# CCW Guidance Note

# Assessing the impact of windfarm developments on peatlands in Wales.

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## *Contents*



# 1. INTRODUCTION

## 1.1. Aims of this guidance

The aims of this guidance are to identify the main impacts posed by windfarm developments for peatland habitats, and to guide CCW's input to the scoping and all subsequent phases of environmental assessments and associated case-work. It should be used to indicate to developers the issues/topics that we would expect to be covered in windfarm impact assessments. CCW's underpinning Position Statement on peat in Wales should be read in conjunction with this technical guidance. This guidance has a strong upland emphasis, reflecting the dominant deployment to-date of terrestrial windfarms in Wales. This guidance does not consider landscape issues.

This guidance has been prepared by Pete Jones, with significant inputs from Carol Fielding, Rob McCall, Peter Minto, Ken Perry and Sandra Wells. Its production follows a CCW training workshop in May 2008 to develop common approaches and key guidance to aid assessments of windfarm impacts across Wales. Feedback on this guidance will be gratefully received.

**1.2 Introduction to the upland peatland resource**

Rainfall, temperature, topography, and past land-use have combined to favour the widespread development of blanket bog in Wales. It occurs widely above 300 m and is most prevalent on upland plateaux, broad ridges and gentle slopes – similar circumstances to those favoured for wind-farm development. Yeo (1997) and Jones *et al*. (2003) provide recent overviews of the resource; the latter also provides up-to-date distribution maps and a breakdown of habitat extent across each of the 24 Welsh Local Biodiversity Action Plan areas. Upland fens (primarily soligenous flushes) are also widespread in the uplands, and are often associated with peat and blanket bog. Many existing and planned windfarms include areas of peatland habitat, or at least peat.

The Welsh blanket bog resource is of critical significance in both a UK and wider European context. Welsh mires reflect much of the overall variation in the character of the resource across the UK, the only major omission being the hyper-oceanic mires of northern Scotland. Wales is also significant in a biogeographic context; this habitat is absent across much of the equivalent latitudinal range in England, with good quality examples scarce until north of the Peak District. Blanket mire in the south of Wales (including the successor counties of Glamorgan and Gwent) lies close to its southern limit in NW Europe. Our mires provide the major locus for a restricted but specialised range of plants and animals, and with other upland habitats play a key role in terms of ecological connectivity.

Welsh blankets bogs have already been very heavily impacted by man, and ongoing loss and degradation is occurring. Of the original estimated resource of *c*. 70,600 ha, just 22,600 ha of the remaining 54,600 ha is considered to represent the less modified blanket bog category of the Phase I habitat classification. The surviving resource remains vulnerable to a range of impacts, including climate change and atmospheric deposition, as well as obvious site management effects such as drainage, grazing regime and burning. Windfarm infrastructure has the potential to add further pressures to already stressed systems.

**1.3. Overview of potential impacts of windfarm developments for peatlands.**

Assessing the impact of windfarm developments on peat and peatland habitats is critical given the importance of peatland habitats as a nature conservation resource, their wider environmental role in terms of carbon storage and sequestration, and their particular sensitivity to the construction and existence of infrastructure typically associated with windfarms. These topics are considered in detail in section 4.

Potential impacts of wind farm developments on peatland habitats include direct habitat loss through construction of windfarm infrastructure, and habitat modification or even loss primarily due to adverse changes to hydrology. Direct immediate habitat loss due to access tracks, turbine bases, permanent crane pads etc is straightforward to quantify, but requires good quality data for accurate assessment – see below. Damage caused by altered hydrological regimes is less easily quantified, but in the long-term this may lead to more widespread habitat deterioration and so must be a key focus of impact assessment.

As well as its importance as a nature conservation resource, peat has an important role in carbon sequestration and storage. Losses caused by wind farm construction alone could, unless carefully planned and sited, wholly negate the carbon savings associated with renewable energy generation for a period of years - a serious time lag because of the need to meet government targets for 2010 and 2020, and in the context of climate change research that suggests a threshold effect and the urgency of immediate carbon reductions. In some cases carbon peat losses could continue for the life of the development, as a result of poor design and damage to hydrology.

Given the importance and sensitivity of peatland habitats, CCW's position is that **windfarm developments should avoid impacts to peat as far as possible** through, *inter alia,* careful siting of infrastructure based on accurate survey and site assessment. Operational decisions about whether particular impacts are tolerable will depend on many factors, including site status, the importance of the peatland features, likely significance of impact, potential benefits offered by Habitat Management Plans (section 5.2) and the adequacy of mitigation. Each of these topics is considered further below.

Assessment of each main category of impact is described further in section 4.

## 2. THE BIODIVERSITY AND CARBON CONTEXT.

### 2.1. Biodiversity

The main wetland habitat types encountered on windfarm sites are blanket bog and upland fen. Blanket bog is a globally confined resource and a priority habitat under the UKBAP. Annex 1 of the EU Habitats & Species Directive contains 'active blanket bog' which is afforded priority habitat status and includes areas which still support a significant area of vegetation that is normally peat forming, as well as areas that are temporarily at a standstill (after fire for example). Upland fen is represented primarily by soligenous flushes and springs, with topogenous fen scarce. Soligenous fens may occur on peat, or on shallower organic soils with a significant mineral content. Upland fens (soligenous and topogenous forms) are now included as BAP priority habitats. Both habitats are thus 'habitats of principal importance for the conservation of biological diversity' as defined under section 42 of the Natural Environment and Rural Communities (NERC) Act 2006. Blanket bog is well represented within Local Biodiversity Action Plans in Wales, upland fens less so. Technical Advice Note (TAN) 5 '*Nature Conservation and Planning'* (2009) confirms that BAP habitats (and species) can be a material consideration in the planning process (Welsh Assembly Government, 2009, section 6.5); Environment Strategy Wales outcomes 19, 20 and 21 are also highly relevant to the protection of the non-statutory resource. Articles 1 and 10 of the Habitats and Species Directive are also relevant to the conservation of blanket bog outside the protected sites series. The definition of favourable conservation status (Article 1) requires the natural range and area covered by the habitat to be stable or increasing and the specific structures and functions necessary for its long-term maintenance to be in place; in this context, the presence of upland peat can be regarded as a key indication of natural range. Article 10 of the Directive (covering ecological coherence and connectivity functions) is especially applicable to blanket bog as our only extensive and locally continuous peatland habitat.

### 2.2. Carbon

Peat plays an important role in carbon storage, and active mire vegetation can add to this store through peat growth and subsequent carbon sequestration. The carbon storage function of peats in Wales is very significant; peat soils contain 30% of the soil carbon resource of Wales despite possibly occupying only 3% of the land surface (ECOSSE, 2007). The annual carbon fixing potential of peats in Wales is relatively modest on a unit area basis, but significant in total, particularly in relation to other forms of semi-natural vegetation in the Welsh uplands. Furthermore, there is huge potential for switching many peatland areas from net sources to net sinks of carbon.

The balance between net C sequestration and emission is easily disrupted, and any losses caused by construction overlap alone could negate carbon savings from wind energy generation for a period of time. This is a serious issue because of the need to meet government targets for 2010 and 2020, and in the context of climate change research that suggests a threshold effect and the urgency of immediate carbon reductions. In some cases peat carbon losses could continue for the life of the development, as a result of poor design and damage to hydrology. Climate change will further damage the resilience of peatlands as a natural ecosystem resource, and thus potential sink for carbon.

