1 Brief

Slide 1

1.1 This Brief of Evidence pertains to the Geotechnical Issues including Peat Stability and Stone Road Construction for the proposed Corrib Onshore Gas Pipeline. The relevant geotechnical reports are included in the Environmental Impact Statement (EIS) Volume 2 of 3, Book 4 of 5, Appendix M (M1) and Volume 2 of 3, Book 5 of 5, Appendix M (M2 to M6).

1.2 The slides presented with this Brief of Evidence are annotated extracts from the EIS.

2 Qualifications and Experience

Slide 2

2.1 My name is Turlough Johnston and I am the Managing Director of Applied Ground Engineering Consultants (AGEC) Limited, an independent geotechnical engineering consultancy. AGEC was commissioned by Shell E&P Ireland Limited (SEPIL) to undertake and report on a stability assessment for the proposed onshore pipeline within peat areas. AGEC was also commissioned to carry out a geotechnical assessment on the proposed use of stone road construction in areas of peat for the proposed onshore pipeline and to carry out a geotechnical assessment of the site for the proposed Landfall Valve Installation. AGEC provided specialist geotechnical advice on the Landslides at Pollathomish in 2004.

2.2 I am a Chartered Engineering Geologist and have been working in these technical disciplines for more than twenty years both in Ireland and internationally. My experience includes major infrastructure projects and private development projects over challenging ground conditions both in Ireland and overseas.

2.3 My qualifications and professional affiliations are;

Bachelor of Science (Honours) Geology, University of London
Master of Science Engineering Geology, Imperial College, London
Diploma in Construction Law, Trinity College, Dublin
Chartered Engineering Geologist
Member of the Geotechnical Society of Ireland / Engineers Ireland
Member of the British Geotechnical Association
Member of the Society of Construction Law
Fellow of the Geological Society of London
Fellow of the Institution of Civil Engineering Surveyors

3 Knowledge of the Site and Related Activities

Slide 3

3.1 I have been involved in the Corrib Onshore Gas project since 2002. My involvement has included the design of ground investigations, the interpretation of the ground conditions, the geotechnical assessment and design with respect to peat areas for the Bellanaboy Bridge Gas Terminal site and the Onshore Pipeline. AGEC has been involved continuously from the geotechnical investigations through to the establishment and recording of geotechnical monitoring for the Terminal construction. I have been a frequent visitor to the Terminal during its construction and throughout the ground investigations and construction activities.

3.2 In 2004 AGEC was instructed by SEPIL to carry out a site investigation for the previously approved onshore pipeline from the Corrib Gas Terminal Site to the Glenamoy River Estuary (EIS Volume 2 of 3, Book 4 of 5, Appendix M1-B). The purpose of the 2004 site investigation was to determine the ground conditions of the pipeline route for the construction of the pipeline, particularly the peat condition, and to assess the depth and strength of the peat for assessment of peat stability. The site investigation work was carried out between May and July 2004 and consisted of 105 nos. peat depth probes, 8 nos. trial pits, 28 nos. peat samples and 28 nos. shear vane tests.

3.3 I had oversight of the following AGEC reports;

(1) 'Final Report on Onshore gas Pipeline – Glenamoy River Estuary to Corrib Gas Terminal (Ch 89600 to 92391) Geotechnical Interpretative Report' prepared for SEPIL in November 2005 and included in EIS Volume 2 of 3, Book 4 of 5, Appendix M (M1). This report describes the ground investigation work undertaken and provides interpretation of its findings to develop a geotechnical ground model. Relevant geotechnical design parameters are derived and recommendations are made with regard to construction related geotechnical considerations.

(2) 'Report on Corrib Onshore Pipeline Peat Stability Assessment' prepared for SEPIL in January 2009 and included in EIS Volume 2 of 3, Book 4 of 5, Appendix M2. This report examines the stability of the natural peat slopes along the route of the proposed pipeline.

(3) 'Report on Corrib Onshore Pipeline Geotechnical Assessment of Stone Road Construction in Peat Areas' prepared for SEPIL in January 2009 and included in Volume 2 of 3, Book 5 of 5, Appendix M3. This report includes typical stone road details, a comparison of alternative road/access construction methods in peat, characterisation of peat conditions encountered and a stability assessment of the stone road with respect to construction loading, effect on surrounding peat and effect of potential impact on stone road from hypothetical peat failure.

4 Scope of Evidence

Slide 4

4.1 This evidence considers the following:

(1) The geotechnical investigations undertaken and the sources of geotechnical information referenced. It is noteworthy that over Rossport Commonage the frequency of probing is every 38m and in addition the peat and mineral soil exposures along Sruwaddacon Bay has been mapped in detail

(2) A geotechnical overview of the proposed pipeline route from Glengad to the Terminal including the two marine crossings **Slide 5**

(3) The peat stability assessment of the proposed pipeline route from the landfall at Glengad Headland to the Bellanaboy Bridge Gas Terminal site passing through peat lands in three areas namely Rossport (Commonage), South of Sruwaddacon Bay to L-1202 and L-1202 to Terminal Site

(4) The geotechnical assessment of the proposed use of stone road construction in peat areas and a geotechnical overview of the marine crossings using trenchless technology

(5) The geotechnical risk register as presented in Appendix M4 of the EIS and a geotechnical assessment of the cliff at the proposed site of the Landfall Valve Installation (LVI) **Slide 6**

(6) Commentaries on the landslides that occurred at Pollathomish in September, 2003 and on the Peat Landslip on L-1202 Road, Aughoose, Erris, May 2008

(7) This evidence also discusses the commitments to geotechnical supervision and monitoring for construction and the geotechnical monitoring for pipeline operation

4.2 This evidence draws from geotechnical mapping and reports compiled by various authors and contributors from AGEC and RPS.

