

Lewis Wind Farm Proposals observations on the official Environmental Impact Statement

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CHAPTER 1 : INTRODUCTION

The EIS produced for Lewis Wind Energy by Boreas Ecology forms part of the supporting documentation for a planning application to construct a wind farm on the Isle of Lewis. More specifically, the planning application explicitly avoids the candidate Special Area for Conservation (cSAC) that lies across the central part of northern Lewis, but instead appears almost specifically to target the area of the Special Protection Area (SPA) that lies outside the cSAC. Although the reasons for pursuing such a locational strategy do not form part of the present review, the implications of this strategy for the peatland environment certainly do, because the present review aims to evaluate the extent to which the EIS correctly and adequately assesses the potential impacts of the Lewis Wind Farm development on the peatland environment.

Wind farm development proposals

The two broad forms of development required to establish a wind farm are construction of turbine bases, and construction of access roads. The former involves impacts at specific point locations while the latter represents a linear network development through the ecosystem. In terms of spatial impact, clearly the road system is a much more extensive feature than the individual turbine bases, but because peatland systems react as whole hydrological entities, even individual turbine excavations have the potential to result in widespread impact.

Concerns about the approach adopted by the EIS are centred, at least for the peatland ecology issues, around the four main aspects:

- ⚡ it is not at all clear that the EIS really understands some of the basic structures and functional processes of peat bog systems;
- ⚡ as a consequence the EIS does not recognise adequately some of the resulting key issues in relation to impact assessment;
- ⚡ there are significant questions about the way in which the EIS interprets both its own data and information gathered from other sources;
- ⚡ as a consequence of all the above, the assessments of risk and predictions of impact made by the EIS appear to be open to strong challenge.

The Lewis Wind Farm EIS - a deconstructivist approach

The EIS presents an impressively wide-ranging and detailed set of information based on what has clearly been a substantial amount of field work and information-gathering. The environmental consultant, Tom Dargie, has an acknowledged track record in terms of detailed analytical approaches applied to peatland ecosystems, and his meticulous approach to methodological development is evident here. However, one of the potential weaknesses in the EIS is that the sheer volume of information reflects what might be

described as a 'deconstructivist' approach to the issue – by breaking the system down into its component parts, Dargie assumes that predictions can be made about the way in which these various components will react in response to construction of the wind farm. This approach might work, but it depends on three things:

- €# firstly, it is important that the correct information is gathered. Dismantling a stationary car to determine its functional abilities is not an approach likely to succeed if the investigator catalogues the engine as '*large, inert lump of metal*'.
- €# secondly, while an understanding of component behaviours is important, it is equally important to see the system as an entire functioning entity, an entity that generally represents more than the sum of its component parts. Thus an understanding of the way in which all the parts function in two separate cars is unlikely to help predict the outcome of a race between the two vehicles.
- €# finally, it is vital that this functioning entity is analysed within the context of real-life conditions rather than any idealised yet inherently imperfect models of real life conditions. Thus even with road-test reports for both cars from the manufacturer and all the auto magazines, it would still be virtually impossible to predict that, two weeks later, one of the cars will be found lying destroyed in a ditch because of black ice on a sharp bend. Such predictions are impossible without an analysis of the likely journeys to be undertaken, combined with weather predictions that are more accurate than is currently possible, plus a means of predicting the driver's level of attention at any particular moment, and many other imponderables. This degree of real-life uncertainty is precisely why the UK Government has embraced the *precautionary principle* in relation to development impacts; it is important that those carrying out EIA work also embrace this principle.

After reading the EIS in detail, however, the reader is left with no real sense that peatlands function as integrated entities at all, nor that any significant uncertainties exist. To understand precisely why this represents a serious failing of the EIS, it is perhaps helpful to provide a review that looks at the essential characteristics of a functioning blanket mire ecosystem. This review is provided as Annex 1 to the present report. In particular the hierarchical and functional linkages that form such a fundamental part of a blanket mire system are explored at some length in this review for two reasons:

- €# firstly, it is generally safe to assume that the reader has only a limited understanding of peatland systems in general, and an even hazier idea of the particular hydrological processes that govern them;
- €# the Lewis Windfarm EIS acknowledges the existence of such features in terms of their structure or use in classification, but appears to show little understanding of their *functional* significance.

Consequently when looking at the specific approaches, assertions and proposals contained in the Lewis EIA, the reader will be referred to these core issues on several occasions throughout the remainder of this report.

CHAPTER 2 : SCOPING

From this point onwards, in order to avoid confusion between references to figures and tables in this present report and those found in the various EIS reports, figures, tables and sections from the EIS reports will be indicated thus:

[Table 11.3, EIS Report]

There is no denying that the Lewis EIS Report contains a very large amount of valuable information that is relevant to the assessment of any potential impact arising from the wind farm development. For example, more than 5,000 individual vegetation stands were investigated and, for each of these areas, more than 50 attributes were collected. However, the *quantity* of information is only part of the picture. The crucial question is whether the data acquired are the appropriate data, and whether this information has then been interpreted and used in the most appropriate way.

The scoping phase of an EIA is the first and arguably most crucial step in determining the appropriate range of information to gather, and over what spatial extent and timescale this must be gathered.

Establishing geographical limits of the EIA for the peatbog environment

One of the key steps in any EIA process involves determining the geographical boundary over which assessment will be undertaken. This boundary determines the range of relevant environmental issues to be addressed by the EIA. For peatbog systems, determination of the spatial extent necessary for EIA is particularly important, given the lack of understanding that generally prevails about the way in which peat bogs tend to act as whole systems (see Annex 1).

Although providing an obvious boundary, the specific area of physical development rarely provides an adequate boundary for the associated EIA. As the European Commission guidelines for the process of defining EIA boundaries observe (European Commission 1999):

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

In terms of habitat evaluation, the Lewis EIS Report unsurprisingly identifies peatland habitat as the predominant type, and directs much of its attention to

the topic. Given that the conservation agencies (through the JNCC) provide fairly detailed guidance about the evaluation of peatland systems, it might be expected that the Lewis EIS Report would follow at least the core elements of this guidance. The purpose of such guidance is to ensure that the appropriate functional units are identified when evaluating or assessing peat bog systems. In particular, the spatial extent of such functional units is unlikely to be correctly identified unless the underlying principles set out in the guidance are understood and applied appropriately.

The Nature Conservancy Council (and the Nature Conservancy before it) had a long tradition of identifying peatlands first and foremost as hydro-morphological units (Ratcliffe 1977). The process of site assessment and evaluation for all habitats has been further assisted since the 1990s by the steady rolling out of the National Vegetation Classification (NVC), which was created to provide a consistent and coherent framework for vegetation description in site assessment (Rodwell 1991). However, it must be emphasised that the NVC was designed to form only part of the assessment process for most habitat types. The JNCC recognised even before the NVC was published that this vegetation classification could not, indeed should not, replace the existing hydromorphological approach for peat bogs but instead could provide additional ecological insight to the evaluation and assessment process. The SSSI Guidelines were therefore revised for peat bogs (JNCC 1994) to combine both the NVC and the already-established hydromorphological approach.

For blanket bog, these Guidelines have this to say:

From the manner of its development, blanket bog often represents a complex of mire units (mesotopes) and typically includes minerotrophic [...] elements and transitions to vegetation on non-peat soils. Usually a range of fairly distinct mesotopes can be identified within the general expanse of more or less peat-covered land (Lindsay in press). These should be examined for hydrological connections, and linked groups then drawn together into macrotopes.

The first stage in defining and assessing a peat bog system thus involves identification and delineation of the basic hydrological units (this should be clear from the review in Annex 1). As highlighted by the Guidelines, these basic units would normally be the mesotopes. Small-scale microtope patterns (see Annex 1) may prove helpful in the identification and delineation process at this stage. Following mesotope delineation it is possible to begin defining the boundaries of the associated macrotopes. Each macrotope represents a discrete hydro-morphological peatland complex that is largely independent from adjacent areas in terms of its hydro-morphological processes.

For any peatbog habitat associated with a development proposal, the scoping process should thus first seek to identify the boundaries of the relevant peatland macrotopes. The combination of these macrotopes boundaries should then be used to define the geographical limits of the EIA assessment area necessary for the peat bog habitat.

Scoping for the Lewis peatlands

If some form of impact assessment is to be made of a peat-dominated area, it would seem logical and good professional practice to make full use of the approach recommended and used by the official conservation bodies. It thus seems peculiarly perverse that the Lewis EIA process should instead choose to define a series of catchments based on traditional river catchment boundaries, supplementing these with a set of areas defined on the basis of 'landform and hydrological process'. The established approach to hydromorphological description of blanket mire systems is thus not used as the main guiding principle for the peatland aspects of the EIA. This, inevitably, has serious consequences for all subsequent conclusions and assessment of impacts arrived at by the Lewis EIS report.

The Lewis EIS recognises that, in terms of the hydromorphological approach, a "comprehensive hierarchy for bog classification has been developed". However, the system is described as "recent" (although no such comment is made about the NVC which is significantly more recent), with the implied suggestion that it is too 'recent' to have been employed in evaluating the Lewis wind farm proposal. It is worth emphasising that the hydro-morphological hierarchy was first introduced by Ingram's translation of Ivanov more than 20 years ago (Ivanov 1981), before being summarised in its present form by Lindsay *et al.* (1988). The hierarchy then appeared within the first published SSSI Guidelines the following year (NCC 1989). Indeed it is sufficiently well-established for it to have been presented recently as the globally-recommended approach to functional description of peat bogs within *Wise Use of Mires and Peatlands* (Joosten and Clarke 2002), which is a publication adopted by all 110-plus Contracting Parties (*i.e.* governments) to the Ramsar Convention.

The EIS claims [Appendix 11B] that there is only a 'weak correspondence' between forms found in the survey area and those described within the SSSI Guidelines. It suggests that the various hydromorphological types described in the SSSI Guidelines are based on types found mainly in Caithness and Sutherland, and consequently the hydromorphological classes are not adequate to describe the forms encountered in Lewis. This is not the case. The system was developed from work throughout Britain and has been used successfully from Shetland to Dartmoor, as well as in many other parts of the world.

Nevertheless the Lewis EIS chooses not to use the hydro-morphological system as the basis for its hydrological assessment of the survey area. This is a major failing of the EIS at the very start of the EIA process, because the the hydromorphological hierarchy not only provides an internally coherent picture of the various components of a bog landscape, it provides the means by which a meaningful EIA boundary for the peatland habitat can be determined. It can also give an invaluable insight into the likely responses of the various peatland components to disturbance.

It is important to realise that the macrotope unit is the level at which hydrologically-secure boundaries are identified; if the boundary is drawn correctly, hydrological impacts outside the macrotope boundary should not have an impact on features within the macrotope. It is even more important to understand the consequences of this for EIA scoping. Assessment of the possible impact caused by (for example) a road passing through a peat bog area should not be limited to some arbitrary distance either side of the road. An oil-spill into a water body is not restricted to some limited area immediately around the spill - the Exxon Valdez may have ruptured on a single rock, but its impact was felt throughout Prince Regent Sound. Equally, the area of potential impact for the Lewis Wind Farm is not just the line of the road, it is the whole composite area of macrotopes affected by the course of the road. The potential impact-distance is thus determined by the combined extent of the relevant macrotope boundaries.

Consequently the map of potential hydrological impact for a road crossing a blanket peat area must be drawn around the outer composite boundary of the macrotopes through which the road passes. The resulting area should then form the basis for more detailed EIA investigation. As the Lewis EIS does not attempt to map either mesotopes or macrotopes, it is not capable of drawing up a map that shows the true area of potential impact for the peatland interest.

The area defined for detailed investigation in relation to potential impacts of the wind farm development on the peatland habitat is set out in the Lewis EIS Technical Report. This area is termed the Habitat Survey Area (HSA) by the Lewis EIS Technical Report, and will be referred to as the HSA throughout the remainder of the present report.

CHAPTER 3 : DATA GATHERING

Hydrological units

The main hydrological approach adopted by the EIS Report focuses on :

- €# river catchments; and
- €# hydrological zones, which are defined on the basis of 'broad hydrological type'.

CATCHMENT BOUNDARIES

Undertaken largely as a desk-based exercise in this case, the identification of river drainage basins (catchments) is a valuable tool when the main focus of interest is the passage of water through the landscape. It is thus helpful in the assessment of likely impacts relating to sedimentation, siltation, pollution, and changes to streamflows.

When the main feature of interest is not throughflow but is instead focused on areas where water is held in slow-seepage stores (*i.e.* peatlands) distributed across the landscape (and particularly across watersheds), the catchment concept can hinder rather than help functional understanding. The conflicting picture that emerges in terms of differing and largely incompatible hydrological boundaries is explored further below.

HYDROLOGICAL ZONES

'Hydrological zone types' (HZs) were identified on the basis of topography, soil moisture and hydrological characteristics. The Lewis EIS notes that these zones are generally delineated schematically, being more sharply defined only within the immediate vicinity of the turbines. The boundaries of these HZs appear to be based partly on catchment principles, as they run along the lines of water-divides in some places, but elsewhere the basis of the boundary is less clear. It is also not clear what part these HZs are expected to play in the overall picture of hydrological function and stability in the face of potential impacts.

One of the HZ types is based on the concept of what is termed a 'perched pool network'. The boundary provided for this type tends to follow the area of most obvious pool patterning (microtope) rather than identify the edge of any mesotope boundary. As can be seen in Annex 1, Figures A1-A4, a distinct microtope pattern of bog pools often only lies over one part of the mesotope. Simply defining a peatland unit on the basis of a region of microtope (as is done for the perched pool network category) gives rise to the delineation of boundaries that embrace only part of the functional mesotope unit. Consequently the use of pool pattern alone to define peat units, as used in the Lewis EIA to define HZs, is unlikely to result in meaningful peatland hydrological boundaries because there is no underlying functional logic for defining units.

The hydro-morphological approach of the agency SSSI Guidelines (NCC 1989), on the other hand, *is* based on an underlying functional peatland logic and thus gives rise to boundaries that are meaningful in terms of defining habitat components, identifying conservation units, and assessing potential impacts. The pattern of pools is indeed important, but the pool areas on their own cannot be used to define the functional components that must be protected.

HYDROMORPHOLOGICAL TYPES

Chapter 10 and Appendix 10D of the Lewis EIS contain the main discussion about blanket mire as a series of interconnected hydrological entities. Within this discussion, the terms mesotope and macrotope are introduced, as are watershed mires. However, whilst these terms are introduced and compared, there is little evidence of any attempt to incorporate the functional implications of these concepts into the EIS process.

It is possibly significant that no mention of stereo-pairs of aerial photographs, nor of mirror stereoscopes, is made in the account of the EIS methodology. However, by using such equipment, a vertical 3-dimensional view of the landscape can be obtained, and from this it is possible to draw out a *flow net* for each mesotope and its associated connecting ground. Such flow nets indicate the pattern of surface water movement across each mesotope, and form the first key step in defining the hydromorphological components of the peat landscape (Ivanov 1981).

An example of a flow net for one area within the Lewis peatlands, drawn up by the present author, can be seen in Figure 1. A number of mesotopes have been highlighted in pale blue shading, and the darker blue dashed lines with arrows represent flow nets for three mesotopes - two are spur/saddle types, while the third smaller one is a simple spur mire. The resulting composite macrotope boundaries are displayed as pecked black lines.

Complete evaluation of the various interconnected peatland units within the development area as a whole would involve drawing up flow nets for all areas of ground. Where the flow net either passes directly onto mineral ground, or into a water body that sits directly on mineral ground, this may indicate a section of boundary for a macrotope. However, this is only the case if that section can link directly with other adjacent sections, which can themselves then link to form an enclosed macrotope unit.

The focus within the Lewis EIS Report on catchments and hydrological zones to some extent obscures the fact that the essential process of mesotope and macrotope definition has not been carried out. However, it is difficult to over-emphasise the seriousness of this omission. Without such definitions, it is almost impossible to assemble a meaningful assessment of potential hydro-morphological impacts.

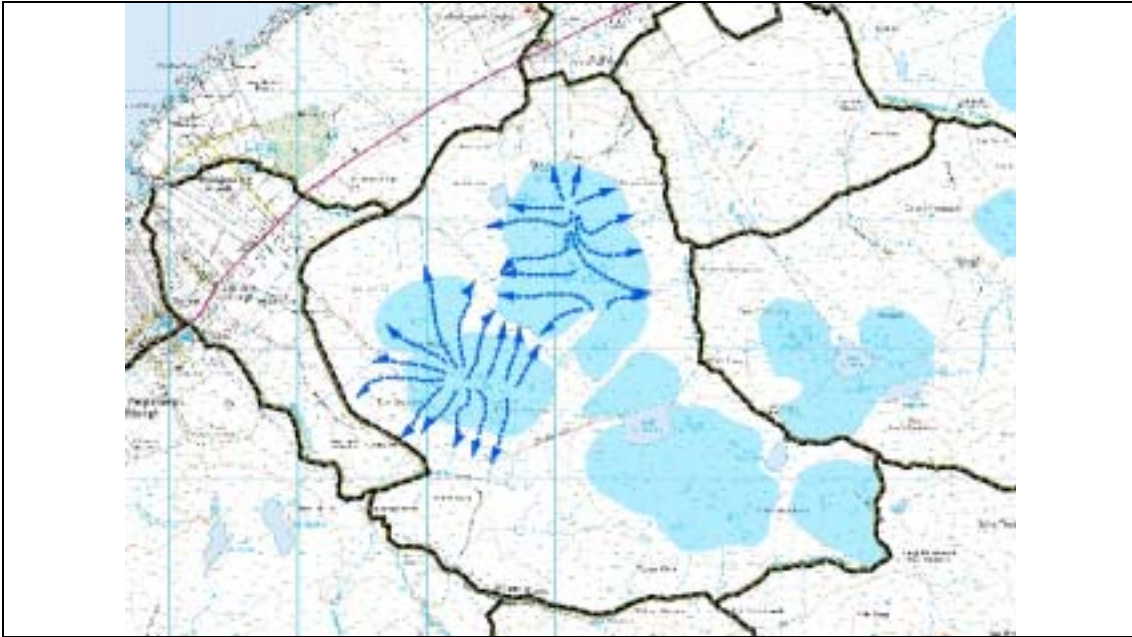


Figure 1. An example of a 'flow net' analysis for part of the blanket mire landscape near Borne, Lewis. Provisional mesotopes are shaded pale blue, and the flow nets for some of these have been drawn (indicated by the dark-blue pecked lines; arrows show the direction of water movement). The boundaries of the composite macrotopes are indicated by heavy pecked black lines. The OS 1:25,000 scale map is provided as background.

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Peat depths/thickness

If the proposed road and turbine sites had been planned for an area where significant stretches of the road and substantial numbers of turbines were to be built on mineral soil, the lack of any mesotope and macrotope definitions might have been less serious. However, the Lewis EIS looked at peat thickness within the survey area and the results make it clear that the great majority of the area does consist of peat bog mesotopes rather than habitats of mineral soil. Specifically, during the HSA survey a note was made of whether the peat was more than 1 metre deep. Where it was less than 1 metre, a note was made of the actual depth. Where the thickness was greater than 1 metre, it was simply noted that the thickness exceeded 1 metre.

It is unfortunate that *actual* depths were not obtained during the course of the survey. Peat soils are generally defined as having an organic deposit of 30 cm or more, but the typical bog environment is generally associated with depths of 1 metre or more. From this perspective, the peat thicknesses obtained from the EIS survey can at least confirm the extent of true bog, although the engineering and impact issues of a peat layer 1 metre thick are potentially orders of magnitude different from those where the peat thickness is 5 metres deep.

