jessie Kennedy and Susan Wagstaff of JBA Consulting, with associates Roger Meade (RMA), Alastair Headley (Plant Ecol), John McIlwaine and Graeme Swindles (Bradford University) carried out the work.

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PURPOSE

This document has been prepared solely as a draft report for Natural England. JBA Consulting accepts no responsibility or liability for any use that is made of this document other than by the Client for the purposes for which it was originally commissioned and prepared.

ACKNOWLEDGMENTS

Malsen Environmental and Natural England would like to thank the operators of the main case study sites (Scout Moor, Wharrels Hill and Coal Clough) for agreeing access and providing information. Additionally we would like to thank those in local councils who provided EIA planning information with regard to wind farms, and Richard Lindsay of University of East London for providing reference suggestions.

EXECUTIVE SUMMARY

Assessment of the Impact of Wind Farm development on Blanket Peatland

Blanket mire covers about 1.5m hectares of England, Scotland, Northern Ireland and Wales, mostly in the uplands, and is often a dominant part of our landscape. Its altitudinal limit depends on its location with the UK and is found even at sea level in the extreme north and west. It is composed of peat deposits up to several metres thick and represents a significant store of carbon as partially decomposed plant material. It is also an important biodiversity resource because of its plant communities and the animals and plants inhabiting it. It also represents a group of locations in which wind velocities are reliably high, and where the agricultural value is relatively low. The development of wind farms on peat raises a number of issues, some of which are not easy to resolve. This report describes the issues, reviews the available literature and provides guidance at stages from drawing up wind farm proposals, through Environmental Impact assessment requirements, to the provision of effective mitigation where this is possible.

Although peat is a widespread substance its physical properties differ from those with which engineers are more experienced. For example, it is mostly water, relatively light and compressible, but has very low internal cohesion. As a continuous deposit that may have accumulated without interruption over several thousands of years it has a two-layered structure that enables water to flow through its top few tens of centimetres. It is waterlogged below, and the anoxic conditions make it an ideal environment for the preservation of human artefacts and even bodies, and of other biogenic indicators of past human activity and climate.

The living biological (biodiversity) resource is concentrated at and above (birds) the surface where growth can take place, but is dependent on maintaining the hydrological and hydro-chemical conditions arising from the long and uninterrupted accumulation of the peat. The growth of the Sphagnum mosses and cotton sedges, so important in the continued accumulation of peat, can only occur where the rain-fed water table remains within a few centimetres of the peat surface for most of the year.

Changes have taken place over time so that much of the UK's blanket peat is no longer peat-forming, and is described as degraded. The processes involved in degradation, such as the lowering of the water table and the concentration of surface water flow so that the peat becomes eroded from ever-widening gullies, are incremental, and can lead to complete peat loss in locations such as Holme Moss, West Yorkshire. In such areas the peat can no longer support the specific plant cover which makes up its biodiversity importance; and erosion of the peat results in sedimentation and increased colour (dissolved organic carbon) down stream which have negative impacts on water resources, such as drinking water reservoirs. Much of the UK's upland peat is degraded. It may retain vestiges of its previous vegetation, or contain replacement plant types characteristic of non-peat environments. The UK BAP has a target to restore 70% of the degraded area to active bog. It is against this background, of a mixed intact and degraded resource, that the potential impact of wind farms on deep peat has been assessed.

Wind farm developments can have impacts at the construction, operational and de-commissioning stages. The types of impact are common to all stages, and involve: changes in water levels and flow, and dissection of the peat mass, but the duration and intensity varies. In summary, impacts result from the construction of access roads, the casting of turbine bases, the installation of turbines, drainage works associated with the construction process and operation of the site, ongoing maintenance, and then removal of turbines at decommissioning.

Roads may 'float' on the peat surface or be cut and filled to the sub-peat base. They require vegetation to be removed, waste peat to be disposed of, non-peat materials to be introduced, the movement of water over the peat surface and through its layers to be interrupted. They change the balance of water availability to different parts of the peat bog and channel surface flow so that is has a greater risk of initiating, or exacerbating, erosion. The digging of voids to caste turbine bases generates waste peat, introduces alkaline concrete and requires some drainage, as do the tracks. Drainage measures have the potential to lower the water level in the blanket bog, resulting in degradation and oxidation of peat. At sites which have a risk of peat slide, there is the additional risk of catastrophic peat failure and landslide. This can have catastrophic consequences for land and the environment, including water resources and fish populations, downstream. The actions taken in construction and operation of wind farms can add to the risk of peat slide.

Although the impacts on intact and degraded bog are much the same, on a degraded bog there are opportunities for the wind farm construction works to include measures that would improve the condition of the degraded bog, which are not present with an intact bog. On all types of blanket bog, how a wind farms is designed, constructed and operated makes a significant difference to how much the blanket bog is affected. Tracks can be designed to reduce the existing erosive forces, and be engineered so as not to create new ones. The blocking of existing drains and moor-grips can lead to beneficial changes towards 'favourable condition', the index of quality condition used in biodiversity assessments.

The ease with which erosion can be triggered, and the amount of material that can be eroded, increases with the depth of the peat deposit. In general, there are far more risks associated with the development of wind farms on deep peat than on peat less than 0.5m thick, or on the fringes around blanket peat. The imperatives for avoiding development on blanket bog sites are greater for those sites with international and national conservation designations. This leaves the remainder blanket bog resource relatively unprotected. These guidelines are intended to ensure that, where there are choices, wise judgements are made, so that the necessary proportion of the resource remains intact for biodiversity improvement and for atmospheric carbon capture in designated and undesignated sites alike.

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ABBREVIATIONS

Agency	The Environment Agency
AONB	Area of Outstanding Natural Beauty
BGS	British Geological Survey
CIRIA	Company providing research and training in the construction industry
DEFRA	Department of the Environment, Food and Rural Affairs (formerly MAFF)
DTM	Digital Terrain Model
EIA	Environmental Impact Assessment
H2	Standardised Test Value (FEH)
JBA	JBA Consulting – Engineers & Scientists
LiDAR	Light Detection And Ranging
NTS	Northern Telemetry System
PPG	Planning Policy Guidance
Ramsar	The intergovernmental Convention on Wetlands, signed in Ramsar, Iran, in 1971
SAC	Special Area of Conservation, protected under the EU Habitats Directive
SEA	Strategic Environmental Assessment
SEPA	Scottish Environment Protection Agency
SPA	Special Protection Area for birds, protected under the EU Habitats Directive
SSSI	Site of Special Scientific Interest
SUDS	Sustainable Urban Drainage Systems

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1 INTRODUCTION

1.1 Background

Blanket Bog is a Biodiversity Action Plan (BAP) habitat. The peat it forms represents the largest terrestrial carbon store in the UK. Blanket Bog development is dependent on a number of very specific conditions including sufficient rainfall, suitable temperature, topography as well as past land-use. In the North West of England, upland blanket bog typically occurs on the gentle slopes and plateaux of the South Pennines, West Pennines, North Pennines, Bowland Fells and Shap Fells in Cumbria. Blanket bog cannot develop on very steep slopes – as the bog drains under gravity, and even that formed on gentle slopes is prone to splitting and downwasting.

Many existing and planned wind farms in the North of England are located on areas supporting blanket bog habitat, or dominated by blanket peat. Assessing the impact of wind farm developments in such circumstances is essential, given the importance of peatland habitats as a nature conservation resource, and their sensitivity to development pressures. Additionally the large area of blanket bog in the UK, in excess of 1.5m ha, forms an important carbon store that may be diminished if the bog is drained or degraded.

Blanket bog is vulnerable to climatic change, recreational pressures, and poor management even without the direct impacts of wind farm development. The interactions between the different factors affecting blanket bog, and future trends, need to be better understood to ensure that, at the very least, wind farm development does not increase long term risk, and at best leads to greater sustainability of the carbon store and biodiversity resource.

1.1.1 Rationale for Research

Areas of upland blanket bog without any nature conservation or landscape designation are often targeted by wind farm developers. They are high, exposed, windy places often sparsely populated, and relatively unprotected by statutory regulations. National targets for renewable energy mean that there is a need to ensure that the different scales and types of on-shore wind farms are guided towards those areas that can most appropriately accommodate such a development without significant adverse effects on the natural environment.

Natural England's draft policy on wind energy (English Nature, 2001) acknowledges both the targets for renewable energy and the potential for damage to the environment that wind farms can cause. The draft policy suggests that each development should be considered on the basis of the balance of benefits and risks. This report aims to provide an evidence base to enable proper determination of the impacts of wind farm development on blanket bog.

Such a framework will help Natural England ensure that applications make realistic assessments of the environmental impact of proposed developments. Also, information on good practice and measures to mitigate against adverse environmental impacts allow developers to consider and compare the likely costs of mitigation and rehabilitation measures on peatlands when considering the siting of proposed wind farms.

1.2 Purpose of this report

The key aim of this report is to research the impacts of wind farms on blanket peat and produce guidance covering the main impacts posed by wind farm developments on peatland habitats.

1.2.1 Who is this report for?

This report is primarily for Natural England to aid input to wind farm site selection, scoping and all subsequent phases of wind farm environmental assessments and other associated casework. However, the guidance developed in the appendices also informs Local Authorities and Developers.

1.2.2 Report Structure

Overall the project has the following aims:

- To understand and collate evidence of the impact of wind farm developments on blanket bogs. This is undertaken via an extensive literature review – presented in Chapter 2 and in Appendix A.1.

- Develop comparative case studies for existing wind farms on peat and non-peat areas in northern England – presented in Chapter 3 and Appendix A.2.
- To develop a set of assessment criteria against which a development proposal can be tested to determine the scale of impact and enable an appropriate response to the Environmental Impact Assessment – presented in Chapter 4 and Appendix B1.
- Develop recommendations for good practice for developers and local authorities – presented in Appendix B2 and B3.

2 EVIDENCE OF IMPACT OF WIND FARMS ON BLANKET BOG

2.1 Introduction

Potential impacts from wind farms include: direct habitat loss through construction of wind farm infrastructure, and habitat modification and (in the long-term) habitat loss if there are adverse changes to the overall hydrology and structural integrity of the peatland.

Direct immediate habitat loss is due to access tracks, turbine bases, permanent crane pads and other ancillary infrastructure. Damage to biodiversity interests caused by altered hydrological regimes is less easily quantified, but in the long-term this may lead to more widespread habitat deterioration and so is a key focus of impact assessment. Impacts on carbon storage and sequestration reflect the wider environmental consequences of wind farm development on peatland sites, and also provide a useful integrated measure of impact on habitat quality and function. Wind farm developments also impact upon the landscape value of a site, and affect the geostratigraphic and archaeological interest, both in terms of their direct impacts, indirect impacts on peat hydrology and the methods used for their restoration and aftercare.

2.2 Literature Review

A list of the literature reviewed can be found at the end of Part 2 of the report (Appendices and References) and the tabulated detailed literature review is provided in Appendix A.1. The literature review is focussed on the particular impacts of wind farm development on blanket bog.

A wider, more general, consideration of the impacts of wind farm development on nature conservation is provided in the document: 'Wind farm development and nature conservation – a guidance document for nature conservation organisations and developers when consulting over wind farm proposals in England (English Nature, RSPB, WWF-UK, BWEA, March 2001). This document has steered wind farms away from designated environmental sites and has resulted in a many applications for wind farms on non-designated blanket bogs and degraded blanket bogs.

2.3 Blanket Peat Context

Blanket bog is one of the most extensive semi natural habitats found in the UK (approx 1.5m ha). Its distribution is complex, in that it is found mainly in the uplands in England, but is extensive even at sea level in the north and west under greater rainfall and humidity. Some of these areas are designated nature conservation sites including Special Areas of Conservation (SAC), Special Protection Areas (SPA), Ramsar sites, SSSIs and Natural Nature Reserves (NNR). Sites may also have other designations as landscape areas such as Areas of Outstanding Natural Beauty (AONB) or National Parks. Blanket peat sites with international designations (SAC/SPA) include parts of the North Pennines (http://www.naturalengland.org.uk).

Blanket bog is a Biodiversity Action Plan (BAP) priority habitat (**http://www.ukbap.org.uk**) and a Natura 2000 Annex 1 priority habitat (EC Habitats Directive). 'Active' blanket bog is defined by the EU as 'still supporting a significant area of vegetation that is normally peat forming'. The term 'blanket bog' refers to the rain-fed part of the system with the term 'blanket mire' including parts of the peat deposit also fed by water that has drained through or across the peat. Blanket mire habitat is restricted to cool, wet and typically oceanic climates. In the UK there are around 1.5 million hectares and this is a significant component of the total global resource.

Studies indicate that most blanket peat development began 5,000-6,000 years ago, but some peats began to form between 9,000 – 1,500 years ago. There is evidence to suggest that some areas of blanket bog began to form following clearance of the original forest cover by early man, but the relative significance of this activity and changing climate on the historical and contemporary extent of the resource has yet to be determined. A similar though more recent effect is seen in New Zealand, where 'pakihi', a type of blanket mire, has developed in Maori forest clearances.

A blanket bog drapes ('blankets') the underlying topography in a layer of peat. High (>1000mm/annum) and/or frequent rainfall (>200 days with more than 0.5mm) is needed to maintain constantly high water levels or surface water that allows bog mosses to survive (Hobbs, 1986).

The nature of peat is determined by its vegetation content and the environment in which it formed, this means it can vary significantly over a small geographical area (Hobbs, 1986). The habitats which develop include a diverse range of vegetation and fauna (Stroud *et al*, 1987). Both vegetation and the water environment (both water levels and quality) are sensitive to human and natural processes and their interactions (Holden *et al*, 2007a). Research has found that the peat system may change in response to environmental processes and their interactions and that the changes may be irreversible (Holden *et al* (2007a), Wallage *et al* (2006), Yelloff *et al* (2006)).

The rate of peat accumulation is determined by the net balance between the rate of input of plant litter and the rate at which it decomposes, which in turn is determined by the degree of oxidation of the peat environment, which is in part controlled by the water balance (Hobbs, 1986). Peat is often between 0.5 and 3m deep but can be deeper than 5m. There is no agreed minimum depth which can support blanket bog vegetation although thin or degraded peat may have wet heath rather than typical blanket mire vegetation. Such distinctions are relevant for habitat mapping. Thicker peat is generated with higher rainfall, higher water levels and concomitant anoxia, and occurs on the plateaux. The limiting slope for deep peat is 20 degrees, although thin peat may accumulate on slopes up to 45 degrees. Slopes are better drained and so the surface is drier, and less peat can accumulate. The kinetic energy associated with moving water leads to the development of deeper drainage channels on steeply sloping peat. The depth of a peat deposit is related to the time over which it has accumulated, but other factors, such as periods of dryness and net decay make a precise correlation with time difficult. Typical accumulation rates of blanket peat are up to around 0.5m/1,000 years (typically 10-40cm/1,000 years).

There are competing land uses in the UK uplands. These include water collection (reservoirs), agriculture, commercial forestry, sport and leisure and tourism (Holden et al, 2007a). Drivers for change in the uplands currently include land management (for example grazing, drainage and forestry) and socio economic change, atmospheric deposition of N_{ox} and $S_{ox,}$ and in the future climate change may have consequences for moorland processes (Holden et al (2007a), Holden, Chapman, Evans, Hubacek, Kay and Warburton (2007b)). The different land uses and activities within peatland areas are examples of peat ecosystem services, or the services provided by the natural environment that benefit people. In general terms peat ecosystem services can include food, fuel, cultural services, climate regulation, water purification, flood protection, nutrient cycling and soil formation (Defra, 2007). The value of these services can be estimated, for example the United Utilities and RSPB SCAMP project, which focussed on management and restoration of upland catchments, found benefits of £1.2M to £2.6M in reduced water treatment costs of restoring peat (Defra, 2007).

Wind farms are being proposed, not on virgin territory, but in an environment where other uses, values and services are already well-established.

2.4 Blanket Peat – Conceptual Model

Understanding the development and structure of blanket peat is an important step in understanding the likely impact of wind farm development. The structure of peat controls the movement of water through the subsurface and this, combined with drainage overland, is a key factor for vegetation growth and peat accumulation. Peat structure also determines the cohesive strength of the peat which is an important control on erosion and slope stability.

Peat is formed by the partial decomposition of plant material and will accumulate in an environment where the rate of litter fall is faster than the rate of decay (Hobbs, 1986). The standard conceptual model of blanket peat development divides the bog into upper and lower functional layers. The upper layer is known as the acrotelm and consists of living plants and organic matter decaying rapidly in the presence of oxygen, and is relatively permeable. The deeper underlying layer (known as the catotelm) is permanently saturated, decay processes are slower and oxygen is absent, and is less permeable to water movement.

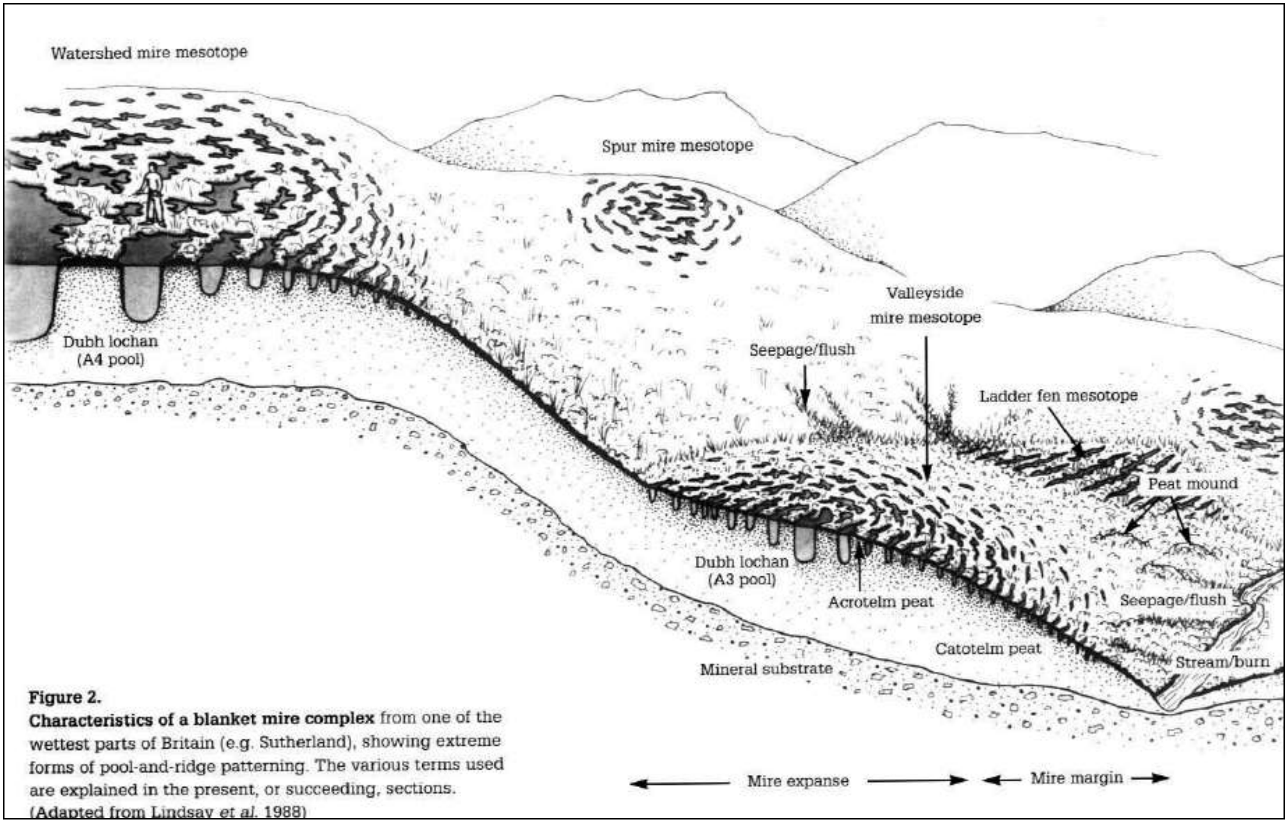


Figure 2-1 Section though a Blanket Mire complex

This model of peat structure is discussed in more detail in a range of sources including Hobbs (1986), Lindsey *et al*, (1988), Warburton and Evans (2007), Lindsay and Bragg (2005), Lindsay, Charman, Everingham, O'Reilly, Palmer, Rowell and Stroud (1988). The relative characteristics of each layer are detailed in Table 2-1, following.

Table 2-1 Properties of Peat Bogs

Acrotelm Properties	Catotelm Properties
Top 2 - 30 cm of the bog (typically 2 – 10cm thick)	The underlying part of the bog
Variable water table	Continually saturated
Oxic (oxygen present)	Anoxic (no free oxygen present)
Decomposition of soft plant tissue	Very slow (anoxic) decomposition of peat
Higher permeability (<0.1-3x10^{-5}m/s)	Very low permeability (3x10^{-7}-6x10^{-10}m/s i.e. 0.026-0.000052m/d)
Live vegetation and dead fibres	Pseudo-fibrous/amorphous texture
Low level of humification (low Von Post Number (indicator of humification i.e. decomposition of the peat)	Level of humification is variable (typically Von Post Number 7 to 9, but may be as low as 3)
Some tensile strength	Very limited strength
Notes. These are generalised properties. Source Hobbs 1986.	

In this conceptual model most water movement occurs in the upper acrotelm and is controlled by the level of groundwater in the acrotelm which may fluctuate over time. Water movement in the catotelm is very slow, controlled by the generally low hydraulic conductivity of the peat. Holden and Burt (2003) carried out field tests of hydraulic conductivity in peat. The dominant plant remains can have a significant influence on the hydraulic conductivity of peat (Charman, 2002 and Rycroft et al 1975).

The field work showed that the peat was highly variable in its physical properties and the calculated value of hydraulic conductivity was sensitive to assumptions made in the calculation. This highlights some of the issues when working with peat – it can be highly variable, both vertically and horizontally, across a small area and standard geotechnical methods may not always be appropriate. Recent work by Holden (2005) has suggested that there may also be more water movement than previously thought in the lower layers of the peat via macropores and pipes, formed, for example, from the erosion of root passages.

Other work by Bromley, Robinson and Barker (2004) on the lowland raised bog at Thorne Moor has indicated that permeability measurements in peat vary over several orders of magnitude when measured at different scales, using a variety of techniques. They trialled a method of using ditches and nearby water levels for estimating a more large scale value of permeability.

Humification (decay) results in peat varying from a light coloured mass of Sphagnum moss (and other peat forming plants) leaves, stems and roots of considerable tensile strength (Von Post number H1) through to a dark brown or black structure-less jelly (Von Post number H10), see Table 2-2 for further detail. The strength of peat is derived from both its fibrous structure and chemical interactions between the plant tissue and water (Hobbs, 1986). Generally, the fresher and more fibrous the peat: the higher the tensile and shear strength and the greater the water content, void ratio and permeability. The liquid limit[1] of peat is related to the cation exchange capacity (CEC) which determines how water is bound to the plant matter. Generally ombrotrophic peat (dependent upon rainfall – e.g. blanket bogs) has a very high CEC (similar to montmorillonite clay) although unhumified Sphagnum peat can have a CEC an order of magnitude higher than clays. As the degree of humification increases, the liquid limit of the peat decreases.

Table 2-2 Von Post Classification of Peat Deposits

Degree of decomposition	Nature of Liquid expressed on squeezing	Proportion of peat extruded between fingers	Horizon
H1	Clear, colourless	None	Fibrous peat
H2	Almost clear	None	Fibrous peat
H3	Slightly turbid, brown yellow brown.	None	Fibrous peat
H4	Strongly turbid, brown.	None	Semi-fibrous peat
H5	Strongly turbid, a little peat in suspension	Very little	Semi-fibrous peat
H6	Muddy, much peat in suspension	One third	Semi-fibrous peat
H7	Strongly muddy	One half	Humified peat
H8	Thick mud, little free water	Two thirds	Humified peat
H9	No free water	Nearly all	Humified peat
H10	No free water	All	Humified peat
Notes. After von Post and Granlund, 1926. von Post, L. & Granlund, E., *Sveriges Geol. Unders*., **C335**, 127 (1926).			

The stratigraphy of a peat body is determined by the conditions prevailing during its development. These may vary considerably over centuries (including dry cool periods and wet mild periods), and the type of peat laid down reflects these circumstances. This means that the structure of blanket peat may be highly variable (Hobbs (1986).

In the diplotemic (two-layered) conceptual model water can move rapidly through the upper layer, but slowly through the lower layers as controlled by the hydraulic conductivity of the peat. Additionally, water moves through pipes and macropores which may be some distance below the surface, often concentrated along the base of the peat interface with the underlying sediment (especially where this is of low permeability).

Peat properties may vary significantly across a small area: which can be important when making assumptions about its properties and likely behaviour. Care is required when using standard

[1] The water content above which a substance behaves as a liquid rather than a solid

geotechnical methods developed for other materials to model its behaviour, as these are not always easily applicable, (this is discussed in more detail in section 2.12).

Summary

Developing a conceptual model of blanket peat is an essential step in understanding the potential impacts of wind farm development in these areas. In particular:

- It is clear from the literature review that peat (blanket peat being no exception) differs from other materials for which hydrological models have been developed.
- Peat is strongly anisotropic; its properties vary over short distances, both vertically and horizontally.
- Peat has little cohesive strength, being largely composed of water, and can mass flow in its semi-fluid state.
- Peat can erode as smaller particles when subject to the energy of moving surface water (ditches, streams), dissolved organic carbon is also lost from peat bodies via drainage waters.
- Fast water movement in ditches and streams cause head-ward erosion.
- Its biodiversity value is dependent on maintaining its original (as laid down) structural integrity and a high water level.

2.5 Impacts of wind farm development on blanket bog

Wind farm development can be divided into several stages, and actions and decisions made at each stage have the potential to impact on the surrounding area. Blanket bog is a sensitive environment and this section reviews what is known about the impact of wind farms on blanket bogs.

Wind farm development can be divided into stages:

- Preparation – scoping, planning and environmental impact assessment.
- Construction – construction of turbine bases, roads and cabling, and operation of construction site.
- Function – operation of the wind farm.
- Decommissioning – removal of wind farm infrastructure.
- Aftercare – restoration of the site.

The impacts on blanket peat of each stage are reviewed in the following sections.

2.6 Preparation

2.6.1 Preparation - Scoping and Site Selection

Wind farm developers first have to identify an appropriate site. English Nature (now Natural England), RSPB, WWF-UK and BWEA produced a guidance document in 2001. This provides guidance on the development and siting of wind farms and how to limit their impact on the natural environment. Key guidelines relevant to development on peatlands are avoiding any adverse effects on the integrity (a term used in the Habitats Directive UK Regulations) of:

- statutory international sites;
- national wildlife importance sites;
- on key habitats of species listed in Annex IV of the Habitats Directive; or
- On hydrological processes which might have an adverse impact on the conservation of wildlife, geomophological or geological features.

In addition, the guidance recommends that, in cases where a wind farm development is likely to have adverse effect on a site of regional or local nature conservation importance, it should only be permitted if there are reasons for the proposal which outweigh the need to safeguard the nature conservation value of a site or feature. The guidance also recommends early consultation with key national nature conservation organisations, from the outset of the site selection process, which may enable avoidance or mitigation measures to be identified for sensitive locations. Planning Policy

Statement 9 (PPS 9) (2004) produced by the government states that strategic and specific wind farm developments should abide by sustainable principles to protect biodiversity and geological conservation interest.

The Irish Wind Energy Association (2008) has produced practical guidelines for the planning and construction of wind farms in Ireland. These guidelines recommend that feasibility studies cover the following issues: planning, environmental aspects, archaeology, visual impact, wind resources and proximity to other developments, as well as consultations with external parties to identify potential issues.

Summary

Key points regarding site selection identified from the available literature are:

- Avoidance of sites of nature conservation interest (including biodiversity and geological sites);
- Avoid indirect impacts on sites of nature conservation interest;
- Early consultation between developers and nature conservation organisations.

It is important to consider the ecological value of the site (whether designated or not) and to safeguard the hydrological process which maintain the groundwater dependant ecology of blanket peat.

2.6.2 Preparation - Planning Framework

Wind farm developments require planning consent. In England this is guided by Planning Policy Statements (PPS), a number of which are relevant to wind farm developments. PPS 1 (2005) outlines the Government's sustainable principles of social progress, effective protection of the environment, prudent use of natural resources and maintenance of high and stable levels of growth and employment which apply to all developments. PPS 7 (2004) specifies that rural development (which includes most wind farms) should be in line with the principles of sustainable development. PPS 22 (2004) sets out the government's objectives for renewable energy and that renewable energy projects should be encouraged within a planning framework that identifies suitable locations for them. The companion guide to PPS 22 (2004) gives practical guidance on the implementation of PPS 22 giving detailed guidance on wind farms and likely planning issues, including: landscape and visual impact; ecology and ornithology, which are particularly relevant to wind farms on blanket peat.

There are equivalent planning documents in Scotland (Scottish Planning Policy (SPP) 6 (2007) and Scottish Executive Planning Advice Note 45 (PAN 45)) and Wales (Planning Policy Wales (2002) and planning note TAN 8 (2005)), which contain specific guidance about wind farms which should be noted by local authorities in England.

There are other more general planning policies which are relevant to wind farm developments: PPS 23, which sets out pollution prevention and control measures, is especially relevant for wind farms developed in sensitive environments, such as blanket peat. Planning Policy Guidance 14 (PPG 14) gives advice on developments on unstable ground which includes wind farm developments on peat. Peat is a compressible material, very sensitive to the local water environment, and may be affected by site drainage schemes.