5 Geotechnical Investigations & Sources of Geotechnical Information

Slide 7

5.1 The proposed route has been the subject of significant geotechnical investigations reported as follows:

- AGEC 2004 Final Report on Onshore Gas Pipeline Glenamoy River Estuary to Corrib Gas Terminal Site Investigation Factual report (EIS Volume 2/3, Book 4/5 App. M1-B)
- Geotechnical & Environmental Services 2007; Corrib Onshore Pipeline Route Selection Geotechnical Ground Investigation Factual Report (EIS Volume 2/3, Book 4/5 App. M1-B)
- Irish Drilling Limited 2008 Site Investigations Factual Report (EIS Volume 2/3, Book 4/5 App. M1-B)
- RPS 2008 In Situ Testing of Peat on the Onshore Pipeline Route (EIS Volume 2/3, Book 4/5 App. M1-B)
- AGEC Walkover and Engineering Geomorphological Mapping (EIS Volume 2/3, Book 5/5 App. M2)

5.2 Other sources referenced from publicly available data include:

- Geological Survey of Ireland, 1992. Geology of North Mayo. Sheet 6
- Geological Survey of Ireland, 2004. Geology of Galway Bay. A Geological Description to accompany the bedrock geology 1: 100,000 scale Map Series, Sheet 6, North Mayo
- Ordnance Survey of Ireland, Sheet 89
- Osiris Projects, 2007. Corrib Gas Pipeline Landfall Sruwaddacon Bay Geophysical Survey

- Tobin, 2003. Report on the Landslides at Dooncarton, Glengad, Barnachuille and Pollathomish, County Mayo available

6 Geotechnical Overview of the Proposed Pipeline Route

Slide 8

6.1 Most of the proposed pipeline route will be within peat or inorganic soils. Bedrock will only be encountered during installation of the proposed pipeline at the two marine crossings and at the locations of the Landfall Valve Installation (LVI) at Glengad. Where the proposed pipeline is to be constructed in inorganic soils, it will be founded generally within medium dense to dense sand or gravel. A detailed geotechnical assessment of the sections of the route in inorganic soils is included in Appendix M1 of the EIS. Where the proposed pipeline is to be constructed in peat, it will be founded within a stone road construction. The stone road will bear on the underlying mineral soil with typically 0.5m of peat left in situ where appropriate. A detailed geotechnical assessment of the sections of the route in peat is included in Appendices M2 and M3 of the EIS.

Slide 9

6.2 Ground conditions at Glengad between ch. 83,400 and ch. 83,910 are recorded as made ground/topsoil underlain by loose to dense sands and medium to very dense gravels to depths of between about 3.85mbgl and 5.0mbgl. Weak to strong moderately weathered psammite bedrock with locally highly weathered zones were recorded below the overburden material.

Slide 10/11

6.3 Ground conditions at the Lower Crossing, Glengad to Rossport between ch.83,910 and ch. 84,510 are recorded as mainly sands with some gravel and silt layers up to depths of 3.0mbgl increasing to 20mbgl overlying bedrock. Bedrock is recorded as psammite and quartz muscovite schist and is recorded between 9.3mbgl and 24.8mbgl. Shallower rock was encountered closer to the banks of the channel with deeper overburden deposits towards the middle of the channel.

Slide 12/13/14

6.4 Ground conditions between ch. 84,510 and ch. 85,990 Rossport Landfall to Rossport Commonage (Rossport West) are recorded as topsoil overlying medium dense to very dense sand and/or gravel deposits from 0.4mbgl to 8.1mbgl. Bedrock is recorded as Psammite; with a discontinuous band of pelitic schist observed between 12.5mbgl and 18.8mbgl. Groundwater was struck in exploratory holes between 1m and 4mbgl.

Slide 15/16/17/18

6.5 Ground conditions between ch. 85,990 and ch. 88,520 (Rossport Commonage) are recorded as typically peat over mineral soil. No exploratory borehole investigation was carried out within the Commonage due to access issues but peat probing was performed. Probe depths within the peat varied between 0.25m and 5m with a general average thickness of 2.8m. The undrained shear strength of the peat varies both laterally and with depth and the peat has a relatively stronger and more fibrous upper layer (Acrotelm) which is typically about a metre thick. The exposed mineral soil lying stratigraphically below the peat is recorded as firm to locally soft grey/brown to reddish brown slightly sandy to sandy slightly gravelly to gravelly silt. Locally the mineral soil is recorded as silty gravelly sand.

Slides 19/20/21

6.6 Ground conditions at the Crossing of Sruwaddacon Bay (Upper Crossing) between ch. 88,520 and ch. 89,550 are recorded as mainly sands with some gravel and silt and clay layers overlying bedrock. Bedrock is recorded as psammite, which have been altered due to metamorphism and foliations due to faulting in the area. Bedrock was encountered between 3.3mbgl and 16.3mbgl. Shallower rock was encountered closer to the banks of the bay with deeper overburden deposits towards the middle of the bay.

Slides 22/23/24

6.7 Ground conditions between ch. 89,550 to ch. 91,000 (South of Sruwaddacon Bay to L-1202) are recorded as grassland over peat between ch. 89,500 and about ch. 90,360 with the remainder recorded as forestry. Peat depths are recorded between 0.4m to 4.2mbgl overlying granular and cohesive soils which in turn overlies bedrock between 8.8m and 25.4mbgl. Peat is recorded as very soft fibrous and decomposed; the cohesive mineral soil is recorded as locally very soft to soft sandy gravelly clay and as stiff slightly sandy gravelly clay. Bedrock is recorded as moderately weak to moderately strong psammite. Groundwater was struck in exploratory holes between ground level and 2.3mbgl.

Slides 25/26/27/28/29

6.8 Ground conditions between ch. 91,000 to 92,560 (L-1202 to Terminal Site) are recorded as peat over mineral soil with peat depths from about 2.1m to 4.6m with an average thickness of 3.3m. Peat is recorded as very soft to soft and the mineral soil is recorded as grey/brown slightly silty gravelly sand with occasional cobbles (Upper Till) overlying blue grey clayey gravelly fine sand with occasional cobbles (Lower Till). A section of stone road has been successfully completed at the approach to the Terminal as shown on Slides 27 and 28.

7 Peat Stability Assessment Approach

Slides 30/31/32/33

7.1 The peat stability assessment along the proposed onshore pipeline included a walkover survey in December 2008 by AGEC personnel along the pipeline route and mapping of the peat, mineral soil and rock exposures along Sruwaddacon Bay. A report was produced (See Appendix M2 of the EIS) to provide a record of the salient geomorphological features of the route and to provide an assessment of shallow ground conditions, particularly peat conditions and evidence of peat instability that may pose a risk to the pipeline route due to potential sliding failure. At the same time a review of available records of peat failures in the area was also undertaken.

7.2 Following the walkover survey and review, an assessment of the ground conditions was undertaken in order to determine the engineering properties of peat and underlying soils. These engineering properties were used to establish a ground model to assess the stability of peat areas.

7.3 A quantitative stability analysis was carried out to determine the Factor of Safety (FoS) of the existing natural peat slopes in three areas where blanket peat exists along the proposed onshore pipeline route, namely; Rossport (Commonage), South of Sruwaddacon Bay to L1202 and L1202 to Terminal.

