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# FLOATING ROADS ON PEAT

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A Report into Good Practice in Design, Construction and Use of Floating Roads on Peat with particular reference to Wind Farm Developments in Scotland

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## Background

Wind farm development in Scotland is accelerating rapidly, with over 5000 MW of wind farm capacity installed and consented. A new website “*Good practice during wind farm construction*” at [www.goodpracticeduringwindfarmconstruction.co.uk](http://www.goodpracticeduringwindfarmconstruction.co.uk), is being developed to share experience amongst the industry, planning authorities and those more broadly involved in the planning and development of wind farms.

This report is a complementary guidance to the Good Practice website on the single subject of floating roads on peat. It relies heavily on the ‘Good Practice Guidance’ and acknowledges its input. It is aimed at:

- Wind farm developers
- Construction companies and contractors working on wind farm sites
- Consultants and advisers supporting the wind farm industry
- Planning officers working on wind farm applications
- Statutory consultees such as SNH, SEPA and others with an interest in wind farm construction
- Ecological Clerks of Works
- Archaeological Clerks of Works
- Geotechnical Clerks of Works
- Community groups considering wind farms

## How to use this report

The information contained in this report has been prepared by a joint working group involving Scottish Natural Heritage (SNH), Forestry Commission (Scotland) (FCS) and representatives from companies involved in the wind farm industry. Its aim is to document what is considered to be good practice in the wind farm industry in general when dealing with floating roads on peat and to demonstrate what can be achieved on wind farm sites in Scotland. The examples given are offered as an aid to good practice and are not intended to recommend a particular manufacturer, method or product.

A wide range of issues needs to be considered when designing and constructing a wind farm, particularly over peat, and for this reason it is impossible to offer specific guidance which can be appropriate to all wind farms. Every site is different and each will require a tailored approach.

## Sources of further information

Key sources of further information include:

[www.snh.org.uk](http://www.snh.org.uk)

[www.sepa.org.uk](http://www.sepa.org.uk)

[www.scottishrenewables.com](http://www.scottishrenewables.com)

## **Planning conditions**

Construction activities can have a significant detrimental effect on nature conservation or pollution prevention interests and these will often be controlled by attaching conditions to the planning consent. Further guidance on the use of planning conditions can be found in [Scottish Government Planning Circular 4/1998](#).

In addition, it is the responsibility of the developer of the wind farm to ensure that planning conditions are adhered to. SNH and SEPA will often advise the determining authority (either the Planning Authority or the Scottish Government Energy Consents Unit) if conditions are required to meet nature conservation or pollution prevention objectives. Such conditions will usually be developed in consultation with the developer, SEPA, SNH and the determining authority as required.

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# 1. INTRODUCTION

This report has been prepared to provide an introduction to building floating roads on peat and how they can be used in the internal roads networks of wind farm developments. It has been prepared following consultations with all sectors of the wind farm industry; developers, designers, contractors, planners, ecologists, by means of workshops, meetings, interviews and discussions. Two formal workshops were held during the course of 2009 as part of these consultations.

1. Workshop No1, "Workshop on Floating Roads over Peat", 24 February 2009
2. Workshop No2, "Floating Roads Workshop No 2 – "Design & construction", 15 June 2009

The report is an amalgamation of the view of the wider wind farm industry and what it considers to be good practice. It summarises the main issues highlighted during the consultations and considers how modern survey, design, construction and monitoring practices can help to create 'fit for purpose' floating roads for use on modern wind farm developments.

The work supplements the recommended practices for floating roads contained in the SNH/SEPA guidance document "Good Practice during Wind Farm Construction" (2010). Comments taken from the Good Practice Guidance are shown in italics.

## 1.1. THE BRIEF FOR THE STUDY

The brief for the study was to "review the successes and failures in floating roads on peat, both modern and historical, and develop best practice guidance". The work was to be general in nature, and not necessarily to be limited to renewable energy projects, but as most floating roads are being proposed and built within the context of wind farms, those involved in that industry were expected to be a key audience.

The study was to focus on all aspects of floating road installation, from the identification of routes, through to road design, construction methods and maintenance. It was to consider not just the immediate footprint of roads but also indirect effects, including those of peat stability and issues associated with peatslide risk assessment. The final output was to be a good practice guide aimed at engineers, planning officials, scientific advisers and environmental and engineering consultants and be accessible to community groups and members of the general public.



## 1.2. ACKNOWLEDGEMENTS

The research and preparation of this report was commissioned by Scottish Natural Heritage and undertaken by Forestry Civil Engineering over the period February 2009 to March 2010. Grateful thanks are offered to all who offered contributions and attended the Workshops.

Particular thanks are given to the following organisations:

### **Agencies**

Forestry Civil Engineering  
Scottish Natural Heritage

### **Developers**

SSE Renewables  
ESB International

### **Consultants**

Entec UK Ltd  
Grontmij  
Halcrow  
Mouchel  
Scott Wilson Ltd  
SLR Consulting Ltd  
Wind Prospect Ltd

### **Contractors**

D A MacDonald (Contractors) Ltd  
Lagan Construction Limited  
RJ McLeod (Contractors) Ltd

### **Geogrid manufacturers**

NAUE Geosynthetics Ltd  
Tensar International Ltd

## 2. FLOATING ROADS ON PEAT

What is a floating road?

A floating road on peat in its simplest form is a road that is constructed directly on top of the peat relying on the strength of the in-situ peat for its support. The road does not actually “float” on the peat rather an equilibrium builds up between the weight of the road and the in situ strength of the peat whereby the combined system comes into balance.

Modern construction practice generally calls for a geosynthetic layer to be placed on the surface of the peat before the road is constructed to give a working platform for the road and provide a separation layer between the road and the peat below. This layer, however, does not support the road. The road is supported by the peat.

### 2.1. WHEN SHOULD A FLOATING ROAD BE USED?

This would appear to be a relatively simple question to answer but in practice it is not so easy. Floating road construction is not an activity that can be applied uniformly across all sites. Each site will be different, with unique circumstances due to the geomorphology of the peat and topography, and each will require a tailored approach to suit the particular local conditions on the site. Some sections will not permit floating construction.

The question of “When to float a road” was discussed extensively over the course of the Study by a wide range of respondents. Depths ranging from 0.6m to 1.5m and above were suggested without reaching a consensus figure that could be recommended. All respondents did agree however that the decision on whether to excavate or float a road at a particular location would be dependent on the specific circumstances prevailing at the particular location. These included:

- The type and characteristics of the peat;
- The length of the road section;
- The wind farm road layout;
- The volume of peat requiring to be excavated in the ‘cut-road’ option;
- The location of borrow pits, in particular haul distances, for fill material;
- The Contractor’s construction method preference;
- The construction equipment available;
- The number of vehicle movements for each option;
- The footprint of the road on the local habitat;
- Restoration requirements;
- Peat re-use considerations;
- CO2 implications;
- and more

These circumstances, and others, are considered within the body of this report. Similar considerations will also govern the economic minimum length for a section a floating road.

## 3. PEAT AS A ROAD FOUNDATION

### 3.1. INTRODUCTION

Peat in its normal, unloaded state, is a very weak material on which to build a road but if it can be carefully loaded, allowing time for it to consolidate and increase in strength, it can be transformed into a very useable foundation.

This section considers the suitability of peat as a material on which to build a road and its behaviour when loaded. The discussion is broken down into 5 parts as below.

- 1) Peat as a road foundation
- 2) Initial considerations
- 3) Basic engineering properties of peat
- 4) Behaviour of peat when loaded – the good and the bad
- 5) Consolidation & settlement

### 3.2. PEAT AS A ROAD FOUNDATION

Peat is not universally recognised as a foundation on which to build a road and the construction of roads on peat has all too frequently been considered to be a 'black art' by some authorities. As a result many engineers opt for conservative forms of construction such as excavation and displacement techniques to minimise perceived construction risks. These conservative practices are, however, expensive, especially when dealing with deep peat deposits, and ignore the extensive body of experience of floating roads around the world. Excavation and displacement techniques are also primary users of scarce natural resources in times when sustainable construction methods are demanded, and they are only really affordable for the construction of high speed, high volume national roads that demand carriageway surfaces with high tolerances.

The internal road networks of wind farm developments on the other hand do not need to have such high specification routes and can consequently utilise the in situ peat as a serviceable subgrade. These roads can take advantage of the known benefits of floating road construction in deeper peat, such as lower cost and environmental impact than excavated construction, to produce safe and cost effective access routes that are directly suited to their design need.

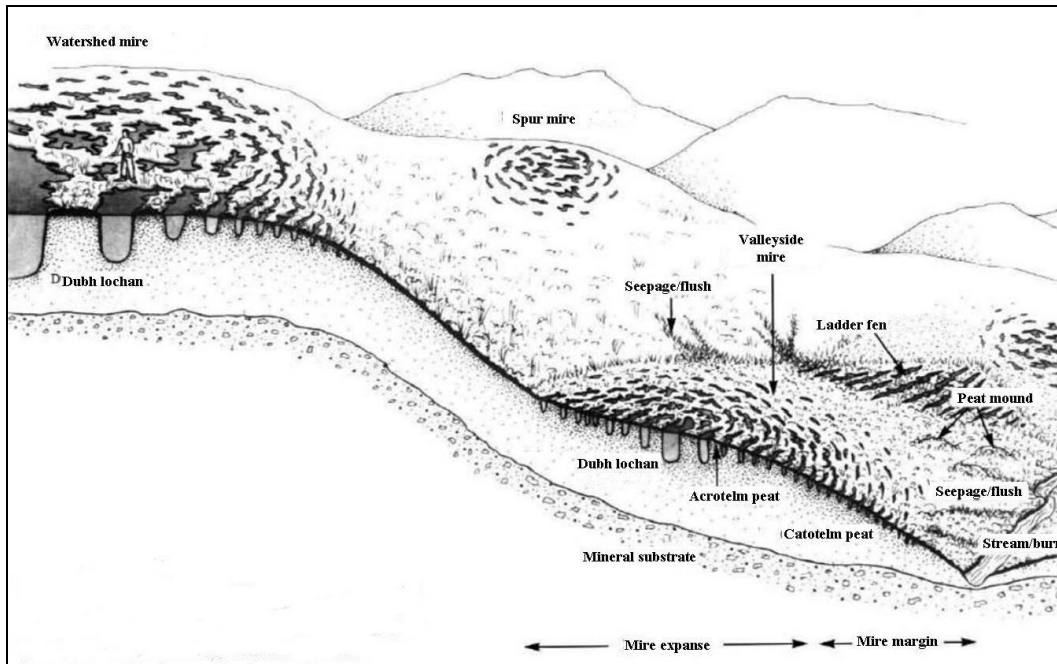
In order to do this however the mechanism of floating construction must be understood, and applied appropriately, with slow controlled loading, to achieve the best results. This is not always easy in the tight construction programme of a wind farm development but all Contributors to the Project Workshops agreed that suitable provision had to be made in programmes to permit floating road sections to be correctly designed and constructed.

### 3.3. INITIAL CONSIDERATIONS

The term 'peat' can cover a wide range of organic soil types. The Soil Survey of Scotland defines peat as having a surface horizon greater than 50cm thick with an organic matter content of more than 60 percent. Peat is a natural material and as a result is seldom uniform. A basic understanding of its properties is therefore necessary before it can be considered as a suitable foundation for a floating road.

Peat forms in a landscape when the natural decay processes fail to keep up with the amount of vegetation being produced. This usually happens on waterlogged land starved of oxygen, where the lack of oxygen prevents the natural micro-organisms from decomposing the dead plant material. Where these conditions occur the dying vegetation does not decay at the end of the growing season as normal but instead accumulates year on year as a layer of peat. Over thousands of years this slow accumulation of organic

material can create a continuous deposit over the landscape, that in Scotland takes the form of a 'blanket bog' as illustrated in Figure 3.1 below. This form of bog typically takes approximately 1000 years to form 0.5 metres of peat.



**Figure 3.1 Cross-section through a peat landscape (adapted from Lindsay et al, 1986 and Natural England 2010)**

The most important feature in the peat development scenario is water and in particular the water balance within the peat. For a peatland to survive, the water balance cannot be negative, i.e. the water input must keep up with the water loss.

Within each peat landscape the in situ peat is highly variable due to the way that it has been formed and this gives rise to a range of highly variable characteristics, both horizontally and vertically, in the peat deposit. Such variations are associated with the origins of the peat, the type of plant from which it was derived, the mineral content of the deposit, and the amount of decay or humification that has occurred. This variation (heterogeneity) is particularly noticeable with depth as peat deposits are generally formed in layers, which may differ considerably in their nature. Fresh fibrous peat tends to occur at the top of a deposit (Acrotelm) while the lower layers (Catotelm) are frequently composed of soft, relatively dense and highly decayed material. Within the catotelm, decayed tree stumps, or peat with a plate-like structure derived from decayed rushes, may be encountered.

Engineers and ecologists will generally view peat from different standpoints. To an ecologist peat will be a habitat, a living system, a carbon sink supported on a major carbon store, whereas to an engineer it will be a subgrade or a foundation on which to build a structure. These differences in perception can lead to misunderstandings when engineers talk about how a peat deposit will “behave” under loading. A little understanding, and an appreciation of the other person’s viewpoint, will help close the different standpoints when discussing engineering proposals over peat.

It is certainly the case that the engineer should have an understanding of how the particular peat deposit has grown on site, its “geomorphology”, in order to appreciate better its basic engineering properties for road construction design. This is generally obtained from a good site investigation by an engineering geologist, or equivalent professional, with a sound understanding of peat. This is discussed later in the report.

### 3.4. BASIC ENGINEERING PROPERTIES OF PEAT

Peat is generally considered to fall into 3 main groups for engineering purposes: 'amorphous-granular peat' (i.e. well decayed peat), 'fine fibrous peat' and 'course fibrous peat' (Radforth, 1969). The first group of amorphous-granular peats have high colloidal mineral elements and tend to hold their water locked in an adsorbed state around the grain structure much like clay. The two fibrous peat groups, 'fine-fibrous' and 'coarse-fibrous' peat, are woodier and hold most of their water within the peat mass as free water. These three groups of peat are a direct consequence of how and where the peat deposit grew and, as a result, govern the main engineering properties of the particular peat.

Natural peat in the ground can also be classified by the 10 classes of the "Von Post" system. These are based on the state of the decay of the peat through descriptions of hand squeezing samples.

Degree of Humification	Identification Guide
H1	Completely unconverted and mud-free peat which when pressed in the hand only gives off clear water. Plant remains are still easily identifiable.
H2	Practically unconverted and mud-free peat which when pressed in the hand gives off almost clear colourless water. Plant remains are still easily identifiable
H3	Very slightly decomposed or very slightly muddy peat which when pressed in the hand gives off marked muddy water, but no peat substance passes through the fingers. The pressed residue is thickish. Plant remains have lost some of their identifiable features.
H4	Slightly decomposed or slightly muddy peat which when pressed in the hand gives off marked muddy water. The pressed residue is thick. Plant remains have lost more of their identifiable features.
H5	Moderately decomposed or muddy peat. Growth structure evident but slightly obliterated. Some amorphous peat substance passes through the fingers when pressed but mostly muddy water. The pressed residue is very thick.
H6	Moderately decomposed or very muddy peat with indistinct growth structure. When pressed approximately 1/3 of the peat substance passes through the fingers. The remainder extremely thick but with more obvious growth structure than in the case of unpressed peat.
H7	Fairly well decomposed or markedly muddy peat but the growth structure can just be seen. When pressed about half the peat substance passes through the fingers. If water is also released this is dark and peaty.
H8	Well decomposed or very muddy peat with very indistinct growth structure. When pressed about 2/3 of the peat substance passes through the fingers and at times a thick liquid. The remainder consists mainly of more resistant fibres and roots.
H9	Practically completely decomposed or mud-like peat in which almost no growth structure is evident. Almost all the peat substance passes through the fingers as a uniform paste when pressed
H10	Completely decomposed or mud peat where no growth structure can be seen. The entire peat substance passes through the fingers when pressed

**Table 3.1 Degree of Humification of Peat. Source: L Von Post & E Granlund, 1926.**

The most distinctive characteristic of a virgin peat deposit however is its high water content and most of the basic engineering characteristics of peat as a foundation material result from this simple property. For example, the shear strength of a peat deposit depends on its water content, degree of decay and mineral content, with water content having a high influence.

Shear strength is a key parameter for floating roads applications and normally the higher the water content of the peat the lower its shear strength, the more fibrous the peat the greater its shear strength, and the higher the degree of decay of the peat the lower its shear strength. The strength of a peat in a deposit will seldom be directly related to depth. Frequently a peat bog will show a decrease in strength with depth due to the changing character of the peat, particularly where it becomes less fibrous and more amorphous with depth, but this is not always the case. Each site will invariably have its own particular characteristics that are a consequence of how the peat was formed. A simple visual classification together with water content can give an early indication of many of the important parameters of interest to the engineer for floating roads, but this should be followed up by a ground investigation to inform the design.

Further details of the basic engineering properties of peats can be found in Hobbs (1986) and Munro (2004).

### 3.5. BEHAVIOUR OF PEAT REACTION WHEN LOADED – THE GOOD AND THE BAD

Peat can react in two ways when load is applied to its surface:

- A. slowly, with a steady settlement and volume change as water is forced out of the peat mass. This is the desired method for the construction of a floating road and permits the peat to gradually compress and consolidate allowing time for it to gain in strength and take up the new load. For this to happen the loading phases need to be carefully controlled in order to keep the stresses induced in the peat below the strength of the peat at the time. This is a key consideration for the construction of a stable floating road.
- B. rapidly, accompanied by sudden spread and shear of the peat causing failure. This rapid failure scenario has to be avoided in floating road construction by carefully managing the loading phases of the road. It can however be used as an effective engineering technique (“displacement”) where it is intended that the road should be founded on the hard strata below. This practice is outwith the remit of this report however.

It is therefore vitally important that the Designer should have an appreciation of how construction loading rates can affect the consolidation and settlement behaviour of peat in order to avoid a failure on site. Modern site investigation and analysis techniques can quantify such risks so that appropriate measures can be put in place to ensure that the works can be constructed safely.

### 3.6. CONSOLIDATION & SETTLEMENT

In the normal course of events the consolidation and settlement of a peat can be seen to follow two main phases, ‘primary consolidation’ and ‘secondary compression’ as shown on the ‘time v settlement’ graph of Figure 3.2. (There is also an instantaneous ‘elastic’ phase that happens as the load is initially placed on the peat, but this is generally discounted in the monitoring of consolidation as it is almost impossible to measure. This phase is shown as the theoretical initial settlement of 0.05m at the commencement of the graph below). The graph is given as an indication of what can happen to a typical floating road constructed on peat and should not be taken as a standard or scaled from.

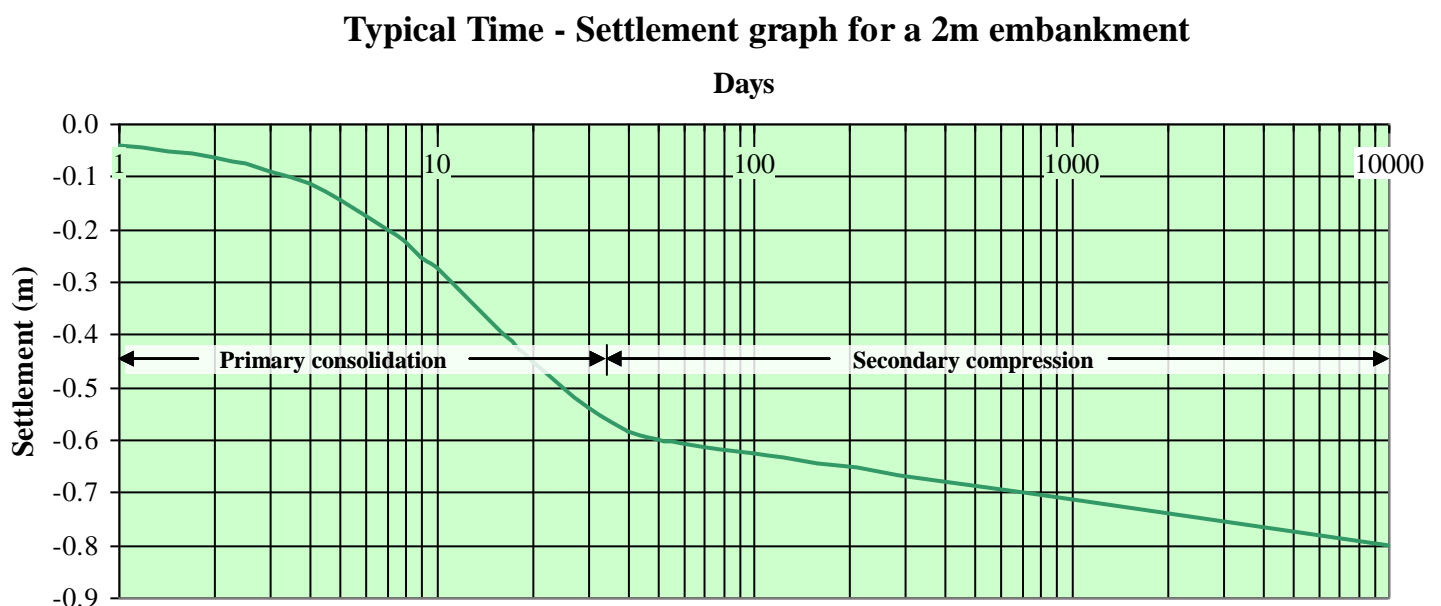


Figure 3.2 ‘Time v Settlement’ graph for a 2m floating road on peat. (Chapter 6, The Muskeg Handbook, National Research Council of Canada)

The two processes of primary consolidation and secondary compression are described below.

## Primary consolidation

Peat in its natural state is a highly permeable material and the magnitude of the initial primary consolidation settlement under load is normally fairly large and the period of settlement short, usually days. During this primary phase the new load is jointly supported by the free water within the peat and the peat vegetal mass. As the vegetal structure takes up the load it compresses, and strengthens, and causes load to be transferred back into the free water increasing the pore water pressures locally. This pressure in turn releases into the adjacent unloaded peat causing load to be taken up again by peat vegetal structure with further settlement, strength improvement and load transfer.

Normally this primary consolidation process takes place within the time it takes to place the layers of the road and its magnitude is usually dependent on the weight of the road and the thickness of the peat deposit and any other compressible layers. Once the phase has passed, and the primary excess water pressures have dissipated, the settlement under load continues at a much slower 'secondary compression' rate which is generally accepted to be linear with the logarithm of time.

## Secondary compression

In the secondary compression phase the load on the peat continues to transfer from the water within the peat to the internal peat skeleton as the peat continues to respond to the applied load. This is generally accepted to be the result of the loaded plant fragments within the peat mass slipping and re-organising to form a denser matrix. As these peat fragments come together, and the pore voids close up, the permeability through the peat reduces in response.

This simple 2 phase 'primary consolidation' and 'secondary compression' scenario does not of course give the full picture of the complex consolidation and strength improvement processes at work in peat, but it does give an indication of the continuous dynamic consolidation process within the loaded peat mass. The amount of primary consolidation that is incurred at a location will vary with type of peat but it can be generally approximated to around 50 per cent of the total settlement over time. For the purposes of design, secondary compression is normally accepted to take place over a period of 30 years (or 10,000 days as in Figure 3.2) – around the time taken to construct, operate and decommission a typical wind farm.

