Viking Wind Farm Construction Compounds - Main Compound

June 2019

Volume 4: Technical Appendices

Environmental Impact Assessment Report

RAMBOLL

viking energy

Harnessing Shetland's natural resources

VOLUME 4: TECHNICAL APPENDICES

Technical Appendix 2.1: Project Description Details

2.1.1 Construction Compound Locations

2.1.1.1 Table 2.1.1 details the Easting and Northing coordinates of the 4 corners of each proposed construction compound's search area.

Table 2.1.1: Construction Compound Locations (Easting, Northing - British National Grid, OS GB 1936 Datum)

Reference (per Fig 1.2)	Point 1	Point 2	Point 3	Point 4
Main Compound	442087.4605, 1155084.3229	442334.5536, 1155039.9337	442289.2056, 1154793.9804	442043.1616, 1154838.2792
West Compound	437500.6846, 1150756.4764	437676.5737, 1150851.6763	437771.7737, 1150675.7872	437595.8846, 1150580.5873
North Compound	441396.3698, 1160460.9893	441592.6299, 1160499.4837	441631.1245, 1160303.2233	441434.8642, 1160264.7288

2.1.2 Land Use Areas

2.1.2.2 Table 2.1.2 sets out the worse-case area of land disturbed during construction operations. The construction compounds are temporary and the land would be reinstated following the completion of the construction phase of Viking Wind Farm.

Table 2.1.2: Indicative Land Use Areas Disturbed During Construction

Wind Farm Element	Area (sq m)	Assumptions
Main Compound		
Compound Search Area	62,500	(250 m x 250 m)
Access Track	486.9	541 m (length) x 9 m (width)
Main Compound Total	62,986.9	
West Compound		
Compound Search Area	40,000	(200 m x 200 m)
Access Track	390.6	434 m (length) x 9 m (width)
West Compound Total	40,390.6	
North Compound		
Compound Search Area	40,000	(200 m x 200 m)
Access Track	243	27 m (length) x 9 m (width)
North Compound Total	40,243	

APPENDIX 2.2: OUTLINE CONSTRUCTION TRAFFIC MANAGEMENT PLAN

Viking Energy Windfarm LLP
June 2019

1. INTRODUCTION

1.1 General

The Outline Construction Traffic Management Plan (CTMP) identifies the high level principles for managing the effects of vehicles associated with the proposed development during construction. The Outline CTMP would be updated should the proposed development be granted planning permission and when a contractor is appointed.

It is the responsibility of the applicant to implement the Outline CTMP, to monitor its application and to propose and make modifications to the Plan during the planning and construction process, if necessary. Monitoring of the Outline CTMP would be undertaken and any necessary amendments would be made in consultation with the appropriate authorities.

The Outline CTMP is intended to be a working document that evolves during the construction period. The Outline CTMP only applies to the construction stage of the proposed development and does not apply to the on-going operation or decommissioning of the proposed development.

1.2 Proposed Development

The proposed development is described in Chapter 2: Development Description of the EIA Report, this also details the proposed access to the site.

It is likely that any Traffic Management Measures would be transferred/incorporated into a wider traffic management plan for the s36C Consented Viking Wind Farm.

2. CONSTRUCTION TRAFFIC & MITIGATION

2.1 Construction Programme

Subject to securing planning permission, it is the intention of the applicant to commence construction around November 2019. The construction of the proposed development would take approximately 6 months.

2.2 Construction Traffic

The construction traffic would comprise of construction workers, HGVs carrying construction materials / plant, as well as abnormal loads.

The main sources traffic during the construction phase would be as follows:

- delivery and removal of plant / materials in relation to site mobilisation and set up of site compound;
- delivery of aggregates and geotextile materials to construct site access roads;
- delivery of roadstone wearing course for access roads and hardstanding areas at the site;
- miscellaneous deliveries; and
- construction worker travel movements.

2.3 Measures to Minimise and Mitigate Construction Traffic Impacts

There are a number of traffic management measures proposed to help reduce the impact of general construction traffic (HGVs). A number of these measures are also applicable to abnormal vehicle movements for example signage. These measures are described below.

Minimise the Volume of Imported and Exported Material

In order to minimise the volume of imported material such as aggregates for on-site track construction. The applicant is committed to the use of borrow pits to obtain suitable stone.

In addition to importation of material, the applicant is committed to re-using materials on-site such as soil that has been stripped from the site during the construction phase. This material would be stockpiled and the majority used to landscape the site on completion of the construction activities.

Delivery Control

The appointed contractor would be required to plan and manage deliveries and collections from the site to minimise the impact on the surrounding road network and to minimise the impact on the local community. The contractor shall consider the following measures during the construction period:

- The number of delivery trips shall be minimised through a combination of consolidated ordering, rationalising suppliers and consolidated deliveries.
- On-site waste shall be minimised through recycling and re-use to minimise the number of collections from site.
- During peak construction periods, deliveries to the site would be staged with drivers given specific time windows for arrival on-site. The release of vehicles from the site would also be controlled to prevent large convoys of vehicles.

Sustainability

The appointed contractor would plan and execute the construction of the proposed development with a demonstrably high regard to sustainability. In particular the following objectives would be set in place:

- Minimisation of vehicle movements to / from the site.
- Promotion of shared transport arrangements for site operatives.
- Thorough pre-planning of operations on-site to optimise the redistribution of earthworks materials together with minimisation of haul distances.
- Reduce the amount of aggregates used on-site by means of alternative construction techniques and the use of borrow pits.
- Apply a reduce-reuse-recycle philosophy to all waste processing activities.
- Conform to construction / building codes of practice in relation to sustainability objectives and procedures.

The appointed contractor would report to and work with the appointed site Liaison Officer.

Speed Limit

It is proposed to impose a maximum 30 mph speed limit for all construction related traffic along the private roads / tracks, which would be reinforced through temporary construction traffic speed limit signs.

Local residents should be able to report any instances of speeding to the site Liaison Officer who would take necessary action to prevent a repeat.

On-site operatives would be briefed on the speed limit through induction sessions and through regular staff briefings. Other parties responsible for site deliveries would also be instructed on the restrictions and made aware of the requirements relating to existing road users.

Signage

Temporary construction site signage would be erected on the local road network in the vicinity of the proposed development site to warn people of construction activities and associated construction vehicles. The purpose of such signage is to provide driver information and to maintain road safety along the construction vehicle route. The exact nature and location of the signage would be agreed with the relevant authorities. Figure 2.1 illustrates examples of the type of signage which could be utilised.

Figure 2.1: Example Construction Signage

Site Operating Hours

Works hours are expected to be 07:00 to 19:00 on Monday to Friday, 07:00 to 16:00 on Saturdays with no construction work taking place on Sunday or on local or national public holidays. The purpose of the working hour restrictions is to find a balance between progressing the proposed development at an acceptable speed and minimising the impact upon local residents.

Workforce Travel and Parking Arrangements

Given the location of the proposed development site, it is unlikely that any of the on-site workforce would walk or cycle to the site even though it is intended to draw a proportion of the workforce from the local area. It is more likely that the majority of the workforce would travel to the site either by private car or via a contractor's works bus.

Car parking for the workforce would be provided entirely within the confines of the site boundary and would not be permitted on the adjacent road network so that sight lines are maintained at the site access junction and to minimise the impact on existing road users. Car sharing would be promoted to construction staff by the contractor during the induction process. Consideration would also be given to the provision of a park and ride facility where workers can park and be transported to site using a works mini-bus. Any temporary park and ride facility location would be agreed with appropriate authorities.

Staff Induction

All site staff would be informed about traffic management arrangements and procedures via site induction literature.

2.4 Movement of Abnormal Loads

The appointed site Liaison Officer would provide the Local Authority, Police Scotlandand local residents with advanced warning of any abnormal load movements.

Mitigating Measures to reduce the impact of Abnormal Load Movements

- All abnormal load movements would be restricted out-with the peak hours when existing traffic flows on the route would be low. Information on the movement of abnormal loads would also be provided to the local press to help inform the public.
- Local residents along the route would be informed when the abnormal loads would be travelling along the route to ensure that interaction between the local community and abnormal load delivery vehicles is minimised.
- It is noted that the abnormal load deliveries are usually undertaken in convoys. The usual makeup of a convoy is three abnormal load vehicles accompanied by three escort vehicles. The escort vehicles are in place to provide manoeuvring assistance, warning of hazards and to report information on clearances etc to the drivers of the abnormal load vehicles.
- Advance temporary warning signs would be installed at various points along the applicable roads and the site to advise drivers that abnormal loads would be operating on the route with dates and times provided. The purpose of the signs is to provide driver information which would allow people to either avoid the area until the convoy has passed, take an alternative route or to proceed with caution.
- If a road closure is required, arrangements would be put in place to facilitate local access to properties on the closed route and to ensure safe passage of any emergency vehicles which may require access.
- The Liaison Officer in consultation with the haulier would be responsible for disseminating abnormal load information to key stakeholders.

Pinch Point Mitigation

It is important to note that the majority of mitigation measures are temporary e.g removal of street furniture. The Liaison Officer would be responsible for overseeing temporary mitigation in consultation with the haulier and key stakeholders.

3. IMPLEMENTATION AND MONITORING OF THE PLAN

3.1 General

The implementation of the Outline CTMP would be the responsibility of the applicant who would also be responsible for monitoring the Plan. Further evolution of this Outline CTMP would likely be required during the detailed project planning stages and during the construction period itself.