7.4 The stability analysis was carried out for both the short and long term conditions and examined both the potential failure in the peat within the basal zone of the peat and the potential failure in the mineral soil just below the peat mineral soil interface.

7.5 The results of the stability analysis (for all potential failure models) showed that the natural peat slopes along the proposed pipeline route have an acceptable FoS of 1.5 or greater in accordance with relevant standards (BS 6031:1981 Code of Practice for Earthworks and Eurocode 7) where the peat is not loaded, i.e. where no vertical force is applied from construction.

7.6 I wish to bring to the Board’s attention the summary of findings of the peat stability assessment report for the proposed onshore pipeline route from the landfall at Glengad Headland to the Bellanaboy Gas Terminal site as follows:

(1) An assessment of the peat stability along the proposed onshore pipeline route was carried out and included the following: walkover survey of the

route and production of geomorphological plans, review of ground investigation and interpretation of ground conditions, and quantitative assessment of peat stability.

(2) The proposed onshore pipeline route is approximately 9.2km long, from the landfall at Glengad Headland to the Terminal. The onshore pipeline crosses approximately 5.7km of peat land which comprises about 60% of the total route.

(3) The general geology along the route and the depth of peat is shown on AGEC Drawings 864_05_005 to 010 (EIS Volume 2 of 3, Book 5 of 5, Appendix M2). The deepest peat is recorded within the Rossport (Commonage), where peat is up to 5.4m deep.

(4) The walkover survey of the pipeline route was carried out to identify salient ground conditions, in particular evidence of peat instability that may pose a potential risk to the pipeline route. The findings of the walkover survey of the route identified no apparent signs of peat instability that would pose a risk to the pipeline route.

(5) A stability assessment of the route was carried out using an infinite slope approach to model the stability of natural peat slopes. The stability analysis examined the following potential failure models:

   (a) Potential failure in the peat within the basal zone of the peat (total stress and effective stress condition), and

   (b) Potential failure in the mineral soil just below the peat-mineral interface (total and effective stress condition).

(6) The stability analysis examined two load cases namely (1) no applied loading and (2) 10kPa applied loading.

(7) The results of the stability analysis (for all potential failure models) showed that the natural peat slopes along the proposed pipeline route have an acceptable FoS of 1.5 or greater in accordance with relevant standards (BS 6031:1981 Code of Practice for Earthworks and Eurocode 7) where the peat is not loaded.

(8) In the case where the peat is loaded by 10kPa the FoS was less than 1.5 for undrained failure within the basal zone of the peat at two locations (ch. 87,219 and 89,867)

(9) The localised areas where the FoS was low corresponded to locations where there were particularly low undrained shear strength values (1 and 2kPa) recorded from the in situ hand vanes;

(a) At about ch. 87,219 in Rossport (Commonage) the undrained FoS is 1.3. This corresponds to a notably low value of undrained strength (1kPa) and is located close to a series of shallow bog pools. Given the increasing slope inclination to the east of this location, it is considered that this area represents an increased risk of peat instability without appropriate mitigation measures as detailed in the Geotechnical Risk Register (Appendix M4 of the EIS).

(b) At about ch. 89,867 South of Sruwaddacon Bay results of analysis show that the FoS is 1.3. This corresponds to an area of relatively intact peat, where the peat strength is 1kPa at 1mbgl. The strength used in the analysis (1kPa) is notably low and possibly not representative of the peat conditions.

(c) At about ch. 91,688 on the approach to the Terminal results of analysis show that the FoS is 1.0 for load condition (2). This corresponds to a notably low value of undrained strength (2kPa) with a slight increase in the slope inclination at this location. The strength used in the analysis (2kPa) is notably low and possibly not representative of the peat conditions. A stone road has already been safely constructed in this area.

(10) In general the high FoS's calculated for the proposed pipeline route would indicate that there is very limited potential for instability of the natural peat slopes. The high FoS's for the route would correspond to the findings of the walkover survey of the route which identified no apparent signs of peat failure.

(11) I wish to bring to the Board's attention the findings of the walkover survey of the route which identified the following critical areas with respect to peat stability:

(a) Areas of machine cut peat within the commonage. There are extensive areas of machine cut peat (for example ch 86,250 to 86,600, ch 87,300 to 87,450). The use of stone road construction method will mitigate against any significant peat failure risk in these areas; though temporary excavations in cut areas may need to be supported to avoid local collapse of excavation.

(b) Areas of wet/weak peat. There is a series of shallow bog pools within an area of relatively intact peat (ch 87,200 to 87,300). This area has notably weak and deep peat and its location at the crest of a slope represents an area of greater risk.

(c) Areas of deep peat. Around ch 88,100 there is an area of significantly deep peat (up to 5m deep). This area possibly has a significant thickness of weak amorphous peat at depth.

(12) Extensive ground investigations have been carried out along the route though investigation has been limited in some areas due to access difficulties. Using the investigation data the stability assessment has shown that the natural peat slopes have a satisfactory FoS. Notwithstanding the above, confirmatory ground investigation will be carried out in selected areas to re-confirm the ground conditions as part of the monitoring program which will form an integrated part of the construction spread. It is recommended that the following confirmatory ground investigative methods are undertaken:

(a) In situ vane tests (using mechanical vane) and undisturbed sampling for associated laboratory testing in peat to establish strength and general characteristics.

(b) In situ tests and undisturbed sampling for associated laboratory testing in underlying mineral soil to establish strength and general characteristics.

(c) Particular locations for investigation are within Rossport (Commonage) as a whole and particularly within machine cut peat areas (for example ch 86,250 to 86,600, ch 87,300 to 87,450), in the vicinity of the series of shallow bog pools (ch 87,200 to 87,300) and the area of deep peat around ch 88,100.

7.7 I wish to bring to the Board's attention the conclusions reached in the Peat Stability Assessment report as follows:

(1) The walkover survey of the pipeline route, carried out to identify salient ground conditions and in particular evidence of peat instability, **identified <u>no</u> evidence of peat failure that would pose a risk to the pipeline route**.

(2) Results of a stability analysis showed that the natural peat slopes along the proposed pipeline route have a satisfactory FoS. The high calculated FoS for the route corresponds to the findings of the walkover survey of the route **which identified <u>no</u> evidence of peat failure**.

(3) Several localised areas of weaker peat were identified along the route. These areas are **<u>not considered to represent a significant risk</u>** to the pipeline construction, particularly when taking into account the use of a stone road construction method in the peat.

(4) Taking into account the findings of the walkover survey, the results of the stability assessment and the proposed stone road construction method it is considered that the pipeline can be **<u>safely constructed</u>** along the proposed pipeline route.