The Climate Change Act set out targets for a 80% reduction in greenhouse gas emissions (GHG) by 2050 and established the Committee on Climate Change to set 5-yearly budgets from 2009 onwards. Wales' contribution to the proposed emission reductions will be achieved through delivery of the *One Wales* commitment to a 3% per annum reduction in those Welsh emissions outside of the EU ETS. The means to deliver these reductions has been set out in the draft Welsh Climate Change Strategy programme of action, that was consulted on in summer 2009. In the consultation, 'soil carbon conservation' and 'the role of sinks in achieving emission reduction' were both identified by WAG as 'key challenges' within the mitigation measures proposed for the agriculture and land use sector. Clearly the protection of peat and the restoration of actively sequestering peatland ecosystems are important to addressing them. The management of peatlands was also identified as important for adaptation, as exemplified in the draft strategy by reference to the restoration work being undertaken on the Migneint. Furthermore, a recent (2009) report by the Sustainable Development Commission identifies the protection of 'all significant carbon stores' as one of the six priorities for action across Wales.

The Climate Change Act gives WAG and Welsh Ministers the power to require reporting authorities such as CCW to produce an assessment of both the impacts of climate change and the way in which they will consider the need for adaptation. The production of this guidance is a component of CCW's response to the delivery of both the One Wales and WAG Climate Change Strategy in terms of mitigation within the land use sector, and also the requirement of the Climate Change Act for reporting authorities such as CCW to consider the impacts of climate change and the need for adaptation.

## 3. OVERALL ASSESSMENT OF IMPACTS ON PEATLAND HABITATS AND PEAT.

Potential impacts on peat and peatland habitats should be a key part of windfarm Environmental Impact Assessment (EIA). Annex IV of the EIA Directive (Council Directive 85/337/EEC) requires that developers should outline the main alternatives (to a development at a particular site) considered, and provide 'a description of the measures envisaged to prevent, reduce and where possible offset any significant adverse effects on the environment'. To enable this, EIA should commence early in the design process and through iteration achieve as far as possible the removal of adverse impacts. Peat and peatland habitats are of sufficient significance to merit mapping and assessment as part of the suite of primary constraints to scheme design. EIA in this context should be based on a consideration of all of the factors considered under section 4 below and include detailed assessment of the impact of trackways, turbine bases and associated infrastructure. EIA should clearly demonstrate the extent to which impacts on peat and peatland habitats have been taken into account. **In practice, this requires assessment of the whole peatland resource within the application area (and not just the layout imprint).**

Impact assessments should reflect the fact that peatland habitats represent a particularly sensitive receptor. Habitat composition and condition is dependent on the integrity of the living mire surface and underlying peat profile, and natural hydrological processes. Even relatively minor changes in hydrological regime have the potential to cause or contribute to further degradation in what are often already stressed systems, and may even switch peatlands from net sinks to net sources of carbon.

Afforested peatlands may retain significant semi-natural habitat interest, but even where heavily modified still represent an important potential conservation resource. The Wales Biodiversity Partnership Upland Ecosystem Group is currently considering targets for the restoration of bog on areas of peat currently under other land-cover types, and future policy and guidance development is likely to reflect the growing importance attached to peat and its restoration for biodiversity and other ecosystem benefits. Consequently, impact assessment should cover impacts on the surviving habitat resource as well as the implications of windfarm development for future habitat restoration.

Habitat and peat depth mapping should be used to inform a final design iteration that minimises any overlap of windfarm infrastructure on peat. Based on the criteria set out in this guidance, the impact of any residual overlap must be clearly described in terms of the character and significance of what will be lost and the impact in terms of adjacent habitat and the wider peatland unit. The latter aspects should include a detailed site-specific assessment of hydrological and resultant ecological impacts through the design lifetime of the site, and also the wider environmental implications in terms of carbon. References to the use of best practice (in mitigating impacts) should be fully supported by evidence relating to the actual long-term efficacy of such techniques in comparable peatland situations.

The issue of habitat loss is a key area of concern because of the very limited potential which is believed to exist for the development of new peat profiles and areas of peatland habitat[1]. Furthermore, whatever potential does exist may reduce over time due to the contracting climatic envelope conducive to bog development. The Welsh peat resource is estimated to represent only 3% of the land surface, less than the equivalent UK figure of *c*. 7%, and given its importance yet relatively modest extent and often localised distribution in Wales, the argument for avoiding impacts on peat as far as possible is clear. This is reflected indirectly in TAN 8 which states (para 2.4) “Not all of the land within the SSAs may be technically, economically and/or environmentally suitable for major wind power proposals”. It may therefore be appropriate in some cases to object to a scheme because of the inclusion and siting of particular turbines. The Ministerial Interim Planning Policy Statement on renewable energy requires minimization of impacts which again would support an objection to a particular part of a scheme and to require agreement on micro-siting or removal of turbines. The draft National Position Statement on Renewable Energy (DEC, 2009) also highlights the sensitivity of peat.

Habitat loss resulting from all forms of windfarm infrastructure should be regarded as permanent. Even if ‘cut & fill’ type tracks were removed, insufficient stock-piled peat would be left on-site after *c*. 20 years operation to re-profile them. Tracks constructed as floating roads will be regarded as resulting in permanent loss of underlying habitat because of the inherent uncertainty associated with restoration following track removal.

Excavated mass concrete foundations left *in-situ* post de-commissioning are unlikely to develop a functional peat profile and given they are unlikely to be removed should again be regarded as representing a permanent loss of habitat.

Alternative methods and processes in carrying out the development should clearly be part of the EIA and in the case of wind turbines on or adjacent to peat, including afforested peat, should include the net balance between losses of carbon through peat loss and degradation,

[1] Note that recovery of semi-natural bog vegetation from non-mire vegetation is classed as restoration and not habitat creation.

and gains as a result of compensation restoration and management. The former should be a consideration in the development of compensation measures.

## 4. METHODOLOGY FOR ASSESSMENT OF RESOURCE

Impact assessment should begin with characterisation and evaluation to develop a thorough understanding of the peatland resource. This requires reliable information on the character of the surface vegetation (see section 4.1) and the underlying peat (section 4.2) and is essential to identify the habitat resource likely to be affected by windfarm development. Information relating to the direct imprint of the development is only one aspect of the assessment - hydrology and hydro-ecology (section 4.3) and peat mass stability (section 4.4) must also be examined in detail to determine wider-scale impacts in relation to scheme design. Assessment of impacts on carbon flux and storage (section 4.6) represent another critical area. The full range of criteria outlined in this section should be used to inform scheme siting and design at a range of scales, for example by helping to rule out layouts or schemes with significant adverse impacts on biodiversity and carbon due to peat loss/degradation, and through using more detailed iterative studies to identify ways in which impacts can be avoided and mitigated through design of specific elements of the scheme.

### 4.1. Peatland habitat characterisation and evaluation

This should be performed at least to Phase I level, but with the important caveat that forms of bog dominated by graminoids or ericoids are still recognised as peatland habitat where present on ~0.5 m of peat. Failure to do so has been a common pitfall of many site assessments in Wales (and elsewhere). Peat depth measurements should be undertaken at frequent intervals, and ideally at the same time as the habitat mapping to ensure that depth is tested at habitat boundaries. This is important because characterisation as bog (*sensu* Phase I) is to an extent conditional on the presence of 0.5 m or more of peat. It is preferable that surveyors record actual depths (rather than < or > 0.5 m), even if only to the nearest 10 cm. One important reason for this is that vegetation obviously referable to blanket bog (i.e. with frequent *Eriophorum vaginatum* and sphagna) can occur on shallower peats (to around 35 cm) and such habitat should still be mapped as bog[2] – see Table 4.1. Section 4.2 offers an outline methodology for assessing peat depth.