For the specific line of the wind farm roads, peat thicknesses were also measured, up to a maximum of 5 metres. Thus a model can be created for peat thickness along the lines of the roads themselves. However, for a truly functional model of peat behaviour, it is important to have a map of peat thickness across the whole area, not just in long thin ribbons. With a true thickness map for the whole area it is possible to look beyond peat depths in the immediate vicinity of development and see what relationship these thicknesses of peat have to the peat lenses of the various mesotopes and indeed macrotopes within the EIA scoping area for the development.

Conversely, it is difficult to see how a realistic view of this relationship can be obtained *without* a complete map of peat thickness for the relevant macrotopes. A map of peat thickness for the whole peatland scoping area is really essential if the scale of potential impacts on the various mire units is to be assessed effectively.

Peat erosion

The major focus of interest for the EIA field survey, receiving even more attention than the vegetation, is the phenomenon of peatland erosion. It is stated in the Lewis EIS Technical Report that the peatland areas of Lewis display a range of eroding forms that have not been adequately described or classified, and it is suggested that these add a number of undescribed hydro-morphological types to the JNCC classification of peat bog systems.

This is not the case, because all these eroding systems still exist as basic hydro-morphological entities such as watershed or saddle mire, but what erosion does is to create a variety of additional surface patterns (*microtopes* - see Annex 1) that replace the usual patterns of hummocks, hollows and pools. These additional patterns represent various stages of pattern breakdown or recovery, and can be classified according to whether they are linear, dendritic, intense or widely scattered. The classification that emerges from the EIA survey is nonetheless a valuable categorisation of erosion types that can equally be applied in Shetland, the Grampians, or the Peak District.

While the categorisation of these various states of erosion is useful, interpretation of the dynamics and implications of this erosion is generally less so, and will be explored in subsequent chapters.

Vegetation data

NVC MAPPING AND QUADRAT SAMPLING

Vegetation survey was based on the NVC, which is the standard vegetation mapping system used by the conservation agencies. A certain period of training was provided for the EIA survey team, but after this the team generally assigned vegetation directly to NVC types in the field without taking detailed quadrats. The survey team did record detailed quadrats on a sampling basis, recording a total of 332 quadrats distributed across most of the vegetation types encountered. These quadrats were recorded according

to the method set out in Rodwell (1991). Most of these quadrats were taken during the first field season, which means that there were relatively few quantitative species samples for the westernmost part of the development area.

Part of the purpose of taking quadrats when carrying out NVC survey is to provide a check that vegetation stands are being assigned correctly to NVC types on those occasions when quadrats are not taken. Without corroborating quadrat data, there is no way of checking that such NVC assignments are correct. It is simply not practicable to take quadrats from every individual vegetation stand encountered, and thus a sporadic process of sampling combined with direct NVC assignment is common practice. It is important, nonetheless, to have a logical sampling strategy for this sampling process.

QUADRAT SAMPLING STRATEGY

It is not clear from the Lewis EIS what sort of sampling strategy was used to take quadrats. It seems that quadrats were initially taken as a means of training survey staff and confirming tentative NVC assignments, but as most quadrats were taken in 2002, the spread of such corroborating quadrats is heavily skewed away from the areas of vegetation affected by Group 3 and Group 4 turbines. A more logical sampling strategy would have ensured that samples were taken reasonably evenly across the whole range of the study area and throughout the span of the survey programme. It is quite possible for surveyors to suffer from 'classification drift' over a period of time, especially as new types of vegetation or variants on old types are encountered. It is thus good practice to maintain a fairly steady rate of corroborative sampling throughout a survey in order to ensure consistency of assignment - or at least to have some raw data that can be used to judge the degree of classification drift.

QUADRAT SAMPLING INTENSITY

In all, 332 quadrats were taken as part of the Lewis EIA investigations from the 5139 vegetation stands recorded from the study area. The stands were defined digitally as polygons for input to GIS. The total number of quadrat samples obtained thus represents a corroborative record of only 6% across the whole range of stands. This is quite a small percentage, and of course the percentage is even lower for the stands recorded in 2003. It means, for example, that 94% of vegetation stands must be taken on trust as having been correctly assigned in the field, because there is no easy way of checking this assignment after the event.

The limited number of samples in total also means that, for example, only five quadrats were taken for the whole of the H10b heath sub-community - a community that is described as being a widespread feature. Five quadrats is the absolute minimum needed for an NVC determination. For even the most extensive mire communities in the whole study area - M15c and M17b - only 25 quadrats in total were obtained.

As explained above, quadrat sampling is carried out in order to provide a form of objective checking that NVC assignments are being made correctly. As long

as evidence from these samples shows that such assignments are indeed consistently correct, a reduced sampling strategy may be justified for later stages in the survey. Direct NVC assignment as the basic form of field survey may be rapid, but it introduces significant potential for observer error and observer bias. In the case of the Lewis EIS, examination of the quadrat data reveals significant areas of concern. These concerns are reviewed and discussed in Chapter 4.

Land management impacts

The Lewis EIS field survey attempts to apply the survey methodology developed by SNH (MacDonald *et al.* 1998) for evaluating the impacts of various land management practices on upland ecosystems. The EIS approach to the methodology is somewhat curious from the very start. The SNH published guidance is described in the Technical Report as “expensive to purchase and not easy to use in the field”. At £30 each for the two volumes, this would seem a very modest price within the context of a multi-million pound development scheme (no such comment is made about the equally expensive floras that are cited as the taxonomic authorities for the report). As for the difficulty of using the handbook in the field, a series of field record sheets is provided at the back, and these can be photocopied to be used as record sheets in the field.

Rather than doing this, a modified version was created for the Lewis EIS survey containing the “core contents of the methodology”. The field survey team then used this modified version to record existing land-use impacts. The only evidence of precisely what was recorded is found in Table A1.5 of Appendix 1 of the EIS Technical Report. From this, there would appear to have been only a very small number of management impact attributes associated with each surveyed polygon.

If this was indeed all that was recorded, it does not seem likely that some of the important points concerning impacts on peatlands, particularly burning, were recorded. In particular, MacDonald *et al.* (1998) emphasise that intense burning of blanket bog tends to generate a firm surface that is uneven and characterised by dense lumps that arise when fire resistors such as *Trichophorum cespitosum* form increasingly dense tussocks. Abundant *Racomitrium lanuginosum* is described as a characteristic indicator of past intense fire damage.

There seems to be no record of surface texture, nor the presence of dense tussocks, and the presence of *Racomitrium lanuginosum* is not used as a fire-indicator. Similar issues relate to the effects of grazing and trampling. Consequently it is difficult to see what type of information was actually obtained with a view to making informed decisions about the part played by burning and/or grazing in creating the present condition of the Lewis peatlands. Equally, it is difficult to understand how any useful conclusions about land management impacts could be drawn from what seems to be the information gathered.

CHAPTER 4 : RESULTS OF THE FIELD SURVEY

Peat thickness

The results of the EIS peat thickness investigations will be examined first because peat thickness determines whether (and where) peatland habitat should form the primary focus of impact assessment. The results indicate that the majority of the proposed development will indeed be built on true bog peat rather than thinner organic or even mineral soils. A map series of peat thickness generated from the results provided by the EIS polygon data can be seen in Annex 2. This series of maps shows that the great majority of the road network will be built on peat that is at least 1 metre deep. Indeed it seems from the measurements obtained for the line of the road network itself that the most typical peat thickness is around 2 m - 2.5 m, though some localities are described as being more than 5 metres deep.

The first important conclusion from this result is that the EIA boundary for assessing peatland habitat impacts should indeed be based as a minimum on the defined boundaries of macrotopes and component mesotopes that contain either roads or turbines, or other construction facilities. Only by adopting such a boundary can the EIA provide an accurate assessment of likely impacts throughout the mesotope-macrotope complexes.

One of the other key implications of the peat depth survey is that large sections of the road network will be constructed as 'floating' roads. The Lewis EIS report states that where the peat thickness is greater than 1 metre, floating roads (or rock-fill) techniques will be the preferred method of construction. The issues of such road construction (and there are many issues to consider) will be examined in the next chapter.

The main difficulty with the peat thickness survey is that the data obtained for *actual* peat depth are restricted to the specific lines of the roads. More widespread sampling across the whole of the HSA only provides a figure for *minimum* peat depth and gives no information for thicknesses of greater than 1 metre. It is thus not possible to generate a model of true peat thickness for the whole study area. As discussed in the previous chapter, this is unfortunate because an evaluation of the possible impacts of development on the peatland habitat at the mesotope and macrotope level would be greatly assisted by such a model.

Catchments, Hydrological Zones and Hydromorphological Boundaries

The Lewis EIS Report defines a total of 28 catchments and four Hydrological Zones (HZs), although, as discussed below, the HZs are defined for a limited geographical area only, rather than for the whole of the HSA.

CATCHMENTS

The catchment approach generates a set of boundaries that create precisely the wrong impression of where features of peatland sensitivity may exist. It

creates boundaries that are almost the worst possible form of boundary in terms of peatland function. The extent to which catchments fail to provide adequate functional units can be seen by comparing the macrotope boundaries already indicated in Figure 1 with the catchment boundaries drawn up for the Lewis EIS (see Figure 2).

It is clear from Figure 2 that the preponderance of watershed, saddle and spur mires in the area means that a traditional river catchment approach is not appropriate to the task of defining such hydrological units. The identified catchment boundaries not surprisingly cut directly through the majority of mesotopes and thus provide no useful peatland boundaries.

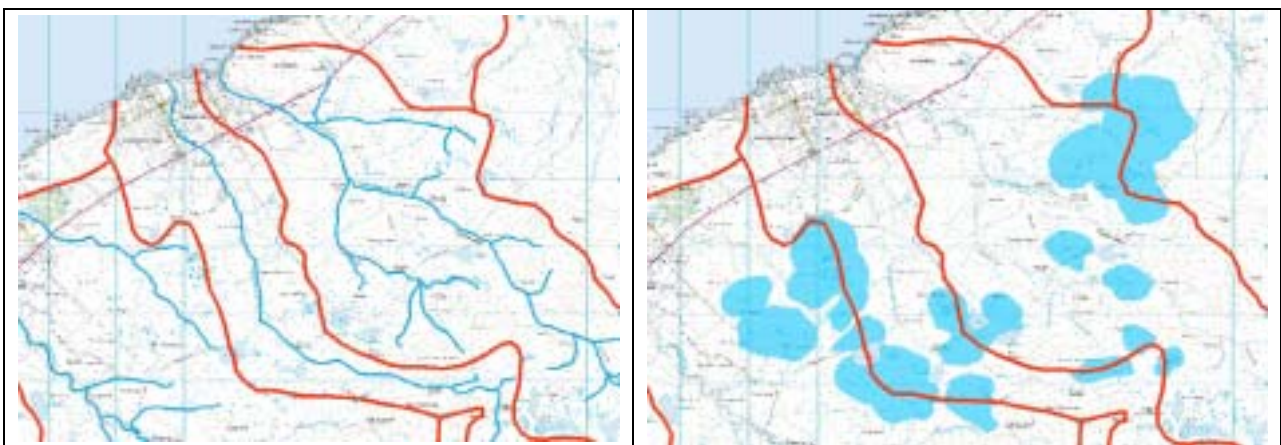


Figure 2. Both maps show part of the Lewis development site, with Ordnance Survey 1:25,000 map information. The map on the left shows main river systems in blue, while the catchment boundaries defined in the Lewis EIS: Fig 6.2 are shown in red. It can be seen that the catchment boundaries cut through several watershed mire systems (as indicated by the mass of small blue bog pools on the OS map). The map on the right again shows the catchment boundaries in red. In addition, however, it shows the approximate extent of several peat bog mesotopes (in mid-blue shading). From this it is evident that a catchment approach tends to cut through the centres of many bog systems.

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HYDROLOGICAL ZONES (HZs)

For the Hydrological Zones, the Report explains that:

“away from the immediate turbine locations the distributions of the [HZs] are schematic and are intended only to provide an indication as to the overall hydrologic conditions within the catchments affecting the site.”

It is not at all clear what is meant by “the immediate turbine locations” and thus it is not clear over what parts of the EIS Figure 10.5 there is detailed mapping of the HZs and where this mapping is more ‘schematic’. There is also no explanation of what exactly is meant by ‘schematic’ so it is difficult to judge the level of confidence that can be placed on such boundaries.

Notwithstanding these issues, the HZs show a somewhat better match with the concept of a mesotope unit. This is in part because one of the HZs is described as ‘perched pool networks’, and from the definition it is evident that these are usually watershed mire mesotopes *sensu* NCC (1989) and Lindsay (1995). However, because there is no underlying hydrological logic to the *boundaries* of the HZs, much of the boundary length for the HZs still tends to cut through mesotope units rather than follow any mesotope or macrotope boundary.

The lack of precision over exactly where the HZ boundaries are accurate, and where they are schematic only, combined with the manner in which the boundaries are drawn up, means that from a functional (and thus impact assessment) point of view, the HZs are of limited value.

HYDROLOGICAL ZONES AND HYDROMORPHOLOGICAL TYPES

After defining the range of Hydrological Zones, the EIS Report then attempts to demonstrate a correlation between these zones and the JNCC hydromorphological types. A comparison and partial correlation is presented, but no information is provided for, and no consideration is given to, the functional implications of the various hydromorphological types discussed.

In practice the boundaries of many Hydrological Zones do not match at all well with equivalent boundaries for the hydromorphological units. The whole functional value of the JNCC hydromorphological units - namely the definition of landscape components that are complete hydrological entities that will react to impacts as whole entities - plays no part in the Lewis EIS description. Watershed mires and valleyside mires are described, but apparently not with any intention of identifying secure peatland boundaries (or indeed with any evident understanding that this can be done). From the perspective of peatland impact assessment, the hydrological investigations carried out as part of the Lewis EIS provide very little, if any, useful insight into potential peatland problems.

Erosion classes

A total of 8 erosion classes are identified, along with reasonably clear oblique aerial photographs to illustrate each pattern type. These classes consist of two types that are described as ‘largely intact’ and devoid of erosion gullies (Class 1 and 2), a third that is described as ‘low density’ gullying (Class 3), then four categories with a high density of gullies. Two of these are described as showing signs either of stability or revegetation (Class 4 and 6), while two are described as actively eroding (Class 5 and 7). The final type is associated with extensive peat cutting and is highly variable in character (Class 8).

Of the eight classes identified, only two (Classes 5 and 7) thus appear to indicate active loss of peat through erosion (rather than through oxidation of exposed peat faces). The remaining five demonstrate a degree of system stability and even some vegetation recovery (setting aside Class 8 and its peat cuttings for the moment).

Identification and classification of these erosion types is a useful exercise in terms of defining baseline conditions for the possible area of development impact. The results emphasise the fact that although a considerable proportion of the blanket bog mesotopes within the HSA show signs of erosion, the majority of the area is characterised by erosion classes that indicate stability or even regeneration of the system (see Table 1).

Table 1. The extent of erosion classes identified for the HSA, and the proportion which indicate stability or revegetation, compared with classes that indicate active erosion. Data have been taken directly from the Lewis Wind Farm EIS Technical Report (Table 11B.4).

Erosion Class	Erosion status	Area (ha)	% of HSA
1	stable	1440	5.8%
2	stable	3186	12.8
3	stable	3395	13.7
4	stable/revegetating	4306	17.3
5	eroding	927	3.7
6	stable/revegetating	4348	17.5
7	eroding	1857	7.5
8	variable	2153	8.7
Total stable	(not including Class 8)	16,675	67%
Total eroding		2,784	11%

It is worth emphasising that the erosion classes presented by the Lewis EIS Report represent *microtope* features within the peatland system (*i.e.* patches of uniformly repeated pattern *within* a mesotope) and thus form only part of each mesotope unit within which they occur. It would probably be more functionally meaningful to present the area totals for the mesotopes within which these erosion patterns are found, rather than the area totals for only the microtopes themselves, because this would give a truer idea of the total functional area associated with these erosion patterns. From a review of the GIS datasets, such an approach would certainly increase substantially the area defined as stable or revegetating. However, the data have been presented in this form by the Technical Report, and so to enable direct comparison with other elements of that report, the area totals are taken directly from the Technical Report Table 11B.4.

Land management impacts

The recording of land management impacts in the manner described in the previous chapter is shown to have stark consequences when the results of the EIS field survey come to be considered. It is stated in the Lewis EIS Report that little evidence was found for either intense or frequent burning, while trampling and grazing impacts were 'mainly absent or light'. Consequently the widespread scale of erosion across the survey area is assumed to be a result of natural processes.

The question of erosion and its origins will be discussed in the next chapter, but for the moment it is important to consider the claim that there is little evidence for either burning or grazing within the survey area. Having myself walked over extensive areas of the Lewis peatlands as far back as 1977 (see Goode and Lindsay 1978) and on several occasions since, I am very conscious of the fact that the ground within the blanket bog regions is generally either distinctly uneven with marked tussocks and lumps underfoot, or is soft and spongy with mounds of *Racomitrium lanuginosum*. As discussed in the previous chapter, MacDonald *et al.* (1998) clearly state that these are features indicative of burning - often intense burning.

It would be necessary to undertake a certain amount of survey, but I have no doubt that by doing so the widespread nature of this uneven and 'lumpy' ground could be demonstrated. This could be supplemented with a few short peat cores in which the surface stratigraphy is examined for charcoal. These together should be sufficient to demonstrate the presence and frequency of past burning events.

Vegetation mapping

One of the strongly-argued themes that emerges from the EIS field survey results is that a large proportion of the vegetation consists of comparatively dry vegetation types. Most of the vegetation is identified as blanket mire types, embracing all bog types from wet heath/blanket bog M15 to cotton grass M20 blanket bog. There is nevertheless a preponderance of both M17 (as would be expected for such an oceanic locality) and of M15. The most extensive detailed NVC types by far, according to the survey results, are the M15c and M17b *Cladonia* sub-communities, both of which are characterised within the published NVC account (Rodwell 1991) as somewhat drier vegetation forms than the typical examples of their respective NVC vegetation types.

Both the Technical Report and the main Lewis EIS Report repeatedly emphasise the extensive nature of these dry vegetation types, with M15c being the slightly more extensive of the two main types (25.4% of the HSA) while M17b reportedly covers 25.1% of the area. In addition, a decision was made during the survey programme to assign the dry vegetation found along the edges of erosion gullies, and across the expanses of drier eroded areas, to the NVC type H10b dry heath, *Racomitrium lanuginosum* sub-community, although these vegetation stands were formed on deep peat. As a result, this

third vegetation type then became the third most widespread NVC type, covering 8.5% of the HSA.

The assignment of NVC types by the Lewis EIS survey programme deserves closer examination, because it is curious that the two other NVC surveys referred to by the Technical Report (Dayton 2003; Quarmby *et al.* 1997) do not mention either M15c or H10b. The Lewis EIS Report specifically states that Dayton (2003) does not record H10b for the adjacent cSAC area, and explains this by observing: "*It is likely that the cSAC NVC survey overlooked this type...*". The survey by Quarmby *et al.* (1997) consisted of remote-sensing methods combined with detailed ground-truth survey. The identified NVC types listed by Quarmby *et al.* (1997) for the peatland areas of the HSA make almost no mention of M15 wet heath. The lack of identified M15 is further emphasised on the resulting classified satellite images available from SNH's SBBI web-site. Neither the Lewis EIS Report nor the associated Technical Report comment on this apparent anomaly - not even to suggest that M15 and H10 were overlooked.

