6.0 SOILS AND GEOLOGY

6.1 INTRODUCTION

6.1.1 Background

At the request of Jennings O'Donovan & Partners Consulting Engineers (JOD), Whiteford Geoservices Ltd (WGS) undertook a hydrogeological and geotechnical study of the proposed Yellow River Wind Farm near Rhode, County Offaly.

The purpose of this work is to:

- Undertake a study of soils, water and general ground stability conditions at the proposed site.
- Identify likely impacts of the proposed development upon these aspects of the environment including a peat slip risk assessment.
- Identify mitigation measures to avoid, remediate or reduce the impacts identified.
- Identify residual impacts of the development after implementation of mitigation measures recommended.

6.1.2 Relevant Legislation

This study was undertaken in accordance with The Planning (Environmental Impact Assessment) (Amendment) Regulations (Ireland) 2002, as well as Statutory Instrument 2007 No. 684, known as The Waste Water Discharge (Authorisation) Regulations 2007. This complies with the European Directive 85/33/EEC, as amended by 97/11/EC, which require Environmental Impact Assessment for certain types of major development before development consent is granted.

The following report is based upon the documentation contained in the Scottish Executive's "*Peat Slide Hazard and Risk Assessment – Best Practice Guide for Proposed Electricity Generation Developments*", published as a final version in December 2006. Unless otherwise stated, all assessments and conclusions contained within this report are made with reference to this publication. These guidelines are commonly in use in Ireland and have been accepted as authoritative, by the relevant Public Bodies.

In addition to this planning legislation, other environmental legislation that is relevant to the hydrological aspects of this study is as follows:

Quality of Water Intended for Human Consumption (80/778/EEC) and Quality of Water Intended for Human Consumption Directives (98/83/EC).

The Groundwater Directive (80/68/EEC) and The Groundwater Regulations (Ireland) 2003.

Dangerous Substances Directive (2006/11/EC) and The Surface Waters (Dangerous Substances) (Classifications) Regulations 2003.

Water Act and Water (Ireland) Order 2003.

Integrated Pollution Prevention Control (IPPC) Directive (Ireland) 2007.

The Water Framework Directive (2000/60/EC) and The Water (Water Framework Directive) Regulations (Ireland) 2006.

The Water Framework Directive (WFD) which was passed by the European Union (EU) in 2000 but will not come into legal effect until 2015, is a wide-reaching legislation that will eventually replace a number of the previous water quality directives (for example, those on Water Abstraction) while implementation of others (for example, The Integrated Pollution Prevention and Control and Habitats Directives) will form part of the 'basic measures' for the Water Framework Directive.

6.1.3 Schedule of Works

Whiteford Geoservices Ltd (WGS) personnel visited the site from October 4th to 9th 2012 and on May 20th and 21st 2013 to undertake assessments of topography, geology, drainage and ground stability conditions at the site.

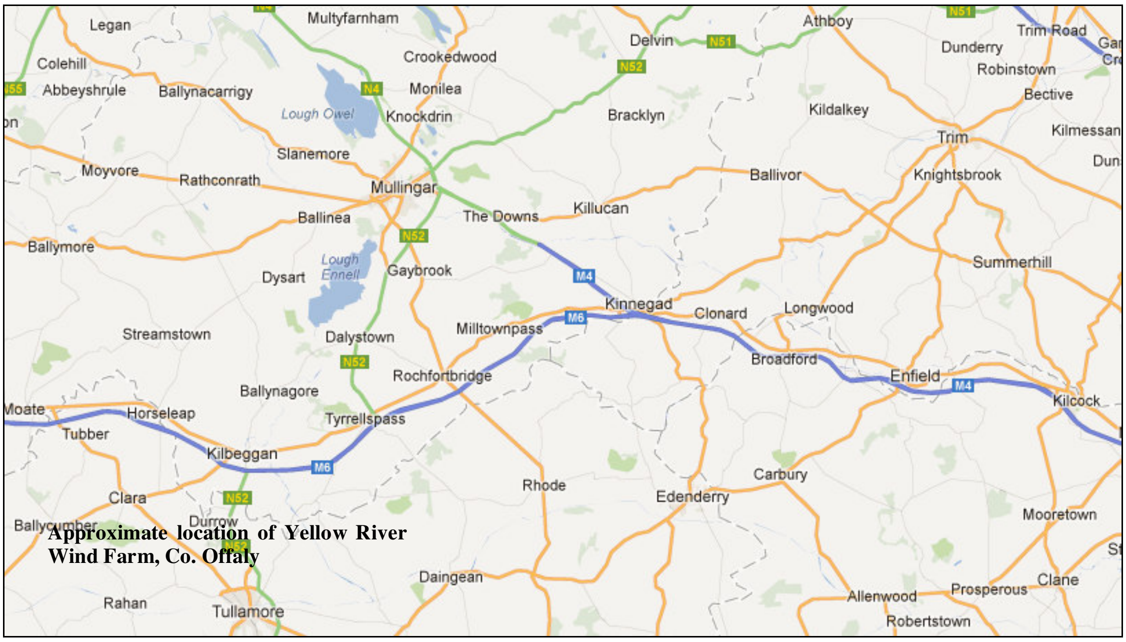

Figure 6.1 - Site Location Plan

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6.2 METHODOLOGY

6.2.1 Desk Study

WGS undertook a desk study assessment of the soils, geology, hydrology and slope aspects of the proposed development site in October 2012. This involved the following components:

Acquire and compile all maps of the proposed wind farm development.