PPS 25 requires that developments in areas at risk of flooding, or greater than 1 Ha in size, should have a flood risk assessment. This requires wind farm developers to assess whether the wind farm might have an adverse impact on flood risk locally, or in the wider catchment. Wind farm developments that significantly change water movement through blanket peat, or which have particularly large areas of hard standing (not usually the case), might increase the flood risk downstream.

The Department of Environment, Heritage and Local Government in Ireland (2007) have developed guidelines for planning of wind farms. These are set within the Irish planning system. They provide guidance for assessing suitability of sites for wind farm development and an annex about development of wind farms on peat which gives best practice advice on wind farm development which can be applied to English peat land areas.

In summary, wind farm developments in England are currently controlled by planning policies which include requirement for sustainability objectives for renewable energy and minimising flood risk. There are other policies which control the site construction and operation including working on unstable ground and pollution prevention and control. However, the existing guidelines do not generally explicitly address the particular issues and sensitivities presented by blanket peat environments, and their dependence on high groundwater levels.

2.6.3 Preparation - Environmental Impact Assessment

An Environmental Impact Assessment (EIA) sets out the ways in which a development may affect the environment. General EIA guidance is available. The Department of Communities and Local Government (DCLG) (2000) and The Royal Town Planning Institute (2001) describe the stages in the procedure (see Appendix B.3). These include screening sites, scoping the EIA, describing the site, forecasting the impacts, determining their significance and identifying mitigation and environmental enhancements. The DCLG commissioned a review of the scoping stage of the EIA (2006) and concluded that this is very important for a successful EIA and confirms the view of other authors that effective consultation between developers and consultees is essential.

Scottish Natural Heritage (2nd Edition, 2005 (**http://www.snh.org.uk/publications/on-line/heritagemanagement/EIA/**) and the Institute of Ecology and Environmental Management (IEEM) ((**http://www.ieem.net/ecia/index.html**) have produced guidance for carrying out an EIA. These outline methods of assessing significance of impacts. For wind farm developments on peat the assessment of significance is based on:

- an analysis of the sensitivity of peat to change;
- the amount and type of change – as determined by the design of the development;
- the likelihood of an impact and how the wind farm would affect the peat (in comparison with no wind farm at the location).

In general peat is very sensitive to changes, however, the particular site and context of the development and current status of the peat should be considered in assessing the sensitivity of the peat.

The significance of an impact is a combination of these factors, based on how likely the event is to occur, and the sensitivity of the receptor. For example, an event which is unlikely to occur, impacting on an insensitive receptor, would have a low significance. The overall impacts may be assessed using a table or matrix, a general example for an EIA is found at **http://www.ieem.net/ecia/impact-assess.html#assess** and examples for peat risks can be seen in MacCullough (2005), Scottish Executive (2006). Alternative examples can be found for other developments (e.g. a matrix of impacts or a bridge design in Poole can be found at (**http://www.boroughofpoole.com/downloads/assets/1101216675.pdf**). However, there is no statutory definition of significance.

Specific guidance for wind farms is also available. Wind farms are listed under schedule 2 of the Town and Country Planning (Environmental Impact Assessment) Regulations 1999 (SI No. 293) and this means that an EIA may be required on a wind farms greater than a particular size (2 turbines or a hub height greater than 15m), if there may be a significant environmental impact. The Department for Communities and Local Government (DCLG) circular 02/99 states that a wind farm of 5 or more turbines, or above 5MW, is likely to have a significant impact and so require an Environmental Impact Assessment (EIA). These regulations give local authorities the opportunity to specify that an EIA is required for larger wind farms that are to be built on blanket bogs. However, the local authority can still request that the environmental impact on blanket bog (or other receptors) is assessed as part of the planning application, even if a formal EIA is not required.

The Department for Communities and Local Government (2001) have produced a guide for developers to help understand the EIA requirement. The Department of Environment, Heritage and Local Government (Ireland) (2007) wind farm planning guidelines list the potential impacts of wind farms and the role of the EIA. More detailed guidelines have been produced by the Irish Wind Energy Association (2008). These recommend that the EIA for a wind farm development on blanket peat should include the following:

- Slope stability
- Dewatering effects
- Sediment, erosion and nutrient control
- Impact of tracks and drains on hydrology and ecology
- Re-vegetation measures.

They recommend that the design should be examined in the light of these issues which reflect the unique properties and ecological value of peat. Although these guidelines have been written in the context of the Irish planning regulations, much of the advice and recommendations are generally applicable to wind farm developments on blanket peat.

The Electricity Works (Environmental Impact Assessment) (Scotland) Regulations (2000) include an annex which outlines the content of an EIA statement. The Scottish Executive have produced best practice guide for peat land slide hazards and risks associated with electricity generation developments (2006). These address the peat stability requirement for working on peat and are relevant to developments in England: further details are provided in section 2.12.

The literature contains reviews of environmental impact assessments for wind farm developments on blanket peat. These include the EIA and associated documents for a wind farm on the summit of Cashlaundrumlahan Mountain, near Derrybrien in County Galway Ireland where there was a serious bog burst during construction of the site in 2003 (Lindsay and Bragg, 2005) and a proposed wind farm on the Lewis Peatlands SPA (Lindsay and Freeman, 2008).

The Derrybrien review (Lindsay and Bragg, 2005) is focussed towards review of the peat stability assessment, although the report provides a general overview of the EIA process, reviewing factors that should inform an EIA. The current baseline conditions at the site, particularly those affecting peat integrity are important, these include: agricultural impacts, burning and erosion, moor gripping (including ditch orientation), erosion, forestry and peat removal. Additionally, the report provides: a review of mechanisms for peat movement and an assessment of potential impacts of wind farm construction and operation, which includes road construction, excavation of turbine bases, turbine towers and blades. The authors stress the importance of interactions of impacts and cumulative effects noting that the geographical boundary of the EIA may need to be wider than just the site boundary as the effects may be felt downstream. It should be noted that general EIA guidance produced by the Institute of Ecology and Environmental Management comments that the geographical extent of the EIA may not be clear at the beginning of the project and may need to evolve during the scoping stage (**http://www.ieem.net/ecia/index.html**). The Derry Brien scheme was submitted to the planning authorities as three smaller schemes and the authors note that assessment of the scheme as a whole during the planning process might have identified the need for a more rigorous EIA.

Lindsay and Freeman (2008) provide a critical review of an EIA for a proposed wind farm on the Isle of Lewis. In particular, the authors are critical of the developers' intention to make small adjustments to the site plan in response to unforeseen ground conditions or to minimise environmental impact. However, this is not unusual as the EIA may be based on outline rather than detailed design, and some limits of deviation from the proposed site layout plans may be agreed as part of planning conditions (see Appendix B.3). Planning permission may also stipulate that any variation in location of infrastructure greater than a certain distance (e.g. 50m) needs to be approved by the planning authority as a variation to the planning condition. It may be preferable in terms of minimising impacts to peat, and to avoid working in areas at a greater risk of peat slippage, to permit small variations to the site design, provided that there are no other adverse impacts (e.g. to landscape), than for development to be undertaken in areas of particularly deep and unstable peat. However, best practice would be for significant areas of particular ecological value, and locations of deep or unstable peat, to be identified at the EIA stage before the finalisation of the site layout.

Lindsay and Freeman also criticise the description of baseline vegetation, baseline erosion and the impacts on water quality. They argue that the EIA does not cover an adequate area and the site is unsuitable for wind farm development. Dargie (2007) responds to these criticisms suggesting that the adjustments are small on the scale of the development and that impacts are proportionally small. This review and response highlights the uncertainty that can arise within the EIA process. Lindsay and Freeman (2008) recommend that an EIA should:

- assess impacts in light of any potential changes to the original design
- conduct an adequate peat slide risk assessment
- use widely recognised methods where possible
- assess all potentially major issues (e.g. water quality).

Summary

Key points regarding the Environmental Impact Assessment of wind farms on peat identified from the literature are that the EIA should:

- Include an assessment of dewatering effects, sediment, erosion and nutrient control, peat stability, impact of tracks and drains on hydrology and ecology, water quality and re-vegetation measures. This should be based on a thorough understanding of the baseline conditions at the site, including the habitat types present.
- Include an assessment of cumulative impacts and impacts outside the site boundary. The

geographical boundary of the EIA may need to be much larger than the development site area and may be revised during the scoping stage of the EIA.

- Assess the impacts of any potential changes to the original design.
- Use widely recognised methods. It should be noted that the unusual properties of peat and its variable nature mean that geotechnical techniques developed for mineral soils should be applied cautiously on peat, as the physical properties of peat differ from other soils and sediments. These differing properties should be accounted for in working within a peat environment.
- Assess a scheme as a whole rather than in smaller sections.

2.7 Construction

The next stage of wind farm development is the construction. This includes access roads, turbine bases, electrical infrastructure including cabling and installation of turbines. Particular issues for the fragile peat environment include traffic access and management, construction methods and pollution prevention and control. CIRIA (2005) have produced guidance on implementing environmental good practice on site which should be followed during construction. However, these should be implemented with regard to the bog hydrology and ecology, and not just with regard to management of the construction site.

2.7.1 Track Construction

Access roads are required for wind farm construction and operation. Constructing roads across peatlands is challenging (MacCulloch, 2006). This is due to the fragile nature of peat and variability in peat properties, which mean that some difficult engineering conditions are likely to be encountered. Therefore measures should be in place to minimise the impact of any peat settlement or slumping.

Guidance by SNH (2005) questions whether tracks are required, and in cases where tracks are needed suggests that they are designed to be of minimum length and to avoid sensitive areas. Existing tracks should be re-used where possible. It is suggested that the initial width of wind farm tracks (up to 6-7m) can be reduced following construction to around 3-5m, to reduce the impact of the tracks on the environment. The maximum gradients typical of wind farm tracks are around 8 – 10% (1in12 to 1in10), although short lengths (less than 200 m) can be at a slightly higher gradient of 12.5% (1in8). However, tracks should normally have gradients of less than 2.5% (1in40) to permit efficient drainage of the surface. They need to bear the weight of large cranes needed to erect the turbines. These cranes are often delivered to site in pieces, weighing up to 72 tonnes, but may be moved as one unit (weighing up to 200 tonnes) via the site tracks between turbine sites.

The impact of all types of tracks on blanket bog habitat is of concern. SNH (2005) indicates that floating tracks may dink with serious consequences for the ecology and hydrology of the bog, construction costs, stability and carrying capacity of the track. It is suggested that deep areas of soft peat are avoided for tracks. In circumstances where geotextiles may be used, branches and brash are suggested as a better base layer than geotextiles in many circumstances, and are cheaper and may be available on site if there is forestry. However, the gradual decomposition of such materials may impact on the track carrying capacity over time.

MacCulloch indicates that wind farm developers often use techniques developed by the forestry industry including excavated tracks (economic in peat less than 2m) or ‘floating’ roads (in peat > 2m). However, MacCulloch was writing for the Forestry Commission in Scotland where peat depths may be greater than in areas of blanket bog in England. In recent wind farm developments in England (such as Scout Moor see Section 3.2), roads have been floated over peat depths of more than 60 cm. In the thinner peat bodies often present in England, excavation of roads to depths of 2m would result in very significant dissection of large areas of blanket peat, and it might be preferable to float roads over much thinner thicknesses of peat for instance thicknesses of greater than 0.5 m. However, there are likely to be impacts on the flow of water through and over the blanket bog whatever method of track construction is selected. The relative impacts of different track construction methods are described in the following tables. Cut tracks are constructed by excavating to rock (or a suitable, solid substrate) and then building the track using solid fill. This type of track has a very solid construction and is capable of taking very heavy loads. Cut tracks are, however, most disruptive of ground conditions, particularly hydrology and subsurface drainage. Effective drainage is therefore required to ensure that downslope blanket bog areas are not subject to erosion and do not dry out. Depending on the quality of design, construction and re-vegetation, cut tracks can result in landscape and visual impacts, for example where there are areas of exposed cut or fill, or where notches are visible on the skyline (SNH 2005).

Table 2-3 Advantages and Disadvantages of Cut Tracks (SNH, 2005)

	Advantages	Disadvantages
Engineering	Solid construction, capable of taking heavy loads	None
Landscape		Sections of cutting and embankment can be very visible
Biodiversity	Creates a source of soils and turfs for track-edge restoration	Direct loss of habitat
	Drainage across tracks can be controlled through planned installation of culverts	Can result in large scale disturbance and fragmentation of habitats
Geodiversity	Earth heritage impacts and opportunities can be pre-assessed	Direct impacts on earth heritage interest if not planned, managed and constructed properly
	Creates a locally compatible source of fill for track construction	Potential for large scale destruction of earth heritage interest
	Drainage and siltation can be controlled through planned installation of culverts	Fragmentation of earth heritage interest
		Potential for obscuring large sections of earth heritage interest

Geotextile tracks can be used to negotiate soft ground. Geotextiles are laid out along the route of the track to provide structural strength whilst reducing the depth of the sub-base which is required to carry a given load. Geotextiles can be used to construct temporary tracks, for example providing access to a borrow pit. The geogrid should be laid directly onto vegetation and the sub-base constructed on top. Careful removal will be required to ensure that the ground below the track is not damaged. Such tracks are likely to sink to some degree on peat and have similar concerns on peat to floating tracks.

Table 2-4 Advantages and Disadvantages of Geotextile Tracks (SNH, 2005)

	Advantages	Disadvantages
Engineering	Reduces the required track sub-base depth	Not as strong as cut tracks and can be subject to shearing
	Can facilitate temporary access	
Landscape	Avoidance of landscape and visual impacts associated with cuttings and embankments. Landscape and visual impacts limited to the track running surface	If track is raised it may create a prominent linear feature
Biodiversity	Less disturbance of habitats along the route of the track	Direct loss and fragmentation of habitat
	Soils remain intact	Can result in large scale disturbance and fragmentation of habitats
	Through drainage can be facilitated	
Geodiversity	Comparatively few direct earth heritage impacts	Requires construction material sourced elsewhere on or off site
		Potential for obscuring large sections of earth heritage features
		Soil sealing and loss under the track
		Risk of compaction and poor drainage under tracks on more organic soils

Floating tracks are sometimes used in areas of deep peat (typically 1 metre or more, but recently in depth as low as 0.6m in England [Scout Moor Wind Farm]) where conventional methods of track construction are neither practical nor desirable. Floating tracks avoid the need to excavate the peat and refill with imported rock. They are built up on the existing ground surface with layers of crushed rock reinforced with geotextile membranes (or brash / tree branches) to build up a strong base. The base is typically wider than the final track width, which results in spreading the track load, but also the impacts of the track. The weight of the track structure has the effect of compacting the underlying substrate. While this provides the track with additional strength, it can cause drainage or subsidence problems. Given the sensitivity of upland peat habitats, these effects can be of considerable concern. Drainage through or under the floating track should be maintained to prevent the structure acting as a dam, impounding water on the uphill side and causing drought on the downhill side. Regular maintenance inspections are required to monitor the operation of such drainage. The pattern of compaction is not easily predicted and the track may become distorted or may settle unevenly. This can reduce the track's load carrying ability and may require additional material to be added. This, in turn, may accelerate compaction and compound problems of poor drainage. Construction of the track should allow for continued drainage across the line of the track even under compaction and settlement. This may be achieved through the sub-base (by using coarse granular material) or by constructing drains through the peat at regular points along the length of the track (SNH, 2005).

Where floating tracks cross sloping ground (up to about 10°), some form of retaining structure is required to support the down-slope side. Without this, the track will tend to distort down-slope. From an engineering perspective, it may be sensible to use a combination of cut tracks on sloping ground and floating tracks in flatter and wetter areas. Floating tracks are not universally suitable, however. In areas of particularly wet peat it will be difficult if not impossible to achieve a floating track without very significant effects on hydrology and therefore on local habitats, and risking track failure. Tracks should avoid such areas altogether (SNH, 2005).

Table 2-5 Advantages and Disadvantages of Floating Tracks (amended from SNH, 2005)

	Advantages	Disadvantages
Engineering	Can provide access across areas of deep peat	Not suitable in areas of very wet peat
		Not suitable in more steeply sloping areas
		Subject to compaction and settlement, creating uneven running surface
		Load bearing capacity may be compromised
		Compaction makes installation of culverts problematic but can be avoided by good construction techniques.
Landscape	Avoidance of landscape and visual impacts associated with cuttings and embankments	Local visual impact where track has subsided or failed
	Landscape and visual impacts limited to the track running surface	
Biodiversity	Comparatively limited habitat disturbance	Direct loss
	Some through drainage of deep peat habitats can often (although not always) be maintained	Fragmentation of habitat but peat soil can remain largely intact, although peat will be compressed and so have a reduced permeability
		Tracks often sink down to bedrock, displacing peat
		Often results in upslope ponding of water as through drainage rarely unimpeded
		Does not create soils and turfs for track-edge restoration
Geodiversity	Less disturbance of sensitive materials; peat soil can remain largely intact	Requires construction material sourced elsewhere on or off site
	Some through drainage of deep peat habitats can often (although not always) be maintained	Potential for obscuring large sections of earth heritage features

Other approaches to road construction include:

- Tyre bales comprise around 110 to 120 car tyres, compressed into a lightweight block. Bales are secured by five galvanised steel tie-wires running through the bale. They have considerable potential for use in construction particularly where their light weight and ease of handling are beneficial. They have a porosity of around 50% and a permeability of approximately 0.4m/s, which makes them ideal for drainage applications. Studies have suggested that leachate levels from bales generally fall below allowable regulatory limits and will have a negligible impact on the water quality in close proximity to tyres. The construction of low-volume roads over soft ground represents one of the most promising applications for tyre bales. In the UK a public road was constructed in 2002 by the Highland Council and performed satisfactorily (until 2005 the date of the paper), despite heavy loading (Winter et al 2005).
- Problems were encountered with constructing roads over deep peat (8m depth) in East Sumatra, where drainage of the peat was not acceptable for ecological reasons (Barry et al 1995). Following some sinking of roads a technique was used which comprised timber piles pushed through the peat into the underlying soft clay. Various different combinations of piles, corduroy raft (lengths of timber placed side by side across the route and are then covered with a thick brash mat. Under extreme conditions the raft must be strengthened continually), stone pavement and geogrid were combined to assess the best method of road construction. The cost at 1991 prices was US$350,000/km, which is very expensive.

From an engineering perspective, it is important that the choice of materials reflects local ground conditions and the use to which the track is to be put (SNH, 2005). In order to minimise the impacts of all types of tracks on blanket bog the track should be constructed in such a way as to allow the passage of water (over the bog vegetation, and through the bog) in a similar manner as prior to the track construction, in order to preserve the hydrological integrity of the blanket bog unit.

Traffic on wind farm roads during construction (100 vehicles/day) is higher than on forestry roads (30 – 40 vehicles/ day) and this poses problems for road design and maintenance, particularly as vehicle loads are heavy, the maximum gradient of the road must be low and the cornering radii and width of the road may be large (Scottish Natural Heritage, 2005). To reduce the risk of failure of roads constructed over peat, the loading of the peat should be controlled so that the peat has time to undergo primary consolidation and so does not liquefy due to excess pore pressure. This can be achieved by limiting the loads carried by vehicles during road construction and initial usage. However, there may be time pressure to construct roads and infrastructure quickly, which may result in to rapid loading of peat and resultant failure (see MacCulloch (2006) for further information). This means that, to reduce the risk of peat failure sufficient time should be allowed for construction activities.

MacCulloch (2006) has developed clear practical guidance, including a geotechnical risk assessment which should be followed when designing and constructing roads across peat. Scottish Natural Heritage (2005) have also produced guidance which deals specifically with tracks across blanket peat and tracks built for wind farms. These provide practical guidance on suitable methods of construction and a framework in which the impacts of the tracks on natural heritage can be mitigated. Both these construction guidelines are relevant to wind farm developments in England. Other guidance includes CIRIA guidance on road crossings (1997), and SEPA guidance on road crossing design for migratory fish (**www.scotland.gov.uk/consultations/transport/rcmf-06.asp**) which provides guidance about reducing flow velocity, an important factor in initiating peat erosion.

Loss of both water and solids from roads has to be managed during construction and operation of the wind farm. Runoff (a potential cause of peat erosion) may be routed away from the road and possibly through culverts beneath the road. Road surfaces are drained to avoid ponding of water or interception of large volumes of water. Sloping tracks may act as conduits for water even if they do not have drains on either side. Runoff from tracks may carry a high sediment load, depending upon the construction and maintenance of the road. Splatter from vehicles can also spread sediment into adjacent water courses. Methods for managing runoff and sediment include best practice design of tracks and drains, use of some SUDS techniques, and methods such as swales, silt traps, geotextile fences, settlement ponds and buffer strips (Scottish Natural Heritage, 2005).

Generally floated roads are used over deep peat (more than 0.5m). For floating roads to succeed, they have to be carefully constructed and aim not to result in the failure of either the surface acrotelm (where present) or the underlying catotelm. Measures such as construction of drainage ditches alongside floating roads which cut through the acrotelm will generate weaknesses in the peat structure and so may initiate failure of the road. Additionally, the orientation of the road with regard to the peat is important, as tracks following contours will have the potential to slide down slope. The rate of loading of roads is important in determining their subsidence into the peat body. However, in some locations such as Derrry Brien, floated roads have failed and have also gradually sunk into the peat leaving them prone to flooding and likely to provide a channel for water flow (Philips J, Sept 2005). However, the compression of the peat, particularly the acrotelm, beneath the weight of the road is likely to result in a reduction in permeability of the peat, and so alter the flow of water through the peat.

Track construction impacts on biodiversity within its immediate location and on a wider scale through changes to the hydrology of the peat-dominated environment. The introduction or exposure of mineral soil or rock encourages minerotrophic species and those able to survive where water flows, such as the Soft rush *Juncus effusus*. Any mineral other than extremely base poor ones, such as granite, is likely to encourage additional plant species, and these may even include orchids, such as Heath sptted orchid *Dactylorhiza ericetorum*. It is for the conservation bodies to advise as to whether this is a welcome bio-diversification, or if it should be seen as the pollution of the blanket bog environment with an uncharacteristic flora. The minerotrophic effects, even from limestone, are likely to be very localised, and geological formations exist in which the juxtaposition of base-rich and base-poor plant communities are entirely natural, such as on the Sugar Limestone of the Cairnwell, Scotland (McVean % Ratcliffe, 1962) and at Swarth Moor, Ribblesdale, England. It should be noted that the base-rich flora of artificial tracks topped with lime-rich blast furnace waste at Thorne Moors, South Yorkshire, are included as reasons for notification as an SSSI.

Generally, at present the main track construction techniques used are likely to have at least a local impact on the peat hydrology. If this results in lowering of water levels, a change in water quality or erosion, this will negatively impact the ecology. If there is a raising of water levels this may have a benefit on the bog ecology. The wider impact will depend upon how the tracks interact with the wider bog hydrology. In low permeability peat the extent of the impact may be less than in more permeable peat.

2.7.2 Turbine Base Construction

Construction of turbine bases on peat is subject to many of the same issues as road construction. In addition, excavations are deeper, down to bedrock for installation of a concrete foundation pad. Once the pad concrete has set the excavation is generally back filled with rock overburden and provides the area of hard standing for installation and maintenance (Lindsay and Bragg (2005)). The excavated peat faces will drain and oxidise with resultant slumping if they are exposed to the atmosphere. On flat sites the excavation may fill until water is at the same level as the surrounding peat. On sloping sites the excavation may fill to the lip on the downslope side and the upslope face may continue to drain the peat. In practice, excavations may be dewatered as construction is difficult in ponded water. If this is the case, the peat faces will continue to drain the surrounding peat through the dewatering phase. The structure, surface profile and drainage of the material used for backfill determine how drainage occurs after construction. It is unlikely that the material will have the same hydrological properties as the original peat and soil. If the backfill is more permeable than the original peat, water will continue to drain from the surrounding peat after the construction phase (Lindsay and Bragg (2005). Where the turbine base and associated crane pad area is located on a slope, the final profile of the ground will be stepped to allow for the flat base and pad area – this may result in drying of the uphill side of the area.

Lindsay and Bragg (2005) also comment that developers generally drain the area around turbine bases to avoid uplift of foundations during construction (which may happen if they are below the water table) and to reduce the potential for deterioration in strength of concrete due to interaction between submerged concrete and peaty water containing humic acids.

Initially following casting concrete there is concrete bleed of liquid from the concrete, which should be managed according the best practice which should be outlined in the site construction method statement (CMS). Following the first few days when the concrete is initially cured, the concrete is likely to be fairly inert. However, if leachate from concrete is a concern the concrete foundations within the peat could be coated in an inert coating (following best practice such as British Standard BN EN 206-1 and relevant guidance e.g. Design Manual for Highway Works).

Exposed concrete is likely to attract a bryophyte (moss) flora uncharacteristic of the blanket mire, but it has no potential to spread into the peat areas. A typical moss would be *Homalothecium sericeum*.

2.7.3 Cable Installation

Electrical cabling must be installed at a wind farm, between turbines and the site sub-station, and from the site to a grid connection. This may require digging of trenches which may alter the drainage pattern during, and after, construction. Alternatively, trenchless techniques, such as insertion using a deep ploughing technique, may be used.

There are also potential risks associated with sediment transport and water quality during construction, as ditches and trenches can provide rapid flow pathways which are capable of initiating erosion. Guidelines recommend minimising the effects by: installing cables along-side existing roads where possible; backfilling trenches with peat spoil and replacing the existing turf vegetated side up (Department of Environment, Heritage and Local Government, 2007). CIRIA (2006) guidance is available providing technical advice for controlling water pollution from linear construction projects, which is applicable to both cable installation and track construction.

2.7.4 Forestry Management During Construction

Wind farm sites may include forested areas where tree felling is required. Best practice guidance (Forestry Commission, 2003) should be followed to minimise the impact on the water environment. Nutrients can be released following felling operations, and this may be a particular problem in peaty soils. Soil erosion is an important transport mechanism as nutrients bound to soil particles may be released in receiving waters. Upland waters are naturally nutrient-poor and biological activity is usually phosphorus limited. Any organic matter, such as brash and dead roots, left on site following clear felling has the potential to decay and release nutrients. This breakdown may take a number of years. In extreme cases phosphorous enrichment can produce algal growths, resulting in oxygen fluctuations and disruption of ecosystems (Forestry Commission, 2003).

Peaty soils with a depth of over 30 cm peat, such as areas of blanket bog with forestry, have a particular risk of nutrient release following felling of trees, as the peat is easily eroded and nutrients can leach from the felled area. If mineral soils with a high clay content, or which are strongly acid, are present, they will tend to bind phosphorous (Department of Agriculture, Fisheries and Food, 2007).

2.7.5 Peat Wastage and Water Quality Impacts

The structure and properties of peat are unique and may lead to loss of peat mass during construction. This can be due to erosion at a large scale resulting destruction of habitat locally and downstream as watercourses are loaded with peat material. Additional peat loss can occur through drainage of peat, lowering the water table and so allowing oxidation of peat and so loss of peat mass. Large scale peat landslide can also result in peat loss from a site: this is discussed in more detail in section 2.12 below.

Construction activities have contributed to peat wastage during wind farm development for example at Derrybrien (Lindsay and Bragg, 2005). The Scottish Executive Best Practice guide (2006) identifies potential triggers relevant to wind farm construction as:

- Alteration to drainage patterns
- Rapid ground accelerations from blasting or mechanical vibration
- Unloading the peat mass by cutting into the toe of a slope
- Loading of the peat mass by heavy plant, structures or overburden
- Digging and tipping.

There is also the potential for wind farms to have an impact on water quality both locally and further downstream of the wind farm. Peat environments are sensitive to local water quality which can affect vegetation growth and habitats (Hobbs (1986), Berry and Butt (2002), Holden *et al*, (2004), Yellof *et al* (2006), Holden *et al* (2007a, 2007b)).

There are guidelines for the management of water quality during construction activities and these are relevant to wind farm developments on peat. CIRIA provide guidance for sustainable urban drainage techniques (2004), which provides a source of techniques which may be applicable for controlling runoff from wind farm infrastructure and also for control of water pollution (2001 and 2006). The drainage to ground SUDS techniques can only be applied with care, if at all, in a peat environment as drainage to peat can cause instabilities. The 2006 document provides technical guidance for controlling runoff from a linear construction project and the framework presented in the guidance has the potential to limit the risk of pollution associated with roads, cabling and drainage associated with wind farm development.

The Environment Agency publishes a number of Pollution Prevention Guidelines (PPG). These set out the requirements of the law that developers must comply with, but also provide practical advice that should be adhered to during the development process. Of relevance to wind farm developments are:

- PPG 1 – General Guide to the Prevention of Pollution (2001 due for review in 2007);
- PPG 2 – Above Ground Oil Storage Tanks (2004);
- PPG 5 – Works In, Near or Liable to Affect Watercourses (2008);
- PPG 6 – Working at Construction and Demolition Sites (2001);
- PPG 7 – Refuelling Facilities (2004);
- PPG 13 – Vehicle Washing and Cleaning (2007);
- PPG 18 – Managing Fire Water and Major Spillages (2000);
- PPG 21 – Pollution Incident Response Planning (2004);
- PPG 26 – Dealing with Spillages on Highways (2002).

The DETR circular (02/99) and PPG 4 (Environment Agency, 2006) provide guidance to ensure that sites without mains sewage deal adequately with sewage. During construction there is a risk of pollution from concrete. Dransfield (2004) lays out a procedure for assessing the leaching of admixtures from concrete. The risk of ecological damage, particularly to water quality, from use of concrete may need to be assessed for a wind farm development. Blanket peat environments are generally very low nutrient, with limited dissolved solids, so small inputs to water chemistry can change the overall water quality significantly.