8 Stone Road in Peat Areas Assessment Approach

Slide 34

8.1 The proposed use of stone road construction in the three areas of peat was assessed and a geotechnical report entitled "Report on Corrib Onshore Pipeline Geotechnical Assessment of Stone Road Construction in Peat Areas" was compiled (see Appendix M3 in the EIS). This report included a comparison of alternative road construction methods in peat, an assessment of ground investigation data, an interpretation of ground conditions and a quantitative stability assessment of the proposed stone road.

Slide 35

8.2 As stated, stone road construction is proposed in Rossport (Commonage), South of Sruwaddacon Bay to L-1202, and L-1202 to Terminal Site.

Slide 36

8.3 The construction of a stone road is proposed in peat and will entail the careful excavation of peat acrotelm turves, excavation of catotelm peat to 0.5m above mineral soil (where appropriate) along the onshore pipeline route and replacement with suitable granular fill to effectively form a stone road within the peat. Plugs of low permeability material will be installed at 50m (or less) centres to prevent longitudinal sub-surface drainage and the onshore pipeline will be installed within the proposed stone road.

Slide 37/38/39

8.4 Reinstatement of the acrotelm turves, above a regulation layer of peat, will be managed in a staggered pattern and all gaps between turves will be hand-filled with turf cut-offs to the satisfaction of the supervising personnel.

8.5 A comparison of alternative road/access construction methods in peat was undertaken and many of the alternative construction methods for permanent public trafficked roads are presented in the Report. These methods are not necessarily directly applicable to the stone road which is temporarily required for the construction plant to lay the proposed pipeline.

8.6 Three construction methods are addressed in the report (EIS Volume 2 of 3, Book 5 of 5, Appendix M3) namely:

- Type 1: Peat excavation as the preferred method in most cases.
- Type 2: Peat displacement as the proposed method for deeper peat in combination with Type 1.
- Type 3: Peat left in situ with reinforcing elements is not proposed.

8.7 Stability analysis was carried out to determine the FoS of a stone road constructed within the peat land areas with the road founded on mineral soil below the peat or on approximately 0.5m of peat where appropriate.

8.8 The possible effect on the stone road due to a potential impact from a peat slide is considered as follows:

(1) The inclusion of the stone road within the peat slope provides an increase in the stability of the peat slope due to the increase in shear resistance to sliding provided by the higher shear resistance of the stone fill. As such, in the unlikely case where a peat slide occurred the stone road would provide greater resistance to peat movement than the peat itself.

(2) A review of methods to retain potential peat slides shows that stone barrages, comprising essentially stone fill with similar geometry to the proposed stone road, have been used to contain peat slides.

(3) A significant proportion of the proposed route alignment of the stone road is within shallow slopes close to the watershed divide or is aligned normal to the slope contours. This alignment reduces the potential of a peat slide impacting on the stone road.

(4) In the unlikely event of a peat slide affecting the road, the loading of the peat slide against the stone road is considered to be akin to the passive pressure exerted by the peat. The upper limits of passive pressure are controlled by the undrained strength of the peat. Given the low strength of the peat the pressure exerted onto the stone road by a potential peat slide is considered to be relatively low compared to a slide in mineral soil.

8.9 I wish to bring to the Board's attention the summary of findings of the geotechnical assessment of the proposed use of stone road construction in areas of peat as follows:

(1) An assessment of the use of stone road construction in areas of peat along the proposed onshore pipeline route was carried out and included the following: comparison of alternative road construction methods in peat, assessment of ground investigation data and interpretation of ground conditions, and quantitative stability assessment of stone road.

(2) A comparison of alternative road construction methods in peat was carried out (Table 1 of the Report (Appendix M3)). Based on this

comparison the stone road construction would be considered the preferred solution as it greatly reduces the risk of peat failure associated with placement of load onto the peat surface. The stone road provides a dependable working platform and is a comparatively low risk construction method in peat.

(3) There are three sections where the proposed pipeline crosses over peat areas and where stone road construction is envisaged, namely: Rossport (Commonage) (ch. 85,960 to ch. 88,600), South of Sruwaddacon Bay to L-1202 (ch. 89,500 to ch. 91,000), and L-1202 to Terminal Site (ch. 91,000 to 92,560).

(4) The walkover survey (Report on Onshore Pipeline Peat Stability Assessment. AGEC, 2009) of the proposed route identified several features which should be taken into consideration when constructing the proposed pipeline;

(a) Areas of machine cut peat within the commonage. There are extensive areas of machine cut peat (for example ch 86,250 to 86,600, ch 87,300 to 87,450).

(b) There is a series of shallow bog pools within an area of relatively intact peat (ch 87,200 to 87,300). The bog pools possibly indicate wetter/weaker peat at depth and excavation works may need to allow for measures to support excavation faces.

(c) Around ch 88,100 there is an area of significantly deep peat (up to 5m deep). Possible temporary excavation support may be required in these areas or partial excavation and displacement method adopted in placing the stone fill.

(d) Several areas of potentially weaker peat have been identified (for example at about ch 87,219, 89,867). Whilst areas of weak peat will be investigated prior to construction, excavation works would nonetheless need to allow for measures to temporarily support excavation faces where weaker peat is encountered.

(5) The Geotechnical Risk Register in Appendix M4 of the EIS details mitigation measures to reduce the potential risk associated with construction work in deep/weak peat.

(6) Stability analysis was carried out to examine various stability cases with respect to the stone road (Table 4 of the Report). The results of the stability analyses are as follows:

(a) Without any construction loading the stone road has a significant inherent stability both for circular type failure and sliding failure. This would be expected with such a gravity fill structure.

(b) Loading from construction placed onto the surface of the stone road gives a satisfactory FoS. The highest loading intensity on the road will be during lifting of lengths of pipeline by the pipe laying crane. The results show that the FoS during pipe laying is sensitive to an elevated water table in the stone road; as such it is advisable that the water table is monitored in the stone road prior to and during pipe laying. Given that the road edge is often poorly compacted the pipe laying plant when lifting shall be prevented from working within 1.0m of the road edge.

(c) The placement of turves/peat onto bog mats beside the stone road was examined. The placement of turves/peat 1.0m high (10kPa load) onto the bog mat gives a FoS above the 1.3 threshold whilst the placement of turves/peat 2.0m high (20kPa) gives a FoS below 1.0. The height of peat placed on the bog mats shall not exceed 1.0m to ensure stability.

(d) The long term stability of peat slopes with the inclusion of the stone road will result in an increased degree of stability as the stone road provides an increase in shear resistance to sliding due to the higher shear resistance of the stone fill.