## Summary

Peat should be loaded slowly to allow the underlying peat to respond to the increasing load and be given sufficient time to consolidate and gain strength rather than shear. **If a floated road is placed too quickly so as to approach, or exceed, the in situ strength of the underlying peat then failure can follow.** If peat is loaded too quickly, without allowing time for water pressures to be released, the in situ peat will effectively have the shear strength of its water, i.e. zero. This has to be avoided at all costs. Modern design methodologies and risk management strategies can help prevent this but designers should be aware that serious shear stresses can be induced in peat, even by moderate fills, if loadings are not sufficiently controlled.

## 4. PLANNING FLOATING ROADS ON PEAT

### 4.1. INTRODUCTION

The internal access road layouts of wind farms have not normally had a high profile in the planning of wind farm developments to date. So far the main considerations in planning a wind farm have generally been:

- access to the grid
- dealing with stakeholders, SEPA, SNH, local Councils, roads authorities, utility companies, etc
- the siting of the wind turbine generators (WTG) to maximise energy yield
- landscape and visual impact
- ecology
- ornithology
- archaeology
- hydrology and geology
- traffic
- noise
- electromagnetic interference (TV signals), radar interference
- other social and leisure issues

This is understandable, in part at least, as a typical wind farm development will be the result of a number of iterations of layouts as knowledge concerning the site develops and the views of consultees become clearer. However the absence of consideration of site access roads early in the planning process is considered to be an omission in the process as they provide essential access for all of the stages of the wind farm project. The access road layout may be a small component in the overall cost of a wind farm but it is also critical to the efficient construction and satisfactory operation of the final development. Until recently the final engineering layout of the internal road network has not generally been considered in any detail within the planning process and only an indication of the road layout has usually been provided.

This is not a satisfactory situation and it has been a main concern of all Contributors to this report that site access roads should have a higher profile in the Environmental Impact Assessment (EIA) and planning process. The overwhelming view of all Contributors was that greater time should be allocated to the design of the access road network in the “Front End Engineering Design (FEED)” so as to minimise construction problems on site, and save abortive work. FEED relates to the Best Practicable Environmental Option (BPEO) as set out by the Royal Commission on Environmental Pollution (RCEP). The strong message that came out of the industry members consulted was that:

- The engineering issues of access roads should be considered earlier in the process and sufficient time given for their construction;
- There should be a balance between ecology considerations and the ‘buildability’ of developments;
- The vertical and horizontal alignments of roads were essential elements in assessing the impacts and buildability of access roads. They should be considered within the EIA to inform the planning stage;
- The proposed route should be physically checked on the ground before being committed to in formal documentation.

This is especially the case for the planning of floating road sections over peat as the design and efficiency of these roads in service will be directly dependent on how much time and thought has been put into the route selection. Well designed floating roads can only be assured through early involvement in the wind farm design process.

This section will consider the planning of floating roads under the following headings:

1. Identification of the routes



2. Pre-construction considerations
3. Construction (Design and Management) Regulations 2007
4. Geotechnical risk management
5. Construction method statements
6. Controls and monitoring
7. Record keeping

## 4.2. IDENTIFICATION OF THE ROUTES

The identification of the access road layout of a wind farm development is usually an iterative procedure within the EIA that is subject to change as new information comes to light. Because of this it is accepted that Developers will not wish to commit substantial resources and large sums of money to the internal road layout of a wind farm project ahead of Consent being granted. Sufficient work should however always be undertaken to assess the layout adequately, including obtaining inputs from construction engineers, to ensure that the wind farm is buildable.

It is recommended that the internal road network should be developed alongside the Wind Turbine Generator (WTG) layout to a level sufficient to produce a good approximation of the likely final development. This is particularly important at the formal planning stage to ensure that planners and statutory consultees are sufficiently well informed to make a responsible and informed decision on the information presented. For this to happen it is essential that the basic engineering of the proposed wind farm is understood, and that construction engineers have an input, so that the layout submitted is buildable at reasonable cost.

Practical approaches taken by Developers include:

1. Select a route which minimises the length and/or depth of peat to be crossed;
2. Select a route which the minimises crossings of active bog habitat;
3. Incorporate a gradient on the vertical alignment of the route to assist drainage
4. Include transitions from the excavated sections to the floating sections to ensure that the specified longitudinal gradient can be achieved.

## 4.3. PRE-CONSTRUCTION CONSIDERATIONS

*“Pre-Construction is the incorporation of construction due diligence during the EIA stage of the project development, and prior to site mobilisation planning. It is about planning ahead and being proactive in your construction strategy. Getting the pre-construction right will increase safety, reduce risk, cost and programme delay, and increase stakeholder confidence in the project”.* (Good Practice Guidance 2010)

The pre-construction considerations for floating roads on peat essentially involve understanding the conditions that govern construction of floating road sections and thereafter managing the perceived risks. Two stages are considered: the EIA and post consent:

### **The EIA stage**

For the early stages of a wind farm project involving peat this means addressing the requirements of the Scottish Government’s Energy Consents Unit’s “Peat Landslide Hazard and Risk Assessments; Best Practice Guide for Proposed Electricity Generation Developments” during the formulation of the EIA by:

- establishing a system of geotechnical risk management in the Development;
- assessing the baseline condition by means of a desk study, site walkover, and initial ground investigation;
- identifying the impact of the infrastructure on the baseline;

- carrying out a robust peat landslide hazard assessment;
- ranking the perceived hazard and risk;
- taking risk avoidance measures;
- considering construction methodologies to construct the works, i.e. the “buildability” of the development;
- identifying mitigation measures and preparing contingency plans to deal with any residual risks.

A useful report giving practical information on how to meet these requirements is “Guidelines for the Risk Management of Peat Slips on the Construction of Low Volume/Low Cost Roads over Peat” (MacCulloch 2006).

Useful information on reporting, investigations, design and post monitoring is also given in the Eurocodes EN 1997 -1 and 2 (“Eurocode 7”).

### **The Post Consent stage**

In the post Consent stage, prior to construction, the engineering considerations should focus on the detailed processes required to construct the Works safely, i.e.:

- detailed ground investigations and testing;
- detailed engineering design of the infrastructure, particularly those elements located in the medium to high hazard areas;
- micro-siting of infrastructure elements as a result of any pertinent new information;
- slope stability analyses;
- drainage design;
- sediment management and control;
- landscaping measures (restoration and reinstatement);
- etc

This detailed phase should refine the considerations set out in the EIA and build on them to produce a working plan to execute the Works.

## **4.4. CONSTRUCTION (DESIGN AND MANAGEMENT) REGULATIONS 2007**

*“As part of fulfilling a Client’s (the Developer’s) responsibilities under the CDM Regs, a pre-construction information pack (PCIP) should be prepared for tendering contractors. In addition, sufficient time should be allowed for the appointed contractor to complete any detailed design”. (Good Practice Guidance, 2010)*

These comments from the Good Practice Guidance are particularly appropriate for wind farm projects involving peat and show how a wind farm Developer can have a major influence over the way a wind farm project is run. It was the clear consensus of the representatives attending Workshop No 2 that greater time should be given to the planning and execution of the internal roads on wind farm projects particularly if floating sections of road are to be considered.

The decision on whether or not to build a section of floating road will normally be based on a wide range of considerations with time being a major factor and it was felt that the Contractor for the Works should be involved in them, if at all possible, if only to assure the ‘buildability’ of the project. A floating road built slowly in stages, with time allowed for consolidation and settlement, will result in a stronger, lighter and more serviceable structure than one built in haste for immediate trafficking. This aspect has to be recognised and sufficient time built into the project at the pre-construction stage to permit floating road sections to be constructed appropriately.

Additionally both horizontal and vertical alignments of access roads should be considered early in the process as both have a direct effect on loadings for floating road sections. Finally any possible extensions to the wind

farm should be considered and planned into the design, especially where there is the likelihood that they may place additional loading on the floating road sections.

## 4.5. GEOTECHNICAL RISK MANAGEMENT

Geotechnical risk management is now required for all Section 36 wind farm projects in Scotland involving peat, (“Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments”, 2006). It should also be considered to be good practice for all wind farm developments involving peat regardless of size. Examples of possible geotechnical risk management systems are outlined in Clayton (2001).

Following from the Derrybrien peatslide in County Galway, Ireland on 16 October 2003, the Scottish Government’s Energy Consents Unit now expect all wind farms applications in Scotland involving peat to provide a peatslide risk assessment within their EIA to show that the lessons learned from the Derrybrien incident have been incorporated. These include:

- construction work practices should be restricted to those that do not adversely affect existing stability;
- concentrated loadings, such as surplus excavated materials, should not be placed on areas of marginally stable ground;
- concentrated water flows onto peat slopes should be avoided;
- robust drainage plans should be developed and implemented;
- ground investigations should continue during the works together with monitoring systems to warn of potential peatslide movements;
- suitably qualified and experienced geotechnical personnel should be on site at all times.

The Energy Consents Unit also expect every application to commit to a system of geotechnical risk management and contain a geotechnical risk register, to ensure that all identified geotechnical risks are transmitted to the persons who need to know.

This should extend to all works associated with the wind farm development and not only tracks and turbines. All ancillary works, such as cable trenching, erection of overhead power lines, tree felling operations and the like, that could affect the stability of the peat should also be considered as part of the geotechnical risk management process of the development.

As with the CDM Regulations 2007, the attitude of the Developer is the key to effective geotechnical risk management. For it to work it must have a strong commitment from the top.

Brief summaries of recommended geotechnical risk management systems, peatslide risk assessment and the geotechnical risk register are given in Appendix 4.

## 4.6. CONSTRUCTION METHOD STATEMENTS

*“The use of Construction Method Statements (CMS) to guide a development is common practice across the construction industry. With the ability to cover a wide range of subjects, including; environmental, hydrological and ecological considerations; Health and Safety on site; and build procedures, the construction method statement ensures consistency across the site for the duration of a build, as well as providing, a reliable reference and information source for all personnel involved in a particular development”. (Good Practice Guidance 2010)*

General recommendations for Construction Method Statements are given in the Good Practice website. The construction method statement considerations within this report will relate solely to floating roads on peat:

- A. At the planning stage within the EIA – general CMSs to permit planners, ecologists and others to assess the impacts of the planned methods of construction

- B. Construction stage - detailed CMSs necessary to construct the Works
- C. Operational stage – the regular CMSs to keep the Works serviceable

#### **a) At the planning stage within the EIA**

The clear message from Workshop No.2 was that all Construction Method Statements provided as part of the EIA should be sufficiently detailed and descriptive to permit planners and consultees to assess the proposal. Contributors accepted that it was not in the interests of developers to be too prescriptive in the early planning stages in detailing construction method statements as this can stifle innovation in the later construction process. However politicians, planners and land managers need to have sufficient guidance on how to assess the information supplied by developers in the scoping appraisal as well as for the subsequent approval of the construction method statement. In the case of floating roads this means:

- the strategy for the use of floating roads;
- seasonal considerations;
- the expected road cross-section and thickness;
- an assessment of the amount of settlement;
- the planned geogrids, if any;
- the assessment of the risk of peatslide;
- drainage arrangements;
- the treatment of verges and slideslopes.

#### **b) Construction stage - detailed CMSs**

The construction method statement for the construction stage of a floating road should be sufficiently detailed to address the practical construction issues expected:

- engineering details, e.g. horizontal and vertical alignments, road cross-section and thickness, road cross-section and thickness, materials;
- construction procedures and controls;
- monitoring recommendations;
- 'stop rules', i.e. circumstances when construction activities should cease, such as extreme weather conditions

#### **c ) Operational stage – CMS's to deal with repair and maintenance issues**

Construction method statements here should include details of:

- frequency of inspection
- matters to address
- method of repairs
- routine maintenance activities
- cyclic maintenance activities
- repair and replacement of structures

### **4.7. CONTROLS AND MONITORING**

Floating roads on peat by their very nature need to be subject to regular engineering control and monitoring to ensure that construction and consolidation is proceeding as intended. Typically such monitoring measures will deal with the factors that can affect the stability of the finished structure, i.e.

- a. method and speed of construction
- b. weather and the seasons
- c. settlement
- d. displacement

#### **a) The method and speed of construction**

The method and speed of construction can have a profound effect on the final performance of a floating road section. Contributors to the report considered that good practice here included:

- early engineering involvement (Front End Engineering Design – FEED);
- using proven methods of working that will produce known outcomes;
- adherence to the agreed construction method statements;
- regular systems of monitoring;
- good record keeping.

Most construction programmes are governed by turbine delivery schedules and Contributors felt that it would be more appropriate for road layouts to be constructed earlier in the programme and allowed to ‘bed-in’, rather than be squeezed into a timeframe to suit delivery requirements that did not permit sufficient construction time.

It was accepted that the speed of construction of a floating road had a critical effect on the underlying peat and that an early engineering involvement was considered essential to manage this appropriately. The preferred option of Contributors was to extend the programme to allow time for the peat to gain strength and establish equilibrium. It was mentioned that 50m/day of road construction could be a good rate of progress in good weather, whereas 25m/day may be the best that could be achievable in poor weather.

An example offered on the effects of the speed of construction was the use of a 35 ton dump truck. This truck would be more productive hauling fill material than a 25 ton dump truck but would also involve much heavier axle loadings and consequently cause greater damage. Slowing down construction rates and providing additional consolidation time was acknowledged to have a cost but contributors at Workshop No.2 felt that this was acceptable in the benefits to the finished road. It was also voiced that experienced engineering input was essential to prevent the peat being overloaded during the placing of the construction layers. Staged construction was offered as a technique that would permit the peat to gain in strength before the next layer was laid. This could lower the possibility of failure from that of a ‘dumped’ road where the road is constructed quickly in one operation as a single layer.

Finally it was the clear view of Contributors that it was not acceptable in risk management terms to place the responsibility for this construction of a floating road section on the plant operator at the head of the road. An approach of geotechnical risk management (Clayton, 2001) and “observational method” (BS EN 1997 “Geotechnical Design”) was considered to be the most satisfactory method.

#### **b) Weather and the seasons**

*“For a number of reasons it is important to consider the time of year and scheduling of wind farm construction to minimise impacts on the surrounding environment. The current turbine supply market and the availability of specialist contractors will limit the opportunities for a developer to fundamentally alter a construction schedule to take account of these issues. Nonetheless, careful scheduling and an awareness of the different issues likely to arise at different times of year will be beneficial, particularly in the context of planning for drainage and the impact of flooding events”. (Good Practice Guidance 2010)*

Discussions during the Workshops confirmed that winter was not a good time to construct a wind farm and that, ideally, wind farm works over peat should be constructed during the drier months. It was however accepted that the decision on when to construct would probably be outwith the scope of the Engineer and that economic considerations would in all likelihood be the deciding factor. Construction considerations in this event had to focus on the effects of weather and season and particularly how they could be mitigated on site.

Typical considerations for weather monitoring and control of works on site included:

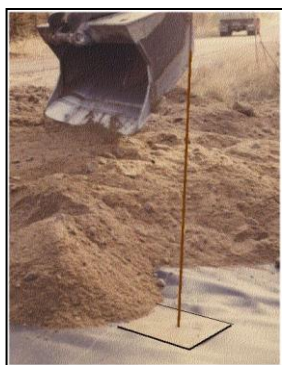
- Local weather forecasts from the Met Office
- Flood warnings issued by SEPA
- Continuous rain gauge monitoring
- Sediment control and monitoring
- ‘Stop rules’. These should be site-specific backed up with site measuring equipment, and should not rely on data from a meteorological station which may be distant and with possibly different in altitude and aspect. Examples of some rules used in Ireland were:
  - High intensity rainfall > 10mm per hour
  - Long duration rainfall >25mm within 24 hours
  - “7 day rule”: review work practices if the running 7 day cumulative rainfall is greater than 50% of the monthly average rainfall. Alternatively use a cumulative rainfall of 50mm within 7 days

Good practice is invariably based on good data, and good weather records are an indispensable aid to good construction risk management on site.

### c) Settlement

Monitoring the settlement of a floating road during construction, and post construction, was considered to have a number of benefits.

- In the short term during the construction phase, monitoring can confirm that settlement and consolidation are going according to plan. This is an important check, and a good system can identify any departures from design early enough in the work so that appropriate action can be taken.
- In the medium term during the operational phase of a wind farm, monitoring can confirm the rate of ‘secondary compression’ settlement of the road. If this rate is not in accordance with the design plan modifications can be implemented to bring it into line.



The simplest visual settlement measuring device is the ‘surface settlement plate’, Figure 4.1, which consists of a flat plate (usually 500mm x 500mm) on to which is welded a rod of sufficient length to ensure that the end is exposed above the finished road. The plate is positioned on the surface to be monitored, usually the edge of the geogrid or the original ground surface, and a record taken of the level of the exposed end as the settlement happens. As an added sophistication the rod can be sheathed in a duct to protect it during settlement of the overlying fill. These plates can then be referenced back to fixed ground control points for consistency of monitoring.

**Figure 4.1 Surface Settlement Plate**

Iceland employs a derivative of the settlement plate method that uses a sectional rod that can be extended to suit the depth of the road. This type of plate is usually installed in the centre of the road to permit the contractor to monitor layer thicknesses. The top of the rod is kept below the surface of the road to allow compaction to be carried out.

### d) Displacement

“Line of sight” pegs or posts are generally considered to be the simplest method for identifying transverse displacement, or slide. This type of simple monitoring is considered essential during the construction of floating sections of road to monitor stability but can also be useful in the medium term to confirm that the works continue to remain stable.

Other, more expensive, monitoring arrangements include:

- Inclinometers
- GPS sensors
- Tiltmeters
- Wire extensometers
- Remote telemetry

These arrangements are described in the Scottish Executive's "Peat Landslide Hazard and Risk Assessments, Best Practice Guide for Proposed Electricity Generation Developments" report (2006).

## 4.8. RECORD KEEPING

Good recordkeeping can bring significant benefits to floating roads projects. Settlement records can confirm that the construction is proceeding as planned and the correct level of consolidation is being achieved. Records from previous projects can be similarly beneficial as a bank of knowledge in highlighting lessons learned from previous projects.

Data gathered during a project is seldom "single-use". Well recorded data can be utilized in many ways for many years not only in the design of the road but also in the performance management of the completed road and its service life. With good monitoring and record keeping data can be used as a reference source, increasing the background knowledge base for future works. Contributors recommended that records should be kept of all construction, inspection and maintenance activities on floating roads to control the works better and inform future projects. Types of records recommended included:

### **Construction records**

Copies of drawings, specifications, construction (i.e. "as built"), and monitoring records should be retained centrally, particularly if they differ from the design. Good information is invariably required at a later date. Information on local peat deposits, peat characteristics, settlement behaviour can also be useful in increasing the base of peat behavioral knowledge for future projects.

### **Inspection and maintenance records**

Feedback from site in the form of inspection and maintenance records can offer worthwhile information for future projects and risk management. These types of records monitor the performance of the road and as such are invaluable in confirming the adequacy, or otherwise, of designs and installation practices. Ideally these records should, as a minimum, take the form of:

- date of inspection/maintenance and the name and professional status of the person carrying it out;
- description of the problem;
- sketch plans, sketches and photographs to indicate location and condition;
- condition of the road and any matters of concern work done and result.

## 5. CHARACTERISATION OF GROUND CONDITIONS

As already mentioned in Section 3 a basic characterisation of the in situ peat along the line of the road should always be carried out before embarking on a floating construction. This characterisation need not be extensive or expensive but should be done in all cases, and always with suitably qualified professionals with experience of construction on peat. The investigations carried out for peatslide stability assessment in the planning stage usually provide a good starting point but these will normally require to be extended to provide the detailed information on the final alignment as it becomes known.

The basics of the site investigation for the design process are essentially similar to those set out in Section 4 to inform planning, i.e.

- Desk study - continuing the desk study commenced in the feasibility study
- Walkover and ground verification - updating the previous work
- Ground investigation and sampling – additional investigation and specific sampling
- Analysis

Guidance on these stages is given in The Scottish Executive's "Peat Landslide Hazard and Risk Assessments, Best Practice Guide for Proposed Electricity Generation Developments" (2006).

All site investigations commissioned should however have an aim, and should not be carried out just to 'tick the boxes'. Only those investigations that are actually necessary to provide the design information should be considered. The sections that follow offer guidance on suitable investigation strategies for wind farm road layouts with floating roads sections.

### 5.1. SITE INVESTIGATION (BS5930)

Site investigation, like the design process, is never a single activity. It is normally an iterative procedure that runs through planning and design until all relevant information has been collected and assessed. It may be that new information will cause old information to be re-investigated and for this reason it is important that investigations should run their course until sufficient information has been gathered to inform adequately the design and address the ground risks identified.

The generally recognised site investigation methods for floating roads on peat are set out in Table 5.1.

Survey Method	Description	Comment
Desk study	Office based research into local maps, aerial photography, records, reports, network defects, maintenance histories as well as similar local projects, local peat properties, results of projects, etc.	Initial background research for the project to gather all relevant records together to enable project planning. <b>Essential</b>
Site Visit, Walkover and Ground Verification	Visual inspection of the site by an experienced engineer with experience of construction involving peat. Looking at the surface features of the site, the presence of any ditches, watercourses, incipient or historical erosion features, subsurface pipes, surface topography, peat workings, waterlogged areas, areas of free water, etc.	Practical, low cost survey to "ground truth" and inform the Desk Study to get an improved understanding of the site and the difficulties it presents. <b>Essential</b>
Probing	Steel rods pushed into the peat to establish the depth of the peat. Some form of probing exercise will be necessary in every project involving peat.	A simple, robust method for determining the depth of a peat deposit. In experienced hands it can also give a simple indication of peat characteristics (water content and shear strength). <b>Essential</b>
Groundwater wells	Hand driven wells at selected sites on floating road sections to assess the permeability of the peat so possible extent of dewatering / drying can be quantified.	Simple low cost method that is becoming increasingly requested by SEPA <b>Recommended</b>



**Table 5.1 Common site investigation methods for floating roads on peat**

The first two methods in the Table, the desk study and site visit, may appear at first reading to be simple exercises that can be omitted when funding is limited, but this would be wholly wrong. Desk studies and fieldwork are essential pre-requisites in gathering relevant data on peat distribution, depths and topographic characteristics.

The desk study can produce invaluable information on what has gone before, such as road maintenance histories, aerial photography (from the National Collection of Aerial Photography held at RCAHMS), topographic mapping, digital terrain models, records of similar local works, geology (from BGS), soils records (from the Macaulay Institute), previous ground investigations, peat properties, availability of materials, etc. This is vital to the designer if lessons are to be learned from past experiences.