**Table 4.1.** Summary table to guide decisions on habitat classification based on peat depth and simple vegetation markers.

<table>
<tr><td>Eriophorum vaginatum</td><td colspan="2">Occasional or rare</td><td colspan="2">Frequent</td></tr>
<tr><td>Tall Junci & Sphagna</td><td>Infrequent</td><td>Frequent</td><td>Frequent</td><td>Infrequent</td></tr>
<tr><td>Peat < 0.5 m</td><td>Heath or acid grassland</td><td rowspan="2">Acid flush</td><td rowspan="2">Modified bog or acid flush E. vaginatum variant, depending on context.</td><td rowspan="2">Bog</td></tr>
<tr><td>Peat > 0.5 m</td><td>Bog</td></tr>
</table>

In many cases Phase I habitat maps will need to be supplemented with target notes or sub-mapped to describe vegetation to National Vegetation Classification (NVC; Rodwell [ed], 1991) plant community/sub-community level; these include:

- to describe and quantify habitat quality;
- where vegetation on deep peat falls outside the perceived core range of blanket bog vegetation in the UK;

[2] Shallow peats may have resulted from comparatively recent (within the 20th. century) peat cutting or erosion and may thus be a poor reflection of the potential for deep peat formation at any given location.

- at critical locations where access tracks, turbines, crane pads and other high impact structures are planned;
- where re-siting or design could eliminate or minimise impacts on peatland habitats;
- to enable the selection of compensation sites comparable with impacted sites.

Descriptions to community level should be based on the NVC whilst also employing the expanded suite of ombrogenous and related mire communities described recently for Wales by Turner (2006). Table 4.2 provides a synopsis of the main NVC communities and Turner additions recognised to-date in Wales.

**Table 4.2.** Synopsis of the main NVC communities and additions recognised to-date in Wales from predominantly upland peatlands. With the possible exception of U6, all of these communities are potentially peat forming.

| Community name | Distribution / abundance | Comments |
|---|---|---|
| **M1** *Sphagnum auriculatum* (*denticulatum*) bog-pool community | Rare | A localised feature of intact and usually high quality mires. |
| **M2** *Sphagnum cuspidatum / recurvum* (*fallax*) bog pool community | Widespread, but often localised and of small extent | This bog-pool and bog hollow community indicates high and stable water tables (especially where *S. cuspidatum* is prominent) and is a valuable component (and indicator) of microtopographic differentiation into hummocks and hollows. |
| **M3** *Eriophorum angustifolium* bog-pool community | Widespread but rarely extensive | Occurs commonly as a stage in the recovery of eroded wet peat and can thus be taken as indicating natural recovery and a comparatively intact hydrology. Also an important bog-pool element, especially in the south. |
| **M4** *Carex rostrata – Sphagnum recurvum* (*fallax*) mire | Widespread , but less common in south | Mostly a community of soligenous zones within blanket mire, and thus a valuable component of habitat heterogeneity in response to variations in hydrological regime. A key element of upland fens, often with a ‘poor-fit’ to the NVC. |
| **M6** *Carex echinata – Sphagnum recurvum (fallax)/auriculatum* (*denticulatum*) mire. (Turner, 2006) | Widespread and often abundant | The main form of soligenous mire in the Welsh uplands and now covered by the upland fens priority habitat type. |
| **M6** *Eriophorum vaginatum* variant | Probably widespread – mainly upland | Vegetation transitional between soligenous fen and bog. |
| **M15** *Scirpus cespitosus – Erica tetralix* wet heath. | Widespread – often abundant | M15 on peat is usually a product of past adverse management, but is of significant intrinsic value and often shows evidence of recovery back to bog |
| **M16** *Erica tetralix – Sphagnum compactum* wet heath | Localised | A localised component of wet heath on peat and of significant intrinsic value. |
| **M17** *Scirpus cespitosus – Eriophorum vaginatum* blanket mire | Widespread in west and at lower altitudes | M17 becomes more prevalent at lower altitudes and in the west. M17, 18 and 19 are the key components of the bog plane proper on the least modified bogs. |
| **M18** *Erica tetralix – Sphagnum papillosum* raised and blanket mire. | Widespread, but rarely extensive | M18 generally marks out areas of deep wet peat on cols and saddles. |
| **M19** *Calluna vulgaris – Eriophorum vaginatum* blanket mire. | Widespread and extensive in the north. | M19 is the natural climax community of undrained bogs across much of Wales, particularly at moderate-high altitudes. |

| | | |
|---|---|---|
| **M20** *Eriophorum vaginatum* blanket and raised mire. | Widespread in the north | Over-grazing and burning have led to the widespread dominance of M20 in the north. |
| **M25** *Molinia caerulea – Potentilla erecta* mire | Widespread in south and west | M25 replaces M20 as the dominant community of modified bogs in mid and south Wales, with burning, sheep grazing and atmospheric deposition all implicated as causal agents of its development. |
| **M25** *Eriophorum vaginatum* variant (Turner, 2006) | Probably widespread in south and mid Wales. | Marked by frequent *Eriophorum vaginatum* within a context of overall dominance by *Molinia*. Such mires are likely to offer better potential for the restoration of reasonable quality bog than *Molinia* monocultures alone. Survey during the *Eriophorum* flowering period (May to July) is strongly recommended to prevent over-mapping of M25 (Figure 4.1). |
| Nodum 19 (Turner, 2006) | Widespread at medium-low altitudes | Vegetation with frequent *Eriophorum vaginatum* and exhibiting the characteristic graminoid-ericoid-sphagna blend of M17-19, but with *Sphagnum recurvum* and/or *S. subnitens* in place of the core oligotrophic Sphagna of these communities. |
| **U6** *Juncus squarrosus – Nardus stricta* acid grassland | Northern | Highly modified peatland vegetation, but with an often appreciable cover of oligotrophic Sphagna. Can recover to bog under appropriate management, and may be an important 'matrix' element linking together blocks of less strongly modified bog. |

*Habitat evaluation.*
Evaluation of habitat quality and importance has been a weak-point of many windfarm Environmental Statement (ES) submissions to-date. The main reasons for this are (i) failure to recognise the full extent of peatland habitat as a result of mis-classification, (ii) the tendency to adopt classic blanket bog vegetation (e.g. M19) as the 'benchmark standard' of habitat quality in areas of Wales where other often modified but nonetheless valuable forms of peatland vegetation prevail, and (iii) the tendency to regard localised pockets of bog and fen as inferior.

The first issue can only be resolved by careful and accurate habitat mapping by experienced surveyors. Habitat mapping should be undertaken to community/sub-community level for all turbine locations and track crossings. Assigning polygons to multiple communities should be avoided in such cases, unless the vegetation represents a genuine mosaic of intermixed communities/sub-communities.

Habitat quality should be assessed on a site-specific basis using the Common Standards Monitoring (CSM) guidance developed for upland habitats by JNCC (JNCC, 2009) as a basis. Attributes which may be used to support judgements of quality within the specific context of blanket bog are summarised in Table 4.3.