The applicant may employ a number of contractors on the site and all would fall under the umbrella of the Outline CTMP and would have an obligation to adhere to the Plan, this obligation would form part of the procurement process and would be written into any contract of employment.

3.2 Responsibilities of The Applicant

The applicant would nominate a person to be responsible for the co-ordination of all elements of traffic and transport during the construction process (Liaison Officer). This person would liaise with the local community so that the community have a direct point of contact within the developer organisation who they may contact for information purposes or to discuss matters pertaining to traffic management or site operation.

The applicant would review and update the number of site personnel, traffic numbers, and the construction programme as the project progresses. Regular updates would be provided to Local Authority and Police Scotland. Any significant changes would be discussed and agreed with both the Local Authority. Regular meetings, where required, would be organised for monitoring purposes.

3.3 Transport Co-ordination

The applicant would be responsible for the co-ordination of all elements of heavy goods and abnormal vehicle transport to and from the construction site. They would be responsible for coordination and liaison with contractors, Local Authority, Police Scotland, emergency services and the local community.

The Liaison Officer would inform the Local Authority of any significant matters that may affect traffic movement by means of reports issued at regular intervals or by day-to-day reports of any significant essential changes to transport plans necessitated by circumstances.

Contact details for the Liaison Officer would be made available to all relevant parties prior to commencement of works on site. The details would be provided to the local community via a newsletter, and through the press.

3.4 Monitoring of the CTMP

The Outline CTMP would be monitored by the applicant / the contractor who in turn would report to the Local Authority. A report would be prepared by the applicant on a monthly basis and issued to the Local Authority. This report would include comparisons with this document and would identify any changes in projected traffic flows associated with construction vehicles and traffic associated with the employed workforce.

As necessary, meetings would be held with the Local Authority and the applicant to discuss the CTMP and to discuss any issues raised by the local community.

Use of the agreed routes by hauliers would be monitored by spot checks undertaken by the applicant and / or the roads authority. These spot checks would take the form of occasional observations at key locations.

The information collected by these two means would be held by the applicant and would be available to the Local Authority, Police Scotland and the local community on request.

3.5 Local Community Consultation

The key to the success of the CTMP would be how it is promoted to the local community and how it is adapted to take on board any feedback received.

As indicated above, the applicant would provide a Liaison Officer to act as a point of contact with the local community. The Liaison Officer would be responsible for keeping the local community informed of progress on the site and warning them of upcoming activities which may give rise to increased construction vehicle movements.

The Liaison Officer would be able to attend Community Council meetings to provide a report and to be on hand to answer any questions that the local community may have. A website would be set up to provide information to the general public and contact details would be provided for the Liaison Officer (telephone number and email address) so that members of the public have an opportunity to ask questions and provide feedback.

The applicant would also make use of the local press in order to disseminate information regarding traffic management and the movement of abnormal loads.

3.6 Liaison with other Construction Sites

Should the construction period of the proposed development were to coincide with other developments in the area, the Liaison Officer would be responsible for consultation with other local authorities to ascertain if the proposed development site may impact other proposed development sites and vice versa. The Liaison Officer would identify if there are any opportunities to mitigate traffic impacts through a collaborated approach with others.

3.7 Community Liaison

The applicant will disseminate information regarding the construction work using a variety of methods, including through websites, email, written correspondence, posters and leaflets. An email address for the nominated liaison officer would be provided so that members of the public can ask for information or submit queries.

The applicant is happy to respond to enquiries from members of the public regarding the construction of the proposed development and update residents through traditional methods particularly for those without the internet.

4. SUMMARY AND CONCLUSIONS

The Outline Construction Traffic Management Plan (CTMP) identifies the high level principles for managing the effects of vehicles associated with the proposed development during construction. The Outline CTMP would be updated should the proposed development be granted planning permission and when a contractor is appointed.

It is the responsibility of the applicant to implement the Outline CTMP, to monitor its application and to propose and make modifications to the Plan during the planning and construction process, if necessary. Monitoring of the Outline CTMP would be undertaken and any necessary amendments would be made in consultation with the appropriate authorities.

The Outline CTMP is intended to be a working document that evolves during the construction period. The Outline CTMP only applies to the construction stage of the proposed development and does not apply to the on-going operation or decommissioning of the proposed development.

The main sources traffic during the construction phase would be as follows:

- delivery and removal of plant / materials in relation to site mobilisation and set up of site compound;
- delivery of aggregates and geotextile materials to construct site access roads;
- delivery of roadstone wearing course for access roads and hardstanding areas at the site;
- miscellaneous deliveries; and
- construction worker travel movements.

The applicant would nominate a site Liaison Officer who would be responsible for all elements of transport during the construction process. The Liaison Officer would review and update the number of site personnel, traffic numbers, and the construction programme as the project progresses. Any significant changes would be discussed and agreed with the Local Authority and Police Scotland.

The Liaison Officer would be the key point of contact with the local community and would be responsible for the dissemination of information to the public.

Discussions with contractors at the tender stages would allow the objectives of the CTMP to be considered in contractual agreements and employment contracts.

The applicant would be responsible for the CTMP. A nominated Liaison Officer would be responsible for promoting, monitoring and reviewing the Plan throughout the construction process. The Liaison Officer would consult with key stakeholders and the local community on a regular basis via a variety of communication mediums including the press, internet and monthly construction update reports.

VIKING WIND FARM CONSTRUCTION COMPOUNDS (MAIN, WEST, NORTH)

Peat Landslide Hazard and Risk Assessment

Prepared for: Viking Energy Ltd

Technical Appendix 2.3
SLR Ref: 428.00660.00067
Version No: v2
June 2019

BASIS OF REPORT

This document has been prepared by SLR Consulting Limited with reasonable skill, care and diligence, and taking account of the manpower, timescales and resources devoted to it by agreement with Viking Energy Ltd as part or all of the services it has been appointed by the Client to carry out. It is subject to the terms and conditions of that appointment.

SLR shall not be liable for the use of or reliance on any information, advice, recommendations and opinions in this document for any purpose by any person other than the Client. Reliance may be granted to a third party only in the event that SLR and the third party have executed a reliance agreement or collateral warranty.

Information reported herein may be based on the interpretation of public domain data collected by SLR, and/or information supplied by the Client and/or its other advisors and associates. These data have been accepted in good faith as being accurate and valid.

The copyright and intellectual property in all drawings, reports, specifications, bills of quantities, calculations and other information set out in this report remain vested in SLR unless the terms of appointment state otherwise.

This document may contain information of a specialised and/or highly technical nature and the Client is advised to seek clarification on any elements which may be unclear to it.

Information, advice, recommendations and opinions in this document should only be relied upon in the context of the whole document and any documents referenced explicitly herein and should then only be used within the context of the appointment.

CONTENTS

DOCUMENT REFERENCES

TABLES

PHOTOGRAPHS

APPENDICES

FIGURES

1.0 Introduction

SLR Consulting Ltd (SLR) was commissioned by Viking Energy Ltd to undertake a peat landslide hazard and risk assessment at three proposed temporary construction compounds to support the construction phase of the Viking Wind Farm development, located across central mainland Shetland. The site locations are identified in Figure 1.

The purpose of this report is to consider the potential risk of peat landslides occurring at the Sites such that suitable controls and appropriate methodologies can be employed during the construction of the proposed development to mitigate against these risks. This report presents the findings of the peat slide hazard and risk assessment based on the data obtained by peat depth surveys which were undertaken by SLR between July 2018 and May 2019.

The work has been undertaken by a team of geologists, with over 15 years' experience in undertaking peat assessments. The team was led by an Engineering Geologist with 35 years' experience in geology (B.Sc.) and engineering (M.Sc.) and over 15 years in renewable energy. He has managed and undertaken geotechnical risk registers and peat landslide and hazard risk assessments for wind farms, electricity infrastructure including substations, overhead and buried cabling routes. He has successfully completed over 25 PLHRA's under the original guidance (2005) and recent guidance 2017.

The methods adopted for the assessment follow the best practice guidance [1] issued by the Scottish Government for investigation, assessment and reporting for wind farms in peat areas.

1.1 Objectives of Report

The Peat Stability Assessment is primarily concerned with the influence of the peat on the proposed development of the temporary construction compounds in support of the construction phase of the Viking Wind Farm development.

The main objective is to assess the potential peat stability at the proposed development sites, identify areas of potential concern and identify mitigation measures to ensure the maintenance of peat stability before, during and after construction. All aspects of construction should be based on ensuring minimum disruption to the peat areas where possible.

[1] Peat Landslide Hazard and Risk Assessment (Scottish Government, April 2017)

2.0 Site Information and Development Background

Scottish Ministers granted a Section 36C variation application for the Viking Wind Farm in May 2019. The variation provides consent for an increase in the maximum wind turbine tip height from 145 m to 155 m and an increase to the maximum wind turbine rotor diameter from 110 m to 120 m, alongside the consented wind farm infrastructure layout (which was unchanged by the variation application).

The construction of temporary construction compounds is included as part of the extant consent, however the Applicant has identified a requirement to increase the size of the compounds in order to facilitate the expeditious construction of the proposed wind farm. As such the Applicant is proposing to bring forward applications for permission to construct three temporary construction compounds.