Study geotechnical reporting available within the public domain for the locality. Particular use was made of the following report, issued in June 2000, for the proposed N6 dual carriageway:-

- *"N6 Kinnegad to Athlone Dual Carriageway, Geotechnical Constraints" report, produced by Riada Consult on behalf of Westmeath County Council*

Study and assess the proposed locations of turbines and access roads with regard to available data on site topography and slope gradients.

Study and assess the proposed locations of turbines and access roads with regard to available data on site soils, subsoils and bedrock geology.

Study and assess the proposed locations of turbines and access roads relative to aerial photographs.

Overlay Geological Survey of Ireland (GSI) online data to determine site bedrock geology and the presence of any major faults or other anomalies.

Use of Geological Survey of Ireland (GSI) Quaternary mapping to determine soil classification on the site.

Consultation with the Geological Survey of Ireland (GSI) in relation to other publications in the fields of geology and hydrogeology resources of Co. Offaly.

Consultation with the Met Eireann Office for meteorological records pertaining to the site.

Consultation with the Water Service of Ireland to identify water supply sources in the vicinity of the proposed wind farm.

Conduct peat slip risk assessment to identify any potential hazards at turbine positions and along access roads.

The equipment and materials used during this desk study consisted of:

- AutoCAD (Graphics)
- Microsoft Excel (Database)
- Microsoft Word (Report)
- PDF (Report)
- Thales DGPS System
- Peat probing rods

6.2.2 Site Investigations

WGS carried out preliminary site investigations at the site of the proposed development in October 2012 and May 2013.

These works consisted of:

- Bedrock and subsoils outcrop logging and characterisation at turbines, other structures and access roads.

- Two machine excavated trial pits to a maximum depth of 3.25m below existing ground level.

- Peat depth probing. Peat probing was undertaken manually by pushing a series of rods into the ground at a selection of proposed turbine positions until a significant change in resistance was registered within the sub-soil. The depth to this increase in resistance was then measured and recorded.

- Shear strength of the peat was measured using a hand held shear vane.

- The purpose of these investigation methods was to assess the impact of external factors (such as local hydrology, vegetation etc) on the tensional forces binding the peat and hence its tendency towards failure, by shear, during construction works.

- Recording of GPS co-ordinates for all investigation points in the study.

6.2.1 Impact Assessment Methodology

From the desk and field data acquired, the following calculations and assessments were undertaken in order to evaluate the stability and type of soils, geology, contamination of water and slope aspects of the environment at the proposed development site for Yellow River Wind Farm:

- Characterisation of the sites topographical, geological, hydrological and geomorphological regime from the data acquired

- Consideration of ground stability issues as a result of the proposed development, its design and methodology of construction

- Assess the combined data acquired and evaluate any likely impacts on the soils, geology and water aspects of the environment

- If impacts are identified, consider measures that would mitigate or reduce the identified impact

- Present and report these findings in a clear and logical format that complies with EIS reporting requirements[20]

6.2.2 Characteristics of the Development

The proposed site is composed of approximately 1,002.234 hectares, with the development footprint measuring 20.58 hectares. The proposed site for Yellow River Wind Farm is located to the north and south of the Yellow River and its tributaries. Two proposed turbine locations are situated to the south of the Mongagh River, which forms part of the County Offaly border.

Within Kilmurray's quarry settlement lagoons have formed due to current quarrying operations. Turbines 1 – 7 are bordered to the north by by Roadstone quarry and a Bord Na Mona peat bog, where a number of large drains are in place within this site.

The majority of the proposed development site consists of improved grassland, currently in use as agricultural pastureland. Turbines 8 - 12 consist of peat bog and heath grassland, the maximum depth of which was found to be 3.60m, with an average depth of around 0.50m.

Analysis of preliminary trial hole investigations indicate that peaty, clayey topsoil overlies a natural sequence of glacial sands and gravels at the proposed site.

Loose to medium dense sand, with varying gravel content, was found to be present within both excavations and continued at the terminal depths of 2.80m and 3.25m below existing ground level. Due to the somewhat unconsolidated and granular nature of the soils, excavations were unstable and wall collapses were observed during site works.

Groundwater, generally in a state of moderately weak to moderately strong flow, was encountered during excavation works at depths ranging from 2.20m to 3.10m b.g.l.

[20] Statutory Rule 1999 No. 73 "The Planning (Environmental Impact Assessment) Regulations (Northern Ireland) 1999".

Slope ranges are negligible over the survey area and the site of the development is generally flat.

Primarily, the scope of the proposed development can be characterised as follows:

- Total site area **1,002.234 ha**
- Development footprint **20.58 ha**
- Peat Depth Range **0 – 3.6m**. Average peat depth **0.5 m**.
- Construction of foundations for 32 wind turbines (Excavations diameter 18m, Depth 2m)
- Hardstands area (**1,250m^2**) and associated splays (**745 m^2**) **Total Area 1,995m^2**
- Temporary construction compound, approximately **50 m x 30 m**.
- Clear fell of plantation forestry area 1.5 ha per turbine (four turbines T1; T25; T26 and T27 = 6 ha) plus part of T2 area = 0.77 ha plus areas felled for new roads, total clear felling 3.63 ha. (2,425m of road x 15 m wide corridor) **Overall Clear fell area Total 10.4 ha**
- T11 scrub area to be felled = **1.5 ha**
- Construction of approximately **18,275 m** of new access tracks having a minimum finished width of 5 m with passing bays
- Upgrading of approximately **5,916 m** of tracks by widening, strengthening and bend improvement.
- Installation of site drainage network.
- Installation of underground ducts and cabling from each turbine to the substation. Cable trenches, which will typically be 0.5 – 1.0m wide and 0.75 – 1.00m deep, will generally follow the edge of the site access tracks and will be installed in conjunction with the tracks. The excavated material will be laid alongside the trench for use in reinstatement following the laying of cables.
- Construction of Substation Control Buildings and Compound on site area **1,850 m^2**

- Erection of 1 permanent meteorological mast, comprising a lattice steel tower.
- Stream/River crossings **9**
- Upgrade of existing bridges **1**
- The terrain is sloping with gradients between 1:40 and 1:100.