Habitat evaluation should take full account of biogeographical variations in the composition and quality of the blanket mire resource. For example, forms of modified bog are especially prevalent in mid and south Wales (Figure 4.2), and the ambient nitrogen deposition regime[3] is likely to place inevitable restrictions on the representation of the core oligotrophic Sphagna associated with good quality peat-forming mires.

[3] For this and other reasons, assessments should make reference to the ambient N deposition regime and how it compares with the published critical load for blanket bog. The web-based Air Pollution Information Service (APIS) tool (www.apis.ac.uk) provides loading estimates for total N and other atmospheric pollutants for each 5 km square across the UK.

**Figure 4.1**. Modified blanket bog on 70 cm of peat with dominant *Molinia caerulea* and frequent/locally abundant *Eriophorum vaginatum*. Rhondda, Glamorgan, August 2007.

**Table 4.3.** Summary of some key attributes of habitat quality. Attributes marked ++ are highly desirable. * Oligotrophic Sphagna may be especially sparse in parts of mid and south Wales.

| ***Attribute*** | ***Positive / negative*** |
|---|---|
| Presence of surface patterning into hummocks and hollows | ++ |
| > 10 % cover of oligotrophic Sphagna (mainly *S. papillosum*, *S, capillifolium* and *S. cuspidatum*)* | ++ |
| No one ericoid or graminoid present at > 50% cover | + |
| M2, M17-M19 the predominant vegetation cover | ++ |
| > 10% cover of any Sphagna | + |
| Absence of drains, absence of functional drainage | + |
| Absence of readily visible bare peat (> 10 x 10 cm patches) in > 50 % of 'sample' points. | + |
| Presence of bog markers (e.g. *Eriophorum vaginatum*, classic bog hepatics such as *Mylia* and *Odontoschisma*) within M25 or U6 swards | + |
| Water table level moderate to high | ++ |

Viable areas of active blanket mire in such contexts are of significant value even where ericoids and oligotrophic Sphagna are sparse or absent.

Habitat extent and continuity are important attributes of quality and both issues have a bearing on habitat viability. However, viability is also strongly related to the hydrotopographic context of the peatland. For example, a relatively small block of habitat located within a topographic hollow is likely to be more viable than a larger block of peat on a moisture shedding slope.

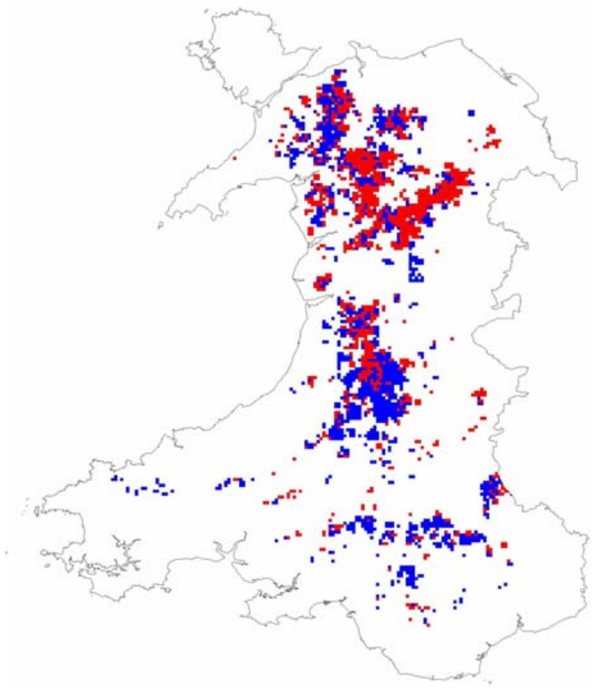

**Figure 4.2**. Distribution of 1 km squares with blanket bog in Wales. This map records the presence of blanket bog and whether the majority cover is modified (blue) or un-modified (red), but not its extent. Blanket bog does occur in 1 km squares additional to those presented in this figure. Data derived from Habitat Survey of Wales (1979-1997). Analysis by Dr Jane Stevens, CCW.

Although a large coherent block of bog is likely to be more resilient to hydrological impacts and climate change than multiple small blocks, scattered blocks of bog vegetation separated by acid grassland are encountered widely in Wales and often reflect variations in the underlying bedrock topography; they should not be under-valued in Environmental Statements.

Erosion is often symptomatic of degradation, but with the important caveat that some forms of plateaux type erosion may be very long-standing and apparently natural features. Most erosion features are now technically restorable, and the significance of erosion as a negative attribute of habitat quality should be kept in perspective in habitat evaluation.

The hydrotopographic context/s of the peatland should be noted as this has some bearing on sensitivity to hydrological changes and is also a criterion employed in SSSI selection. Habitat evaluation may include consideration of the extent to which sites meet minimum standards for notification, but it is important to recognise that the selection guidelines (JNCC, 1994) are now relatively dated, particularly in terms of the priority given to modified and relatively patchy expanses of mire in southern Britain. Evaluation of habitat in terms of its local importance should utilise the recently published *Wildlife Sites Wales Guidance* (Wales Biodiversity Partnership, 2008). It is important to note that even relatively small expanses of modified bog may be of significance, particularly edge-of-range examples in areas with a relatively limited representation of this habitat. Assessment of habitat viability should recognise that even small tracts of bog are likely to be viable in the long-term[4] given

[4] The long-term influence of climate change remains uncertain, but favourable management will aid habitat resilience.

appropriate management and the general trend of improvements in air quality. Habitat evaluation should, in general, be underpinned by an appreciation of NERC duty emphasis on the conservation of 'habitats of principal importance for the conservation of biological diversity'; Environment Strategy Wales outcomes 19, 20 and 21 underpin conservation of the non-statutory resource.

The consequences of windfarm construction and operation for long-term habitat quality should be assessed in detail, and hydroecological impacts are considered in section 4.3. Additional impacts occurring during or after construction are listed in Table 4.4.

**Table 4.4.** Additional impacts on peatland habitats and species which may result from windfarm construction.

| Issue | Comments and requirements for assessment |
|---|---|
| Construction impacts beyond the immediate infrastructure footprint. | Windfarm construction offers the potential for vehicle damage or soil disturbance on adjacent habitat. Whilst many areas can be left to re-vegetate naturally, impacts on sensitive habitats, notably peatlands, require specific assessment as part of the EIA. Construction method statements should also include specific provision for such impacts. |
| Impacts resulting from ineffective or inappropriate restoration of peat batters and other areas of exposed peat. | Re-worked peat exposed on track batters, around turbine bases, crane pads and borrow pits will be prone to erosion and oxidation. Measures to prevent this need to be identified. |
| Dust emissions from access tracks during construction and subsequent use. | The core oligotrophic mire communities are particularly sensitive to dust. Fill and surface dressings derived from limestone or other calcareous rock-types should not be used, and appropriate dust suppression practices adopted during both construction and use. |
| Habitat fragmentation and connectivity | Trackways impose a dry-land barrier to the movement of wetland species, but the effects have been all but ignored in most assessments to-date. |
| Alterations to grazing regime | Access tracks will be used by grazing stock with the result that localised changes in grazing pressure may result. Alterations to the grazing regime may influence the quality of the habitat for a wide range of species, include key-stone taxa such as curlew. |

*Afforested peatlands*
Conifer plantations cover over half of the peat area occurring within the TAN 8 Strategic Search Areas (SSA) in Wales. Afforested peatlands will already be impacted by shading and drainage, but the prospects for vegetation recovery can be good given recent advances in restoration practice[5]. This suggests that impact assessments for peatlands under forestry should be subject to the same set of protocols as un-afforested mires.