2.8 Biodiversity Impacts

The vegetation of blanket mire falls within a small range of NVC plant communities, some being more indicative of degradation than others. It is the categories of M17 (*Scirpus cespitosus – Eriophorum* Blanket Mire), M18 (*Erica tetralix – Sphagnum papillosum* Raised and Blanket Mire), some sub-communities of M19 (*Calluna vulgaris – Eroiphorum vaginatum* Blanket Mire) and *Sphagnum* rich stands of M20 that are associated with the 'active' bog in which the net accumulation of peat is more likely to occur.

Some stands dominated by *Eriophorum vaginatum* (cotton grass) may also be peat forming as this can be a dominant remain in many layers of peat bogs. There is no agreed way of unequivocally demonstrating that a peat surface is 'active' (net accumulation of peat), and the judgement is based on a series of indicators, such as extent and health of Sphagnum mosses, and the degree of permanent wetness. For example some lichen rich communities of M17 may be judged as non-active.

Other communities, such as flush, fen and swamp types, also form an integral part of the blanket mire landscape, and many of these may be peat-forming, even in the absence of Sphagnum mosses. Many of the typical plant species, such as *Calluna vulgaris* (heather), *Erica Tetralix* (cross-leaved heath), *Trichophorum cespitosum* (deer grass), *Eriophorum* species (cotton grass) and several of the bog moss *Sphagnum* species, occur throughout much of the range of the habitat, although their relative proportions vary across the country (**http://www.ukbap.org.uk** and **http://www.jncc.gov.uk**).

Deep peat does not always bear the above plant communities. Surface drainage and overgrazing may produce types of acid grassland or even bracken. These include U5 *Nardus stricta-Galium saxatile* grassland and U6 *Juncus squarrosus-Festuca ovina* grassland. Bowes Moor SSSI and Muggleswick, Stanhope and Edmundbyers Commons and Blanchland Moor SSSI (North Pennines SPA) both have these communities, and their distribution suggests they are at least in part over deep peat (Natural England Conservation Objectives). In other places, such as the West Pennines (Lancashire County Council, 2008), *Molinia caerulea* may become dominant over shallow or deep peat, and be associated with variable amounts of Sphagnum moss species. No work has been found to indicate what needs to be done to restore a cotton-grass based plant community from these degraded conditions, though impedance of artificial drainage and cessation of additions of fertiliser and/or lime would be necessary first steps.

The location of deep peat may also be masked by the tall heather of the *Calluna vulgaris-Deschampsia flexuosa* heath. While this community is more typical of soils such as found over free-draining gritstones, it can also extend onto dry peat. It is shown to be widespread in the Peak District (Rodwell (Ed), 1991), where cotton-grass based vegetation is still found on much of the deep peat.

It is important to point out that, although the nature and quality of the plant communities is dependent on maintaining the structure and hydrology of the peat, a peat body bearing degraded vegetation is still as vulnerable locally to additional physical damage (shrinkage, erosion, mass movement) as is an undamaged deposit.

Apparently degraded blanket peat is not always a consequence of human activity. Hulme and Blyth (1985) describe eroding peat in the Shetlands as part of a natural process. Nevertheless, the ground remains peat covered and the implication is that vegetation is able to re-establish on the surface left behind. It is not unreasonable to suppose that blanket peat on the edge of the climatic range within which it can form will be more susceptible to periods of nil growth and in which erosion is periodically the dominant process as the climate oscillates in the direction of dryness. Erosion features, whether natural or man-induced, are not currently included as features of scientific interest by the JNCC (JNCC, 1994).

Natural England is currently developing an inventory of upland deep peat in England from aerial photographs, which indicates a total area of approximately 320,000ha. However, only some of this is blanket bog – previous estimates based upon BAP inventory values give areas of around 280,000 ha of blanket bog. This work has already been undertaken in Scotland. Blanket bog habitat is defined as 50cm of peat (with appropriate vegetation), peat soil is generally defined as 40cm of peat.

As discussed in section 2.4 the development of blanket peat depends on a complex interaction of water and vegetation. Development of wind farms can have a direct impact on vegetation, particularly during construction. Guidance produced by English Nature, RSPB, WWF-UK and BWEA (2001) outlines how to minimise impact on the local environment. In the longer term biodiversity may be affected by vegetation changing in response to new local hydrological conditions associated with the wind farm development. The impact of wind farms on hydrology is discussed in detail in section 2.9 below.

The UK Biodiversity Action Plan (2001) details the Habitat Action Plan (HAP) for blanket bog (**http://www.ukbap.org.uk** originally published in 1999). The Blanket peat HAP contains objectives and targets for blanket bog, these include:

- Maintaining the extent and distribution of blanket mire in favourable condition; and
- Targets for improving the condition of degraded blanket mire (phased improvements resulting in approximately 75% of restorable blanket mire in, or approaching, favourable condition by 2015).

This means that wind farm developments have the potential to adversely affect the UK BAP target even if they are located on an area of degraded peat that might otherwise be restored, and result in damage to habitats or make the peat more difficult to restore. It is important that wind farm developments are implemented in such a way as not to prejudice future restoration of blanket bog areas. Dargie (2004) gives examples of sites where habitat mitigation measures have been implemented during wind farm development. These have included blocking of drains, reduction of grazing and offsetting of impacts by creation of new areas of blanket bog (usually through deforestation of adjacent land).

Holden, Chapman and Labadz (2004), note that vegetation on peat is highly sensitive to water levels. Large changes in vegetation type can result from small changes in groundwater levels and this may lead to a change in the assemblage of species and the overall habitat.

An indirect and potentially important impact on blanket bogs from wind farm construction is the improved access given to moors via the new access tracks. This can result in an increase in winter sheep grazing as a consequence of farmers being able to bring large loads of supplementary winter feed (e.g. turnips) on to the moors at some of the well established wind farms in central Wales. This will have a particular detrimental effect on the vegetation, particularly increased browsing of dwarf-shrubs (heather), local enrichment and trampling of bogmosses. Improved access can also lead to increased illegal use of moorland, including bogs, by off-road traffic, especially mountain and trail bikes (this is seen at the Scout Moor Wind Farm site).

Figure 2-2 Storage of Turnips on Blanket Bog at Carno Wind Farm (Wales)

Construction may also have direct impacts on vegetation and habitat. Guidelines for wind farm developers from the Department of Environment, Heritage and Local Government in Ireland (2007) recommend storing vegetated turf off-site, watering in dry periods and using it to recover bare areas. They also recommend keeping grazing stock from re-vegetated areas until the vegetation has re-established. It is important not to spread excess peat on top of existing vegetation, as this will result in both the drying out of the spare peat (with a loss of peat mass) and also the destruction of the vegetation (Philips 2005), and the extent of the impact of the construction on vegetation will become larger than necessary.

2.9 Hydrology Impacts

Understanding how blanket peat works as an integrated hydrological system is essential to assessing the impact of wind farms. Section 2.4 described the conceptual model of blanket peat, and 2.8 the range of vegetation found on it. This is a two layer system with the potential for rapid flow through the upper acrotelm and slow flow through the lower catotelm. In addition, there may be rapid flow pathways via natural pipes which may develop in the lower levels of the peat. However, in a degraded blanket bog situation the upper acrotelm layer may be mostly (or completely) absent due to oxidation and degradation of this near surface recent peat layer and the absence of current peat accumulation. The absence of the acrotelm and the presence of areas of bare peat leave peat particularly vulnerable to erosion because surface water creates channels in the surface that gradually deepen and get wider, rather than flow on a broad front through a porous acrotelm.

Rain provides the main input of water to an upland blanket peat system. There may also be a contribution from groundwater and local runoff from outcrops of rocks and mineral deposits within the blanket mire macrotope. Some water is lost to evaporation and run-off. The remainder moves through the permeable acrotelm and reaches the catotelm. Hobbs (1986) considers water storage in peat which includes water stored in pores or cavities (which can be drained by gravity), water held in places by capillary forces which can only be removed by peat consolidation or compaction and water within the peat structure which is very difficult to extract.

The creation of channels may be initiated by large volumes of surface water arising from storm peaks, too great to be contained in the acrotelm. Some outflow from peat may also be along peat pipes within the deeper catotelm peat. Baseflow via slow seepage from the catotelm only makes a significant contribution to water outflow from peatlands during prolonged dry periods. The surface water runoff has the capacity to produce a strongly peat-forming environment through the sustenance of Sphagnum mosses when spread over a larger area, such as via diffuse overland flow, but also to cause erosion where the flow is concentrated within channels. Even relatively small channels, or lines of concentrated flow, such as those generated by vehicle tracks, once they start transmitting water have the potential to erode over time and form erosional features.

2.9.1 Peat Permeability

The rate of water movement through the peat matrix is controlled by the hydraulic conductivity (see Section 2.4). Holden and Burt (2003) investigated the hydraulic conductivity in a set of field tests at Moor House National Nature Reserve and found that the results were sensitive to the assumptions made about compressible nature of peat and the effective stress. They also stated that the blanket bog was highly variable and included preferential flow paths. This is of particular relevance to wind farm developers as ground conditions and the local impact of the development may vary across short distances.

Gilman (1994) showed that the effects of drains has effects over at most 50m. This is generally for fen peats. Similar effects will be seen in ‘active’ blanket bog where there is a thick acrotelm. Where drainage channels intersect underground channels in the peat (peat pipes) their effects can spread over 50 m of more Headley (2009b). However where the blanket bog has very little or no acrotelm the short distances of effects of drains is seen as in Ireland and parts of the ‘Flow Country’ in Scotland. Here the high levels of humification of the blanket bog peat and lack of an acrotelm (typical of much of the Pennine blanket bogs) results in narrow zones of drying out either side of drains in the order of 5 to 10m at the most. In some cases the zone of influence only extends for 2m (Burke 1961 and Dargie pers. comm.). However, it must be remembered that the lack of an acrotelm is an unsatisfactory degraded condition, a prime target for improvement under the blanket bog HAP.

2.9.2 Blanket Bog Water Levels

Water levels control the balance between peat accumulation and decomposition (Holden, Chapman and Labadz, 2004). Lowering of the water table can cause settlement of peat (Hobbs (1986), Holden *et al* (2004)) reducing the porosity due to compaction of the peat. Not surprisingly un-compacted peat can store greater quantities of water and discharge from a blanket bog with a thick unsaturated acrotelm will be slower during heavy rainfall events than those without an acrotelm where surface run-off drains rapidly to small defined channels. The average position of the water table relative to the peat surface and its variation is an important control on the type of vegetation that can be supported (Holden *et al*, 2004). This controls the degree of waterlogging and the amount of capillary water available for mosses.

Wind farm developments affect the drainage from blanket peat. Turbine bases affect local drainage during construction and may have a longer term impact on flow pathways and water levels determined by their construction (Lindsay and Bragg, 2005). Roads may interrupt the natural drainage network including both the subsurface flow through the peat and where they cross water courses. This may cause ponding of surface water on the upslope side of a track and lowered water levels on the downslope side. The risks of increased erosion associated with outflow from areas of ponded water can be significant locally. Lindsay and Bragg (2005) state that floating roads often start to subside by compaction of the acrotelm during dryer periods. Over time the lowered road surface starts to provide a flow pathway, unless the level of the road is maintained above that of the surrounding bog.

Holden *et al* (2004) outline the potential negative impacts of drainage as:

- Downstream flooding
- Subsidence
- Increased aerobic decomposition of peat (leading to the peat becoming a net source of carbon)
- Changes in vegetation.

2.9.3 Water Quality Impacts

Activities such as drainage on blanket peat, including wind farm developments, have the potential to affect water quality (Holden *et al* (2004), Wallage *et al* (2006)). Rainwater fed bogs generally have very low nutrient waters (nitrogen, phosphorus and potassium) and an ionic content similar to that of rain water, but with more hydrogen ions (low pH) arising from cation exchange in the living Sphagnum moss and in peat. The time that water spends in the peat influences its chemical composition. Downstream, water quality can also be affected by a change in sediment processes where watercourses can be loaded with sediment following erosion.

Water quality is one of the factors influencing vegetation; and input of nutrients, e.g. following forestry removal, or diversion of groundwater with a higher mineralisation can result in the development of different, more fen-like, vegetation. Areas of localised water flow from wind farm tracks has resulted in the expansion of poor-fen vegetation dominated by star sedge or soft rush (M6 *Carex echinata-Sphagnum recurvum/*auriculatum mire) on blanket bogs in Scotland (Dargie *pers. comm*.). These may be local effects associated with lowered water levels and pollution or wider effects due to change in runoff rates and pathways. The M6 NVC community is common on hillsides flushed with groundwater or irrigated by surface water flow.

Mobilisation of fine sediment during construction activities, or following erosion, can have important consequences downstream, particularly for public water supply where the cost of treatment can be significantly affected by water quality (Holden *et al*, 2007a and 2007b). Increased sediment loads to rivers with fisheries can potentially result in increased sedimentation within salmonid breeding grounds (‘redds’).

The construction materials used in wind farms sites should be such that they do not have a significant impact on the water quality environment. In particular the use of materials in the construction of roads has the potential to leach dissolved solids into drainage water and materials which are relatively inert should be used. Limestone materials should not be used in roads. Water in contact with it is likely to be more alkaline and contain basic ions that may change the vegetation in the immediate surroundings, but see 2.7.1.

2.10 Wind Farm Operation

During operation of a wind farm the medium and long term impacts on the peat are associated with the permanent site infrastructure such as roads, turbine bases and hard standings. These can include alteration of surface and groundwater flow patterns, peat subsidence, sediment release and chemical pollution. Changes to the blanket peat can lead to changes in the vegetation, habitats and biodiversity.

Surface flows may be locally altered by new drainage systems. Groundwater flow patterns (and the diplotelmic structure of the mire) may also be locally modified by turbine bases, the foundations of the substation and cable trenches, which may act as groundwater conduits, or barriers. There may be localised disruption of flow paths near the turbines and a slight lowering of the groundwater table near drainage ditches. The impact of wind farms on blanket peat hydrology is discussed in detail in section 2.9 above.

Hard standing areas are impermeable and water flows rapidly away from these surfaces: this may increase the rate of runoff, and hence increase the erosive energy. Poorly designed surface water crossings, particularly piped crossings can result in upstream flooding and downstream erosion. Sediment can also be released from poorly made tracks where ruts provide a preferential flow pathway that will erode quickly. These impacts can be reduced or avoided by use of the available best practices (e.g. track design and construction – MacCullough (2005), SNH (2005)).

Where there is significant lowering of water levels around turbine bases, resulting from drainage. Peat subsidence may occur in response to long term lowering of water table following changes to drainage patterns round turbine bases (Lindsay and Bragg, 2005).

There may also be a gradual lowering of any floating tracks, and of any drained areas, due to peat compaction or loss, as a result of oxidation or loading, resulting in ground lowering and subsidence. This can result in tracks acting as water courses with high erosive energy.

2.10.1 Decommissioning

The impacts of decommissioning a wind farm are potentially similar to construction impacts. In particular, traffic access and management, engineering methods and pollution prevention and control concerns are similar (though potentially of lower magnitude) in decommissioning and have been discussed in section 2.7 above. In addition, there may be an impact from waste disposal which must be sensitivity managed in a fragile environment.

The British Wind Energy Association state on their website that the way a wind farm should be decommissioned may be specified as part of the planning conditions. These typically state that all visible traces of the wind farm should be removed although it may be better to leave tracks and turbine bases in place as this minimises disturbance. However, an assessment should be made of the impact that the existing tracks and bases have had on the blanket peat. Turbine bases may be reduced in height to below the level of the surrounding area and covered with peat, stone or other local material (British Wind Energy Association (1994), Scottish Power (undated Wind farm Sustainable energy Policy)). The Irish Wind Energy Association (2008) state that based on experience in other countries repowering is more likely than complete decommissioning of the site. Repowering is currently being considered at sites in the UK (Ovenden Moor, Chelker Reservoir, Coal Clough – see section 3.2 for further details). This typically involves construction of new turbine bases and decommissioning of the original bases, with some requirement for new tracks. In some cases turbine base locations and tracks may be reused – which will have a lower impact.

A DEFRA research project carried out by the Moors for the Future partnership (2008) has collected information about peat restoration and erosion control methods currently employed across the UK. This is a useful source of information for wind farm developers considering the most appropriate methods to use for site decommissioning.

2.10.2 Site Aftercare

Partial removal of the wind farm infrastructure will not automatically restore the blanket peat to its condition prior to the development as impacts on surface and groundwater flow will remain and vegetation is unlikely to recover to its original condition whilst the bog is partially drained. Peat restoration has been investigated, generally with a focus towards restoring previously drained peat lands. Holden, Chapman and Labadz (2004) identified two main restoration goals. These are restoring the water table and re-colonisation with important plant species.

Restoring the water table is generally carried out by blocking ditches. Although, if there has been drainage, headward erosion, oxidation and cracking of the peat fabric, the peat may no longer be able to hold enough water to maintain the required water levels during drier periods. Re-colonisation can also be difficult, particularly in more marginal peatlands.

Wallage, Holden and McDonald (2006) and Worrall, Armstong and Holden (2007) have investigated the water quality and runoff associated with restoration. Wallage *et al* (2006) found that drain blocking activities did reduce colour and dissolved organic carbon. However, they found that there was still a difference between original intact areas and the restored areas and attributed this to modified flow pathways through the peat. They concluded that it may not be possible with current techniques to fully restore the hydrology and biochemistry back to their pre-drainage conditions. Yellof, Labadz and Hunt (2006) found that in the South Pennines marginal and degraded peatland habitats are more prone to significant and irreversible changes.

A constant theme of this, and other research, is that once peatlands have been changed by human activities it is very difficult to reverse these changes although their main impacts can be reduced. This applies to changes carried out to improve agriculture, forestry and game management as well as wind farm construction. Holden *et al* (2007) identified that more work is required to understand how activities in the uplands affect environmental processes which rarely operate in isolation. Links between processes are a key control on peatland development and the consequence of changes in management may be unexpected, as feedback mechanisms between hydrology, vegetation and land management can be complex. They state that successful restoration of some moorlands may depend on a number of factors and this is important to consider when planning restoration of wind farm sites.

Holden *et al* (2007), note that the impact of activities in the uplands mean that many moors are not in a truly natural state and restoration activities aim to return them to a habitat state as it would have been a few decades or a century ago. The baseline condition of the wind farm location when the EIA is undertaken may not be favourable, and this may influence the restoration activities. However, the overall aim in blanket bog areas to return the bog to active peat forming vegetation, is valid whether the peatland is in a natural or altered state.

2.10.3 Summary

Key impacts of wind farms on hydrology have been identified as:

- Lowering of water levels associated with drainage around infrastructure. Potential consequences include vegetation changes, subsidence and increased decomposition of peat.
- Change in stream flow in response to change in site drainage. This includes rapid runoff following development of preferential flow pathways or an increase in paved areas and flooding associated with restrictions (e.g. culverts and bridges). This can result in downstream erosion of the bog surface.
- Change in local water quality due to change in drainage pathways and residence time of water within the peat.
- Change in downstream water quality due to change in runoff patterns or sediment supply.

2.11 Overall Impacts – Blanket peat integrity

1. Previous sections have identified that blanket peat is a complex system with close links between surface and groundwater, vegetation, habitat and water quality. Wind farm development can have an impact on any of these components and in turn affect the overall blanket peat integrity. Blanket peat integrity is the continued functioning of an extensive area of blanket mire as a peat-forming ecosystem in which the hydrology has inter-dependent linkages across its entire extent.

Conservation guidelines (English Nature *et al*, 2001) state that wind farms should avoid adverse impacts on sites of high conservation value. This directs developments to areas of lower conservation value, i.e. non-designated sites. However, these sites include blanket bog with a range of blanket bog development, in a variety of conditions, with a variation in current ecological interest. Within a non-designated site areas of particular ecological interest, with blanket bog habitat in good condition should be avoided in preference for areas which have less blanket bog habitat interest or are more degraded. There may be a requirement to balance the potential impacts on blanket bog compared to other environmental receptors within the site selection, and site layout design stages of the wind farm proposal.

The integrity of these sites may already have been affected by a range of land management activities, for example forestry, drainage, grazing, moor burning, old peat cuttings (Holden *et al* (2007a, 2007b) and quarrying or mining. Historical management of some blanket bog areas has resulted in degradation of the blanket bog integrity through:

- Removal of the top layer of peat, including the acrotelm e.g. through cutting or burning;
- Dissection of the peat mass through gullying – this may be initiated by gripping or small drainage works which have evolved though erosion over many tens of years to large open gullies cutting down to the underlying sediment.
- Dissection of the top of the peat through drainage, e.g. for forestry.

These processes have the potential to reduce the integrity of the blanket bog as a hydrological unit. A peat hydrological unit can be defined as a single continuous area of peat where:

- The peat is continuous, and has a continuous water table.
- The peat lies within the same water catchment (of the surface and groundwater within the peat).
- Impacts on the water level, or hydrology, of the peat in one location have the potential to impact the peat in another location.

Boundaries of a hydrological peat unit could include the following:

- A surface water course which completely cuts the peat body (e.g. a gulley).
- The edge of the peat.

The hydrological unit that a blanket bog forms should be considered in the setting of boundaries for assessing environmental impacts. The area considered for environmental impacts must include the direct and indirect impacts. Sufficient land should be included within the proposed development boundary to account for: any potential micro-siting; the full extent of the works including areas impacted near to infrastructure; successful implementation of proposed mitigation and any habitat enhancement measures.

2.11.1 Sites with Significant Erosion

Erosion is an important factor causing degradation of blanket bog. Human activities such as improvement for grazing are thought to have contributed to the extensive erosion seen in UK peatlands such as the Pennines (Holden *et al* (2007a), Holden *et al* (2007b), Yeloff, Labadz and Hunt (2006), Warburton, Holden and Mills (2004)). Peat is a soft material and can easily be removed by frost-heave, water flow and wind once the surface vegetation is removed (Warburton and Evans, 2007). This clearly has an adverse impact on the integrity of the site and may affect water levels (and therefore vegetation) but may also have an impact further downstream with changes in water quality (dissolved organic carbon) and sediment transport in watercourses. Wind farm activities have the potential to initiate erosion processes or to increase erosion. A Defra research project carried out by the Moors for the Future partnership (2008) has collected information about peat restoration and erosion control methods currently employed across the UK. Wind farm developers should take account of this information along with standard industry good practice (e.g. PPG 14 (Annex 1 (1996)), CIRIA (2005)).

2.11.2 Sites Dissected by Gullies

Gullying, or drainage (e.g. gripping), which has cut the whole way through the peat, dissects it into separate hydrological units. In some areas these gullies have a wide area of slumped or wasted peat covering tens of meters around the gulley, forming a low valley within the peat topography. Where this has occurred, the hydrological integrity of the blanket bog is already disrupted, and the emphasis needs to be on blocking gullies to prevent further loss of peat. The impact of a wind farm may seem small compared to the impact of the gullying, but has the potential to exacerbate an already damaging situation.

There is scope in these situations that careful siting of tracks and associated drainage on the site could be used to reduce rapid runoff. This combined with mitigation measures to block gullies could result in a reduction in the erosion from sites which have already been severely eroded and begin to repair the peat-forming ability of the bog. It is clearly easier to block small narrow gullies than very large gullies with a wide area of surrounding degraded peat.

2.11.3 Impacts of Forestry on Blanket Bog

Wind farms sometimes focus on sites which have been forested, or are adjacent to forested areas. Research on the impact of forestry on blanket peat has been carried out (reviews can be found in Lindsay *et al* (1988), Lindsay and Bragg (2005), MacCullough (2005), Holden *et al* (2007b)). Key impacts are lowering of water levels in the peat in response to drainage, water demand for tree growth and interception of water by the forest canopy. The consequence of this is change in vegetation type (Lindsay *et al* (1988) comment that the original vegetation is almost totally destroyed in 10 – 15 years), subsidence and shrinkage of the peat and change in soil structure (Stroud *et al* (1987)). Fertiliser is often added. There is generally no blanket bog vegetation interest remaining at mature forestry sites, unless small areas of open bog have been left unplanted. Active peat formation may re-commence after felling if suitable restoration measures are implemented. However, the original state of the peat is unlikely to be regained, due to the widespread drainage measures implemented during forestry, which will have impacted the fabric of the peat.

Developing windfarms in afforested blanket mire has potential risks, e.g. associated with peat slippage, but may also offer biodiversity gains through restoration management, and this could be of significance given the very limited ecological interest under a standing crop of trees.

The relevance of the intact peat conceptual model to peat degraded by forestry is unknown. The emphasis must be on re-establishing a diplotelmic mire, and this involved the rejuvenation of the acrotelm vegetation by maintaining a constantly wet surface suitable for the growth of Sphagnum mosses and cotton-sedges. The impact of a proposed windfarm has to be considered in the context of the potential for successful implementation of such restoration measures.

2.12 Peat Stability and Landslide

Peat instability, either natural or induced by human activity, can have a major impact on blanket peat integrity. Assessing likely impacts on this is important for several reasons, not least that the hydrology of the wider peat body and the vegetation depending on it relies on the peat body remaining intact. Large scale movement of peat has been attributed to wind farm development, notably at Derrybrien in Co Galway where a significant peat slide occurred during wind farm construction (Lindsay and Bragg, 2005). This followed heavy rain after a dry period and peat moved downstream with a significant impact on water quality and water supply, and caused a serious fish kill incident. Other examples of peat landslide have been reported including: Pollatomish, Co Mayo in 2003; Cuilcagh, Co Fermanagh (where peat slides appear to have been initiated by peat cutting and heavy rainfall (both reported in Geological Survey of Ireland (2005)); and Channerwick, Shetland in 2003.

Warburton *et al* (2004) discuss peat slides in the North Pennines summarising 18 peat slip events which occurred between 1870 and 1995. In general the peat slid at the interface between the peat and underlying clay or in the clay just below the peat layer. They have identified that in seven of these events there was evidence of moor gripping or peat cutting, and in nine events peat pipes were reported. However, in seven events neither of these potential triggers was reported. This demonstrates that although human activity is associated with peat instability there are cases where the peat is intact but can spontaneously develop instabilities, particularly after heavy rainfall.

Work by Dykes, Gunn and Gonvery (2008), on Cuilcagh Mountain upland suggests that slowly changing internal thresholds, rather than human factors may account for areas which are particularly prone to landslides. The northern and eastern sides of the Cuilcagh Mountain upland, in northwest Ireland, are mantled with over 50 km^2 of blanket bog that has experienced an unusually high spatial and temporal frequency of peat mass movements. In all, 29 peaty-debris slides, nine bog slides, two peat slides and five more peat landslides of uncertain type have been recorded within this study area. Field and laboratory investigations of the peat at several of the more recent failure sites showed it to be typical of Irish and Pennine (northern England) blanket bogs in most physical and hydrological respects. Field geomorphological evidence and modelling of stability thresholds indicate that the particular susceptibility of the Cuilcagh Mountain blanket bog to failure arises from two local factors

- The attainment of threshold maximum peat depths on the East Cuilcagh plateau; and
- The unconformable deposition of thin layers of glacial till (in places) and blanket peat over the pre-existing topographic surface formed from the major shale formations that underlie the northern slopes.

With two exceptions, there is no conclusive evidence that human activities and management strategies for the Cuilcagh area have had any significant influence on the occurrence of the peat landslides. The high frequency of large rainfall events since 1961 that did not trigger landslides suggests that failures are unlikely to become more frequent in response to climate change effects because they are controlled by slowly changing internal thresholds.

Generally, surface fibrous, non-humified peat is fairly permeable, and therefore can drain effectively. This type of peat may be quite stable. However, in more humified (decomposed) peat instabilities may develop, and unhumified peat is usually underlain by humified strata.

The Geological Survey Ireland (2006) have identified mechanisms for peat landslide including:

- Slippage of peat: as a raft of peat along the base of the peat or a weak humified layer within the peat, or as rotational slides of peat and sediment. Slides may occur on fairly flat plateaus of blanket peat bog and on the sides of blanket bogs. Failures can initiate with sliding and may degenerate into peaty flows of debris, before becoming incorporated in stream channels as peaty debris floods. Peat can travel several kilometers, particularly if it enters a watercourse.
- Bog bursts or liquefaction of peat usually involve rupture or tearing of the peat layer with liquefied peat often being expelled along the margin of the peat mass or through tears on the peat surface.

Peat slides are generally used to describe slab-like transitional failures with a shear mechanism operating within a discrete shear plane usually at the base of the peat. Peat slides are similar in nature to landslides in other materials and tend to occur in shallow peat (up to 2 m) on steeper slopes (5-15^{o}). In contrast bog bursts tend to occur on deeper peat (greater then 1.5m depth) and on shallower slopes (2-10^{o}) (Scottish Executive, 2006).

Although the mechanisms that lead to mass movement of peat are not yet fully understood a series of common factors has been identified (Geological Survey Ireland 2006, Warburton *et al*., 2004):

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

Peat slides are also often associated with intense rainfall, but have also occurred during drier periods. Generally peat slides are a particularly likely when a number of risk factors coincide at the same location. Areas of quaking bog or where bog has developed over water bodies are particularly liable to movement.

Areas near to water courses pose a particular risk as there is a convergence of flow within the ground here, and so potentially higher water pressures. This is a natural process around all water courses where there is some permeability and movement of groundwater naturally towards the water course. However, water courses can also provide a route for any peat slide, or flow, and result in significant impacts downstream, including fish kills.

In addition, there can be other practical problems related to working with peat. These include:

- Local slippage of peat or slumping into excavations.
- Drainage problems around areas which are dewatered, and the impact of pressure changes associated with dewatering resulting in instability.
- The unit weight of peat is similar to that of water. Hobbs (1986) stated a value of 94% of water (by volume) in a 5m core of peat. Naturally occurring excess water pressure at, or close to, the base of the peat can cause buoyancy or uplift and corresponding instability problems.
- Blasting for rock extraction has the potential to destabilize peat (Lindsay and Bragg 2005).