6.3 RECEIVING ENVIRONMENT

6.3.1 Geology

Land in the vicinity of the proposed Yellow River Wind Farm site is predominantly underlain by Visean Basinal Limestone and Shale, Waulsortain Mudbanks, Marine Shelf Facies, and Carboniferous Volcs and minor intrusions. The Dominant rock in the central portion of the site is Walsortian Mudbank, with Marine Shelf Facies prevelant in the eastern portion and Visean Basal Limestone prevelant in the western part. Carboniferous Volcs intrude on the north western part of the site.

Consultation with the GSI online database indicates that there are no solution cavities or abandoned mines on or near the proposed site.

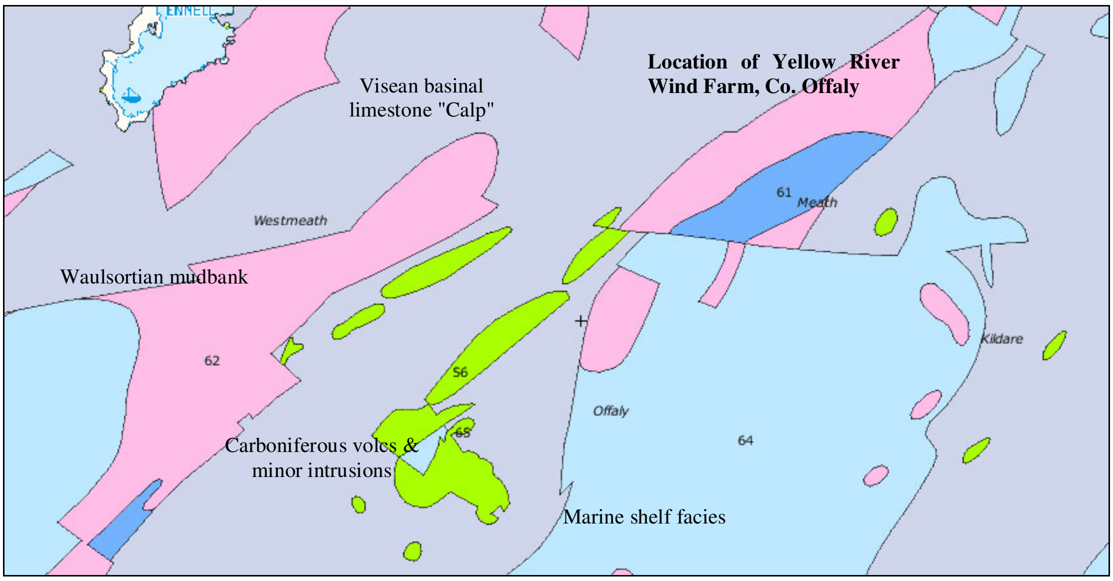

Figure 6.2 - Site Geology

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Consultation with the Geological Survey of Ireland indicates that there are 3 Nr. active quarries within a 15km radius of the proposed site of Yellow River Wind Farm.

Two further quarries are present closer to the site; one being situated within the proposed boundary of Yellow River Wind Farm. Kilmurray Sand and Gravel quarry, located approximately 3km north-west of Rhode village on the R400, is currently operational. A Roadstone Quarry, also in operation, is located immediately north of Kilmurray's quarry.

No shafts or adits were recorded within 10km of the proposed site.

Please refer to Figure 6.3 below for a schematic representation of active quarries near the Yellow River Wind Farm site.

Quarry Location **Proposed Wind Farm Development**

Figure 6.3 Location of active quarry sites within 15km radius of proposed Yellow River Wind Farm

6.3.2 Regional Hydrogeology

Aquifer Classification

Consultation was made with the Geological survey of Ireland's National Draft Bedrock Aquifer map.

The geology of the site comprises superficial drift deposits overlying Carboniferous Limestone. The drift deposits are likely to vary from impermeable clay to very permeable, clean sands and gravels. Layers of permeable and impermeable material can alternate in the vertical and horizontal planes producing complex bodies. The groundwater in the drift deposits can be in contact with the Limestone or exist as distinct bodies perched above the solid geology. Some permeable lenses of gravel may be small and distinct which may produce high initial flows but quickly decline because they are not replenished. However, where such a layer of clean gravel is in contact with a water body, high flows can continue for some considerable time. The complexity of drift hydrogeology is such that two permeable layers may have a water table at the same elevation but not be connected.

Essentially, surface water is anticipated to enter the sub-surface where it is permeable and will continue vertically downwards until it comes into contact with either an impermeable stratum or the water table. At this point the surface water will migrate in the same direction as the groundwater or according to the gradient of the impermeable stratum.

The Carboniferous Limestone yields groundwater via the fissures and not the matrix. Experience has shown that only a few and not all the fissures may control the movement through the rock material. Where the fissures are clean and wider than 5mm, and there is an adequate source, flow can be considerable. When assessing the presence of groundwater in a fissured Limestone the concept of a water table can be misleading. For example, a borehole drilled into the rock mass may be dry while another sunk a short distance away may intersect a water bearing fissure. Lowering of the water table in the Limestone due to construction processes such as cutting may result in the consolidation of the overlying glacial deposits.