### 4.2. Peat depth assessment

Accurate and thorough determination of the extent and variation in depth of peat deposits within application sites is necessary as it underpins all other assessment requirements. Standard sources of mapped information resulting from the British Geological Survey (as drift edition maps) or Soil Survey of England & Wales provide an indication of peat distribution, but should only be used as a guide in planning field survey. Soil maps prepared by the Forestry Commission in advance of planting programmes are generally of higher quality, but still require corroboration and to-date are not available in digital format for FC holdings across Wales.

[5] www.peatlands.org.uk provides a useful but not yet exhaustive gateway to relevant projects in the UK.

Formal mapping and characterisation of peat using the standard Soil Survey Methodology is unlikely to be warranted. Characterisation of the degree of peat humification according to the Von Post (H1 – H10) scheme (Annex I) is more relevant as this parameter shows some correlation with saturated hydraulic conductivity (a measure of how fast water moves through the peat); it is also quite easy to assess from field examination of peat retrieved from auger sampling. This is worth undertaking at selected auger hole locations (and particularly along the proposed alignment of access tracks) in order to gain a qualitative understanding of peat permeability.

Probing to determine peat depth is an acceptable methodology, but this should be 'calibrated' periodically with hand-augering to ensure that what 'feels' like peat actually is[6]. Probing can be undertaken with bamboo canes but these are prone to splitting and may cause injury – solid high density polyethylene or aluminium rods (the latter available from B & Q) are preferable. Insulating tape or scribe marks can be used to mark 10 cm intervals. Locations of depth probing and augering should be recorded using a GPS.

Peat depth data should be presented either as open (i.e. contours only) or closed colour shaded peat depth contour maps (with assessment points marked) or (more usually) as coloured circles indicating specific depth classes according to the suggested scheme below.

| Depth range(cm) | Colour codes |
|---|---|
| 0 – 50 | Blue or green |
| > 50 – 100 | Yellow |
| >100 – 150 | Orange |
| > 150 - 300 | Red |
| >300 | Purple |

The analytical method employed for the production of contoured representations of peat depth should be clearly stated, and raw peat depth data provided in an Annex with NGRs to at least 8 but preferably 10 figures (excluding 100 km identifier).

Peat depth measurements should be recorded in the vicinity of all planned windfarm infrastructure. Transects of peat depth measurements laid at right angles to access track alignments are highly desirable to inform re-siting. However, when assessing the appropriateness of any peat depth mapping undertaken in relation to the resource and the impacts, the ES needs to demonstrate that impacts on peat have been avoided or minimised. It is unlikely this can be achieved if measurements are only provided for the immediate vicinity of proposed windfarm infrastructure. For this reason, sufficient peat depth data should be collected to provide an understanding of the overall distribution of peat within the application site.

### 4.3. Hydrological impacts

*Introduction*

Impact assessment should address both water quantity and water quality and consider surface water resources as well as groundwater and peat hydrology. The Environment Agency should review all surface- and groundwater impacts, but in practice CCW usually leads with detailed guidance and feedback on peat hydrology. Peat hydrology is a critical issue in the context of

[6] Depth probing is a reliable method given that peat soils are comparatively soft and underlain usually by stiff gritty podzolic horizons overlying consolidated drift. However, soft silty inorganic deposits can 'masquerade' as peat when tested using depth probing alone.

this guidance because most assessments to-date of the hydrological and hydro-ecological consequences of windfarm developments in Wales have been qualitative in nature and based largely on opinion, with very little use of field-derived quantitative information from the application site or related sites to support claims of absence of or insignificant effect. Furthermore, most assessments fail to link predicted changes in peat or wider site hydrology to resultant changes in bog or fen habitat quality. It is worth noting that very little is known about the long-term effects of various forms of floating and 'cut and fill' type tracks on blanket bog hydrology (Lindsay, 2009). Consequently, judgements of little or no impact should be regarded with considerable caution, unless supported by a substantial body of site-specific evidence and, ideally, evidence for comparable impacted sites subject to long-term monitoring.

Hydrological impact assessment is a technical subject area and specialist advice[7] should be sought in assessing EIAs for sites with a significant peat cover.

Potential impacts for water quantity and water quality resulting from windfarm development are wide ranging, but include the following:

- damage to peat including peat drainage;
- long-term disruption of natural flow paths within and on top of the peat body;
- entrance of sediment into watercourses via dust or suspended in run-off;
- changes in runoff regime;
- creation of new drainage pathways as a result of windfarm infrastructure (chiefly tracks and cable trenches);
- concrete spillages and leachate from concrete residues entering the water environment from construction areas (wind turbine foundations, crane pads, substation compounds and lay down areas);
- chemical spillages during refuelling / maintenance of plant;
- erosion of exposed ground and track surfaces, producing silt- or particulate peat-laden runoff which enters local watercourses;

Only the first two points will be considered further in this guidance.

*Hydroecological impacts*

Blanket bog and fen require a high and stable water table regime sustained by rainfall. The development of peat is critical to this requirement, not least because its inherently low permeability prevents free drainage. However, recent work has demonstrated the inherent heterogeneity of blanket peat in terms of its hydraulic properties. Point to point variation in hydraulic conductivity (a measure of the rate of water movement within saturated media) is one element of this, together with the relatively recent discovery of the role and frequency of peat pipes – macropores which permit the rapid movement of water through the peat profile.

Windfarm construction involving infrastructure development on or adjacent to peat is likely to result in a range of hydroecological impacts as summarised in Table 4.5.

Impact assessments for windfarms involving the deployment of infrastructure on or directly adjacent to peat should include a quantitative site-specific assessment of the impact of the development upon hydrological regimes in terms of water levels within adjacent peats, water movement within the peatland unit, and the likely effects of changes in either attribute upon mire quality, carbon storage and the potential for C sequestration. Suggested information needs for this assessment are summarised in Table 4.6. It is important that habitat survey and

[7] HQ support is available for CCW staff.

evaluation (include peat depth assessment) should be used to help scope the requirement for detailed hydrological assessment.

**Table 4.5.** Overview of the main consequences of wind-farm infrastructure for peat hydrology. Note that wider hydrological implications for streamflow are not considered here.

| *Activity* | *Potential impacts* | *Potential consequences* |
|---|---|---|
| 'Cut & fill' tracks | Increased drainage from adjacent peat into road base and, potentially, drift or fractured surface bedrock exposed during construction. | Lowered water tables and oxidative wastage of adjacent peat leading to sloping surface and accelerated drainage. Shrinkage of peat 'away' from track edges is also possible. |
| | Impeded drainage from adjacent peat | Wetter conditions on upslope slide, drier on down slope. |
| | Severed or impeded cross-track flow. | Implications for wider hydrological regime of peat body. |
| 'Floating' roads | Loading reduces hydraulic conductivity of peat beneath track, leading to reduced cross-track flow. Loading may result in collapse of peat pipes. | Wetter conditions on upslope slide, drier on down slope. Reduced cross-track flow has wider implications for the hydrological regime of the peat body. |
| | Impeded surface flow on upslope side, loss of surface water inputs downslope. | Wetter conditions on upslope slide, drier on down slope. Loss or degradation of mire pool / soakway features downslope. |
| | Formation of ripples due to peat displacement. | Localised raising of peat above water table, leading to changes in vegetation quality and possibly peat oxidation and erosion. |
| Turbines | Increased drainage into void during construction, or shrinkage cracks post construction and infill. | Lowered water tables and oxidative wastage of adjacent peat leading to turbine bases sloping surface and accelerated drainage. Shrinkage of peat 'away' from the edge of infrastructure is also possible. |

The confidence attached to hydroecological impact assessments will depend to a large degree on the effort invested in site investigation.