(7) Confirmatory geotechnical investigation in various areas will form an integrated part of the construction spread (refer to AGEC Report on Onshore Pipeline Peat Stability Assessment, 2009).

8.10 I wish to bring to the Board's attention the conclusions reached in the report entitled "Geotechnical Assessment of Stone Road Construction in Peat Areas" are as follows:

(1) Stone road construction in peat areas **is a <u>proven method</u> of construction in weak ground**, and for many such situations is the preferred construction method.

(2) Analyses were carried out to assess the stability of the stone road under various load cases. The results clearly show that the stone road has **<u>adequate stability</u>** and **<u>provides a robust and stable platform for construction and long term stability</u>**, as would be expected from such a large gravity fill structure.

(3) The likely effects of a potential peat slide on the stone road are considered to be very limited. Furthermore, **<u>installing the pipeline within the stone road will provide a significant degree of protection for the pipeline</u>**, in the unlikely event of a peat slide, compared to installing the pipeline within the peat.

(4) The long-term stability of the stone road in the peat was examined. The installation of the stone road into the peat provides a **<u>greater degree of stability against a peat slide</u>**. This is as a result of the greater shear resistance to sliding provided by the stone fill within the road.

9 Geotechnical Overview of the Marine Crossings using Trenchless Technology

Slide 40

9.1 The proposed route includes five watercourse crossings including two small stream crossings, one short estuarine river crossing (EIS Chapter 13 Figure 13.1 Sites 4, 5 and 6) and two crossings of Sruwaddacon Bay. The proposed Lower Crossing of Sruwaddacon Bay, Glengad to Rossport is approximately 600m in length while the Upper Crossing of Sruwaddacon Bay is approximately 1,000m in length. The three minor crossings are proposed using conventional open cut methods and it is proposed to deploy a trenchless method, i.e. micro-tunnelling for the Lower and Upper Crossings. The ground conditions for the Lower and Upper Crossings were described briefly above.

9.2 The trenchless method (Micro Tunnelling) is suitable for a wide variety of soil conditions and minimises the potential impact on the seabed and the overall disturbance of

Sruwaddacon Bay. The trenchless method will utilise launch and reception pits, the precise locations of which will be chosen by the appointed specialist tunnelling contractor but the general locations are described in the EIS. Significant geotechnical investigations, both invasive and non-invasive, have been undertaken to gain an understanding of the ground conditions for the crossings.

Slide 41

9.3 The geotechnical issues to be considered for the construction of the Lower Crossing include dealing with groundwater in the launch and reception pits and stability of the pits, the stability of the ground surrounding the micro-tunnel and reusability of material arisings. Groundwater with medium inflow was struck at 1.1mbgl on the eastern shore and monitoring has demonstrated that due to tidal influence, the water level ranges between 1.1mbgl to 3.6mbgl. Construction of the pits may require some temporary dewatering. The use of bentonite during micro-tunnelling and the deployment of a sleeve pipe will ensure tunnel stability in the soils and weak rock. If the micro-tunnel cutter head encounters localised difficulties, then an intervention pit may be sunk to progress tunnelling. Grading test results on samples derived from geotechnical investigations indicate that the tunnel arisings, once separated from the bentonite, can be re-used as an engineering fill.

Slide 42

9.4 Similarly, the geotechnical issues to be considered for the construction of the Upper Crossing include dealing with groundwater in the launch and reception pits, the stability of the ground surrounding the micro-tunnel and reusability of material arisings. Similar to the Lower Crossing, the tunnel stability in soils and weak rock will be ensured by the use of bentonite during micro-tunnelling and the deployment of a sleeve pipe. The pit required on the southern side of the Bay will be located within a peat area and will require a temporary retaining structure. Anchoring of pipe jacking systems into rock is anticipated at the proposed launch pit. On the northern side of the Bay, peat depths of between 0.5m and 1.5m are recorded. Similarly a temporary retaining structure such as a sheet piled pit will be required.

10 Geotechnical Risk Register

10.1 A geotechnical risk register has been compiled to demonstrate the degree of hazard and risk and is presented in Appendix M4. The register includes details of the proposed construction methods and the contingency measures to deal with geotechnical challenges and simultaneously minimise geotechnical risk.

10.2 The purpose of the register is to provide and outline a description of hazards, identify the likely cause, describe the potential impact of the hazard and identify the design and construction controls to be implemented in order to minimise the geotechnical risk. The register will be actively used throughout the detailed design and construction and will be updated to reflect additionally acquired data and experience. Pipe laying on land, tunnelling operations, temporary works and 'in operation' conditions are considered in the risk register with hazards, impacts and design and construction controls and also contingency measures included in the register.

10.3 The list of hazards identified in this register has been compiled based on specific critical hazards that are relevant to this scheme having regard to considerations such as safety and health, environmental, programme and cost.

10.4 The degree of risk is determined by combining the probability and impact assessments where the probability numerical value of a hazard occurring (P) is multiplied by the impact numerical value (I) to calculate the risk value (R); i.e. P x I = R. The probability and impact of a hazard have been judged on a qualitative scale as annotated on Table 1 and the severity of the risk is annotated on Table 2 of Appendix M4 of the EIS.

10.5 The P value assigned to a Hazard is necessarily reduced by applying Risk Control Measures which are a combination of Design Control and Construction Control. The reduction of a P value results in the commensurate reduction of an R value, i.e. the risk is reduced. The register is annotated with Hazards that have been calculated at an "Unacceptable" risk rating prior to any risk control measures applied and subsequently the risk rating has been reduced to a level of "Early Attention" and in most cases to a lower level of "At least regular attention". This is a critical element in managing geotechnical risk successfully.

11 Geotechnical Assessment of the Cliff at the proposed site of the Landfall Valve Installation (LVI)

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11.1 The LVI site is located in Glengad on a minor peninsula in Broadhaven Bay located on the western side of the mouth to Sruwaddacon Bay. The LVI comprises a minor compound located some 50m from the cliff face. The offshore pipeline is proposed to come ashore on the west side of the site with the cliff line re-constructed in fill.

11.2 The geotechnical assessment included:

(1) Mapping of cliff face and foreshore area to assess likely failure modes of cliff based on observed failure/erosion of cliff face,

(2) Estimate of likely regression of cliff face and a geotechnical analysis of cliff face with simulated loading and determination of FoS,

(3) Stability assessment of cliff with respect to possible adverse temporary loading/vibrations from winch/deadman anchor during proposed pipe laying works,

(4) Demonstration that the LVI is located at a safe distance from the influence zone of cliff regression and that temporary works will not result in destabilisation of the cliff.