The National Draft Bedrock Aquifer map indicates that the site is underlain by locally important aquifers, which are generally moderately productive.

Groundwater Vulnerability

The groundwater vulnerability varies within the boundaries of the proposed development. The majority of the site is located within areas of low to moderate vulnerability. Regions of the site within landholdings containing turbines T15, T16, T17, T18, T19, T20 and T21 present areas of increased groundwater vulnerability.

Wind farm drainage has been designed to adequately cope with the groundwater conditions identified at the most vulnerable turbine locations. Please refer to sections 2.7.12 and 3.2.4 for further details.

Well Database

Consultation with the Geological Survey of Ireland's database indicates that there have been a high number of exploratory wells undertaken within the land surrounding the proposed development area.

6.3.3 Local Hydrology

Site Drainage

Across the proposed site development there are a number of drains in place. The majority of these occur along the boundaries between individual fields on agricultural land. Most are approximately 2.00m wide and 1.00m deep. Within the peat bog areas drains are present more frequently, although it was not possible to determine the full extent of the site drainage system.

Please refer to the site walk-over and reconnaissance section for details of existing site drainage features identified within the vicinity of each proposed turbine location.

Local Watercourses

The proposed development site for Yellow River Wind Farm is located to the north and south of the Yellow River and its tributaries. Two proposed turbine locations are situated to the south of the Mongagh River, which forms part of the County Offaly border.

Within Kilmurray's quarry settlement lagoons have formed due to the quarry currently in operation. Turbines 1 - 7 are bordered to the north by Roadstone quarry and a Bord Na Mona peat bog, where a number of large drains are in place within this site.

Palaeo-Karst Features

Karst topography is defined as "An assemblage of topographic forms resulting from dissolution of the bedrock and consisting primarily of closely spaced sinkholes." [21] Karst topography can form in regions of exceptionally soluble rocks, including Limestone. Large areas of the proposed site development are underlain by Visean Basinal Limestone.

During completion of the walkover survey the proposed site development area has been visually assessed to determine if any karstic features are present. The presence of such features has, in some cases, resulted in structural instability.

6.3.4 Soils and Sub-soils

The Quaternary Geological Map of Ireland, published by the Geological Survey of Ireland (GSI), shows that the study site is mainly mantled by peat which is underlain by glacial subsoils.

WGS observed that the proposed Wind Farm site consists generally of cutaway raised bog and improved agriculatural grassland.

The table 6.1 lists the findings of the peat probing and illustrates the presumed peat thickness.

[21] (Skinner and Porter, 1987: p259)

Turbine	Deepest peat depth in Turbine Vicinity (m)
T1	0.25
T2	0.05
T3	0.10
T4	0.50
T5	0.00
T6	0.48
T7	3.00
T8	0.52
T9	1.50
T10	0.05
T11	0.50
T12	0.03
T13	0.48
T14	1.00
T15	1.00
T16	0.50
T17	0.50
T18	0.50
T19	0.21
T20	0.50
T21	0.50
T22	0.50
T23	0.50
T24	0.50
T25	0.50
T26	0.50
T27	0.22
T28	0.18
T29	0.14
T30	1.46
T31	0.64
T32	0.95

Table 6.1 – Generalised Peat Depth Distribution

Although the results of probing indicate a presumed peat depth range of 0 to 3.60m at the location of proposed structures, it should be noted that it is assumed that the depth of peat corresponds to an increase in resistance on the probes

Obstructions within the peat would cause an increase in resistance or refusal, resulting in an inaccurate interpretation. Results of probing should therefore be considered to be indicative only.

All proposed turbine locations are situated on relatively flat ground, where slopes have been confirmed to be < 5 degrees to the horizontal.

6.3.5 Potential For Bog Failure

Based on topography and collected peat depth thickness at each turbine an assessment was made of the potential for peat movement. From this information Table 6.2 of potential risks was produced. The Peat Slide Risk Assessment Report can be found in **Appendix K**.

Reference is made, in this section, to "*Peat Slide Hazard and Risk Assessment Best Practice Guide for Proposed Electricity General Developments*", produced by The Scottish Executive & Halcrow Group Ltd (Dec 2006).

Stability Issue	New Access Routes	Turbine Base Location
Existing Slopes	The slopes encountered at the proposed site are generally low and vary between approximately 0 – 5 degrees to the horizontal.	Slopes encountered at the proposed turbine locations are generally low and display magnitudes of 0 – 5 degrees to the horizontal.
Landslip / Bog Slide	*Excavations* The favoured method of construction for new access roads is to found, where possible, directly on top of the natural soils present immediately underlying the peat. Where this is carried out and slopes are of low to moderate magnitude (0 – 5 degrees) the potential for bog slide, at a time post-dating the completion of the site works, is classified to be at INSIGNIFICANT RISK . *"Floated" Road Construction* Where the peat thickness is in excess of 1.50m, "floated road" construction is considered to be more effective than excavation. Current information suggests that this method of construction will be applicable to short stretches of access road in the vicinity of turbines T7, T8, T9, T10 and T23.	From topography and peat depth data the following assessment is made at each proposed turbine location. Walkover assessment confirms that only 7 out of the 32 proposed turbine locations are within areas where peat could be considered the prevailing superficial soil type. The turbines affected are T7, T8, T9, T10, T23, T30 and T31. *Excavations* At turbine locations T8, T10, T23, T30 and T32 the peat cover present is not significant and the proposed locations of the turbine bases are situated on slopes of negligible magnitude. Consequently, these proposed turbine locations can be classified - INSIGNIFICANT RISK. At turbine locations T7 and T9 peat thicknesses in excess of 2.5m and potentially in excess of 4m are present. However, given the negligible ground slopes and relative distance from sensitive receptors peat slide risk is determined to be - INSIGNIFICANT RISK The designation INSIGNIFICANT RISK does not however mean that the risks of constructing within PEAT can be ignored. This designation makes the assumption that correct procedures will be adopted and implemented fully during the construction period. If SIGNIFICANT RISK were to be encountered specific procedures would be appropriate to mitigate the risk and reduce it to an acceptable level.