The site walkover and ground verification process has a similarly vital role to play in checking how the actual conditions on the ground compare with the information discovered during the desk study. This practical “ground truthing” exercise in the site investigation process must be carried out by personnel experienced in the interpretation of peat features and how they can influence design. For example, a change in vegetation can indicate changes in hydrology to an experienced eye. Good advice on the things to look out for in a walkover is contained in “Guidelines for the Risk Management of Peat Slips on the Construction of Low Volume/Low Cost Roads over Peat” (MacCulloch 2006). Recommendations on what a site walkover should record include

- Peat depth
- Side slope angle
- Convexity of Slope
- Surface Hydrology
- Sub-surface Hydrology and permeability
- Habitat/ecology
- Previous Instability
- Cracking
- Peat Workings
- Peat Classification

The site walkover is also a good opportunity of assessing if a potential failure would be localised or trigger a domino effect of further, and possibly larger, peatslides.

Both the desk study and site walkover are vital precursors to the ground investigation and subsequent analysis of the site. Too often hard pressed engineers are tempted to omit these elements on the grounds of economy and speed. This is always a mistake. All forms of records, good and bad, add to the knowledge base for the project and they can also often trigger possible solutions if designers are sufficiently aware and open-minded.

## 5.2. GROUND INVESTIGATION

Ground investigation will by necessity be tailored to the specific site and professional advice should be sought to identify the most appropriate strategy. It will however usually involve some of the following:

Survey Method	Description	Comment
Probing (as above)	Steel rods pushed into the peat to establish depth. Some form of probing exercise will be necessary in every project involving peat.	A simple, robust method for determining the depth of a peat deposit or as a calibration exercise for a non invasive survey method such as GPR. <b>Essential</b>
Sampling	Invasive ground investigations such as trial pits, piston sampler, auger, window sampling, etc for obtaining physical samples for use in determining the	Hand dug trial pits can pose health & safety risks but they can allow an indication of water flows within the peat. Window sampling can provide a less risky alternative. Coring & sampling can

	thicknesses and properties of the road structure and subgrade.	also provide useful data to calibrate and supplement other methods. <b>Some sampling recommended</b>
Penetration Testing	Similar to probing but with the probe measuring the relative stiffness and strengths of the layers that it passes through.	Can be a very useful test when there are layers of peat and other materials below the road. <b>Useful information for the design if the budget is available.</b>
Shear vane	Invasive technique to obtain a measure of the shear strength of soils, especially clay. Usually measured at a range of depths. Vane sizes in peat normally range from 200mm x 100mm to 100mm x 50mm. The vane rod should be sleeved to eliminate rod friction effects	Can give an indication of in situ shear strength but results should be used with caution and not relied upon. Some authorities (Landva, 1980) state that the results can be misleading in peat. <b>Use with caution.</b>
Ball penetrometer	A relatively new method of measuring shear strength similar to the shear vane but without its disadvantages in fibrous peat.	A new method that could advance the ground investigation in peat. <b>Worth a trial to advance the technology.</b>
Mexecone penetrometer (aka Farnell Penetrometer)	A lightweight hand held penetrometer which can give an indication of in-situ penetration resistance of a soil and its CBR value direct from a dial.	The equipment is simple to use and gives its results quickly. Limited to 600mm deep without extension pieces. <b>Useful for an indication of CBR for geogrid design.</b>
Ground Penetrating Radar, GPR	Increasingly used non invasive method for peatland surveys, particularly useful for establishing the thickness of the existing road layers and soils depths prior to widening and strengthening.	Radargrams can show clear boundaries between the road, underlying peat and rockhead and can be used to monitor the long term behaviour of the road with good accuracy. <b>Recommended for existing roads</b>
Groundwater wells	Hand driven wells at selected sites on floating road sections to assess the permeability of the peat so possible extent of dewatering / drying can be quantified.	Simple low cost method that is becoming increasingly requested by SEPA <b>Recommended</b>

**Table 5.2 Common ground investigation methods for floating roads on peat**

It will not normally be cost-effective to use all of the methods listed in Table 5.2. Usually a combination of methods will be selected for a particular site to ensure that all of the relevant information is collected. It is, however, vitally important that the appropriate information is gathered on which to base a design and that conservative values are selected for peat properties, particularly the undrained shear strength. All should be given a suitably cautious value to reflect:

- variability in the peat;
- variability in the underlying substrate;
- variability in the groundwater conditions;
- variability in the basal slope;
- non-uniform loading;
- transient dynamic machine loading;
- unforeseen effects, e.g. adjacent tree felling, erection of power lines, cable trenches, etc.

The Good Practice Guidance (2010) recommends that *“A suitably qualified professional engineering geologist / geotechnical engineer will be able to advise on appropriate methods of ground investigation. This may include (but not be limited to), peat probing, trial pitting, boreholes, geophysics and appropriate sampling and laboratory testing and reporting”*.

The extent and frequency of any ground investigation works will by necessity be dependent on the particular circumstances at each site but, as an example, Forestry Civil Engineering recommend that probing is carried out at 50m centres along the planned road alignment unless local conditions warrant closer intervals. A typical case for a closer spacing would be sections where the local hydrology visibly changes. Further details on ground investigation methods can be found in The Scottish Executive’s “Peat Landslide Hazard and Risk Assessments, Best Practice Guide for Proposed Electricity Generation Developments” (2006).

## **Sampling and testing**

As with site investigation generally, all sampling and testing commissioned should have a purpose and not just be undertaken to create data. Any sampling should be appropriate for the design being considered and any testing done should be necessary for the design process. Common sampling and testing strategies include:

- Depth of peat by probing and/or ground penetrating radar. (Contributors considered probing particularly useful to inform the road alignment.)
- Peat and stratigraphy from sampling by screw auger. The stratigraphy of a peat deposit is a direct consequence of its development and as such can be expected to be highly variable. Any sampling strategy will require to be flexible enough to react to the information revealed.
- Bulk density, shear strength and water content from undisturbed samples if possible. Undisturbed in situ tests were considered to be better than laboratory tests on disturbed samples. It can often be difficult to get accurate or meaningful results from tests on peat and all test results should be treated with care. Shear strength at depth was considered to be useful for determining road alignment.

Changes in parameters between summer and winter were not thought to be significant especially if groundwater levels were unaffected. (This can be confirmed by a number of hand driven ground water wells at selected locations.) The frequency of probing was considered to be site specific, with more probing being better than less. A strategy of probing every 50m on average was suggested, with closer intervals depending on circumstances and infrastructure.

## **Laboratory testing**

Laboratory testing can be carried out to supplement site sampling and testing where deemed necessary but, as with site sampling and testing, these should have a purpose and not just be undertaken to create data. Typical laboratory tests on undisturbed piston samples and block samples include:

- water content
- organic content
- laboratory vane testing
- direct simple shear tests

Peat however is a highly variable material and the values derived from a limited number of laboratory tests should be treated with caution and only considered as indications of in situ properties, not as definitive values.

## 6. DESIGN OF FLOATING ROADS

### 6.1. INTRODUCTION

Most modern floating wind farm roads are usually designed as stabilised haul roads with one or two layers of geogrid depending on the particular site circumstances and the geogrid selected. The main benefit of inclusion of a geogrid is that the overall thickness of the road structure can be significantly reduced whilst retaining the load spreading capabilities of the road. This has a number of environmental and engineering advantages not least in the reduced effects of the floating road on the peat due to its lighter weight. Benefits cited include:

- Road construction thickness can be reduced by more than 50% compared with a road on peat without geogrids. This can result in a reduction in the amount of fill that needs to be won and transported. This reduces fuel use, noise, dust and other pollutants associated with heavy plant operations;
- Although the use of geogrids will not eliminate settlement, the fact that the road is thinner will mean that the road is lighter and that settlement will be less than an equivalent road without geogrids ;
- The installation of a geogrid can reduce differential settlement through spreading loads and creating a more even distribution of pressures across the peat surface. This can result in an improved performance of the finished road.
- Floating roads can usually be expected to cause less compression of the underlying peat and thus have a lesser effect on the hydrology of the site. This is not always the case however and can depend on the thickness of peat being floated over. Thin peat deposits (< 1m) can compress significantly, particularly as much of this form of peat can be acrotelmic and highly compressible, which can have a significant adverse impact on hydrology;
- By maintaining the surface layer of vegetation, it is arguable that the basic ecology of the site will not be affected to the same degree as would occur if traditional construction methods were adopted;
- The environmental impact of construction activities and traffic can be reduced due to the quantities of aggregate required;
- Lower carbon footprint than that of an equivalent excavated road, and less carbon released through excavation of the existing peatland.

Good practice in the design of a geogrid stabilised floating road over peat can be summarised in 6 stages:

1. carrying out an appropriate ground survey to characterise the local hydrology and peat;
2. identifying an appropriate value for the in situ peat strength;
3. estimating the expected traffic loading for the particular road section;
4. designing the road to suit the local conditions;
5. monitoring the work during construction;
6. recording all actions and outcomes for use in future projects.

Stages 1 and 2, the survey and analysis, can cost of the order of 1-3% of the total civil construction costs of a project, depending on the size of the works, and up to 5% of the total costs for very challenging projects. Contributors felt that this was money well spent if it resulted in the formulation of a good solution. Their general view was that sufficient resources should always be allocated to the site investigation and analysis to enable a sound determination of the specific circumstances at the particular site to be made.

### 6.2. DESIGN ASSUMPTIONS

The geotechnical design of a section of stabilised floating road will usually be based on a number of basic assumptions:

1. that peat gains in strength through consolidation and settlement under load (Section 3);

2. that the gain in strength of peat under the application of the first structural layer will be sufficient to create a working platform for the subsequent stages;
3. that the road can be designed for the expected level of construction traffic that will pass over it;
4. that it can be designed by calculation, or more usually by semi-empirical rules based on experience;
5. that the road will incorporate geogrid(s);
6. that the width of the road will be determined by stability requirements and the geometrical requirements of the in-service traffic;
7. that the rutting on the road will be limited to a maximum rut depth of 100mm.

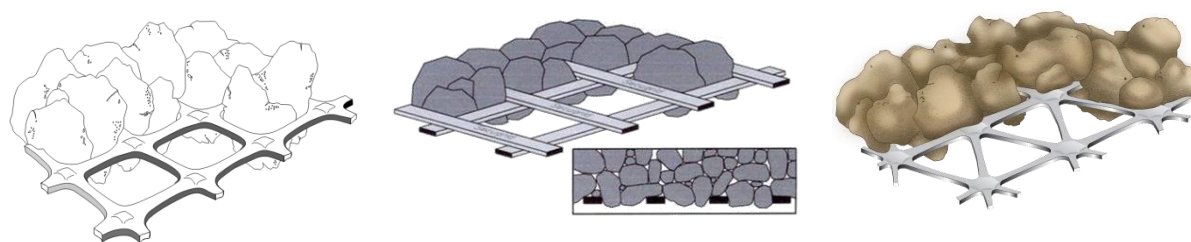
### 6.3. GEOGRIDS AND INTERLOCK

A wide range of geogrids are available on the market today from a host of manufacturers in different materials and formats. All however should comply with BS EN 13249 : 2001 “Geotextiles and geotextile-related products - Characteristics required for use in the construction of roads and other trafficked areas (excluding railways and asphalt inclusion)”. In addition, from 2010, it is likely that geogrid products in the UK will also be required to carry the CE marking of the Construction Products Directive. This will not be an onerous requirement as most of the main geogrid manufacturers already comply with both. An important aspect of the CE marking is that manufacturers will have to provide technical information on their products in the form of declared values when delivering products to the project.

The types of geogrids currently available today include (Giroud, 2009):

- woven geogrids, i.e. geogrids that consist of two sets of perpendicular woven ribs or yarns (often made of stretched polyester fibres) coated with a protective polymer (e.g. PVC or based on PVC);
- welded geogrids, i.e. geogrids that consist of two sets of perpendicular straps (also called “flat bars”), typically made of stretched polyester, welded at their junctions; and
- extruded geogrids which are monolithic structures that consist of two sets of perpendicular ribs typically made of drawn polyethylene or polypropylene. The term “extruded” is shorthand for ‘extruded-punched-drawn’, as these geogrids are, in fact, produced by extrusion, punching and drawing.

This wide variety of geogrids results in a wide variety of material properties and modes of interaction with soils and aggregates but all essentially work on the principle of interlock with the road base aggregates. When a load is applied to the interlocking system the stabilising mechanism is established. Two mechanisms recognised for this are lateral confinement and “tensioned membrane”. Some manufacturer’s schematics of geogrids and aggregate interlock are shown in Figure 6.1 following.



**Fig 6.1 Diagrams of typical geogrids and interlock**

In a normal road construction roadstone aggregates are very effective in compression but not good at resisting tensile forces. A geogrid on the other hand is excellent at resisting tensile forces and dealing with tensile effects.

Tensile forces in floating roads occur in response to dynamic traffic loads, settlement and differential settlement. Where this happens, an interaction occurs between the geogrid and aggregate by which the geogrid intercepts the developing strains through the interlock process and distributes them to maintain the integrity of the base of the construction. In effect the aggregates lock into the apertures of the geogrid and form a composite mechanically stabilised layer with the geogrid. This creates an increased stiffness in the

geogrid and helps to distribute the loads over a wider area than that of a road without geogrids. A geogrid stabilised floating road does not eliminate settlement but the geogrid makes it better able to distribute the loadings across the width of the geogrid and as such helps to reduce differential settlement over weaker areas.

The key to achieving effective interlock with a geogrid is having the correct size and shape of aggregate relative to the geogrid being used. This will depend, among other factors, on the relative geometry of the geogrid and the aggregate, i.e. the relationship between the shape of the geogrid apertures and the arrangement of the aggregate particles. The factors that govern the interlocking between the geogrid and aggregate are stated by Giroud (2009) as:

- the geogrid aperture size relative to aggregate size and grading,
- the geogrid aperture shape,
- the shape and stiffness of ribs, and
- the stiffness (more than strength) of junction between ribs

Ideally, there should be such an intimate match between the geogrid and the aggregate that an interlocked “composite layer” is created. Round gravels, moraines and large stones are not therefore generally suitable for use in the interlock layer. “As dug” material may be suitable for use in the interlock area provided that it is sufficiently well graded and angular to produce interlock.

The effectiveness of the interlock layers is also heavily reliant on direct trafficking of the layers by the construction vehicles. Where it is correctly controlled, construction traffic can compact the aggregate stones together and force the angular shapes into the geogrid apertures. This creates the interlock with the geogrid and the stabilising effects within the aggregate layer. The stabilising effect between the aggregate and the geogrid usually diminishes at around 450mm using typical well graded fill materials and this depth is normally taken as the limiting thickness of a road construction layer before another geogrid is required. A 450mm thick initial layer is also normally considered to provide a good intermediate working platform for construction traffic.

It is considered that a system of two geogrids can produce a stiffer road structure than that of a single geogrid and this can help to minimise differential settlement across the peat. The ground penetrating radar cross-sections in Appendix 5 appear to confirm the presence of a “stiff layer” in the floating roads surveyed but further research will be needed before this can be confirmed with any degree of confidence.

A separator grade geotextile can additionally be beneficially used where there is a chance of fine material getting into the aggregate layer, e.g. areas without vegetation cover, or an aggregate layer of open graded material. Fines from the subgrade soil can reduce the effectiveness of the geogrid/aggregate interlock and consequently affect the performance of the finished road. Contributors considered that soils with a fines content >15% should be considered as a fine material and treated with a separator geotextile. It is worth noting here that the aggregates used in the top layers of the road should probably be assessed to ensure that they do not generate fines under trafficking that could subsequently be washed into sensitive water courses.

## 6.4. CONSTRUCTION TRAFFIC

Traffic flow has a direct impact on the design of a floating road and a well prepared traffic management plan will help to identify the loads to be expected and their timing. This is a particularly important consideration for floating road sections as their final design and performance will be heavily dependent on an accurate assessment of the construction traffic that will use the road. A floating road is constructed in stages and the first stage, the working platform, has to be sufficiently robust to cater for the construction traffic that builds it. A good traffic management plan should include details of all traffic expected over the course of the wind farm development. This should include:

- construction vehicles during the construction of the roads;
- construction vehicles after the construction of the roads;
- heavy lift construction plant and infrastructure components;

- static loads of specific heavy lift construction plant;
- general maintenance vehicles after the construction of the roads;
- heavy lift maintenance vehicles after the construction of the roads;
- any forestry or other land use requirements after construction;
- the potential for wind farm extension and any additional loadings that this may produce on the road infrastructure;
- the likely loadings of the future decommissioning stage of the wind farm.

Of these, the construction haulage vehicles can be expected to have the most damaging effect on the road even though the turbine delivery vehicles and craneage can generally be substantially heavier.

## 6.5. ROAD DESIGN WITH GEOGRIDS

In the normal course of events a floating road section will be designed by the geogrid manufacturer, or by a consultant assisted by the geogrid manufacturer. It can also be designed in-house by a contractor with experience in road construction over peat. Whichever organisation carries out the design however it must have a geotechnical input to fully understand the principles at work in the floating road. This aspect is particularly important when designing and constructing a floating road over sidelong ground to ensure that the geotechnical issues are sufficiently addressed. The liability for the design will rest with the designer.

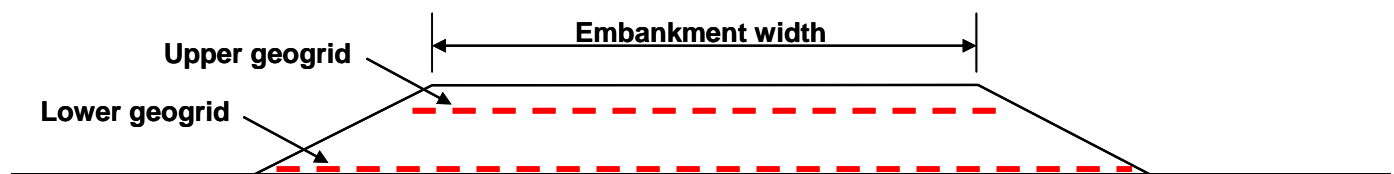


Figure 6.2 Typical stabilised floating road cross-section with geogrids

Different manufacturers/consultants/contractors will use different design methodologies to arrive at their recommendations but most will base their design on the shear strength of the peat, the weight of the floating road, and the traffic that will pass over it. Design can be by calculation or, more usually by the application of semi-empirical rules based on experience. EN 1997 (Geotechnical Design).

In the normal course of events the total expected traffic will be reduced to an estimated number of 8 tonne “standard axles” that will pass over the road. In this, axle loads greater than 8 tonnes are reduced to 8 tonne equivalents using the “fourth power rule” of  $N = (W/8)^4$ , where “W” is the axle load and “N” is the number of equivalent 8 tonne axles. For example a typical Volvo A30E dump truck has a front axle load of approximately 15.0 tonnes and a rear (two axles) load of 36.1 tonnes when travelling loaded, and a 12.5 tonnes front axle and 10.6 tonnes rear load when unloaded. This equates to approximately 70.5 standard axles of 8 tonnes for a typical return haul journey of loaded/unloaded, excluding dynamic effects:

### Equivalent axles

$$\begin{aligned}
 &= [\text{loaded journey axles}] + [\text{unloaded journey axles}] \\
 &= [(15/8)^4 + (18.05/8)^4 + (18.05/8)^4] + [(12.5/8)^4 + (5.3/8)^4 + (5.3/8)^4] \\
 &= [12.4 + 25.9 + 25.9] + [6.0 + 0.2 + 0.2] = 70.5 \text{ axles}
 \end{aligned}$$

In floating road design it is normal to design each section of road in the wind farm layout for its own particular traffic loading and ground conditions. In this the traffic loading will be dependent on:

- The road layout of the wind farm
- The location of any borrow pits or stockpiles
- The planned construction sequence
- The construction traffic flows

The road construction traffic flow is invariably the dominant consideration in the loading analysis as it creates higher traffic flows than later operations and consequently has the potential to cause the greatest amount of damage. If the construction traffic flow is not adequately assessed in the design a “loop effect” can be inadvertently created during the works on site where the road construction is insufficient for the traffic needed to build it:

- insufficient road design
- weak construction
- greater fill material needed
- more vehicle movements required for haulage
- greater traffic on the road
- deeper construction required
- more fill material needed, and so on.

This is particularly critical in the initial placement of aggregate on to the geogrid to form the first working platform on the peat. An insufficient geogrid at this stage could rupture and tear under loading causing failure of the final road structure. It is therefore important to get the road section design “right first time” so that it is sufficient at all stages of construction for the level of traffic that will use it.

A typical spreadsheet showing the process for a multi-road wind farm development, based on the estimated traffic flow and CBR of the peat, is shown in Table 6.1 below.

Road Section	CBR	Axle Passes for access construction	Approximate visits	Lower grid	Thickness A	Upper grid	Thickness B	Total Thickness
<b>T47-T60</b>	<b>0.5</b>	60636	854	LG	450	UG	350	800
	<b>1.0</b>	49275	694	LG	450	UG	200	650
<b>T54-T58</b>	<b>0.5</b>	15620	220	LG	450	UG	225	675
	<b>1.0</b>	14981	211	LG	450	UG	200	650
<b>T48-T47</b>	<b>0.5</b>	9940	140	LG	450	UG	200	650
	<b>1.0</b>	6887	97	LG	450			450
<b>T55 Link</b>	<b>0.5</b>	7952	112	LG	450	UG	200	650
	<b>1.0</b>	5467	77	LG	450			450
<b>T34-T43</b>	<b>0.5</b>	71144	1002	LG	450	UG	350	800
	<b>1.0</b>	57796	814	LG	450	UG	200	650
<b>T27-T40</b>	<b>0.5</b>	60210	848	LG	450	UG	350	800
	<b>1.0</b>	48920	689	LG	450	UG	200	650
<b>T5-Junc T33</b>	<b>0.5</b>	75617	1065	LG	450	UG	350	800
	<b>1.0</b>	61448	865	LG	450	UG	200	650
<b>Spurs</b>	<b>0.5</b>	16685	235	LG	450	UG	235	685
	<b>1.0</b>	15833	223	LG	450	UG	200	650
<b>Widening</b>	<b>0.5</b>			LG	450	UG	350	800
	<b>1.0</b>			LG	450	UG	250	700

**Table 6.1 Example of a geogrid design spreadsheet for wind farm road sections based on haulage by Volvo A30E dump trucks**

**CBR = “California Bearing Ratio”, a measure of the in situ stiffness of peat used by a number of designers in the UK**



Examples of typical recommended geogrid arrangements from geogrid manufacturers are shown below:

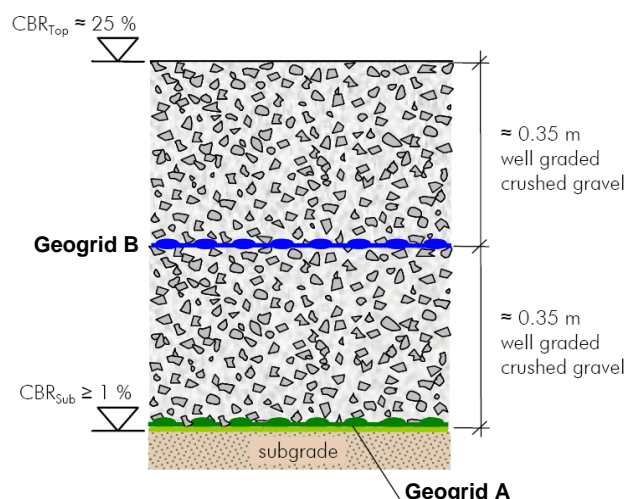


Fig 6.3 Geogrid Manufacturer A

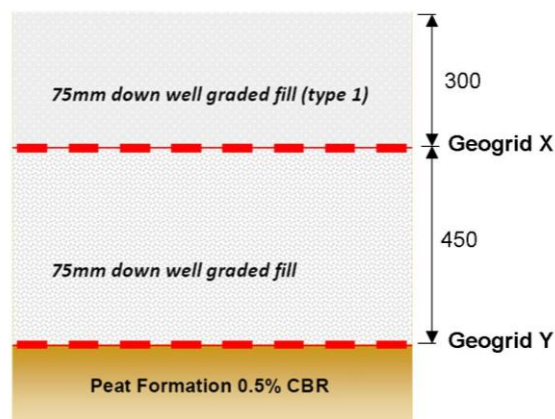


Fig 6.4 Geogrid manufacturer B

## 6.6. TRAFFICKING

The newly installed geogrid should be trafficked carefully during and after construction to avoid unnecessary damage. In particular:

- The road should be trafficked gently to minimise dynamic loadings such as cornering, braking, accelerating
- Wheel loads should be contained within the width of the geogrid, preferably at least 500mm away from the edge of the geogrid. Marker pins should be used to delineate the width of the safe running zone where the upper layer of geogrid does not extend to the full finished road width. Care should be taken reversing vehicles to ensure that they stay within the geogrid.