Warburton *et al* (2004) identify number of possible failure mechanisms in peat:

- Shear failure by loading: where an intense rainfall event can suddenly increase the weight and thus loading of the peat on a slope.
- Buoyancy effect: where routing of water to the base of the peat through pipes generates artesian pressure; and as the pore water pressure increases, the cohesion of the peat decreases.
- Liquefaction: where routing of water to the peat base, and/or a bottleneck in the subsurface

drainage pattern cause the water content of the peat to increase, forcing the peat above its liquid limit.

- Surface rupture: where the peat at the base swells to a greater extent than peat above it.
- Marginal rupture: where basal peat at the margins is undercut by streams or human peat cutting.

In areas where there is a susceptibility to peat instability combined with a specific trigger factor (such as certain wind farm construction activities) instabilities may occur. However, historical activities combined with recent weather conditions, or merely the site peat properties and configuration, may provide sufficient trigger for peat instability.

A number of specific trigger factors have been identified on other peat sites (Scottish Executive, 2006; Lindsay and Bragg, 2005) which include, but are not limited to:

- High levels of prolonged rainfall, or very intense rainfall, have been associated with a number of peat slides (Pollatomish 19 Sept 2003 >80 mm rain in 2 hours; Straduff townland Co. Sligo May 1995 50 mm rain in one day; 19 Sept 2003 in Shetland, Scotland 100 mm rainfall in 3 hours). Failures in blanket bog tend to be more common in the wetter autumn and winter months.
- Some peat slides, e.g. Derrybrien, were associated with dry weather. Dry weather can result in cracking of peat which can allow rapid infiltration of rainfall to the base of the peat and reduce the cohesion of the surface peat acrotelm. The presence of fibres (e.g. unhumified cotton grass stems) in the upper less humified layers of peat can sometimes increase stability, although these fibres are not so intact in humified deeper peat.
- Snow melt - causing development of high pore-water pressures.
- Natural erosion of the slope surface and base of the slope.
- Low permeability bedrock resulting in a high runoff, and the potential for concentrated flow along the base of the peat.
- Rapid ground accelerations e.g. earthquakes causing a decrease in shear strength; rock blasting or mechanical vibrations could also have a similar effect.
- Man-made impacts, including undercutting of slopes, removal of retaining walls, and land drainage. Loading of the peat may also cause instability e.g. placement of excavated peat at the side of an excavation, passage or placement of heavy plant, or construction of structures.
- In addition, previous activities on site may have left a natural weakness on the site regarding stability including:
    - Grazing of animals resulting in damage to the peat surface and erosion;
    - Forestry resulting in cracking of the peat parallel to the lines of trees (a factor in the Derrybrien slide);
    - Burning of vegetation resulting in erosion of the upper acrotelm.

Climate change may exacerbate peat slides as summers may become drier and winters wetter, thus resulting in greater drying out and then rapid rewetting of peat. However, it has been suggested by other authors (Dykes et al 2008) that as some high levels of rainfall do not generate peat slides failures may be more related to slowly changing internal thresholds.

Further details of potential triggers of peat instability and contributory factors are given in reports by Lindsay and Bragg (2005) and MacCulloch (2006).

For sites which have a significant depth of peat, a peat stability assessment is required to determine the risk of peat slippage during construction or wind farm operation. There are geotechnical techniques which have been developed to assess whether slopes are likely to fail, including the factor of safety assessment. The Scottish Executive (2006) report describes a method for assessing the peat slide risk, including an assessment of the risk of an event, which is the product of the likelihood of it happening and the consequences of the event. Calculation of the factor of safety for peat soils has been reviewed by other authors including the Geological Survey of Ireland (2006) and MacCulloch (2006) who question whether this technique is directly applicable to peat land slides due to the unusual geotechnical properties of peat and its variable nature.

Peat has unusual properties for a solid material, which result in standard engineering methods being difficult to apply. Unusual properties of peat include: its high water content, its limited strength controlled by both its fibrous nature and the formation of chemical complexes between the plant tissues and water (Hobbs (1986), Lindsay *et al* (1988)). This leads to unusual engineering properties including low unit weight, high influence of water, low shear strength and high angle of friction. Assessment of peat with these properties may be at the limit of current geotechnical methods (Geological survey of Ireland (2006), Holden and Burt (2003)). Peat is compressible with the rate of compression controlled by the way that water is held in the peat (Hobbs, 1986), again this is unusual.

The high organic content of peat means it tends to shrink if dried out. This is partly an increase in decomposition in the presence of oxygen and also a change in the structure of the peat following the drainage of pore water (Hobbs, 1986). Peat is soft and if vegetation is removed it is vulnerable to erosion by wind and water (Yeloff *et al*, 2006). Peat is also vulnerable to landslip with significant impacts locally and downstream (Warburton *et al* (2004), Lindsay and Bragg (2005)).

Holden and Burt (2003) also found that the compressibility of peat, and its response to changing pore water pressure, affected results in hydraulic conductivity tests when standard methods were used. This indicates that wind farm developers should be extremely cautious when using standard methods to assess peat behaviour. MacCulloch (2006) recommends using low shear strength values and high water content values to produce conservative designs for roads across peat but also states that initial construction method statements should not stifle innovation. Compared to mineral soils peat is compressible, has low shear strength and a high angle of friction and the role of fibres and the anisotropy of peat in stabilizing bogs is not well understood (Geological Survey of Ireland, 2006).

Measurement and monitoring of water levels is identified as being of value before and during wind farm development and operation where peat slide is a potential risk (Scottish Executive, 2006). They comment that the need for monitoring depends on the ground conditions at the site and the guidance includes an appendix summarising suitable instrumentation for monitoring peat properties at sites at risk of instability (including groundwater levels, pore water pressure, overland flow, rainfall, ground movement, and shear surface movement). Additionally, the Environment Agency (2002) have published a guide to monitoring water levels and flows at wetland sites. This includes advice about producing an effective system which generates good data and is relevant when setting up monitoring systems around wind farms.

Summary

Key points for wind farm developers are:

- Instabilities in peat can lead to rapid movement of significant volumes of peat downslope with serious consequences for blanket peat integrity, water courses downstream and health and safety;
- There are a number of potential trigger factors (see section 4.4.9 and above page 25) which include certain wind farm construction activities;
- Sites on a convex slope, close to water course or where there is a hydrological connection between the surface and the basal layers of the peat may be more likely to slip;
- Caution is needed when using standard techniques to estimate the likelihood of peat failure
- Sites prone to failure are likely to have a number of risk factors present on site, including evidence of small scale failure, which can provide an indication that a site poses a particular risk.
- The best mitigation of peat slippage is to avoid unstable areas although other mitigation measures are possible to reduce the risk of failure. Unstable areas are often associated with a higher number of risk factors, or have a history of previous slippage or instability. However, failure may occur without human intervention on a site.

2.13 Carbon Cycle and Stores

Peat soils store carbon in the dead plant remains and its decomposition products form the peat (Moore and Bellamy 1974. Holden *et al*, 2007b). Damage to the peat integrity (i.e. to a peat hydrological unit and the fabric of the peat within the peat body unit) either during construction or inadvertently (by taking actions that lead to increased erosion or instability) can lead to the release of carbon.

2.13.1 Overall Impacts - Carbon budgets, storage and the effects of wind farms on blanket bogs

Peatlands are the single largest carbon reserve in the UK (Moors for the Future, 2007) storing around 3 billion tonnes of carbon (compared to 150 million tonnes of carbon in UK woodland). Peatlands in England and Wales could absorb around 400,000 tonnes of carbon a year, if in pristine condition. However, peatlands are not all currently peat-forming, and some are degrading. 80% of all carbon losses from UK soils are derived from upland peat soils. In the Peak District up to 100 tonnes of carbon are lost annually per km^2 in some eroding catchments where wildfires have caused large areas of bare peat devoid of vegetation.

Healthy blanket bogs and peat soils have the ability to store carbon (Holden *et al*. 2007). This is because the inputs of carbon into the blanket bogs are greater than the outputs, due to the low rates of decomposition and the chemical stability of the peat mass when saturated. The placing of wind farms on blanket bogs can disrupt their carbon budget, leading to a greater carbon outputs from the system and turning it from a carbon sink to a carbon source. Peatland restoration projects can help to return bogs back to being carbon sinks. However wind farms can cause physical and chemical changes, which are often difficult or impossible[2] to reverse.

2.13.2 Carbon Budget of Blanket bogs

Inputs of carbon (C) exceed the outputs in blanket mire and the balance is deposited as peat. Worrall et al. (2003) list three inputs into upland peat carbon budgets (Figure 2-3):

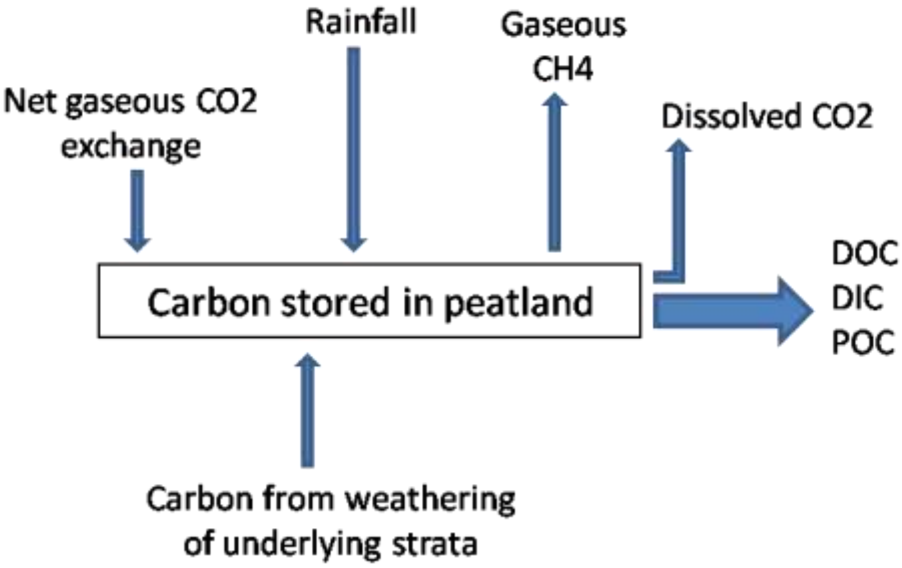
- Carbon dioxide and methane sequestration from the atmosphere;
- Dissolved Organic Carbon (DOC) and inorganic C from rainwater;
- Inorganic C from weathered rocks.

And the outputs of the carbon budget are:

- Carbon dioxide and methane released to the atmosphere through degradations;
- Fluvial outputs of Dissolved Inorganic Carbon (DIC), Particulate Organic carbon (POC) and DOC.

[2] Techniques are currently unavailable.

Figure 2-3 Carbon uptake and release pathways for upland peat (modified from Worrall et al. 2003)



(Notes: DOC – Dissolved Organic Carbon; DIC - Dissolved Inorganic Carbon; POC – Particulate Organic Carbon; CH4 – Methane)

The relative rates of the inputs and outputs are determined by a number of factors, but the dominant controls are groundwater table position, the peat water chemistry, the plant communities and temperature.

The factors leading to the degradation of a blanket bog can turn it from a carbon sink to a carbon source. Drainage schemes can increase the output of carbon in several ways. Firstly it can lower the water table, increasing the aeration and rate of oxidation and consequently the rate of decomposition of the dead organic matter; it then releases carbon to the atmosphere at a faster rate and forms more readily-mobilised DOC (Holden et al. 2004). This increase is compounded by the additional oxidation of toxic phenolic compounds if present which inhibit microbial activity (Wallage *et al*. 2006) even further.

Secondly, drainage can change the hydrology of peat by creating an increased number of natural pipes and other macropores[3]. Greater volumes of water passing through the peat matrix, rather than over its surface or through macropores, can cause DOC in pore water to be flushed from deeper peats (Wallage et al. 2006). This process can also increase the development of peat pipes (macropores) within deeper peat.

Lowered groundwater tables also change the plant rooting environment and different plants inhabiting the drier surface layers may curtail overall peat formation and carbon capture. The effect of activities such as drainage and over grazing can leave peat more prone to mass movements (Warburton et al. 2004). Mass movements disturb peat, leaving it more exposed and prone to erosion and so to carbon loss.

2.13.3 Wind Farms and their impact on Carbon storage

Wind farms generate low carbon electricity without the use of fossil fuels, and so can have a net carbon benefit compared to electricity generated using fossil fuels. However, there are a number of factors involved in the construction and operation of a wind farm which influences how much carbon benefit the wind farm can provided. Some literature (see later) refers to a carbon payback period, before a wind farm can actively contribute to carbon savings.

[3] Macropore is a generic term for a flowpath through peat that is visible to the naked eye and is thus much more conductive than the pathway through the small pores between microscopically small components of the peat.

Wind farms can affect the carbon budget of a blanket bog area in several ways (Hall 2006, Nayak et al. 2006):

- Direct impact: in the building of infrastructure large volumes of peat can be dug up and vegetation is removed. If left, they could have continued to sequester carbon. Extracted peat when stockpiled will decompose and release carbon.

- Drainage schemes: these affect the carbon dynamics by changing the hydrology. A drier surface does not provide peat-forming conditions, so there is no net carbon capture.

- Deforestation: wind farms can require forests around them to be removed to improve wind conditions or to allow access to a site. There is an obvious loss in biomass with deforestation, and concomitant carbon release. However, there is also often opportunity to reverse the balance by restoring active bog where trees are removed, and thus have net capture of carbon. These may have to be balanced against other consequences of deforestation, such as significant increases in sediment and carbon fluxes to local rivers.

- Mass movements: cut and fills, drainage and other engineering works can all increase the risk of mass movements of peat, with a corresponding loss in peat mass and concomitant loss of stored carbon and ability to store carbon in the future.

Additionally, wind farms can have wider impacts on the global carbon cycle. Their fabrication and construction generates carbon. Fossil-fired power stations must be maintained at inefficient back up levels, ready for periods when the wind is not blowing.

2.13.4 Carbon budgets and restoration schemes of upland peat

A number of studies have been conducted to assess the effectiveness of peat restoration schemes (http://www.moorsforthefuture.org.uk/mftf/research/peat_compendium_project.htm).
Wallage et al. 2006 compared the dissolved organic carbon (DOC) of upland peats which were intact, drained and drain-blocked. This showed that drain-blocked peats had lower DOC concentration in its water than even intact peats. Wallage et al. 2006 suggested that this was because, when the peats had been drained, they had been flushed of soluble or fine particulate carbon, so the quantity available for quick release in the peat had lowered.

Water from drained peat blocks was darker than intact peat, suggesting that the oxidation of phenolic compounds allows enzymes to mobilise more humic acids (which are dark in colour) than before. Another cause of more humic acids being mobilised from drain-block peats is that when drained, pipes can form. These increase the movement of water through the deeper peats, allowing greater mobilisation of leachable substances.

Studies (Worral et al. 2007 and Holden 2005) have showed that it is difficult to restore the carbon budget of bogs back to a pristine situation regarding carbon once they have been drained, as large quantities of carbon have already been lost from the system and the fabric of the peat body has been modified. However, the present-day outputs of carbon from peats can be significantly reduced, and reestablishment of peat forming vegetation following restoration works may be able to return a degraded blanket bog from a carbon source to a carbon sink.

2.14 Assessment of Carbon Fluxes at Wind Farm Sites

A number of methods have been developed to assess the carbon fluxes from peatland (Worral et al. 2003, Scottish Executive 2007, Hall 2006 and Nayak et al. 2006 and others). The following review of methods comments on which would be most effective in assessing the impact of wind farms on the carbon budget of blanket bogs.

Worrall's method (2003) quantifies the individual inputs and outputs of the carbon cycle over a year by sampling, laboratory analysis and through equations based on measurable parameters such as temperature. It would be difficult to implement this method for most wind farm developments as it requires the collection of a large data set over at least a year. Additionally, the quantification of the rates of litter input (c. 300-700 g m^{-2} $annum^{-1}$) and net carbon dioxide exchange have large error components and consequently detecting a significant difference between two large mean values which is usually small (c. 20 g m^{-2} $annum^{-1}$) is likely to be difficult (Niklaus et al, 2000).

The ECOSSE model (Scottish Executive 2007) estimates the carbon store in organic soils in Scotland and Wales and predicts the effects of climate change and land use changes on greenhouse gas emissions. The scale and complexity of the model is too great to be usefully applied to individual wind farm proposals and would need to be adapted.

The Scottish Government funded the development of a calculator (Nayak et al 2006) to give a consistent and robust method for evaluating C savings from wind farms. The SNH and SEPA supported the Scottish Government in managing this project and a wider body of stakeholders were consulted, including field visits to operational wind farms, a workshop, and direct input on specific details of the work. The report provided inputs and views on the approach devised to estimate C losses and savings from wind farms on peat soils for large scale wind farm developments in Scotland. It raised concerns about the reliability of methods used to calculate the time taken for these facilities to reduce greenhouse gas emissions. The calculator that resulted from the Scottish project which is used in the case studies below has yet to be formally adopted as guidance. Adjustments to the calculator may occur as the state of the knowledge improves or as a result of the consultations.

Nayak et al. (2006) developed site specific equations to calculate the carbon saving from wind farms. Their aim was to create a model which produces similar results to ECOSSE, which could be practically implemented for individual wind farm developments. The Nayak et al. method uses an Excel spreadsheet of fifteen worksheets requiring the following information to be inputted to calculate the carbon saving:

- Number of turbines, foundation and hard standing dimensions, turbine capacity and assumptions about efficiency;
- Drainage of turbine bases;
- Forestry felling areas;
- Borrow pits in peat areas;
- Road type and drainage;
- Cable lengths (if not alongside roads);
- Proposed restoration following construction and following decommissioning;
- Air temperature;
- Peat depth;
- Water level;
- The extent of water table lowering around drainage features;
- Soil pH.

These items should be obtainable from the site developers, site visits and figures in published papers. However, if site specific information is missing, such as details of the depth of peat on site, less accurate estimations can be obtained by using IPCC[4] generic values within simplified equations. The Nayak method appears to be the most suitable for calculating the carbon saving of wind farms on blanket bogs and is used in the case studies.

2.14.1 Catastrophic Peat Loss

There are two instances of rare but significant ways in which large and rapid peat loss may occur..

1. Fire (natural or deliberate) can occur on peatlands whether or not a wind farm is present, and the risk is at it highest in dry weather. The reaction of the managing authorities is usually to close the moorland to the public when the risk is high. No studies have been found to show how the presence of a wind farm affects the risk of fire. There may be increased access to wind farm sites on common land, due to the presence of new tracks. However,

[4] Inter Governmental Panel on Climate Change

regular inspection (in some locations daily) of wind farm sites would provide for regular monitoring of fire risk. Additionally, the presence of tracks on wind farm sites would enable access to fire fighting vehicles, and act as a narrow fire break. It is in the interests of the wind farm operator not to have a fire on a site where they have very significant infrastructure. Provision should be made within the emergency procedures for a site for a response plan in the case of fire.

2. Peat slide – this is discussed in detail in section 2.12 which indicates where there is a risk of peat slide, and how it might be mitigated. The most reliable mitigation measure is to avoid high risk sites.

2.15 Overall Impacts – Landscape

2.15.1 Introduction

Landscape character and visual impact assessment (LVIA) is a widely used, recognised and documented tool for assessing the potential impacts of development on the landscape and visual resource. Impacts can only be predicted where the scale or magnitude of change has been accurately described.

The main direct factors currently taken into consideration during the assessment process are the wind farm extent, height of turbines and associated ancillary structures such as buildings and tracks. However there are a number of less obvious and indirect impacts which might arise and could lead to increased and unpredicted change in the landscape and visual resource.

These are summarised in the following table.

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Table 2-6 Framework of Potential Additional Landscape and Visual Impacts of Wind Farms in Upland Peat Landscapes

	Issues	Impacts	Effects on landscape fabric
Physical Changes	Access & Micro-siting	Track Width	Wind farm development can introduce significant lengths of new access tracks into the landscape (Crook Hill 5km, Scout Moor Wind Farm 12.8km, Lewis Wind Farm 170km). These are considered within the landscape and visual impacts sections of an Environmental Statement (ES) as a matter of course. However, access track widths are usually considered in terms of 'carriageway' width. The actual zone of impact on peat bogs is dependant on a number of factors and may extend to much greater distances beyond its edge (2m to over 50m in certain circumstances) resulting in them being more conspicuous, for example through long-term habitat changes adjacent to tracks. The changes might arise from disturbance, introduction of new materials, changes in localised drainage and compression of the peat substrate. This potential impact needs to be recognised within the LVIA ES chapter to demonstrate an understanding of this indirect impact on the peat habitat and the effect it has on landscape fabric and mitigation planned accordingly.
		Alignment	Track alignment needs to be considered in terms of its actual fit with topography, ground conditions and landscape character. Deviations in track alignments predicted within the ES and the final constructed track alignments may mean that actual track length is greater than first envisaged and therefore the impacts on landscape fabric may be underestimated and actual impacts greater than those predicted. (Lindsey R.A., and Freeman, J. (2008), "Lewis Wind Farm E.I.S: A Critical Review"). The assessment methodology needs to account for these factors so that landscape fabric changes are not underestimated and mitigation is considered during the early planning stages of the project.
		Cutting & Filling	As a result of track alignment increased cutting and filling may be required to facilitate the preferred alignment. This potentially introduces highly visible change to the landscape fabric. LVIA assessments may need to be revisited to reassess the additional impact such change has on the landscape fabric.
		Turbine Micro-siting	Micro-siting is the final post-planning permission positioning of individual turbines following detailed geo-technical assessment or during works on site. This may have an impact on the landscape fabric arising from increased track length. The scale of landscape fabric change could be underestimated. Conversely access track length may be reduced if turbines are eventually situated closer to the main access tracks.
		Materials	Due to the acidic nature of peat bog habitats materials should be carefully selected to demonstrate an understanding of the potential long-term impacts material choice may have on habitats and landscape appearance.
		Road Network Modifications	Roads in the vicinity of sites may need to be modified to accommodate turbine delivery. These changes may result in an 'urbanisation' of the rural landscape fabric by the introduction of road widening, kerbs, wide bell-shaped accesses and the removal of other landscape elements such as stone bridges, walls, gateposts, hedges and trees ("Wind Energy Development in Northern Ireland's Landscapes". Draft Supplementary Planning Guidance to accompany Planning Policy Statement 18 'Renewable Energy' February 2008). LVIAs need to account for these offsite changes which may be temporary or permanent.

Table 2-6 Framework of Potential Additional Landscape and Visual Impacts of Wind Farms in Upland Peat Landscapes

	Issues	Impacts	Effects on landscape fabric
	Drainage	Landscape-Scale Change	Potentially irreversible change to peat bogs over large areas through drying out and resulting change to vegetation cover may result in significant unintended change to the landscape fabric and appearance which should be to be considered when mitigation measures are being planned. Wider catchment impacts such as changes in watercourses, geo-morphology, increased erosion and scour, water quality changes have the potential to change the landscape fabric of the water course valley landscapes and may need to be considered. This is probably only likely on large-scale developments, or where there is cumulative impact from a number of wind farms within an area.
		Localised Effects	Localised effects such as drying out and increased wetting/ponding in areas, exposing peat and changing vegetation, may lead to changes in landscape fabric and appearance.
	Residual effects	Decommissioning	Changes to landscape fabric are often described as temporary and reversible. Features such as tracks and turbine bases may be left in-situ during decommissioning and vegetated/turfed over, however little is known about the efficacy of such practices (as far as it is known no wind farms have been decommissioned to date in the uplands of Britain) which may potentially result in a permanent visible change to the landscape fabric. In their recent consultation draft "Designing Wind farms in the Landscape" Scottish Natural Heritage (SNH) recognise that decommissioning after 25 years is an unlikely outcome and that sites will be repowered and will continue to exist for many years to come. This repowering of existing sites is starting to take place now (e.g. Chelker Reservoir –application refused 3-3-2009 at planning committee meeting, and Ovenden Moor – application in progress) earlier than expected during their life cycles presumably to benefit from technological advancements. However it is not yet clear how repowering will re-use existing site infrastructure (access tracks, cabling, foundations etc.) or whether new infrastructure is required which could lead to cumulative damage during each subsequent repowering. The Chelker Reservoir repowering proposed to re-use two of the turbine location and to merely upgrade the existing site tracks, suggesting that some of the existing infrastructure on sites can be re-used and some locations of infrastructure re-used.
Cultural Changes	Land management	Management Practices	The introduction of turbines into upland areas may lead to changes in grazing patterns. Adjacent areas may be subject to increased grazing (see Section 2.6) and hefted sheep may be displaced through fragmentation of land resulting from fencing off access tracks during construction. Planned burns may have to be restricted or stopped entirely (this is likely to provide a benefit to the blanket bog biodiversity). The movement of construction traffic across the site will transport seeds of mobile species. Due to the changes in drainage and the construction activities a zone of different vegetation usually establishes along the margins of tracks and around turbine bases and any hard standings. These changes in land management practice can lead to changes to the existing vegetation. Typically the margins of tracks are dominated by soft rush which is atypical of blanket bog habitat and increases the visual contrast between the track and surrounding blanket bog vegetation. This may result in changes to the landscape appearance over extensive areas which ought to be taken into consideration.

Table 2-6 Framework of Potential Additional Landscape and Visual Impacts of Wind Farms in Upland Peat Landscapes

	Issues	Impacts	Effects on landscape fabric
		Management Agreements	Securing collective agreement on land management changes where common land is concerned or securing agreement from land owners/tenant farmers can lead to doubt about the deliverability of landscape and biodiversity gains as part of any proposals. Re-vegetation of bare peat and soils on common land where agreement of all the commoners is required may be difficult. These areas require fencing to exclude livestock, principally sheep, or all livestock needs to be removed from the common affected to allow seedlings or transplants to establish again resulting in change to the landscape fabric.
	Land use	Public Access	The introduction of extensive lengths of new access tracks may lead to indirect impacts such as increases in public assess and use. The illegal use of moorland for various damaging vehicular pursuits which usually results in the destruction of the integrity of the peat surface and increase in the amount of bare peat may follow and so appropriate access restriction should be planned.

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2.16 Overall Impacts – Archaeology

2.16.1 Background

Peatlands are unique ecological and hydrological environments as they contain distinct and often-threatened flora and fauna and take several millennia to mature (Charman, 2002). In addition to being an effective mechanism for fixing and storing carbon, they are of archaeological importance (often regardless of preservation status) and represent an archive for palaeoenvironmental research.

2.16.2 Archaeological Value of Peat Bogs

In order to establish the impact of a wind farm upon a peat bog from an archaeological and palaeo-climatological point of view it is essential to understand exactly what sort of archaeological resource it represents.

The surface of a peat bog is not only a contemporary landscape and habitat but also an archive of past environments and human activity. Under a microscope it is possible for vital pieces of evidence such as pollen, coleoptera (beetles), tephra (volcanic ash) are visible and that combined with details the rate of peat growth can allow past environments to be reconstructed (O'Connor & Evans 2005). This can go much further than just creating a climatic chronology but also can provide evidence of human impact upon not just that particular site but the wider environment and how humans helped shape these environments.

Due to the presence of organic material it is possible to use absolute dating methods such as Carbon 14 to tie these to other events such as significant climatic changes and other forms of evidence. One such source of evidence is tephra chronology uses volcanic ash to link events across large geographically discontinuous areas. Each volcano produces a range of ashy material the larger parts of which fall close to the volcano but the finer material, particles of less than 2mm, is propelled high into the atmosphere and spreads over considerable distances. Each volcano's ash is unique and therefore traceable on a continental scale. The effect of large eruption has a significant effect on the climate as the ash is thrown high into the atmosphere reducing the amount of sunlight reaching the earth's surface as well as effecting the prevailing weather patterns. In recent times, 1980, the eruption of Mount St Helens produced ash that spread around the northern hemisphere. The effect of each volcanic eruption depends upon its scale on the Volcanic Explosivity Index (VEI) which ranges from 0 - 8. The eruption of the Hekla volcano in Iceland in circa 1,000BC was rated as a 5 on this scale and has been detected via remains in Irish Peat bogs, Greenland Ice cores and the Bristlecone pines of California. Climatologists believe such an eruption would have had an effect on the world's climate for up to 50 years. Archaeologists have noted that it is around this time that significant environmental change took place in Britain with the beginning of substantial areas of uplands becoming raised bog partly due to climatic deterioration but also do to the natural soil conditions and over exploitation by humans. Peat bogs therefore have the ability to make significant contributions to our understanding of past climates.

Pollen is a key resource to the palaeo-climatologist and peat bogs are a critical element as their anaerobic conditions allow the pollen, or spores, that the wind blew through the air, and deposited on the bog to be preserved (Moore et al 1994). So, if an area was covered by oak wood the bog would have captured oak pollen and as it grew, the original surface would be buried along with the oak pollen and any other pollen and spores present in the air at the time. Subsequent archaeological examination of the peat would reveal that the oak pollen was still preserved, pointing to the fact that there was a lot of oak in the countryside at that time, even if the wood has now completely gone.

The pollen in the uppermost parts of lowland raised bogs, often just the top metre, contains the history of the climate and the development of the recent landscape. This surface peat is the most vulnerable to surface interference such as damage from drainage and removal by mechanised cutting. As with all such studies on peat, it is only possible to get this amount of information from it if the bog surfaces remain intact.

As well as preserving evidence of past environments it is also possible to look at past land use. People returned to Northern Britain at the end of the last Ice Age having been displaced by the Ice sheet into the dry basin of the North Sea or the Southern England (Smith 1992). Initially these people were hunters and gatherers but around 6,000 years ago agricultural came to the British Isles. In many places this was before the onset of blanket, or upland, peat. The settlements and field enclosures the Neolithic farmers established were important for separating grazing animals from crops of wheat or barley and are gradually being uncovered (Bradley 2007).