This peat landslide hazard risk assessment (PLHRA) has been prepared to assess peat stability and the risk of landslides at each proposed construction compound. The location of each compound is illustrated in Figure 1. The indicative dimensions of the construction compounds are shown in the table below.

Table 2-1
Site Information

Construction Compounds Name	Dimensions (m)	Footprint (Ha)
North	200 x 200	4
Main	250 x 250	6.25
West	200 x 200	4

The proposed construction compounds are to be created by excavation of peat/soils to create a level platform, the excavated peat/soils are to be stockpiled and used in the restoration of the site following construction of the proposed Viking Wind Farm.

Photograph 2-1
General view of ground conditions at North Construction Compound
Photograph Location: 441610, 1160364, Direction of View: Northwest

Photograph 2-2
General view of ground conditions at Main Construction Compound
Photograph Location: 442190, 1155053, Direction of View: South Southwest

Photograph 2-3
General view of ground conditions at West Construction Compound

Photograph Location: 437707, 1150835, Direction of View: South

3.0 Scope of Report

The scope of the report is primarily concerned with the influence of peat on the design, construction and operation of the proposed development and secondly to minimise the disturbance of peat where possible, if it is present.

The principle objective was to assess the extent of organic peat (>0.5 m) and peaty soils (<0.5 m) on the sites with the purpose of identifying instability at the site, areas of potential concern and any mitigation measures required to ensure the maintenance of peat stability before, during and after construction.

This information should allow development options to be considered so that where possible, there is minimum disruption to peat areas by avoidance of deeper peat through design consideration.

The objectives were achieved by completion of the following:

- Review of geological, hydrological and topographical information;
- Geomorphological mapping of the sites to identify the prevailing conditions influencing the potential for, or any evidence of, active, incipient or relict peat instability, including a photographic record and identification of their location and report on the potential risk of future instability, describing the likely causes and contributory factors;
- Identifying potential controls to be imposed on the construction contractor to minimise the risk of peat instability occurring at the proposed development; and
- Provide recommendations for further work or specific construction methodologies to suit the ground conditions at the proposed development to mitigate any unacceptable risk of potential peat instability.

Probing has been undertaken on an approximately 25 m^2 grid across the sites. The results have been used to produce a peat thickness and peat landslide risk map. Further details are given in subsequent sections of this report.

3.1.1 Topographic Surveys

All of the surveys were based on 5m DTM data which was used to determine slopes across the proposed development sites and to determine slope coefficient (score) factors at each probe hole location. Each site has been characterised into slope classes and a slope plan produced to identify slope areas where potential gradients are more or less susceptible to slope failure mechanisms.

3.1.2 Aerial Photo Interpretation

The aerial photography reviewed indicates changes in vegetation on the ground, and it is also possible to identify stream courses, ditches, erosion features and roads/tracks. The aerial photographs were used in conjunction with the Site DTM data to identify the major geomorphological features such as the breaks of slope and landslips. These were inspected where identified during site visits when more detailed assessment of the proposed development sites was undertaken.

Interpretation of available aerial photographs was undertaken to assess and identify evidence of historic peat instability. The photographs were examined to highlight features of interest, including:

- possible extension and/or compression features;
- areas of historic failure scars and debris;
- evidence of peat creep;
- areas with apparently poor drainage;
- areas with concentrations of surface drainage networks; and
- steeply incised stream cuttings within peat deposits; and
- Historic peat workings

From the aerial photograph and topographic survey interpretation no significant features or obvious evidence of concern were identified that indicate evidence of peat instability which warranted further attention. Only limited aerial photography was available, varying in coverage at each site, dating back to 2003, with photos in 2008 at all sites and additional photography at the Main Construction Compound (2010) and the West Construction Compound (2013). Areas of outcropping bedrock were visible at the West Construction Compound with haggy peat deposits visible at the North and Main Construction Compounds. There was no significant evidence of historic peat workings within any of the site boundaries.

None of these features demonstrate any significant evidence of failure in the vicinity of the proposed developments. A summary of the geomorphology of the proposed development sites is included in Figure 7a-c. Areas of thick peat coverage are highlighted along with areas where bedrock is likely to outcrop at surface.

3.1.3 Peat Landslide Hazard and Risk Assessment

The purpose of a peat landslide hazard and risk assessment (PLHRA) is to identify those parts of the sites that are naturally susceptible to a higher risk of instability so that they can be avoided or accommodated through design consideration. It should be noted that all peat slopes have a risk of instability and the vast majority of peat slope failures occur naturally.

Development of the construction compounds would only increase the risk of peat slope instability if good geotechnical construction practice is ignored. In order to avoid increasing the risk of peat slope instability, the proposed developments will be constructed to comply with a Construction and Environmental Management Plan (CEMP) which incorporates the recommendations of this peat landslide hazard and risk assessment.

Without the guidance contained in a Construction Method Statement or CEMP, the following factors would potentially increase the risk of instability:

- Construction of access tracks;
- Excavation and stockpiling;
- Construction of hardstanding area; and
- Blocking of natural drainage, inappropriate new drainage or drainage discharge.

It is important to note that peat instability and the impacts of any instability are not constrained by artificial site or ownership boundaries but by topographic and geomorphologic boundaries. This assessment has reviewed a study area for each proposed construction compound that is defined by topography and geomorphology, not land ownership or site boundary. This is to ensure that the assessment adequately covers the areal extent of the possible impact.

The risk assessment is based on ground models developed using a Geographical Information System (GIS) specifically for this site. A numerical analysis was undertaken in which coefficients were allocated for each of the factors influencing peat stability and their impact on possible receptors. This aspect is described in greater detail in Section 8.0.

This system outlined above was developed in accordance with the guidelines on PLHRA by the Scottish Government (SG) for the investigation, assessment, and reporting for wind farms in peat areas. The analysis and interpretation is based upon the results obtained from this process as well as previous experience and the results of case studies elsewhere. Where deviations from this guidance have occurred, this is highlighted and explained in the text.

4.0 Geological Setting

4.1.1 Superficial Geology

Each site is mapped as comprising peat deposits. Areas of shallow bedrock are also mapped at the West Construction Compound.

The Superficial geology of each site is detailed in Figure 2a-c.

4.1.2 Solid Geology

The geology of the sites comprises predominately Neoproterozoic age metasediments and metaigneous rocks of the Dalradian Supergroup.

The North and Main Construction Compounds comprise granofelsic psammite and granofelsic semipelite of the Colla Firth Formation with the granite gneissose of the Colla Firth Permeation and Injection Belt also present at the Main Construction Compound.

The West Construction Compound comprises pelite, semipelite, psammite and schistose of the Scatsta Quartzite Formation. There are no major faults mapped within the site boundaries at North Construction Compound and Main Construction Compound, with a north northwest- south southeast trending fault cross-cutting West Construction Compound.

The solid geology of the sites is shown in Figure 3a-c. Details of the geological units present at the sites are shown in Table 4-1.

Table 4-1
Solid Geology Summary

Age	Stratigraphic Group	Unit	Description
Neoproterozoic (1000 – 542 Ma)	Whiteness Division (Dalradian Supergroup)	Colla Firth Permeation and Injection Belt	Granite gneissose
	Whiteness Division (Dalradian Supergroup)	Colla Firth Formation	Granofelsic psammite and granofelsic semipelite
	Scatsta Division (Dalradian Supergroup)	Scatsta Quartzitic Formation	Pelite, semipelite, psammite, schistose.

4.1.3 Mining and Quarrying

There have been no historic mining or quarrying activities known within the Site boundaries at the Main Construction Compound and West Construction Compound, the site at North Construction Compound has been quarried historically and is currently unrestored – see Photograph 4-1 below.

Photograph 4-1
Disused quarry at North Construction Compound
Photograph Location: 441498, 1160272, Direction of View: Northeast

4.1.4 Hydrogeology

The solid geology underlying each site is classified as a low productivity aquifer, where flow is virtually all through fractures and discontinuities. Small amounts of groundwater may be present within near surface fractures and from springs locally.

5.0 Peat Instability

This section reviews the nature of peat and how current and past activities can influence stability. The factors which are likely to influence the potential for peat instability are:

- Significant peat depths over impermeable bedrock or minimal soil;
- The presence of slope gradients greater than 4^{o} (approximately) and general topography;
- Natural drainage paths;
- Evidence of past failures, including soil creep;
- Drainage features at the base of slopes which could lead to undercutting;
- Artificial drainage;
- Recent climate patterns e.g. increased rainfall.

It should be noted that peat instability is not a recent phenomenon and there is documentary evidence of peat landslides dating back over 500 years[2]. Many landslides that involve peat have no human interference that could be considered as a trigger and this should be borne in mind when considering the susceptibility of a site to potential instability.

5.1 Background Information Regarding Peat

Peat is found in extensively across Shetland and is defined as the partly decomposed plant remains that have accumulated in-situ, rather than being deposited by sedimentation. When peat forming plants die, they do not decay completely as their remains become water logged due to regular rainfall. The effect of water logging is to exclude air and hence limit the degree of decomposition. Consequently, instead of decaying to carbon dioxide and water, the partially decomposed material is incorporated into the underlying material and the peat 'grows' in-situ.

Peat is characterised by low density, high moisture content, high compressibility and low shear strength, all of which are related to the degree of decomposition and hence residual plant fabric and structure. To some extent, it is this structure that affects the retention or expulsion of water in the system and differentiates one peat from another.