**Table 4.6**. Summary of suggested information needs for hydro-ecological impact assessment.

| *Information need* | *Description and relevance to impact assessment* |
|---|---|
| Existing water table regime and the degree to which it has been affected by current and past site management | Any infrastructure development on deep peat should be informed by an assessment of water table conditions during winter and summer, even if only a walk-over survey initially to determine variations in ground wetness set within the climatic context of the year. Such assessments should be referred to a standardised terminology (ideally that of Table 4.7). More quantitative evaluations of baseline hydrology can be undertaken using dipwells equipped with data-loggers. |
| Saturated hydraulic conductivity ($k$) of peat and how it varies spatially and with depth | This important parameter determines the rate at which water moves through peat. It varies spatially and with depth. Some appreciation of it is essential to understand the likely hydrological effects of trackways. Any modelling work will be highly dependent on $k$ values. Surface peat layers in intact less modified mires may be highly conductive (high $k$ values) and thus highly sensitive to alterations in hydraulic gradient. |
| Depth of peat | Peat depth influences the cross-sectional area available for water flow, and presumably also provides a larger volume in which pipe development may occur. |

| | |
|---|---|
| Slope / topography | Topographic gradients influence the direction and rate of surface and groundwater movement and must, therefore, be a material consideration in terms of windfarm design. Detailed topographic data can be acquired relatively easily and are invaluable for modelling (see below). |
| Effect of loading on peat (& other soil type) mechanics | Floating trackways cause loading of underlying peats, with consequent reductions in the value of *k*. The effect of this on both water levels and water flow should be assessed for both static (no load) and worst-case (i.e. cranes) vehicle loadings. |
| Distribution (in relation to infrastructure) and functionality of macropores (peat pipes) | Macropores enable the rapid movement of water within the peatland. Cut & fill tracks represent an essentially homogenous intrusion into what may be a heterogeneous (in terms of water flow) peat profile. This may result in retention of water on the upslope side of tracks and dehydration on the downslope, or drainage into the track base. Cross-track continuity between macropores is highly desirable, but difficult to engineer. Ground Penetrating Radar provides a cost-effective means of detecting peat pipes (Holden *et al*, 2002). |
| Track type (cut & fill or floating), structural composition, location in relation to peat body and topography. | Both main types of track are usually based on a stony or gravel matrix. Knowledge of the hydraulic properties of consolidated tracks and adjacent cable-runs will be needed to assess likely changes in flow regime in adjacent peats. The likelihood of flow being routed down the length of trackways/cable runs should be assessed and measures to 'force' flow at right angles to the track (such as periodic cross-track bunds) examined. |
| Hydroecological requirements of proximal mire communities | Typical communities of the mire plane require a high and seasonally stable water level regime within the range c. –15 to –2 cm relative to the peat surface. Modified bog vegetation needs a similar regime for restoration and to minimise carbon loss. The surface of bog hollows typically exhibits some vertical movement in response to changes in water table level – water levels are likely to lie in the range +5 to –5 cm. |
| Nature of hydrological interaction between peat and underlying deposits | Blanket bog is likely to be relatively isolated from any underlying groundwater contact, but there may be some exchange of water between overlying peats and drift soil pipes (Figure 4.3) and water within superficial layers of bedrock. Tracks and in particular turbine bases may extend into these layers and thus alter patterns of water movement. |
| Current rainfall regime of site | Given the importance of rainfall to mire hydrology, ES submissions should place the findings of hydrological impact assessment within the specific context of current average rainfall and also likely future trends in rainfall. |
| Effect of climate change on bog hydrology and condition over lifetime of windfarm. | Climate change is likely to reduce the viability of some areas of bog, and may also result in increased sensitivity to hydrological impacts. The effects of climate change should be taken into account in impact assessment and consideration of compensation measures. |
| Modelling | Numerical models can be used to predict the response of mire water tables to changes in boundary conditions, in this case tracks. This approach has not been used widely to-date in windfarm impact assessments, but should be considered where there is a significant overlap of development infrastructure and peat. Model runs should include an assessment of how water tables respond to a typical 30 day summer drought.<br><br>Models based on topographic criteria offer a potentially cost-effective means of examining the influence of trackways and drainage infrastructure (Lane *et al*, 2004). |

**Table 4.7.** Terms employed by Shaw & Wheeler (1991) to describe water table position relative to peat surface level for different water table depth ranges.

| Term | *V. Low* | *Low* | *Moderate* | *High* | *V. High* |
|---|---|---|---|---|---|
| Water table depth range (cm); - = below soil, + = above soil (flooded) | < - 25 | -25 to –10 | -9 to + 1 | +1 to +9 | > + 10 |

**Figure 4.3**. Soil pipe (arrowed) at base of drift below a blanket peat profile, Migneint, Gwynedd.

**4.4. Peat mass stability**

Mass movement of peat (peat slides) has been reported rarely in the Welsh uplands, but the likelihood of it occurring can be increased by a range of activities associated with windfarm construction. Peat slides describe the downhill mass movement of peat and range from minor displacements of peat, to more extensive flows of peaty debris – the latter are commonly referred to as 'bog bursts'. The prominence of peat slides within the particular context of windfarms and their construction owes much to the recent (2003) infamous Derrybrien bog-slide in Co. Galway (Eire) (Lindsay & Bragg, 2004). Peat slides result in a range of direct habitat impacts, including drainage associated with cracks within the peat body and exposed peat faces, and also wastage of peat. Wider environmental effects include the inwash of particulate peat to adjacent watercourses, or in the worst cases blockage of natural drainage features. Some of the key factors which increase the risk of peat slides are summarised in Table 4.8 (based in part on Land Use Consultants & Mott McDonald , 2006).

Peat stability assessments should be considered in all cases where developments involve the construction of tracks and turbines on peat. In the future, the Infrastructure Planning Commission may instruct applicants to assess the risk of 'landslide connected to any development work' (DEC, 2009). A detailed best practice guide is provided by The Scottish Executive (2006), and some of the key factors to consider are listed in Table 4.8.

Peat stability analysis should focus on both blanket and flush peats. The latter can be especially prone to movement because of their occurrence on slopes, the focussed nature of water movement, and the often less consolidated character of the peat. Mass failure of flush systems has been observed in Wales.

**Table 4.8.** Identification of some key factors of significance for peat slides.

| *Factor* | *Significance* |
|---|---|
| Peat thickness | Peat instability is more likely where deposits exceed 1 m thickness, although slides on shallower deposits are known. |
| Slope | Slope provides a gravitational driver for slides. |
| Rainfall | Intense rainfall can cause significant and relatively rapid increases in pore water pressure and this is believed to be a significant trigger mechanism for slides. |
| Context within peat body | Peat at the edge of the main peat body may be especially susceptible to movement, especially where adjacent to breaks of slope. This is relevant to many developments where track crossings have been routed towards the edge of the peat body to minimise wider hydrological effects. |
| Surface & sub-surface hydrology | Drains create steep hydraulic gradients and cause localised zones of peat weakness. Peat pipes enable the rapid transfer of water within the peat body, and can result in temporary surcharging of some areas with water during or after intense rainfall. Alterations to both surface and sub-surface hydrology are likely to result from windfarm construction. |
| Surface loading | Excavated peat and imported road base material may each contribute to this. |

### 4.5. Earth science and palaeoecology

Welsh upland peatlands are a key resource for palaeoecological studies of vegetation and landscape development, and the nature of human influence on each. The latter aspect has been of particular importance in a Welsh context, with studies of Welsh blanket mires in particular revealing the significance of prehistoric cultures as an agent in the initiation of blanket peat development. Many key studies of European or even global significance have been undertaken in Wales, often on non-statutory sites. It is obviously preferable that direct impacts to sites which have played a role in the development of palaeoecology are completely avoided, and Caseldine (1990) provides a valuable though now dated gazetteer of investigated sites.