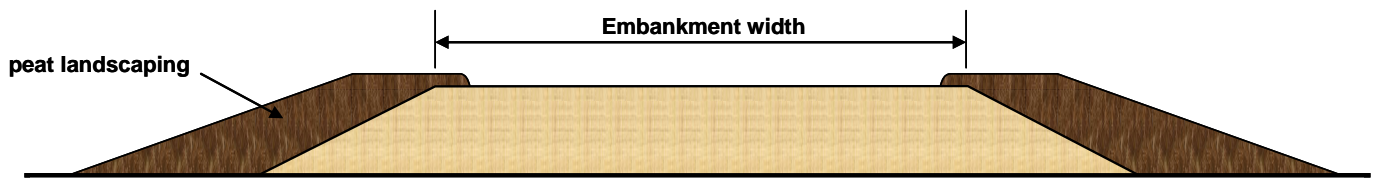
## 6.7. DESIGN DETAILS

The following design details are offered as examples of good practice:

- Verges/landscaping
- Transitions from floating to excavated
- Transitions at hardstandings
- Dealing with forestry furrows
- Sloping surfaces

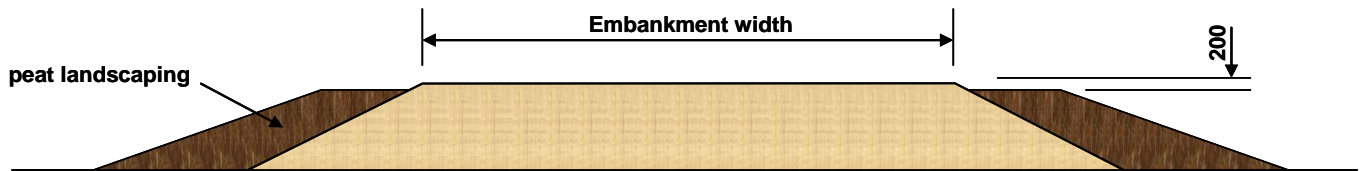
### Verges/landscaping

The provision of verges and landscaping can offer a useful opportunity to utilise sensitively surplus peat arisings from excavations on the site. Care should be taken however when placing this material so as not to over-deposit arisings to the detriment of the Works. For example, the provision of high verges can prevent surface water from immediately draining off the road and this can create local ponding on the road which can infiltrate the road and weaken its construction.



**Fig 6.5** Example of over-depositing peat in high verges and landscaping preventing water draining off the road

A better solution is to construct low verges on the sides of the road to permit any surface water to drain naturally, and diffusely, where it arises.



**Fig 6.6** Recommended low verges and landscaping to permit surface water to drain off the road

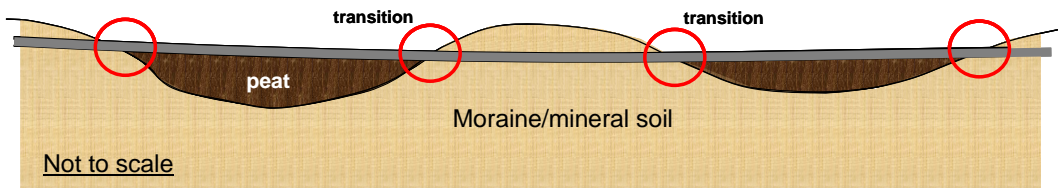


**Fig 6.7** Photograph of a low verge and landscaping permitting surface water to drain off the road

These types of verges may also be suitable locations for burying cables to avoid excavating cable trenches in virgin material. If this is being planned the verges should be constructed wider to accommodate the cabling. Cabling in verges is not however recommended for forest roads unless they are capable of supporting wheel loads of 50kN.

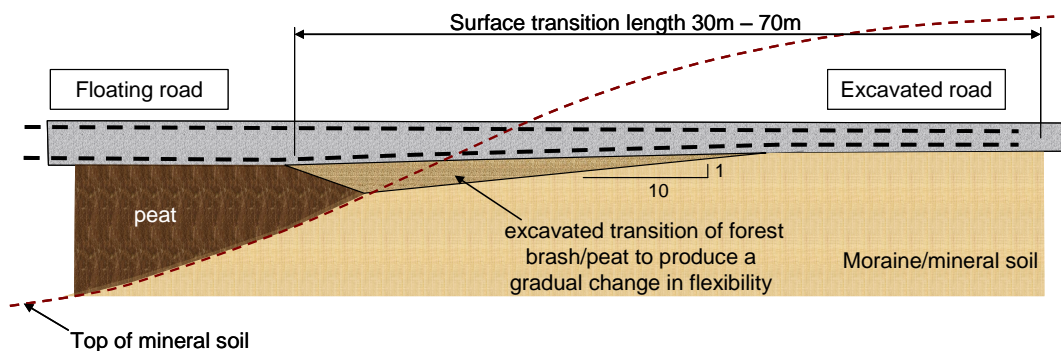
### **Transitions from floating road to excavated construction**

A typical wind farm is likely to have a range of road construction solutions and the transitions between the different types of construction need to be addressed to avoid sharp changes in road surface conditions. This is especially the case for the transition between a floating road section and a road section constructed on a firm foundation. This transition needs to cater for the substantial change in flexibility of the respective structures. For this reason it will not always be appropriate to follow the perceived 'rules' on whether to float or excavate.



**Fig 6.8 Longitudinal section through floating road sections**

Good practice for a transition to or from peat is to create a transition length at the change in construction character that permits a gradual change in the stiffness of the road construction, rather than a quick change from hard to soft, or vice-versa. A typical way of achieving this is by the provision of a basal transition of compressible forest brash and/or peat arisings as shown in Figure 6.9.



**Fig 6.9 Transition detail between floating and excavated construction.**

The length of the transition on the surface of the road will be determined by the specific conditions at the particular site and the configuration of the delivery vehicles involved, but a basal transition slope of 1:10 would appear to constitute good practice to produce a gradual change in subgrade flexibility. This may necessitate some overblasting at the entry to rock cut sections. The geogrid of the floating road should be run on to the sound material by at least 5m to assure continuity.

### Transitions at hardstandings

Floating roads adjacent to hardstandings pose their own problems depending on the construction of the hardstanding. In the usual case of a floating road leading to a hardstanding constructed to a firm layer good practice would be to construct the access road to a similar fashion to avoid possible differential settlements. In this case suitable transitions should be constructed on the approaches to the combined hardstanding/road.

### Dealing with forestry furrows

Constructing a floating road on a peatland that has been previously forested and cleared of trees poses its own difficulties in overcoming the irregular shape of the former forest floor and the presence of tree stumps. A common solution for this is to place a brash mat of forest materials across the forest floor to create an even surface on which to lay the initial geogrid.



Fig 6.10 Photograph of typical clear felled forest

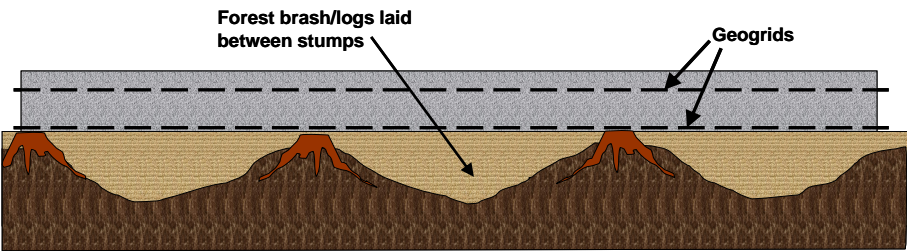


Fig 6.11 Brash mat laid between tree stumps on felled forest

Care should be taken however when overlaying stumps to ensure that the stumps are sufficiently covered as tracking of machines over exposed stumps can impose significant point loads into the underlying peat. This aspect should be taken account of in any assessment of loading conditions.

### Sloping surfaces

The construction of a floating road on sloping ground, longitudinal or transverse, poses its own particular geotechnical problems that should be addressed by a suitably qualified professional civil engineer/engineering geologist/geotechnical engineer. This should include stability checks of the completed floating road under all expected loading conditions with appropriate factors of safety that reflect the risk tolerance of the Developer/Client.

A practical problem in constructing a floating road on sidelong ground is the effect of the slope and how it affects the local road thickness. If this is underestimated the uphill side of the road may be too thin, with insufficient aggregate, causing rutting to develop. If constructed too thickly, there is a similar potential for the downhill side to be made too thick with insufficient geogrid layers causing consolidation and settlement in the aggregate. Good practice in this situation is to design the road and geogrid for the uphill wheel path as shown in Figure 6.12 below and include an intermediate geogrid if the downhill depth becomes excessive. It is not usual to construct floating roads on slopes greater than 5%.

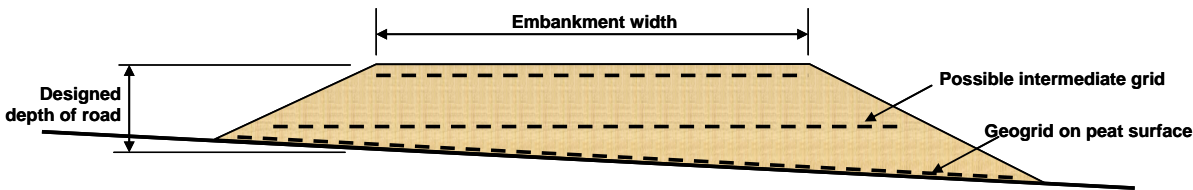


Fig 6.12 Floating road on a sidelong sloping surface

## 6.8. STABILITY ISSUES

There are a number of important stability issues that need to be considered in the design of floating roads over peat that are outwith the scope of this report. They include:

- the overall stability of the finished road and its expected loading conditions. These considerations should include all stages of the construction process from first layer through to the completed structure together with any live loadings from expected traffic;
- the effects of unexpected stationary loads, such as the breakdown of a heavy vehicle or crane
- the risk of peat slide

All of these stability issues should be addressed by a suitably qualified professional civil engineer/engineering geologist/geotechnical engineer.

## 6.9. USING AND UPGRADING EXISTING FLOATING ROADS

### Basic considerations

A basic rule when using or upgrading an existing road over peat is not to do any work to the existing road/peat balance that would cause the existing equilibrium to be destabilized. This means adding layers, load, or lowering the ground water table.

The peat below an existing road on peat, even one that has settlement problems, can normally be expected to have been loaded over a period of time and will have increased in strength to support the general weight of the road. This increase in strength can be used to advantage when planning to use the road, provided that nothing is done that will cause further settlement being triggered, unless by deliberate design where the consequences are known and accepted.

This is not always easy to achieve in practice as each project brings its own problems of traffic management, construction sequences, disruption, and others. It may be that on some sites minor modifications of the existing road will not be possible and that the design will have to add layers to the road. In these cases the additional load will have to be accepted, but its effects on the equilibrium of the existing road/peat arrangement should be understood and expected in advance.

In the normal course of events a position of equilibrium quickly builds up between a road structure and the underlying peat whereby the peat gains sufficient strength through the release of porewater to support the weight of the road. Any application of new load once this equilibrium has been established will cause a further disturbance that will restart the consolidation and settlement process over again.

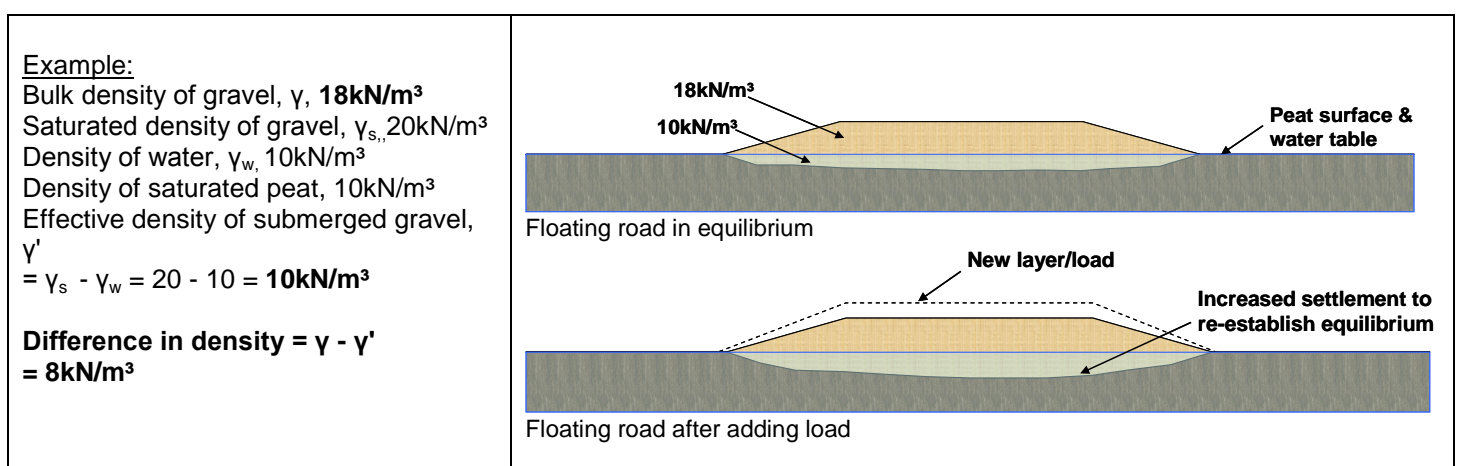


Figure 6.13 Effect of adding load to a floating road (after Carlsten, 1988)



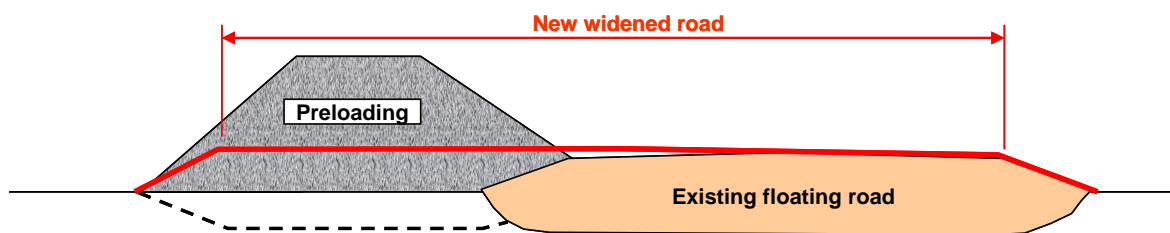
## Widening

There are two generally accepted methods of widening a floating road on peat: (a) by preloading, and (b) by using geogrids.

### (a) Widening by preloading

Widening of a floating road over peat by preloading is unusual on wind farm developments but it can be done. In this the area to be widening is surcharged over time with a controlled loading in excess of the weight of the final floating road. When the surcharged area has been sufficiently consolidated, and reached a strength equal to that below the existing road, the excess material is removed to leave the widened area in place. A description of the process is contained in the ROADDEX report “Dealing with Bearing Capacity Problems on Low Volume Roads Constructed on Peat” (Munro 2004).

An example of a widening from Sweden discussed in the ROADDEX report is shown in Figures 6.14 and 6.15 below.



*Figure 6.14 Widening of a floating road by preloading*

A photograph of the preloading in place during the strengthening period is shown in Figure 6.15.



**Figure 6.15 Widening by preloading on a public road over peat in Sweden**

As with the construction of a new floating road, the basic rule when using or upgrading an existing road over peat is not to do any work that would disturb the existing road/peat equilibrium. The main problem that can arise in this is not having sufficient time to construct the works slowly enough to bring the adjacent bog up to a strength equal to the peat below the road. A preloading exercise can take around 90 to 100 days to be effective. This is not always possible in the tight timescale of a wind farm development.

### (b) Widening using geogrids

An alternative method to preloading, or a method that can be used in combination with it, is a widening using geogrids as shown in Figure 6.16.

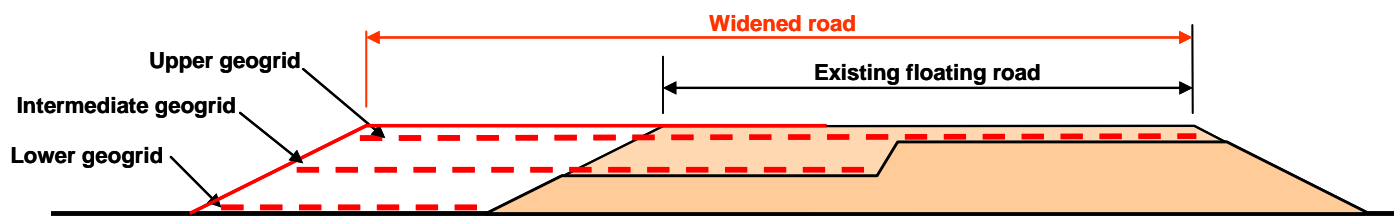


Figure 6.16 Widening of a floating road using geogrids

In this the existing floating road is cut back to approximately half its width and a 3 layer geogrid arrangement installed:

- on the surface of the widening to provide the initial interlock layer;
- at mid level to provide a form of reinforcement between the new and the old;
- 100mm below the final running surface to limit differential settlement.

This method can have the disadvantage that the widened area can settle differentially relative to the exiting road. This may not be a bad thing if the settlement is limited and may only increase the crossfall across the widened area. Close monitoring is essential to ensure that this is controlled.

## 6.10. TIMBER RAFT CONSTRUCTION (FCE METHOD)

Timber raft construction using local forest materials is the oldest method of strengthening haul roads over peat. The technology has been around for hundreds of years and involves laying a platform of natural reinforcing materials on the peatland surface to support and distribute the loads of the new road until such time as the underlying peat can gain sufficient strength to support the floating road on its own.

The most basic form of platform to date has been a 150mm-250mm thick mattress of brushwood laid directly on to the peatland. The design of this structure varies according to local tradition, and available timber resources, but essentially comprises a mat of branches (spruce or similar) to build up a carpet of vegetation capable of supporting the gravel fill without failure.

Protective mattresses can similarly been made using 'fascines' as structural members. In this method bundles of woody material are tied together to form bundles approximately 3m long and 150mm-250mm diameter. These are either simply laid alongside each other on the peatland surface or tied in a grillage at 1.2m centres and backfilled with brash.

The current Forestry Civil Engineering method for constructing a floating road section over peat using a timber raft is:

- Probe the roadline at approximately 50m intervals, (more often if circumstances warrant) and record the locations by GPS. These will be used to determine the sections of road which will be floated and which will require a timber mat.
- Fell timber just before use to preserve its moisture content;
- Prepare a formation 7-8m wide;
- Where necessary excavate intercepting ditches greater than 6.1m from the road centreline;
- Lift tree stumps outwith 5 metres of the centreline of the formation and place these inverted between undisturbed roots within the area of formation. Cover with all available brash to form an even mat and seal with a minimum of 300mm of suitable onsite material as a regulating layer for the geogrid. (The depth of the timber mat will vary depending on the quantity of timber and brash available from the roadline felling as all available brash is generally placed on the road. Additional timber should be brought in on those sections where it is felt that the mat is not providing suitable structural integrity.)
- Place a 40N geogrid on the prepared regulating layer.

- The optimal depth of rock is between 600mm and 1000mm however settlement on areas of poor quality peat will require additional depth of rock and geogrids. There may also be sections where the water content is so high and the fibrous structure of the peat is poor that it will not be possible to float the road. Where additional rock is required the depths will be recorded.
- On completion of the roads by the contractor FCE will survey the finished roads using ground penetrating radar to provide a vertical profile of the construction of the road.
- The above method is recognised as an acceptable form of construction by geogrid manufacturers.



**Figure 6.17 Photographs of the recommended FCE method for timber raft construction**



## 7. CONSTRUCTION OF FLOATING ROADS

### 7.1. INTRODUCTION

The construction process for a floating road with geogrids is now a fairly well understood operation with a long pedigree that, when executed correctly, can result in a sound floating structure capable of supporting all of the loads likely to be generated by a wind farm development.

A typical peatland does not have a flat, even surface however and invariably has undulations and hollows as well as variations in topography. As a result of this a floating road will seldom have a uniform thickness, and where these variations are large the weight of the road can become an issue if not dealt with appropriately. An example of a possible way of dealing with these variations is given in Figure 6.10 in Chapter 6 for a previously forested area.

### 7.2. RATE OF CONSTRUCTION

Workshop No.1 considered the rate of construction for floating roads and concluded that a rate of 50m/day of road construction could be a good rate of progress in good weather, whereas 25m/day might be the best that could be achievable in poor weather. This rate assumes that the supply of aggregate is not a problem and that time is allowed in the programme to permit the peat to consolidate before loading again. A minimum distance of 50m was recommended between the placing of layers to avoid overloading the previous layer. But as with the construction of all roads over peat the key to a successful construction over peat is allowing sufficient time for the peat to gain strength, and keeping a focus on quality at all times.

Construction sequence

### 7.3. CONSTRUCTION SEQUENCE

The following construction sequence is an aggregation of good practice observations from Contributors to the Study and is taken from all sectors of the wind farm industry. The sequence has been deliberately written to be non-specific to any particular manufacturer or geogrid and is not intended to recommend a specific design solution.

#### 7.3.1. Site preparation

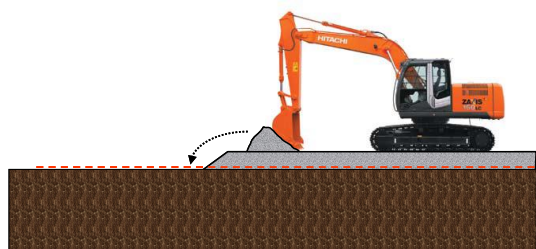
1. Mark out the line of road. Install advance drainage ahead of construction where necessary.
2. Clear the intended floating road area of major protrusions such as rocks, trees, bushes etc down to ground level leaving any residual stumps and roots in place.
3. Leave the local surface vegetation and soils in place if possible. In many cases the existing vegetation and root mat may be the strongest layer in the system and care should be taken to preserve this layer if at all possible. If the layer needs to be removed for any reason the characteristics of the exposed layer, and materials beneath, should be determined and used for design purposes.
4. Fill any local hollows and depressions with a suitable local lightweight fill such as tree brash, logs, or a combination of lightweight fill and suitable material. (Brash mats and fascines can also be used to form an initial surface on difficult ground.)
5. Broken vegetation surfaces, very wet areas, and areas with high fines contents may need to be covered with a separator grade geomembrane to prevent contamination of the aggregate layers. This geotextile may be covered with a thin regulating layer of aggregate prior to installing the main geogrid if considered necessary.