11.3 I wish to bring to the Board's attention the summary of the findings of geotechnical assessment as follows:

(1) The cliff was typically 3 to 4m high and was formed mostly of glacial soil with some colluvium and bedrock exposed at several locations along the base of the cliff.

(2) The foreshore (beach) immediately fronting the cliff comprised gravel and rounded cobbles, which likely represented a beach berm that tides would rarely completely cover. The width of the beach berm was about 8 to 10m. Several factors indicate that storm wave action seldom reached the cliff, namely:

(a) Occurrence of vegetation at the base of the cliff line, particularly the north facing cliff.

(b) The base of the cliffs showed no marked wave under-cutting and given the relatively erodible nature of the cliff any wave action would be pronounced.

(c) Highest line of seaweed/flotsam was noted some distance from the base of the cliff.

(3) Visual inspection of the cliff showed that the cliff was slowly retreating inland as a result of repeated minor failure and erosion from the face. Evidence of retreat of the cliff was as follows:

(a) Localised slumps that comprised failure volumes of about 4 to 8m^3

(b) Recently placed temporary fill slope within the cliff that eroded by an estimated 1m to perhaps 2m within 18 months. However this was always planned as a temporary slope

(c) Accumulation of failed material from the cliff as a result of minor discrete failure of stones from the face and general erosion from the face

(d) Lack of vegetation on cliff face, particularly on the west facing cliff, that indicated some active cliff erosion

(4) Based on field observation, the estimated regression of the natural cliff, excluding the recently placed fill slope, over say a 5 year period is estimated at about 0 to 0.01 m per m run. Historical review indicates the rate of regression is up to about 0.03m per year over the last about 160 years. Locally greater rates of infrequent regression up to 2m would be expected due to localised minor slumping.

(5) The north facing part of the cliff appears to be regressing less as evidenced by the presence of established vegetation at the toe of the face and bird nesting sites. This section of cliff does not face open water so would not be as prone to wave action as the west facing part of the cliff.

(6) Stability analyses were carried out for the cliff to determine the FoS. The results showed that the existing local stability of the cliff is marginal, as

evidenced by localised slumping of the cliff face. The FoS for the LVI building is in excess of 3, which is acceptable.

(7) To ensure an adequate FoS for works near the cliff, then works should be set-back from cliff edge as follows:

(a) Temporary Works to be set-back 5m distance or greater from cliff edge, and

(b) Permanent Works, where there is an applied load, to be set-back 7m distance or greater from the cliff edge.

(8) Compliance with these set-back distances from the cliff edge will avoid undue disturbance of the cliff particularly where birds' nests are present.

11.4 I wish to bring to the Board's attention the conclusions reached in the report entitled 'Geotechnical Assessment Report for Site of Landfall Valve Installation (LVI)' are;

(1) Given the low rate of cliff regression, the distance of the LVI building from the cliff and the proposed set-back distances for the works it is considered that there is no risk to the LVI and proposed works due to cliff regression for the design life of the project.

(2) Stability of the existing cliff with respect to the location of the LVI and proposed works has been examined. The LVI and proposed works have an acceptable level of stability. Set-back distances for proposed temporary works near the cliff edge are recommended to ensure no adverse loading of the cliff.

12 Commentary on the Landslides at Pollathomish in September, 2003

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12.1 Commentary is provided in Appendix M2 of the EIS.

12.2 The Geological Survey of Ireland (GSI 2006), Irish Landslides Working Group report a number of peat failure events within Mayo, some of which are historical events. There are some 120 landslide events recorded in the GSI database for Ireland to date with 12 of these events occurring in County Mayo. This is publicly available information.

12.3 On 19 September 2003 a cluster of 40 separate shallow landslides, (recorded as one event in the GSI 2006 report) including significant peat failures, occurred on Dooncarton Mountain (Pollathomish) during an exceptional rainfall event. The trigger for landslides was the exceptional rainfall (in excess of 100 year return period) in combination with steep topography (generally greater than 20 degrees and up to 40 degrees) and local soil characteristics.

12.4 The prevailing topographic and soil characteristics on Dooncarton Mountain are notably different from the conditions that exist along the pipeline route. A notable pre-condition to failure on Dooncarton Mountain was the combination of steep slopes (generally greater than 20 degrees and up to 40 degrees) and thin peat cover. In contrast to Dooncarton Mountain, the slope inclinations within the peat areas along the proposed pipeline route are gentle with inclinations not exceeding about 5 degrees and with peat cover generally exceeding 2m.

12.5 An assessment of an unlikely debris flow from Dooncarton Mountain reaching the pipeline has been assessed empirically by RPS (See Appendix M1 EIS ‘Report on Geotechnical Assessment of Non-Peat Areas’). The effect of an unlikely debris flow failure from Dooncarton Mountain on reaching the pipeline has been assessed for three different heights of debris failure; 1m, 2m and 3m. The analysis demonstrates that the movement determined at the locations of the buried pipe will not jeopardise the integrity of the pipeline (See Appendix M1 EIS ‘Report on Geotechnical Assessment of Non-Peat Areas’).

12.6 Report of the Dooncarton Mountain failure shows that no debris material, other than debris washed down drainage channels reached the area where the proposed pipeline is to be constructed.

12.7 Since the failures in 2003, the local authorities have carries out stabilisation works on Dooncarton Mountain. This included reinstating the berm between the commonage and the privately owned properties, improving drainage systems and repairing and installing landslide barriers. These measures will further reduce the prospect of a landslide reaching Glengad headland.

12.8 The effect of an unlikely debris flow failure from Dooncarton Mountain on reaching the pipeline has been assessed for three different heights of debris failure; 1m, 2m and 3m. The analysis demonstrates that the movement determined at the locations of the buried pipe will not jeopardise the integrity of the pipeline (See Appendix M1 EIS 'Report on Geotechnical Assessment of Non-Peat Areas').

13 Commentary on the Peat Landslip on L-1202 Road, Aughoose, Erris, May 2008

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13.1 Commentary is provided in Appendix M2 of the EIS.

13.2 In comparison to the events at Dooncarton in September 2003, the peat landslip on L-1202 road, Aughoose, Erris in May 2008 was relatively minor in nature. The incident was located adjacent to a minor public road (L-1202), approximately 1.25km from the junction with the R314 in Aughoose. The incident occurred during widening works for the road by Mayo County Council on 8 May 2008.