Sometime objects are recovered from peat bogs, the most common objects being worked wood. They can vary from a single piece of wood with a deliberately sharpened end to a structure such as a trackway, logboat, platform or house footing. All such finds are worth recording and investigating as they may be an indication of a more complex site in the vicinity.

Wooden Trackways can occur at any depth in a raised bog as they have been constructed for thousands of years. They are found in many forms and were used for a variety of reasons as the shortest crossings across peatland. They served as parts of major routeways or provided paths called droveways across soft ground for farm animals going to and from pasture. In the most primitive form, a layer of brushwood was often laid down to provide a dry trackway, perhaps in exceptionally wet weather as at Garvin's trackway in the Somerset Levels. Some times wattle panels, referred to as hurdle tracks by some, were used in a technology borrowed from house building as at Walton Heath in Somerset.

In both Ireland and Scotland structures such as megalithic tombs and stone circles were buried beneath the growing peat in upland areas from about 1200 BC onward. Many of these sites were uncovered when the peat on the blanket bog was being hand-cut, and monuments such as Creggandevesky court tomb in County Tyrone were hidden in this way until the 20th century (Shee Twohig 2004). There are undoubtedly many more remaining to be discovered. These are less common features in England but in upland areas there are still features such as cairns, cairn fields and burnt mounds that can be seen in upland areas such as the Yorkshire Dales e.g. Kingsdale Head near Ingleton.

The discovery of human remains in peatlands is always of great public interest. This is because peat preserves not only the skeleton but also the skin, hair, internal organs and clothing of the bog body. This enables archaeologists to analyse the stomach contents, diseases, date of death and how the person died. The preservation conditions allow the examination the fabric, weave, colour and stitching techniques of clothing and leather items is particularly valuable for dating the body (Turner & Scaife 1995). The conditions in the peat responsible for preservation are changed when the peat is drained or disturbed in other ways.

2.16.3 Overall Impacts – Archaeology

Human activities (including windfarm developments) affect three key characteristics of peat bogs:

- Water content
- Nutrient levels
- Surface vegetation.

Removing water from any peatland has an impact on the archaeological value of the site. Organic materials are preserved in peat because the high water content inhibits the presence and actions of microorganisms. Removing water can result in increased microbial activity, causing the decay of preserved organic material such as: wooden containers, clothing, timber structures such as trackways and houses and even human remains.

Wind farms and communication masts can affect peat land habitats and have long-term effects on the stability of the bog itself. This is described in detail in previous sections, and affects the archaeology and palaeoecology as described above,

2.16.4 Baseline Archaeology Situation

Environmental Impact Assessments for the construction of wind farms on peatlands need to be holistic in nature and take the following factors into consideration:

- Stratigraphy and extent of the peat
- Geomorphology of the peat forming environment and associated substrate
- Plant and faunal ecology of the site
- Archaeology and palaeoenvironmental record
- Potential changes to carbon storage.

The most important factor to establish when looking at the impact on the archaeological and palaeo-climatological record will be to establish the current state of the peat deposits. If these have already been subjected to disturbance, aeration and reduced water levels then much of the archaeological and environmental record has already been lost and construction of a wind farm is unlikely to have a significant impact upon the resource bar that which occurs as a result of direct grounds works. If however the sites are in 'prime' condition it can represent an important fragile and non-renewable resource. This would require detailed and careful mitigation on a site by site basis as the standard techniques of archaeological appraisal of aerial photography and geophysical survey are of limited value.

In order to establish the extent and depth of the peat and to search for stratigraphic features that may be of palaeo-environmental and/or archaeological interest a thorough auger survey is needed.

An auger survey is also important from a paleo-environmental assessment view point as it will provide a detailed description of the structure of the peat. A suitable mitigation strategy could then be framed once the nature of the deposits had been assessed. It would be advisable for an archaeological watching brief to be undertaken as part of any construction project.

The condition of organic remains within a bog that has been degraded by gullying, fire damage and other forms of reduced water table leading to desiccation will be poor. Much, if not all of the organic material is likely to have been compromised and therefore of limited use. Any structural remains are likely to be in the same position as they would on any 'dry' land site that had not been subject to disturbance. The archaeological significance of such a bog is therefore greatly reduced. The determination of the potential of any site would need to be assessed via an augur survey as this would provide valuable information on the nature and extent of the peat and it potential from both an archaeological and environmental viewpoint.

2.17 Gaps in Existing Literature

Most authors agree that peat has unusual properties for a solid material, and this has resulted in a limited body of information applicable to working in peat environments, where there are increasing pressures for wind farm developments. Many authors identify gaps in the current knowledge and understanding of blanket peat both in environmental and engineering terms. Identifying these gaps is important in understanding the uncertainties in assessments of the impact of wind farms.

Uncertainties in Engineering Properties and Best Engineering Techniques

- The suitability of standard geotechnical techniques, developed for mineral soils, in a peat environment is uncertain. These techniques include slope stability analysis, including factor of safety (MacCulloch, 2005; Geological Survey of Ireland, 2006) and hydrogeological analysis (Holden and Burt, 2003).
- Strength of peat – there is scope for improvement in methods of measuring peat strength, and in understanding of the behaviour of peat at low effective stresses (Geological Survey of Ireland, 2006).
- Further research could shed light on the key factors in triggering peat slide – whether these are a combination of external factors, e.g. recent rainfall, disturbance of the peat body; or more gradual thresholds within the peat which, once exceeded, result in slippage.
- There is uncertainty regarding the best engineering methods to use in peatland environments to have the least hydrological and habitat impact. Various methods of road construction are possible – including cut and fill roads and floating roads. However, the long term impact of some of these, e.g. floating roads, has not been monitored and documented clearly. There is scope for further investigation and monitoring of the evidence for the impacts of various construction techniques, so that the best techniques for a peat environment can be selected. The techniques which allow the same movement of water as the peat body are those which are likely to have least impact. Generally access to turbines is required for maintenance throughout the life of a wind farm, but other options to permanent tracks, such as temporary tracks and low pressure vehicles could possibly be investigated for instance with regard to access to borrow pit locations.
- If there are uncertainties on a site, observations of critical areas including surface movements in response to moisture content, water pressure and density (Geological Survey of Ireland) are important to understand the processes occurring.

Environmental Processes and Restoration Measures

- There is scope for improved understanding of interactions between natural processes, such as those associated with climate, and their impact on peat. This will improve predictions of the impact of natural and climate-scale changes (Holden *et al*, 2007a, 2007b).
- Peat restoration techniques, include monitoring of existing schemes (Moors For the Future, 2008, **http://peatlands.org.uk/**) are detailed in this compendium of current peat restoration

and management projects).

Monitoring of the Impacts of Wind Farms on Blanket Peat

- It would be useful to collect information about the longer term impacts of wind farms In particular, the long term impacts of tracks and turbine bases in a peat environment. Data from monitoring of actual sites would be useful.
- Wind farms require tracks and these can result in increased environmental pressure on blanket bog environments. The practical implications of new wind farm access tracks could be monitored and investigated, particularly in the light of the Countryside and Rights of Way Act 2000 (CROW - **http://www.openaccess.gov.uk/wps/portal/home/welcome**), which provides for wider walking access to open country and common land. On some sites, such as Scout Moor, additional illegal access by trail bikes and vehicles, facilitated by wind farm tracks, has resulted in damage to the surface of the blanket bog. The ability of sites to limit access by illegal vehicles is important in reducing the impact of increased ease of access on blanket bog habitats.
- Additionally, the impacts following decommission and restoration are not currently documented.

Carbon dynamics

- There is little known of what types of vegetation are actually ‘active’ blanket bog as there are very few studies that have measured net carbon exchange over one or more years, and there is no reason to suppose that any particular plant communities always has the same peat-forming properties. Additionally, in thoroughly humified peat, identification of the plant remains is difficult. Most classifications of ‘active’ blanket bog vegetation types are based on the dominant plant remains in blanket bog peat and the types of vegetation associated with these peat types, or the presence of an acrotelm. It is entirely possible that any peat stratigraphic profile contains periods of rapid growth (Sphagnum-rich) and those of slow growth or even net loss (*Eriophorum vaginatum*-rich; wood peat). In degraded systems there is generally limited or no peat accumulation, and a net loss of carbon from the system due to erosion, oxidation and dissolution.

3 CASE STUDIES

3.1 Introduction

A number of case studies were selected to investigate the effects of wind farms built on blanket bog and how these match with the predictions made in the Environmental Impact Assessment stage of the planning process.

3.2 Case Studies

3.2.1 Case Study Selection

Three main case studies were selected based upon the type of site and availability of data:

1. Scout Moor, Lancashire;
2. Coal Clough, Lancashire;
3. Wharrels Hill, Cumbria (an example of a non-blanket peat site).

Additionally, the following sites or proposed sites are also discussed in brief as they present relevant aspects which are useful to consider.

1. Reaps Moss, Crooks Hill and Todmorden Moor Wind Farms.
2. Chelker Reservoir Wind Farm.
3. Cefn Croes Wind Farm

3.2.2 Carbon Assessment of Case Studies

The Scout Moor wind farm is constructed on blanket bog. The Nayak et al. (2008) calculator was used to estimate carbon losses and gains. It determines potential carbon (C) losses and savings associated with wind farm developments on peat land, taking into account peat removal, drainage habitat improvement and site restoration. The information required by the calculator is given in 2.14, and the data used are given in Appendix A2.

A number of factors can be quantified:

- The reduction in the bog plants' ability to fix C from the atmosphere due to the degradation of their habitat.
- Wind farms damage to the storage capacity of the peat:
  - Through excavation and the building of structures on site.
  - By increasing drainage on site, groundwater levels are lowered creating aerobic conditions in the peat, increasing oxidation and so allowing more CO_2 to be released.
  - By increased leaching of particulate and dissolved organic carbon from peat as it is drained; this freed C is then able to enter the atmosphere.
- Other carbon losses and gains:
  - Deforestation often occurs during the development of wind farms.
  - Developments can also result in carbon storage by peatland restoration: improving the peat's ability to capture and store C. If restoration occurs at the end of a wind farm's lifespan, it can mean that there are no further losses of C from peatland degradation at the site.
- The amount of carbon saved by avoiding the use of fossil fuel power stations.
- The carbon required to construct and build the wind farm.

By quantifying the changes in carbon fluxes associated with these factors, the calculator provides: the amount of carbon saved by avoiding using fossil fuel power stations; losses of carbon from the wind farm; and the amount of carbon gained through site and blanket bog improvements. This is used to calculate the 'payback' time of the wind farm development before the carbon losses due to its construction and the damage to the peat is off-set.

3.2.3 Scout Moor

Scout Moor Wind farm consists of 26 turbines, over 545 ha and is located 15 km north of Manchester. The planning applicant was Scout Moor Wind Farm Limited, a joint Venture Company between United Utilities Green Energy Ltd and Peel Investments (North) Ltd. The farm was constructed between 2007 and 2008, after planning permission was granted in May 2005, subject to conditions. This followed an inquiry held by the Planning Inspectorate which approved the project.

The site lies on a plateau with a substantial wind resource, on land outside landscape, ecological or archaeological national designations. The site is dominated by moorland acid grassland and blanket bog.

The site was assessed with the site operator and this included a site walkover with a limited amount of peat coring. Details are provided in Appendix A.2.2.

This case study focuses on a recently constructed wind farm, where a detailed EIA (Environmental Impact Assessment) and other supporting additional studies were undertaken. The construction on site was documented in a detailed Construction Method Statement (CMS).

The following main points arose from the site visit and from a review of the planning documentation:

- **Road side drains and culverts** – had limited impact, but in some locations there were negative impacts through work which had increased the potential for erosion. Areas of existing previous erosion and also recent erosion due to access by trail bikes were also seen.
- **Floated roads** had some pooling of water on the upstream side, indicating that the peat beneath the roads had insufficient hydraulic conductivity to keep it drained. However, the areas of pooled water provided additional habitat value. No drying of the peat was seen on the downstream side of the tracks.
- **Turbine foundations.** Large areas of peat had been excavated around the foundation due to peat slumping into the hole created for the foundations during the construction phase which as a result necessitated a large excavation hole. Drainage from the foundation and crane pad areas has the potential to cause downstream erosion. However, there was only limited up-gradient drying out.
- **The cable access route** to the site was installed with a deep mole plough and appeared to have limited or no impact, which was not within the main blanket peat area.
- **Management of peat soil** and placement of peat around the track areas (often on top of undisturbed vegetation) had a much wider impact than might otherwise have been the case. Soil and sediment types appeared to have been mixed and seeding had been undertaken with seed types not typical of blanket bog vegetation. The seeds had only resulted in partial cover because the site is heavily grazed. Many of the issues surrounding soil management were not assessed within the ES.
- **Within the ES,** the importance of mitigation measures and the reasoning behind them was not made clear. This resulted in many mitigation measures not being adopted in the Construction Method Statement and those that did being of limited effectiveness. This lack of adoption means that it is difficult to assess the predicted impacts in the ES with what has actually occurred since.

In summary: working on blanket peat poses technical problems which were not fully recognised in the EIA process. At this site, once disturbed, the peat lost its strength, leading to the zones of evident direct disturbance being greater than would be found on equivalent mineral soil sites. The areas excavated for foundations are large. Easily eroded peat material has been placed by the sides of roads. Despite this, the impacts of the wind farm have, overall, been relatively small. The pre-development degraded state of the bog reduced the sensitivity of the blanket bog to further degradation. The blanket bog consists of low permeability, hydraulically isolated units and this reduces the zones of influence of drainage, roads and other development features. This means that the hydrogeological, hydrological and ecological impacts appear to be constrained to within a small distance of the development footprint.

3.2.4 Carbon Impacts - Scout Moor

An estimation of the carbon payback period of the Scout Moor wind farm was based upon the site observations. The payback time has been calculated at between 8 and 17 months with a net emission of carbon dioxide of 114490 tonnes. 43% of the emissions are from disturbance and damage to the blanket bog, particularly from the large excavation areas caused by slumping. Further details are provided in Appendix **Error! Reference source not found.**.

3.2.5 Coal Clough

Coal Clough is a 24-turbine wind farm two kilometres north of Cornholme, Lancashire. It was commissioned in the 1992 and each turbine is relatively small with a capacity of approximately 0.4 MW.

The site lies on the edge of a plateau, above the Cliverger Valley. The site bears rough pasture on clay rich mineral soils grazed by cattle and sheep and contains several areas of blanket bog occupying approximately a fifth of the site.

The site was assessed with the site operator and this included a site walkover with a limited amount of peat coring. Details are provided in Appendix A.2.2.

The following main points were noted:

- **Development footprint**. Although areas of blanket bog constitute approximately a fifth of the site, none of the development was built upon it. This may reflect construction expediency and/or the maximization of wind resources (blanket bog occupies depression on site), or other factors such as deliberate avoidance of deep peat.
- **Impact on blanket bog**. There are minimal impacts from the wind farm development on the areas of blanket bog habitat because the tracks and turbines have been built on ridges away from the bog.
- **Track drainage**. There are no drainage ditches alongside the site access tracks. Surface run-off is not concentrated at particular discharge points so there is less potential for gulleying and nutrient enrichment of the blanket bog.

In summary; the site presents a good example of how a wind farm development footprint can be constructed in such a way as to avoid blanket bog habitat areas.

3.2.6 Carbon Impacts - Coal Clough

There was no peat present around the infrastructure of the wind farm at the Coal Clough site and so the wind farm development has not resulted in loss of carbon from peat.

3.2.7 Wharrels Hill

Wharrels Hill is an 8 turbine wind farm near the village of Bothel, Cumbria. The site was granted planning permission in 2002 by the planning inspectorate on appeal, after the initial application was rejected by Allerdale Borough Council on the grounds of landscape and visual impact.

The site lies on improved grassland and is included for comparison with wind farms built on blanket bog. The site was assessed with the site operator and this included a site walkover and a limited amount of peat coring. Details are provided in Appendix A.2.6.

The following main points were noted on site and from a review of the planning documentation:

- There were no planning conditions relating to hydrology or ecology, reflecting the limited concerns the proposed wind farm posed for the ecology and hydrology.
- The road layout on site bears little resemblance to the one laid out in the ES and the access route into the site is completely different. It is difficult to judge whether this has increased the landscape impacts of the site but the development footprint is less than that originally proposed.
- Neither the roads nor the turbine bases are accompanied by any drainage ditches and it appear that run-off is controlled through infiltration which should be sufficient, given the apparently well drained nature of the surface and the underlying limestone geology.
- The development has had negligible impact on the sites hydrology. All turbines are located over 400 m from the nearest stream. In the south east of the site, a site track passes within 4 m of a well (Photograph A23), and there would be the potential for the road runoff to impact the water quality in the well.
- The only possible ecological impact from this wind farm is bird strike.

- An old kiln is located at least 40 m from any part of the development footprint. Any impacts of the wind farm on it (archaeology) would be negligible.

3.2.8 Carbon Impacts - Wharrels Hill

There was no peat present at the Wharrels Hill site and so the wind farm development has not resulted in loss of carbon from peat.

3.2.9 Reaps Moss, Crook Hill and Todmorden Moor

The planning application submitted by Coronation Power for wind farms at Reaps Moss, Crook Hill and Todmorden Moor has recently gone to public inquiry (January 2009) due to the non-determination of the application by the planning authority and the subsequent appeal against this decision by the developer.

From an ecological perspective one of the reasons why the proposed developments at these sites went to public inquiry was due to the Environmental Statements not giving sufficient detail and information of the impacts of the proposed wind farms on the peatlands, their current ecology and how areas were to be restored. This was mainly due to little supporting data being provided to support the conclusions presented in the Environmental Statements on the types of habitat present and their condition as well as the species present. A total of about ten plant taxa were listed for all three sites combined. Additionally, there was insufficient evidence presented to allay concerns that the proposed developments would not have a permanent and significant detrimental effect on the peatlands through increased drainage and potentially erosion of the peat mass at all three sites.

The presence of blanket bog habitat was not recognised at Crook Hill and Todmorden Moor in the vegetation mapping, though it is known to occur. The ecological and conservation value of the blanket bog habitats were not assessed and the following information is required to assess the value of any blanket bog habitat (Headley 2009a, b, c, d).

1) The location and extent of areas of blanket bog vegetation was not determined.
2) The area of blanket bog directly and indirectly affected by the proposed development was not assessed.
3) The types of blanket bog vegetation present were not determined correctly, i.e. incorrect and poor quality vegetation mapping.
4) The condition of the blanket bog habitat was not assessed, only a subjective assessment of it being degraded.
5) The species of plant present were not listed.

From a hydrological and hydrogeological perspective there was concern that the development footprint and redline planning boundary was insufficient to include deviation of access tracks and infrastructure locations. One of the planning boundaries was the limit of the land which had been removed from common land (and an equivalent amount of compensatory land supplied to be designated common land). However, this would require mitigation measures to be provided outside of the planning boundary on the common land, which was likely to complicate the implementation of the mitigation.

Additionally there appeared to be some confusion over the ‘site boundary’ in the case of Reaps Moss and the planning inquiry evidence for the Local Authority highlighted the following.

‘The red edge prescribing the extent of the application site has been drawn tightly around the land where works are to take place. However, the blue-edge prescribing the extent of the other land within the control of the Appellant embraces a couple of large fields immediately to the west of the intended turbine positions. In arriving at a decision upon the Appeal proposal the Inspector also needs to be mindful that within the ES and SER are various plans said to show the Site Boundary, but which differ from the land within the red and blue edges markedly.’ Ref: **http://persona.uk.com/todmorden/LPA_Docs/Proofs/LPA-18-A.pdf**, Neil Birtles, Rossendale Borough Council.

There was a lack of specification of the mitigation measures proposed for the drainage, including the feasibility of the mitigation measures. The peatland hydrogeology was poorly described in terms of why peat has developed at these locations and how the peatlands function hydrologically. As a result of the lack of a clear conceptual hydrogeology model of the sites, the basis for predicting impacts of the development and protecting and restoring the peat was uncertain (Russell, 2009a, b).

Not withstanding this, Maslen, Headley and Russell (December 2008) noted on a site visit that opportunities existed to site some of the turbines off the blanket bog on mineral soils within a few hundred metres of their planned locations on deep peat. However, the opportunities for doing this were unexplored in the ES.

The provision and adherence to agreed written guidance for siting wind farms for what is required to assess the environmental impacts on blanket bog for both Natural England, developers and planning authorities could have helped to focus the planning submissions and responses, with the possibility that an expensive public inquiry could possibly have been avoided.

3.2.10 Chelker Reservoir Wind Farm

This is an example of an early wind farm, on a mineral soils site, for which a planning application for repowering of the site has recently been made. The site is located in a relatively undeveloped area immediately to the north of Chelker Reservoir. The site is in the Craven District of North Yorkshire, approximately 6.5km to the east of Skipton. Scattered farms are located in the immediate vicinity of the site. The settlements of Draughton, Halton East, Beamsley, Addingham, Keighley and Ilkley are located approximately 2.5 km to the northeast.

The current four 300 kW wind turbines were installed in 1991. Each is a 25 m high tower and has a twin bladed rotor 33 m in length. In May 2008 Yorkshire Water Services (YWS) submitted a planning application to remove and replace the four existing turbines, as they are suffering increased downtime due to failure of component parts. The proposal included two larger turbines with a proposed turbine tip height of 125 m, hub height of 80 m, blade length of 45 m and a rotor diameter of 90 m. The land upon which the wind turbines would be built is part of the Bolton Abbey estate. It proposed to re-use two of the existing turbine locations and the existing access tracks.

On 3 March 2009 the planning application was refused. In summary, the reasons for rejection include:

- The impact on the historical landscape. The blade tip would be seen from a number of historical locations – having a significant impact on the historical landscape, in particular, the priory at Bolton Abby and Farfield Hall both of which are Grade 1 listed buildings.
- The visual impact. The turbines would be seen from a wide area and from the Yorkshire Dales National Park. The potential harm outweighs the objective of providing renewable energy resources.
- Detrimental impact on the residential amenities of the householders located close by. The proposed development which is substantially increased in height (in comparison to the existing turbines on site) would have a negative impact on the quality of life of residents who live in close proximity to the site.
- Detraction from quality of the recreational experience. The reasonably-expected enjoyment of the landscape setting of the Yorkshire Dales National Park would be reduced,.

In contrast, the recent repowering of the Catton Moor Wind Farm site located on a mineral soil resulted in new turbine bases and significantly extended tracks (NE email communication).

The potential for re-use of existing infrastructure (for instance tracks) or the existing infrastructure locations (e.g. turbine locations) of wind farms is important with regard to impacts on blanket bogs. Where the existing infrastructure can be re-used in a re-powering situation the impact of repowering on a blanket bog is much less (in terms of additional disruption of the fabric of the peat body) than where additional tracks and turbine bases are proposed, provided that the impact of the existing tracks, turbines and any drainage is fairly minimal. Re-powering would also provide the opportunity to address any erosion, drainage or drying out problems associated with the existing infrastructure.

3.2.11 Cefn Croes Wind Farm

Cefn Croes is a 39 turbine site, with 1.5 MW turbine capacity constructed in 2004 for Falck Renewables. Evidence presented at the Scout Moor Wind Farm Inquiry by Dr K Little (Cefn Croes Action Group), suggested that there was limited monitoring of the section 106 agreements, as the relevant enforcement agencies had few resources to monitor construction departures from planning conditions, and she alleged that there were violations of the planning conditions and section 106 agreement at the site.

Other issues raised in the proof of evidence included:

- The presence of a new road network opening up the area to 4x4s, ATVs and trail bikes with resultant impacts on the environment.
- The initial land take of disturbed land around infrastructure (including borrow pits, disturbed ground and areas of deposited spoil) is larger than the estimated final land take.
- Mitigation measures to limit the pollution potential in runoff may be ineffective – e.g. the displacement of straw bales used to limit sediment runoff (they are not effective if they are displaced and runoff can bypass them).

One of the planning conditions was the development of a land management plan (LMP, 2004) for multiple objectives, including the bog habitat. It is to be funded by the wind energy company, and implemented via the Environmental Management Committee, comprising representatives from the energy company, local landowners, council and other interested parties. Another was to undertake hydrological monitoring. This has subsequently been undertaken (SLR, 2007).

A detailed study of mire restoration at Cefn Croes with potential for use elsewhere included:

- Damming of perimeter drainage ditch at regular intervals using reworked peat.
- Completion of surface scrapes and profiling to promote water distribution and retention.
- Covering and compacting peat layers over exposed surfaces of mineral layers in the perimeter drainage ditch and access road ditch.
- Filling in of perimeter ditch in steep section where dam integrity may potentially be compromised by storm events.

Monitoring of the 2005 restoration works was undertaken in 2007 by SLR, with representatives of Ceredigion County Council and the Environmental Management Committee (EMC) present during the site visit. The locations of the monitoring points were agreed and fixed point photography undertaken to provide a visual history of the restoration of the site. The hydrological monitoring programme includes:

- Six-monthly: water levels, peat thickness and fixed point photography
- Two-yearly: assessment of recorded data, from six monthly measurements, visual inspection of the site, reporting on findings and recommending additional works.

3.2.12 Summary of Case Studies

The case studies and examples presented have provided information regarding:

- Sites which are proposed for development, e.g. Reaps Moss, Todmorden and Crook Hill – these highlight the importance of an adequate EIA to be prepared by the developer, prompt response to be provided by the planning authority, clear comments by statutory consultees, and the value of following agreed guidelines.
- Sites which have recently been developed, e.g. Scout Moor Wind Farm – here the case study highlights the importance of linking the EIA to the subsequent construction method statement (CMS), the requirement to be specific in terms of mitigation measures, and the importance of using contractors on site who understand the nature of peat bog vegetation. This site also highlights that some blanket bog sites are already very degraded by gullying, in which case there are many dissected peat bodies present on site. This provides the potential for restoration measures to be undertaken, and these should not be compromised by the way in which the wind farm is developed.
- The possibilities of preparing land management plans with associated funds for habitat improvement such as have been used at Scout Moor and Cefn Croes, but that it is important that such funds are accessed and used appropriately.
- Older sites which have been present for some time, and where more long term impacts can be observed. The trend to re-powering rather than dismantling of older sites is noted.

It is important that applications are framed in such a way that the development can be implemented in a manner which results in the minimum of impact on the blanket bog environment. This includes specifying sufficient area within the application for implementation of environmental mitigation and any environmental improvement. Additionally, there should be the means, via the Construction Method Statement (and associated plans and procedures), planning conditions and agreements, to implement the proposals in the manner described in the EIA.

Where some of the land is common land, the issues of deregistering the common land, and application of planning conditions to areas of common and private land should be considered at an early stage in the process. This relates particularly to the benefits from fencing areas (probably on a temporary basis) which need to be protected from grazing pressure in order for vegetation to be restored.

3.2.13 Summary of Carbon Impacts

Where there are no organic soils, (e.g. peat) at a wind farm site then there is no loss of soil or sediment carbon arising from the wind farm construction, although there will be carbon costs associated with the manufacture and transport of the infrastructure.

Where there is an organic soil there will be carbon loss from the construction process and, depending upon the site drainage and vegetation restoration arrangements, more on-going carbon losses in the longer term. However, on degraded peatland sites which are already losing carbon due to low water tables, there is the potential for restoration of the blanket bog and so a net reduction in carbon losses. This only holds true where the construction of the wind farm enables effective restoration measures to be implemented.

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4 ASSESSMENT CRITERIA FOR DEVELOPMENT PROPOSALS

4.1 Environmental Impact Assessment Background

4.1.1 What is Environmental Impact Assessment?

Environmental Impact Assessment (EIA) can be defined as "a systematic process to identify, predict and evaluate the environmental effects of proposed actions and projects. The process is applied prior to major decisions and commitments being made." (Sadler B & Fuller K et al 2002).

The objectives of EIA are to:-

- Improve the environmental design of the proposal;
- Check the environmental acceptability of the proposals/capacity of the site and the receiving environment;
- Ensure that resources are used appropriately and efficiently;
- Identify appropriate measures for mitigating the potential impacts of the proposal;
- Avoid irreversible changes and serious damage to the environment
- Safeguard valued resources, natural areas and ecosystems;
- Enhance the social aspects of a proposal and;
- Protect human health and safety.

(IEMA Guidelines for Environmental Impact Assessment, 2004)

The EIA process should be an iterative process which shapes the design of the development as new environmental information comes to light.

4.1.2 Legislation and Guidance

EC Directive 85/337 (Council Directive of 27 June 1985 on the Assessment of Certain Private and Public Projects on the Environment"), also known as the EIA Directive, requires that member states adopt "all measures necessary to ensure that, before consent is given, projects likely to have significant effects on the environment by virtue, *inter alia*, of their nature, size or location are made subject to a requirement for development consent and an assessment with regard to their effects" (Article 2[1]). The EIA Directive was subsequently amended in 1999 by Directive 97/11/EC.

In England and Wales, Directive 97/11/EC has been implemented through the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999.

Guidance on the EIA process can be found in IEMA's "Guidelines for Environmental Impact Assessment" (2004).

Guidance on the 1999 Regulations can be found in DETR Circular 02/99 (DETR, 1999).

The Planning Practice Standard on EIA (The Royal Town Planning Institute, 2001) provides advice and information regarding best practice, and DETR (2000) provides a guide to EIA procedures.

4.1.3 Environmental Impact Assessment Process

The assessment process involves the following steps:

- Screening – This is the stage which determines whether an EIA is required.
- Scoping – This stage of the process which defines the topics which the EIA should consider.
- Assessment - This is the stage where the various topics defined during the Scoping Stage are assessed.
- Presentation of findings – The findings are presented in the form of an Environmental Statement (ES) which should include a non-technical summary (NTS), a description of the development, studies including prediction of impacts and evaluation of the significance of the impacts and identification of mitigation measures.