Concern has already been expressed earlier in the present report about the direct assignment of NVC types in the field without any apparent strategy for regular sampling to provide an independent check that assignments continue to be correct. Concern also now exists about the way in which some vegetation types have been explicitly assigned to particular NVC types. The three main NVC types emerging from the Lewis EIS survey programme deserve closer inspection, both in terms of their explicit assignment and in the light of the sample quadrats that are provided for each NVC type in the Lewis Technical Report. As explained in Chapter 3, the detailed quadrat data are taken to provide a means of checking that in-field assignments are both reasonable and have remained consistent.

Comparison of a relatively small number of sample quadrats against the published NVC tables is a somewhat inexact science, in part because there is considerable overlap between different NVC types, and important aspects of the vegetation descriptions rely on differing abundances of similar species, rather than their simple presence or absence. Nevertheless, it is possible to use the published NVC tables in such a way that some fairly clear species-indicators emerge for any given NVC types.

The method is based on the simple phytosociological principle of 'species-faithfulness' to particular vegetation types, and contrasts this with species that may be constant (and often quite abundant) but not faithful to a particular vegetation type. In comparing any NVC types, it is possible to identify those species that are significantly common to both. These species may be useful in providing a description of the vegetation types, but they are likely to be less effective in distinguishing *between* the two types. By simply highlighting those species that are present in reasonable numbers, but which are faithful to one type or another, it is possible to identify species that are unique to one type or another. By also highlighting species that occur commonly in one type but only very occasionally in another type, it is possible also to identify what might be called 'indicator' species, which are not as definitive as unique species, but

nevertheless give a strong indication of NVC type. The method, in other words, highlights *difference* to identify vegetation types (rather than relative similarity between types, which is what tends to happen when looking at the constant and abundant species in similar vegetation types).

Using this combination of species it is possible to make relatively clear assignments of particular quadrats, and to judge the accuracy of established assignments. The three main NVC types reported for the HSA are examined below both in terms of this species comparison, and also, in the case of H10b, the explicit decision to use this NVC sub-community.

H10B - DRY HEATH : RACOMITRIUM LANUGINOSUM SUB-COMMUNITY

The validity of using H10b

The NVC description for this sub-community states that it does not normally extend onto even shallow peat soils and is generally a community restricted generally to freely-draining conditions on mineral soils. However, the NVC also states that a form of H10 appears to have become established along the *“dried and fretted margins of quite deep blanket peat that has been drained or cut - such a development appears to be in train on the most severely degraded stretches of blanket mire on Lewis and Harris ... where there is exposure and wind erosion of the peat mantle down to underlying mineral material [this results in] the Racomitrium sub-community.”*

Such a description does not suggest that extensive areas of deep blanket peat are likely to be assigned to H10, but only those areas along the margins of the peat expanse, and in particular where peat removal has been sufficiently severe to expose the underlying mineral base.

The decision to assign significant areas of the blanket bog vegetation to what is generally a dry heath community clearly has significant implications for the assessment of habitat quality - an area of blanket bog that now only supports a dry heath community is unlikely to be assessed as being of the same quality as an area of blanket bog that still supports typical blanket bog vegetation. The Technical Report states (in Technical Report Table 7) that H10b was recorded from: *“the edges of blanket bog gullies and dry, very eroded original bog surfaces ... It is close to the variation in the published NVC table.”*

A total extent of 2,113 ha for H10b would seem to suggest that a very considerable area of blanket mire was assigned to this NVC type. It would also be interesting to know what is meant by ‘close to the variation’ in the NVC table. Of course, one of the problems now is that the reported results cannot be checked, other than going out and re-surveying the area, because the assignment of NVC type was carried out directly in the field.

Nonetheless, the decision to assign such areas to H10b, at least at the scale that appears to have been employed, must be seriously questioned. This is especially so as extensive use of H10b inevitably results in a perceived lowering of quality for those areas so assigned, and, because of its extensive nature, by implication a lowering of the value of the HSA as a whole.

NVC quadrat comparison

It is, however, at least possible to examine the set of quadrat data provided as a sample for each NVC type (or at least for most of them). The Lewis Technical Report provides five quadrats for H10b. This, incidentally, seems to be a very small number of samples for what is reported to be the 3rd most extensive NVC type recorded in the HSA. It is instructive, however, to compare these quadrats with the published NVC tables for H10b and, for comparison, with the published tables for M17.

The five quadrats presented in the Lewis Technical Report for H10b (Technical Report Table A5.4) display a degree of uniformity within the constant and most abundant species, which are *Calluna vulgaris*, *Racomitrium lanuginosum*, and *Erica cinerea*. However, the abundance levels recorded for each of these species in each quadrat are also levels that can occur in M17b. High constancy values displayed for these species in Technical Report Table A5.4 are simply a result of putting these quadrats together and calculating the constancy within this group of quadrats. The result would be the same for *any* group of quadrats that contained these species whether at high or low abundance.

Species that occur at moderate abundance and frequency within the published NVC tables tend to be of particular interest and value when making comparisons between NVC types. Thus it can be seen from Figure 3 that, when comparing H10a and H10b with M17b, the species that are unique to H10b are *Carex pilulifera*, *Festuca vivipera*, *Cladonia furcata* and *Cetraria islandica*, while indicator species are *Empetrum nigrum nigrum*, *Huperzia selago*, *Corniculata uculeata*, *Carex panicea* and *Festuca ovina*. It is interesting to note that only one of these species (*Carex panicea*) occurs within the H10b quadrats listed in the Lewis EIS Technical Report, Table A5.4. Indeed even this one species only occurs in a single quadrat.

The remaining four quadrats contain *Eriophorum angustifolium*, *E. vaginatum*, *Polygala serpyllifolia* and *Hypnum jutlandicum* which are all species that are unique indicators for M17b, when comparing between H10b and M17b. This high proportion of unique indicators for M17b would suggest that in fact four of the five quadrats presented in Technical Report Table A5.4 could be better assigned to M17b. This has significant implications for the remainder of the NVC survey, because if this high proportion of the 'type' samples presented for H10b should in fact be classed as M17b, what then is the position for the 2,000 or so hectares that were assigned to H10b directly in the field? Only a programme of re-survey could answer this.

	H10a unique	H10a indicators	H10b unique	H10b indicators	M17b unique	M17b indicators
Carex binervis	Pink					
Agrostis capillaris						
Blechnum spicant						
Campylopus paradoxus		Pink				
Galium saxatile						
Rhytidiadelphus loreus						
Pleurozium schreberi						
Dicranum scoparium						
Carex pilulifera			Orange			
Festuca vivipera						
Cladonia furcata						
Cetraria islandica						
Empetrum nigrum nigrum				Orange		
Huperzia selago						
Cornicularia aculeata						
Carex panicea						
Festuca ovina						
Eriophorum angustifolium					Blue	
Eriophorum vaginatum						
Sphagnum papillosum						
Drosera rotundifolia						
Cladonia arbuscula						
Mylia taylori						
Hypnum jutlandicum						
Polygala serpyllifolia						
Narthecium ossifragum						Blue
Sphagnum capillifolium						
Luzula multiflora						

Figure 3. Summary species table listing those species (within this particular comparison) that are unique to each of the three NVC types listed here. Also shown are species that are good indicators of each group, although not unique to the group. This table can be used to compare the species listed in [Table A5.4 of the EIS Technical Report](#) for NVC sub-community H10b, with the published NVC tables for both H10 and M17b. The many species common to all three NVC types shown above are not listed here, as they provide relatively little help in making distinctions *between* these types. Species-table data based on tables provided by Rodwell (1991).

M15c SCIRPUS CESPITOSUS - ERICA TETRALIX WET HEATH - CLADONIA SPP. SUB-COMMUNITY

This community is reported to be the most extensive NVC type within the HSA, covering some 6,300 ha, and is mapped according to the GIS data across many areas of obvious and extensive deep peat yet M15c is described by the NVC as “*being especially associated with thinner or better-drained areas of ombrogenous peat*” (Rodwell 1991).

Indeed the extensive nature of wide, flat watershed, saddle and spur mires within the HSA make it particularly surprising that H15 should have emerged as the dominant vegetation type. There are particular concerns where the landform is flat or gently-sloping (and thus likely to or evidently do support deep peat) yet such areas have been assigned to the M15c NVC type.

Turning to the sample quadrats assigned to this NVC type, again it must be said that there is some concern about the sampling intensity, because only ten samples were recorded for a type that covers such a large area and which represents the most extensive type recorded. Strictly speaking, this means that only 0.0006% of the type was quantitatively sampled.

Looking at the NVC species tables and identifying the key distinguishing species, it is possible to compare the ten quadrats taken for M15c with the indicator species for M15 and M17 NVC types. Interestingly, the data in Rodwell (1991) suggest that M15c has no species that are either unique, or can even act as indicator species for the type. As can be seen in Figure 4, every species listed in the published NVC tables (Rodwell 1991) for M15c either occurs in the other M15 sub-associations, or is found in the M17 sub-associations.

Examination of the quadrats listed specifically for M15c in Table A5.17 of the Lewis EIS Technical Report reveals that in fact several of these quadrats contain species that are very clear indicators for M17 vegetation types. *Pleurozia purpurea* occurs in five of the ten listed quadrats, and is accompanied in four of these by *Cladonia arbuscula* which also occurs without *P. purpurea* in a sixth quadrat. Both of these species are strong indicators of M17a vegetation, and indeed two such quadrats also contain significant *Sphagnum* cover. Meanwhile a seventh quadrat contains indications of a vegetation with characteristics of both M17a and M17c. The remaining three quadrats cannot be described as obviously and uniquely M15c - it would be possible to argue an equally strong case for assigning all these three quadrats to M17.

M17B SCIRPUS CESPITOSUS - ERIOPHORUM VAGINATUM MIRE, CLADONIA SPP. SUB-COMMUNITY

Reported as covering 6,236 ha of the HSA, which represents almost exactly a quarter of the study area, this is a vegetation type that is characteristic of deep peat. It occurs as a somewhat drier form of M17 than is found widely in the M17a of pool-and-hummock microtopes, although Rodwell (1991) emphasises that the type does occur within such pool-dominated areas, where it can be found dominating the summits of the higher hummocks.

	M15a indicator	M15b indicator	M15c indicator	M15d indicator	M17a indicator	M17b indicator	M17c indicator
Breutelia chrysocoma	Yellow						
Succisa pratensis							
Carex pulicaris							
Selaginella selaginoides							
Juncus bulbosus							
Viola palustris							
Euphrasia officinalis							
Drepanocladus revolvens							
Aneura pinguis							
Campyllum stellatum							
Scorpidium scorpioides							
Dactyloriza maculata							
Sphagnum recurvum		Orange					
Carex panicea							
Campylopus paradoxus		Orange					
Juncus acutiflorus							
Festuca ovina				Red			
Galium saxatile							
Carex pilulifera							
Cladonia chlorophaea							
Anthoxanthum odoratum							
Pleurozia purpurea					Cyan		
Sphagnum tenellum							
Sphagnum compactum							
Cladonia arbuscula						Blue	
Hylcomium splendens							
Diplophyllum albicans							
Mylia taylori							
Polytrichum alpestre							Purple
Aulacomnium palustre							

Figure 4. Summary species table listing those species (within this particular comparison) that are good indicators of each NVC sub-community given above. Although not unique to a particular sub-community, each species listed above occurs with sufficient regularity within that sub-community, and is sufficiently infrequent in other sub-communities, that the species can be used as an indicator. This table can be used to compare the species listed in [Table A5.17, EIS Technical Report](#) for NVC sub-community M15c, with the published NVC tables for other M15 sub-communities, and with the NVC table for M17 sub-communities. The many species common to all seven NVC types shown above are not listed here, as they offer relatively little help in making distinctions *between* these types. Species-table data based on tables provided by Rodwell (1991).

Rodwell (1991) also emphasises the particular part played by burning in creating extensive tracts of M17b in the north and west of Britain - thus echoing the concerns made above about the limited evidence for burning found throughout the HSA by the Lewis EIS survey. If the type is indeed so extensive in the HSA, this might be taken as further strong evidence for intense or regular burning of the vegetation in the past, although the EIS Technical Report clearly does not interpret the evidence in this way.

Looking at the sample quadrats assigned to M17b in the Lewis EIS Technical Report, a total of 15 samples were obtained, which is the largest number of samples for any vegetation type recorded during the survey. Nonetheless, 15 samples from a total area of some 6,200 ha still represents a relatively small level of sampling.

Looking at the NVC species tables and identifying the key distinguishing species, it is possible to compare the 15 quadrats taken for M17b with indicator species of other M17 NVC sub-community types. As can be seen in Figure 5, a very clear set of indicator species for the three M17 sub-communities can be identified from the published NVC tables (Rodwell 1991).

However, examination of the quadrats listed for M17b in Table A5.20 of the Lewis EIS Technical Report reveals that several quadrats contain species which could indeed be described as very clear indicators for M17 vegetation types, but not for the M17b sub-community. *Pleurozia purpurea* occurs in four of the 15 listed quadrats, and is accompanied in two of these by *Odontoschisma sphagni* which also occurs without *P. purpurea* in two further quadrats. Both of these species are strong indicators of M17a vegetation, and indeed all six such quadrats also contain significant *Sphagnum* cover.

It is difficult to see why six of the 15 quadrats for M17b have been assigned the way they have, rather than, for most of them, the more obvious M17a. If this represents the accuracy of direct NVC assignment in the field, this would indicate that up to 2,500 ha of the area currently assigned to M17b may in fact be M17a. Once again, it is impossible to determine whether this is the case without carrying out re-survey of the area.

IMPLICATIONS OF VEGETATION RE-ASSIGNMENT

Careful examination of the vegetation survey data has revealed significant area of concern in terms of the data classes used and the assignment by the EIS survey team of NVC vegetation types in the field. The tendency in all these cases has been to make the vegetation appear generally drier than perhaps it really is.

On the limited sample evidence presented by the Technical Report, it appears that the Lewis EIS Report presents the vegetation data in a way that minimises the extent of wetter vegetation types and maximises the extent of drier types. By detailed examination of the data provided in the Lewis EIS Technical Report, a general indication has been obtained for the possible margin of error shown in the NVC assignments of the EIS survey team. This

margin of error can be used to review the survey data and generate an alternative set of figures for the extent of the various NVC types. These revised figures can be seen in Table 2. It is not claimed that this second set of figures is any more accurate than the first; merely that, in contrast to the Lewis EIS Report, it gives some indication of the potential upper limit for the extent of wetter NVC communities and lower limit for the drier types.

Even if the true situation lies somewhere mid-way between these two sets of figures, this still represents a very considerable shift from drier to wetter ground within the HSA.

Table 2. Revised figures for the extent of certain key NVC types recorded for the HSA. Figures have been revised on the basis of proportions of quadrats listed in the Lewis EIS Technical Report and re-assigned according to the procedures set out in the text above.				
NVC type	EIS area (ha)	% of HSA	Revised area (ha)	New % of HSA
H10b	2113	8.5%	423	1.7%
M15c	6313	25.4%	1894	7.6%
M17b	6236	25.1%	8621	34.7%
M17a	604	2.4%	3722	15%

	M17a indicator	M17b indicator	M17c indicator
Pleurozia purpurea	■		
Sphagnum tenellum			
Odontoshizma sphagni			
Myrica gale			
Carex echinata			
Sphagnum auriculatum			
Sphagnum compactum			
Sphagnum palustre			
Cladonia arbuscula		■	
Diplophyllum albicans			
Hylcomium splendens			
Luzula multiflora			
Erica cinerea			
Mylia taylori			
Vaccinium myrtillus			■
Deschampsia flexuosa			
Dicranum scoparium			
Pleurozium schreberi			
Rhytidiadelphus loreus			
Agrostis canina			
Aulacomnium palustre			
Carex nigra			
Empetrum nigrum nigrum			
Plagiothecium undulatum			
Polytrichum alpestre			
Polytrichum commune			

Figure 5. Summary species table indicating those species (within this particular comparison) that are good indicators for each of the NVC types listed here, although not unique to the group. This table can be used to compare the species listed in [Table A5.20 of the EIS Technical Report](#) for NVC sub-community M17b with the species listed in the published NVC tables for M17. The many species common to all three NVC sub-communities shown above are not listed here, as they provide relatively little help in making distinctions *between* these types. Species-table data based on tables provided by Rodwell (1991).

CHAPTER 5 : DATA AND LANDSCAPE INTERPRETATION

So far, assessment of the Lewis EIS Report has concentrated on the process of data gathering, and the nature of the data obtained. Already within these stages a number of issues have emerged which raise significant questions over both the data collection process and the type of data obtained. The most serious of these issues are that:

- ⊘ the definition of peatland units has been carried out inappropriately, and in such a way that it is not possible to identify the functional units of peat bog within the HSA;
- ⊘ the vegetation has been surveyed and classified in a way that does not match with the detailed data gathered during the survey; and
- ⊘ the resulting vegetation classification appears to result in a substantial over-estimate of dry vegetation types at the expense of wetter types.

These issues alone are serious enough, but the way in which the Lewis EIS Report then *interprets* the data raises a considerable number of other issues and additional serious concerns.

Vegetation data, erosion classes and 'active' blanket bog

One of the central themes to emerge from the Lewis EIS Report's interpretation of the data obtained for the HSA is that much of the ground within the HSA is exceptionally dry and subject to heavy erosion. Emphasis is placed on the extensive presence of vegetation types such as dry heath (H10b) and wet heath (M15c) rather than the more typical blanket bog communities of M17 and M18. The dry nature of the bog surface is described as "*inimicable to many Sphagnum species*" and instead dominated by *Racomitrium lanuginosum*.

EROSION - A NATURAL PROCESS OR THE RESULT OF HUMAN IMPACT?

Erosion is described as extensive and indicative of a general progressive degradation of the bog systems by resulting de-watering. The de-watering process is dealt with at length in Section 11.3.3 (Chapter 11) of the Lewis EIS Report. It is described as a natural consequence of structures known as 'peat pipes', which lead to breakdown of the normal pool pattern microtope to form an erosion complex that acts as a drainage network. Other possibilities, such as wind action causing wave-driven erosion of pool margins, are also mentioned, as is the body of evidence that indicates the inherent stability of pool systems.

The Lewis EIS Report then challenges the concept of "*pools representing stability*", stating that this "*hypothesis simply does not fit the evidence of ground conditions in the HSA. Good pool systems certainly are present and might have remained in similar form for a long time, but there are many more examples of evacuated pools, collapsed inter-pool ridges and a great variety of erosional forms.*" The Report goes on to state that "*Dewatering is therefore a significant natural agent in switching local hydrology from long-term stability*

under very wet conditions to a rapidly changing eroding bog surface with increasingly dry conditions.”

To deal with this last paragraph first, the Lewis EIS Report really misses the point about the “pools represent stability” model (although a more accurate name would be ‘microtopography means stability’), and in doing so reveals a significant lack of understanding about the relationship between bog pools and stability. This relationship consists of three parts, and is explained very clearly by Ivanov (1981):

- ≠# the surface of a bog consists of two basic elements - an element that permits relatively free flow of water (a hollow or pool), and an element that resists water flow (the ridge or hummock) - and it is the relative proportion of these two elements in forming a microtope pattern that provides a means of maintaining stability of flow through the surface layers within the prevailing climate;
- ≠# when these two elements form what Ivanov (1981) describes as a ‘strip-ridge’ structure type of microtope, consisting of lines of ridges and hollows, the relative cover of these two elements tends to vary in response to changing levels of water input (rainfall) or output (evaporation, drainage), resulting in faster water flow through the surface when pools dominate, and slower water flow when ridges dominate, thus maintaining a relatively stable water table overall in the face of climate changes. Such changes in the strip-ridge structure over time have been painstakingly demonstrated by Barber (1981);
- ≠# where the microtope pattern consists of deep pools, however, Ivanov (1981) shows that the strip-ridge model of adjustment cannot work because such pools are fixed physical structures and cannot expand or contract in the same way. Consequently when such pool systems are subject to sudden hydrological change or impact, they tend to collapse into an erosional phase (more gradual climatic shifts produce growth or shrinkage of the general bog surface, which provides the necessary adjustment).