13.3 The L-1202 incident comprised movement of peat over a length of about 40m along the north side of the road. The movement appeared to extend some 15 to 20m distance away from the road and affected an area possibly up to 800m^2 with peat depth estimated at 2 to 3m. Total affected volume was estimated at up to 2400m^3.

13.4 The upper section (about 1m thick) of the failure appeared to be fibrous and was underlain by more amorphous peat. The incident area was vegetated by coarse grass, reeds with occasional bushes, trees and tree stumps with forestry some 30 to 50m from the edge of the road. The lateral extent of the landslip was possibly controlled by the presence of drainage ditches that run perpendicular to the road.

13.5 It is noteworthy that the existing road is a floating road and appeared to be essentially undamaged by the incident.

13.6 The reasons for the incident are not known in detail but based on descriptions of the event and a cursory inspection of the site the possible cause of the landslip was bearing failure of the in situ peat due to excessive loading. The loading was likely as a result of placement of excavated peat and quarry stone placed during the road widening. This loading likely caused a bearing failure within the in situ peat that would have initially failed as rotational movement resulting in heave followed by limited translational movement.

13.7 The inadvertent loading of weak peat has been identified in a number of peat failures. For the construction of the pipeline it is proposed to limit placing of load onto the peat surface by the construction of a stone road through the peat areas and consequently the risk of peat failure to construction is minimal.

13.8 Stone road construction within peat areas is a recognised construction method for access in particularly deep peat areas and has been used for example on the Mayo-Galway gas pipeline. The constructed stone road provides a stable platform for subsequent construction work, so reducing construction impact on the surrounding peat, and provides secure ground in which to install the pipeline.

14 Geotechnical Supervision and Monitoring as part of the Integrated Construction Program and Geotechnical Monitoring during Operation

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14.1 The following general guidelines based on the successful and safe construction within the Terminal footprint and other relevant projects are given for construction practices in order to reduce the likelihood of peat instability (for details refer to Geotechnical Risk Register Appendix M4).

14.2 Construction practices and management of the works should take into general consideration, but not be limited to the following;

(1) Avoidance of placing arisings from excavations and local concentrated loads on peat slope other than engineered deposition,

(2) Avoidance of uncontrolled concentrated water flow. All water discharged from excavations during work shall be directed into suitably designed drainage lines or natural drains,

(3) Avoidance of unstable excavations where inspection has noted a risk of collapse. All excavation shall be suitably controlled or supported as appropriate to prevent collapse and development of tension cracks,

(4) Avoidance of placing fill and excavations in the vicinity of steeper peat slopes,

(5) Areas of machine saw cut peat (also referred to as 'ploughed' or 'cut by sausage machine') should be inspected by suitable experienced

personnel prior to works commencing in these areas (noted in Rossport Commonage),

(6) Geotechnical supervision during works by suitably qualified and experienced personnel. Supervision shall be on a full-time basis for the duration of the construction works,

(7) As construction progresses, on-going assessment of ground conditions will be carried out to confirm the findings with respect to stability contained within the Peat Stability Assessment report (See Appendix M2 of EIS). The results of on-going ground investigation will be assessed by suitably qualified geotechnical personnel,

(8) Installation and monitoring of geotechnical instrumentation, as appropriate, in areas of possible poor ground, as indicated from stability assessment for example by collapsed v-ditches, continued and accelerated settlement of floating roads, sidewall instability at shallow inclinations of excavations, wet ground areas, machine saw cut areas. Monitoring works will include periodic monitoring of piezometers where installed,

(9) A formalised reporting procedure will be adopted on site that records site workings, monitoring results and any observations that may be pertinent to the stability of the works,

(10) Contingency plan to detail level of response to observed poor ground conditions,

(11) Routine inspection of stone road site by maintenance personnel to include an assessment of ground stability conditions,

(12) Periodic inspection of the route following completion of works by suitably experienced and qualified geotechnical personnel,

(13) GPS devices, in the stone road and in the peat fields adjacent to the pipeline in the stone road, will be located along the onshore pipeline route and provide measurements to confirm stability throughout the life of the onshore pipeline (See Brief of Evidence Dr. John Purvis).

(14) A Geotechnical Risk Register has been compiled and will be maintained for the duration of construction program.

15 Third Party Submissions in Respect of the Proposal

15.1 A number of Third Party Submissions in respect of this application have been received and refer to '*concerns regarding the running of this high pressure gas pipeline close to houses through bog and through an area with a history of landslides*' and '*through 9 km of what is effectively floating bog'*. These concerns are addressed within the EIS documents namely EIS Volume 2 of 3, Book 4 of 5, Appendix M1-B and EIS Volume 2 of 3, Book 5 of 5 Appendices M2 to M6.

15.2 One submission refers to '*the construction methodology for the BGE gas pipeline changed from the use of temporary floating roads or bog mats, to the excavation and installation of stone haul roads/working areas along the length of the pipeline, similar to what is recommended for this project. The use of the amended methodology changed significantly the nature, severity and duration of the ecological and environmental effects of that project, and the same effect could happen here*'. Our response is as follows;

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(1) There are three areas where the proposed Corrib Onshore Gas pipeline crosses over peat land and where stone road construction is proposed in Rossport (Commonage) some 2,640m in length, South of Sruwaddacon Bay to L-1202 some 1,500m in length and L-1202 to Terminal Site some 1,560m in length. The total length of pipeline proposed in peat land is 5,700m.

(2) The methodology proposed to construct the pipeline in peat areas is significantly different than noted in the submission.

(3) The proposed construction will limit the stockpiling of peat turves to no greater than 1.0m high on the upslope side of the stone road. Reinstatement of turves is expected to be completed within three working months.

(4) The proposed pipeline will be installed within the stone road and the area immediately downslope of the stone road will not be affected by stone road construction.

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(5) Over Rossport Commonage the route passes through an area of generally open peat land which comprised very gentle slopes with inclinations from 0 to 3 degrees increasing to about 4.5 degrees as the route approaches the shoreline in the south, where there are extensive peat cuttings.

(6) The replacement of peat turves will be undertaken to ensure that the area of the stone road is covered first by a peat catotelm regulating layer prior to placing the final peat turve. The proposed juxta-positioning of peat turves in a patchwork array will ensure that there will be limited edge continuity of individual peat turves so as to avoid preferential pathways for surface drainage which could cause ongoing erosion. Any gaps and voids will be filled with hand placed peat sods.

(7) The finished surface of the reinstated stone road area will not be proud of the adjacent ground levels.

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(8) Turves will be only left proud (nominally ~100mm) at the areas of the plugs to ensure pre-existing natural transverse drainage continues and that longitudinal drainage is avoided.