Lindsay[3] defined two main types of peat bog, raised bog and blanket bog, which are prevalent on the west coast of Europe along the Atlantic seaboard. In Britain, the dominant peat land is blanket bog which occurs on the gentle slopes of upland plateaux, ridges and benches and is predominantly supplied with water and nutrients in the form of precipitation. Blanket peat is usually considered to be hydrologically disconnected from the underlying mineral layer.

[2] Smith, L.T., (Ed) (1910), 'The literary of John Leland in or about the years 1535-1543.' Vol.5, Part IX. London: AF Bell and Sons.

[3] Lindsay, R.A., (1995), 'Bogs: The ecology, classification and conservation of Ombrotrophic Mires.' Scottish Natural Heritage, Perth

There are two distinct layers within a peat bog, the upper acrotelm and the lower catotelm. The acrotelm is the fibrous surface to the peat bog[4], typically less than 0.5 m thick; which exists between the growing bog surface and the lowest position of the water table in dry summers. Below this are various stages of decomposition of the vegetation as it slowly becomes assimilated into the body of the peat.

For geotechnical purposes the degree of decomposition (humification) can be estimated in the field by applying the ‘squeezing test’ proposed by von Post and Grunland [5] (1926). The humification value ranges from H1 (no decomposition) to H10 (highly decomposed). The extended system set out by Hobbs [6] provides a means of correlating the types of peat with their physical, chemical and structural properties.

The relative position of the water table within the peat controls the balance between accumulation and decomposition and therefore its stability, hence artificial adjustment of the water table by drainage requires careful consideration.

5.1.1 Peat Shear Strength

In geotechnical terms, the shear strength of a soil is the physical characteristic that provides stability and coherence to a body of soil. For mineral soils such as clays or sands, such strength is variously given by an inter-particle friction value and cohesion. Depending whether the mineral soil is predominantly cohesive (clay) or non-cohesive (sand) governs which of the components of strength control the behaviour of the soil.

For peat soils, where the major constituent is organic and there is likely to be little or no mineral component, the geotechnical definition of shear strength does not strictly apply. At present there is no real alternative method for defining the shear strength of peat, therefore the geotechnical definition is generally adopted, in the knowledge that it should be used with great caution.

As noted before, the acrotelm or near surface peat comprises a tangle of fresh and slightly rotted roots and vegetable fibres. These roots and fibres impart a significant tensile shear strength capacity to the material which provides it with a significant load carrying capacity. The acrotelm is, in effect, a fibre reinforced soil.

In the more decomposed catotelm, the tensile shear strength is reduced as the roots and fibres become more rotted. However, the loss in strength due to decomposition is off-set to a limited degree, by a gain in strength due to the overburden pressure. In geotechnical engineering there is an established relationship for recently deposited soils, between the shear strength of a sample and the thickness of overburden above it.

Consequently, it is almost impossible to predict a shear strength profile in peat and attempts to measure the shear strength using normal geotechnical methods can be misleading. Typical values of shear strength from hand shear vanes would be in the range 20-60 kilopascal (kPa) although values over 100 kPa have been recorded in peat elsewhere. The higher strengths are almost certainly the influence of roots or other non-decomposed material. It is believed that the strength of peat should be quoted as a cohesion value as there are few, if any, discrete particles to give the material a significant frictional resistance. It should be noted, however, that any quotation of shear strength for peat should be treated with extreme caution.

[4] Ingram, H.A.P., (1978), ‘Soil layers in mires: function and terminology’. Journal of Soil Science, 29, 224-227.

[5] Von Post, L. and Grunland, E., (1926), ‘Sodra Sveriges torvillganger 1’ Sverges Geol. Unders. Avh., C335, 1-127.

[6] Hobbs, N.B., (1986), ‘Mire morphology and the properties and behaviour of some British and foreign peats.’ Quarterly Journal of Engineering Geology, London, 19, 7-80.

5.1.2 Peat Stability – Factors to be considered

There is considerable observational information relating to debris and peat flows although the actual mechanisms involved in peat instability are not fully understood. The main influences on slope stability are geological, geotechnical, geomorphic, hydrological, topographic, climatic, agricultural and human influences such as drainage and construction activity. Peat is affected to a degree by changes in any of the above list and it is vital to appreciate that changes to the existing equilibrium would affect the level of slope stability during construction and operation of the scheme.

Some of the contributory factors to peat instability are summarised below:

- The geographical limits which could be affected by potential instability are not confined to the artificial boundaries imposed by land ownership; landslip occurring above a site could affect the site and property down slope or downstream of the site for several kilometres;
- Agriculture and grazing has a substantial effect on peat areas and this can be compounded in areas that have been managed to improve grazing. Grazing compacts the peat surface reducing the rainwater infiltration and the additional nutrients change the ecological balance of the original peat bog. Agricultural management can include surface drainage and periodic burning, both of which can leave the surface of the peat bare for a period of time resulting in temporary desiccation of the surface. Subsequent wetting of the peat and resumption of peat accumulation results in the former desiccated and possibly ash covered surface (following burning) being incorporated into the body of the peat which introduces a weak discontinuity in the profile; this in turn becomes another unknown factor in the stability assessment.
- Natural Drainage – some of the precipitation falling onto a natural upland peat bog would be absorbed into the low permeability catotelm peat. However, most of the water would run-off as sheet flow through upper, high permeability acrotelm. Thus, the water is transmitted to the lower slopes in a reasonably controlled manner through a range of interconnections that operate at different scales and speed. Failure to understand this and to disrupt the transmission process for the groundwater could result in instability.
- Artificial Drainage - Where agricultural drainage has been used to improve the quality of the grazing , it reduces the overall volume of water entering the bog and transfers this water to the edges more rapidly. This can result in ditches and streams becoming enlarged, causing increased erosion and a greater silt burden in the stream water.

5.2 Peat Mass Stability

The principal surface indicator of peat slide potential is cracking of the peat land surface and it is the identification of crack patterns in the field and the attendant causes of the cracking that is fundamental to a peat stability assessment.

Sites that have exhibited natural instability in the past are likely to be more susceptible to future instability during and following construction, therefore it is important to identify such instability as part of the Peat Stability Assessment.

5.2.1 Types of Failure

The result of instability in peat is the down-slope mass movement of the material; there are a number of definitions of peat instability which are used to characterise the type of failure. A brief description is given below:

- Bog Bursts or Bog Flows – the emergence of a fluid form of well humified, amorphous peat from the surface of a bog, followed by the settling of the residual peat, in-situ [7];
- Peat Slides – the failure of the peat at or below the peat/ substratum interface leading to translational sliding of detached blocks of surface vegetation together with the whole underlying peat stratum[7]; and
- Bog slide – an intermediate form of instability where failure occurs on a surface within the peat mass with rafts of surface vegetation being carried by the movement of a mass of liquid peat.

5.2.2 Bog Bursts

Accounts of bog bursts are generally associated with very wet climates or areas which have received storm rainfall events. Bog bursts can be associated with particularly wet peat landscapes; therefore it is possible to identify broad regions of a higher susceptibility to these failures. The constraints used to identify the areas of higher susceptibility to bog burst failure are given below:

- Peat thickness in excess of 1.5 m with no upper limit;
- Shallow gradients, generally within the range of 2 to 10^{o}, peat thicker than 1.5 m is generally not observed on slopes steeper than 10^{o}, also moisture content is generally reduced on steeper slopes due to drainage);
- Ground which is annually waterlogged to within the upper 1 m below ground level, (the groundwater level may rise above this but rarely falls below) [8];
- Greater humification of the lower catotelm within the waterlogged ground; and
- Lower surface tensile strength of the fibrous peat and vegetation.

The humified mass can be considered as analogous to a heavy liquid and the stability of this mass is maintained

[7] Dykes, A.P and Kirk, K.J., (2001), 'Initiation of a multiple peat slide on Cuilcagh Mountain, Northern Ireland.' Earth Surface Processes and Landforms, 26, 395-408.

[8] Crisp, D.T., Dawes, M. & Welch, D. (1964), 'A Pennine Peat Slide', The Geographical Journal, Vol 130, No4, pp519-524.

by the strength of the surface or acrotelm peat. Should the surface become weakened through erosion or desiccation or the construction of a surface drainage ditch for agricultural or forestry reasons or through turbary (peat cutting), failure is made more likely.

5.2.3 Peat Slides

Peat slides tend to be translational failures with a defined shear surface at or close to the interface with the substrate.

The factors generally considered to influence susceptibility to peat slide failures are listed below:

- Peat depth up to 2 m;
- Slope gradients between 5° and 15°;
- Natural or artificial drainage cut into the surrounding peat landscape;
- Greater humification of the lower catotelm within the waterlogged ground; and
- Lower surface tensile strength of the fibrous peat and vegetation.

It is noted that some of the factors causing instability are common to both bog bursts and peat slides.

The peat – substrate interface is the primary zone of failure and is enhanced by elevated water content at this boundary and softening or weathering of the lower mineral surface. For this reason, any investigation or probing should try to distinguish the nature of the lower mineral substrate.

5.2.4 Bog Slides

A bog slide is a variation on a peat slide where part of the peat mass is subject to movement, usually on an internal layer of material, which may be more prone to movement, such as an interface between the acrotelmic and catotelmic layer.