Given this model of ‘microtope means stability’, and given that there is no evidence for a sudden substantial decrease in precipitation across Lewis in recent years, there is no obvious natural explanation for the widespread erosion seen in the pool systems that dominate the blanket mires of Lewis. The evidence points instead to some form of significant impact such as burning, which physically breaks down the ridges between pools. There is no doubt that occasionally a peat pipe can lead to localised breakdown of pool systems, but these types of pipe are different in nature from the type illustrated in, for example, Figure A2h of the Technical Report (which is a streamline that has become overwhelmed by peat growth).

Consequently when the Lewis EIS Report states that “*dewatering is a significant natural agent in switching local hydrology from long term stability ... to a rapidly changing eroding bog surface...*” it does so partly on the basis of a misunderstanding of the role played by the microtopography in peatbog stability. The pools cannot *adjust* in the face of sudden changes because

they are fixed structures and so collapse into an erosion complex. To conclude instead that all such erosion is an inevitable natural consequence of bog development indicates a failure to understand the mechanisms inherent in the hydro-morphological hierarchy, and reflects theories of erosion that date back to the 1950s and early 1960s (Conway 1954, Bower 1962).

The question of whether widespread peatland erosion can represent a natural process or not is still subject to some debate and investigation, but Tallis (1995) and Mackay (1997) draw together the evidence from a wide variety of research and review the likely mechanisms. Both conclude that the evidence points primarily to human impact - even for erosion events as long ago as 4,000 BP. Tallis (1995) observes that the impact of forest clearance on the margins of blanket mire areas seems to have led to headward erosion of watercourses into the main body of peat in these earliest records. Burning and grazing are identified by both authors as the major stimulus to blanket bog erosion during modern times.

Indeed the Lewis EIS Report cites Tallis (1995), but only to select and build upon a comment about the instability of wet peatlands, while the main thrust of the information presented by Tallis is not mentioned. Similarly, the Lewis EIS Report overlooks the strong indication given by MacDonald *et al.* (1998) that extensive *Racomitrium lanuginosum* swards are an indication of burning. These features, and other available information, suggest strongly that the erosion found across much of the HSA is the result of human impact rather than a natural cycle of growth, decay and re-growth.

Consequently it is not an inevitable natural process that the bogs within the HSA will continue to degrade and decline, as suggested by the Lewis EIS Report. The present condition of the blanket bog areas is most likely to be a result of human activity. The Lewis EIS Report itself states that such activities have decreased substantially in recent years. Recovery of the habitat may be slow for the reasons outlined by Tallis (1995) and others mentioned above, but recovery can nevertheless be expected - indeed evidence for this is provided by the Lewis EIS report (see below).

PRESENT CONDITION OF EROSION COMPLEXES

The Lewis EIS Report speaks repeatedly of the 'dry and eroded' nature of the blanket bog habitat, and this is used to describe most of the eroded categories as being of low conservation significance in relation to the possible impact of the proposed development. Thus, for example, Section 11.4.2 of the Lewis EIS Report makes it clear that great efforts were made to avoid Erosion Class 1 areas. Meanwhile its accompanying Table 11.5 makes it clear that by far the largest proportion of Erosion Classes to be affected by the development (within the zone of impact defined by the Lewis EIS Report) will be Erosion Classes 3, 4 and 6.

Although erosion is repeatedly treated as a sign of low conservation quality by the Lewis EIS Report, it is worth re-stating the fact that five of the eight classes identified in the EIS Technical Report consist of ground which is described as either stable or re-vegetating, and these classes together cover

some 67% of the HSA area (see Chapter 4). The generally negative emphasis that the Lewis EIS Report places on erosion is unjustified, particularly as the proportion of active erosion makes up such a small part of the HSA (11%), and especially in the light of the re-assessment made of vegetation recorded for the HSA discussed in Chapter 4 (and see below).

CONDITION OF VEGETATION IN THE HSA

It has already been shown that there is a strong argument for re-assessing the extent of various NVC types throughout the HSA. Such a re-assessment of the extent for each type is important. This is because conservation quality and possible development impact is assessed within the Lewis EIS Report partly on the basis of NVC type, distribution and extent throughout the HSA as a whole, but more particularly within the vicinity of the proposed development.

The Lewis EIS Report presents figures for the various NVC types that suggest a somewhat limited total area for typical blanket bog vegetation, together with an extensive cover of such types as dry heath and wet heath. This inevitably reduces the severity of the environmental footprint associated with the development, because much of the impact would be felt by vegetation types of lower environmental quality.

Chapter 4 of the present report has, in contrast, indicated that the extent of dry vegetation types has been substantially exaggerated by the Lewis EIS Report, and wetter more 'bogland' types have been similarly under-estimated. As a consequence, the potential area of high conservation value within the HSA as a whole, and the area of high-quality ground potentially impacted by the proposed development, may both be significantly larger than stated by the Lewis EIS Report.

In addition, an expansion of the wetter vegetation types and reduction in the area of types such as dry heath, would add further conservation value to the various defined Erosion Classes and, given the characteristics of each, it would seem likely that a substantially greater proportion of the increased wetter types would be found within the stable or re-vegetating classes.

DEFINITION OF 'ACTIVE' BLANKET BOG

The question of 'active' blanket bog is important because although 'blanket bog' is listed in Annex 1 of the EU Habitats Directive, only 'active' blanket bog has priority status under the Directive. The Lewis EIS Technical Report provides a GIS analysis for the distribution of active blanket bog within the HSA. Three different maps are produced in the course of this analysis:

- ⚡ An area based on the distribution of M1, M2, M15, M17, M18, M19 and M20 NVC types (Technical Report Figure 27). This map is described as "*likely to best correspond with the defined NVC components in the UK interpretation of the Annex 1 Habitats Directive type.*" However, the EIS Technical Report goes on to observe that the map takes no account of the "*likely presence of non-active blanket bog*" and

describes the map as a 'catch-all' that represents the maximum likely extent of active blanket bog.

It is worth noting here, in the light of a possible need to re-assess the extent of various NVC types within the HSA, that even this 'catch-all' map of active blanket bog may under-estimate the full extent of active blanket bog because substantial areas of H10b are not included within the map. Potentially, an additional 1,500 ha or so could be added to this definition of active blanket bog.

- €# An area based on M1, M2, and then M15, M17, M18, M19 and M20 within Erosion Classes 1-3. This map (Technical Report, Figure 28) is described as a "*constrained definition of active blanket bog*", but even this is regarded as too broad because some areas of H10 dry heath would be incorporated.

This definition of active blanket bog raises a number of important issues. Firstly, as observed above, the extent of H10 dry heath is possibly much less than is suggested by the IES survey results. Secondly, by excluding Erosion Classes 4 and 6 from the concept of 'active' bog, the analysis excludes two types that are described by the EIS Technical Report as being stable or re-vegetating. The associated vegetation of these two classes is rich in *Racomitrium lanuginosum*, which is a recognised (and demonstrable) former of peat (e.g. Moore 1977). Furthermore, the JNCC guidance for active blanket bog states:

"...Thus sites, particularly those at higher altitude, characterised by extensive erosion features, may still be classed as 'active' if they otherwise support extensive areas of typical bog vegetation, and especially if the erosion gullies show signs of recolonisation."

From this definition it would seem very clear that Erosion Classes 4 and 6 both fall within the term 'active' blanket bog. If so, a further 8,600 ha should be added to the map of 'constrained active blanket bog'. Further additions are possible should any of the ground originally recorded as H10b be re-assigned to blanket bog types; this could add a further 1,500 ha. It is thus possible that a further 10,000 ha of the HSA should be classified as 'active blanket bog', even under the conservatively constrained definition.

- €# As a final stage of analysis, the Lewis EIS Technical Report calculates what it defines as 'non-active' blanket bog, based on its own interpretation of what this category might comprise. It takes M15, M17, M18, M19 and M20 NVC types that are within Erosion Classes 4 to 8, then adds to this all ground defined as H10b (Technical Report, Figure 29). The total area arrived at amounts to 12,324 ha.

It can firstly be observed that there would seem to be no justification in defining the areas of Erosion Classes 4 and 6 as non-active.

Removing only these from the survey total reduces the area defined as non-active to some 3,700 ha - a very substantial reduction. If substantial amounts of H10b are re-classified as blanket bog vegetation types, this could remove a further 1,500 ha from the total, to leave only 2,200 ha as 'non-active blanket bog'.

The most disturbing feature of this EIS Technical Report analysis comes in the final paragraph of that report's Section 7.4.1, where it becomes an established fact that the Technical Report's 'constrained active blanket bog' becomes the *de facto* distribution of 'active blanket bog' while the extended 'non-active blanket bog' becomes the *de facto* distribution of 'non-active blanket bog' for subsequent risk assessment and impact analysis.

It is not possible to undertake a complete GIS re-analysis of the potential extent of 'active blanket bog' in the light of the various inconsistencies and possible errors described above. This is because part of the problem lies in the identification of NVC types directly in the field, so although a quantitative estimate can be arrived at on the basis of the sample quadrats provided, the specific location of altered NVC types cannot be determined without re-survey. Nonetheless, it is possible to re-do the GIS analysis discussed above but this time re-assigning Erosion Classes 4 and 6 to the 'active' category. The resulting map can be seen in Figure 6.

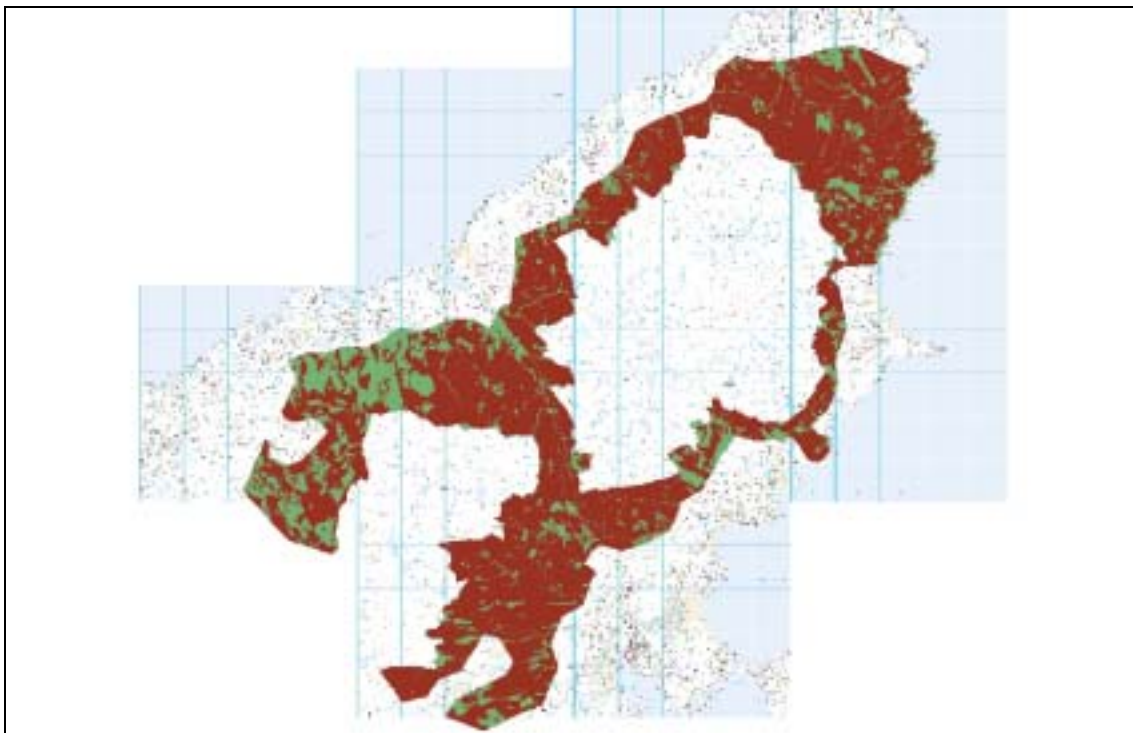


Figure 6. The distribution of 'active blanket bog' (shaded dark red) within the HSA area. Areas within the HSA that are not active bog are shaded mid-green. The definition of 'active bog' is based on all mapped NVC classes M1, M2, M3, M15, M17, M18, M19, M20, that lie within the Erosion Classes 1, 2, 3, 4, and 6. The OS 1:25,000 scale map is provided as background.

(OS map © Crown Copyright : All rights reserved. RSPB Licence No. 100026659)

International conservation status of the HSA area

Section 11.5.2 of the Lewis EIS Report refers to the international conservation status of peatlands within the HSA. It states that although blanket bog is listed as an Annex 1 habitat within the EU Habitats Directive (EC Directive 92/43/EEC), areas of such habitat within the HSA “*must NOT be regarded as international in value unless they fall within ground designated as a candidate Special Area of Conservation (cSAC) and then, only for habitats which are listed as qualifying habitats for that cSAC.*” As a consequence of this statement, the peatland areas of the HSA, even those identified as Annex 1 Priority Habitat ‘active blanket bog’, are defined in the Lewis EIS Report, Table 11.6, as only ‘Regional’ in terms of their Nature Conservation Importance.

This categorisation is clearly made on the basis of the EU Habitats Directive alone, and is even then debatable. It is evident that the categorisation takes no account of the designation of the area enclosed within the SPA as a Ramsar Site for its peatland habitat and bird interest. When a site is accepted onto the Ramsar List, it by definition becomes an internationally important site because the list itself is called:

“The List of Wetlands of International Importance”.

Quite how the Lewis EIS Report can therefore insist that the HSA area is only of regional importance for its peatland habitat interest is not at all clear. It almost appears that Ramsar designation was largely (though not completely) overlooked, because the area’s Ramsar status does not feature significantly in the Risk Evaluation and Impact Assessment exercises of the Lewis EIS Report.

Furthermore, the UK Government has committed itself to adopting as far as it is able the objectives and targets set out in Ramsar Resolution VIII(17) : *Guidelines for Global Action on Peatlands*. This resolution, agreed by Contracting Parties at the 8th Conference of Parties (CoP), in Spain, 2002, makes a clear and specific commitment to peatland conservation and wise use. There is no reference at all in the Lewis EIS to this most recent international commitment (nor to previous commitments to peatland conservation and wise use made by the UK Government at the 6th and 7th CoPs in 1996 and 1999 respectively).

CHAPTER 6 : ASSESSMENT OF IMPACTS AND RISK

Several issues have already been raised concerning the approach adopted by the Lewis EIS Report in identifying basic descriptive units and evaluating the conservation significance of particular areas. As a consequence, it has become evident that the extent of ground possessing significant conservation value is potentially very much greater than is indicated by the Lewis EIS Report.

It has also become evident that the Lewis EIS Report fails to identify the fundamental functional components of the blanket bog landscape. This has created some difficulties in terms of describing and categorising various aspects of the blanket bog habitat, but such failings become most significant and evident when the EIS attempts to assess potential impacts and risks.

For the peatland habitat itself (rather than its associated features such as breeding birds), the two major forms of impact arising from the wind farm development will be:

- €# direct loss of habitat at the sites of construction, whether this be roads, turbines or construction infrastructure;
- €# indirect loss or degradation of habitat caused by drainage effects arising from the sites of constructed features.

Direct loss of habitat

The major causes of direct habitat loss will be through road construction and excavation of the turbine bases. The Lewis EIS Report gives a series of proposed dimensions for various construction elements. From these it is possible to calculate at least an approximate estimate of habitat that will be lost beneath the roads and turbines.

ROAD CONSTRUCTION

It is stated that approximately 170 km of road will be constructed, and that while the road itself will be 5 metres wide, there will be a need to spread material adjacent to the road surface itself, amounting to another 5 metres on either side. A basic calculation from this leads to the conclusion that a minimum surface area amounting to 255 ha will be lost through direct construction work on the road network.

It is possible to overlay this zone across the map shown in Figure 6 (Chapter 5 above), and thus calculate the possible extent of 'active blanket bog' that would be lost to road construction (given the caveats about that map, as discussed in Chapter 5). This reveals that potentially 76% (192 ha) of the proposed road would lie on ground that could be classed as 'active blanket bog'. This contrasts with the 44 ha cited by the Lewis EIS Report (Table 11.7) as active bog lost by *all* direct impacts, not just roads.

TURBINE BASES

The 234 wind turbines proposed for this development are described as requiring an approximate area of 50 metres x 40 metres for their bases, and a consequent total area of 45.5 ha would be lost directly to such construction. It is again possible to calculate the area of 'active blanket bog' as defined previously in Figure 6 (Chapter 5) above. The calculated area amounts to 39.8 ha. Adding this to the 192 ha for direct loss to road construction, and the total amounts to a minimum of 232 ha of active blanket bog that would be lost directly through construction.

One additional factor that should be borne in mind in relation to the turbine excavations is that moderate increases in the linear dimensions of the excavation result in an exponential rise in the area affected. A turbine excavation of 50 metres x 50 metres occupies an area of 0.25 ha, while a turbine base of 75 metres x 75 metres occupies an area of 0.56 ha, and a turbine area of 100 metres x 100 metres involves an area of 1 ha. Consequently the actual size of the turbine excavations is of considerable importance to the calculation of direct impact.

Experience with another windfarm constructed on moderate peat depths suggest that the proposed dimensions may be something of an underestimate of the actual ground required. Figure 7 shows a panorama of a turbine base constructed at Derrybrien, Co. Galway. Here the concrete base for the turbine was only 15 metres x 15 metres, substantially smaller than that proposed for the Lewis wind farm. Despite this, the final area of the excavation for this relatively small turbine base is somewhat larger than 50 metres x 50 metres.

If the 22 metre x 22 metre concrete base proposed for the Lewis wind farm requires the same proportions of excavation compared to the concrete base, the overall excavation is likely to require more than the estimated 50 metres x 40 metres. For every 10 metres added to each dimension, the turbines for the wind farm will require an additional 23.5 ha of ground.

Indirect loss of habitats

The potential for indirect loss of habitat is by far the most significant aspect of the whole wind-farm assessment, at least as far as the peatbog systems are concerned. Considerable attention has already been devoted in the present report to the question of the hydromorphological hierarchy for peatbog systems. This is because indirect impacts from construction projects such as the Lewis wind farm have their primary effects through the process of drainage in its various forms, and these several hydrological effects operate in very specific ways through the hydromorphological hierarchy.



Figure 7. Panorama of turbine-base excavation at Derrybrien, Co. Galway, showing the extent of the excavation within the general blanket bog expanse. The turbine base, visible as the light green circle in the centre of the excavation bed, is approximately 4 metres in diameter. The dimensions of the excavation can thus be seen to be approximately 50 metres x 50 metres. The concrete base into which the base-can is set, is now buried beneath hardcore backfill, but is 15 metres x 15 metres. The size of base proposed for Lewis is significantly larger, at 22 metres x 22 metres.

DRAINAGE AND THE ACROTELM

At this stage, therefore, it is probably helpful to address one of the more basic aspects of peatland hydrology and drainage, and one that is raised in [Chapter 10](#) and repeated in [Appendix 10](#). For both locations in the Lewis EIS Report, a curve is presented of peat moisture as measured from a fresh and an older cut peat face.