### 7.3.2. Placing the geogrids

6. Unroll the geogrid by hand along the line of the road directly on to the prepared area. (Geogrids can also be placed transverse to the road centre line if required without loss of effect. This practice is unusual in wind farm developments.)
7. Overlap adjacent geogrids with a simple overlapping arrangement to the manufacturer's instructions. The minimum transverse overlap is normally 400mm but this can be greater depending on the amount of displacement and transverse tension caused by uneven terrain. This should be confirmed with the geogrid manufacturer. Plastic ties can be used in extreme cases to aid placement but they do not add to the stabilising effect of the geogrids and should be ignored for the purposes of overlap strength. A minimum longitudinal overlap of 1m is considered normal.
8. Protect and maintain the overlaps during the construction of the road. This is normally achieved by careful spreading of the fill on to the geogrid to avoid damage to the geogrid. Additional control can be achieved by placing small heaps of fill locally over the overlaps of the geogrids ahead of the floating road construction, or by tying the geogrids with plastic ties.

### 7.3.3. Placing the aggregate and backfill

9. Place the first layer of material on to the geogrid. This should be a suitably sized "well graded material" that will be able to achieve a sound interlock with the geogrid. The grading of the material will be dependent on the geogrid aperture size and will be specified by the geogrid manufacturer.
10. Cascade the material carefully on to the geogrid to achieve the maximum possible interlock effect. (The recommended method of achieving this effect is to tip local stockpiles of suitable material on to the previously constructed section of road and carefully push this material forward from the constructed road, with a 360° excavator or dozer with an opening bucket, so that it tumbles, or cascades, on to the installed geogrid. Mechanical plant should not be permitted to traffic an exposed geogrid under any circumstances.) Alternatively the aggregate may be gently dropped from a low height on to the geogrid from a backhoe bucket. Under no circumstances should aggregate be dozed directly over the geogrid in thin layers. This may tear or damage the geogrid and render it useless.



**Fig 7.1 Pushed forward from stockpile**

**Fig 7.2 Dropped on to geogrid**

**Methods of "cascading" aggregate on to a geogrid to ensure interlock**

11. The first layer thickness should be at least 150mm thick. The actual thickness will depend on the level of trafficking expected. On very weak soils the initial layer may need to be of the order of 450mm in order to ensure sufficient traffickability to construct the remaining road layers.
12. Take care to avoid damage to the geogrids at all times.
13. Site plant should not be permitted to travel on the geogrids prior to placing the first interlock layer.

### 7.3.4. Compaction

14. Compact the placed layers in accordance with Clause 802 of the Specification for Highway Works. Vibratory compaction should not be used.
15. The degree of compaction applied to the lowest layer of fill may have to be reduced when dealing with exceptionally soft areas. It is common practice in such cases to compact the aggregate by trafficking it in by the wheels and tracks of the construction plant alone.

16. Similarly on very low CBR sites compaction of the lower layers by deadweight roller may not be possible. In this case the aggregate should be trafficked in by the wheels/tracks of the construction plant alone.

#### 7.3.5. Second and subsequent layers

17. Repeat steps 6 to 16 for the second and any subsequent layers.
18. Take care not to place the second layer too quickly after the first layer has been installed to allow time for the underlying peat to gain in strength. It is recommended that the second layer should not be started until there is sufficient length of first layer constructed to roll out a full length of geogrid for the second layer, i.e. a delay of 50m between the first and second layers. This delay is important as peat can exceed its shear strength and fail if it is loaded too quickly. It should also be appreciated that the first layer is usually only a temporary construction platform for construction traffic to build the road and as such will normally not be the full designed thickness of the road, so care should be taken here also not to rupture the first layer with extensive trafficking.
19. Stabilising effects between the geogrid and aggregate backfill usually diminish after 400-500mm and this depth should normally be taken as the limiting thickness of a backfill layer before another geogrid is required.

#### 7.3.6. General

20. The finished designed floating road may require a number of geogrids to be included within the floating road structure. If this is the case, it is essential that the specified design is fully adhered to and that the correct number and type of geogrids are installed at the correct levels in the road layers before heavy trafficking commences.
21. Where possible traffic should be requested to wander across the width of the running surface rather than take a single common path if the width of the running surface permits.
22. Heavy traffic loadings should be kept away from the road edges at all times. Wheel loads should be kept at least 500mm away from the edge of the upper geogrid layer on the finished floating road construction. If for any reason the road surface needs to be constructed wider than the extent of the upper layer of geogrid, a safe running zone should be marked out with marker posts on the finished carriageway to ensure that vehicles remain within the area of the installed geogrid.
23. Care should be taken when reversing vehicles on floating roads that they do not run along the edge of the road but stay within the delineated safe running zone.

## 8. DRAINAGE

### 8.1. INTRODUCTION

This section considers the elements of good drainage practice for floating roads on peat. General guidance on drainage considerations for wind farm developments, such as pre-earthworks, permanent drainage, culverts, headwalls, etc is given in the Good Practice website and is not re-stated here. This section deals solely with the particular drainage considerations and practices associated with floating roads.

This section will deal with:

- The preservation of the local hydrology
- SUDS
- The use of intercepting ditches
- Cross carriageway culverts
- Outfall ditches
- Existing drainage channels & peat pipes
- Springs and flushes
- Excavating ditches after construction

A typical peat deposit has two distinct hydrological zones with different characteristics: the rapid “flash” flow that can happen in the Acrotelm and the slow steady movement of water through the permanently waterlogged, low permeability, Catotelm. Good drainage design should consider both of these hydrological zones and accommodate their needs.

### 8.2. PRESERVATION OF LOCAL HYDROLOGY

The preservation of the local hydrology should always be the key consideration in the drainage arrangements associated with floating roads. The local hydrology not only supports the local ecology and habitat, it also has a great bearing on the engineering as well. The equilibrium between a floating road and the underlying peat will be heavily dependent on a stable local hydrology and the consequences of any drainage measure planned should be fully understood before it is implemented. Any new drainage has the potential to affect the existing water regime and the established equilibrium. The preferred option is to not to do anything that will disturb the existing balance.

### 8.3. SUDS

Paragraph 209 “Drainage and Culverts” of the new 2010 Scottish Planning Policy states:

*“The Water Environment (Controlled Activities) (Scotland) Regulations 2005 require all surface water from new development to be treated by a sustainable drainage system (SUDS) before it is discharged into the water environment, except for single houses or where the discharge will be into coastal water. The aim of SUDS is to mimic natural drainage, encourage infiltration and attenuate both hydraulic and pollutant impacts to minimal adverse impacts on people and the environment. Surface water drainage measures proposed as part of a planning application should have a neutral or better effect on the risk of flooding both on and off the site. Where flooding is an issue, SUDS should be designed to mitigate the adverse effects of a storm inflow into the watercourse or sewer. Local development plans should incorporate the legal requirement for SUDS, promote a coordinated approach to SUDS between new developments and set out expectations in relation to the long term maintenance of SUDS. Planning permission should not be granted unless the proposed arrangements for surface water drainage are adequate and appropriate long term maintenance arrangements will be in place.”*

All drainage works on floating roads should therefore comply with the requirements of SUDS.

## 8.4. THE USE OF INTERCEPTING DITCHES

Unlike standard road construction on firm ground, it will not always be necessary to provide intercepting ditches for floating roads. The first decision to be made when considering drainage associated with floating roads over peat is whether or not intercepting ditches are really needed.

In the normal course of events of a road crossing a flat peat bog the provision of intercepting ditches may not be necessary. A well designed floating road should be able to be constructed to stand above the bog and as a result any rain falling on to the bog and road should be contained within the bog as previously. A poorly designed road constructed in haste on the other hand will not have this certainty. It is likely to have uncontrolled settlement that can result in the finished road level ending lower than the adjacent ground level over time and the new road acting as an open land drain. This 'open drain' scenario has to be avoided.

A floating road constructed across a sloping bog is a different situation. Rain falling on a sloping blanket bog can produce a rapid run off down the slope. A new floating road in this circumstance can create a barrier to the natural surface water flow. Where this happens surface water is likely to be retained against the uphill side of the road creating a potential drainage problem. Good practice here is to intercept the surface water before it reaches the road and take it to a culvert where it can be taken through the floating road to the downslope area of bog. If intercepting ditches have to be excavated to achieve this they should have the least effect on the local hydrology as possible. A 'flat ditch' excavated solely within the Acrotelm will have a lesser effect than a standard "V" shaped drainage ditch that penetrates the Catotelm and triggers settlement. A possible flat ditch cross-section is shown below alongside a typical "V" shaped intercepting ditch. This will lower the existing water table in the bog less than the deeper ditch.

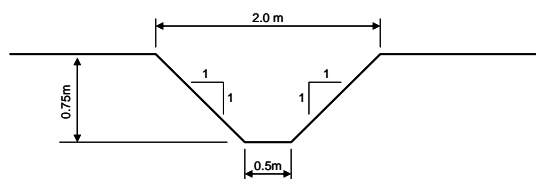


Fig 8.1 Typical V shaped intercepting ditch

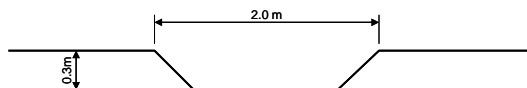


Fig 8.2 Alternative "flat ditch" for floating roads

Ideally ditch design options should be provided within the Environmental Statement (ES). Good practice here is to include a 'tool box' of appropriate drainage measures in the ES which can be adopted on site according to local circumstances.

Advance drainage works, particularly intercepting ditches established ahead of the floating road construction, can sometimes be a good idea but are not always environmentally acceptable. Where they can be provided, the new drains make it possible to stabilise the local hydrology and allow floating construction to proceed with greater confidence of a successful outcome.

## 8.5. CROSS CARRIAGEWAY CULVERTS

Good practice for the design and installation of cross carriageway culverts is set out in "*Good practice during wind farm construction*", (SNH/SEPA 2010). Additional comments from contributors attending Workshop No 2 included:

- the waterway area should be designed by calculation based on the identified catchment using a storm return period of 1 in 200 years to allow for climate change. This is also recommended in the Scottish Planning Policy, 2010;
- additional capacity should be provided to allow for a build up of deposits in the invert;
- design to be informed by observation of existing channel cross-section and if necessary matched;
- the Forestry Commission "Forests and Water Guidelines" (Fourth edition) contains good practical advice;

- all watercourse crossings should be carried out in accordance with the Water Framework Directive 2007, CAR regulations. SEPA commonly requests a schedule of watercourse crossings (x, y coordinates, photos and cross sections) as part of an ES. SEPA has also issued a policy statement on the use of culverts: *SEPA Position Statement to support the implementation of the Water Environment (Controlled Activities) (Scotland) Regulations 2005: Culverting of Watercourses*. This has a presumption against “unjustified enclosed culverting” on transport routes.
- useful cross-sections for stream crossing types have been published by Viking Energy and Mouchel at [http://vikingenergyfiles.opendebate.co.uk/files/Appendix-14.3-Stream-Crossing-Guidance\(4\).pdf](http://vikingenergyfiles.opendebate.co.uk/files/Appendix-14.3-Stream-Crossing-Guidance(4).pdf)

Culverts under floating roads can be installed in the same fashion as normal site access roads using a gravel bed down to a firm layer. This can however have the disadvantage of creating hard areas under the settling carriageway which can result in irregularities in the finished road surface after time.

An alternative practice to the standard excavation method is to install unsupported pipes under the floating road and design these to be oversized, allowing for settlement, so that the desired waterway area can be available after the settlement has taken place. The principle is shown in Figure 8.3 below.

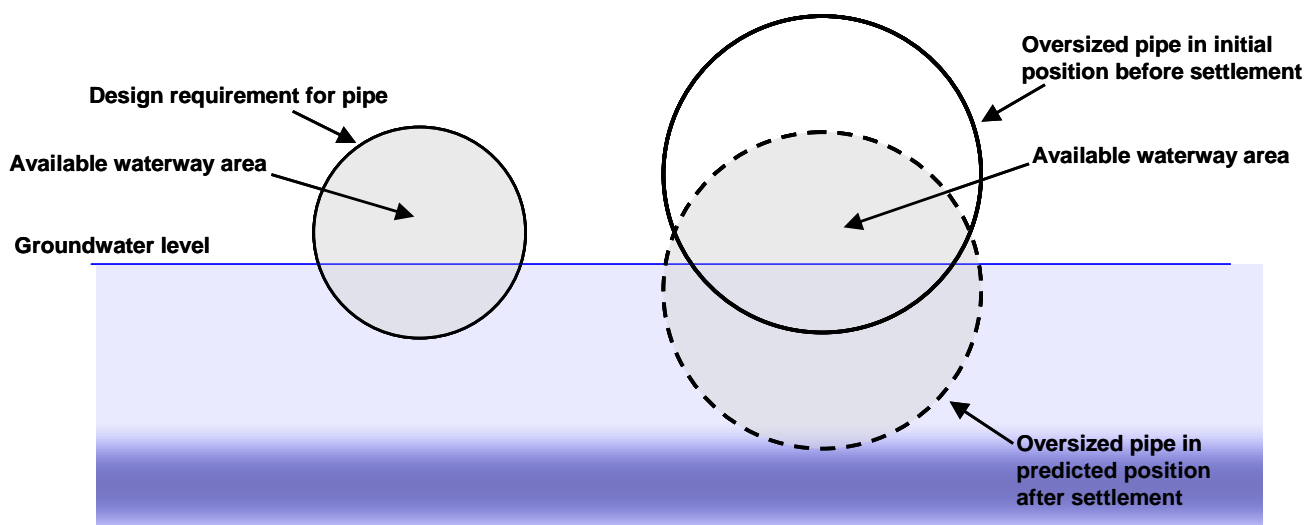


Fig 8.3 Oversizing pipes to allow for settlement

The installation detail for this type of cross-carriageway culvert is to ‘hang’ it in a geogrid with a lightweight surround as shown in Figure 8.4.

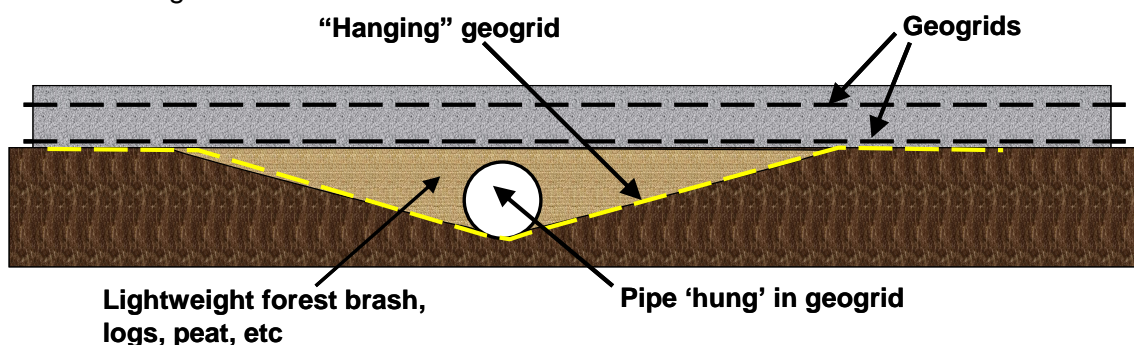


Fig 8.4 “Hanging” a pipe in a geogrid below a floating road

Cross – carriageway culverts can be installed ahead of floating road construction, during the work, or after the road has been constructed by excavation through the finished road. The latter case will however disturb any equilibrium that has been built up between the road and underlying peat, and should be considered to be the least preferred option. Digging through the floating road and the subsequent reconstruction should be carried out in accordance with the guidance given for the repair of a floating road as given in Section 9.

Stone filled trenches, wrapped with a separator geotextile, have been used occasionally as an alternative to pipes in cross-carriageway culverts. These should be used with care however as they can also de-water the peat below the road with unknown results.

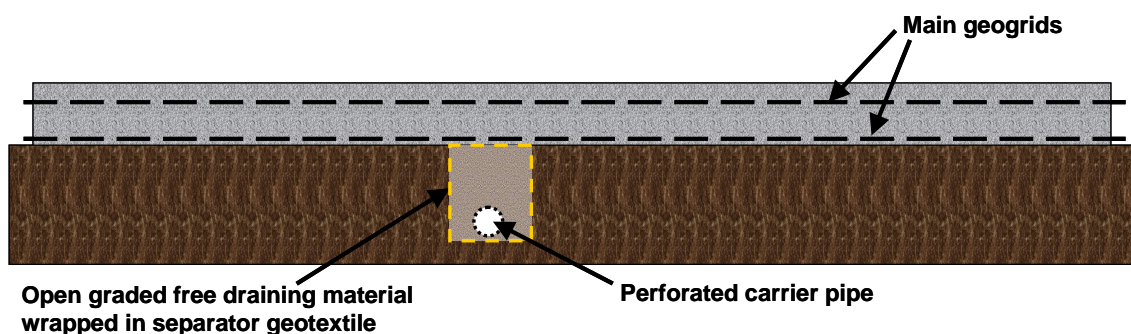


Fig 8.5 Stone filled trench with carrier pipe below a floating road

## 8.6. OUTFALL DITCHES

As with intercepting ditches above, any outfall ditches provided should be as shallow as possible within the Acrotelm to avoid disturbance of the peat and the hydrology of the bog. A diffuse flow pattern across the bog is preferable to a concentrated outfall flow.

## 8.7. EXISTING DRAINAGE CHANNELS & PEAT PIPES

Natural peat drainage channels and subsurface 'pipes' are widespread in Scottish blanket bogs and attention should be given to preserving these natural drainage routes, as with any other drain under the road line, when they are encountered to avoid future problems with blockages.

Drainage paths across the surface of the peat can usually be readily seen and dealt with but subsurface pipes are a little more difficult to detect under floating roads, without resorting to excavation. A thorough walkover of the route can sometimes identify pipe outlets or collapses on the line of the pipe but more often than not the only indication, other than a GPR survey, will be the sound of running water below the surface.

Where drainage paths or peat pipes are detected they should be taken through the floating road in a permanent conduit such as shown in Figure 8.6. The conduit should be of a sufficient 'pipe equivalent' size to accommodate the expected flow through the drain and, as with cross-carriageway culverts above, hung in a geogrid below the floating road.

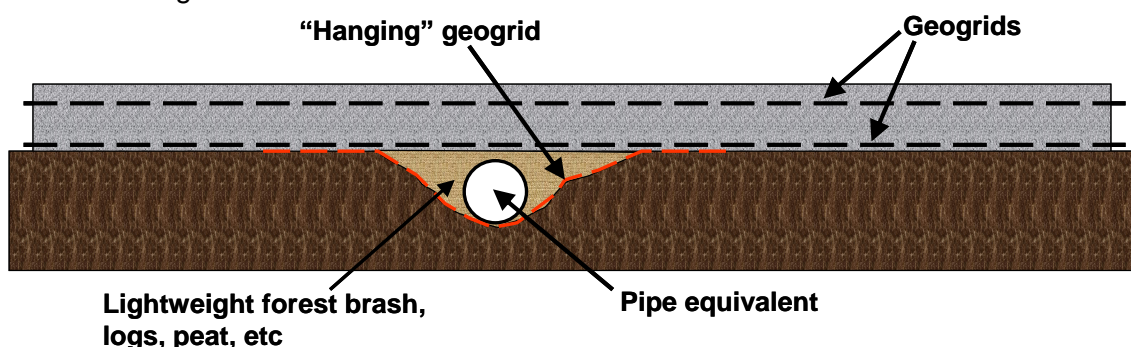


Fig 8.6 Dealing with ditches and natural peat pipes below a floating road

## 8.8. SPRINGS AND FLUSHES

'Springs' and 'Flushes' are descriptive terms for different forms of water that well out of the ground on to the ground surface. In simple terms, a spring is the source of a stream: the point where the water bubbles or flows

out of the ground. A flush on the other hand marks out a place where water flows over the ground more diffusely. Both features generally result in a diffuse flow of water across the ground surface in a shallow depression that, in the case of a floating road, needs to be intercepted and taken through the road without interruption.

An example of good practice to achieve a road crossing using a wrapped, free draining drainage blanket is shown in Figure 8.7.

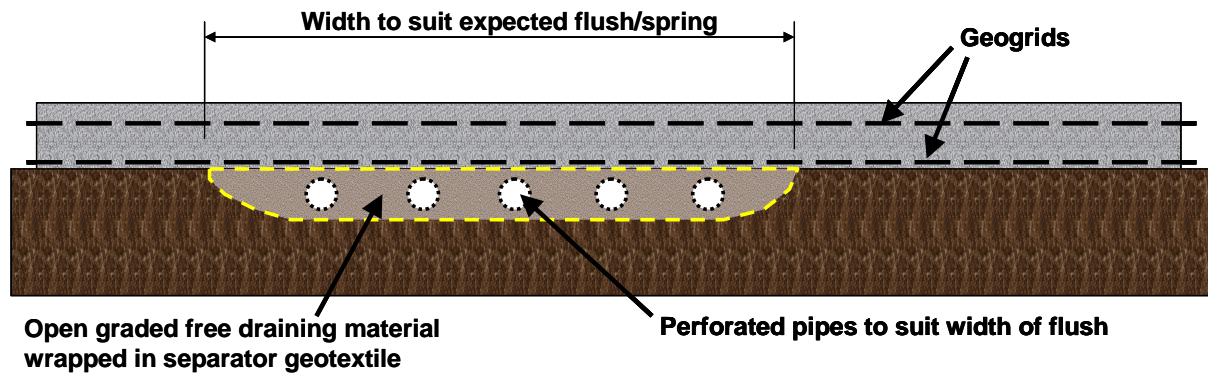


Figure 8.7 Method of dealing with springs or flushes flowing diffusely across the peat surface

## 8.9. EXCAVATING DITCHES AFTER THE CONSTRUCTION OF A FLOATING ROAD

Excavating new ditches, or deepening existing ditches, after construction of a floating road will invariably trigger settlement problems. Ditches excavated into the Catotelm will lower the groundwater table. When the groundwater table is lowered inside a floating road, the hydrostatic uplift on the road, its “buoyancy”, is reduced. This effectively makes the road heavier than previously and causes further compression and settlement in the underlying peat.

The change in water level will usually take time, and will not happen as a single event, but the effect in the long term is the same. The load on the peat will be increased and a settlement will occur.