5.2.5 Natural Instability

The stability of a peat mass is maintained by a complex interrelationship of many factors, some of which may not be immediately obvious. Key factors include sloping rock head and proximity to a water body. Rainfall often acts as the trigger after the slope has already been conditioned to fail by natural processes.

It should also be remembered that peat bogs are growing environments and that there would come a time, on sloping ground, where the forces causing instability, i.e. the weight of the bog, can no longer be resisted by the internal strength of the peat and its interface with the underlying mineral surface. At this point, failure would occur.

The weight of the peat bog or any soils mantling steep hill slopes would be increased during periods of very heavy rain and it is common to see landslips occurring following extreme rain events. This may be a concern for future developments where one of the predicted effects of global warming will be a greater frequency of extreme weather, intense storms being one element.

6.0 Site Work

6.1 Peat Depth Survey

A detailed peat depth survey was undertaken in two phases within the proposed development areas. Probing was initially completed as part of a survey into the wider wind farm site and at the originally consented construction compounds. Following the revision of the construction compound locations, gaps in the data were identified and a second phase of probing was undertaken on an approximately 25m grid at each site.

6.1.1 Methodology

The surveys carried out followed best practice guidance for developments on peatland[9,10].

Peat Depth Analysis

The initial phase of peat probing was completed at the consented construction compound locations and along access tracks and turbine locations.

The second phase of peat probing carried out aimed to supplement the original data and provide a greater resolution of detail at the proposed construction compounds.

The following methods were employed during the second phase of probing:

- The construction compound sites were probed on a grid at approximately 25 m intervals
- Sample locations were generated using Geographic Information System (GIS) and downloaded onto hand-held Geographic Positioning System (GPS) devices which were used to locate sample points in the field;
- A fibre glass peat depth probe was used to each sample point to establish peat depth.

The peat depth data has been uploaded into various figures and analysis assessments included within this report.

6.1.2 Peat/Peaty Soils

North Construction Compound

The peat was found to vary across the site in terms of thickness and coverage. The thickest peat was generally limited to the east of the site. Part of the site is situated on a disused quarry where peat/peaty soils have been removed. The majority of probes (approximately 60%) across both phases of peat probing identified peat (> 0.5 m) of which approximately 29% was classified as thick peat (>1.5 m). The peat identified on site was highly fibrous and often eroded, with peat hags present on site (Photograph 6-1)).

[9] Scottish Renewables & SEPA (2012) 'Developments on Peatland Guidance on the Assessment of Peat Volumes, Reuse of Excavated Peat and the Minimisation of Waste'.

[10] Scottish Natural Heritage (SNH), SEPA, Scottish Government & James Hutton Institute. (2014)' Peat Survey Guidance; Developments on Peatland: Site Surveys'

Photograph 6-1
Haggy Peat Deposits – North Construction Compound
Photograph Location: 441531, 1160370, Direction of View: North

A total of 86 probe holes were undertaken across both survey phases, with the results summarised in Table 6-1 below.

Table 6-1
Peat Probing Data North Construction Compound

Peat Thickness (m)	No. of Probes	Percentage (of total probes undertaken on site)
0 (no peat)	3	3.5
0 – 0.5 (peaty soil)	31	36
0.51 – 1.0 (thin peat)	27	31.4
1.01 – 1.5 (thin peat)	10	11.6
1.51 – 2.0 (thick peat)	12	14
2.01 – 3.0 (thick peat)	3	3.5

In summary the peat depth probing has shown that:

- Approximately 61% of probes intersected peaty soils/peat <1.0m thick;
- Approximately 29% of peat probes undertaken across the entire site found peat in excess of 1 m thick;
- Peat was highly fibrous.

The underlying soil/peat thickness at each location was recorded and the data used to draw the interpreted peat thickness map, presented as Figure 4a.

Main Construction Compound

The peat found on the Main Construction Compound site was generally consistent in coverage and thickness with the thickest peat situated to the north and west of the site. The majority of probes (approximately 90%) across both phases of peat probing identified peat (greater than >0.5 m) with 34% of all probes intersecting thick peat (>1.5m). The peat identified on site was highly fibrous and often eroded with peat hags present on site Photograph 6-2.

Photograph 6-2
Haggy Peat Deposits – Main Construction Compound
Photograph Location: 442116, 1155074, Direction of View: South

A total of 117 probe holes were undertaken across both survey phases, with the results summarised in Table 6-2 below.

Table 6-2
Peat Probing Data Main Construction Compound

Peat Thickness (m)	No. of Probes	Percentage (of total probes undertaken on site)
0 (no peat)	0	0
0 – 0.5 (peaty soil)	12	10.3
0.51 – 1.0 (thin peat)	29	24.8
1.01 – 1.5 (thin peat)	36	30.8
1.51 – 2.0 (thick peat)	30	25.6
2.01 – 3.0 (thick peat)	10	8.5

In summary the peat depth probing has shown that:

- Approximately 90% of probes intersected peat >0.5 m thick;
- Approximately 65% of peat probes undertaken across the entire site found peat in excess of 1 m thick;
- Peat was highly fibrous

The underlying soil/peat thickness at each location was recorded and the data used to draw the interpreted peat thickness map, presented as Figure 4b.

West Construction Compound

Peat coverage at the West Construction Compound site was limited. The majority of probes (approximately 88%) across both phases of peat probing identified no peat (soils <0.5 m thick) with just 12% of probes intersecting soils >0.5 m thick. There were no probes recording soils in excess of 1 m thick.

The slopes on site are detailed in Figure 5b – Slope Plan. The proposed Construction Compound is situated on the edge of a steep slope to the northeast with shallow weathered rock and outcropping bedrock present (Photograph 6-3).

A summary of soil thicknesses is detailed in Table 6-3.

Photograph 6-3
Bedrock outcropping – West Construction Compound
Photograph Location: 437637, 1150680, Direction of View: North

A total of 75 probe holes were undertaken across both survey phases, with the results summarised in Table 6-3 below.

Table 6-3
Peat Probing Data West Construction Compound

Peat Thickness (m)	No. of Probes	Percentage (of total probes undertaken on site)
0 (no peat)	3	4.1
0 – 0.5 (peaty soil)	62	83.8
0.51 – 1.0 (thin peat)	9	12

In summary the peat depth probing has shown that:

- Approximately 88% of probes intersected soils/peaty soils <0.5m thick;

- Approximately 12% of peat probes undertaken across the entire site found soils in excess of 0.5 m thick and no greater than 1.0m;
- Peat is very limited across the West Construction Compound site with thin soils over shallow rock prevalent.

The underlying soil/peat thickness at each location was recorded and the data used to draw the interpreted peat thickness map, presented as Figure 4c.

6.1.3 Substrate

The assessment of the underlying substrate from the probing data was interpreted as thin glacial soils and weathered bedrock/bedrock. Areas of outcropping bedrock were identified on each site but most prevalent at the West Construction Compound site.

6.1.4 Peat Condition

The peat deposits on the North and Main Construction Compounds were variable in thickness with a number of erosion features; mainly haggy peat. There was very limited peat present at the West Construction Compound site.

There are generally three zones within a peat bog, based on Von Post's scale of classification.

- a shallow fibrous zone (typically <0.5m depth) typically ranging from H3-H5;
- an intermediate pseudo-fibrous zone (typically H5-H7); and
- an amorphous zone, generally ranging from H7-H9.

Based on interpretations from probing and peat core samples from adjacent sites, the peat at the North and Main sites will comprise a fibrous and pseudo fibrous zone. Shallow peat deposits generally comprise fibrous to pseudo-fibrous layers with thick peat comprising pseudo-fibrous to amorphous layers.

The peat identified at the North and Main Construction Compound sites is highly fibrous and is expected to typically range from H3-H5 on Von Post's scale of classification.

7.0 Slope Stability/Ground Conditions

The stability of slopes is dependent upon the shear strength of the soil to resist the disturbing forces due to the weight of the soil, the effects of the groundwater and other disturbing influencing forces.

The level of stability of a slope is normally assessed by reference to the factor of safety which is expressed, numerically, as the degree of confidence that exists, for a given set of conditions, against a particular failure mechanism occurring. It is commonly expressed as the ratio of the load or action which would cause failure against the actual load or actions likely to be applied during service. This is readily determined for some types of analysis (e.g. limit equilibrium slope stability analyses).

7.1 Shear Strength

The strength of the peat in the upper acrotelm is significantly influenced by the root and fibres that are abundant in this layer. There are many influences on the stability of the peat and observing or measuring high shear strength should not be used to assume a high degree of stability.

7.2 Stability Risk Assessment

It is apparent that the stability of peat is complex and the numerous inter-relationships that affect the stability are not fully understood.

The problem with a quantitative assessment is that it requires a numerical input and the analysis cannot account for the unquantifiable input required for a comprehensive peat stability assessment. For this reason a purely quantitative assessment should only be considered as a guide and that a qualitative assessment of stability should be used to provide the final recommendations.

A stability risk assessment was undertaken to evaluate the risk of instability occurring associated with the development of temporary construction compounds to support the construction of Viking Wind Farm.

7.3 Results

The results of the probing exercise are detailed in the following sections and the peat depths identified on site are shown in Figure 4a-c.