The data presented in the Lewis EIS are stated to demonstrate that drainage of peat has little impact more than a few metres from the drainage structure. Work by Burke (1961 - not 1968 as cited several times, though correctly in [Section 10.5.4](#)), Hobbs (1986) and Gilman (1994) are cited as confirmation of this general conclusion. Closer examination of Gilman's work, however, reveals that there is more to the issue than is suggested here.

The author often cited prior to Gilman's (1994) publication is Boelter (1972), who examined the draw-down associated with a ditch in a bog in Minnesota. Boelter provides an illustration of the draw-down curve obtained, and concludes that "*there is no significant draw-down more than 10 metres from the ditch*", yet examination of his data reveals a different story. While there is very evident, dramatic draw-down close to the ditch, the water table remains lowered at some considerable distance from the ditch. Even 200 metres from the ditch, at the limits of Boelter's observations, there is still a draw-down of some 5-10 cm. Boelter does not regard this as 'significant', but anyone with an understanding of the hydrological functioning of bog microtopes and nanotopes would recognise the significance of this draw-down.

Ivanov (1981) states that "*the maximum difference in mean long-term [water] levels which does not lead to a change in the quantity or floristic composition of mire plant communities is very small. For several varieties of moss cover it is less than 4-5 cm.*" Thus the draw-down observed in Boelter's (1972) data is twice the scale highlighted by Ivanov.

The significance of this observation is that the surface of a bog consists of a thin living layer that is generally no more than 30-40 cm thick. The vegetation types characteristic of the nanotope structures that make up the surface (hummocks, hollows) are often no more than 10 cm in vertical span (Lindsay, Riggall and Bignal 1983; Lindsay, Riggall and Burd 1985). Consequently a fall in the water table leads, as Ivanov (1981) observes, to a loss of these vegetation types to be replaced by those from higher parts of the nanotope structures. Obviously for those vegetation types closer to the drainage effect, the impact is even more extreme.

Consequently the direct effects of peat bog drainage to the acrotelm should be thought of in terms of tens of metres, or more usually, one or two hundred metres at least. Peatland drainage is often described as 'merely removing surface water', but this surface water is precisely the water that maintains survival of the acrotelm - remove this water and the acrotelm dries up and stops functioning, along with the vegetation associated with it. This in turn has implications for the catotelm beneath, and these implications are discussed below.

The presentation of the drying curve in [Section 10.3.6] of the Lewis EIS Report thus reveals little about the process of peatland drainage, but suggests instead that the author has little understanding of acrotelm hydrology and peatland-vegetation water relations.

CATOTELM RESPONSE TO DRAINAGE

The catotelm response to drainage is not as immediate or evident as that of the acrotelm. The drying curve presented in the Lewis EIS Report highlights the fact that the catotelm, even when exposed for some time, remains relatively saturated. This is often taken to mean that drainage is having little effect on the catotelm. Such a conclusion is wrong.

When the water table falls into the catotelm (which it should never do under natural conditions), the part of the catotelm that becomes exposed to the atmosphere begins to oxidise and decompose. As peat is almost entirely dead plant material, on oxidation it in effect breaks down into CO₂ and water. The CO₂ is lost to the atmosphere and the water is lost to drainage through evaporation.

Consequently the water table does not look as though it is falling very far into the peat because as fast as the water falls, the dry peat vanishes into the atmosphere. That such a process occurs, and occurs as long as the peat is exposed, can be seen from the Holme Fen Post in the Cambridgeshire Fens. The peat here has been drying for 150 years. In this time it has lost a depth of 5 metres - a rate of more than 3 cm per year; the ground surface continues to sink even today.

Thus any single measurement of the water table associated with a drain is likely to show that the catotelm is still largely saturated; what is not evident from this single measurement is the amount of peat that has vanished since the drain was dug. Nor is it clear from such a single measurement how much the peat landform has altered its shape over time as a result. Only repeated measurements over a long time period can reveal the true nature of drainage impacts on the catotelm.

Once again, presentation of the drying curves in [Section 10.3.6] provides little insight into the process of catotelm drainage, but reveals that the author has equally little understanding of the issues.

COMPOSITE PEATLAND RESPONSE TO DRAINAGE

As should be clear from the foregoing, drainage tends to de-water the acrotelm and lead to loss of the vegetation cover that creates the acrotelm and protects the catotelm for drying out. The vegetation may simply undergo a change to a drier type of vegetation, or it may (with the help of impacts such as fire) be lost altogether.

Meanwhile any areas of the catotelm directly exposed by the drainage process (ditch sides, *etc.*) will undergo drying and oxidation, leading to loss of peat material and consequent changes in the surface shape of the bog - in effect the sinking peat surface progressively widens the ditch. This means that the impact of the ditch is felt over a greater area of acrotelm, and so the system establishes a negative feedback loop that can be quite destructive to the surrounding bog vegetation. This process can be seen for a fresh ditch and an older ditch, both illustrated in Figure 8.



J.B. Ratcliffe



Figure 8. On the left is a ditch cut very recently into blanket peat. Even at this young stage, there are evident areas where the ditch sides have slumped. On the right is a ditch that has been established for a considerable number of years. The increased width of the ditch is evident amidst the slumped, collapsed and eroding vegetation. The relatively dry nature of the surrounding bog vegetation can also be seen in the repeated pale hummocks of *Racomitrium lanuginosum*. This vegetation is probably M17a or M18a of the image on the left. Both photographs were taken in Sutherland.

PEATLAND DRAINAGE AND EROSION

In addition to changes in the catotelm morphology and vegetation composition, drainage in blanket bog (though curiously not in raised bog) is liable to stimulate even more dramatic changes to the surface layers of the bog. Where the vegetation cover is lost, or where water flow suddenly becomes uncontrolled, the highly scouring effects of rainfall and surface-water flow can give rise to surface erosion.

The various patterns of such erosion are ably described and catalogued in the Lewis EIS Technical Report. What is less ably dealt with, however, is the relationship between erosion and surface disruption caused by activities such as drainage. Indeed there is a curious internal contradiction within the Lewis EIS Report, because in several places a clear link is made between peat cutting and the initiation of erosion. For example, Chapter 10, Section 10.3.7.4 of the Lewis EIS Report states:

“Peat cutting, irrespective of hydrological zone, has a significant effect on the hydrology. The remaining peat is drier and more prone to erosion and gullyng. Artificial linear drainage patterns are imposed on top of what is otherwise a natural dendritic pattern system or a highly non-linear pool and gully system. This has the effect of speeding up run off, increasing erosion in the channels and changing the environmental conditions.”

Precisely. I could not put it better myself - except, for ‘peat cutting’, read also drainage and excavation.

Peat cutting, drainage or excavation cut through the acrotelm and catotelm of the bog, creating steep or vertical faces across the natural pattern of flow, down which large volumes of surface water can pour during heavy rain. This scouring flow can quickly begin to remove peat through its erosive power, and this leads to the development either of new erosion gullies or causes the rejuvenation of old gullies that develop upslope by headward erosion.

Figure 9 shows two views of an erosion complex at Blar nam Faioleag in the centre of Barvas Moor. It takes no great imagination to imagine the rejuvenating effect of cutting a ditch, or digging an excavation, across the line of these evident erosion gullies. A river is rejuvenated if the river bed or its outflow is lowered, steadily cutting back along its course and deepening the bed until it once more forms a graded profile. In the same way, initiation of erosion (as with Neolithic clearance of forests on the slopes below the blanket peat cover, described by Tallis 1995), or rejuvenation of an existing erosion complex (as described in the Lewis EIS Report), can result in a dramatically increased level of erosion, peat removal, and consequent habitat loss.

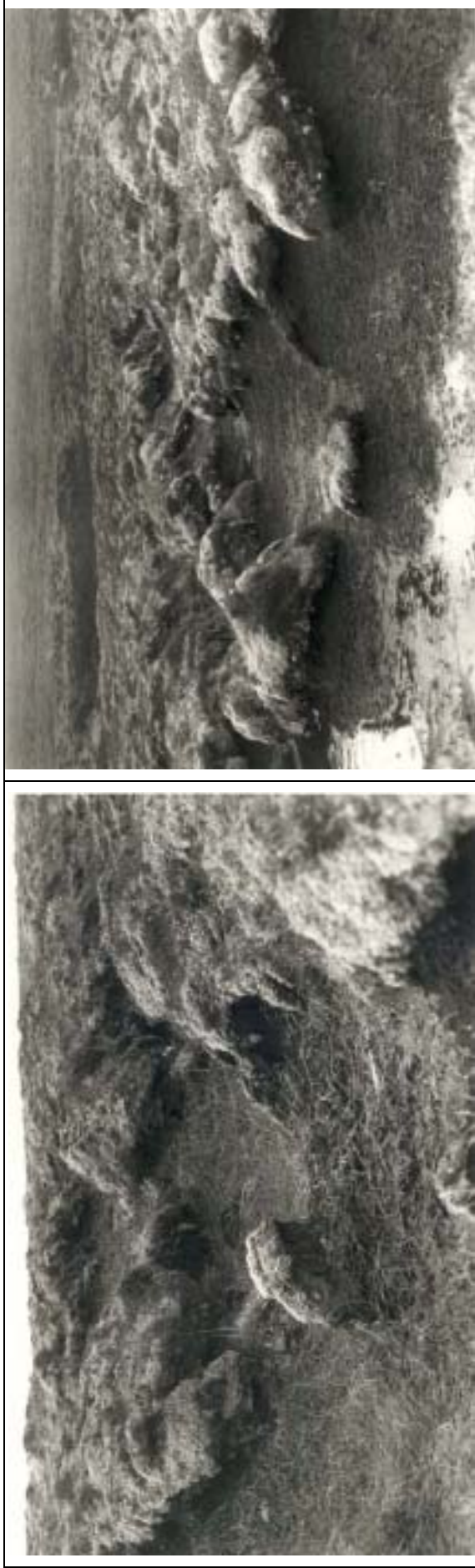


Figure 9. Two views of Blar nam Faoileag, Barvas Moor, photographed from the same location, one looking upslope and the other looking downslope. The effect of cutting a ditch from left-to-right across these photographs, as might occur if a road were constructed here, or of excavating a turbine base, can be imagined fairly readily; substantial deepening, by rejuvenation, of the erosion gullies is a strong possibility.

The effect of cutting a ditch or digging an excavation on an area that is not currently subject to erosion and which supports a relatively wet bog vegetation, is also likely to be dramatic. Figure 10 shows a typical example from Lewis of what the Lewis EIS Report describes as a ‘perched pool network’, but in usual terminology would be a straightforward valleyside mire. It should be fairly obvious that cutting into a system such as this would lead to sudden and serious erosion of the pool system.



Figure 10. A relatively undisturbed valleyside mire from Barvas Moor, Lewis. Clearly the cutting of a ditch or digging of excavation within such an area is likely to lead to catastrophic de-watering of the pool system to form an erosion complex.

The key questions for the Lewis wind farm development arising from the foregoing are:

- €# does drainage really lead to erosion; and, if so,
- €# over what sort of distances is the effect felt?

The Lewis EIS Report itself highlights the impact of peat cutting (imposed linear drainage patterns) on the rate and scale of erosion. However, an example from elsewhere in Britain serves to show the scale of erosion that can result from even apparently small drainage impacts.

Figure 11 shows a vertical aerial photograph of Butterburn Flow, a blanket bog site in the north Pennines. Two ditches can be seen to have been dug into the site, one on the very right-hand margin of the main bog mesotope, the

other cutting across the lower slopes of the mesotope that lies to the north (to the top of the photo) of that drain. The main bog mesotope comprises a watershed/valleyside mire, forming a broad expanse of peat across a low hill, and the crown of the bog supports (or supported) a microtope consisting of low ridges and small hollows.

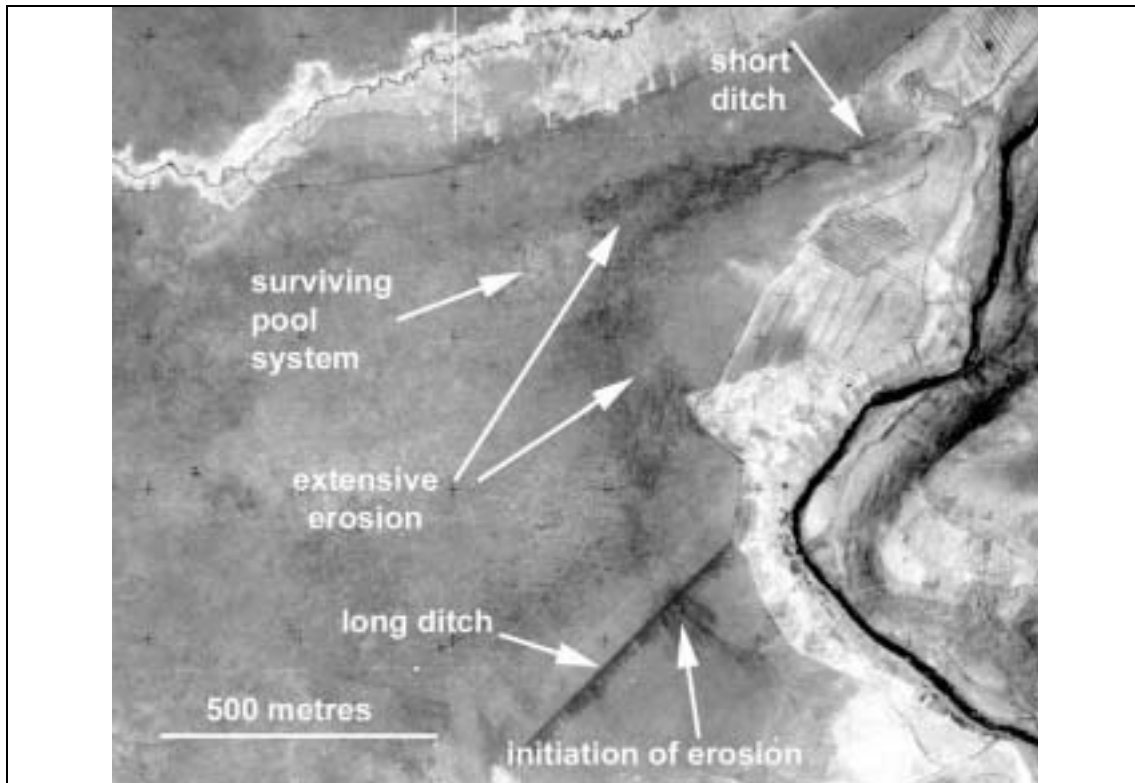


Figure 11. Vertical aerial photograph of Butterburn Flow, Cumbria (north is at the top of the photo). This is an area of blanket bog that originally possessed a natural low-ridge/hollow microtope across the gentle dome of the mesotope. A short ditch cut into the western side of the mesotope has led to extensive erosion through the microtope pattern. Similarly, a ditch cut along the south-eastern margin of the mesotope has also initiated erosion.

Clearly, from Figure 11 it can be seen that not only is initiation of erosion by drainage possible, but that this erosion may extend for very considerable distances. In the case of Butterburn Flow, the erosion complex initiated from one small ditch has extended over an area that stretches for almost 1 km. In effect, if a mesotope supports a microtope pattern, and drainage then disrupts this microtope, the breakdown of this microtope pattern is likely to spread across the whole area of the pattern, and may lead to breakdown of other adjacent microtope patterns within the same mesotope.

If the mesotope also has a key functional linkage with an adjoining mesotope (such as a shared watercourse that lies within the peat), increased run-off from the first mesotope may lead to scouring and consequent lowering of this watercourse, which would then have implications for the hydrological

processes of the adjacent mesotope. This may mean drying of the vegetation along the streamcourse, or even initiation of erosion as water flows off the bog into the deeper streambed. In this way, impacts can spread from one adjacent mesotope to the next.

Such transfer of impacts from mesotope to mesotope is particularly likely if a low-level valleyside mire or spur mire has a watershed mire or saddle mire above it, because erosion generally works its way uphill. Consequently impacts felt initially within the lower parts of a blanket mire landscape may work their way uphill to impact on extensive watershed systems.

This is the significance of the microtope-meostope-macrotope system; it provides a key insight into the functional linkages between the various components of the blanket bog landscape, and gives some potential for assessing the likely effects of any given impact. The foregoing should also make it clear why the Lewis EIS approach is totally inappropriate to the habitat, and gives a completely inadequate assessment of likely impacts.

POSSIBLE ZONE OF INDIRECT ROAD AND TURBINE IMPACTS

The Lewis EIS Report calculates that the total area of likely impact on the blanket bog vegetation from roads and turbines is 1,905 ha. This is on the basis of a buffer zone of 50 metres - a distance agreed with SNH. Quite why SNH felt able to agree to such a distance, in the face of so much other evidence of more extensive effects, is not clear. Even the data contained within the publication on which this buffer is reported to be based (Gilman 1994) shows evidence of hydrological effects extending beyond 50 metres. Furthermore, this buffer takes no account of mesotope or macrotope issues, and so will tend to give a somewhat arbitrary indication of possible effects because it has no fundamental, theoretically sound basis.

If, on the other hand, the issues of vegetation quality, acrotelm drainage, and erosional expansion are considered together, it would seem reasonable (assuming for the moment that anything so arbitrary as a single value has any meaning) to examine a buffer that extends for 250 metres either side of the roads and around the turbines. It is assumed that all roads will require drains, even the so-called 'floating' roads, for reasons that will be explained in the next section.

An assessment can then be made of the road and turbine network in relation, initially, just to the area of the peatland habitat within the SPA that might potentially be affected. The area of 'active blanket bog' (as defined in Figure 6) that may be affected by wind farm construction and the farm's ongoing presence can then be calculated. The results can be seen in Figures 12 and 13 and Table 3.