Table 6.2 – Summary of Peat Slide Analysis for Yellow River Wind Farm

These potential risks have been used to calculate a risk ranking, based on the following:-

- **HAZARD**: the likelihood of the peat slide event occurring

(This relates to the potential for a peat slide to be triggered. Factors considered include the topographic slope, peat thickness, strength of peat, type of peat present and method of construction proposed.)

Table 6.3 gives a general view of some of the factors used to establish HAZARD RISK:-

(The actual calculation of HAZARD is a complex procedure based on a detailed numerical analysis of key indicators.)

Scale of Risk	***Hazard***
0	*Peat not present and average slopes < 5 degrees to the horizontal*
1	*Peat less than 2.50m thick and slopes < 5 degrees to the horizontal*
2	*Peat less than 2.50m thick and slopes 5 – 10 degrees to the horizontal* *Peat 2.50m to 4.00m and slope < 5 degrees to the horizontal* *Where peat cover is greater than 1.50m, the construction of "floated" roads is recommended*
3	*Peat 2.50m to 4.00m thick and slopes > 5 and < 10 degrees to the horizontal*
4	*Peat 2.50m to 4.00m thick and slopes > 10 and < 22.5 degrees to the horizontal* *Peat > 4.00m thick and slopes > 5 and < 10 degrees to the horizontal*

Table 6.3 Qualitative assessment of Peat Slide Hazard

- **EXPOSURE**: the impact that such an event might have at this particular location

(This relates to the receptor in the event of a peat slide. This can range from adjacent areas of blanket bog, to farmland, watercourses, water abstraction sites, roads, un-occupied structures and occupied structures.)

Table 6.4 gives a general view of some of the factors used to establish EXPOSURE RISK:-

Scale of Exposure	*Determining Factors*	*Impact upon total project*
1	*Flat agricultural land or blanket bog within 100m of structure or 50m for roads*	*Very low Impact (< 1%)*
2	*Structure <100m from minor water course or <50m for roads*	*Low Impact (1% - 4%)*
3	*Structure or roads <100m from major water course, or uninhabited building*	*High Impact (4% - 10%)*
4	*Structure <100m from major public road*	*Very High Impact (10% - 100%)*
5	*Structure <100m proximity to inhabited buildings*	*Extremely High Impact (> 100%)*

Table 6.4 Qualitative assessment of Peat Slide Exposure

By assessing each peat slide event against the scales given above, it is possible to assess the hazard ranking by multiplying the hazard and exposure of each event.

This results in a Hazard Ranking value between 0 and 25. (i.e. **HAZARD RANKING = HAZARD x EXPOSURE**). Table 6.5 outlines the suggested action for the different levels of hazard ranking.

Hazard Ranking	*Hazard Ranking Level*	*Action Suggested*
17 - 25	**Serious**	Avoid project development at these locations
11 - 16	**Substantial**	Project should not proceed unless hazard can be avoided or mitigated at these locations, without significant environmental impact, in order to reduce hazard ranking to significant or less.
5 - 10	**Significant**	Project may proceed pending further investigation to refine assessment and mitigate hazard through relocation or re-design at these locations
0 - 4	**Insignificant**	Project should proceed with monitoring and mitigation of peat landslide hazards at these locations as appropriate

Table 6.5 Hazard Ranking and Suggested Actions (in accordance with "Peat Slide Hazard andRisk Assessment – Best Practice Guide for Proposed Electricity Generation Developments", December 2006)

Table 6.6 summarises the relative Hazard Ranking of each Turbine to be constructed at Yellow River Wind Farm

ID	Co-ordinates		Peat Slide Hazard Ranking
	Easting	Northing	
T7	249352	236407	**4**[22]
T8	250187	236156	**2**
T9	250565	236006	**4**
T10	251119	235699	**4**
T23	254931	238582	**2**
T30	235594	240494	**1**
T32	254120	241523	**2**

Table 6.6 Hazard Ranking for each Turbine Location at Yellow River Wind Farm

A similar Hazard Ranking is anticipated for short stretches of the site access roads in the vicinity of these turbines.

6.4 DO NOTHING IMPACT

In the absence of the proposed development the following summarises the affect on the lands:-

There will be no positive impact to Soils and Geology, which would remain relatively unchanged, where site drainage remains effective.

Thus should the wind farm not be constructed, there would be a minor positive impact on the soils and environment with respect to peat stability when compared to the situation where the wind farm is constructed.

However, it should also be recognised that the improvements proposed to site drainage will increase peat stability (where peat is present) through a reduction in hydrostatic pressure. Conversely, the maintenance of effective site drainage cannot be guaranteed.

[22] A selection of 7 proposed turbine locations were visited to estimate peat depth, peat decomposition, ground slopes, presence of relic landforms and proximity to sensitive receptors.

Consequently, following construction there would be a minor improvement in slope stability and this would also have a corresponding minor positive impact in respect to soils and geology.