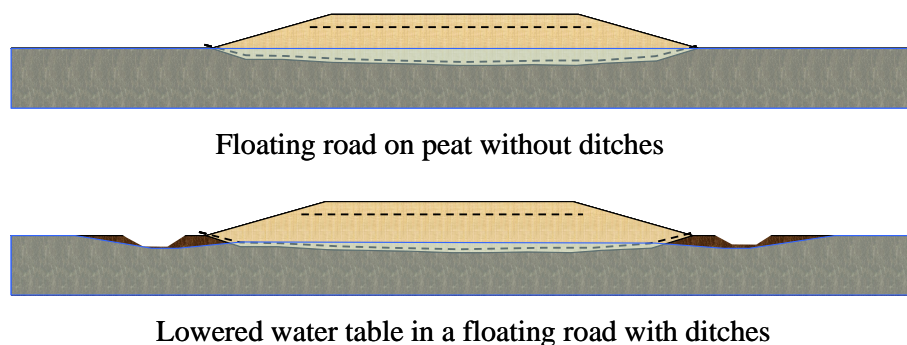


Figure 8.8 Drawdown of water table by ditches beside a floating road

To avoid this effect any intercepting ditches should be installed sufficiently far away from the road to minimize any drawdown of the water table below the road and any consequential settlement. Shallow ditches have the benefit of providing surface drainage paths but these should be excavated with the least intrusion into the water table. Reducing the depth of a ditch limits the local lowering of the groundwater in the peat and the consequent hydrostatic effect on the floating road structure.

Hand driven groundwater monitoring wells can be used to identify existing groundwater levels and permeability of the peat during the ground survey. This can help to predict possible dewatering / drying impacts of any drainage measures.



## 8.10. CABLE TRENCHES

Excavating cable trenches adjacent to a floating road can affect the water table as much as, or even more than, an intercepting ditch depending of the depth of the excavation. This effect should be considered when planning the route, and reinstatement specification, of trenches.

Good practice in the installation of cable trenches is as follows:

- use appropriate equipment and methods to minimise impacts to the local hydrology
- excavate trenches in sections as needed and plan the works to minimise the duration of open trenches;
- backfill the trench as soon as possible with the excavated peat from the location to restore the pre-existing hydrology;
- avoid creating drainage layers in trenches. If necessary install clay cut off barriers across the trench to prevent flows of water along the trench.

Excavating a cable trench through the surface vegetation mat of the peat on a sloping peat bog can create a weakness that can destabilise a previously stable arrangement and expose potential slip planes. Such work should only be considered after a peat stability assessment has been carried out by an experienced geotechnical engineer, and only then very carefully with the agreed mitigations measures in place. An alternative option to excavating into the virgin peat would be to create wider peat flanks on the sides of the floating road, say 1.0 – 1.5m thick, (as in Figure 6.6 above) and bury cables within these. This option could be better for hydrology and ecology / habitat.

Cable trenches adjacent to forest roads are not recommended unless they are capable of supporting wheel loads of 50 kN.

## 9. POST CONSTRUCTION

Post construction considerations for floating roads essentially mean checking that the floating road is performing to plan and that any defects are dealt with expeditiously to prevent the development of long term problems. This requires a system of regular monitoring, maintenance and repair to be effective.

### 9.1. MONITORING

All floating roads settle, hopefully slowly and at a reducing rate, as the peat below moves down the '*secondary compression*' curve. Monitoring the actual rate of settlement in service will confirm how the structure is performing and allow timely actions to be taken to minimise any problems. The settlement of a floating road is not usually a problem in itself but it can affect the hydrology of the bog by cutting off drainage paths and compacting the peat below. Good design will minimise these issues and regular monitoring will help identify any departures from plan.

Monitoring systems for an in-service floating road typically include:

- settlement plates to monitor the rate of settlement
- piezometers/hand driven wells to monitor groundwater levels in the adjacent bog
- gauge boards to monitor water levels in adjacent surface water bodies
- displacement markers to monitor lateral peat movement
- on site rain gauge for local weather records
- video/digital photography as a permanent visual record of the condition of the road on the day of the inspection

These measures should be agreed at the outset of the Works so that suitable practices can be in place, with site records, at handover of the Project.

It is recommended that routine monitoring should be carried out at 6 monthly intervals. Importantly, all monitoring records should be centrally recorded in a robust database to become part of the Developer's knowledge bank for future floating roads on peat. This will avoid projects continually 're-inventing the wheel'.

### 9.2. MAINTENANCE

Floating roads are normally designed to permit a maximum rut depth of 100mm before they require regrading. When this rut depth is reached, the rut should be filled with suitable equivalent replacement aggregate to avoid damage to the geogrid, and vehicles using the road. If long term rut development is left untreated there is a possibility that the tines of maintenance graders could inadvertently grub up sections of poorly installed upper geogrids that do not have sufficient aggregate cover.

Regular preventative maintenance should also be carried out to preserve the life of the road and minimise the need for more extensive remediation. This is normally dealt with under the headings of "routine" and "cyclic" maintenance.

- Routine maintenance – general 'ad hoc' maintenance to keep the infrastructure in a serviceable condition, e.g. filling of potholes as they arise, dealing with any drainage issues as they come to light, etc
- Cyclic maintenance – regular scheduled maintenance, e.g. annual inspections of the Works, surveys, planned maintenance activities such as regrading carriageways, keeping culverts functioning, etc.

### 9.3. REPAIR

Repairs of damaged or failing floating roads with geogrids usually involve dealing with at least one geogrid. Good practice in this is to leave as much of the existing geogrid in place as possible. Even a damaged geogrid will continue to contribute some stability to the road.

Good practice in repairing a floating road with geogrids is to:

- A. Identify the extent of the defective area and strip back the aggregate layer above the geogrid to expose the geogrid and at least a 400mm lap on to sound construction.
- B. Lay the new geogrid on top of the old and backfill with the specified aggregate to achieve interlock.
- C. Compact the new area.

This method can also be used for installing a cross-carriageway culvert under the road, or replacing a defective culvert, after the road has been constructed.

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R Main  
M Marigo  
J Milner-Smith  
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C Quirk  
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G Robb  
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R Shackleton  
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## 11. GLOSSARY

<b>"As dug" material</b>	Ungraded material excavated from a borrow pit.
<b>Acrotelm</b>	The upper layer of peat in a bog within which the water table fluctuates.
<b>Adsorbed water</b>	Water which is bound to soil particles as a result of attraction between electrical charges on their surfaces and water molecules.
<b>Amorphous-granular peat</b>	Peat with a high colloidal mineral component which tend to hold the contained water in an adsorbed state around the grain structure.
<b>Baseline condition</b>	The existing environmental condition before the development is constructed.
<b>Bulk density</b>	The normal in situ density of a soil, i.e. its mass divided by its volume.
<b>Catotelm</b>	The lower layer of peat in a bog which is permanently waterlogged.
<b>Coarse fibrous peat</b>	Descriptive term for a woody peat containing predominantly coarse fibres. This type of peat holds most of its water within the peat mass as free water unlike amorphous peat.
<b>Consolidation</b>	The process by which a soil decreases in volume.
<b>Construction method statement</b>	A written description of how a particular task or activity will be carried out.
<b>Contingency plan</b>	A plan devised for a specific situation when things could go wrong.
<b>Desk study</b>	An examination of all existing information concerning a construction site.
<b>Displacement</b>	The distance of a point from its original position.
<b>Displacement method</b>	A method by which the peat is pushed, or displaced, to the side by the new road construction
<b>Elastic phase</b>	The immediate compression of a soil when a load is applied.
<b>Energy Consents Unit</b>	The Unit of the Scottish Government's Energy Division that has responsibility for on-shore power station applications including wind farms over 50MW and hydro developments over 1 MW.
<b>Equilibrium</b>	The condition in which all acting influences are countered by others, resulting in a stable and balanced system.
<b>Fine fibrous peat</b>	Descriptive term for a non-woody peat containing predominantly fine fibres. This type of peat holds most of its water within the peat mass as free water unlike amorphous peat.
<b>Fines/fine material</b>	The fine particles in a soil or aggregate.
<b>Floating road</b>	A road constructed on top of an organic soil rather than by excavation or displacement. Usually restricted to thin roads close to the natural ground surface.

<b>Formation</b>	The prepared level of a cutting or embankment before the main road structural layers are placed
<b>Free water</b>	Unbound internal water in a soil.
<b>Geogrid</b>	A geosynthetic material consisting of connected parallel sets of tensile ribs with apertures of sufficient size to allow strike-through of surrounding soil, stone, or other geotechnical material.
<b>Geomorphology</b>	The history of how superficial material, including peat, have grown.
<b>Geosynthetic</b>	The generic term used to describe all polymeric products in civil engineering works.
<b>Geotechnical risk</b>	The risk posed to construction by the ground or groundwater conditions at a site.
<b>Geotechnical risk management</b>	The overall application of policies, process and practices dealing with geotechnical risk.
<b>Geotechnical risk register</b>	The file where geotechnical risk is stored. The register usually contains a description of the risk and an assessment of its likelihood and consequence.
<b>Ground investigation</b>	The specialist intrusive phase of site investigation with the associated monitoring, testing and reporting.
<b>Ground penetrating radar</b>	A non-intrusive survey technique that uses high frequency electronic signals to detect buried features.
<b>Ground verification</b>	A check of the site carried out after the Desk Study to confirm that the information gathered is valid.
<b>Hazard</b>	A thing or activity with a potential for consequences.
<b>Horizontal alignment</b>	The horizontal geometric layout of a road.
<b>Humification</b>	The process of decomposition of a peat.
<b>Interlock</b>	The process whereby aggregate particles penetrate and lock together within the apertures of the geogrid.
<b>Interlock layer</b>	The initial layer of aggregate locked into the geogrid that produces a mechanically stabilised structure.
<b>Invert</b>	The internal base of a pipe or culvert
<b>Mitigation</b>	The limitation of the undesirable effects of a particular event
<b>Mitigation measures</b>	Measures to limit the undesirable effects of a particular event
<b>Open graded material</b>	Aggregate in which the void spaces in the compacted aggregate are relatively large.
<b>Permeability</b>	The rate at which water and air moves through a soil
<b>Pore water</b>	The water filling the spaces between the grains of a soil.
<b>Primary consolidation</b>	The process by which a soil decreases in volume through the expulsion of internal water
<b>Regulating layer</b>	A thin layer of material that is laid on a poor surface to bring it up to an acceptable standard for further layers.

<b>Residual risk</b>	The risk remaining after mitigation measures undertaken.
<b>Risk</b>	The combination of the chance of an event and its consequences.
<b>Road stone</b>	Graded crushed rock aggregated used in road construction.
<b>Sampling</b>	The process of obtaining a sample of soil from the ground.
<b>Secondary compression</b>	The compression of soil that takes place after primary consolidation due to creep, compression of organic matter, etc.
<b>Shear strength</b>	The maximum shear stress which a material can withstand without rupture.
<b>Shear vane</b>	In situ test using a 4 blade vane pushed into the ground and rotated to give an indication of the undrained shear strength of a soil.
<b>Site investigation</b>	The overall process of discovery of information concerning a site, the appraisal of data, assessment and reporting.
<b>Staged construction</b>	The construction of a floating road in phases to limit the stresses on the underlying ground.
<b>Standard axle</b>	A load of 8 tonnes applied over a single axle with a dual wheel at each end.
<b>Subgrade</b>	The native material underneath a constructed road.
<b>Surcharge</b>	An additional mass of material on a construction to accelerate consolidation.
<b>Undisturbed sample</b>	A sample of soil whose condition is sufficiently close to the actual condition of the soil in situ to be used to approximate the properties of the soil in the ground.
<b>Vertical alignment</b>	The vertical geometric layout of a road.
<b>Walkover survey</b>	A visual survey of a site carried out after the Desk Study aimed at collecting additional information on ground conditions and land use.
<b>Water content</b>	The ratio of the mass of water to the mass of solids in a soil.
<b>Well graded aggregate</b>	Aggregate having a particle-size distribution which will produce maximum density, i.e. minimum void space.

## **Abbreviations (in alphabetical order)**

<b>BGS</b>	British Geological Survey
<b>BS EN</b>	British European Standard Specification
<b>CAR</b>	The Water Environment (Controlled Activities) (Scotland) Regulations 2005
<b>CBR</b>	California Bearing Ratio
<b>CDM</b>	Construction (Design and Management) Regulations 2007
<b>CE</b>	The EU "passport" mark that enables a product to be legally placed on the market in any Member State
<b>CMS</b>	Construction Method Statement
<b>EIA</b>	Environmental Impact Assessment
<b>FCE</b>	Forestry Civil Engineering
<b>GPR</b>	Ground Penetrating Radar
<b>GPS</b>	Global Positioning System
<b>PCIP</b>	Pre-construction Information Pack
<b>PVC</b>	Polyvinyl chloride
<b>SEPA</b>	The Scottish Environmental Protection Agency
<b>SNH</b>	Scottish Natural Heritage
<b>WTG</b>	Wind Turbine Generator



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## 13. APPENDICES

Appendix 1: SNH requirements

Appendix 2: Workshop No 1 “Initial Meeting”, 24 February 2009

Appendix 3: Workshop No 2 “Construction”, 15 June 2009

Appendix 4: Peatslide risk assessment

Appendix 5: Ground penetrating radar surveys

## 13.1. APPENDIX 1

### SNH requirements

#### Floating roads on peat - a best practice guide

##### 1) Purpose of the work

1.This work will review successes and failures in floating roads on peat, both modern and historical, and develop best practice guidance. It will not be confined to renewable energy projects, but as most floating roads are currently proposed and built within the context of wind farms, those involved in that industry will be a key audience. It will focus on all aspects of installation, from the identification of routes, through road design, construction methods and maintenance. It should consider not just the immediate footprint of roads, but indirect effects including those of peat stability and issues associated with peatslide risk assessment.

2.Where it is concluded that a road should be built across peatland, it is important that the impacts, both long and short term, are as minor as possible. This is because not only are raised and blanket bog (the main peatland types affected by wind farms) on Annex 1 of the EC Habitats Directive and UKBAP priority habitats, but they are the largest terrestrial carbon store we have. The apparent inconsistency of building wind farms, which are promoted because of their potential to ameliorate climate change, on bogs and thus damaging a carbon store and releasing carbon dioxide into the atmosphere is well known. A recent report to Scottish Government helps quantify some of these issues

<http://www.scotland.gov.uk/Resource/Doc/229725/0062213.pdf>

3.While this project is being driven by a requirement to minimise impacts on the natural heritage, it clearly requires an engineering expertise. However the main output, a best practice guide, will be aimed not just at engineers but also at planning officials, scientific advisers and ecologists and should be accessible to informed members of the general public.

##### 2) Background

Some 12% of Scotland is covered by peat. This coverage is extensive in all upland areas but particularly in the northwest highlands and islands. Peat deposits also occur more locally, usually as raised bogs, in the lowlands.

Scotland also has a windy climate. As a consequence wind energy is a favoured means of meeting the Scottish Government's target of 50% of energy production from renewable resources by 2020 (with an interim target of 31% by 2013). Although off-shore wind farms are increasing in number, most wind farms in the foreseeable future will be land-based.

Most land-based wind farms are sited in the uplands as these are, on average, windier than the lowlands. The uplands thus host most of our peat resource and most of our wind resource – hence the frequent co-occurrence of wind farms and peatland. For although 'only' 12% of Scotland may be peat-covered, more than 40% of existing and proposed wind farms are on peat.

Although wind farms are unlikely to be built on areas of peatland with the highest biodiversity value, for example Sites of Special Scientific Interest or Special Areas of Conservation, there are numerous other areas where the biodiversity, and/or other, interests need not necessarily be incompatible with a well designed and constructed wind farm, or other development. It is for these areas that it is important that genuinely 'best practice' techniques are employed, and the object of this project it is to identify and define that practice.

##### 3) Draft Methodology

It is important not only that best practice is identified, defined and described, but that there is sufficient 'buy-in' from the various target audiences that it is recognised, understood, promoted and implemented. Consultation with representatives of the user community must therefore be a theme which runs through the process.

SNH envisage that the following steps will be included:

- A Steering Group to be established, which will include a representative from each of the funding/contributing partners.
- The Steering Group, together with any key user-group representatives, to meet at an early stage to confirm the project brief, determine timetable and milestones, and clarify any outstanding uncertainties.
- A desk-based literature review, including web-based sources, and discussion with key individuals and organisations with relevant experience. A provisional list of these will be agreed at the outset of the contract.
- A small number (perhaps 5 or 6) site visits to assess the impacts of a range of (good and bad) examples, and to compare proposals as per Environmental Statements, Construction Method Statements etc with practice on the ground
- A workshop attended by representatives from key user groups to discuss draft proposals
- Draft and final reports, suitably referenced and QA'd, and providing an audit trail for the best practice guide
- Circulation of draft guidance to user groups
- Final format of guidance to be determined, but will include web-based version.
- QA of final versions of report and guidance prior to publication.

## 13.2. APPENDIX 2

### Workshop No1 “Initial Meeting”, 24 February 2009

*Minute of meeting at the Scottish Natural Heritage Office, Great Glen House, Leachkin Road, Inverness on Tuesday 24 February 2009*

Present:

Andrew Coupar, Policy & Advice Manager, Uplands & Peatlands, Scottish Natural Heritage  
David Kelly, Associate Director, Entec UK Ltd  
Gordon Robb, Technical Director, SLR Consulting Ltd  
Stephen Kennedy, Project Engineer, D A MacDonald (Contractors) Ltd  
James Milner-Smith, Civil Engineering Manager, SSE-Renewables  
Frank MacCulloch, Scotland Country Engineer, Forest Enterprise Civil Engineering  
Ron Munro, Director, Munroconsult Ltd

#### 1. Introductions

The Chairman (AC) welcomed those present and explained that the purpose of the meeting was to have an informal exchange of experiences and ideas. An agenda had been circulated but this was for information only and it was expected that other matters would be raised during course of the discussions. A wide ranging discussion ensued and the following key points were noted.

#### 2. Background and context

The meeting had been called to start the process of preparing a good practice document for floating roads on peat. This document would review the successes and failures in floating roads on peat, both modern and historical, and develop best practice guidelines for their construction and maintenance.

#### 3. Issues:

##### **A) Criteria (floating v. excavated)**

The criteria for determining whether a section of road should be floated or excavated were discussed without reaching an agreed figure. Depths ranging from 0.5m to greater than 1.5m were regularly mentioned across the industry but it was the general opinion of the group that a single depth could not be fixed as each site had to be considered on its merits. The economic depth could be of the order of 1m but the actual decision at an individual location would be dependent on the particular circumstances prevailing at the site. These included:

- Type and characteristics of the peat;
- Access road layout;
- Location of borrow pits;
- Volume of peat needing to be excavated in the ‘cut-track’ option;
- Contractor’s method preference;
- Construction equipment available;
- Number of vehicle movements;
- Habitat footprint;
- Wetland restoration;
- Peat disposal considerations;
- CO<sub>2</sub> implications;
- Etc

It was not possible to identify a minimum length for the construction of a floating road as this would be dependent on local circumstances as well. Transition zones between different types of construction were important however and this should be addressed. The timing of the construction process was important too. The speed of construction had an effect on the underlying peat and time had to be allowed to permit the peat to respond to the load to gain in strength before subsequent layers were added. Quick loading of peat could result in catastrophic failure. Experienced engineering input was essential. It was no longer permissible to place the responsibility for construction of a floating road on the plant operator at the head of the road. An approach based on the "Observational Method", as set out in BS EN 1977, and geotechnical risk management (Clayton 2001) appeared sensible.

It was mentioned that the type of crane required for tower erection could have an effect on the decision on floating construction v. excavation. A crawler crane was capable of faster turbine erection but crane companies were reluctant to permit this type of crane to travel over floating roads. A wheeled crane was more mobile but slower in the erection process.

## **B) Design/Construction**

The design process was an iterative procedure that had to cater for a wide range of interests, from landscape through to turbine supplier requirements. Greater survey input was needed at the outset of developments to give better understanding of conditions on site. In the past Developers had been criticised for a "seat of pants" approach to developments that primarily focussed on fixing turbine locations and leaving the access roads as secondary issues. This practice was changing in newer developments. There needed to be a balance between the 'constructability' of developments and environmental impacts, and the proposed Guidance document could help this. Engineering aspects of a development needed to be considered earlier in the planning process to ensure the 'buildability' of the infrastructure, resulting in less habitat loss and landscape scarring. Peat had to be recognised as both a soil which supports a habitat and an engineering material. It was recognised that both the engineer and SNH had the same aim of minimal environmental impact. Floating roads were seen to be better for preserving hydrological continuity rather than excavated roads, although this was not always the case depending on how the road/peat arrangement responded to load, i.e. rate of settlement, displacement issues, failure.

The speed of construction over peat was considered important. Consideration should be given to extending the programme to allow time for the peat to gain strength and establish equilibrium again. It was mentioned that 100m/day of road construction could be a good rate of progress for excavated roads in good weather, whereas 50m/day may be more achievable in poor weather. A rate/day for floating roads was likely to be half of those rates respectively. Staged construction was also a possibility that would permit the peat to gain in strength before the next layer was laid. This would lower the possibility of failure from that of a 'dumped' road. Monitoring systems on floating roads during construction did not appear to be a common practice. The design and installation of cross-road culverts would require special attention.

At this point Forestry Civil Engineering presented a number of slides on their new GPR/GPS survey vehicle. This vehicle can carry out non-invasive forensic surveys of existing floating roads at normal road speed. The system uses an air coupled antenna, a ground coupled antenna, a GPS location device, video, audio and distance measuring metering to provide a continuous long section along the road, or cross-section. It was explained that the system could check the effectiveness of designs and installations without the need for excavations. Any surveys undertaken would not be attributable to specific wind farm sites. It was agreed that the system had potential and further advice would be taken from Developers.

It was mentioned that there would be a seminar/workshop by the "Good Practice During Wind farm Construction" Group in the SNH Battleby office on 7 May 2009. It may be possible to present some information on floating roads at this event.

## **C) Maintenance**

It was agreed that this should be covered in the guidelines. There was a possibility that the tines of motor graders could grub up poorly placed geo-grids.

## **D) Restoration (?)**

Restoration did not appear to be a major issue at this time. Possibly only small scale and targeted works would be required. Larger projects could have major issues of remedial earthworks, disposal of road construction materials and restoration of habitats. Most developments were still well within their 25 year lives and thought had not yet been given to extensions, re-energising or removal. If restoration becomes an issue site leases may have to be extended. Currently restoration issues only apply to the removal of turbines. The Glendoe scheme may be planning a restoration of a temporary road leading eastwards from the dam.

#### **4. Case Studies/Site Investigation**

It was considered that a range of case studies should be carried out involving different design methodologies, different access needs, etc.

#### **5. Other issues**

- Cables alongside tracks were seen to pose a problem.
- Climate change – roads needed to be ‘future proof’
- Construction method statements – should they be considered?
- Liaise with the Scottish Renewables Forum

#### **6. AOB**

#### **7. Next Steps**

A report will be produced on the investigations and a ‘Best Practice Guideline’ will be published. This will be aimed at engineers, planning officials, scientific advisers and ecologists and will be accessible to the general public. It is planned that the Report and Guidelines will be complete by March 2010.