8.0 Peat Landslide Hazard and Risk Assessment

A preliminary peat risk assessment has been undertaken for each site. Following two phases of peat probing, a site visit by an experienced SLR geotechnical engineer and appraisal of the data, the potential for a peat slide occurring at each site is as follows:

- North Construction Compound: **Low – Medium**. The majority of the site is classified as negligible or low risk of instability, however significant thicknesses of peat are present situated on moderate - steep slopes.
- Main Construction Compound: **Low – Medium**. Much of the site is classified as low risk of instability, however the western edge of the site has been classified as medium risk of instability due to thick peat being situated on steep slopes.
- West Construction Compund: **Low**. The majority of the site is classified as low risk and limited peat deposits have being identified on site during the detailed site walkover and peat probing exercise.

There was no evidence of historical or current peat slide activity at the Site having reviewed historical and current photographs where available.

To further quantify this initial assessment, analysis of the terrain at site utilising GIS has been undertaken to analyse slopes and gradients, Figure 5a-c shows that the majority of slopes within key infrastructure areas are generally <8°. The site specific slope data has been combined with site specific peat depth data and using Scottish Government guidance for the assessment of the risk of instability in peat, an assessment of peat slide risk has been completed.

The method of risk and hazard assessment has been developed with reference to the Scottish Guidance **Error! Bookmark not defined.**. Key factors which may have an effect on the stability of the peat deposits have been identified leading to an assessment of the RISK of instability. The potential impact of any instability, the HAZARD, was then considered for identified potential receptors. Scores were attributed to the key factors that have the greatest influence on peat stability. Risk scores were determined, which, when combined with an assessment of vulnerability of potential targets, were developed into an assessment of the hazard.

In order to differentiate between risk and hazard, the following nomenclature has been adopted (Table 8-1).

Table 8-1
Risk versus Hazard

Risk	Hazard
Negligible	Insignificant
Low	Significant
Medium	Substantial
High	Serious

This section outlines the approach taken and the scores allocated for various factors relevant to peat stability.

At this stage in the proposed development, the objective is to determine the peat areas that would have an effect on the proposed development and to set out the mitigation that could be adopted and incorporated into the overall development plan to ensure that due cognisance is taken in this regard.

The level of slope is normally assessed by reference to the factor of safety which is expressed, numerically, as the degree of confidence that exists, for a given set of conditions, against a particular failure mechanism occurring. It is commonly expressed as the ratio of the load or action which would cause failure against the actual load or actions likely to be applied during service. This is readily determined for some types of analysis (e.g. limit equilibrium slope stability analyses). The following sections present a brief discussion on some of the issues relating to stability and risk assessment.

The stability of peat is a complex subject and there are numerous inter-relationships that affect the stability.

A quantitative assessment requires a numerical input and such an analysis cannot account for the unquantifiable input required for a comprehensive peat stability assessment. For this reason a purely quantitative assessment should only be considered as a guide and a qualitative assessment of stability should be used to inform the final recommendations.

The characteristics of the peat failure phenomena have been incorporated in a stability risk assessment to evaluate the risk of instability occurring within the peat areas. The main factors controlling the stability of the peat mass are the surface gradients, the depth and condition of the peat at each location and the type of substrate.

The natural moisture content and undrained shear strength of the peat are important; however, it is generally accepted that where present, the peat would be saturated and have a very low strength. It is believed to be unrealistic to rely on specific values of shear strength to maintain stability when back analysis of failed slopes indicates that there is often a significant discrepancy between measured strength in peat and stability. Therefore shear strength has been assumed to be constant and worst case, throughout this assessment. It has also been assumed, as a worst case (very conservative), that the groundwater level is coincident with the ground surface.

The key factors identified as being critical to stability and the development of a risk rating system is:

- A – Slope gradient;
- B – Peat thickness;
- C – Substrate type or condition; and
- D – Historic instability.

The risk scores are multiplied together to generate a risk rating which is a measure of the likelihood of peat instability.

8.1 Slope Gradients

The slope gradients were assessed by reference to the mapping and particularly the DTM which was used to generate a gradient map (Figure 5a-c), from which the gradient at each probe location could be determined and input into the risk rating spread sheet (Appendix A). The gradient quoted at each location was based on the average gradient over a 5 m grid.

Table 8-2
Coefficients for Slope Gradients

Slope Angle (^{o})	Slope Angle Coefficients
Slope <2^0	1
2^0≤ Slope <4^0	2
4^0≤ Slope <8^0	4
8^0≤ Slope <12^0	6
>12^o Slope	8

Coefficients for slope gradient have been assigned to ensure the potential for both peat slides (gradients of 4-15^0) and bog slides (gradients of 2-10^0) are addressed.

By simple inspection it is clear that steeper slopes pose a greater risk of instability than shallow gradients. Therefore, a graduated gradient scale from 0^0 to >12^0 (the practical maximum gradient on which peat is commonly observed) has been applied.

8.2 Peat Thickness and Ground Conditions

The ground conditions were assessed by using peat depths recorded during peat probing. Thin peat was classed as being 0.5 m to 1.5 m thick, with deposits in excess of this being classed as thick. The thickness ranges used are intended to reflect the risk of instability associated with both peat slides (in thin peat) and bog slides. Where the probing recorded peat less than 0.5 m thick, this has been considered to be an organic soil rather than peat. Table 8-3 gives the coefficients applied to the various ground conditions.

In addition to peat thickness, the presence of existing landslip debris or indicators of meta-stable conditions such as tension cracks or slumping in the peat suggest the material is likely to become even less stable should the existing ground conditions change. Where evidence of historical slips, collapses, creep or flows is seen, a separate coefficient would be applied.

Table 8-3
Coefficients for Peat Thickness and Ground Conditions

Ground Conditions	Ground Condition Coefficients
Peaty or organic soil (<0.5 m)	1
Thin Peat (0.5 – 1.5 m)	2
Thick Peat (>1.5 m)	3*
Slips /collapses / creep / flows	8

***Note that thicker peat generally occurs in areas of shallow gradients and records indicate that thick peat does not generally occur on the steeper gradients.**

8.3 Substrate

As noted above, most failures in thin peat layers occur at the interface with the underlying substrate; the nature of the substrate has a very large influence on the probable level of stability.

Where sand and/or gravel (derived from glacial till) form the substrate, the effective strength of the interface can be considered to be good with comparatively high friction values. Under these conditions, failure is likely to occur in a zone within the peat, just above the interface. Further factors are necessary to cause a failure of this nature (increased pore pressures within the peat) and occurrence of such events is rare.

Where clay forms the interface, there is likely to be a significant zone of softening in the clay (due to saturation at low normal stresses, poor or none existent vertical drainage and the effect of organic acids), resulting in either very low undrained shear strength or low effective shear strength parameters. The result is that potential shearing could occur either in the peat, on the interface or in the clay; all three possibilities have been documented in the past.

A rock substrate provides a high strength stratum, however, the rock surface can be smooth, and, depending on the dip orientation of the strata, it can provide a very weak interface. For these reasons, at this stage, a rock interface has been given the same risk rating as clay.

Table 8-4
Coefficients for Substrate

Substrate Conditions	Substrate Coefficients
Sand/gravel	1
Clay	2
Rock	2
Not proven	3
Slip material (Existing materials)	5

If the overall thickness of the peat had not been proven, the risk associated with the significant thickness and the unknown substrate would have been given a high rating to accommodate the unknown factors.

8.4 Risk Rating

The risk rating coefficient (score) was derived by multiplying the coefficients for the four key factors (with historic instability as 0) identified the above sections together to produce a risk rating which is a measure of the likelihood of peat instability, and this enables potential areas of concern to be highlighted.

For example, a thin peat (2) x sand/gravel (granular) (1) x slope 6^{o} (4) = 8 (low risk).

For the stability risk assessment, the following Potential Stability Risk classes were applied as shown in Table 8-5.

Table 8-5
Risk Rating

Risk Rating Coefficient	Potential Stability Risk (Pre-Mitigation)	Action
<5	Negligible	No mitigation action required
5 - <15	Low	As for negligible condition plus development of a site specific construction and management plan for peat areas
15 - <31	Medium	As for Low condition plus may require mitigation to improve site conditions.
>31	High	Unacceptable level of risk, the area should be avoided. If unavoidable, detailed investigation and quantitative assessment required to determine stability and sensitivity to minor changes in strength and groundwater regime combined with long term monitoring.

The rating system outlined above differs slightly from that proposed in the SE Guidance as the system adopted here incorporates three inputs compared to two in the guidance, with the potential impact of substrate added in this section.

The table of results; included in Appendix A shows that 277 probe locations were identified within the extent of the Digital Terrain Model, across all sites. The stability risk rating identified the following:

North Construction Compound

- Negligible risk at 16 (18.6 %) locations;
- Low risk at 53 (61.6 %) locations;
- Medium risk at 14 (16.3 %) locations;
- High risk at 0 (0 %) locations; and
- No peat was recorded at 3 locations, hence no risk.

Main Construction Compound

- Negligible risk at 6 (5.1 %) locations;
- Low risk at 86 (73.5 %) locations;
- Medium risk at 25 (21.4 %) locations; and
- High risk at 0 (0 %) locations.

West Construction Compound

- Negligible risk at 3 (4.1 %) probe locations;
- Low risk at 53 (71.6 %) locations;
- Medium risk at 14 (18.9 %) locations;
- High risk at one (1.4 %) location; and
- No peat was recorded at 3 locations, hence no risk.