6.5 POTENTIAL IMPACTS OF THE DEVELOPMENT

6.5.1 Construction Phase

Earthworks Activities

Implementation of the proposed development will result in the removal of peat in parts of the site to facilitate excavation for the construction of access roads and platforms for the wind turbines to a competent stratum or bedrock suitable for placement of foundations.

Ground conditions vary across the site with a fluctuating peat cover. At the turbine bases, excavation is required to around 3.0m dependent on local ground conditions for a suitable foundation for the turbine.

Potential for Bog Failure

Consideration has been given to the potential for bog failures at the Yellow River Wind Farm site. These mass movements of peat can take the form of either bog burst or bog slide. Historical evidence suggests that raised bogs are more prone to bog bursts while bog slides are more common on blanket bogs, however it is noted that there is no historical or visually identifiable evidence of peat slides or ground instability at the development site. (*The site at Yellow River would be considered to be "raised bog" where bogland has been identified.)*

These peat failures generally occur either during or immediately after periods of heavy rainfall. Failures are especially likely to occur where there is a break of slope at the edge of an upland plateau of peat. Records indicate that bog bursts can naturally occur on shallow slope angles of less than 6 degrees while bog slides appear to occur on slopes that are steeper than 6 degrees.

Following recent, well documented bogslides on the slopes of Dooncarton and Barnachuille mountains, Co. Mayo in September 2003 and more significantly at Derrybrien, Co. Galway in October 2003, the potential for bog failure has come to the fore in consideration of planning for wind farm development. The following potential causal factors for bog failure are identified following research and assessment of recent slides and from historical evidence over the last 200 years in Ireland.

1. Research into the history of bogslide occurrence indicates that the majority of bogslides have occurred on the blanket bogs in the west where rainfall is highest. Here, bogslides tend to be more frequent during the autumn and winter months.

2. The following criteria are considered to be the causal or contributory factors to bogslide occurrence:

(a) Slope is the single most important factor for blanket bogs. Bog slides are especially likely to occur where there is a break in slope at the edge of an upland plateau of blanket peat, providing a line of weakness. While initial failure is likely to be slippage (translational or rotational faults) semi-fluid to fully fluid behaviour is the main movement mechanism downslope. Slope gradient imparts kinetic energy to the sliding material.

(b) The depth of peat and its relationship to humification (the degree to which the fibre structure of the peat has decayed), pore water pressure, shear vane strength and other parameters generally indicates that the deeper the peat profile the more unstable it is, if external controls such as slope, drainage, removal of adjoining earth materials are changed. Exact depth thresholds for stability are not applicable due to the variability of peat environments (raised bog, blanket bog or fen habitats) and their site specific conditions. However, as a rule of thumb peat of depths greater than >1.5m is significantly more vulnerable to instability than shallower peat at <1.5m depth, and in particular the top-layer of acrotelm (living) peat at <0.3m.

(c) The pattern of recent precipitation at the site over the last c. 30 years such as intense localised rainfall (or melting snow) is an important trigger mechanism.

(d) Antecedent weather conditions such as drought conditions are identified as a contributing factor. In the case of the recent landslides at Dooncarton and Barnachuille in September 2003 and at Derrybrien October 2003, short intense periods of heavy rainfall followed an exceptionally dry late summer. Historically, the Owenmore bogslide in Erris, Co. Mayo (1819) was also preceded by two months of drought. Sustained dry conditions leads to high soil moisture deficit (SMD). This dries the blanket peat, causing shrinkage and desiccation cracks.

(e) Some bogslides are caused by excessive interference – e.g. opening of turf banks, opening deep drains on blanket bog. All drains should be perpendicular to slope contour not parallel to it.

Finally, the following items are noted:

1. Geological structural features generally play no part in bogslide occurrence.

2. Bogslides are prone in certain upland locations due to their peculiar topography, ground composition and hydrology. When a slide occurs, it acts as a safety valve to restore equilibrium.

3. The most destructive bogslides involve the combination of slide materials with floodwaters, diluting the peat and mud in waterways and accelerating the velocity of the debris flow.

Water Quality

The following impacts both likely and potential are identified:

Suspended solids release during excavations

In a wind farm development, it is the construction phase that poses the highest risk to the site's hydrology, in particular to the quality of surface water due to generally poor aquifer conditions on high elevation terrain. The Yellow River site does not have this high terrain but does have a low lying terrain. Nevertheless, it is likely that during excavation works, storage and re-use of materials, suspended solids will be entrained by sustained rainfall and surface water runoff.

The most vulnerable areas to surface water quality deterioration are (a) access road crossings of man made drains and (b) turbine hardstand and infrastructure development at moderate gradient slopes proximal to existing waterways, which this site should not be threatened by as it has relatively low gradients and no natural waterways within 50m of turbine locations.

Some of the man made drains have steep gradients cut out, which should be taken into account if constructing new access tracks. This is considered to be short-term and temporary but could have significant negative impact. With appropriate environmental engineering controls and measures, this impact can be negated and mitigated against.

Risk of pollution from hydrocarbons

The second pollutant of concern during the construction phase of the project is the potential spillage and release of hydrocarbons from plant equipment and associated transfer stations during the construction phase. An accidental hydrocarbon spillage would have a significant negative impact on both vegetation and water quality at the site.

Temporary sanitation

A temporary site office, service area and sanitation will be required for the construction stage of the development. Associated with this facility is the potential risk of water and soil contamination by wastewater release or chemical contamination of water and soil from temporary sanitation facilities. The level of risk posed is dependent on the type and location of facilities that are put in place.