Figure 12. Map showing total HSA area (mid-green) and area of roads and turbines, with a buffer of 250 metres radius around both these features. The OS 1:25,000 scale map is provided as background. (OS map © Crown Copyright : All rights reserved. RSPB Licence No. 100026659)

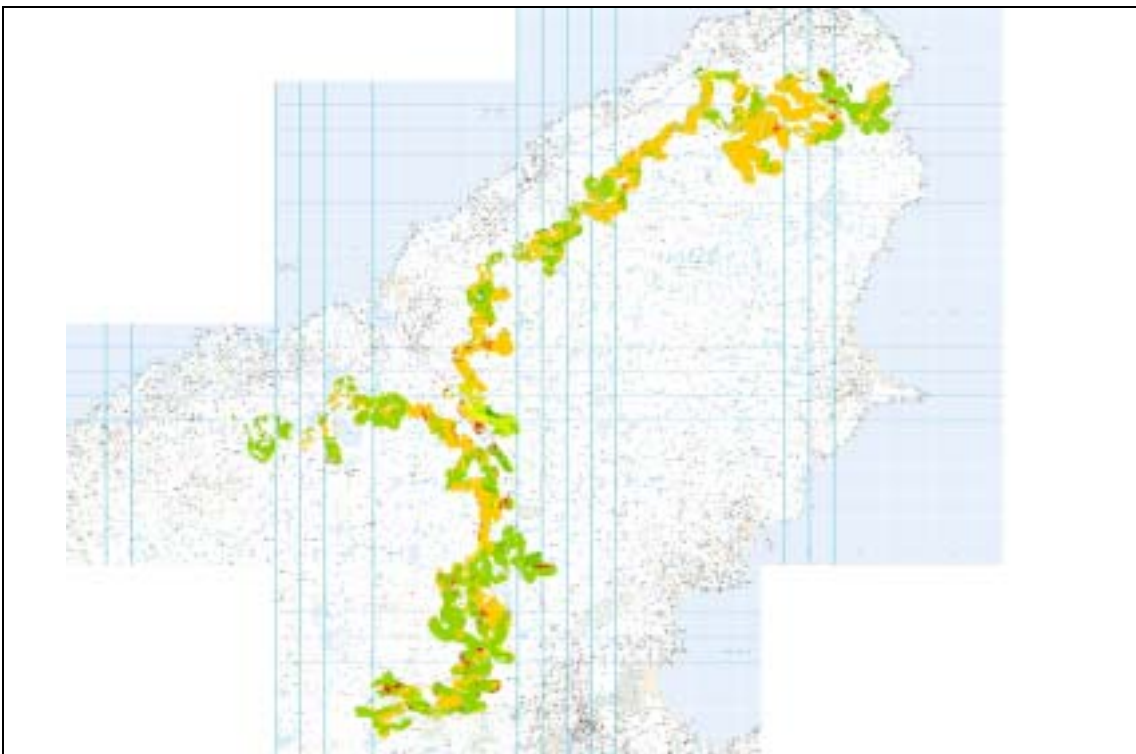


Figure 13. Map showing area of 'active blanket bog' (as defined in Figure 6) contained within the 500 m buffer zone (250 m either side of the road) shown in Figure 12. Green shading = M15; Yellow shading = M17; Orange/red shading = M18-M20. The OS 1:25,000 scale map is provided as background. (OS map © Crown Copyright : All rights reserved. RSPB Licence No. 100026659)

Table 3. The respective areas contained, firstly, within the original assessment of potential impact (PZI) as calculated by the Lewis EIS report, then the area of ground contained within a buffer with radius 250 m around the proposed roads and turbines. The proportion of this compared to the total HSA is shown. Finally, the area of ‘active blanket bog’, as defined in Figure 6, is given.

EIS area of impact (PZI)	Revised area of buffer zone (250 m radius)	% of HSA area within 500 m buffer zone	Active bog in 500 m buffer zone
1905 ha	7720 ha	31%	6255 ha

It is clear from Table 3 that the impact estimates given here are very much higher than those given in, for example, Table 11.7 of the Lewis EIS Report, which lists total area of active blanket bog affected by the development as no more than 189.8 ha. In contrast, the figure for potentially-affected active blanket bog is 6,255 ha, which is 30x the area given in the PZI.

While the increase in potentially-affected area may appear remarkably large, it should be emphasised that the estimate is still potentially highly conservative. This is because there is considerable potential, with construction and maintenance of the windfarm roads and turbine bases, of erosion to be stimulated on the scale shown for Butterburn Flow. If erosion complexes are initiated, or rejuvenated, by the development, there are many areas where the erosion impact could spread for very considerable distances.

The Rules of the Road set out in the Lewis EIS Report to guide road construction ironically make it more likely, rather than less, that damage will occur. For example, running along gently-sloping ground will tend to encourage the use of ground with deeper peat; running the road line *downslope* from an erosion complex or pool system is going to increase the potential for initiating upslope erosion towards the system.

Road construction on peat

Three main methods of road construction are proposed for the Lewis wind farm. For areas of deep peat it is proposed that either ‘floating’ roads or rock-fill roads will be used. For shallower areas of peat, the organic layer will be removed and the road built on the sub-soil.

FLOATING ROADS ON PEAT

It is usually argued that floating roads are less environmentally-damaging for peatland systems because such roads do not need drainage. Indeed the designs for such roads in the Lewis EIS Report do not indicate any drain lines associated with the road-line. It is argued that, because the road floats on a geotextile laid over the peat, there is no need to install drains to keep the road

dry. However, the theory of floating roads is very different from the practice. There are two reasons for this.

Firstly, the road does not in fact float on the peat. It steadily sinks under the weight of material laid onto the peat so that what was once a slightly raised road surface sitting above the general level of the bog (as shown in, for example, [Figure 7.4 of the Lewis EIS Report](#)) eventually settles to a situation where the road surface is level with the bog surface.

At this point the road becomes difficult to use and requires considerable maintenance because extended periods of high water-tables tend to flood the road. High rainfall additionally tends to remove road material where there the road slopes, and water tends to become ponded on the upslope side of the road, further exacerbating the problem.

Indeed the effect on surface water along the side of these floating roads is a major issue that is not really addressed at all by the Lewis EIS Report. As was made clear in Chapter 3 and Annex 1 of the present report, water flows across the bog surface through the acrotelm in the form of a 'flow-net', rather than as a series of well-defined channels. Consequently it is not generally possible to identify particular areas of the bog for which channelled or culverted drains would be any assistance. During heavy rain, large quantities of water are likely to collect along large stretches of the upslope margin of any floating road, but even during periods of low flow, water will still tend to collect in these parts.

Equally, the regions downslope from the road will be deprived of the normal pattern of surface flow-net seepage, and thus will tend to dry out. This in turn leads to drying, cracking and potential erosion of the peat, which creates an even steeper hydraulic gradient across the roadway.

These various problems explain why, in almost all cases, what were originally planned as *undrained* floating roads quite quickly become *drained* floating roads. Drains are needed to take away this ponded water, and a few culverts placed intermittently beneath the floating road cannot generally suffice. Consequently it is usual practice to dig drains parallel with the line of the road in order to prevent the ponding of surface water. An example of this can be seen in Figure 14 from Derrybrien, Co. Galway, where the original undrained floating roads were soon provided with drain lines because upslope ponding was becoming a serious problem.

DRAINED FLOATING ROADS ON PEAT

Having installed drains alongside the floating road network, the effect of the floating roads is just like any other sort of drainage or peat cutting, in terms of its potential to cause vegetation change and initiate erosion. All the problems and impacts summarised by the Lewis EIS Report concerning peat cutting applies equally to such drainage.

However, as the drainage system must be maintained if the drains are to work effectively, the process of catotelm loss through oxidation of the peat becomes a long-term feature of the drains along the roadway. This loss of catotelm material causes the road gradually to sink into the peat, thereby causing greater problems of ponding, and thus requiring even more drainage. This cycle of shrinkage and drainage becomes a negative feedback process, making road maintenance increasingly difficult but also causing the drains to have an increasingly wide influence over the surrounding acrotelm.



Figure 14. Drain installed after construction of the floating road visible on the left of the photograph. The road was constructed as part of a wind farm development at Derrybrien, Co. Galway, where the original proposal was for all roads to be undrained and floating on peat.

This increasing influence on the acrotelm is what leads to initiation of erosion in high-rainfall areas. Initial construction of the road and subsequent installation of the drains may not produce an immediate response, but during the 25 years of the project life there is time for processes such as erosion to

be initiated. The erosion demonstrated for Butterburn Flow in Figure 11 did not happen in a year or two - the problem has developed over the course of several years.

ROCK-FILL ROADS ON PEAT

The proposal put forward in the Lewis EIS Report for road construction across exceptionally deep and unstable peat is that rock-fill techniques should be used. The process involves tipping large rock material onto (and thus into) the bog until the whole depth of peat has been displaced by the rock-fill.

This proposal has the makings of a spectacular disaster. By definition, the peat subjected to this approach will be highly unstable, very deep and extremely liquid. Stephenson attempted the same approach with just such peat when attempting to build the Liverpool to Manchester Railway in the late 1800s. Faced with crossing the very large Chat Moss raised bog with his railway line, Stephenson poured vast quantities of rock into the peat, only to see these vanish without trace. His solution, ironically, was to use a floating-road technique that involved placing fascines of brushwood into the bog, and floating the railway line on this. However, drainage along the railway line has undoubtedly had a substantial effect on the Chat Moss complex over the intervening years.

In the case of the Lewis wind farm, this is an area of deep peat within a high-rainfall area, and such areas will almost certainly sit either on a slope or on a perched watershed. The potential for instability will thus be much greater than those faced by Stephenson in the flat lowlands of England.

Even more pertinent to this proposal than Stephenson's difficulties, perhaps, is the experience of the developers at Derrybrien Wind Farm in Co. Galway. During a dry period in the autumn of 2003, a turbine base was being excavated on peat that is of a similar depth to that generally found at the Lewis wind farm site. Material was being excavated and loaded onto an adjoining area of peat while meanwhile, downslope, there was some drainage work being undertaken. All at once more than 1.5 km of peat covering the hillside (on a very moderate slope) began sliding down the hill in what was to become one of Ireland's largest bog slides ever recorded.

The scale of the bog slide really has to be seen to be grasped, but suffice it to say that 2 km of peat became detached, and ultimately flowed for 20 km down the hillside, along a river system, and into a local loch that had, until that point, contained an important fishery. Part of the scene is shown in Figure 15.

Several aspects of the windfarm construction on Lewis could act as triggers of instability, pre-disposing areas to undergo failure and cause a bog slide. However, the most obvious potential cause of such instability is the intention to use rock-fill on the least stable peats. It is generally considered by engineers who have examined the causes of the Derrybrien bog slide that it was initiated by bearing failure as large quantities of peat were piled onto the peat surface adjoining the excavation of the turbine base. Pouring large rocks

onto an unstable peat surface is a process very similar to that which may have caused the Derrybrien bog slide. One must question the wisdom of such a proposal.



Figure 15. The upper reaches of the bog slide at the Derrybrien Wind Farm, Co. Galway. Approximately 1.5 km of peat slid down the hillside before entering a river system and flowing 20 km into a large local fishing lake, where some 50% of all fish were killed.

CHAPTER 7 : SUMMARY

To summarise:

1. The study area is approached from the perspective of a catchment hydrologist rather than according to the guidance provided by the JNCC for peatland assessment.
2. Consequently a series of hydrological analyses are carried out, but little of real meaning can be drawn from these.
3. The fundamental process of identifying the various levels of hydro-morphological function is not addressed at all.
4. Consequently much of the underlying basis for risk assessment and impact evaluation is missing.
5. The process of vegetation recording included decisions that introduced vegetation classes that represent distinctly dry vegetation types.
6. Relatively few quadrat samples were taken to corroborate the NVC assignments being made in the field. Close examination of the sample quadrats, however, suggests that significant proportions of the drier vegetation types should in fact have been classed as more typical bog communities.
7. Assessment of human impact on the area fails to recognise the impact of past burning practices.
8. Erosion classes are mapped, and the widespread occurrence of erosion is assumed to be a natural process of general drying.
9. Those erosion classes that indicate stability or recovery, and which belong in the category of 'active' according to JNCC guidance, were excluded by the Lewis EIS from the mapping of 'active' bog. Re-calculation of the erosion figures to include these indicates that 67% of erosion is either stable or re-vegetating.
10. Re-calculation of the vegetation data for these 'dry' community types indicates that the most extensive NVC type identified in the EIS Report should be reduced from 25% of the HSA to only 7.6% of the area, while H10b should be reduced from 8.5% to 1.7%.
11. Re-calculation of the area of 'active blanket bog' within the HSA results in a figure of an additional 10,000 ha, which, combined with the area defined by the Lewis Technical report, gives a total for 'active blanket bog' of 17,960 ha - more than double the amount identified in the Technical Report.
12. The peatland interest within the SPA is classified by the EIS Report as being only 'Regional', yet the site is listed by the UK as a 'Wetland of International Importance' under the Ramsar Convention.
13. Some 425 ha of 'active bog' (within the revised definition) would be lost directly through road construction and turbine excavation. This is significantly more than that calculated by the EIS Report.

14. Indirect impacts will consist of drainage of the acrotelm, oxidation of the catotelm, consequent changes to vegetation as much as 200 metres away, and the potential for initiation of erosion over a much larger distance.
15. The potential for erosion to extend throughout the surface pattern (microtope region) of a mire unit (mesotope) is demonstrated for a blanket bog site in the Pennines; erosion has evidently spread for almost a kilometre from the initiating drain.
16. Consequently it is possible to make a conservative assessment of the zone over which impacts from the wind farm may be felt. On the basis of a conservative radius of impact of 250 metres, the revised Potential Zone of Impact (PZI) increases from 1,905 ha to 7,720 ha, of which 6,255 ha could be classed as 'active blanket bog'.
17. This amount of active blanket bog within the PZI represents a 30-fold increase compared with the figure presented in the EIS Report.
18. Road construction will tend to cut across the natural surface 'flow-net' of the bog, and will thus cause problems for both the bog and the road. In particular, roads will require drains, and thus pose as much threat of causing erosion as peat cutting - an activity that is described in the EIS report as clearly initiating or exacerbating the erosion process.
19. Floating roads will not float, but gradually sink into the peat. They will therefore become saturated and require drainage to be usable. They will also pond water on the upslope side, but not in relation to any discernable channels - thus culverts will be of only limited use.
20. Rock-fill roads, intended for use in the least stable areas of peat, have the potential to initiate large-scale instability of the peat mass. Bearing failure under such load on an Irish windfarm site led to the largest bog slide in recent times.

These topics represent some of the key issues that should have been addressed by the EIS but were not. The account gives only a brief outline of each, and does not attempt to represent the total range of topics. As a brief overview, however, it should give some idea of the kinds of issues that can be looked at further, and also give some indication of the type of work required to address these issues.

In conclusion, possibly the most alarming comment in the whole Lewis EIS Report is the confident assertion that:

“Construction of wind farms on deep peat areas are becoming more common and better understood and the mitigation practices to minimise impacts are now recognised and can be incorporated into construction methods and particularly drainage design...”

If the construction of wind farms on deep peat is so well understood, then how does one explain the images in Figure 15, taken just last summer?

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ANNEX 1

PEAT BOGS - STRUCTURE AND FUNCTION

Peat formation

Peat is dead plant material, deposited *in-situ*, which has failed to decompose completely because waterlogging starves decomposer organisms of sufficient oxygen to enable them to function effectively. This waterlogging can arise through such a large variety of mechanisms that peat-forming systems are found on every continent of the globe, and occur so extensively that peatland systems have been estimated to contain more than 25% of all soil carbon stores (Joosten and Clarke 2002). Indeed Immerzi *et al.* (1992) estimate that peatland systems contain 3x more stored carbon than the world's tropical rainforest trees (and an often-overlooked fact is that many of these tropical forests are themselves also peatland systems; it is the more obvious trees that generally attract attention).

A *mire* is any wetland that has a vegetation which is acknowledged as generally being capable of forming peat (there are some circumstances where, for a variety of reasons, a vegetation that is normally associated with peat formation is not currently laying down peat but it otherwise has all the typical structures and functions associated with a peatland system).

Despite the wide variety of mire systems, the processes by which waterlogging occurs can be broadly divided into two types of water source:

- ⌘ those that involve water which comes from the surrounding mineral ground - these are known as minerotrophic mires or, more popularly, as *fens*;
- ⌘ those that are waterlogged by direct inputs from the atmosphere (cloud droplets, mist, rain, snow) - these are known as ombrotrophic mires or, more popularly, as *bogs*.

The peatlands of Lewis represent extensive areas of mire habitat containing both minerotrophic and ombrotrophic mires, but the predominant type is ombrotrophic bog. Consequently the remainder of this Annex will concentrate on processes relevant to bog systems, except where fens are also a significant part of the story.

Peat bog systems

Rain-fed (ombrotrophic) peatland systems occur as two broad types – raised mire and blanket mire. The former represents a (generally) single body of accumulated peat, surrounded by a contact zone with the surrounding mineral ground. The body of peat behaves in such a way that it has demonstrable stability extending over several thousands of years. It does so through feedback mechanisms provided by small-scale hydrological processes within the thin surface layer of the bog. These feedback processes enable the whole bog to maintain overall hydrological stability even in the face of substantial climatic shifts. The system consists of two internal hydrological components - the thin surface layer of peat called the *acrotelm* and the main

body of peat beneath this, called the *catotelm* - and two external components – namely precipitation and the contact zone at the bog margin. The raised mire itself is termed the *mesotope*, representing a hydromorphological body that forms a single integrated ombrotrophic unit (described in more detail below).

This ombrotrophic unit can only maintain hydrological stability by maintaining a connection with the mineral groundwater table at the bog margin. This contact zone is an area where peat forms through waterlogging by both the run-off from the raised bog and from ponding of the mineral groundwater table by the peat mass. Consequently the peat here is minerotrophic or fen peat, because at least part of the water has been in contact with the surrounding mineral soil. This *lagg fen*, as it is known, represents another mesotope with its own characteristic vegetation and hydrological character. The whole assemblage of ombrotrophic raised mire and contact zone of (at least partially) minerotrophic fen is termed a *macrotope*. The important thing to understand about this macrotope is that changes to one mesotope can result in changes to the character and stability of an adjacent mesotope (for example, drainage of the lagg fen affects the adjacent raised bog mesotope). In other words, there is a clear functional link between the two. This functional link is described in more detail below.

Raised bog hydrology

A raised bog in the northern hemisphere generally consists of a mound of *Sphagnum* peat that has accumulated over a period of several thousand years because the dead plant fragments are maintained in a perpetually waterlogged and acidic condition that largely prevents decomposition of slowly-accumulating dead plant material. Such conditions prevail because of three main factors:

- ⚡ the *Sphagnum* plant is adapted to absorbing and retaining water and so rain falling onto the peat mass is retained and passed only slowly down to the mineral soil beneath at a rate which means that a single raindrop may take 90 years to reach the mineral groundwater table;
- ⚡ precipitation is sufficiently regular, and bright, drying sunshine sufficiently infrequent, to ensure that there is an adequate supply of water to replace that which is lost by slow downward seepage due to gravity (and, of course, losses through evapotranspiration);
- ⚡ the thin surface layer of the bog, named the *acrotelm* by Ingram in his translation of Ivanov (Ivanov 1981), protects the main waterlogged mass of peat, named the *catotelm* (Ivanov 1981), from daily fluctuations of precipitation and sunshine and smooths out the intermittent inputs so that the catotelm receives a slow but steady supply of water.

More than 20 years ago Ingram (1982) also developed a theory of bog hydro-morphology that has so far stood the test of time. This Ground Water Mound Theory proposes that the mound of peat in fact reflects the shape of the water held within it, the shape being a half-ellipse, which is the shape adopted by a

drop of water placed on a flat surface. The underlying principles of the GWM Theory have been explored elsewhere (Bragg 1995; Lindsay 2003) and will not be considered further here, but these principles make clear why, given that a raised bog is often some 98% water and only 2% solids by weight, it is hardly surprising to find that it is the water in the bog, rather than the peat matrix, which is now thought to determine the overall shape of a bog.

Indeed, if a bog is considered as a dome of water rather than as a mound of solid material, much bogland behaviour becomes clearer and follows logically from that assumption. In particular, such a view leads logically to the perception of a bog as a *functional* rather than simply a morphological entity, because through this model it is possible to see the implications of the functional linkages, in the same way that all parts of any water body are functionally linked. For example it is clear that the water in one part of a lake is functionally linked to all other parts, as well as to the atmosphere through precipitation, and to the surrounding landscape through its inflow and outflow streams.

Figure A1 shows the essential structures of the mesotope and the macrotope for a raised bog. The ombrotrophic (bog) mesotope consists of the thin acrotelm layer covering the deeper catotelm peat, all given shape by the mound of water contained within the peat matrix. The minerotrophic lagg fen mesotope around the margin of the bog consists of a waterlogged zone derived partly from the mineral ground-water table and partly from run-off from the bog. The whole assemblage of bog and fen forms the macrotope.