Figure 6a-c presents the interpreted risk of peat instability based on the multiplication of the risk coefficients discussed above in Table 8-2 to Table 8-4 and using the detailed mitigation in Table 8-5.

8.5 Hazard Score Development

A further assessment of the medium/high risk locations at each of the sites has been undertaken. It should be noted that the impact assessment is primarily concerned with impacts that affect the environment, ecology, public or infrastructure associated with the proposed development, both on site and potentially off-site. These assessments do not consider the detailed ecological impact of construction induced peat instability; however, the majority of the sensitive receptors within influencing distance of the sites are critical infrastructure (roads and overhead powerlines).

The effect a slope failure may have on the construction sites and associated infrastructure can be easily identified. However the effect of an instability event on features impacted by an event not associated with the proposed development is harder to predict.

In order to address this effect it is not considered appropriate to assess the effect at every potential receptor location close to a site; but rather to assess the effect a particular infrastructure feature would have on the structures or features surrounding it. By adopting such an approach the assessment of infrastructure features where a risk ranking of 'negligible' or 'low' (assessed in the stability risk assessments described above) is discounted from further assessment.

8.6 Receptor Ranking

Now the infrastructure features with a 'medium' or higher risk rating for instability have been identified it is necessary to identify potential impact receptors. These are nearby structures or features that may be affected by peat movements caused during or following construction. Generally, only receptors immediately down gradient of the infrastructure feature could be affected by peat instability therefore the first phase of feature ranking requires topographic ridges and valleys to be identified across the site and surrounding area. From this, receptors at risk from particular infrastructure features can be identified. However, should instability occur on a steep slope, there is the risk of the back scarp of the instability migrating up-slope, there-by affecting areas previously considered not to be at risk.

Following identification of receptors at risk, these are ranked according to their size and sensitivity. Table 8-6 presents the coefficients placed on particular receptor types.

At the Main and West sites, only critical infrastructure (roads and overhead powerlines) are deemed significant receptors potentially at risk from peat slides, there is also a watercourse deemed a receptor at the North site. Communities have been discounted due to distance from infrastructure, the impact therefore, should a slide occur is directly to water courses (at the north site) or critical infrastructure (all sites).

Table 8-6
Coefficients for Impact Receptor Ranking

Nature of Feature	Feature Coefficient
Non-critical infrastructure (minor/private roads, tracks)	1
Watercourses and critical infrastructure (roads, electrical infrastructure, dwellings etc.)	3
Sub-Community (settlement 1-10 residents)	6
Community (settlement of >10 residents)	8

8.7 Receptor Proximity

The proximity of an impact receptor is also critical in assessing the likely level of disruption it may suffer following an instability event. Based on this, two further coefficients – distance from infrastructure feature and relative elevation differences between the infrastructure feature and impact receptor - are applied in deriving an impact ranking.

Table 8-7 and Table 8-8 present the coefficients derived for distance and elevation of impact receptors.

Table 8-7
Coefficient for Impact Feature Distance

Distance from Coefficient Feature	Distance Coefficient
> 1km	1
100 m – 1 km	2
10 – 100 m	3
0 – 10 m	4

Table 8-8
Coefficient for Impact Feature Elevation

Relative Elevation of Feature	Elevation Coefficient
0-10 m	1
10 – 50 m	2
50 – 100 m	3
> 100 m	4

8.7.1 Impact Rating

The impact rating coefficient (score) is derived by multiplying the receptor ranking coefficient (score) by the distance coefficient (score) and the elevation coefficient (score) for each impact receptor associated with a particular infrastructure feature.

Based on distance to impact receptors, in this instance we have identified the main roads (A970 and A971), overhead powerlines as the critical infrastructure receptors that are at greatest risk following an instability event and the Twart Burn as the watercourse receptor (at the north construction compound). Based on Table 8-6 the critical infrastructure and watercourse would have an impact receptor coefficient (score) of 3 and then considering the distance to the receptor and the relative elevation differences on site of receptors, a potential impact can be derived.

For example, critical infrastructure (3) x 479m from the risk area (2) x an elevation difference of 25m (2) = 12 (low).

8.8 Hazard Ranking

The SE guidance recommends that the hazard ranking is assessed using the following formula:

- **Hazard Ranking = Hazard x Exposure**

This philosophy can be applied to the assessment carried out so far in the following approach:

- **Hazard Ranking = Risk Rating x Impact Rating**

In order to achieve a meaningful and manageable result from the hazard ranking, the results of the Stability Risk Assessment and Impact Assessment have been normalised to a standard numerical scale (below).

Table 8-9
Rating Normalisation

Risk Rating		Impact Rating	
Current Scale	Normalised Scale	Current Scale	Normalised Scale
Negligible <5	1	Very Low <10	1
Low 5 - <15	2	Low 11 - 20	2
Medium <15 - 30	3	High 21 - 30	3
High 31 - 50	4	Very High 31-50	4
Very High >51	5	Extremely High >51	5

The method of assessing risk, impact and hazard developed by SLR Consulting incorporates additional critical elements such as the substrate interface and coefficients for the receptor position, distance and elevation and as such is considered to be more rigorous than the assessment scheme proposed by the SE. Whilst the scales used in the SLR method deviate from the SE Guidance (with risk and impact rating scales from 1-4 rather than 1-5), the ultimate Hazard Ranking scale does equate to the SE scale, with hazard rankings divided over four zones.

A simple multiplication of these coefficients would result in potentially large and unwieldy risk and impact rating numbers. We have therefore opted to normalise these values to bring them in line with the values used in the SE Guidance, as illustrated in Table 8-9 above.

Table 8-10
Hazard Ranking

Hazard Ranking	Hazard Ranking Zone	Action
1-4	Insignificant	No mitigation action required although slide management and monitoring shall be employed. Slide management shall include the development of a site specific construction plan for peat areas.
5 - 10	Significant	As for Insignificant condition plus further investigation to refine the assessment combined with detailed quantitative risk assessment to determine appropriate mitigation through relocation or re-design.
11 - 16	Substantial	Consideration of avoiding project development in these areas should be made unless hazard mitigation can be put in place without significant environmental effect.
17-25	Serious	Unacceptable level of hazard; development within the area should be avoided.

8.9 Results

North Construction Compound

The stability risk assessment has demonstrated that the majority of the North Construction Compound lies within an area of negligible and low risk with regards to stability based on Figure 6a.

In regards to key receptors, the A970 road is situated immediately west of the proposed construction compound and an overhead powerline bisects the eastern side of the proposed compound area. There are no communities of any description within the proposed development area or within 1 km of any down slope regions of the site where a peat slide would be likely to travel.

There are no watercourses within the site boundary however the Twart Burn is situated within 30m of the north-eastern site boundary and is considered a receptor.

As much of the peat on site is to be excavated to form the proposed construction compound platform, much of the risk on site can be discounted, however the construction of the proposed development may impact downgradient areas of the site, with the A970 road and the Twart Burn considered receptors at risk should a peat slide occur.

It is critical that appropriate drainage is considered ahead of construction to avoid impeding drainage downgradient and increasing the potential of a peat slide occurring.

Mitigation measures and actions to reduce the risk of peat instability occurring should be adopted during construction; these measures are presented in Section 0.

Main Construction Compound

The stability risk assessment has demonstrated that the majority of the Main Construction Compound lies within an area of low risk with regards to stability based on Figure 6b. There are areas of medium risk on the western side of the site.

As much of the peat on site is to be excavated to form the proposed construction compound platform, much of the risk on site can be discounted, however the construction of the proposed development may impact downgradient areas of the site, with the A970 road and the overhead powerline, downgradient to the west of the site considered receptors at risk should a peat slide occur.

There A970 road is situated within 120m of the western boundary of the proposed construction compound and the overhead powerline sits 60m west of the site. There are no communities of any description within the proposed development area or in any down slope regions of the site where a peat slide would be likely to travel.

There are no watercourses within the site boundary.

It is critical that appropriate drainage, particularly on the western site boundary is considered ahead of construction to avoid impeding drainage downgradient and increasing the potential of a peat slide occurring.

Mitigation measures and actions to reduce the risk of peat instability occurring should be adopted during construction; these measures are presented in Section 0.

West Construction Compound

The stability risk assessment has demonstrated that the majority of the West Construction Compound lies within an area of low risk with regards to stability based on Figure 6c.

Those areas that have been identified as being at medium risk of instability but do not impact the site layout have not been considered in a hazard impact assessment.

The A971 road is situated to the southwest of the proposed construction compound and two overhead powerlines bisect the southern and western side of the proposed construction compound area. There are no communities of any description within the application area or within 1 km of any down slope regions of the site where a peat slide would be likely to travel.

There are no watercourses within the site boundary.

There are limited areas that have been identified as being at medium or high risk of instability. The medium and high risk locations identified have been discounted following review by an experienced engineer as they are not located within influencing distance of the proposed infrastructure or the risk was identified due to the steep gradient however no peat was identified during probing.

Good construction practice should be followed to reduce the risk of peat instability occurring; these measures are presented in Section 0.

8.10 Hazard Rated Locations

As noted in Figure 6a-c, where the risk assessment has identified negligible or low risk of peat instability, no specific mitigation measures are necessary. However, in order to ensure best practise is employed, there would be a need for careful monitoring and the construction management must include careful design of both the permanent and temporary works appropriate for peat soils; these are discussed further in Section 0.