The Water Framework Directive (WFD) highlights that all groundwater has a value irrespective of whether it occurs in a major or minor aquifer. Groundwater also contributes and maintains the surface water network and as a result its contamination should be mitigated.

6.5.2 Operational Phase

Change to Hydrological Regime

The rate and amount of surface water runoff from the site will increase as a function of the replacement of vegetation, peat and subsoils cover (which absorb rainfall) in parts of the site with a concrete/aggregate hardstand at turbine locations, and aggregate mix for proposed access tracks.

Water Quality

A potential impact on water aspects of the environment may arise during the operational phase of the development if regular maintenance, monitoring and auditing of mitigation structures and procedures are not undertaken during the lifetime of the project.

6.6 MITIGATION MEASURES

6.5.3 Construction Phase Mitigation

Earthworks Activities

The removal of bedrock may be unavoidable in places but every effort should be made to ensure that the amount of subsoils to be removed is kept to a minimum in order to limit the impact on the geotechnical and hydrological balance of the site.

It is noted that the "natural hydrology" of parts of the site may have been significantly altered by land drainage, however measures will be emplaced to minimise any additional changes to the existing site hydrology resulting from the construction of the wind farm.

During the construction works, the excavation, storage and re-use of excavated materials have the potential to directly or indirectly negatively impact on water quality. Appropriate engineering controls, such as the installation of a drainage system with settlement / stilling ponds, silt traps, check dams and interceptor drains, will be carried out in tandem with, and where possible, prior to, any excavation work to mitigate potential impacts. In relation to construction works, the most important aspects of these recommendations involve:

1. Deep excavations at turbine base locations in order to construct turbine foundations and hardstandings to support crane loadings.
2. Construction of new site roads and the upgrade of existing site roads.

3. Construction of new sections of "floated road" where excess peat depth is present.
4. Removal of waste peat and glacial spoil and disposal within designated zones.

These recommendations should be included in the Contractor's contract of works for the site. In addition, a construction phase management plan will be in operation to check equipment, materials storage and transfer areas, drainage structures and their attenuation ability on a regular basis. The purpose of this management control is to ensure that the measures in place are operating effectively, prevent accidental leakages, and identify potential breaches in the protective retention and attenuation network during earthworks operations.

Potential for Bog Failure

Site investigations and assessment of the Yellow River Wind Farm site indicate that the site is a low risk for slope failure or mass movements. Areas of moderate risks would be deep peat >2.5m and the presence of very sensitive, very weak peat (<15kPa). It is considered that no proposed turbine is located within such an area.

Applying the precautionary principle however, the following procedures are recommended as best-practise mitigation measures to avoid slope instability at wind farm sites.

These are:

The contractor's methodology statement should be reviewed and approved by a suitably qualified geotechnical engineer prior to site operations.

- Any excavations that may tend to undermine the up-slope component of a peat and or unstable subsoils slope should be sufficiently supported by buttress, frame or rampart to resist lateral slippage.

- Drainage management measures will be installed to effectively drain grounds in tandem with access track construction. Such drains should be positioned at an oblique angle to slope contours to ensure ground stability. Drains on areas of the site with minimal risk of bog failure as identified by site investigations can be positioned at a more acute angle to the slope contour in order to reduce the velocity of surface water drainage.

- Due to peat's fluid-like properties, all peat excavated should be immediately removed from sloping sites. If peat is required for reinstatement, then acrotelm peat (<0.3m shallow, living layer) should be moved to a lower elevation part of the site that is characterised by near-horizontal slopes, is >100m away from any significant break of slope and is >50m away from drains and streams.

- If additional materials are required for the construction process, after exhausting excavated materials during road and infrastructure construction, additional materials may be acquired from local quarries. Wherever possible any imported aggregates should consist of a similar geo-chemistry to the local geology of the site. It should be noted that this is dependent on the quality and variety of aggregate supplied by the local quarries.

- From recent evidence (landslides in Mayo and Galway). Excessively wet periods should be avoided in terms of scheduling significant excavations in peat substrates.

Water Quality

During the construction phase, surface water drainage is generally found to be more at risk to water quality change than groundwater, where the majority of documented pollution events tend to involve suspended solids from sediment flows. The following mitigation measures are recommended to protect surface water and, to a lesser degree, groundwater quality.

Groundwater Dewatering

Any water ingress that may be encountered in the upper weathered zone of the bedrock during the construction phase should be intercepted by a toe drain and diverted to an existing artificial drainage channel and attenuation before release.

The design of the drainage takes into account factors of slope stability and where possible should be sealed at the base. However there should be minimal slope stability issues at the site.

6.5.4 Operational Phase Mitigation

Change to Hydrological Regime

Stilling ponds and interceptors will be removed following the completion of construction works. The proposed Jennings O'Donovan drainage design will be capable of dealing with any additional surface runoff arising from the proposed development.

The proposed drainage design prevents both ***(a) hydraulic loading*** of the existing surface water network and ***(b) provides sufficient attenuation of suspended solids*** prior to outfall to the natural drainage network, in order to maintain the existing environments baseline chemistry. Surface water flows in all existing waterways and drainage should not be impeded in any way by the proposed development. Access tracks that intercept existing waterways will be designed so that the culverts installed to maintain baseline flows are large enough to accommodate peak flow within a 100-year return period.

Water Quality

WGS recommends the following measures to mitigate pollution to surface waters and groundwaters during the lifetime of the project.