- Management and Monitoring: This comprises an audit of EIA process (prediction and mitigation measures), monitoring of the impacts and compliance with planning permission conditions.

The process of assessing the impact of wind farms on blanket bog are described in respect of these stages in the following sections.

The Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999 (The EIA Regulations) sets out how local authorities are to decide whether EIA is required; what an environmental statement should contain and the procedures to be followed. The DETR has also issued Circular 02/99 which further explains these Regulations.

The EIA Regulations cover nearly every form of development which could impact the environment. How the regulations are applied depends whether development is categorised as a Schedule 1 or 2 development.

Schedule 1 – Development defined in Schedule 1 of the Regulations requires EIA in all cases. Wind energy is not listed within Schedule 1 of the Regulations.

Schedule 2 - Development defined in Schedule 2 of the Regulations may require EIA if it is likely to give rise to significant environmental impacts. The Regulations contain criteria and thresholds for the purposes of classifying development as Schedule 2 development.

For wind energy proposals to be defined as Schedule 2 development they must contain more than two turbines, or the hub height of any turbine (or any other structure) exceeds 15 metres.

Some early wind farms (e.g. Hambledon Moor Wind Farm, near Burnley and Accrington) were developed prior to these guidelines and so may not have had an EIA even if they would now fall within the EIA criteria.

Applications for large wind farms whose generating capacity exceeds 50 megawatts are dealt with under Section 36 of the Electricity Act 1989 and are referred to the Sectary of State for Trade and Industry and must be submitted with an Environmental Impact Statement (ES). They are not dealt with by the local planning authority.

Where an EIA is not required, the planning authority can and often do request the same environmental information is supplied in order to reach a decision whether or not to approve the application. (e.g. Bradford Metropolitan District Council - Princes Soft Drinks Bradford Wind Turbine).

EIA covers the whole lifespan of a project: construction, operation and decommissioning. These may have very different timescales for different projects. Guidelines give thresholds of what are significant environmental impacts, which include (Dept. Communities and Local Government, 2000):

- The scale of the development - how big is it: is it more than local in scale;
- Is it in an environmentally sensitive area, e.g. National Park;
- Is it likely to have particularly complex or high environmental impacts e.g. discharge of pollutants.

Developers are encouraged to have initial pre-scoping discussions with Natural England and other consultees at an early stage so that key concerns can be addressed and any major issues highlighted early in the process. However, there is not a statutory requirement for consultation at the screening stage.

4.1.4 The Planning Process

In England, Regional Spatial Strategies (e.g. Northwest Region, 2008) have been developed and include policies promoting the use of renewable energy. Planning authorities are carrying out studies to identify the impact of wind farm developments on landscape. This information is used to identify areas which might be suitable for wind farm developments via supplementary planning reports.

Natural England may seek to influence local planning policies so they explicitly take account of the sensitivities of blanket bogs, or more indirectly via the Biodiversity Action Plan (BAP) targets.

Figures show that planning approval for wind farm projects has fallen from 82% in 2004 to 62% in 2007 (**http://www.businessgreen.com/business-green/news/2210432/wind-farm-planning-rejections**). Additionally, the average amount of time taken to reach a decision on wind farm projects is also at a record high of 24 months, with one project in Scotland having to waiting 63 months for a decision.

4.2 Site Selection prior to Screening and Scoping

Prior to submitting a formal request to an authority for a Screening Decision wind farm developers often sieve a number of potential sites to see which are most suitable for development. Developers are encouraged to have initial discussions with Natural England and other consultees at an early stage (in confidence if required) so that key concerns can be addressed and any major issues highlighted early in the process. However, there is not a statutory requirement for consultation at this stage.

It may only be possible to carry out certain survey work (e.g. birds) at particular times of the year. Therefore early consultation is highly recommended to avoid delays during the planning process.

Generally with regard to geology, soil, peat and water levels surveys these can be undertaken at any time of year. Vegetation surveys are more easily and reliably undertaken in summer.

The development may be confidential at this stage, particularly if all the landowners potentially involved have not given their final agreement to the scheme.

The following guidance is relevant to initial screening and site selection.

- Best Practice Guidelines for Wind Energy Development, British wind Energy Association (1994)
- Best Practice Guidance for the Irish Wind Energy industry, Irish Wind Energy Association (2008)
- Wind Farm Development and Nature Conservation: A Guidance Document for Nature Conservation Organisations and Developers when Consulting over Wind Farm Proposals in England. English Nature, RSPB, WWF-UK, BWEA (2001)

4.2.1 EIA Process

As outlined above a developer may decide that EIA is required for a particular project (DETR, 1999). Alternatively, the developer may apply to the local planning authority for a “screening opinion” as to whether or not EIA is required (DETR, 1999). If the developer disputes the screening opinion then he or she can apply to the Secretary of State for a “screening direction”.

If a screening decision states that EIA is required then the developer usually submits a scoping report to the local planning authority for a “scoping opinion” on what should be included in the ES. The planning authority must adopt a scoping opinion within five weeks of receiving a request, unless an extended period of time has been agreed with the developer in writing (DETR, 1999). If the planning authority does not reply within five weeks (or within any agreed extension) then the developer may apply to the Secretary of State for a “scoping direction” (DETR, 1999).

Under the Environmental Information Regulations 1992, public bodies are required to make environmental information available to any person who requests it (DETR, 1999). Once a developer has informed the local planning authority, in writing, that he or she intends to submit an ES then the authority must inform the following consultation bodies, if appropriate (DETR, 1999; Bell and McGillivray, 2006):

- The principal council for the area (other then the local planning authority)
- The Health and Safety Executive
- The Highways Authority
- Natural England
- English Heritage
- Countryside Council for Wales
- The Environment Agency

Regulation 2(1) of the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999 lists the information required in an ES, including: a description of the development, the data required to identify and assess the main effects of the development on the environment, a description of proposed mitigation measures and an outline of the main alternatives considered. It is also required that the ES contain a non-technical summary. The developer should make a reasonable number of copies of the ES available to the public; a reasonable charge (reflecting printing and distribution costs) may be made (DETR, 2000).

The local planning authority is required to determine the application within 16 weeks of the date of receipt of the ES (DETR, 1999). This period may be extended by written agreement between the planning authority and the developer (DETR, 1999). In determining the application the authority is required to have regard to the ES, as well as other material considerations (DETR, 2000).

If the planning authority considers that insufficient information has been provided by the developer in the ES then it may request further information or verification of information already provided (DETR, 2000). An inadequate ES cannot invalidate a planning application; however, if the developer does not provide enough information to complete the ES then the application must be refused (DETR, 2000). A developer has the right of appeal to the Secretary of State (or, in Wales, the National Assembly for Wales) against an adverse decision by a planning authority.

4.2.2 Biodiversity Action Plan (BAP)

The UK Biodiversity Action Plan (UK BAP) lists blanket bog as a priority habitat. The targets for blanket bog have been identified in its Habitat Action Plan (HAP). These include maintaining areas of blanket bog currently in favourable condition and phased improvements of other areas to reach 75% of restorable blanket mire in, or approaching favourable condition by 2015.

Wind farm developments on blanket peat may affect the condition of the site which could make it more difficult for the UK to achieve the UK BAP.

- If the site is currently in favourable condition the wind farm should not be allowed to change this status;
- If the site is not currently in favourable condition but is restorable then the development should not cause deterioration of the site or be carried out in a way that makes the restoration more difficult.

There is, however, scope for developments to include biodiversity gains within their proposals, such as restoration of areas of blanket bog, which could result in improvement of degraded areas of bog. It is important to ensure that the positive outcomes of mitigation are not at the expense of deterioration in other parts of the site due to development.

4.2.3 Designated Biodiversity Sites

Some areas of blanket peat are designated as national or international biodiversity sites (for example SSSI or SAC) and guidance from English Nature *et al* (2001) advises that development on these sites should not cause adverse impact to either the integrity of the site or its designated features. It is important to note that the onus is on the developer to show unequivocally that such damage will not occur. Developers should be aware that this is a formidable hurdle and will attract the most intense scrutiny. Developers should also be aware that designated site boundaries have frequently been drawn up in ignorance of the extent of the hydrological relationships between areas of bog. An event such as a wind farm proposal would trigger a detailed study and the new understanding of the hydrology would in many cases justify an extension of the designated site boundary, whether or not the statutory nature conservation agency chooses to do so.

If a wind farm is proposed on sites with local and regional designation (e.g. local nature reserve or SINCs – Sites of Importance for Nature Conservation – at a County Level) **and** it is likely to have a significant adverse impact then it should only be permitted if it can be demonstrated that there are reasons for the proposal which out weight the nature conservation value of the site.

It should be noted that the effects of a wind farm can be direct: for example if the proposed wind farm is inside a designated area. The effects of the wind farm can also be indirect for example when the wind farm is located on the boundary of a designated area or when the impact of the wind farm is seen at some distance from the development (e.g. changes to the water quality or sediment transport regimes downstream).

Wind farm developments should not take place on designated sites. If there are over-riding matters of public importance (in the view of the developer) that they should, then a clear assessment of the benefits of the wind farm compared with the loss of biodiversity sites should be carried out.

Summary

If a development is permitted on, or near, a site of nature conservation interest, such as a blanket bog:

- For SSSI and SAC sites there must be **no** risk of adverse impact on the site integrity or designated features. Another site should be selected.
- For locally designated sites (SINC or nature reserve) – any impact on the site should be balanced against the benefits to society from the development.
- For other blanket bogs: there should be a clear assessment of how the site would contribute to the HAP restoration programme with, and without, the proposed development. The potential gains and losses of the development can then be assessed.

However, the overall concern is that areas of blanket bog habitat, particularly blanket bog in good condition, are not adversely affected by a wind farm development, even if the area is not designated in some manner at present.

4.2.4 Peat Condition and the Potential for Peat Slide

Potential wind farm sites should be screened to identify whether a peat slide is likely to occur. The current condition of the peat should be identified. Peatlands in good condition have a higher ecological value, but marginal peatlands may be more vulnerable to further disturbance. Peat condition may have already been affected by:

- Historical drainage;
- Erosion and peat instability;
- Land use including forestry, grazing or any other pressures (e.g. recreation and tourism).

Any anecdotal evidence of historic instability should be taken into account as this can indicate risk of peat slide during construction or operation of the wind farm. If there is a risk of peat slide then a full peat slide risk assessment should be undertaken (see section 4.4.9).

Understanding the likely peat issues at a particular development site will help direct the scope of the Environmental Impact Assessment (EIA) and could help to direct the choice of the wind farm to a site with lower impacts on the peat, and avoid sites with a known instability problem.

4.2.5 In-Combination Impacts and Site Constraints

Wind farm developments can have a larger effect in combination with other developments and screening of sites should take account of this. Combined visual or landscape impacts can be very significant as are direct impacts on peat (see section 2.14.1 for a discussion of some of the indirect landscape related issues. Visual impacts are not covered by this study). Blanket peat drapes over a landscape and separate developments may have an impact on its overall visual integrity. Peat hydrological inter-dependencies are formed and maintained by interactions between water and vegetation, and sites should be screened to identify whether the wind farm may act in combination with other pressures (for example heavily eroded/ grazed areas) to have a more significant impact on the peat.

There is also likely to be a balancing of impacts in the development with a number of constraints on siting of infrastructure (i.e. tracks, turbines, sub-station and site compounds). The reasons for the final site selection and layout of the site should be clearly stated.

4.2.6 Impacts Outside the Site

A wind farm development can have a number of impacts outside the exact footprint of the development and also outside the planning application boundary. These are most apparent with visual and landscape impacts. The development also has the potential to affect hydrology, water quality and sediment downstream of the wind farm. Flow in water courses at both high and low flows can be affected by a change in the site drainage. Water quality can also be affected by a change in the runoff regime. A change in the amount of erosion will affect water quality and also the deposition of sediment downstream in river channels and water bodies including reservoirs. Peat may be eroded by wind and water and large amounts of peat are released in a bog burst or peat slip event. The site should be screened to identify downstream receptors that may be affected by the development these include:

- Sensitive water environments
- Fisheries
- Water abstractors.

4.2.7 Consultation

Local knowledge of a site can be an important part of the screening process. Understanding its history, the local land use and pressures can help to identify potential impacts on the peat and sensitive areas nearby.

Consultation with conservation and other regulatory bodies at an early stage can help to steer the development away from the most sensitive areas. For developments on peat of any significant thickness, examples of relevant organisations include: Natural England and other wildlife and conservation bodies; and the Environment Agency: if the site is in a groundwater source area, a reservoir catchment, or if downstream water quality could be an issue. Local Council Environmental Health Departments often hold details of any private drinking water supplies which may be located downstream of blanket bog sites.

The early consultation stage is an opportunity for Natural England to influence the process. Good practice guidance (Royal Town planning Institute, 2001; DCLG, 2000) recommends early consultation and identifies it as an important part of the process. A review of the EIA process by DCLG (2006) gives a good practice consultation example which identifies informal early consultation between the developer and statutory consultees (including Natural England) as a key to identifying a number of unusual site specific issues which needed more detailed studies from the developer.

Early consultation enables Natural England to influence the proposals by:

- Steering the location of the development;
- Raising and resolving local and site specific issues of concern.

Early consultation enables the developer to avoid unnecessary cost and delay by:

- Steering the location of the development away from sites which are unlikely to obtain planning permission;
- Highlighting what particular aspects should be required within the EIA;
- Avoiding sites where more and expensive mitigation measures may be required;
- Avoiding sites which may have particular engineering problems e.g. unstable peat.

4.3 Assessment at the Scoping Stage

The scoping stage consultation is an opportunity for Natural England to influence the scope of the EIA. Developers provide outline plans for comment by statutory consultees. A review of EIA scoping by DCLG (2006) found that many developers and local authorities identified consultation during the scoping stage as a key part of delivering a successful EIA. The scoping stage was identified as the most important part of the EIA process, particular benefits included:

- Identification of key and cumulative impacts;
- Savings of time and resources (for both developers and consultees);
- Establishing contacts between developers and consultees.

The consultees identify their requirements and recommendations for the scope of the Environmental Impact Assessment. Recommendations may be both standard ones which apply to all wind farm developments, but may also include site specific requirements or concerns.

For wind farms on peat of significant thickness (i.e. 0.5m of greater), standard requirements for the EIA include:

- Understanding of the location and nature of the peat on the site – a conceptual model;
- Impacts of the development on the condition of the blanket bog, particularly with regard to water levels and surface flow patterns;
- Impacts on nature conservation, including the condition of the vegetation;
- Impacts on water quality generally including pollution prevention measures, and specifically regarding fisheries and any other sensitive aquatic receptors (e.g. salmonid rivers, rivers with freshwater pearl Mussels), and private or public drinking water supplies;
- Construction and operation of the site including proposals for road and hardstanding construction, management of drainage, runoff and any bridging/culverting required, soil and sediment management and borrow pits;

- Measures to mitigate any impact on the habitat and, depending upon the habitat status on site, measures to provide for habitat improvement to active bog status on degraded sites.
- Consideration of archaeological issues;
- Outline of potential peat slide or instability issues at the site.

Other recommendations should be realistic. For example some survey and monitoring might take a whole season or longer. A long dataset of hydrological observations may be preferable to draw conclusions which are more robust than those collected on a smaller number of site visits, but may not be necessary for the purposes of the EIA.

The DCLG review (2006) identifies time constraints (for both developers and consultees) as a constraint in the scoping stage. To gain maximum benefit from scoping Natural England should ensure adequate resources are available for commenting on development proposals at the screening stage.

4.3.1 Common Land

Common land is land normally owned by one person but over which others are entitled to exercise certain rights e.g. grazing. The origins of common land can be traced back to the manorial system of land management introduced following the Norman conquest in 1066. In England there are nearly 400,000 hectares of common land in England.

There is now, however, a public right of access to most registered common land under the Countryside and Rights of Way Act 2000.

The Commons Registration Act 1965 introduced for the first time a national requirement to register common land, town or village green, and rights of common. This was subsequently updated in the Commons Act 2006, which creates a statutory framework that will promote the interests of wildlife and the countryside as well as commoners, landowners, and anyone else enjoying common land.

Section 38 of the Commons Act 2006 defines a number of prohibited works which include works which impede access to or over the land, which might include erecting fencing, constructing buildings, digging ditches or resurfacing of land with tarmac and similar materials. Consent to carry out such works is required.

Section 16 of the Commons Act 2006 enables owners of common land to apply to deregister common land. If the land to be released is more than 200 square metres an application must be made at the same time to register 'replacement land'

The issues surrounding common land are highly complex and it is recommended that Developers seek expert legal advice at an early stage to avoid potential problems at a later stage. The complexities can give rise to doubt whether mitigation proposals can effectively be implemented on land which is owned by third parties and over which others have rights.

4.3.2 Application Boundaries

Planning fees were introduced in 1981 and were last amended by the Town and Country Planning (Applications and Deemed Applications) Fees (Amendment) (England) Regulations 2008 [Statutory Instrument 2008 /958], effective from 6 April 2008.

Guidance on the calculation of planning fees has been issued by DCLG in the form of Circular 04/08. For the purposes of fee calculation wind turbines are classed as 'Plant and Machinery' (Section 5 para 40). A fee calculation method for new wind farms is given as:-

"To calculate the fee for a new windfarm, add all the land over which the blades of each turbine can rotate to the area of the footprint of any ancillary structures and engineering works. It is not necessary to include within the red line(s) on an application to put up wind turbines any other land between the turbines if no development is proposed there. On a site of no more than five hectares, £335 should be charged for each 0.1 hectare. Over five hectares, a fixed sum of £16,565 is payable with an additional £100 for each 0.1 hectare in excess of the first five hectares, subject to a maximum in total of £250,000.
By the way, using land within the perimeter of a windfarm for agriculture would not require planning permission for change to a mixed use."

As has been seen recently in the South Pennines Wind Farm Inquiry, defining the redline boundary tightly around the development gives no scope for micro-siting at a later stage. It is recommended that the planning authorities and Natural England consider setting limits of deviation that allow for micro-siting which avoids Developer's submitting a new application to relocate turbines, tracks and other structures which is both time consuming a wasteful of resources for both Developers and the various agencies.

4.4 Environmental Impact Assessment

4.4.1 Aspects of the EIA to assess – what is required

The environmental impact assessment (EIA) can be divided into the following stages:

- Assessment of the baseline condition of the site with observations and measurements.
- Identification of the context of the site including: existing pressures on the peat, existing or planned wind farm or other developments in the area, potential downstream issues and sensitive receptors
- Synthesis of information to develop a conceptual model of site. This should include development of an understanding of: surface and groundwater levels and flow; depth and distribution of peat and its condition (e.g. humification, erosion, other local issues); and an understanding of ecology and habitats of the peatland.
- Use of standard assessment criteria for the magnitude and significance of impacts.
- An assessment of the impacts of the proposed wind farm on peat (both within and outside the site). Key impacts are specifically ecology (and land management), hydrology, water quality and peat stability (including erosion) impacts and landscape and visual impacts, however, the overall impact on the peat body integrity as a whole unit must also be considered. Local knowledge of the site and initial screening work may identify other issues. The impact of the development in its construction, operational and decommissioning stages should be identified including an assessment of the likelihood of the event where possible. All the potential impacts of the development should be outlined.
- Following the outlining of all the potential impacts mitigation measures should be outlined to reduce the impacts of the development. The residual impact of the proposed development following mitigation should then be summarised.
- Cumulative impacts should be clearly assessed. This includes the overall impact of all activities on the site, the impact of the wind development on the wider area including downstream impacts.

This section looks at these stages and considers the information that is relevant to impacts on peat. The assessment of the EIA is divided into impacts of construction, operation and decommissioning, where appropriate.

Relevant general guidance for wind farm environmental impact assessment includes:

- Peat Landslide Hazard and Risk Assessments – Best Practice Guide for Proposed Electricity Generation Developments, Scottish Executive, December 2006.
- British Wind Energy Association (1994) – Best Practice Guidelines for Wind Energy Development.
- Irish Wind Energy Association, 2008, Best Practice Guidelines for the Irish Wind Energy Industry.
- Department of Environment Heritage and Local Government (2007), Wind farm Planning Guidelines.
- The Royal Town Planning Institute (2001) – PPS Note: Environmental Impact Assessment.
- The Department for Communities and Local Government (2000) – Environmental Impact: a Guide to Procedures ISBN 72 772960 8.
- Guidelines for the Risk Management of Peat Slips on the Construction of Low Volume/Low Cost Roads over Peat – Frank MacCulloch, 2006.
- Scottish Natural Heritage (2005) Constructed Tracks in the Scottish Uplands, Land Use Consultants.

Other more detailed guidance (e.g. CIRIA construction guides and Environment Agency Pollution Prevention Guidance Notes (PPG) are referred to in the appropriate sections.

There are detailed reviews of wind farm EIA in the literature and these have been discussed in the literature review (section 2.6.3) and a comprehensive list of references if provided at the end of this report.

4.4.2 Baseline Condition

Although the nature conservation interest may be made up of various attributes, such as birds, invertebrates, mammals, reptiles and amphibians, the close relationship of the vegetation with the peat water table underpins and supports them all. The peat-forming vegetation, or such vestiges as remain on degraded sites, should be described with reference to the geology, hydrology and hydrogeology. Peat habitats are groundwater dependant ecosystems, where groundwater and surface water levels and flows are intrinsically linked to the ecology and resultant habitat.

Geology and Soils

The context of the geology of the site should be described with reference to detailed geological mapping at a 1:50,000 scale (or more detailed) maps published by the British Geological Survey (BGS). This should include both solid bedrock geology and superficial drift deposits. Reference should be made to any structural features including faulting or changes in rock type which may influence the water environment, such as springs and seepages. Seepages of groundwater with a higher mineral ion content than rainwater may give rise to more fen-like vegetation than found on the rain-fed bogs.

Other features, such as mines should be investigated if they are present at the site. Mine water discharges can contain significant concentrations of minerals in solution and very significantly impact water quality, and subsequent vegetation. Areas of mine workings may also be subject to subsidence or instability.

The superficial geology is important as it describes the substrate on which the peat body has developed. Low permeability clays acting as aquitards, such as clay-rich glacial till, assists peat formation by ponding surface water. The interface between a low permeability mineral sediment and peat is often the focus of peat slides. The topography of the drift (and to some extent the bedrock) can influence the depths of peat able to develop, as sumps and hollows will infill with deeper peat. Blanket peat may also be deeper where it overlies valleys within the subsurface geology.

The soils present in the area should be reviewed, as soil type is often closely related to vegetation and the soil type (e.g. blanket bog peat soils, raised bog peat soils, fen peat soils, shallow very acid peaty soils over rock, very acid loamy upland soils with a wet peaty surface, loamy and sandy soils with naturally high groundwater and a peaty surface, http://www.landis.org.uk/soilscapes/), can provide a good indication of the depth of peat likely to be encountered on site. However, such speculation is no substitute for an appropriately detailed peat depth survey, and the soils and peat depths estimated from mapping should be confirmed with on-site observations at key locations (see later).

Hydrogeology

The presence and flow of groundwater at the site should be described. This includes a description of deeper bedrock groundwater, and also more superficial groundwater in the near-surface sediments and peat. The depth of water below the peat surface is of interest, as this shows how far down the oxidising conditions extend. It informs the judgement as to whether the bog is likely to be mainly decomposing and losing carbon, or capturing it. Interactions between groundwater and surface water, including springs and seepage lines should be identified. Drainage to ground in terms of sinks or depressions in the peat surface with no outflow should be noted where observed, as these may be linked to sub-surface diffuse or pipe flow.

Peat pipes are lines of preferential flow through peat mass, or along the base of peat sediment at the junction of the peat and underlying sediment (particularly where this is low permeability). They can be identified by discrete flows out from the peat body often at the down-gradient edges of peat or from the noise of running water beneath the peat surface. However, most are not visible or identifiable. Use of ground penetrating radar (Holden et al 2002) has shown that peat pipes are present in many peat bodies, particularly those which have been subject to drainage, and peat pipes have been implicated as a factor in peat slide.

Topography and Hydrology

The topography of the development site should be described: this includes the surface water catchments and drainage patterns. Any water courses on site should be identified and any existing water quality or quantity data (for instance Water Framework Directive status) should be documented. Airborne LiDAR is a particularly useful technique for determining contours at 20cm intervals, and ground-based techniques are now developed that allow much smaller intervals to be plotted.

The direction of drainage from the locations of proposed turbines and tracks should be identified, as this determines where any down gradient impacts may be focussed.

The slope of the land is important in determining the potential for peat slide, and this should be documented if a peat slide assessment is undertaken.

Peat Description

The baseline description of the site should include a condition assessment of the peat on, and adjacent to, the site. This should be related to the underlying solid geology, superficial geology and any soils present, as these provide the geological and hydrogeological context in which the peat has developed. The peat description should include:

- Extent and location of peat which indicates the potential scale of the impacts (this may have been established during the site screening stages). Peat may cover the entire site, or be present in smaller pockets. If the whole site is covered with peat then it is inevitable that infrastructure will be located on peat. If there are parts of the site without peat, then it is possible that the site can be designed to avoid impacts on the peat, or at least minimise impacts.
- Depths of the peat to the nearest 10cm, as this may influence construction techniques (particularly of tracks), the site layout, and is a control on stability. Properties of the peat are also important for understanding water movement in the peat and the likely impact of drainage. Probing should be at sufficiently frequent intervals to build up a reliable three-dimensional representation of the peat deposit (including turbine and track locations and areas which may be impacted by the development). Peat thickness is important in estimating stability and may also influence site design and construction. Observations of the peat should include depths and also ideally the properties of the peat such as its structure, dominant plant remains (sedge, *Sphagnum*, ericaceous, wood or grass), texture (fibrous, amorphous, etc) and humification. A scale such as the Von Post scale (see section 2.4) can be used to approximately classify peat structure in the field. The descriptions of the peat profile should include the texture and nature of the underlying mineral layer as this is very influential in determining the vertical transmission of water from the main peat mass into the underlying bedrock as well as informing the peat slide risk assessment. Peat depths can be obtained via a variety of methods including:
    - Probing – a suitable probe should be used, which can clearly identify peat in comparison to other substrates. However, care should be taken in interpreting probed peat depths, as probes may just measure soft sediment depths, and not a true peat depth as deeper soft clay sediment underlying the peat may also be penetrated.
    - Augering, e.g. with a peat auger (which can provide peat cores) such as a gauge auger, or Hiller or Russian type chamber auger; alternatively a soil auger could be used, but will provide only partial recovery from peat horizons. This provides more scope for assessing the structure and variability of the peat, and depth to water level by bringing up material for checking from the chosen depth.
- The slope of the site should be recorded at suitable intervals, perhaps from a contour map generated from LiDAR.
- Hydrology and hydrogeology of the peat itself: water moves over and through peat as surface and subsurface flows. Understanding both the rapid pathways of flow through peat (e.g. surface drainage channels, peat cracking and discontinuities, and sub surface peat pipes), and slower seepage zones (through the peat mass) will indicate areas where the wind farm development has most influence on water movement. It may also influence the overall design of the site.

A wind farm can have impacts on intact and degraded peat. If peat is already cracked, fissured and eroded (for example on the edge of a larger peat body that is not intact) then the consequences of the development can still be negative by exacerbating what is already occurring. On the positive side, degraded peat has the additional potential for greater biodiversity gain as a result of bog restoration measures. Conversely, at more pristine blanket bog sites the development will impact on more ecologically interesting bog habitat and may cause its condition to become unfavourable, and there is no scope for improvement via restoration. The development of wind farms on degraded bog sites should only be undertaken in such a manner as to enable their future habitat restoration if opportunities for restoration arise in the future.

If deep peat is present over any significant portion of the site, a screening of the site for peat stability issues should be undertaken at the EIA stage. If the screening indicates a potential peat stability risk, a full peat stability assessment should be undertaken at either the EIA or detailed design stage.

Biodiversity

The biodiversity of blanket bog should be assessed as part of the Environmental Impact Statement. Useful information to inform the scoping stage includes:

- Maps: topographic with drainage system (1:25,000 and 1:10,000), solid geology, drift geology, soil survey (if available). These provide a guide to gross topography, underlying geology, superficial geology, including the extent of the peat deposit, and information relevant to the eco-hydrological interpretation of the wetland from which a conceptual model can be constructed.
- Phase 1 habitat maps (if available). While these are insufficiently detailed for the ecological assessment, they can provide useful steer for how to structure a more detailed survey.
- Searches of local BRC (Biological Research Records Centre) for any plant and animal records for the proposed development area. It is helpful to know which common, characteristic, rare and unusual species are present.