## 13.3. APPENDIX 3

### WORKSHOP NO 2 “CONSTRUCTION”, 15 JUNE 2009

#### Good practice construction management

##### CDM Regulations

- Quote “Duty of Client” in guidance
- When to introduce CDM?
- Engineers should be involved earlier. Should have more time. Should Developers give more time? Engineering involvement should be earlier in the process, (at planning stage). GI consideration of buildability should be earlier in process
- Access roads considered to be temporary works – a contractor problem. No time allowed. In Ireland more time is being given.
- Possible extensions to wind farms may put additional loading on existing roads. May need to be considered.
- Horizontal alignment being considered not vertical alignment, cut or fill
- Developers do not have consent and may not be prepared to do too much in advance of planning permission
- Pre-construction design does not consider deep seated failure
- Balance between ecology and engineering
- Access roads are almost the last thing to be considered but the programme is dependent on the construction of the access roads
- Developers want the contractor to take on design & build

##### Risk management/ communication

- How do we communicate risk
- Short term risks v. long term risks
- Risk based on cost, e.g. Clayton (Robert Bone)
- How you cost a damaged environment
- Extensions of wind farms can result in additional traffic passing over designed roads
- Developer has to make GRR happen – condition in planning?
- Geotechnical Risk Register should be completed

##### Construction method statements

- Guidance on method statements
- Give examples?
- CMSs can be vague for ecologists interpreting descriptions. This increases risk. (K Carmouche)
- List things that need to go into a CMS as a fundamental
- If you don't know the CMS you cannot assess the impact.
- Understand the process, generic
- Community wind farm groups could use the guidance
- Should have ‘stop rules’. Stop criteria for rainfall events should be part of contract conditions. Data available? Local rainfall data from SEPA?
- Method Statements included with planning application should be more specific

##### Controls/monitoring

- More geotechnical input?
- 3 months, 6 months, long term

##### Season

- Winter is not a good time, ideally summer
- No season, but possibly a ‘stop rule’, e.g. rainfall that could trigger a natural slide, or adjacent natural slide
- Continuous rain gauge threshold
- Sediment control
- Peatslide triggered by rainfall
- “lowest rainfall” statement



- There are 3 levels of detail: EIA, pre-construction, construction with reducing level of flexibility for the Contractor (I Clarke, Windprospect)
- What issues are going to be addressed – examples in landfill guidance (Chris Quirk)
- Guidance: “the following things should be addressed.

#### Speed of construction

- There is a cost of slowing down construction but should this be accepted?
- Monitoring systems, fit for purpose
- 35 ton dump truck v 25 ton dump truck = greater productivity but more damage
- Early engineering involvement
- Observational design
- Earlier commercial involvement
- Programme dictated by turbine delivery but better to have road constructed early
- Access road is a small component of the cost of a wind farm but it is on the critical path at all times
- Not give due diligence in planning
- Squeezed in the programme (Hamish Seaton)

#### **Good practice for ground/peat characterisation**

##### Scope of site investigation

- Do something – definitely.
- Peat probing – how much? Depends on when called in to inform the process, layout o design
- Inform the design process
- Geophysics survey (Jim Galloway, Laggan). Does not give peat characteristics – good for depths.
- How to survey forests?

##### Scope of ground investigation

- Cannot get out on to the site early enough. Constraints mapping (R Bone)
- Shear strength?
- Why do it? GI Information must have an end purpose.
- Bulk density, shear strength
- In situ tests better than laboratory tests on disturbed samples
- Be careful in recommendations. Better to say “the following should be addressed in GI” and why
- Mouchel method gives lower bound
- Changes in parameters between summer and winter? Variations over year? Should not happen if groundwater levels remain unchanged
- “Ball Penetrometer”, Mike Long, Ireland
- Probing frequency? Mexe probe? Site specific, the more the better
- Strategy: every 50m on average, closer depending on circumstances and infrastructure
- FCE do 750m per day
- Wind farms are being designed off DTMs, OS Plans, etc.
- Ground truthing is important (F MacCulloch)
- “Proof survey “or “ground truthing” between Lidar / OS/ GPS is necessary to confirm actual ground levels. (Lidar = LIght Detection And Ranging)
- Need to be aware if a failure would be localised or trigger a domino effect
- Early GI is good in general. Factor- in constraints to mapping. Probing in likely road areas to inform road alignment. Shear strength at depth useful in determining road alignment
- Be specific as to why sampling and testing is required – appropriate testing for design and rationale for certain testing should be considered

#### **Good practice design considerations – by the geogrid manufacturers?**

##### Standard axles and rutting criteria

- Wind farm vehicles and construction vehicles.
- Haulage vehicles have greater trafficking and cause more damage. Loop effect. If more stone is needed, more vehicles are needed, creating more load on the road, requiring deeper construction, and consequently more stone

- Construction vehicles are more damaging than turbine delivery vehicles. Design for rut depth of 75-100mm, to protect geogrid
- Nacelle is worst case. It could bottom out.

#### Consolidated peat, < 0.5 CBR

- CBR is not an absolute value
- Method of measuring CBR is important, particularly at low CBRs since method affects result. Depth at which CBR is measured is also relevant. 0.5% CBR assumption after consolidation is probably conservative
- Peat consolidates under load. 0.5 CBR is an assumption of what happens to the peat on loading
- Need to have an early commercial involvement
- Who gives the warranty? Geogrid manufacturers can do this but need data for their designs. Liability for design.
- What are the serviceability standards for an access road? Settlement, maintenance, ....
- Generally work on a "smooth surface" before the delivery of components
- Is there a manufacturer's specification for road standard
- What should be mentioned in the guidance?
- Experience would suggest 0.5 CBR is a safe assumption for general application allowing for an increase in shear strength
- Stiffness values are used in Scandinavia, but these are based on static tests
- Main damage is caused by haulage traffic

#### 2 geogrid system

- 2 geogrid system helps minimise differential settlement
- Well graded aggregate

#### Transitions from floating to excavated

- What is shortest length of floating road section? E.g. 50m transition, 50m floated, 50m transition?
- Depends on site
- Overblast hard area v. fill into soft peat. Could be ecological issues
- Transitions at hardstanding
- Whitelee doughnut
- Whitelee had excavated road alongside hardstanding plus 30m each side
- Transitions. Specific guidance difficult. Ecological changes to be considered 30m – 50m transition length between floating road and hard seems to be an acceptable length.

#### Longitudinal gradient

- Depends on vehicle
- "needs to be addressed", (Whitelee, Chris Quirk)
- Considered during ground investigation

#### Upgrading existing tracks

- Preloading for widening? No time generally allowed for this by the need of the developer to get generation on stream as quickly as possible.

### **Good practice construction methods**

#### Geogrid on to peat surface

- Yes, leave vegetation in place and lay the geogrid on the surface
- Clear felled areas with stumps may need a regulating layer of gravel, woodchip, brash, etc. But leave stumps in place

#### Separator fabric

- As before for black, messy peat. The design for a geogrid installation assumes clean granular. If fines get in the aggregate will become contaminated.
- Good vegetation will act as a separator
- Broken peat may need a separator
- If there is a concern about fines this should be addressed

- Non woven geotextile has better elongation so better than woven in areas where undulations present

#### Aggregate cascaded on to geogrid

- not dozed on. Dozing can push geogrid and damage it. Should be “cascaded” in some fashion so that the aggregate falls on to the geogrid to produce interlock
- Tensar has guidance notes for felled areas
- Grids control differential settlement, not consolidation settlement.
- Cascading stone onto geogrid is better than pushing forwards and risking damaging geogrid

#### < 450mm first layer

- Depends how much trafficking is expected
- Normally around 300mm in general civil engineering but wind farms usually thicker due to initial settlement of peat

#### Geogrid overlap

- Up to 1m depending on tension
- Can use ties in extreme cases to aid placement. Ties do not add reinforcement
- Should guidance include woven geotextiles, tensioned membrane effect with anchorages – no.
- 300mm min overlap but use more to achieve overlap at end of roll. 1m min suggested

#### Speed of construction

- Suggest a range of construction rates, assuming that roadstone supply is not a problem
- One layer = 100m/day
- Two layers = ?
- Best practice to ensure that the road can last 25 years
- 7m formation width general 4.75m roll width so 2 widths would be required

#### Time for consolidation before next layer

- None stated
- But 450mm initial layer is not the designed road only a temporary working platform. Needs to have full depth to be effective
- Allow geogrid length, 50m, before placement of second layer
- Request for explanation of peat consolidation
- Even natural peat has undulations, variations in topography. As a result the road will not be a uniform thickness.
- Progress of 80m – 150m / day laying out road would be a reasonable assumption - 50m max between 1st and 2nd layer to avoid overloading 1st layer
- Big undulations e.g. in cut peat –weight of road becomes an issue for sinking, slip/failure locally additional layers of geogrid
- Locally additional layers of geogrid could be use to stabilise stone depth. Extending footprint would help reduce sinking but may have ecological impacts.

### **Good practice drainage**

#### Preservation of local hydrology

- Storm return period of 1 in 100 years? Climate change may require this to be extended to 1 in 200 years
- Rapid run off from blanket bog
- Do not want to make the road the preferential drain
- Good road drainage may modify the vegetation alongside the road, approx 15m, by altering the habitat
- Cross carriageway culverts – stone trenches have been used
- Timing of drainage installation needs consideration, after road construction has been tried successfully
- Road is much more permeable than peat – could become a large drain – should be avoided
- Dispersed drainage on downhill side is preferable. Look for existing watercourses / drainage paths to tie into
- Longitudinal drainage could be a problem - Impermeable plugs/Attenuation ponds/ Geosynthetic barriers could be used to prevent draining directly into watercourse. Early discussion of drainage with environmental specialists is to be undertaken

### Cross carriageway culverts

- Designed from catchment by calculation
- By observation of existing channel cross-section and matching it
- Water Framework Directive 2007, CAR regulations
- Forestry guidelines recognised as good practice

### Outlet ditches

- Erosion control with polypropylene mats (United Utilities, Chris Quirk)

### **Good practice post construction**

#### Settlement

- Settlement will happen
- May affect drainage
- Greater problem if peat degrades and decays
- Most of the compaction of peat takes place soon after initial loading
- Compaction due to movement of water out of the peat is slow and small
- Final collapse of the peat is long term
- Settlement of floating road into peat - drainage may be affected in 2 ways;
  - Cut off drainage paths
  - Compact peat and make it less permeable

#### Monitoring systems

- Sediment data from timber operations from Frank

#### Sharing information

- How to share info arising from these workshops? This will probably be web based

### **Robert Bone presentation**

- If you are going to end up with risk being expressed in words, why not use words throughout
- Aerial interpretation needs ground verification
- Upper bound approach = shear vane, failure strength
- Lower bound approach = conservative, e.g. Mouchel
- Unmitigated risks should be recorded and passed on
- Halcrow guidelines don't advise on how to use infinite slope model.
- Mouchel use back calculation to give an estimate of the min. shear strength and to calculate a factor of safety for slip

### **Chris Quirk (Naue) presentation**

- Scout Moor Wind Farm
- Resistant to excessive rutting (100mm) and differential settlement
- Polypropylene suffers from creep, polyester stiffer
- Backing cloth separator on geogrid? On reworked peat and peat with vegetation stripped away. But separator needs to be designed.
- Polyester stiffer than polypropylene as a geogrid material
- >15% fines-aggregate should be considered as a fine material
- Use separator where there is a chance of fine material getting into the aggregate e.g. if no vegetation then separator would probably be required, (or if using open graded aggregate)

### **Mike Horton (Tensar) presentation**

- Mechanically stabilised road can be thinner than a road without geogrids = less aggregate, less tax
- Same performance with 40% less stone
- Stabilising effect, up to 450mm thick
- Based on empirical testing by TRRL
- Manufacturer's design suite
- Slide of "Other design considerations"
- Above 450mm thickness of stone the stabilising effect from geogrid diminishes very rapidly so not much point having a thicker stone layer unless using 2 layers of geogrid

- TRRL 1132 Structural Design of Bituminous Roads assumes a min 0.5% CBR
- Triaxial geogrids increases amount of traffic which can be carried, over standard biaxial geogrid

## 13.4. APPENDIX 4

### Peatslide Risk Assessment

#### **Scottish Government guidance**

The Scottish Government's position on peatslide risk assessment is contained in their guidance document "*Peat Landslide Hazard and Risk Assessments, Best Practice Guide for Proposed Electricity Generation Developments*", issued in December 2006. The introduction to this document states:

*"At the project level, large engineering projects involving peat should be planned and carried out using national best practice. This includes geotechnical risk management as discussed in the joint publication by The Institution of Civil Engineers (ICE) and the Department of the Environment and the Transport Regions (DETR) publication "Managing Geotechnical Risk (Improving Productivity in UK building and construction)."*

The *Guide* is now an established part of the planning process of a wind farm development and a wind farm on peat will not obtain consent without an acceptable peatslide risk assessment.

#### **Geotechnical Risk Management**

A range of possible geotechnical risk management systems for large developments such as wind farms is set out in Clayton (2001). Like the CDM regulations 2007, this publication includes:

- the responsibilities of Client, Designer and Constructor;
- the ownership of risk;
- advice on best practice geotechnical risk management and the geotechnical risk register;
- the need for information to be shared across the project team.

It is worth noting that at least one electricity generating company was involved in the preparation of this publication. Clayton recommends that the geotechnical risk management process be started as early as possible in a project.

#### **Peatslide risk assessment**

A typical peatslide risk assessment within an ES should normally address:

##### Confirmation of Geotechnical Risk Management

- Confirmation that a system of geotechnical risk management is in place within the Project;
- A Geotechnical Risk Register.

##### Description of Baseline Conditions

- Desk study of sources of relevant material – methodology, topography, geology, geomorphology, soils, rainfall, hydrology, hydrogeology;
- Desk study report, interpretation and discussion of data, recommendations from the study, the brief for the site reconnaissance and field testing;
- Site reconnaissance and field testing – methodology, data collected (peat depth, peat features, drainage patterns, slope, samples, etc), interpretation, supplementary surveys. Mapping of features, extent of peatland, peat depths, features, hydrology, sensitivity;
- Interpretation of data collected & summary report.

##### Identification of Potential Effects

- Description of those elements of the wind farm located on the identified peatland;

- Sub-division of the Works into zones for assessment purposes.

#### Assessment of the Effects of the Development on the Baseline

- Risk assessment of the effects of the wind farm infrastructure on the peatland baseline conditions in each zone. Risk assessment as Clayton (2001);
- Consideration of the effects of adjacent works on stability, e.g. tree felling, erection of overhead lines, trafficking of adjacent areas by machines, etc;
- Report & mapping.

#### Mitigation

- Mitigation measures, construction methodologies and control measures to reduce the risk of peatslide.

#### Contingency plans

- Peatslide flow paths
- Emergency responses

#### Measures to monitor the Works during construction

- Weather
- Ground movement
- Settlement

The assessment should not be seen as just a single use document to obtain planning permission. It is important that the data and outcomes of the assessment are carried forward in the project process to inform the layout of the wind farm and the detailed engineering design and construction stages. The project geotechnical risk register is a key to this. It records the perceived risks at every stage in the project as well as the recommended mitigation measures.

### ***Geotechnical Risk Register***

The geotechnical risk register is a method of recording the perceived geotechnical risks on a project and the actions taken to manage them. It can be a very simple document, as little as a few pages of A4, but it is a powerful tool to ensure that geotechnical risk information is passed to the people that need it. It generally takes the form of:

- Identifying the hazard
- Assessing the probability of it occurring and its impact if it did
- Managing the risk identified
- Allocating responsibility and action

Good communication between client, designer and contractor is essential for this process to work. Where all parties can agree to sign up for co-operation the risks identified within the project have a better chance of being considered early and contingency planning put in place to meet the risk. Once established the register becomes a live document that is regularly reviewed and updated throughout the project and is available on site for the construction of the Works.

A properly operated geotechnical risk register will ensure that:

- there is a constant focus on risk management and the flow of risk information across the Company;
- there is a single register for risk issues, and that all relevant risk information is considered together in one place, e.g. peatslide risk zones and response plans;
- all staff are regularly reminded of the process and their opportunity to contribute to it;
- geotechnical risk management is regularly considered on Site.
- lessons learned from tackling risks on Site are appropriately recorded and that any new risks identified for the coming period are quickly assessed.
- a highly valuable record is created for reference by future operations to avoid constantly 're-inventing the wheel'.

The essential feature of the geotechnical risk register is that the identified risks remain on the record – and that they are passed down the line to the person who needs them, irrespective of the type of contract that is in force for the construction of the Works. This means that even with the traditional “design & build” contract the

preferred Contractor will be in possession of all of the information previously gathered on the Site relating to risk and that geotechnical risk will be reviewed regularly at weekly site progress meetings.

The role of the geotechnical risk register in recording risks through a typical wind farm project is shown in Figure A4.1 below.

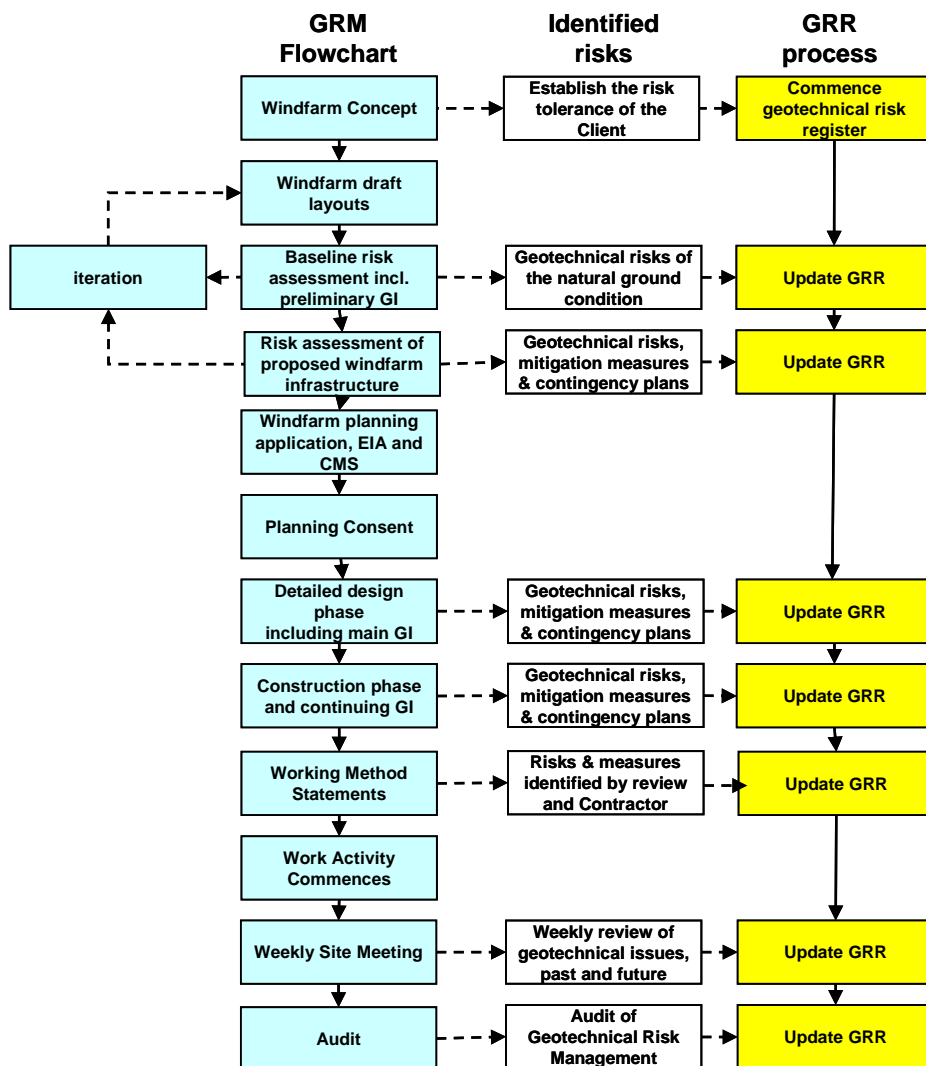


Figure A4.1 The role of the GRR in recording identified risks through a Project

## 13.5. APPENDIX 5

### GPR CROSS-SECTIONS OF FLOATING ROADS

#### Introduction

This Appendix reports the results of GPR surveys carried out on constructed floating roads on peat on three Scottish wind farms. The work was suggested during Workshop No.1 on 24 February 2009 and executed over the summer of 2009 to check the effectiveness of designs and installations without the need for excavations. It was agreed that any surveys carried out would not be attributable to specific wind farm sites.

The work was undertaken by Alan Drake and Gordon McCheyne of Forestry Civil Engineering assisted by Ron Munro of Munroconsult Ltd using the recently commissioned FCE integrated GPR survey vehicle. This vehicle can carry out non-invasive forensic surveys of existing floating roads at normal road speed using a combination of GPR, GPS, video, audio, and distance measuring instrumentation.



Figure A5.1 The FCE GPR survey system. Photo by Alan Drake.

#### Ground penetrating radar

Ground Penetrating Radar (GPR) is a non-destructive ground survey method that is particularly suited to investigate the construction make-up of roads. Its main advantage is that it can provide a continuous profile of the road structure and subgrade soils and is not intrusive to other traffic using the road.

The method is based on transmitting short pulses of electromagnetic energy through materials using either an air coupled or ground coupled antenna. There are many different electromagnetic wavelengths and antenna frequencies that can be used in GPR surveys depending on which layers are being surveyed. For surveys for the top part of a road structure, it is recommended that a high frequency (1.0 – 2.5 GHz) antenna is used because it can discriminate between thin layers but only penetrates approximately 0.5-1.2 m. Lower frequency antennas (400-500 MHz) can penetrate around 1.5 – 4.0 m but can only generally resolve thick layers.



## Surveys conducted

GPR surveys were conducted over the period May to August 2009 on 3 wind farm developments. The GPR data was collected using a GSSI SIR-20 unit with two antennas, an air-coupled 2.2 GHz horn and a 400 MHz ground-coupled antenna. A digital video with GPS coordinates was also taken.

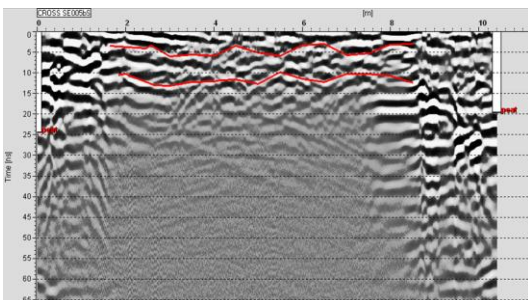
### GPR cross section method

The GPR cross sections were drawn up using a combination of levelling and GPR survey:

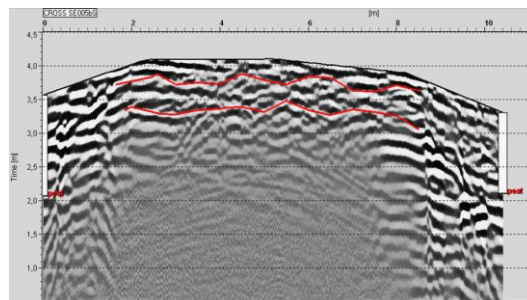
1. A ground cross section of the floating road was produced using an engineer's level, staff and measuring tape;
2. A GPR cross section was then taken across the same location by dragging a 400 MHz ground-coupled antenna across the surface of the road at a slow walking speed, whilst noting the main features of the road (Figure A5.2);
3. This GPR survey was then processed by Roadscanners Oy using RoadDoctorPro® software to produce a cross section radargram showing the road construction and underlying soils. For this, the road construction was interpreted as a single structure, unless individual layers could be seen, and any geogrids plotted where they were evident (Figure A5.3);
4. The GPR radargram interpretation was then superimposed on to the ground cross section to produce the GPR cross section (Figure A5.4).