The areas of the infrastructure that were rated as medium risk, or above, were subjected to a hazard assessment, the worst case locations (closest to critical infrastructure/watercourses have been assessed below); a number of areas were discounted as they do not fall within influencing distance of any of the key infrastructure or there is no significant receptors downgradient that the potential peat slide would be likely to reach.

The procedure adopted was to review Figure 6a-c and identify those areas with a medium risk or greater, that were in close proximity or influencing distance of the proposed infrastructure (roads/overhead powerlines) or watercourses.

The assessment carried out in Table 8-11 was completed as described in the sections above. For example, the location in the North Construction Compound has a risk rating of 3 (derived from Table 8-5 and Table 8-9) with an impact rating of 2 (derived from the process described in 8.7.1 and normalised in Table 8-9). These ratings are multiplied (3x2) to give a hazard ranking of 6 (significant) as detailed in Table 8-10.

Although potential hazard zones identified in Table 8-11 can be mitigated to 'insignificant' it is believed that hazards should be subject to further post consent investigation and on-going monitoring during and after construction. Further details of mitigation during construction are described in Section 0.

Table 8-11
Stability Hazard Ranking Assessment

Site	Location	Risk Rating	Impact Rating	Hazard Ranking	Mitigation	Revised Hazard Ranking
North – Critical Infrastructure	441544,1160305 Central southern area of site	Medium (3)	Low Impact (2)	Significant (3x2)	Appropriate periphery drainage to minimise infiltration during excavation and to avoid impacting natural drainage downgradient. Existing drainage should be replicated, if required and diverted if appropriate.	Insignificant, though will require ongoing monitoring.
North - Watercourse	441555,1160458 North eastern corner of site	Medium (3)	Low Impact (2)	Significant (3x2)	Appropriate periphery drainage to minimise infiltration during excavation and to avoid impacting natural drainage downgradient. Existing drainage should be replicated, if required and diverted if appropriate.	Insignificant, though will require ongoing monitoring.
Main – Critical Infrastructure	442074, 1154855 Western site boundary	Medium (3)	Low Impact (2)	Significant (3x2)	Appropriate periphery drainage to minimise infiltration during excavation and to avoid impacting natural drainage downgradient. Existing drainage should be replicated, if required and diverted if appropriate.	Insignificant, though will require ongoing monitoring.

9.0 Construction Issues and Mitigation Measures

It has been shown that excavation, drainage and general construction activities can have a destabilising influence on peat and that design should allow for the delicate and susceptible condition of the peat. There is no extensive evidence for past peat instability on site, though there is evidence of past slides regionally across Shetland and within the boundary of the proposed Viking Wind Farm development. Appropriate good practice measures and mitigation should be employed to minimise the risk of adverse effects on peat and hydrological receptors.

The following sections highlight the construction issues that should be considered for each general area of construction. Many of the issues raised should be incorporated into the CEMP and construction method statement for each site.

The following is a list of controls that should be considered for incorporation into the development of construction methodologies for the works in all areas of peat during detailed design stage:

- Appropriately experienced and qualified engineering geologist/geotechnical engineer is appointed during the construction phase, to provide advice during the setting out, micro-siting and construction phases of the works;
- Geotechnical Risk Register is developed and maintained by the appointed contractor and regularly reviewed by the geotechnical engineer;
- A minimisation of "undercutting" of peat slopes, but where this cannot be avoided, a more detailed assessment of the area of concern by the geotechnical engineer would be required;
- Methodologies should be developed as a contingency to minimise the effects to watercourses and critical infrastructure should peat instability occur; and
- Use of floating track across areas of deep peat, if appropriate.

Notwithstanding any of the above comments, detailed design and construction practices would need to take into account the particular ground conditions and the specific works at each location throughout the construction period.

The following list of mitigation measures is provided in an attempt to minimise the risk of potentially inducing peat landslides during construction of the proposed development:

9.1 General

- Raise Health and Safety awareness of the peat environment at the proposed development for construction staff by incorporating the issue into the Site Induction. Include peat slide risk assessment information (e.g. peat instability indicators, best practice and emergency procedures) in tool box talks with relevant operatives e.g. plant drivers;
- Introduce a 'Peat Hazard Emergency Plan' to provide instructions for site staff in the event of a peat slide or discovery of peat instability indicators;
- For sections of track that require track side cuttings into peat, suitable slope gradients or support measures would need to be designed to maintain the stability of the adjacent peat terrain;
- Refine/optimise the design through the pre-construction phase following completion of a detailed ground investigation; and

- Develop methodologies to ensure that accelerated degradation and erosion of exposed peat deposits does not occur as the break-up of the peat top mat has significant implications for the morphology, and thus hydrology, of the peat (e.g. minimise off-track plant movements within areas of peat).

9.2 Drainage Measures

Drainage design for the proposed development is a critical mitigation measure in maintaining the hydrological conditions. In order to maintain hydrological conditions the following requirements of the drainage measures should to be met;

- Development of drainage systems that would not create areas of concentrated flow or cause over-, or under-, saturation of peat habitats;
- Development of robust drainage systems that would require minimal maintenance;
- A robust design of drainage systems and associated measures (i.e. silt traps, etc.) to minimise sedimentation into natural watercourses. Method statements should be prepared in advance to mitigate against a slide occurring and should include, but not be limited to, the use of check dams and erosion protection to limit flows and prevent contamination of watercourses; and
- Measures shall be put in place to ensure drainage systems are well maintained, to include the identification and demarcation of zones of sensitive drainage or hydrology in areas of construction, e.g. inclusion of maintenance regimes for drainage systems into a construction management plan or similar.

9.3 Construction Recommendations

The complexity of peat stability has been discussed in this report and by Lindsay and Bragg [Error! Bookmark not defined.], amongst others. Following a review of published work and the observation and analysis undertaken for the proposed development, there would be a negligible hazard from peat instability if the recommendations contained in this report are adopted.

Suitable guidance and documentation in the form of a construction method statement/CEMP would be established before work commences to ensure good construction practices. Due to the complex inter-reactions affecting peat stability it is proposed that the recommendations given below are used as a set of guidelines to generate a detailed design concept. The concept should include the range of potential risks discussed in this report and the design should be sufficiently flexible to allow for continual modification and up-dating as construction progresses.

In order to maintain the current level or improve the stability of the peat mass on the slopes around the proposed developments, it is necessary to ensure that the construction methods do not seriously disrupt the established drainage and that no areas are surcharged, either by water discharge or spoil.

Wherever possible, the following principles should be adopted:

- Maintenance of existing drainage is critical, therefore all existing drainage tracks must be maintained and where necessary, channelled below the proposed track construction. Upslope side drainage ditches to the track would be required on side-long ground; the ditches should be constructed with small dams and cross drains where necessary so that:
    - Water can pass below the track at regular intervals; and

    - Scour and erosion is avoided in the side ditches due the limited volume and velocity, concentrated discharges to the peat on the down slope side of the track are avoided;
- Install additional drainage in areas up-slope to the construction compound to prevent ponding and possible instability;
- Cut and fill earthworks should be avoided in peat greater than 1.0 m deep if possible; if not, the following requirements on side long ground (across contours) should be adopted;
    - Excavate to a sound stratum;
    - The majority of construction surface's to be essentially horizontal with a slight fall to aid drainage;
    - Where the depth of cut is deemed unstable, employ a stepped or benched surface with the intention of minimising the exposed surface of the up-slope cut face;
    - Protect all exposed peat surfaces from erosion and desiccation, by ensuring the integrity and moisture content of the peat is maintained; and
    - The top of cut slopes should be provided with a small bund to retain the peat to prevent desiccation and maintain the local stability of the peat.

9.4 Further Work

This report should be considered as the first stage in the development of a fundamental understanding of the various inter-relationships that govern and control the peat lands at the site.

More detailed ground investigations would be required to facilitate the geotechnical design of the proposed development.

10.0 Conclusion

Each site has been assessed for potential hazards associated with peat instability; the assessment has been based on:

- A walk-over survey by an experienced geologist;
- A thorough inspection of the digital terrain map at a scale of 1:25,000;
- Review of historical and geological maps and publications and aerial photography; and
- Review of peat depth data gathered during peat probing survey.

A detailed geotechnical probing exercise has been undertaken at each site to identify peaty soil/peat and to determine the thickness thereof. The data has been combined with DTM data to model peat stability risk on each site.

There is limited peat at the proposed West Construction Compound with thick peat deposits across much of the North and Main Construction Compounds. Where present, the peat is highly fibrous and erosive features exist (hags).

It is concluded that there is a low risk of instability over the majority of the development sites. There are areas of medium and high risk of instability which have been considered further as part of a hazard impact assessment.

Critical infrastructure would be the key receptor at risk from a peat slide at the North and Main sites (main road, overhead powerline) as well as a watercourse at the North Construction Compound.

The hazard impact assessment concluded that with the employment of appropriate mitigation measures and good construction practice, all these areas can be considered as an insignificant risk; though ongoing monitoring should take place throughout the development.

Additional mitigation measures have been identified in areas where hazards are already considered insignificant to further reduce the risk of potential hazards occurring.

Temporary storage of the peat excavated at the proposed construction compounds should be considered further as part of a peat management plan for the wider Viking Wind Farm site.