The following is a recommended approach to carrying out an adequate ecological survey and assessment of the potential ecological impacts of a wind farm development on blanket bog habitat:

- Walkover survey to map the extent and location of blanket bog habitat, as indicated by the presence of peat in excess of 0.5m thick, the depth threshold used in blanket mire definition.
- Carry out an NVC survey with vegetation mapped to a sub community level. This involves dividing the vegetation up into relatively homogeneous stands and then recording sufficient quadrats within each stand to describe it. The quadrats can either be pooled into groups and the combined species list and constancies used to assign it to an NVC community, perhaps using a computer programme such as MATCH[5], or each individual quadrat can be classified using a programme such as MATCH. (.)
- The vegetation may not be typical of intact blanket bog in degraded sites. The best NVC fit may be a type of acid grassland, for example, and all communities on peat greater than 0.5m thick should be identified and mapped as well as the distribution of classified quadrat points allows.
- Assess whether blanket bog is ‘active’ or ‘inactive’. This can take the JNCC approach of using particular plant communities as indicative of ‘active’ bog and/or testing whether the acrotelm is present by taking a small core or spit of peat.
    - The JNCC approach has been to use the plant communities present as indicators of whether a blanket bog is ‘active’ or not and the plant communities indicative of the presence of ‘active’ blanket bog have been listed (M15, M17, M18, M19, M20 and M25). Some of the plant communities (e.g. M25) and sub-communities are unlikely to accumulate peat and others which may not normally be particularly ‘active’ can accumulate peat if there is a sufficiently high cover of *Sphagnum* (typically >25%). As a general rule a high cover of *Sphagnum* and/or *Eriophorum* species indicates active peat accumulation, but severely burnt and trampled *Eriophorum vaginatum* dominated mire is unlikely to accumulate peat.
    - An alternative approach to using the plant community as an indicator is to see if an acrotelm is present or not. The presence of an acrotelm, even if it is only 1 or 2 cm thick, is a good indication that peat is accumulating, whilst the presence of a relatively hard black peat surface between plants, such as tussocks of *Eriophorum* or *Molinia*, is a clear sign that an acrotelm is absent and that peat is not likely to be accumulating. The presence of an acrotelm can easily be ascertained by taking either a small spit of peat with a spade or taking a small core using a soil corer. An

[5] MATCH is a computer-based programme for classifying lists of plant species, such as collected in quadrats, into National Vegetation Classification plant communities and sub-communities. It provides a coefficient of fit to show how well the sample matches the published account of the community or sub-community to which it is assigned.

indirect and less reliable measure of the presence or absence of an acrotelm is how readily the foot of a surveyor sinks into the peat surface. This approach is used in the assessment of land management impacts (grazing and burning) on blanket bog in MacDonald *et al.* (1998).

  - It is important to recognise that the determination of active bog is a judgement, having taken account of all relevant evidence, as described above. Given that the assessment may have to be accepted by parties on opposing sides, it is wise to obtain a consensus view. Mapping the edges of active areas may be particularly challenging, even though agreement may have been reached that active bog is present.

- Assess the condition of blanket bog habitat. This includes estimating the area of blanket bog habitat affected by drainage ditches, gullies and peat cuttings is not effectively quantified in an objective manner in the condition assessment and these characteristics are some of the most important in affecting the condition and species composition of any blanket bog habitat in England.
  - There are some standard approaches to assessing the condition of blanket bog habitats on the JNCC website. Blanket bog habitat is included in the Common Standards Monitoring guidance for Upland Habitats. Some of the observations are more subjective than others and the scale of assessment varies significantly between the targets.
  - The area of blanket bog habitat affected by drainage ditches, gullies and peat cuttings is not effectively quantified in an objective manner in the condition assessment and these characteristics are some of the most important in affecting the condition and species composition of any blanket bog habitat in England.

The assessment of the ‘ecological’ value of the blanket bog can be made using a number of different criteria. Size (ha), diversity (number of sub-communities), rarity of plant communities, rarity of species, species richness (plants, birds, etc), how intact the blanket bog is and the wetness of the site are probably the most important criteria used for assessing the ecological value of a blanket bog.

From all of the above information it will be possible for a team of ecologists and hydrologists to identify the area of blanket bog habitat that is likely to be affected by drainage. Working with the ecologist/s the hydrologist should be able to identify the areas of blanket bog that will be affected indirectly by enhanced drainage and the extent to which this will occur depending on the design of tracks and turbine bases.

There are many factors that can indicate the quality of a blanket bog and these are shown in the following table. The table also highlights the key interactions between the factors.

Table 4-1 Indicators of Blanket Peat Quality

Factor	Comment	Key Interactions
Individual plant species	Typical blanket bog vegetation includes the following at an overall cover >10%; combined cover of cotton grasses and heathers <80%: • deer grass (*Trichophorum cespitosum)* • cotton grass (*Eriophorum* species) • several bog moss (*Sphagnum)* species • heather (*Calluna vulgaris)* • cross-leaved heath (*Erica Tetralix)*	Water level
Vegetation type	NVC communities: *Isolated pools:* M1 *Sphagnum auriculatum* bog pool community M2 *Sphagnum cuspidatum/recurvum* bog pool community M3 *Eriophorum angustifolium* bog pool community *Widespread communities:* M17 *Scirpus cespitosus-Eriophorum vaginatum* blanket mire M18 Erica tetralix – Sphagnum papillosum raised and blanket mire. M19 *Calluna vulgaris-Eriophorum vaginatum* blanket mire. (M19a *Erica tetralix* sub-community is indicative of better quality; other sub-communities, depending on context, might be taken as degraded). M20 *Eriophorum vaginatum* blanket and raised bog. This is generally considered to be indicative of degraded blanket mire. M25 *Molinia caerulea-Potentilla erecta* mire. A community of degraded blanket mire that can develop a significant cover of Sphagnum mosses locally, where it is considered by some in Lancashire of being peat-forming.	
Water Levels	Not less than within 15cm of the surface in an intact blanket bog, with limited seasonal variation.	Vegetation Water movement
Water movement	May have been changed by previous land management. Absence of unnaturally eroded and over-deepened channels indicates good condition. The converse cannot be automatically attributed to abuse if the site is close to the edge of the climatic range, or even when it is not (Shetlands).	Water levels Water Quality
Forestry	Drainage will have lowered the water level (ditches may be present but hidden by forest debris and brash). Ditches may act as lines of weakness through the peat, and potential lines of structural	Water movement Vegetation Water Level

Factor	Comment	Key Interactions
	failure. Impacts of forestry extend beyond the trees and so wind farm sites next to forestry plantations will be affected by it.	
Drainage history	Moor gripping to improve productivity for grouse or grazing (grants available for this until mid 1980s). Blocked grips may affect site drainage. Peat extraction, especially small-scale domestic under turbary rights.	Water movement Water levels Vegetation
Erosion	May be seen as erosion hags, drainage pathways and bare peat. Erosion can be initiated by: • Pollution • Fires • Drought • Grazing • Drainage • Footpaths and tracks. Or be the consequence of natural processes. It is important to try and attribute the conditions to one or more causes. If the cause of the erosion is known then this can help understand whether this is likely to be made worse by wind farm development.	Water quality Water levels Vegetation
Land Use and Management	Activities which may affect the bog include: • Forestry • Drainage • Grazing • Moor burning.	Vegetation Water level Erosion Stability (via formation of weaker layers) Water Quality
History of Peat Instability	If peat has moved on the site before then it indicates that the baseline conditions on the site (wetness, peat humification, depth, slope or other local factors) may predispose the site to instability. In this case the wind farm development may be more likely to trigger further peat instability.	Erosion Water Quality

A detailed understanding of the current condition is fundamental to identifying the potential impacts of a wind farm on peat and their likely scale.

4.4.3 Context of the Development

The EIA should include an understanding of the area around the wind farm. This helps to identify the impacts away from the immediate site and indicate where the off-site impacts might occur. The detail required will be determined by the location but important information can include:

- Location of any off-site impacts – these are often determined by catchments (both surface and groundwater).
- Sensitive areas – this can include any designated areas (biodiversity, landscape), sensitive water environments (Water Framework Directive), water bodies, fisheries and water abstractions (both licenced public and private abstractions – details available from the

Environment Agency, and small unlicenced domestic water supplies – details may be available from local council Environmental Health Departments or from specific local surveys).

- Other wind farms in the area – this includes other wind farms on the same peat body and wind farms where the combined landscape/visual impact including the indirect impacts on the landscape fabric (see sections 2.14.1) may be significant.
- Other potentially degrading influences on the peat in the area should be identified. These may include forestry, drainage, grazing issues, recreation and tourism.

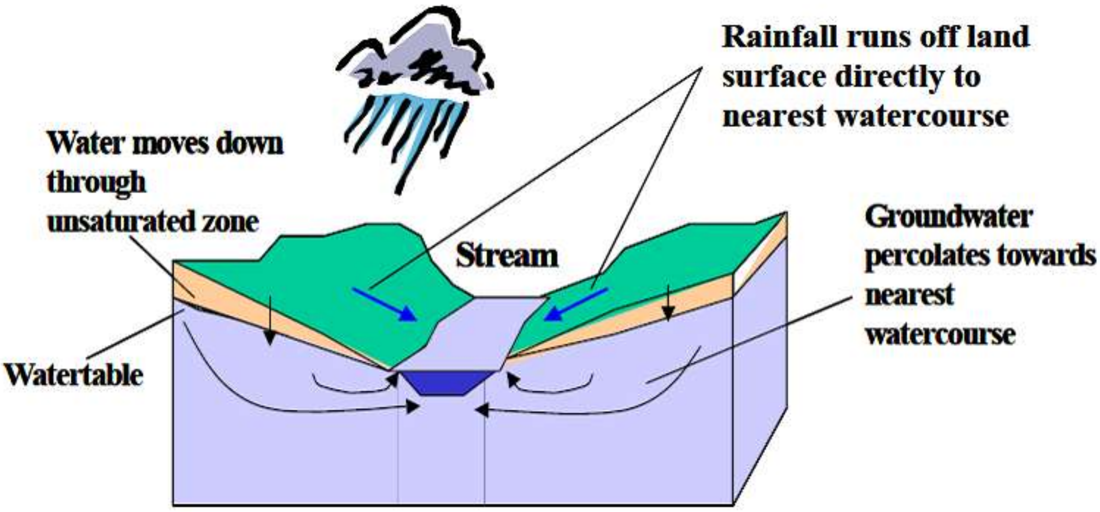
4.4.4 Conceptual Model

The conceptual model distils the known variables into a sketch, map or concise verbal description, indicating how particular factors, such as water inputs, influence the various attributes, such as vegetation. A good conceptual understanding of the site is fundamental to identifying the kind of impacts on the peat and their likely location. The conceptual model should include:

- A clear description of the site.
- An outline of the main peat areas including their approximate thickness, slope and degree of humification (decomposition) of the peat.
- A summary of water movement round the site and the main controls. Flow pathways may be surface or subsurface (for example surface channels (natural and artificial), peat pipes and seepage areas). Controls on water movement include channel and ground slopes and connections between flow pathways.
- The ecology of the site and how the peat habitat has developed, including peat mesotopes (blanket mire, valley mire, etc) and land management.
- If the peat on the site is not intact (i.e. as a result of land management activities or other activities) then the conceptual model should identify how this might have affected the peat.
- The conceptual model should also incorporate other relevant site observations – for example significant erosion or evidence of peat slide and changes in land management.

A simple conceptual model based upon ‘Mineral Extraction Code of Practice for the owners and operators of quarries and other mineral extraction sites, Water Environment (Controlled Activities) (Scotland) Regulations, 2005, SEPA, Version 1 July 2006’. is shown in Figure 4-1 below. A simple model such as this could be extended to include more local detail as required.

Figure 4-1 Simple Conceptual Model of a Typical Catchment



4.4.5 Assessment Criteria

Standard assessment criteria should be used to determine the impact of the development on the blanket bog and how significant this is.

The EIA should use a consistent method, and the approach recommended by Scottish Natural Heritage (Guidance on EIA, 2005) is a suitable example. This describes procedures for assessing the significance of an activity on a natural resource. For wind farm developments on peat the assessment of significance would be based on an analysis of:

- The *sensitivity* of the blanket peat to change and its ability to accommodate the changes likely from the wind farm development.
- The amount and type of change (*magnitude)* which includes the timing (short or long term, one off or continuous), scale (e.g. local or widespread), size (e.g. small or large) and duration (e.g. temporary or permanent) of the impact.
- The *likelihood* of the impact occurring – is it certain/ uncertain, is it predictable? Scottish Executive guidance (2006) includes a 5 point scale of likelihood varying from '*almost certain*' with a probability of > 1 in 3 to 'n*egligible*' with a probability of < 1 in 10^7.
- Comparing the impacts on the blanket peat which would result from the development with the changes that would occur anyway without the wind farm.

The significance is a combination of these factors based on how likely the event is to occur and the sensitivity of the receptor. For example an event which is unlikely to occur on an insensitive receptor would have a low significance.

A similar approach is described by the Institute of Ecology and Environmental Management (IEEM) ((**http://www.ieem.net/ecia/index.html**).

Table 4-2 Assessment of the Magnitude of Impacts

Scale of Impact	Description
Major	Impact resulting in a considerable change in the baseline environmental conditions with severe undesirable (or desirable) consequences on the receiving environment or causing statutory objectives to be exceeded. The impact may be on a large regional scale and include conditions outside the normal environmental baseline variability.
Moderate	Impact resulting in a discernible change in baseline environmental conditions with undesirable (or desirable) conditions or possibly causing statutory objectives to be exceeded. Impact on a local scale.
Minor	Impact resulting in discernible change in baseline environmental conditions with undesirable (or desirable) conditions that can be tolerated.
Negligible	No discernable change in baseline environmental conditions.
Notes. 1. Impacts can be positive or negative. 2. Examples of a major impact would be a high impact on a designated SAC (European site) which resulted in the site losing favourable condition.	

Combined risks are usually identified using a matrix or table of impacts a general example for and EIA is found at (**http://www.ieem.net/ecia/impact-assess.html#assess**), examples can be found in MacCullough (2005), Scottish Executive (2006) or for a non wind farm site in Poole (**http://www.boroughofpoole.com/downloads/assets/1101216675.pdf**).

4.4.6 Impact on Peat Hydrology/Hydrogeology

Wind farms can have an impact on peat hydrology and hydrogeology in the construction, operation and decommissioning phases of the development. Each site is unique and issues of particular local concern may be flagged up during the scoping and initial consultation stages.

Construction Impacts on Peat Hydrology/Hydrogeology

The construction phase of the development causes the most significant impacts, though some may be fairly shortlived. It may have an impact on:

- Drainage – creating new drainage pathways or blocking existing natural[6] ones. Drains created around tracks and turbine base excavations can result in lowering of the water level in the blanket bog and so drying out of peat and reduction in the ecological condition of the site and oxidation of the peat.
- Construction of tracks can impede the flow of water through the blanket bog and the degree of disruption depends on the method of construction.
  - Cut and fill tracks will intrude through the whole of the peat depth (typically on areas of thin peat) and dissect the blanket bog into smaller compartments. This will remove the hydraulic connection between the parts of the bog on either side of the track. This is particularly significant if the track crosses natural flow lines such as when following contours.
  - Floated tracks are more commonly used on deeper peat. Macullogh (2005) notes that cut and fill tracks are not economic if the peat is deeper than 2m. However, the track fill is known in some instances to compress the peat it crosses and can reduce the hydraulic connection of the peat on either side of the track. Floating tracks are designed to have some degree of rigidity and to overlay the acrotelm. This means that they compress the acrotelm and reduce its permeability and ability to transmit diffuse water flow. More fill may need to be added to maintain their level over time

[6] Man- made drainage to which the blanket mire has adapted without damage to peat-formation is included within the natural category.

and this exacerbates the effects, to the extent that water may be ponded up-gradient of the track, making those areas down-gradient drier. The permeability of the floated track is key to its potential to disrupt water flow: tracks constructed of materials of the same permeability as the intact acrotelm would permit a similar level of flow across the track.

- Felling of trees (such as key-hole felling around the areas of proposed infrastructure) – may affect drainage pathways or leave bare, compacted peat which is vulnerable to rapid runoff. This can result in sediment mobilisation and water quality impacts down stream (see section 2.7.4). It should not be assumed that the state of drainage associated with the trees pre-felling is ideal for the blanket mire.
- Removal of soils/vegetation – potential loss of peat mass though oxidation and wind erosion of desiccation of soils, loss of near-surface (acrotelm) rapid flow pathways and increase in surface flow.

There is likely to be some impact on blanket bog from all types of track construction. However, the means of the track construction, and in particular the permeability of the track material are key in how the track interacts with the peat hydrology and in turn its impact on vegetation (see section 2.7.1).

Operational Impacts on Peat Hydrology/Hydrogeology

The site is likely to operate for at least 20 years. Hence impacts during the operational phase, although they may be lower in magnitude, last for a long time. The emerging pattern is that old sites approaching the end of their design life are proposed for re-powering on the same site (e.g. Ovenden Moor Wind Farm near to Bradford, Chelker Reservoir near to Addingham, Coal Clough - Lancashire). During repowering new turbine bases and tracks may be required (e.g. at Catton Moor). If on blanket bog these are likely to result in increased impact, and re-use of turbine location and tracks would have significantly less impact. However, the existing negative impacts on the peat of turbines and tracks should be addressed at the re-powering stage.

Most of the impact of the operational phase is the drainage of the tracks on the site, and the impact of the tracks on the blanket bog integrity. During operation the site may:

- Lower water levels in the blanket bog, due to the on-going drainage of tracks which provide access to the turbines for maintenance. The effect is less than during the construction phase.
- The tracks may change flow pathways across the site, increasing potential for erosion in areas where water flow is now focussed.
- Any floating tracks on site may gradually sink into the peat, and require attention to prevent the tracks forming a pathway for runoff.

Decommissioning Impacts on Peat Hydrology/Hydrogeology

In the decommissioning stage the turbines are removed from the site. In general tracks remain in place and turbine bases are reduced in height and covered with a layer of soil and vegetation. The removal of the turbines and associated activities on site such as the covering of turbine bases with soil may result in some contamination risk to water quality from either pollution incidents or the mobilisation of sediment on site from earthworks.

This is likely to be a significantly lower impact than the construction impacts on the hydrology and hydrogeology of the site. However, the retention of the tracks on site means that the track drainage and structure remains present, and provides a continued disruption to the integrity of the blanket bog. If the tracks are no longer maintained and the track drainage is actively blocked this would reduce the on-going impact of tracts post decommissioning. However, it is wise to assess the degree to which the blanket mire may have adapted to the *status quo* and whether the actions outlined above would bring improvements.

Re-powering of Wind Farm Sites

If the site is to be repowered with new turbines then new bases may be required, with associated new tracks, and additional impacts may be seen. On sites proposed for re-powering, there would be significantly lower impact on blanket peat from re-using tracks and turbine base locations than from constructing at new locations in intact areas of bog, though there may be significant additional risks, depending on the proposals and the design. However, the impacts of existing infrastructure on the blanket bog should be assessed and mitigated as part of the re-powering operation.

4.4.7 Impact on Ecology

The ecology of the blanket mire will be affected *inter alia* by activities which change the hydrology or hydrogeology or the land management regimes in the longer term. These have been discussed in section 4.4.6. The key ecological impacts are:

- Direct losses of blanket bog habitat from the footprint of the development.
- Changes to the water regime as affecting the vegetation:
    - The effects on species composition of the blanket bog vegetation as a consequence of impacts on drainage and water-levels in the peat.
    - The effects on the species composition of the blanket bog vegetation and other receptor habitat types receiving drainage waters enriched with mineral nutrients.
    - The impacts of the changes in concentrations of suspended solids and chemical properties of receiving waters downstream of the proposed development site on the biota within the streams and bodies of standing waters. This may potentially include protected areas many tens of kilometres downstream if catastrophic changes in water quality are not attenuated by dilution over the distances considered.
- The **extent** (area) of blanket bog habitat temporarily lost during construction and how much will be restored. The **quality** (type) of blanket bog vegetation to be restored and how likely it will be restored. Restoration of bog vegetation may take tens of years to occur unless active management measures are implemented.
- How the habitats and species at the site will develop over the life span of the wind farm if the proposed development does not go ahead – with or without management designed to achieve favourable condition.
- Effects on bird and animal species, such as raptors, from changes to the extent, nature and quality of the habitat as defined by structure (hummocks, hollows, gullies) and vegetation.

Operation of the site may also affect habitats and species (a combination of the plant species present and the structure they form for occupation by other forms of wildlife as a consequence of their growth).although the risk can be reduced by good operating practices. Potential sources of habitat damage during operation include:

- Pollution
- Site traffic.

Restoration of vegetation may be proposed as a part of decommissioning. Plans should be realistic given the difficulties of restoring the functional hydrology underpinning peat-forming vegetation, and take account of the degree to which the blanket mire ecosystem has adapted during the life of the wind farm.

4.4.8 Impact on Water Quality

Impacts on water quality can be influenced by changes to water flow patterns and may influence ecological changes in the longer term.

During the construction phase of a wind farm the key impacts on water quality can be:

- Pollution – including substances that can kill or inhibit plants and animals, and those, such as plant nutrients, that influence the species composition and structure of vegetation. It can be minimised by good practice on the site. The EIA should identify both the potential sources and receptors of pollution and this should inform the activities of contractors working on the site.
- Runoff patterns may change during construction of a wind farm on peat, e.g. increase in proportion of surface runoff due to flow in construction trenches or interference with the natural drainage network. This may have an impact on downstream water quality, as well as the overall hydrological budget of the blanket mire.
- Erosion – suspended solids and also nutrients (see above) may increase downstream. Erosion can be influenced by:
    - Soil erodability: silty, sandy soils are generally more erodible than cohesive clay or

organic soils. Peat is likely to erode if the vegetation is removed or water flow is concentrated in channels. The type of mitigation measures effective depend upon the sediment grain size.
  - Vegetation cover reduces erosion – vegetation removal and tree felling increases the potential for erosion.
  - Climate – increased rainfall frequency, intensity and duration increase the risk of erosion.

Operation of a wind farm may affect water quality although the impacts are likely to be small compared to the construction stage. Impacts include:

- Long term change in runoff pattern, particularly a change in the proportion of baseflow and quickflow from the catchment and the size of storm peaks.
- Pollution – this can be minimised by good operating practices on the site which incorporate a clear understanding of the general and site specific risks identified in the EIA.
- Runoff from trackways and hard standing or exposed areas of mineral sediment may have a higher mineral content than runoff from rain-fed bog and result in local vegetation changes.

Decommissioning of a wind farm is unlikely to have significant long term additional impacts on water quality. During the deconstruction phase potential impacts (e.g. pollution) are similar to those during construction work.

4.4.9 Impact on Peat Stability

Issues affecting peat stability should be scoped in the EIA, and if of concern a commitment to a full stability assessment should be given (for instance as part of a planning condition or agreement). For all areas with more than 0.5m of peat thickness peat stability should be considered as a risk and assessed.

The EIA may not include a full peat stability assessment during the EIA as it may be carried out post planning during the detailed design stage. Developers are understandably reluctant to bear the additional cost of carrying out the work before planning permission has been granted.

Peat instability includes local erosion and larger scale effects as peat slips or bog bursts. Seasonal variation in temperature and rainfall. Peat landscapes are particularly susceptible to freezing and thawing action as a mechanism for erosion and sediment generation.

As a minimum the EIA should include an understanding of the risks at the site and a recommendation about whether a full peat assessment is required. Key risk factors for peat stability are:

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

Peat instability is also more likely if there is:

- Very deep peat - >3m
- Low shear strength - <6kPa
- High Von Post number >7
- Slopes of >6^{o}
- Areas near water features.

These can be briefly assessed in the EIA and if these factors are found at the site a full peat assessment can be recommended.

Peat Assessment Report

A full peat assessment report may be required for a wind farm if peat risk factors are found at the site. In Scotland the CAR regulations have been used to require developers to carry out a peat survey and studies are checked by the ECU before approval. In England the peat survey can be a condition of planning but does not need to be checked and approved. However, any planning conditions requiring a peat assessment should also stipulate a suitable means of approval before construction commences on site.

A peat assessment should describe and synthesise results from site investigations including (but not limited to) those shown in the following table. Measurements should be made at turbine locations, along the route of any proposed tracks and other infrastructure plus enough locations elsewhere on the site to give a clear conceptual model of the location and nature of peat on the site.

Table 4-3 Peat Survey Investigation

Investigations	Methods
Peat Description at locations across the site	Full description of peat following Hobbs (1986) Humification of peat on Von Post scale
Mapping of drainage and other water features including seepage areas	Site visit and observations
Peat depth across the site, particularly at track and turbine sites.	Peat probe or Auger
Slope survey across the site, particularly at track and turbine locations and areas of deeper peat.	Desk study using DTM can produce a broad picture of the slope Field measurements including slope aspect will give a more detailed picture
Shear Strength Survey at track and turbine locations, on steeper slopes and in areas of deep peat.	Shear Vane tests – care that the low values of shear strength expected for peat are within the range of the instrument. CBR (California bearing ratio) standard test used in road design

The peat assessment should identify where the risk factors combine as these are the higher risk areas for peat stability.

Risk of peat instability may be estimated using the Factor of Safety calculation (Scottish Executive, 2006; MacCullogh, 2005; Geological Survey of Ireland, 2005). As discussed earlier peat is an unusual material and its strength is derived from its fibrous nature and interaction between the peat and the surrounding water. Standard geotechnical calculation (including the Factor of Safety calculation) should only be used with caution for peat soils as the assumptions within the formula may not hold for peat. Developers should show that they have used conservative estimates of peat properties (e.g. shear strength in their calculations).

The peat study should give an overall picture of risk across the site by combining these risk factors as a table or a map to clearly communicate the location of higher risk areas on the site. Examples are given in Scottish Executive (2006) and MacCullough (2005).

Relevant Guidance includes:

- Irish Wind Farm Planning Guidelines (**http://www.sei.ie/index.asp?docID=-1&locID=276**);
- Peat Landslide Hazard and Risk Assessments – Best Practice Guide for Proposed Electricity Generation Developments, Scottish Executive, December 2006.
- PPG14 – UK Department of the Environment Planning Policy Guidance: Development on Unstable Land. (Annex 1: Landslides and Planning and Annex 2: Subsidence and Planning).
- Guidelines for the Risk Management of Peat Slips on the Construction of Low Volume/Low Cost Roads over Peat – Frank MacCulloch, 2006

4.4.10 Mitigation Measures.

A clear description should be provided of the proposed mitigation of the impacts of the development on the blanket bog. This should include sufficient detail that this can form part of the commitment of the developer at the planning stage to reduction of the impacts of the site. It is important also that this commitment is communicated to the contractor on site during construction, as part of the Construction Method Statement (CMS) so that mitigation measures proposed are implemented. Detailed plans for management of particular aspects of the development, such as peat or sediment management plans, drainage management, soils/peat re-use on site, vegetation management, pollution control and stability management may be developed, and linked to the CMS. These plans can specify precisely how the work on site will be undertaken and managed so as to reduce the impacts to the environment. Further details of required mitigation can be specified within planning conditions. However, whilst it is important to specify mitigation measures, there is the need to include a watching brief for any unpredicted effects over the lifespan of the development.

Mitigation measures are actions that can be taken to reduce the impact of a wind farm development. These can be long term measures incorporated into the design of the site, such as designing infrastructure or site layout in a way that reduces the impact on the peat (e.g. locating infrastructure in less sensitive areas, careful management of runoff from tracks and hardstanding areas). These measures may be permanent as tracks are likely to remain in place after decommissioning of the site. Temporary measures may also be taken to manage construction impacts such as drainage excavations. Mitigation measures can also be employed during operation of the site and can include operational procedures e.g. to reduce the risk of pollution.

It is important to evaluate mitigation measures against the absolute baselines provided by designations such as SSSI and SAC, together with their condition requirements, and against the biodiversity action plan targets. A mitigation measure, or bundle of measures, is not effective or worthy of consideration in the overall balance of damages and benefits if it falls short of any of these.

The success of mitigation measures requires ongoing commitment from the developer and contractors to ensure that operating procedures are followed at all times. Even with mitigation measures in place there will be a residual impact on the blanket peat. Some consequences of the development may be irreversible (e.g. loss of peat mass) and others may be reversible (e.g. lowering of water levels). However even reversible consequences may cause effects elsewhere which are irreversible or which take a long time to recover (an example is damage to downstream species and habitats following a pollution incident). The developer should be clear about the consequences of their actions and realistic about the remaining impacts.

The following sections discuss mitigation measures that can be appropriate for key impacts of wind farms and offer improvements. Key impacts are:

- Drainage
- Change in runoff
- Sediment release
- Water quality
- Tree felling
- Peat stability.

Each section summarises the main measures and their consequences. They are categorised as relating to:

- Site design: measures which can be incorporated into site design. Their impact persists throughout the lifetime of the site and they aim to reduce the impact of the infrastructure on the natural peat ecosystems.
- Construction: these would be of shorter duration and are designed to reduce the impact of construction activities.
- Construction/ operation: these measures would be in place for both the construction and operational stage of the wind farm. They mitigate against impacts (such as traffic and vehicle management) which are seen throughout the lifetime of the site.
- Operation: longer term mitigation measures associated with maintenance and operational impacts.

Mitigation measures are summarised in appendix B.

Mitigation of drainage impacts

Changing the water regime by drainage or rewetting will affect the blanket bog peat. In particular, drainage lowers the water levels and dries the peat, leading to loss of peat mass through oxidation or erosion. Careful site design can help to reduce the long term drainage impacts. Temporary short term drainage will be required during construction of the turbine bases, tracks, hard standing areas and cable trenches.

Lowering water level is reversible (as it can be returned to its original level) but associated changes to vegetation and peat structure may not be reversible. At the site design stage key actions to reduce the long term drainage impacts include:

- Appropriate design of tracks, drainage ditches and drainage systems following good practice guidance (see section 2.7).
- Avoid impediments to surface or groundwater flow. Ensure adequate design and sizing of river crossings (see section 2.7.1). Avoid groundwater barriers and cut-offs.
- Minimise depth of ditches to less than 0.5 m, and provide for regular cross-checks to flows within ditches.

During construction of infrastructure including turbine bases, hardstanding areas, tracks and cable trenches water level should be managed by:

- Management of temporary drainage during construction of cut slopes and tracks. Measures should try to mimic the natural drainage pattern, as deduced from the conceptual model, as far as possible.
- Pumping during construction of turbine bases using level spreaders to dissipate the discharge water. Soakaways or settlement ponds may be used in suitable areas but are not suitable on deep peat as additional water may increase pore pressure and increase the risk of peat slide or liquefaction.