**Fig A5.2** Photograph of cross-section method. The surveyor is dragging the 400 MHz ground-coupled antenna across the surface of the road at a slow walking speed.



**Fig A5.3** GPR cross section radargram



**Fig A5.4** Combined GPR Cross-section

## **Processing and interpretation**

The GPR data was processed and interpreted with RoadDoctorPro® software. This work concentrated on identifying the main features of the respective surveys, i.e.

- Cross-sections: the base of the floating road construction and lower geogrid any intermediate geogrids, if present
- Long section: the base of the floating road construction
- Interpretation of the construction layers of the floating road was not attempted.

## Results - Wind Farm A

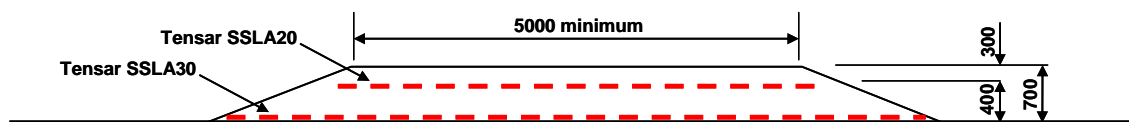
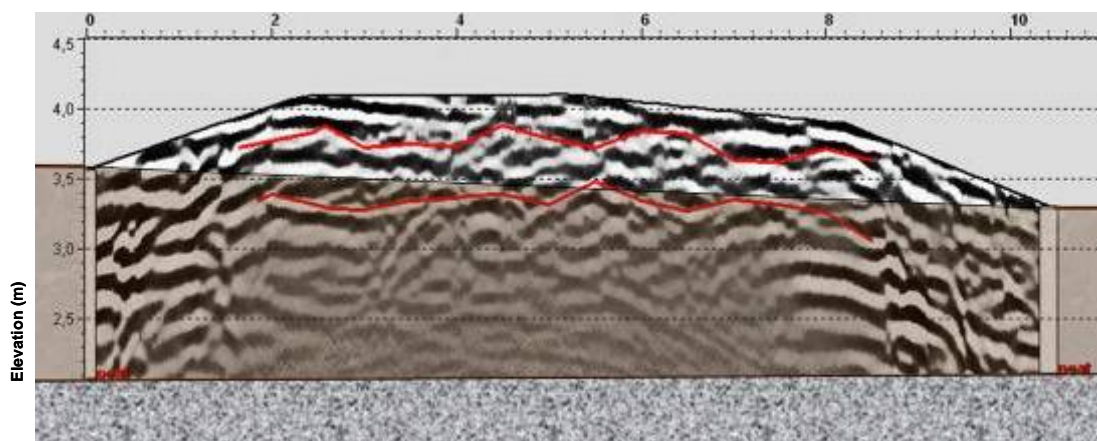


Fig A5.5 Designed floating road cross-section at Wind Farm A

Four GPR cross sections were taken out on “Wind Farm A” on 29 April 2009 by Forestry Civil Engineering (FCE) employing the procedure above. Two of these are discussed below

**Cross-section A(1):** a 6.0 m wide floating road constructed on 1.2 to 1.5 m of peat, with a peat surface cross slope 1.4°



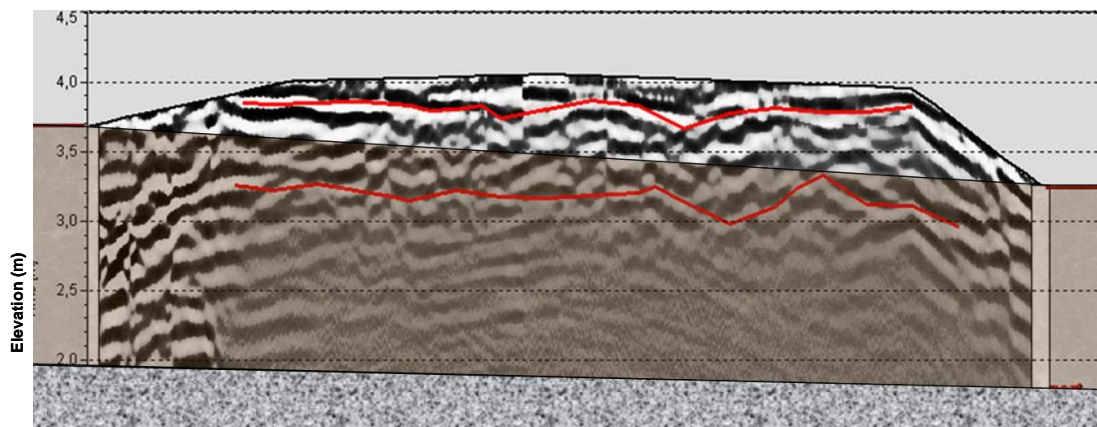
Cross Section A(1)

This cross-section consisted of a 0.6m thick road structure with 2 geogrid layers: a Tensar SSLA30 laid directly on to the natural ground surface and a Tensar SSLA20 installed at mid level, approximately 300mm above the base geogrid.

### Discussion

The 2 geogrid arrangement appeared to have produced a fairly strong initial layer that had settled fairly uniformly into the peat by approximately 200mm. Some rutting was discernable in both geogrids as a result of construction trafficking but this did not appear to any significant degree on the finished road surface.

**Cross-section A(2):** a 6.8 m wide floating road constructed on 1.5-1.8 m peat, with a peat surface cross slope 2.3°



Cross Section A(2)

This cross-section consisted of a 0.6m thick road construction with 2 geogrid layers: a Tensar SSLA30 laid directly on to the natural ground surface and a Tensar SSLA20 installed at mid level, approximately 300mm above the base geogrid.

### Discussion

As with cross-section A(1) the two layer geogrid arrangement appeared to have produced a fairly strong layer that had settled fairly uniformly into the peat by approximately 200-400mm. Some rutting was discernable in the geogrids as a result of installation and construction trafficking but this did not appear to any significant degree on the visible finished road surface.

## Results - Wind Farm B

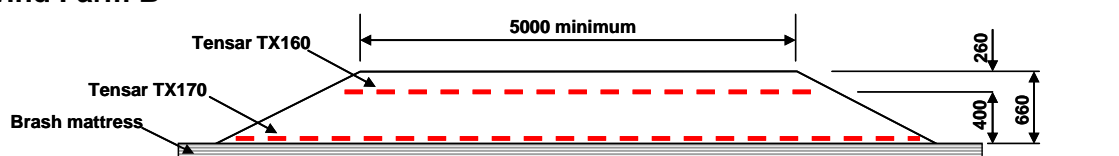


Fig A5.6 Designed floating road cross-section at Wind Farm B

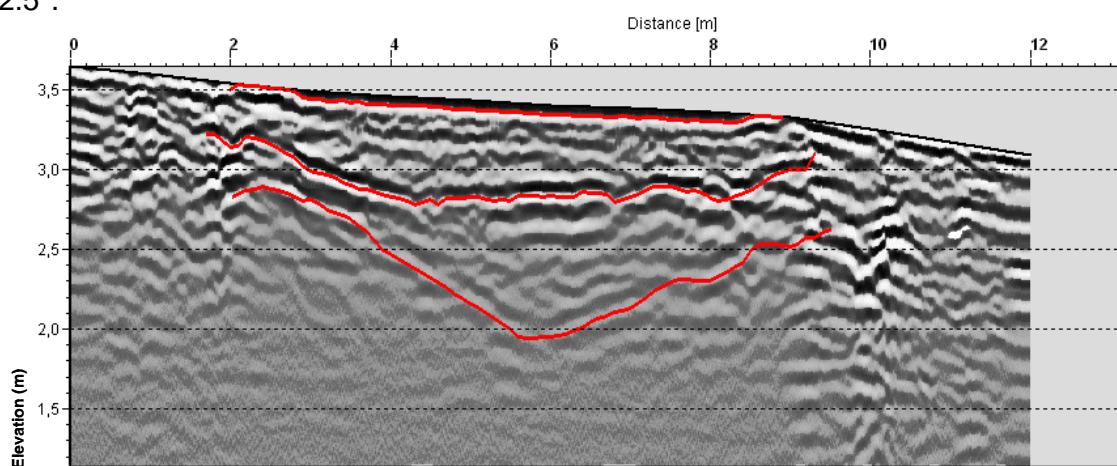
Eight GPR cross sections were taken on “Wind Farm B” on 7 August 2009 by Forestry Civil Engineering (FCE) employing the standard procedure above. This wind farm constructed the floating road on a mattress of brash from the former woodland on the site. The brash had been laid at right angles to the road line and tracked into place by machines. This had the effect of pushing the brash down into the peat until such time that a working platform could be provided on which to build the floating road. A notable feature of the in-service road on the day of the GPR survey was the angle of brash exposed at the side of the road. This was estimated to be at an angle of up to 30° from the horizontal at some locations as shown in Figure A5.7. Once an acceptable working platform was achieved the designed geogrid and road material were placed directly on top of the brash in the normal fashion.



Fig A5.7 Deflected brash mat exposed at edge of floating road on Wind Farm B

Three GPR cross-sections are discussed:

**Cross-section B(1):** a 6.8 m wide floating road constructed on 2.6 m of peat, with a peat surface cross slope 2.5°.



Cross Section B(1)

This cross-section consisted of a 0.6m thick road construction with 2 geogrid layers: a Tensor TX170 laid on top of the brash mat surface and a further Tensor TX160 installed at mid level of the road, approximately 400mm above the base geogrid. The lowest interpreted line is the base of the brash mat showing the deflection bowl produced under tracking.

### Discussion

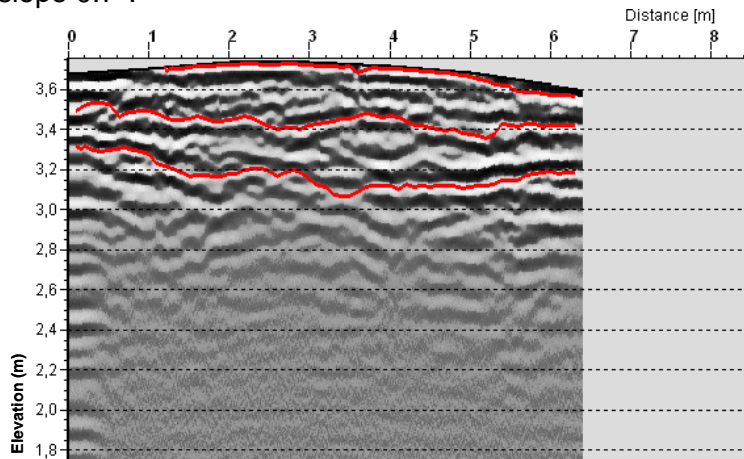
The surveyed floating road on this wind farm site did not sit above the surrounding peatland, as in the case of Wind Farm A, but instead finished closer to the former original necessitating intercepting ditches in places.



This may have been due to the compressibility of the brash mat materials used, or the very high water content of the peat on the site, but this was not investigated.

The 2 geogrid arrangement however again appeared to have produced a fairly strong interlock layer above the brash mat that had settled fairly uniformly. Unfortunately construction work, loading and landscaping adjacent to the road work did not permit the original adjacent ground level to be accurately identified so it was not possible to determine settlement below the road.

**Cross-section B(2):** a 6.4 m wide floating road constructed on 4m to 5m of peat, with a peat surface cross slope 0.7°.



**Cross Section B(2)**

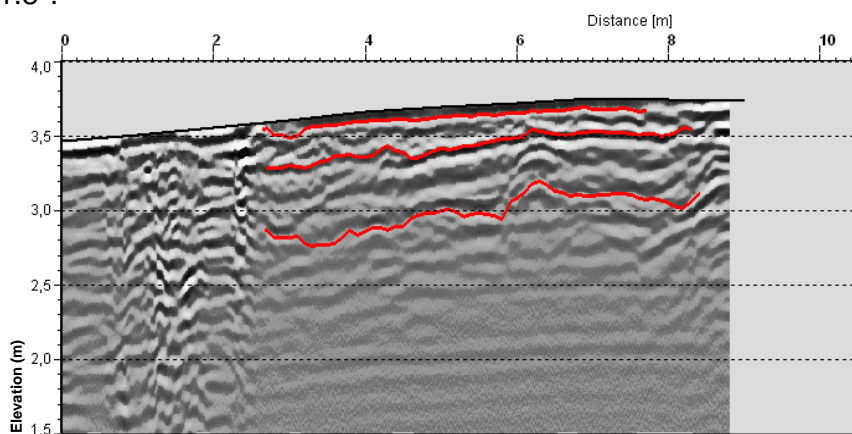
This cross-section consisted of a 0.8m thick road construction with 3 geogrid: a Tensar TX170 laid on top of the brash mat surface, a further Tensar TX160 geogrid installed at mid level, approximately 400mm above the base geogrid, and a second TX160 installed at 100mm below the running surface.

### Discussion

This section of floating road was constructed on a particularly wet area of bog with visible standing water at the side. Site staff reported that 3 layers of geogrids had been used at the location due to the particularly wet ground conditions encountered. It is likely therefore that the construction layers at this cross section were submerged, with similar dielectric values, making the layers more difficult to differentiate. Notwithstanding these conditions the installed triple geogrid arrangement again appeared to have produced a fairly strong interlock layer above the brash mat that had settled fairly uniformly.

As with cross-section B(1), construction work, loading and landscaping adjacent to the road work did not permit the original adjacent ground level to be identified. It was not therefore possible to determine the level of settlement below the road at this cross section.

**Cross-section B(3):** an 8.8 m wide floating road constructed on >9m of peat, with a peat surface cross slope 1.8°.



**Cross Section B(3)**

This cross-section consisted of a 0.7m thick road construction with 3 geogrid layers: a Tensar TX170 laid directly on to the natural ground surface, a further Tensar TX160 geogrid installed at mid level, approximately 400mm above the base geogrid, and a second TX160 installed at 100mm below the running surface.

### Discussion

The installed 3 geogrid arrangement again appeared to have produced a fairly strong interlock layer that had settled uniformly into the peat, albeit with a tilt to the left by approximately 2° reflecting the natural slope of the ground. Unfortunately construction work, loading and landscaping adjacent to the road work did not permit the original adjacent ground level to be identified. It was not therefore possible to determine the level of settlement below the road.

## Results - Wind Farm C

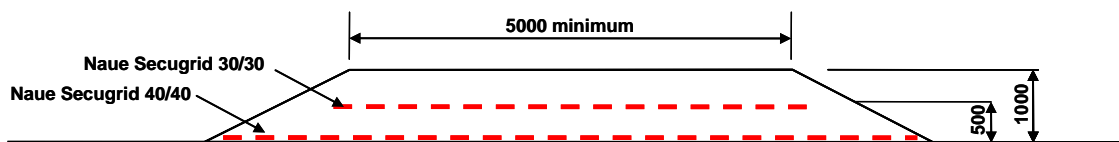
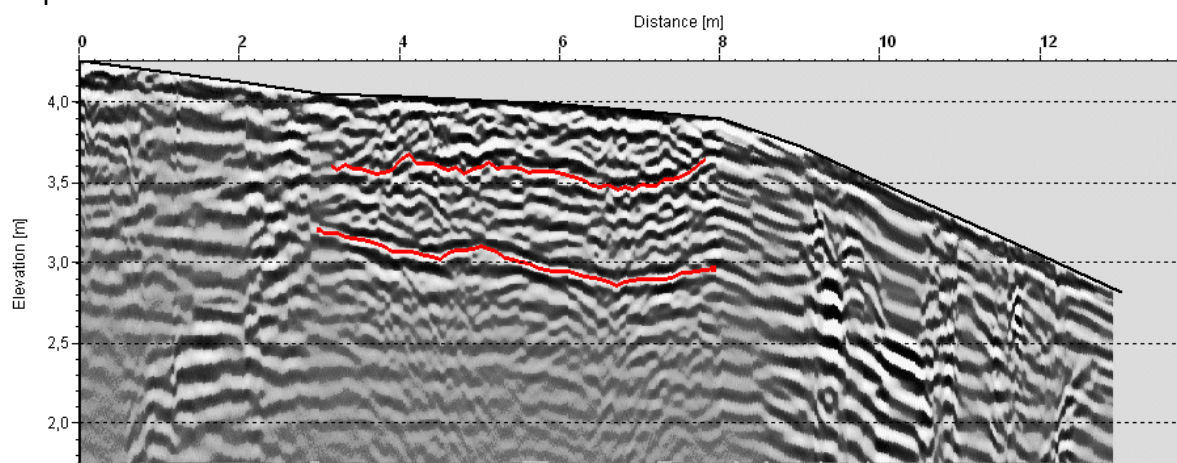


Fig A5.8 Designed floating road cross-section at Wind Farm C

A series of GPR cross sections were taken on “Wind Farm C” on 3 September 2009 by Forestry Civil Engineering (FCE) employing the standard procedure above. Three are discussed below.

**Cross-section C(1):** a 5.3 m wide floating road constructed on 1.0 to 1.2m of peat, with a peat surface cross slope 6.2°



Cross Section C(1)

This cross-section consisted of a 1.0m thick road construction with 2 geogrid layers: a Naue Secugrid 40/40 laid directly on to the natural ground surface and a further Naue Secugrid 30/30 installed at mid level, approximately 500mm above the base geogrid.

### Discussion

The 2 geogrid arrangement appeared to have produced a good interlock layer that had settled fairly uniformly into the peat by approximately 200mm. Some minor rutting was discernable in both geogrids as a result of installation and construction trafficking but this did not appear to any significant degree on the finished road surface.

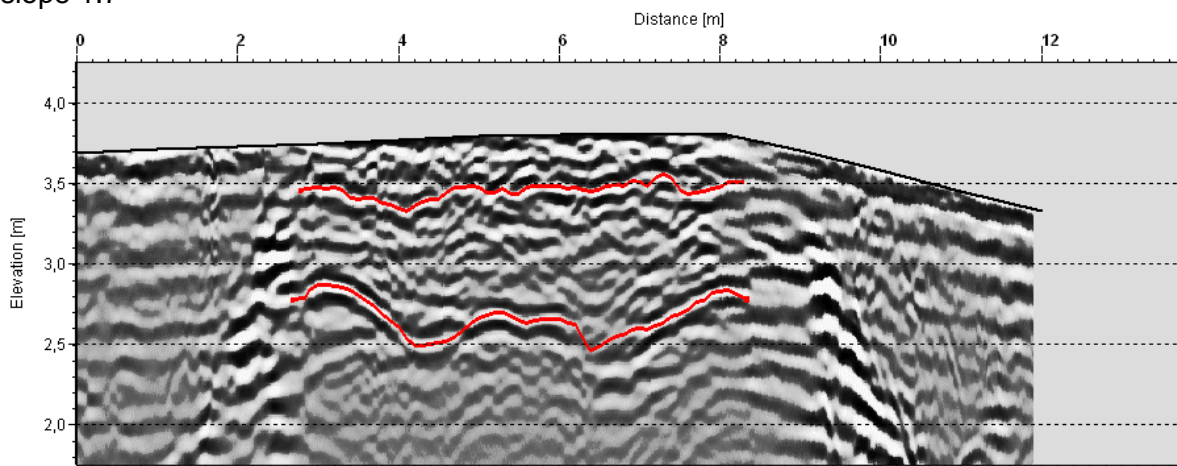
Unfortunately landscaping adjacent to the road with surplus peat did not permit the original adjacent ground level to be identified. The fresh layers of peat were so similar to the native material below so as to make an interpretation of the original ground surface impossible. It was not therefore possible to determine the settlement below the road.





**Fig A5.9** Photograph showing landscaping on verges on Wind Farm C

**Cross-section C(2):** a 5.1 m wide floating road constructed on 1.0 to 1.2 m of peat, with a peat surface cross slope  $1.7^\circ$



**Cross Section C(2)**

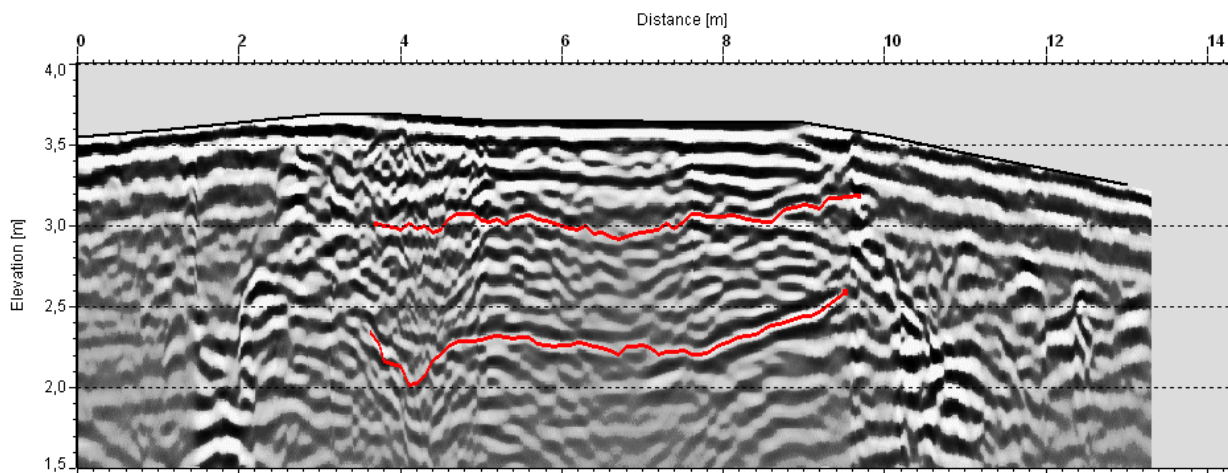
This cross-section consisted of a 1.0m thick road construction with 2 geogrid layers: a Naue Secugrid 40/40 laid directly on to the natural ground surface and a further Naue Secugrid 30/30 installed at mid level, approximately 500mm above the base geogrid.

### Discussion

The 2 geogrid arrangement appeared to have produced a fairly strong initial layer that had settled fairly uniformly into the peat by approximately 200mm. Some rutting was discernible on the lower geogrid, possibly due to early trafficking by construction plant, but this appeared to have been rectified by the inclusion of the upper geogrid and was not visible to any significant degree on the finished road surface.

Unfortunately, as already mentioned, landscaping adjacent to the road work did not permit the original adjacent ground level to be identified. It was not therefore possible to determine the settlement below the road.

**Cross-section C(3):** a 5.9 m wide floating road constructed on 1.0 m of peat, with a peat surface cross slope 1.4°



**Cross Section C(3)**

This cross-section consisted of a 0.9m thick road construction with 2 geogrid layers: a Naue Secugrid 40/40 laid directly on to the natural ground surface and a further Naue Secugrid 30/30 installed at mid level, approximately 500mm above the base geogrid.

### Discussion

The 2 geogrid arrangement appeared to have produced a fairly strong initial layer that had settled fairly uniformly into the peat by approximately 200mm. Some rutting was discernable in both geogrids as a result of installation and construction trafficking but this did not appear to any significant degree on the finished road surface.

Unfortunately landscaping adjacent to the road work did not permit the original adjacent ground level to be identified. It was not therefore possible to determine the settlement below the road.