(9) Details of the proposed finished works are annotated on **Additional** AGEC Drawings Nos: 864_02_004 to 007.

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(10) The peat within the SAC is generally not recorded as 'very deep soft, wet, peat' but and at one location (ch. 88,100) the depth of peat is circa 5m. However, this depth is not representative as generally through the commonage and within the SAC peat cover varies from about 1m to about 5m. Moisture contents have been recorded from 83% to 91% for the Commonage and are comparable to moisture contents recorded for the peat extracted from the Terminal site. There are extensive areas of cuttings where the peat has been completely removed to expose the mineral soil together with areas of machine cut peat (Please refer to EIS Volume 2 of 3, Book 5 of 5, Appendix M2 Geomorphological Plan 2/3 Ch 86,400 to Ch 89,554). Of the 800m length of pipeline through the SAC, some 100m length of pipeline has been recorded as passing through peat with depths between 4.0m and 5.4m. The remaining

length of pipeline through the SAC is within peat generally less than 3m in depth. Peat shear strengths throughout the SAC are generally 5kPa or greater.

(11) The proposed stone road material will be acquired from local quarries and will be siliceous psammitic quartzite, i.e. no carbonate rock will be imported. The pH of the rock material will be commensurate with the peat chemistry and the permeability of the proposed stone road will be in the region of 10^{-6} m/s, i.e. low permeability, which is due to the fines content.

(12) The 'proposed permanently embedded road and pipeline structures' will include a basal peat layer (0.5m) where required to impede vertical drainage, low permeability plugs at a maximum of 50m centres for the full height of the stone road to impede longitudinal drainage and raised peat turves at intervals over the re-instated road to impede surface runoff and promote appropriate wetting of replaced turves. Where required the plugs and raised turves can be installed at closer spacing in areas where bog pools or natural drainage paths are mapped.

(13) The potential for collapse of peat faces during construction has been addressed in the Geotechnical Risk Register within the EIS (Volume 2 of, Book 5 of 5, Appendix M4). Confirmatory probing of peat as part of the construction program and continual geotechnical monitoring during the construction of the stone road will ensure that collapse of peat side faces does not occur. The construction of the stone road has been described in detail in the EIS report entitled 'Geotechnical Assessment of Stone Road Construction in Peat Areas' (EIS Volume 2 of 3, Book 5 of 5, Appendix M3). The proposed construction methods in the peat areas are Type 1 and Type 2.

(14) Type 1 construction method is the excavation of the peat. This is the preferred construction method in most cases as it greatly reduces the risk of failure due to placement of load, and also eliminates subsequent settlement and maintenance. This construction method provides a dependable working platform and can be relatively costly where deep peat is to be excavated. The proposed stone road construction is Type 1 where peat is essentially shallow. However, in areas of deeper/weaker peat where it is not practical to excavate all peat to depth then peat displacement method (Type 2) will be deployed.

(15) Type 2 construction method is a displacement method and is proposed for the stone road in combination with Type 1 in deeper peat. This method requires peat to be displaced by placement of sufficient load. Whilst used in several countries the effect of controlling the local peat displacement in the peat can be difficult. This method will ensure that the sides of the peat are never left unsupported and it prevents any potential collapse.

(16) It is noteworthy that open excavation in peat will be determined by the depth and undrained shear strength of the peat to ensure that sidewall collapse does not occur. Therefore in areas of weaker and/or deeper peat, the displacement method will be deployed such that an open excavation in these areas is limited.

(17) Peat instability and high moisture content has been addressed in the Geotechnical Risk Register within the EIS (Volume 2 of, Book 5 of 5, Appendix M4).

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(18) The risk rating attached to a 'trench slope failure' is reduced by the application of Risk Control Measures, both Design and Construction to render the Risk Rating to a level of "Early Attention" and in most cases to a lower level of "At least regular attention". Sidewall collapse in the excavation of trial pits in previous site investigations, namely 2002 and 2004, was recorded due to low strength peat. However it is noteworthy that where sidewall collapse and 'running saturated silts' have been recorded on site investigation logs for trial pits, a stone road has been safely constructed and this demonstrates that where a geotechnical hazard is recognised as a high risk, the application of design and control measures can ensure successful and safe construction.

(19) The report by the Geological Survey of Ireland (GSI) entitled 'Landslides in Ireland' specifically refers to peat depths of 0.5m and slopes of greater than 15 degrees in the Pollathomish area. The GSI report refers to the vulnerability of slopes 'under extreme environmental conditions'. This is reflected in the multiple landslides that occurred at Pollathomish in September 2003 where 40 failures occurred with less than half of these failures recorded as peat failures. The failures were attributed to an extreme rainfall event.

(20) The criteria that have been used in the qualitative geotechnical assessment within the Peat Stability Assessment Report (EIS Volume 2 of 3, Book 5 of 5 Appendix M2) are numerous compared to the two criteria quoted by the GSI report.

(21) The criteria used in the AGEC geotechnical qualitative assessment include for example;

- the **peat characteristics** such as strength, depth, degree of saturation and degree of humification
- the **drainage characteristics** such as man-made ditches, blocked ditches, springs, sinks and marshy ground
- the **underlying geology** including the mineral soil and the bedrock
- the **surface morphology characteristics** such as inclination, convex/concave slope, shallow valley, infilled valley, rock exposures and sharp break in slopes
- the **land use** including peat cuttings (old/new/water filled/drained/backfilled), agricultural and reclaimed
- and any **signs of distress** such as landslip scars, tension cracks, disturbed ground and closed-in drains.

(22) Hence, using the above criteria, the qualitative geotechnical assessment undertaken by way of an engineering geomorphological walkover survey for the proposed pipeline facilitates a detailed understanding of the potential for peat failures/slides. The walkover survey of the pipeline route, carried out to identify salient ground conditions and in particular evidence of peat instability, identified **no evidence of peat failure** that would pose a risk to the pipeline route. Results of the quantitative geotechnical assessment, i.e. the stability analysis, showed that the natural peat slopes along the proposed pipeline route have an **acceptable FoS**. The high calculated FoS for the route corresponds to the findings of the walkover survey of the route which identified no evidence of peat failure. Several localised areas of weaker peat were identified along the route. These areas are **not** considered to represent a significant risk to the pipeline construction, particularly when taking into account the use of a stone road construction method in the peat. Taking into account the **findings of the walkover survey**, the **results of the stability assessment** and the proposed

stone road construction method it is considered that the pipeline can be **safely constructed** along the proposed pipeline route.