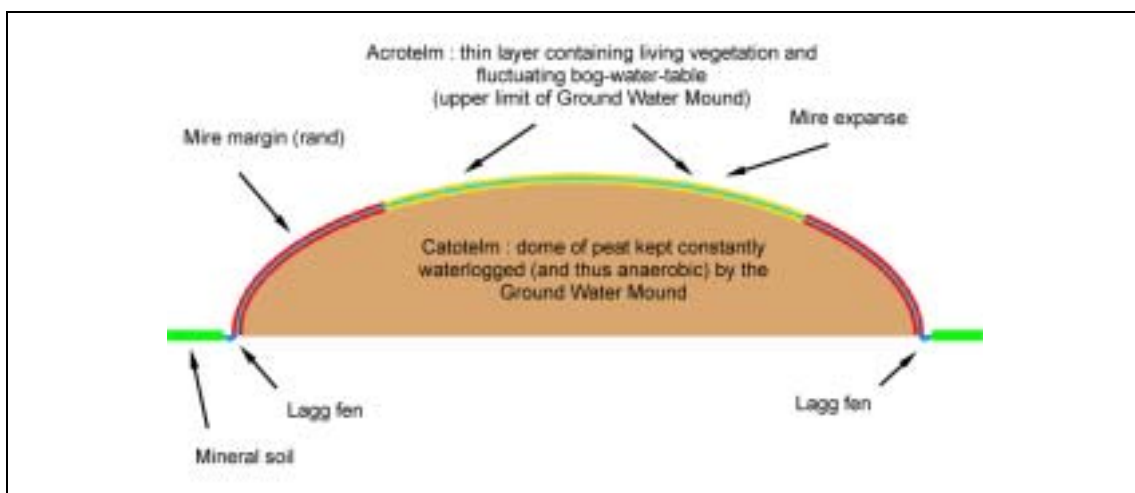


Figure A1. Raised bog system showing the relationship between the main dome of rain-fed peat (the bog mesotope) and the minerotrophic fen (lagg fen) formed at the contact zone between bog peat and the mineral ground. The shape of the dome is formed by the mound of water contained within the peat. The thin acrotelm layer contains the fluctuating bog water table (blue line), and consists of two broad zones - a zone of steep hydrological gradient at the margins which is dominated by red-coloured hummock-forming *Sphagnum* species, and the central zone of lower hydrological gradient which is dominated by low ridges and hollows formed by yellow-coloured *Sphagnum* species. The whole system is a macrotope consisting of

two inter-connected mesotopes.

The thin acrotelm layer contains the living vegetation. This is normally dominated by *Sphagnum* bog mosses, and each species has a characteristic growth-form - some tend to grow as hummocks while others dominate small depressions in the surface. These growth-forms create a small-scale surface pattern of undulating structures which is generically known as a 'hummock-hollow microtopography', although the pattern actually consists of several small-scale structures in addition to 'hummock' and 'hollow', described by Sjörs more than 50 years ago (Sjörs 1948). Hummock-forming species are generally most well-adapted to drying conditions because the tightly-packed stems of *Sphagnum* act like a wick, holding moisture in the hummock. Hollows, on the other hand, though sensitive to drying conditions, permit relatively free flow of water in wet conditions and thus enable excess water to flow away rapidly through the surface layer towards the bog margin.

It can be seen from Figure A1 that water flow in the acrotelm is more rapid in the marginal parts of the bog because there is an obvious physical gradient that becomes increasingly steep towards the edge of the peat mass. Run-off therefore tends to be quicker in this region. Drought periods are consequently longer here, and the small-scale surface pattern in this part thus becomes dominated by red hummock-forming *Sphagnum* species. In central parts of the dome, where the gradients are gentler and run-off is slower, the small-scale pattern is dominated by yellow *Sphagnum* species that form low lawns and shallow hollows or pools. The relationship between hydrological gradient, hydrological stability and small-scale surface has been explored in detail by Barber (1981), Ivanov, (1981), Lindsay *et al.* (1988), Lindsay (1995) and Lindsay (2003). For the moment, it is sufficient to understand that:

- ## the surface vegetation of the bog consists of a range of such small-scale features as hummock, low ridge, hollow and pool, collectively termed *nanotopes*; and that
- ## by varying the proportions of these features across the surface in a regular pattern termed a *microtope*, it is possible to maintain relatively even flow through the surface layers despite relatively large-scale shifts in climate over periods of several millennia.

However, the eco-hydrological function of the acrotelm will be considered in more detail later in relation to comments in the Lewis EIS about the effects of drainage.

Concentrating instead for the moment on the functional behaviour of the acrotelm, however, the most telling demonstration of the functional linkages within the acrotelm and between mesotopes can be seen in the case of a raised bog system where part of the bog has been removed by peat extraction. Recalling that a droplet of water sitting on a flat surface is a good model for the acrotelm of a raised bog, we can first imagine this droplet sitting on a glass sheet, and being frozen to form a half-ellipse of ice. If a section of this droplet is then removed by making a vertical cut with a sharp blade, and

the droplet subsequently allowed to thaw, the water droplet will gradually change shape as it thaws because the vertical face of the ice block is an unstable shape. Eventually, once the whole droplet has thawed, it will be found to have formed a new half-ellipse. This new half-ellipse will be smaller than the original because some of the water has been removed, and thus its total diameter and its maximum height will diminish.

This is one of the important consequences of the Ground Water Mound Theory for bogs - remove part of the bog and over a period of time the bog will sink to a new stable shape, just as a droplet of water would. This sequence of change can be seen in Figure A2. Also apparent from Figure A2 is the impact on the pattern of small-scale surface features in the acrotelm, with a significant decrease in the extent of low ridges and hollows and so the effects of peat removal have an impact at all levels of the eco-hydromorphological hierarchy. An impact at one margin of the bog system ultimately has an effect across the whole bog macrotope, because not only has the bog mesotope changed shape, but the fen mesotope has also changed location and total extent.

The mathematical basis on which the Ground Water Mound Theory is founded permits quantitative models to be constructed for occasions where the catotelm peat of the raised bog dome is disrupted in this way. Many raised bogs have a relatively simple plan shape which is either circular or oval, and mathematical solutions exist for such shapes, thus allowing a 3-dimensional model of the resulting changes to be created, as demonstrated by Bragg (1995). However, where the shape of the bog is more complex, there are few exact solutions available from the mathematical literature. Some shapes, such as a rectangle or a triangle, can be modelled using available simple exact solutions, but other shapes either rely on a process of approximation to a simple exact solution, or must be subject to a more complex form of analysis in which the site is divided into many small segments and each segment is modelled. This is known as *finite element modelling*.

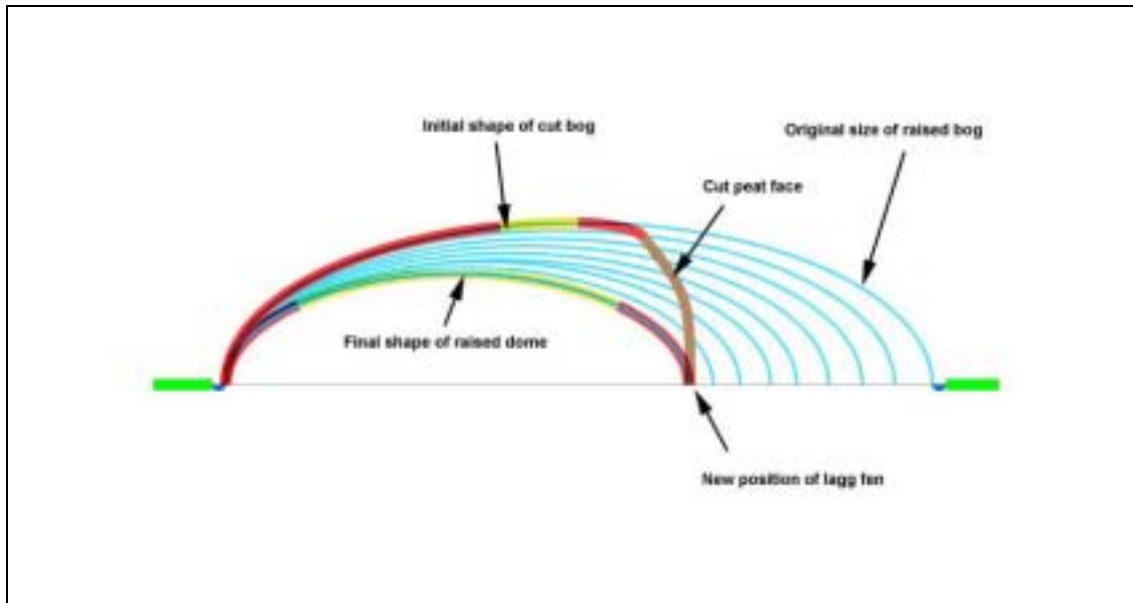


Figure A2. Effect of removing part of a raised bog. The process of morphological and vegetation change, as the bog settles to a new stable shape, can be seen in the change from the blue shape of the original groundwater mound, through the disrupted cut shape and ultimately to the new stable groundwater mound based on the new diameter of the bog. The pattern of small-scale surface features and vegetation has changed, as has the position of the lagg fen mesotope.

Blanket bog hydrology

Blanket mire systems add further levels of complexity to the basic raised mire model. Firstly, whereas in a raised bog it can generally be assumed that much if not all of the domed catotelm morphology results from peat accumulation, in a blanket mire this can never be assumed. This is because there are generally two types of ombrotrophic peat that make up a blanket mire landscape. A raised mire tends to develop from *terrestrialisation* of a shallow lake. Certain parts of a blanket mire complex may also develop in this way. However, other parts of the blanket mire complex develop because flat plateaux and gently-sloping ground may be sufficiently waterlogged by regular precipitation for peat to form directly on the ground surface through a process known as *paludification*.

Thus the blanket mire complex generally consists of some areas of peat that have formed in basins through terrestrialisation, whereas other parts (the paludified components) may lie on high points or even on markedly sloping parts of the landscape. Given (as already observed) that peat is essentially 98% water and only 2% solids by weight, this means that for significant parts of the blanket mire complex an essentially aquatic system is being held in place on sloping ground against the force of gravity simply by the matrix of peat. Given that the shape of each blanket mire mesotope may thus be highly irregular because parts of the catotelm morphology may owe more to the underlying topography than to peat formation, it is generally necessary to

obtain a good picture of the underlying landform beneath the peat before any sort of modelling can be undertaken. The complexities of such morphology mean that it is almost always necessary to analyse such sites using finite element modelling.

Another source of complexity is found in the marginal contact zone of each blanket mire mesotope. Whereas the raised mire margin links directly to the groundwater contact zone through the lagg fen, in a blanket mire the picture is more complicated. The margin of one mesotope (mire unit) is more likely to link directly to the margins of an adjoining blanket mire mesotope, which itself may then link to another mesotope. Some of these mesotopes may be bog, others may be fen, but the overall complex represents a continuous blanket of peat (thus the name blanket mire) that may extend unbroken for very considerable distances across the landscape. These linkages may embrace a number of mesotopes before finally encountering a groundwater contact zone that marks the edge of the peatland complex and thus the edge of the particular macrotope. The whole interior of the macrotope complex is hydrologically linked, and thus damage to any one mesotope may have hydrological consequences for an adjoining mesotope, with the additional potential to cause a domino effect whereby a series of adjoining mesotopes may ultimately suffer hydrological change.

Blanket mire landscapes rarely occur as single macrotopes. Normally the expanse of blanket mire can be divided up into a series of macrotopes. Within each macrotope there may be many linked individual mesotopes. Each macrotope boundary represents a clear break in the peat cover, and is defined by the hydrological limits of the various interlinked mesotopes. The edge to the macrotope may be a streamcourse that sits on mineral sub-soil, or a steep slope of mineral ground, or (given the impact of human activity within such regions) a road or trackway that in effect breaks the hydrological connection. The boundaries of each mesotope may be somewhat less sharply-defined than is typical for a raised mire because many mesotopes merge quite gradually into other mesotopes; thus a watershed mire lying across a broad ridge may then merge without any distinct transition into a valleyside mire further downslope (see Figure A3).

Blanket mires also tend to give rise to more complex questions than raised bogs about hydrological boundaries at the landscape scale. Hydrological boundaries within the landscape are most typically defined on the basis of *catchments*. However, there is a fundamental difference between a catchment boundary (or *watershed*) and a macrotope boundary. A catchment boundary is determined purely on the basis of water-divides (watersheds) and defines the complete drainage basin of a river system. A macrotope boundary, on the other hand, results from the accumulated assembly of interlinked peatland mesotope units, some of which may lie *across* watershed boundaries. This is particularly true of watershed mires that, by definition, lies across catchment boundaries; a catchment boundary will generally cut across the middle of such a mesotope. Catchment boundaries by very their nature cannot thus be used to define the functional

boundary of the mesotope or the associated macrotope unit for a blanket mire system.

Under natural conditions, the hydrological and physical linkages between the various mesotopes provide the necessary degree of collective stability for the blanket mire complex, but where hydrological disruption occurs to one or more parts of the complex, this stability can be lost. The resulting instability may lead to a breakdown of the surface hydrology, expressed as peat loss through various intensities of erosion, or it may give rise to large-scale catastrophic peat movements, commonly known as a bog slide. That such disruption is not merely possible but widespread can be seen from the almost ubiquitous presence of surface erosion throughout the blanket mire landscapes of Britain and Ireland, and also from the regularity of catastrophic events. One of the most recent of these events involved the spectacular collapse of 1.5 km of peat from a hillside in Ireland during windfarm construction, the peat travelling more than 20 km before finally flowing into a large and economically-important fishing lake (Lindsay & Bragg 2004).

When dealing with blanket mire systems it is thus vitally important at all times to keep in mind the larger picture of hydrological stability for the complex as a whole. It is not enough simply to focus on areas that will be directly effected by any development proposal; it is essential that these specific proposals be examined in terms of their possible impact on the entire functioning system. The true expression of this functioning system should embrace the whole hierarchy of peatland structures from the macrotope scale down to the vegetation types within the individual small-scale surface structures (*nanotopes*) such as hummock, or hollow, and of course the vegetation that creates the peat in the first place. This integrated multi-scale system is summarised as a diagram of the functional hierarchy in Figure A4.

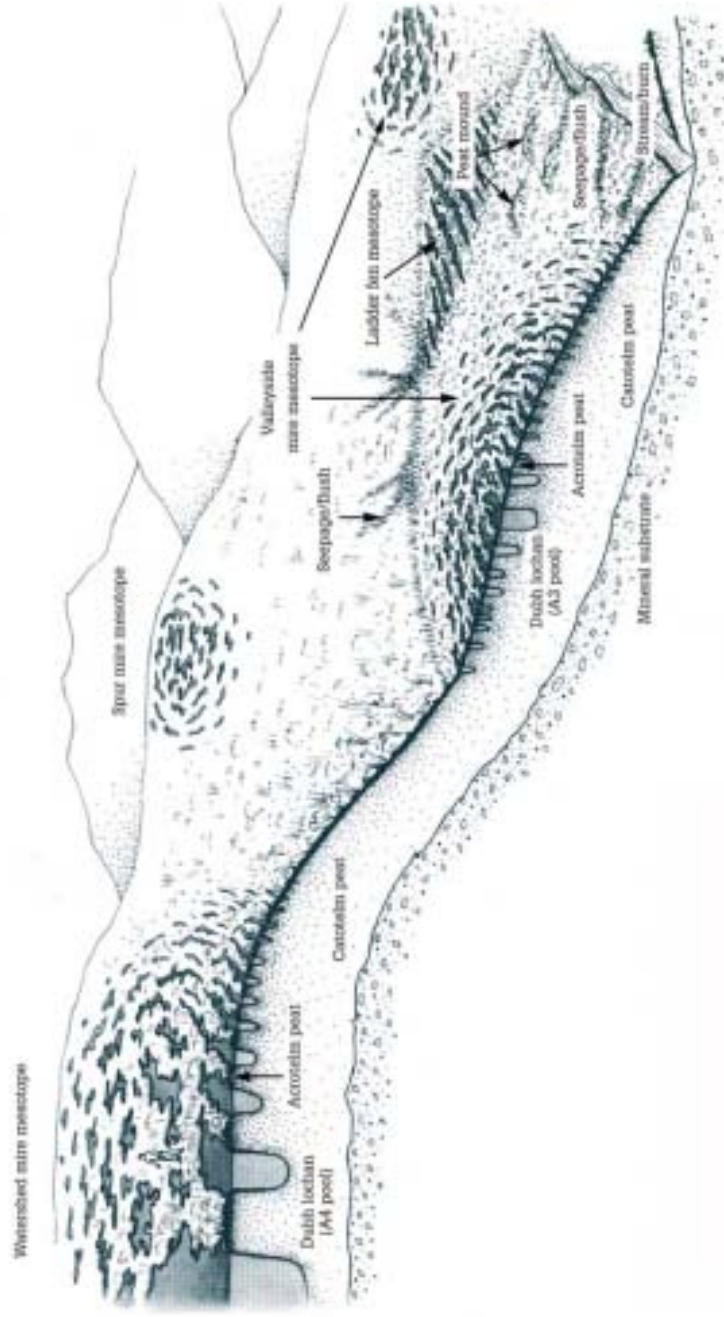


Figure A3. Schematic representation of blanket mire, adapted from Lindsay *et al.* (1988), showing the relationship between peat depth and slope of the underlying mineral substrate, as well as the physical (and associated hydrological) inter-relationships between the various structural components of a blanket bog complex [or macrotope]. (Depth of peat exaggerated compared to horizontal scale).