A regular programme of environmental site maintenance for the drainage network and drainage culverts to ensure their performance to standards at the site. Some changes in the drainage network may be required as a result of unanticipated changes in the hydrological regime at the site during the operation phase of the project.

Although no onsite refuelling is proposed at the site, on completion of the construction phase, if fuelling has occurred on site, the fuel tanks and oil interceptor used at the fuel transfer area should be removed by a suitably qualified contractor. An audit of ground and water conditions immediately under and around the transfer area is recommended to investigate whether any leakage has occurred to the hydrological system and whether some clean-up measures are required. Aside from the use of lubricant oils at the substation (low volume), fuels should not be stored on site for the operation phase of the project.

The substation compound is likely to require substation transformer cooling oil or gas. This should be stored in containers within a safe part of the substation compound, minimising accidental leakage and / or fire hazards. Consideration should also be given to a bunded area for the oil. Similarly, any other potentially harmful substances used to service the substation should be stored in an environmentally safe manner to mitigate impact to the soils and water.

6.6 RESIDUAL IMPACTS OF THE DEVELOPMENT

Residual impacts that are most likely to occur at the Yellow River Wind Farm site during the construction phase would be as follows:

There will be a change in ground conditions at the site with the replacement of natural materials such as peat, subsoils and possibly bedrock by concrete, subgrade and surfacing materials. This is a direct permanent change to the materials composition at the site.

Limited temporary decrease in water quality on a local level is likely to arise from the release of suspended solids and sediments during the excavation and construction process, particularly following rainfall events after a sustained dry period. This local deterioration in water quality will subsequently be reduced naturally by dilution and by managed mitigation prior to exiting from the site boundary to main catchments.

Residual impacts that are most likely to occur at the Yellow River wind farm site during the operational phase would be as follows:

Changes in ground surfacing including areas of new hardstands will impact on the hydrology of the site and may result in increased runoff of rainwater and increased drainage discharge. It is assumed this should not have a significant impact on the hydrology of the site.

The drainage infrastructure that will be emplaced as part of the roads and turbines development will also change the subsurface hydrology by replacing a natural diffuse drainage system with line interceptors and point discharges to buffered outfalls.

Careful design of this drainage to mimic natural conditions will help to mitigate negative impacts of artificial drainage.

6.8 MONITORING

All drainage systems should be properly maintained at regular intervals.

Slopes, disposal sites and roads should be inspected regularly.

Regular analysis of watercourses should be undertaken.

All activity on site and at boundaries should be monitored and a register kept.

Only authorised and suitably qualified persons on site – strictly restricted access at all times.

The site should be inspected regularly for fire hazards.

6.7 CONCLUSION

Successful adherence to the mitigation measures contained within this report allows the optimal level of risk to be attained at each proposed turbine and access roads at the proposed development site of Yellow River Wind Farm.

Appraisal of the Hazard Rankings for each proposed turbine location indicates that the site (encompassing the "worst case scenario" turbines T7, T8, T9, T10, T23, T30 and T32) carry **INSIGNIFICANT** Hazard Rankings as determined in accordance with the guidelines outlined by The Scottish Executive & Halcrow Group Ltd in "*Peat Slide Hazard and Risk Assessment - Best Practice Guide for Proposed Electricity Generation Developments*", December 2006.

Excavation of peat so that road bases can be founded directly onto the underlying glacial soils remains the optimal approach. There is normally a higher degree of risk associated with this method in areas where peat is greater than 1.50m depth and in such cases "floating" road construction is the preferred method of access road emplacement.

In the case of Yellow River Wind Farm the thickness of sensitive peat appears to be generally <1.5m, although thicker sequences of peat are present in the vicinity of T7, T9 and T23. However the presence of deep peat cannot be ruled out at the locations of T8, T10, T30 or T32, where with obstructions, such as buried tree branches, trunks and stumps may be present within the bogland soils.

Regardless of the above the Hazard Ranking attributable to the access roads and turbine locations remains **INSIGNIFICANT**, according the Scottish Executive guidance.

The Yellow River Wind Farm site is suitable for development as proposed. Peat slide risk has indicated an INSIGNIFICANT risk of instability in relation to all aspects of the proposed development.

6.8 REFERENCES

1 Geological Survey of Ireland Datasets Public Viewer www.gsi.ie

2. Ordnance Survey of Ireland. www.osi.ie

3. Geological Map of Ireland, 1:750,000 3rd Edition 1962.

4. Skinner, B. and Porter, S. (1987) *Physical Geology,* John Wiley & Sons, Inc.Long, C B and McConnell, B.J. 1999. Geology Of South Kerry. GSI, Dublin.

5. Close, M. H. 1867. Notes On The General Glaciation Of Ireland. Journal Of Royal Geological Society Ireland

6. Craig, R F. 1997. Soil Mechanics. Sixth Edition. E & FN Spon, London

7. Cullen, K T & Co. Ltd. 1997. Glenbeha Spring, Roscrea Source Protection Strategy.

8. Daly, D, And Warren, W. 1994. Mapping Of Groundwater Vulnerability To Pollution. Geological Survey Of Ireland (Dublin) Guidelines.

9. Geological Survey Of Ireland. Aquifer Classification and Vulnerability Maps for County Offaly.

10. GSI In Collaboration With Offaly County Council, Lisduff. 2001. Dunkerrin Water Scheme Lisduff Well, Groundwater Source Protection Zones.

11. Site Investigation Steering Group. 1993. Site Investigation In Construction – Without Site Investigation Ground Is A Hazard, Thomas Telford, London

12. Skinner, B J, And Porter S C. 1987. Physical Geology, John Wiley & Sons, Inc.