Loss of peat mass through desiccation and erosion of dried peat or through oxidation is not reversible. Measures to reduce loss of peat mass include:

- Maintaining the water table. Limit drainage to small areas where it is absolutely necessary, and for as short a timescale as possible.
- Avoiding vegetation removal and exposure of the peat surface.
- Covering of stockpiles of peat to reduce desiccation and oxidation.
- Limiting the height of peat stockpiles to 1 m.

Mitigating the Change in Runoff Pattern

Wind farm development may change the pattern of water run-off from blanket peat to streams and rivers. This may be in response to changes in the existing natural or man-made drainage network or to shorter term changes during construction and/or operation of the wind farm. Changing the run-off from blanket peat can affect flow downstream, higher flow peaks may lead to flooding around water courses and a decrease in low flows may affect downstream biodiversity. Change in run-off rates may also cause erosion and may affect downstream water quality through release of additional sediment or nutrients.

Change in flows in downstream watercourses are reversible, however changes to biodiversity may take a long time to recover, if at all. Mitigation measures can include:

Site Design

- Minimise the length of drains to avoid intercepting large volumes of surface and seepage water, concentrating flows or diverting water into adjacent catchments.
- Camber tracks to avoid ponding and to maximise runoff.
- Use coarse erosion-resistant aggregate on tracks to reduce runoff.
- Install interceptor drains on steeper tracks.
- Intercept large volumes of water on tracks with porous materials to minimise direct discharge to watercourses.
- Use level spreaders on tracks with frequent water discharge.

Construction

- Backfill cable trenches as soon as possible. Open trenches should be drained temporarily. Use clay bunds in backfilled trenches to prevent any flow of water along their length.
- Pumping of water from turbine bases during construction either to be to areas of ground capable of absorbing the water (soakaways) or to settlement ponds prior to discharge. Avoid discharging water to soakaways in areas of deep peat, use level spreaders to remove water. Any water thus discharged must be free from contaminants arising from fresh concrete.

Operation

- Check crossings for blockages especially during and after heavy rainfall.
- Maintain track surfaces.

Although eroded peat cannot be replaced, it may be possible in some cases to stabilise the remaining peat. Water erosion can be minimised by the following measures.

Site Design

- Cross drains to prevent excessive build up of water in roadside ditches. Avoid concentrating flow peaks.
- Channel run-off from hard standing areas to avoid concentrating flow.
- Use low gradients in drainage ditches to avoid erosive flow velocities. Check dams / erosion protection in ditches with slope greater than 5%. Do not create ditches with a slope greater than 15%.

Operation

- Check crossings for blockages especially during and after heavy rainfall.
- Maintain track surfaces

Change in water quality may be reversible but vegetation and fish/ invertebrates which have been affected by the change in water quality may take a long time to recover.

Site Design

- Use settlement ponds and silt traps and treat run-off in line with best practice.
- Monitor water quality in key watercourses to ensure sediment load does not exceed acceptable limits.

Mitigation of Sediment Release

The most effective means of mitigation is to limit sediment generation. A **sediment and erosion control plan** for the site can identify key risks and which can be reduced by careful construction programming (e.g. avoiding work in certain areas during wet weather). Contingency measures for wet weather should be incorporated into a construction method statement. Daily sediment checks should be made including and the recording of any environmental protection actions necessary. Plans and mitigation measures should be specific rather than refer generically to the use of best practice.

Site Design

- Manage track drainage to reduce sedimentation.
- Construct water crossings to reduce flow at either end and use edge constraints to reduce splatter from vehicle wheels.
- Use buffer zones, silt fences, silt traps and settlement ponds to avoid sediment reaching watercourses.
- Produce a sediment and erosion control plan. Ensure that all contractors on the site understand and comply with the plan.

Construction

- Locate construction activities away from water courses, with a minimum 50m buffer (except at water course track crossings).
- Minimise the total exposed ground at any time by careful phasing of construction activities.
- Minimise soil stockpiles.
- Re-vegetate exposed areas as soon as possible.
- Revise the sediment control plan if new sources of sediment are identified during construction.
- Wheel washing activities should be conducted in designated areas with runoff in a re-circulating system as it is unlikely to be suitable for disposal via soakaways.

Operation

- Maintain tracks to avoid rutting.

Mitigation of water quality impacts

A Pollution Prevention Plan (PPP) will be required throughout all phases of wind farm development (construction and operation) and should be monitored by a suitable qualified person, with relevant experience and training. The plan should cover all potentially polluting activities, and all personnel working on the site should be trained in its use. Its aim is to ensure that construction activities are conducted in an appropriate manner to minimise environmental impacts and to ensure adherence to best practice methods by all parties, including sub-contractors. As a minimum, the PPP should consider the standard best International practice including but not limited to:

- Irish Wind Energy Association, 2008, *Best Practice Guidelines for the Irish Wind Energy Industry.*
- Department of Environment Heritage and Local Government (2007), *Wind farm Planning Guidelines*
- CIRIA (2005) *Environmental good practice on site.*
- CIRIA *Sustainable Urban Drainage Systems Design Manual for Scotland and Northern Ireland*, March 2000.
- CIRIA (*2004)*. *Interim Code of Practice for Sustainable Urban Drainage Techniques, National SuDS Working Group*
- National Roads Authority (2008), *Guidelines for the crossing or watercourses, during the construction of national road schemes.*
- CIRIA (2006) *Control of water pollution from linear construction projects. Technical guidance (C648*).
- CIRIA (2001) *Control of water pollution from construction sites. Guidance for consultants and contractors (C532)*
- UK Pollution Prevention Guidelines (PPG):
  - PPG1 (2008): *General guide to the prevention of water pollution*
  - PPG2 (2008): *Above ground oil storage tanks*
  - PPG4 (2006): *The disposal of sewage where no mains drainage is available*
  - PPG5 (2007): *Works in, near or liable to affect watercourses*
  - PPG6 (2008): *Working at construction and demolition sites*
  - PPG8 (2008): *Safe storage and disposal of used oil*
  - PPG21(2008): *Pollution incident response planning*
  - PPG26 (2008): *Dealing with spillages on highways.*

Pollution is reversible but its effects on the site and on downstream biodiversity can take a long time to recover. Measures to reduce the risk of chemical pollution and water quality impacts include:

Site Design

- Store equipment, materials and chemicals in site compound away from watercourses. Chemical, fuel and oil stores sited on impervious bases within a secured bund. Best practice guidelines to be followed.

Construction

- Intercept clean water upstream of construction ditches and pipe to a suitable location for dispersal, that will not have negative impacts on the structure and plant cover of the blanket mire.
- Locate construction activities away from watercourses.
- Construct toilet facilities using good practice guidelines. There must be absolutely no prospect of the products gaining access to the blanket mire, even in a ‘worst case scenario’.
- Avoid concrete batching on site. If wet concrete operations are required a suitable risk assessment should be completed prior to works being carried out. Measures to prevent discharge of alkaline wastewaters or contaminated storm water to watercourses should be

outlined in a work method statement before commencement of works.

Construction/ Operation

- Wheel washing activities in designated areas with runoff to soakaways that have already been assessed as having no negative impacts on the blanket mire.
- Manage runoff from hard standing.
- Use drip trays under standing machinery.
- Refuel vehicles in designated areas away from drainage and watercourses. Provide spill kits.
- No maintenance of vehicles and construction plant (other than emergency maintenance) to be carried out on site.
- Toilet facilities to be constructed following good practice guidelines (see above).
- Cement and concrete – avoid concrete batching on site and wet concrete operations within or adjacent to watercourses (see above).
- Forestry clearance has the potential for sediment and nutrient release. However, following best practice guidelines should limit the impact of tree felling on water quality.

Overall, to assess the impact of the mitigation measures and to ensure that there are no impacts on the blanket bog habitat which are not predicted in the EIA, monitoring of the blanket bog should be undertaken post construction to ensure there is no impact above that predicted and that mitigation measures have been effective. Such monitoring is in the interests of the industry as a whole as well as those of individual developers.

Mitigation of Tree Felling

Tree felling may take place during wind farm construction. The key impacts are nutrient and sediment release and erosion. The impacts of tree felling can be reduced by:

Construction

- Follow best practice tree felling guidelines.
- Re-vegetate exposed areas as soon as possible using plants of local provenance that are appropriate to the blanket mire.
- Minimise exposed ground and stockpiles.

Construction/ Operation

- Monitor ground conditions around felled areas to identify any stability issues that arise, the most likely areas being on slopes.

Mitigation of Peat Stability Risks

It is very important that peat stability risks are managed during the wind farm construction and operation. The contractor responsible for the construction of the wind farm has the responsibility for management of the risks associated with working with peat. The contractor should develop a comprehensive working method statement to address the peat risks via a peat management plan, reference should be made to best practice guides regarding their actions on site. Relevant guidelines include, but are not limited to:

- Guidelines for the Risk Management of Peat Slips on the Construction of Low Volume/Low Cost Roads over Peat – Frank MacCulloch, 2006;
- Irish Wind Farm Planning Guidelines (**http://www.sei.ie/index.asp?docID=-1&locID=276**);
- Quarrying and Ancillary Activities – Guidelines for Planning Authorities – April 2004, Department of Environment Heritage and Local Government (www.environ.ie/en/Publications/DevelopmentandHousing/Planning/FileDownLoad,1606,en.pdf -);
- Peat Landslide Hazard and Risk Assessments – Best Practice Guide for Proposed Electricity Generation Developments, Scottish Executive, December 2006.
- PPG14 – UK Department of the Environment Planning Policy Guidance: Development on Unstable Land. (Annex 1: Landslides and Planning and Annex 2: Subsidence and Planning).

The most effective mitigation of peat risks is to avoid working in the areas and at times (e.g. very heavy rainfall, ground saturation) most susceptible to peat instabilities. Works on site with the potential to trigger slides include loading of peat such as heavy vehicle movement over peat or placement of material over peat, excavations within peat, dewatering or drainage lowering water levels in peat. These should be avoided during times of very high rainfall, high groundwater levels (or rapid changes in groundwater level) when the risk of slide is higher.

Monitoring should include groundwater levels and any evidence of peat movement, such as localised slumping, cracking or liquifaction. Changes in groundwater levels, and in particular unusually high groundwater levels, can indicate that the ground is very saturated and at this time peat slide risk may be higher. Localised movement indicates that an area is unstable and activities in such areas should be limited.

In addition the following mitigation measures, amongst others, can be used (Lindsay and Bragg 2005, MacCulloch 2006):

Site Design

- Construction of catchwall fences or ditches in areas at potentially higher risk of slippage. These can slow, or halt, run-out of peat slides.
- Detailed geotechnical stability analysis can be undertaken at turbine sites and along access tracks to assess the factor of safety.
- Implementation of a monitoring plan to monitor peat and groundwater levels to provide potential warning of peat instability (as described above). This should include development of a programme of monitoring to identify any actual ground movements, with comprehensive documentation; and development of detailed plans for permanent remediation of any failures throughout the site (as described above).

Construction

- Monitor groundwater levels during construction.
- Careful design of dewatering and additional support during excavations.
- Control placement of material on the peat. Temporary storage of excavated material should be on less sensitive (i.e. flatter, firmer areas of shallow peat).
- Ground conditions in and around felled areas should be monitored for signs of potential slippage, especially on slopes. The felling of trees may influence ground conditions and help promote instability. Peat beneath the tree root zone may have little structure or strength.

Construction/ Operation

- Do not discharge of water over the peat surface. e.g. pumping out of excavations with no drainage system to manage the dewatering water
- Manage peat loading. This may include limitation of vehicle loadings under certain conditions (e.g. very wet) and the use of low pressure vehicles on the peat.
- Avoid soakaways, SUDs or drainage into areas of deep and/ or potentially unstable peat. Use surface level spreader.
- Minimise vibration from construction activities or traffic.

Operation

- Maintenance of natural and engineered drainage.
- Monitor groundwater levels during construction activities. A significant increase in water level may be associated with an increase in peat instability, but of benefit for bog vegetation recovery. The implications of water level rise need to be assessed.

The drains may be developed before construction of tracks or turbine bases and associated hard standing. If this is the case then monitoring of the drainage and the response of the peat to drainage should be undertaken prior to the construction. Monitoring is a key mitigation measure and should include the following:

- Groundwater levels in piezometers
- Displacement markers
- Rainfall monitoring via an on-site rain gauge
- Consideration of the weather forecast regarding heavy, prolonged and intense rainfall.

If monitoring indicates movement, or conditions likely to result in peat slippage, then activities on site should be adjusted to reduce the impact on the peat. Wind farm operators should avoid heavy vehicle loading of tracks (or by any third party likely to use their tracks) during very wet periods, or at times of high rainfall, as this can increase the risk of peat failure. On-going monitoring and documentation should be made of any indicators of peat slippage on site as this can occur at any time.

Peat slide is a risk throughout the life of the wind farm. The strength of peat is due to its structure and composition. Activities which cut through the peat body can make it weaker. Natural triggers for peat instability (e.g. very high rainfall) may occur at any time these, and other triggers (e.g. loading of peat by heavy vehicles), will occur during site operation. If a peat body has been weakened for example by construction of a track then the risk of peat slide in response to a trigger is increased.

4.4.11 Cumulative Impacts

The EIA should acknowledge that impacts may be cumulative and interaction between parts of the peat system mean that impacts may be more widespread than the footprint of the development. The EIA should how an understanding of the interactions within the blanket bog system and the locations where these may be more significant to the satisfaction of specialists whose role it is to comment on the proposals.

4.4.12 Detailed Design

The EIA needs to be sufficiently detailed to show that provision has been made to mitigate all the identified impacts to an acceptable degree of probability. Assertions should be backed up with appropriate evidence from other sites and studies, and not rely on vague promises to abide by best practice. These mitigation measures should include provision for site construction method statements which would provide for the mitigation to be implemented on site.

Where possible the following should be identified:

- Outline methods of drainage control
- Location of borrow pits

  Location of crane pads.

Parts of the design may not be finalised at the EIA stage, or small changes in design may occur at a post planning the detailed design stage. The EIA and planning submission needs to have covered the site in sufficient detail that these possibilities are included within the EIA. For instance:

- The site planning boundary needs to encompass sufficient land around the actual turbine and track footprint to allow for any activities which may occur outside these areas or any potential for relocation of tracks/turbines.
- Areas of potential biodiversity gain should also be within the planning boundary and under the control of the applicant.

The EIA understanding should be sufficient to cope with small changes in detail design and as changes are made during construction, micro-siting decisions, usually based on local ground conditions.

In areas of peat and low strength underlying sediments (e.g. weak clays), the detailed design and depth of the turbine foundations may depend upon the thickness of the peat and underlying sediments overlying bedrock. The detailed design should anticipate matters such as variable local depths of peat and other sediments and variable competence of these materials. This may include peat which is prone to liquefaction and the requirement for piled foundations.

4.4.13 Experience of working in Peat Environments

The real impacts of the development are often dependent on the working practices of the contractor on site. Contractors with proven experience of working in peat environments, and an awareness of the potential problems are more likely to have successful outcomes. There is currently no scheme of accreditation and judgements must be made on CVs and references.

A lack of experience by a contractor can result in unnecessary activities which have a detrimental impact on peat being undertaken and appropriate actions left undone. Examples of inappropriate activities include:

- Seeding peat with grass seed not suitable for the site in question;

- Spreading peat over intact vegetation – so destroying the vegetation and allowing the peat to dry out and oxidise;
- Spreading peat over very steep slopes around turbine locations to 'restore' the area – the peat will merely dry out and slump
- Mixing peat, glacial sediment and rock.

4.4.14 Post Construction Monitoring

Where there are particular concerns regarding the development or a desire to ensure that proposed mitigation measures are implemented, post construction monitoring can be undertaken. This could include:

- Ecology (e.g. birds, protected species), and habitat composition and condition including re-vegetation rates
- Water levels
- Sediment levels in runoff.

Relevant required monitoring requirements should be specified in a planning condition (see Appendix B.3.1).

4.5 Comparison of Peat and Non-Peat Environments

The magnitude of impacts of a wind farm on its site and surroundings is proportional to the sensitivity of that site. The unique properties of peat underlie its sensitivity; this results in the potential magnitude of impacts from the construction of a wind farm on peat being far greater than a similar sized development on a non-peat site.
There are several properties to peat, especially its hydrology and the species it supports, which increases its sensitivity to impacts. These include:

- Sensitivity of the peat to drying out through disturbances to the vegetation cover and integrity of the peat profile;
- High susceptibility to landslides (i.e. peat slides);
- The fragility of the peat environment to erosion, resulting from drainage works and disruption of the peat surface;
- The low rates of mineralisation and consequent very low nutrient status of peat environments are easily modified and can change habitats from a rain-fed to a fen-like habitat.
- The hydrology of all the peat in intact un-degraded blanket bogs is connected to a greater or lesser degree, and this increases its sensitivity to the impact of drainage schemes.
- Its acidic nature (pH 4 – 4.5 in intact blanket bog, and around 3.5 in degraded bog) can hinder the reestablishment of vegetation on bare and disturbed ground. This is compounded when a high intensity of grazing prevents the adequate re-establishment of native species by vegetative spread and by the setting of seed from adjacent areas of intact vegetation.
- Peat is a valuable archaeological resource and its reducing environment can preserve important finds that would otherwise decay.

4.5.1 Peat specific impacts at Scout Moor

At Scout Moor, the magnitude of several impacts was increased by the siting of much of the development on blanket bog:

- The construction of deep turbine foundations in thick peat required far larger excavation than those foundations placed off blanket bog habitat. This is due, not only to the depth of the peat, but also to the low strength of disturbed peat, which caused slumping around the excavation, creating areas of disturbance up to 40 m wide. Slumping of peat in excavations meant that the disturbed area was far larger than if the excavations were in a more cohesive substrate.

- Attempts to re-vegetate areas surrounding roads and over turbine bases/foundations through seeding have had limited success. This is thought to be partly due to the acid nature of the soils and the naturally small seed bank in the peat. With areas, such as Scout Moor where there is overgrazing and frequent frost-heave in winter, it is difficult to establish any vegetation on disturbed ground. Re-vegetating disturbed areas of peat fails more often than re-vegetation on areas without peat. This leaves significant areas of bare peat that are prone to erosion and oxidation.

- The excavated peat had little cohesive strength; this meant that it had limited potential for use on the site. Disposing of excavated peat without damaging more peat posed a significant problem. However, there might have been opportunities for the constructive use of spare peat in bog restoration, rather then using it to spread over existing bog vegetation.

- Developments on peat will affect the carbon budget of the site. The drainage, degradation and excavation of peat can increase the output of carbon from the peat and release carbon dioxide to the atmosphere.

The Scout Moor wind farms site shows that not all peat sites have the same sensitivity to impacts. Scout Moor had already been ecologically degraded in several ways: ditches (cutting the entire peat thickness) had dissected the blanket bog into several separate hydrogeological units; the humification of the peat had reduced its permeability and consequently reduced the zone of influence of drainage ditches and tracks.

4.5.2 Comparison of blanket bog sites with Wharrels Hill

Wharrels Hill wind farm lies on improved pasture and has very little of ecological or hydrological value, though there are a few feature of archaeological interest. The sensitivity of the sites to impacts, from the wind farm development are far lower for several reasons.

- The impact on archaeological features of interest, if outside the development footprint, would be negligible. Unlike peat sites where drainage would affect the preservation conditions for archaeological finds, damage would only occur through direct contact with the footprint of the development.

- The ecological value of the fauna and flora at Wharrels Hill was low, thus the significance of the impact, even if the magnitude was greater, could only be limited.

- The physical properties of the sandy loam, overlying carboniferous limestone, reduced the need for drainage; the size of excavation areas; and the zone of impact of site access roads. The soil is not prone to erosion and has revegetated quickly, thus extended areas of bare ground were not created or, if created, have not persisted.

- The hydrology was not sensitive. There were no streams with the area of development and the long distances to any watercourse would reduce the potential for increases in sediment loads as a result of the development. This is unlike many peat sites, where watercourses have to be bridged and ditches and culverts are constructed along roads. The likelihood of being near or crossing watercourse and the potential for easily erodible soils to enter them on peat sites is far greater than non-peat sites.

These factors combined at Wharrels Hill to cause few ecological, hydrological or ecological impacts.

4.5.3 Potential Suitability of Peat Sites for Wind Farm Siting

Potential non-peat sites may have other sensitivities, which may make them overall less favourable locations for siting a wind farm than blanket bog in a given geographical area, such as proximity to houses or other landuses, and visual impacts. Though peat sites are often more sensitive to wind farm developments with regard to ecology and hydrology, in a number of other ways their use may present potential opportunities for wind farm development. Potential benefits of upland peat sites for wind farm development include:

- They are located on the top of windy hills and therefore maximising energy capture;
- They are often some distance from properties and consequently reducing the impacts from flicker and noise;
- Blanket bogs often have limited existing land use, so the land is potentially available. This is particularly of interest to farmers, who may find grazing blanket bogs of marginal economic value and of very limited value for supporting livestock.

These reasons and others are potentially why increasingly developers are targeting areas which often have blanket bog habitat. There is an awareness that designated sites should be avoided, and so developments are being focussed towards non-designated blanket bog, but this conflicts with the national BAP targets for the habitat.

4.5.4 Conclusions

The properties of peat and the nature of its hydrology and ecology make blanket mire particularly sensitive to impacts from wind farm developments. The magnitude and significance of impacts are controlled by site specific factors, construction techniques and mitigation measures. Peat sites may be advantageous in terms of perceived land value, but the perception is at odds with their high biodiversity importance and their role in atmospheric carbon regulation. Their sensitivity means that greater care in site construction activities and implementing mitigation measures is required than would be for a less sensitive non-peat site.

There are opportunities on degraded blanket peat sites for peatland restoration to be implemented as part of the wind farm proposals, and these could bring benefits to the site provided they outweigh potential damage to the peat resource.

5 CONCLUSIONS

5.1 Summary of Findings

This report has reviewed the literature available regarding the impacts of wind farms on blanket peat. The impacts on peat have been summarised and an outline of the assessment process for the peat has been provided. This includes the properties of blanket peat which should be considered in an environmental impact assessment.

5.2 Blanket Bogs

The following key points are noted:

- The vegetation on blanket bogs is very sensitive to lowering of the water table and activities which may result in erosion of the peat.
- Intact blanket peat forms a drape over the topography which is a single hydrological unit. All functions of the blanket bog, including hydrology, its relationships with geology and near surface sediment and soils, need to be considered in the environmental impact assessment. This should include a conceptual hydrological/hydrogeological model of the site with the blanket bog in the context of underlying geology, topography and drainage.
- Some degraded blanket bogs are dissected by gullies that completely cut through the blanket bog into the underlying sediment (e.g. glacial sediments or bedrock). Where the peat is completely cut by a gulley there is no longer a hydraulic connection between each side of the gulley. In this situation the blanket bog is likely to function as a series of discrete peat units perched on the underlying sediment and each will have its own independent water table.
- Intact blanket peat has a surface layer of peat which is more permeable, called the acrotelm. This has a relatively high permeability, often a lighter colour than deeper peat, a lower degree of decomposition of the plant matter (low humification), and comprises recently growing plant matter.
- The catotelm underlies the acrotelm and has a darker colour, greater degree of decomposition and humification and lower permeability. Peat pipes may have developed along stratigraphic discontinuities within the catotelm and also along the peat-mineral interface.
- Degraded blanket bog is likely to have a reduced or absent acrotelm layer, as there is no longer any active accumulation of plant matter. The peat is highly humified from its base to the surface.

5.3 Impacts of Wind Farms on Blanket Bog

- The physical properties of the peat are fundamental in determining the impact of any drainage on its water levels and stability. The hydraulic conductivity, or permeability to water movement, is one of the most important factors. Where the peat has a low permeability and water movement is slow then the impact of drainage associated with tracks and hardstanding areas may be only 2-10m from the infrastructure, though it will vary seasonally. Where the permeability of the peat is higher, or peat pipes are intersected the zone of influence may be much wider.
- Roads change surface water flow patterns and can concentrate them so as to start peat erosion. The growth of Sphagnum mosses, one of the major peat forming plants, may become starved of its water supply when surface water is channelled by roads and associated drainage.
- A wind farm development will have the greatest impact on intact blanket bog, by affecting its structure and biodiversity. Conversely, where the peat body is already completely dissected by gullies, new tracks across them could be designed to reduce the runoff rates from the site, particularly if in combination with measures to slow down the flow of water or to spread it over the surface for the benefit of peat-forming Sphagnum. However, the peat stability impacts of blocking gullies would also have to be assessed.
- Drainage around the turbine base and other infrastructure such as roads will change the current water flow patterns across and through the peatland. Its impact is likely to be negative on intact bogs, but both negative and positive in degraded bogs, depending on the extent and nature of

existing damage. In particular changes to the chemical composition of drainage water can result in changes in vegetation, and discharge of drainage water over peat can result in liquifaction.

- Increased risk of peat slide is likely on intact and degraded sites as a consequence of excavations, installations, lorry movements and changed water flow patterns.

5.4 Siting of Wind Farms on Blanket Bog

The following guidelines should be followed:

1. Where there is a mixture of habitats the infrastructure should be concentrated on the non-blanket bog areas, as indicated by the depth of peat, rather than by contemporary vegetation.
2. In general infrastructure should avoid areas of deep peat (i.e. greater than 0.5 m depth). On many sites there are areas of deep and shallower peat – the deep peat should be avoided in the site design. There should be evidence in the EIA that deep peat has been avoided where choices exist.
3. Where the blanket bog is reasonably intact and not dissected by gullies which cut the full thickness of the peat, the roads should be located away from deep peat.
4. If roads do cross deep degraded peat they should constructed in a manner not to disrupt the flow of water through or over the bog, but to stem the flow through the gullies in favour of a wide spread over the peat surface.
5. The hydrological impact of a wind farm on degraded peat where the peat body is dissected into a number of separate peat areas may be less than on an intact bog, though if poorly designed can simply exacerbate an already bad erosive condition. The design of the wind farm layout, location of turbines, roads and mitigation measures has the potential to help or hinder the future restoration of the blanket bog.
    a. Construction of tracks crossing gullies has the potential to be used to partially block the gullies and to construct partial blocking of gullies, to reduce erosion, runoff and promote blanket bog restoration. Care will be needed to manage this geotechnically, to avoid peat slippage.
    b. The orientation of roads has the potential to be located either parallel or across the natural drainage through the peat, and consideration of the impacts of this needs to be made.
        i. Drainage associated with tracks located parallel to natural drainage, need to be designed so that there are checks in the drainage channels to reduce runoff rates and velocities to background levels.
        ii. Tracks perpendicular to natural drainage lines will disrupt the diffuse nature of flow, but may also impede flow which may be currently directed down erosional channels. The impact of this needs to be assessed in the EIA.
6. It is very important that the mitigation measures indicated in the EIA are carried forward to the construction method statement and so implemented on site. For this purposes it is important that the mitigation measures are specific and quantified. Use of contractors familiar with working on peat sites is an advantage. The use of mitigation measures and proposed restoration should be controlled via a planning condition. Monitoring may also be specified in planning conditions.
7. Provision should be made for the potential to incorporate restoration measures into the site design. These could include:
    a. Blocking of erosional drainage channels;
    b. Promoting of re-vegetation of degraded areas.

5.5 Development Assessment Criteria

The following table has been produced to summarise the Environmental Assessment Criteria that should be assess for any wind farm development on blanket bog. There are four categories of site sensitivity for each criterion.

- Green – This factor is not an obstacle requiring mitigation (low sensitivity, low likelihood of significant impact).
- Amber – Convincing mitigation measures and good site practices required to minimise impact.
- Red – Considerable requirement for mitigation measures and good site practices likely to minimise impact, however, some negative impacts are likely to remain.
- Black – Impacts are likely to be significant even with the implementation of mitigation measures and good site practices.

The following table should steer development towards less sensitive sites, and less sensitive areas within particular sites. It should be noted that cumulative sensitivities and impacts should be considered although a number of the factors listed are interrelated.

Table 5-1 Proposed Wind Farm Development Site Sensitivity

Environmental Assessment Criteria	Site Sensitivity			
Ecological Designations	None	Local	National	International
Within the HAP restoration target				
Degree of existing peat degradation	Highly degraded	Degraded	Non-pristine	Intact
Degree of pre-development drainage	High density, effective drainage, dissecting the peat	Some drainage but not dissecting the whole peat thickness	Limited historical drainage	No drainage
Depth of Peat (intersected by infrastructure)	0 – 0.3 m	0.3 m – 0.5 m	0.5 – 2 m	2+ m [1]
Peat stability risk: slip or bog burst	Low	Medium[2]	High[3]	Almost Certain[4]
Ecological Sensitivity	Moorland Grassland	Degraded blanket bog	Mixed degraded and intact bog	Intact Sphagnum Moss blanket bog
Archaeological feature of Interest	None	Low importance	High Importance	International Importance
Amount of development footprint on blanket bog.	None or limited	Some overlap	High proportion	
Is future restorability of the bog compromised?	No	Probably ok – needs careful site design	Uncertain – concerns should be addressed in EIA	Yes – restoration will be more difficult /impossible following development

1. There are generally increasing difficulties in working with deep peat. However, depths of peat in the English uplands (usually only up to a couple of meters) are much lower than found elsewhere in the UK and Ireland.
2. Peat Stability Assessment needs considering at EIA stage, but this shows limited risk factors. Full peat stability assessment required as part of planning condition.
3. Full Peat Stability Assessment likely to be required at EIA stage (or if not undertaken as a planning requirement). A number of risk factors are present.
4. Peat Stability Assessment indicates high likelihood of slip or burst and there is existing evidence of slippage on site.

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