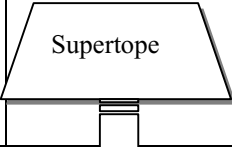
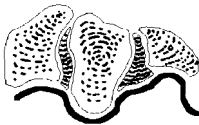
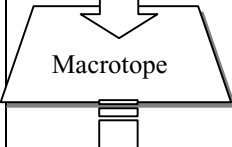
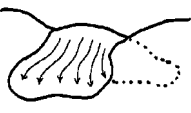
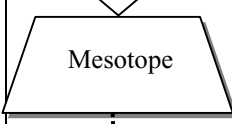
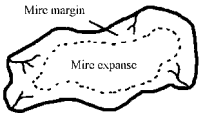


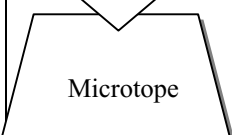
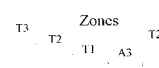
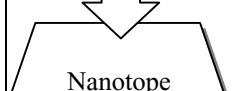
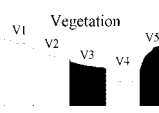
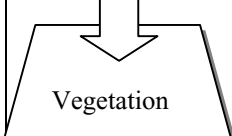
Feature	Hierarchical level	Description and alternate names	Source of description and method of evaluation	Utility for classification and evaluation
 <p>Mire macrotopes within two supertope regions</p>	 <p>Supertope</p>	Position of linked mire units within the regional landscape.	IMCG 1998 <i>landscape analysis</i>	Regional overview
	 <p>Macrotope</p>	Assemblage of hydrologically linked mire units. (<i>complex</i> : Sjörs, 1948, Moen 1985)	Ivanov 1981 <i>aerial photography, hydrotopography</i>	Identification of boundary for minimum, hydrologically sound, conservation unit
	 <p>Mesotope</p>	Distinct, recognisable hydrotopographic unit (<i>synsite</i> : Moen 1985, <i>Level 2, Form</i> : Zoltai and Pollett 1983)	Ivanov 1981; Lindsay <i>et al</i> 1988; <i>air photos, mire morphology</i>	Identification of individual, recognisable units for comparison
 <p>Mire margin Mire expansion</p>	 <p>Mesotope</p>	Distinction between mire-margin and mire expansion (<i>mire sites</i> : Moen 1985)	Sjörs 1948 <i>air photos, vegetation morphology</i>	Recognition of two or more distinct parts; in Europe, the margin often partly removed
	 <p>Microtope</p>	Repeated surface pattern - e.g. pool system (<i>mire features</i> : Moen 1985, <i>surface physio-gnomy</i> : Zoltai and Pollett 1983, <i>hummock-hollow mosaic</i> : Tansley 1949)	Ivanov 1981 <i>air photos, fractal geometry, image recognⁿ?</i>	Identification of hydrological character and naturalness; source of comparative diversity
 <p>Zones T3 T2 T1 A3 T2</p>	 <p>Nanotope</p>	Individual surface features (e.g. hummock, pool)	IMCG 1998 Lindsay 1995, <i>-et al.</i> 1985, 1988 Ivanov 1981 <i>field survey</i>	Source of niches for individual species; comparison of diversity and damage
 <p>Vegetation V1 V2 V3 V4 V5</p>	 <p>Vegetation</p>	Distribution of vegetation within surface structures	A large literature exists, but see Sjörs 1948, Moen 1985, Eurola, Hicks and Kaakinen 1983, Lindsay 1995	Source of comparative diversity; indicator of "naturalness"

Figure A4. The eco-hydromorphological hierarchy of peat bog systems, extending from the macro-landscape scale of the *supertope* to the distribution of vegetation types within the nanotope structures. (Adapted from Lindsay 1995, Joosten and Clarke 2002)

ANNEX 2
MAPS OF MINIMUM PEAT THICKNESS FOR DEVELOPMENT AREA

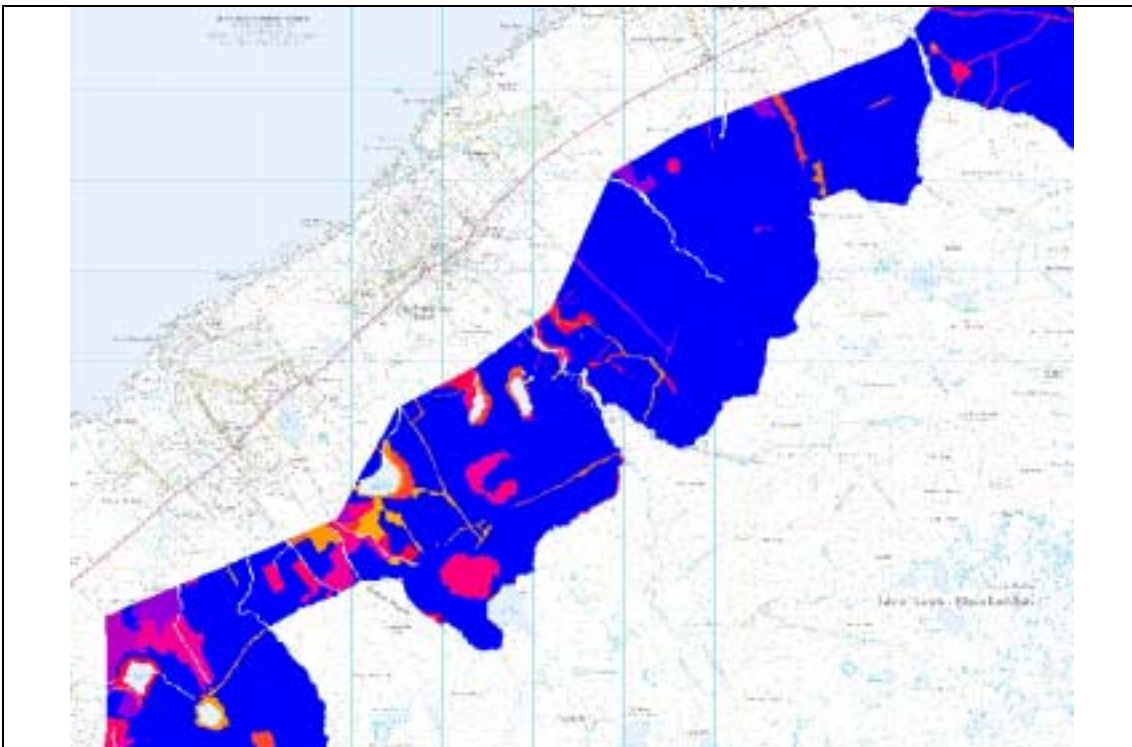
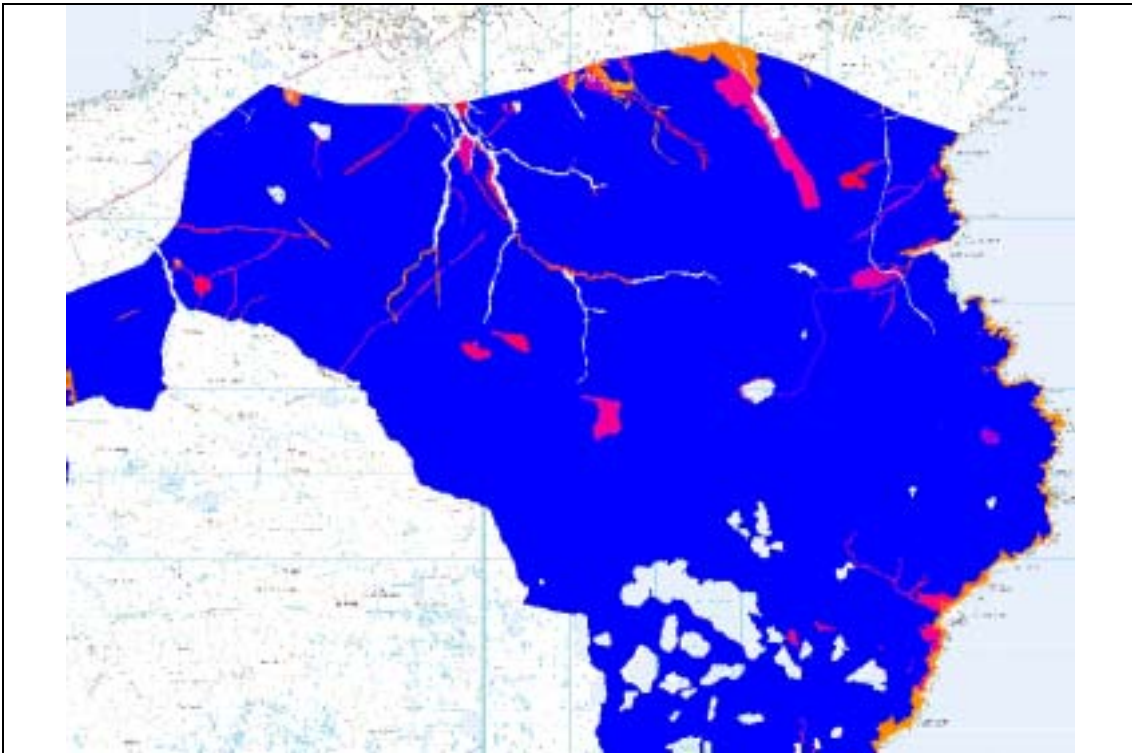


Figure 8(a & b). Map of wind farm roads and peat thickness. Blue represents peat with a thickness of more than 1 metre. The colour gradient runs from blue to purple to red to orange, with orange representing peat that is less than 10 cm thick. The OS 1:25,000 scale map is provided as background.

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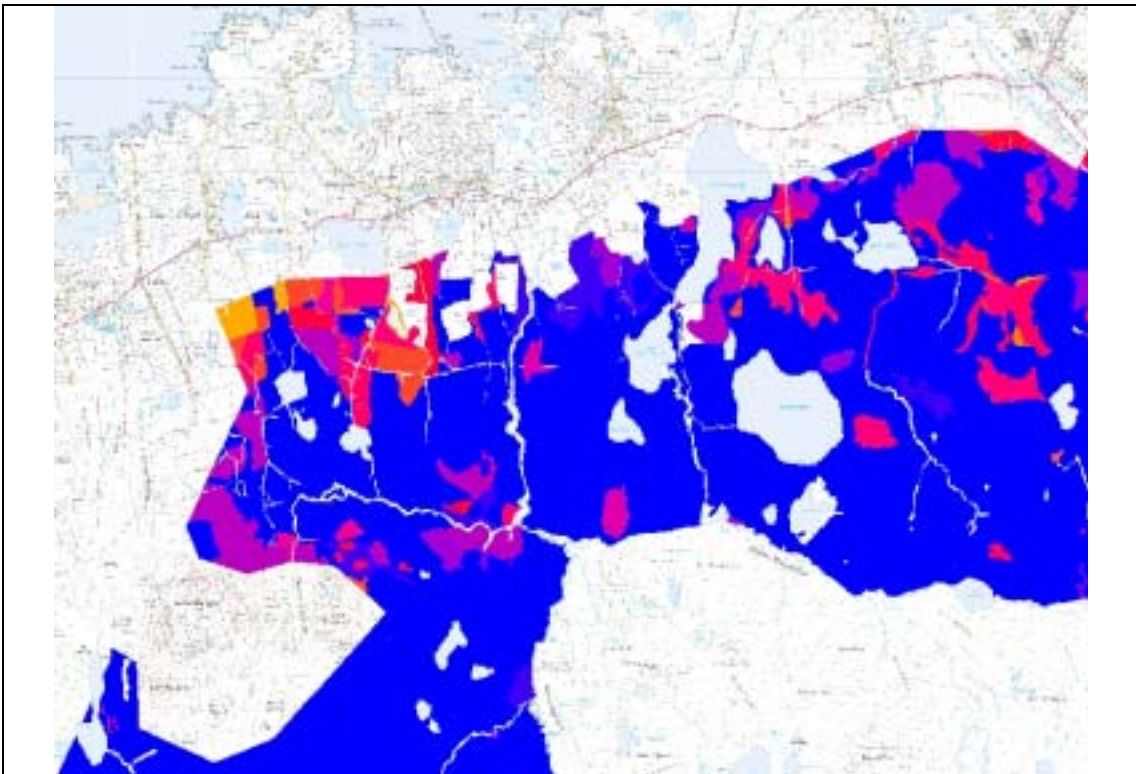
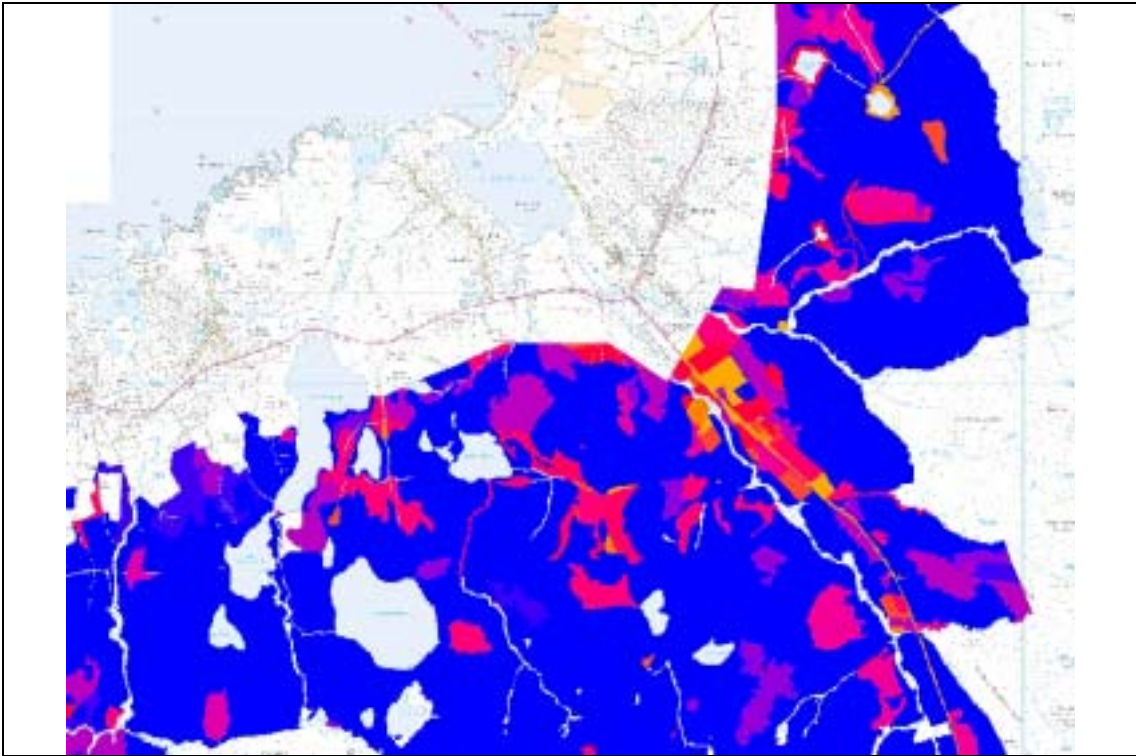


Figure 8(c&d). Wind farm roads and peat thickness. Colours as described above. The OS 1:25,000 scale map is provided as background.

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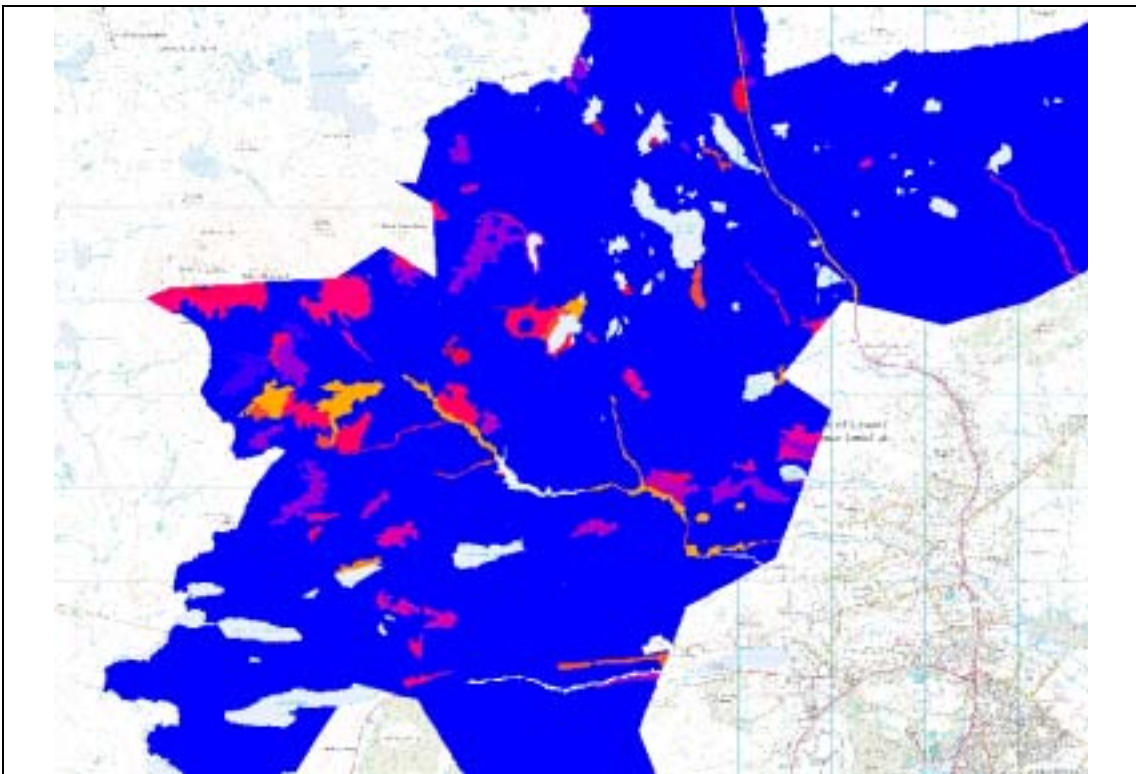
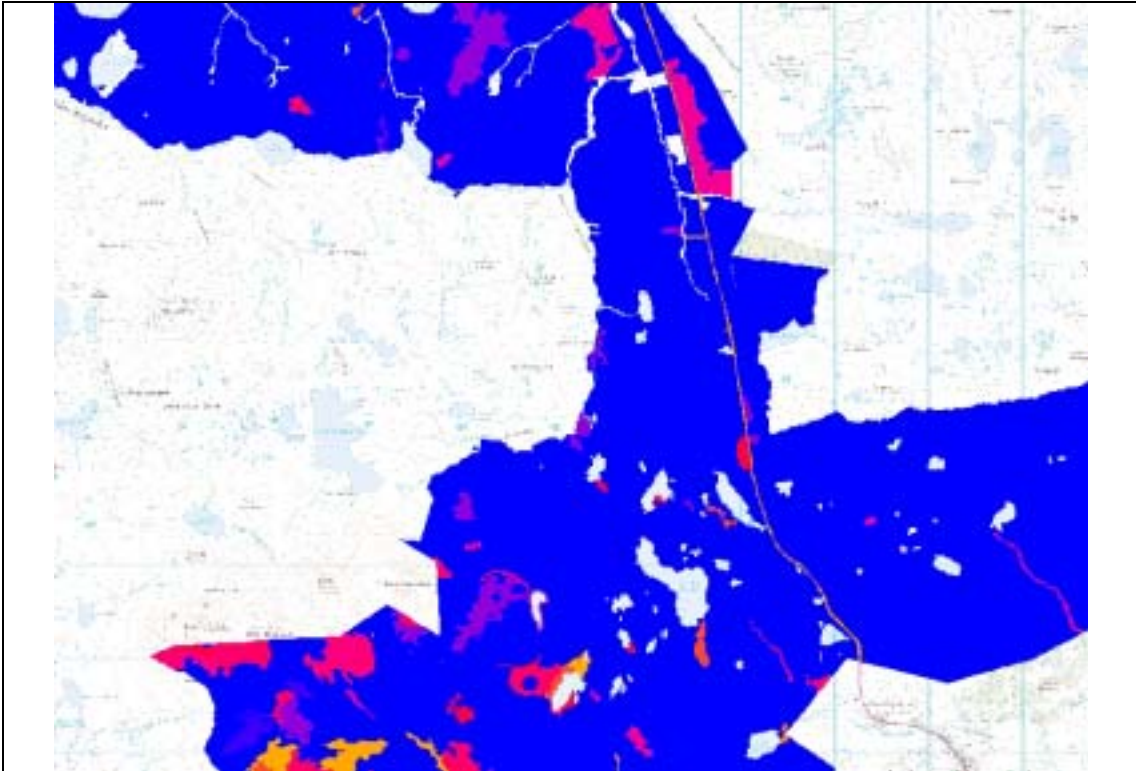


Figure 8(e & f). Wind farm roads and peat thickness. Colour codes as described above. The OS 1:25,000 scale map is provided as background.

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ANNEX 3. : DELIMITATION OF THE cSAC

The blanket mire mosaic of Lewis was identified as long ago as 1988 (Lindsay *et al.* 1988) as the second largest expanse of Atlantic blanket mire remaining in Britain after the Flow Country of Caithness and Sutherland. Although significant parts of the area have been designated as cSAC, other parts of what would seem to be 'active blanket bog' have been excluded, even though they are contiguous with the areas designated. It would be interesting to know the basis on which such areas were excluded from the cSAC.

Indeed, although the majority of the cSAC boundary appears to follow the lines of macrotope boundaries, there are some sections of the boundary that cross through the middle of distinct blanket bog mesotopes. Such a boundary would thus not appear to be as hydrologically sound as it could be. Further analysis of mesotopes and macrotopes would be necessary, supplemented by information obtainable from stereo aerial photographs, in order to make a more informed judgement about the current boundary and the potential - even desirability - for extending it to embrace complete macrotopes. If such areas should also prove to contain active blanket bog vegetation, this may strengthen the case for enlarging the area of the cSAC.