Any impact on peat is likely to have deleterious consequences for the associated palaeoecological/environmental archive, which requires stable anoxic conditions for its preservation. Damage to the surface morphology of peat, particularly in relation to surrounding Quaternary landforms, may also reduce the geomorphological interest associated with sites. Impact assessment in such contexts should focus on the issues identified in Table 4.9.

Deep well preserved ombrogenous peats probably represent the most sensitive receptor in this context, particularly if these are represented by highly localised deposits at sites with an otherwise thin or non-existent peat cover. Extended impacts (e.g. tracks) cutting across extensive sequences of peat represent another key sensitivity. Site assessment by trained palaeoecologists should be considered in both contexts, and collection of 'rescue cores' by staff competent in the use of analytical sampling and storage techniques considered as a last resort.

**Table 4.9**. Summary of potential windfarm impacts and consequences for palaeoeecological and wider earth science features.

| Potential impact | Potential consequences |
|---|---|
| Increased drainage | • Loss or degradation of the palaeoecological/environmental archive.<br>• Loss of recent (post-industrial revolution) history within near-surface peats possible at some distance from point of disturbance due to extended drainage effects.<br>• Fossilisation of accumulating sequences due to cessation of peat growth. |
| Peat excavation | • Irreversible loss of the archive.<br>• Degradation of adjacent peat profile. |
| Infrastructure placement on or adjacent to peat | • Interruption of soil catena's.<br>• Interruption of natural zonations between earth science features.<br>• Mass displacement of peat leading to loss or severe disruption of peat stratigraphy.<br>• Compression of palaeo-ecological/environmental archive – differential destruction of archive components. |

### 4.6. Carbon loss and carbon gain

Changes in peat carbon balance resulting from windfarms will arise from direct losses associated with the excavation of peat from trackways, turbine bases and associated infrastructure, and indirect losses caused by the wider disturbance to hydrological regimes adjacent to these and other structures. A methodology for calculating carbon loss and any carbon gain resulting from compensation was published in June 2008 by the Scottish Executive (Nayak *et al*., 2008). The method requires a range of input variables which should, ideally, be based upon site specific measurement and evaluation. Where this has not been undertaken, values are available in the literature relating to net C sequestration, peat carbon content and peat bulk density. While this is the most up-to-date and comprehensive methodology available, a recent critical review (Lindsay, 2009) has proposed a range of alternative values for some of the default values employed in the carbon calculator, and consideration should be given to their adoption where appropriate to a given site. The Scottish methodology provides a useful and partly populated worksheet structure for undertaking these calculations of carbon loss and gain.

Impact assessments should separate carbon savings associated with wind energy production from the carbon balance of the peatland pre and post impact. This is because carbon balance calculations focussed on peatland function will help provide an overall integrated measure of the impact of the scheme, as well as opportunities for reducing impacts. For example, iterative use of the carbon calculator may help identify how specific changes to the scheme layout could halt or contribute to reductions in C loss resulting from peat loss and degradation. In some circumstances it may be appropriate to consider using carbon balance calculations to help identify compensation targets for peat restoration. Gains resulting from renewable energy generation should be kept separate from these exercises because renewable energy production does not represent appropriate 'like-for-like' mitigation for carbon losses caused by impacts on habitat extent and function.

Irrespective of whether a Habitat Management Plan delivers net sequestration, EIAs should estimate how much carbon loss in the form of particulate and dissolved organic carbon fractions is likely to occur as a result of construction and windfarm operation[8], and also assess the impact of these emissions upon receiving headwaters.

## 5. MITIGATION, AND COMPENSATION

### 5.1. Mitigation Measures

The EIA should examine ways in which the impact of trackways, turbine bases and associated infrastructure can be avoided or minimised. Where avoidance of some damage is not possible, opportunities for mitigation and compensation will be an important part of the EIA – key measures are identified in Table 5.1.

**Table 5.1**. Summary of key mitigation and compensation measures.

| Broad impact | Options for mitigation | Options for compensation |
|---|---|---|
| Habitat loss | Habitat loss should be minimised.<br><br>Examine piling construction methodologies as an alternative to bulk excavation of foundations.<br><br>Minimise infrastructure overlap with peat.<br><br>Minimise construction / area of permanent crane pads.<br><br>Minimise carbon loss through use of excavated peat for compensatory restoration – i.e. by placing peat in permanently anoxic contexts such as peat dams and infilled grips. | Very limited potential for genuine compensation by habitat creation.<br><br>Restoration of extended areas of bog in comparable contexts should at least match that lost through development.<br><br>Conifer removal and hydrological restoration beyond imprint of key-holes and over a sufficient area to restore viable areas of bog. |
| Habitat fragment-ation | Minimise track overlap with peat. | Restore connectivity elsewhere on-site or in comparable nearby sites, for example by restoring semi-natural ericoid dominated vegetation on intervening tongues of dry ground, or by restoring bog vegetation on highly modified intervening peats, including afforested peat. |
| Habitat degradation | Minimise infrastructure overlap with peat.<br><br>Employ best-practice construction and restoration methodologies throughout.<br><br>Follow advice of Nayak *et al* (2008) in stock-piling peat.  Avoid protracted storage, as far as possible phase compensation ditch-blocking with peat removal.<br><br>Minimise width of peat batters on floating roads. Top-off with a milled surface to avoid erosion-probe peat sods, and reseed with an acid grassland/ericoid mix within a biodegradable stabiliser mat. | Restore areas of degraded bog elsewhere within the application site or on comparable sites nearby, including afforested peat.<br><br>Areas of bog restored through compensation should be commensurate with worst-case assessment of habitat loss and damage. |

[8] Elevated DOC and sediment load have been noted in streams downgradient of windfarm construction on peat – see Grieve & Gilvear (2008).

### 5.2. Compensation measures: Habitat Management Plans

Habitat Management Plans (HMPs) are a key element of windfarm developments and represent an important compensatory mechanism for habitat loss and degradation. They also have the potential to make significant contributions to national and Local Biodiversity Action Plan targets for blanket bog and fen conservation and restoration. HMPs should have delivery of favourable condition (or at least favourable management) for peatland features as their main objectives. Habitat Management Plans should cover the application site and any separate compensation areas. The latter, which must be under the long-term control of the developer, should be considered in cases where the application site itself offers insufficient opportunity for compensation through restoration. This may include afforested sites, though in such cases compensation would be better aimed at securing early removal of conifers and subsequent hydrological repair.

Habitat management plans should address each of the causal factors which contribute to unfavourable condition, as summarised in Table 5.2.

**Table 5.2**. Summary of key factors to be addressed in Habitat Management Plans for windfarm developments.

| Factor | Key issues for HMP to address |
|---|---|
| Grazing | Development of more mixed (i.e. not exclusively sheep dominated) regimes, following Glastir high level prescription guidance for stocking rates and periodicity. |
| Fire | Prevent further fires |
| Erosion | Prevent further gulley erosion, undertake restoration of eroded areas. |
| Drainage | Block drains |
| Off-road vehicle damage / other recreational damage. | Prevent unlawful vehicle access. Consider provision of alternative sites for recreational off-road use. |
| Afforestation | Pre-harvest removal of conifers from locations with potential for the restoration of semi-natural bog vegetation. Avoidance of key-holing in preference to larger-scale deforestation to both maximise potential for bog restoration and led to potential improvements in turbine efficiency. |
| Graminoid dominance | Domination by graminoids (chiefly *Molinia caerulea* and *Eriophorum vaginatum*) is the main symptom of degradation in Welsh blanket bogs. Measures to open up the graminoid cover such as mowing and graminicide application, followed by re-seeding, could be trialled much more widely, and in a variety of contexts (see Anderson *et al*, 2006). |

Conifer plantations account for a significant proportion of the SSA land area in Wales and include substantial areas of afforested peat. Afforestation has profound impacts on peat (Anderson, 2001), including its ability to sequester and retain carbon, but there is nevertheless significant potential for restoring previously afforested peatlands. Indeed, windfarm developments which include areas of afforested peatland could achieve net gains for peatland biodiversity by (i) reducing the need for additional infrastructure through use of existing forest tracks, and (ii) removal of trees from areas defined as both offering good potential for peat restoration and improved windflow for turbines. The benefits of achieving double-wins for carbon through both peat restoration and enhanced turbine efficiency are obvious, and the significance of afforested peat will increase as climate change reduces the environmental envelope suitable for peat growth.

## 6. MONITORING

Post-construction impacts on peatland features should be evaluated, but the term monitoring is in some respects inappropriate given that in this context it may not relate to conservation objectives, nor lead to a management response. The term is nevertheless retained because of its widespread use by developers.

There is a particular need for the windfarm industry to adopt common and comparable practices relating to both vegetation and hydrological monitoring. There is also a need to co-ordinate effort to ensure monitoring across a representative series of sites such that best practice can be identified and key lessons learnt. Lack of information concerning the nature of hydrological impacts in particular hampers predictions of effect and also the development of best practice, particularly in terms of road construction on deep peat.

Vegetation monitoring should be undertaken to determine trends in the composition and condition of vegetation in relation to two main impacts, namely key structures such as trackways, and changes in management resulting from HMP implementation. A variety of methods can be used for this purpose – examples are listed in Table 6.1.

Hydrological monitoring should be considered to assess the impact of trackways and also hydrological repair actions (Table 4.1). Dipwell installations are cheap and easy to monitor – more specialised approaches should be informed by expert advice.

The monitoring activities identified in Table 6.1 are neither exhaustive nor necessarily applicable to every site.

**Table 6.1**. Summary of possible approaches to vegetation and hydrological monitoring

| Monitoring activity | Purpose | Method | Sampling interval | Where within site |
|---|---|---|---|---|
| Condition assessment of habitat features | To assess habitat condition in relation to site-specific performance indicators, informed by JNCC's common standards methodology | Relocatable grid layouts, with assessment conducted in grid cells. | Every 3 to 6 years | |
| Repeatable digital photography at relocatable points | To provide a general record of habitat condition in relation to site impacts/restoration. | Photographs taken at fixed points and along fixed bearings, ideally using the same focal length and in similar weather conditions and at the same time of year. | At least every 3 years | At locations where HMP / infrastructure impacts are likely to be registered. |
| Surveillance of habitat features in relation to specific impacts | To provide more detailed information on trends in the cover/abundance of key indicator species in relation to site impacts and restoration. | Permanent plots, measurement of rooted frequency / cover abundance. | At least every 3 years | |

| | | | | |
|---|---|---|---|---|
| Water table behaviour pre and post impact / restoration. | To assess changes in hydrological regime as a result of windfarm infrastructure, and to assess success of ditch blocking | Plastic slotted dipwells installed along transects up and downslope of tracks/infilled ditches. Manual dip measurement or automated loggers. May need to consider earth anchors to avoid 'mire breathing' effects. Dipwells should be levelled to a common datum. | Every two (ideal) to four weeks. Hourly if automatic. | Spanning tracks and infilled ditches. |
| Runoff | | Weirs with data-loggers | Continuous | Areas of focussed runoff downgradient of tracks / blocked ditches. |
| Rainfall | A local rainfall record is highly desirable for interpretation of hydrological data | Manual: Standard 127 mm diameter Snowdon-type rain gauge (manually read) with large storage bottle (c £120). | To coincide with water table measurements. | At an average site elevation – protected from livestock. |
| | | Automatic: IH pattern or comparable automated gauge (c. £350). | Daily, or hourly to coincide with automatic water level loggers. | |
| Runoff chemistry | To monitor D/POC/inorganic nutrient export to headwater streams in relation to site impacts and restoration. | Water sampling with analysis undertaken by accredited laboratories with experience of peat water chemistry | At least monthly. | Down-gradient of impacts/restoration sites. |

## 7. FURTHER ADVICE AND GUIDANCE FOR CCW STAFF

Key sources of advice have been referred to throughout this guidance. There is an urgent need for properly controlled and reported case studies examining the long-term consequences of windfarm infrastructure on peat hydrology and habitat condition, and this needs to feed into the development of best practice. Experience gained in Scotland is being reviewed and fed into best practice guidance on floating road construction (due 2010), but a distillation of experience gained across the UK is also needed to take into account key biogeographical variations in the character of the blanket bog resource.

Specialist case-work officers and conservation officers in CCW have considerable experience in assessing windfarm impacts on peat. Specialist support is also available at HQ for peatland ecology and hydrology (PSJ) and carbon (RMcC) and for hydrological issues also via CCWs Hydrological Advice Framework Agreement (2009-2013). The latter includes contractors with specialist knowledge of assessing hydrological impacts on terrestrial wetlands, and researchers with specific expertise in blanket bog hydrology and peat carbon flux.

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**Annex I.** The Von Post system of recording humification (adapted from Burton & Hodgson, 1987).

| **Von Post Humification score** | **Characteristics**. Decomposition status in italics. Comments about water/peat refer to the characteristics of the material when squeezed. |
|---|---|
| H1 | *Undecomposed*. Yields only clear colourless water. |
| H2 | *Mostly undecomposed* – plant structures still quite distinct. Yields yellow-brown but almost clear water. |
| H3 | *V weakly decomposed*, plant structures distinct. Yields turbid brown water but no peat. |
| H4 | *Weakly decomposed*, plant structures distinct. Yields muddy, dark, turbid water but no peat. |
| H5 | *Moderately decomposed* – plant structures becoming indistinct. Yields much turbid brown water and *c*. 10% of peat volume. |
| H6 | *Strongly decomposed* – plant structures somewhat indistinct , but clearer after squeezing. Yields one-third of the peat and muddy water. |
| H7 | *Strongly decomposed* – plant structures indistinct but visible. Yields *c*. one half of the peat and strongly muddy water. |
| H8 | *V strongly decomposed* – only resistant plant structures visible. Yields two-thirds of peat, little free water. |
| H9 | *Almost completely decomposed*, nearly all of the peat extruded. No free water. |
| H10 | *Completely decomposed* - all of the peat extruded. No free water. |