EirGrid Evidence Based Environmental Studies Study 7: Soils & Geology

Literature review and evidence based field study on the effects of high voltage transmission development on soils and geology

May 2016

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SUMMARY

Soils and geology are important natural resources. The building of any infrastructure can impact on the local soils and geology. This report looks at the impacts of electricity transmission infrastructure on soils and geology.

This is an independent, evidence-based study carried out by experts in EIA. The study examines the actual effects of high voltage transmission projects on soils and geology at a number of sites.

Purpose of this study:

- To conduct a literature review on the impacts of high voltage transmission projects on soil and geology;
- To complete a case study of site assessments on a number of transmission line projects and evaluate impacts and mitigation at pre, during, and post-construction stage;
- To provide a factual basis for the development of best practice recommendations and guidelines for electricity transmission projects.

The routing of transmission projects is a complicated process. A balance is needed between a number of issues, including our obligations to make sure we have a safe and secure transmission grid, land use constraints, cost, engineering and other technical requirements. We must also consider the impacts on the natural environment. Transmission projects have the potential to impact on soils and geology due to the variety of ground conditions that may be crossed and the excavations involved. This must be considered when planning transmission development routes. We refer to this as route planning.

This study includes a literature review that looks at common impacts from linear type developments such as pipelines, roads and overhead lines. The review found that impacts to soils and geology are most likely to occur during the construction period.

The main negative impact from construction on soils/geology is soil movement. This can result in sedimentation and siltation and often ends up in watercourses.

Other possible impacts may be contamination of soils or geological features by cement or fuel/oil spills during construction. Soil compaction and ground disruption are temporary impacts.

This study includes a field survey. Five categories of sites were visited that covered standard, non-standard and worst case conditions. This meant a range of soil types were assessed. For example, the worst case site was chosen in upland, peat area with steep slopes.

Site visits were made in 2011/2012; before, during and after construction.

Assessments on site were made using approved geomorphological mapping techniques with follow- up surveys. A check sheet was made for the project. This helped record all the important information in terms of soil release. Using this method any impacts on the sites were recorded and compared.

The results showed that minor, localised impacts during construction were evident on some of the sites.

In all of the cases where soil release was found, silt traps were in place. However it should be noted that bad weather was also evident which can increase the amount of soil being released.

No cases of soil release were found at the post-construction stage.

It was found that the construction phase is the time when impacts on soil and geology are most likely. However, with adequate mitigation measures in place, no long term impacts should occur.

In the site visits, cases of soil release were found up to 20 metres (m) from the source. Therefore it is recommended to aim for a 50m buffer between a structure and a watercourse.

If a natural buffer is unsuitable, or a route cannot avoid an area with soft/fine soils, measures during construction such as silt curtains are recommended. It is also recommended to monitor on-site mitigation such as silt curtains/traps, especially during bad weather. This should help alert staff to any failing mitigation or to new situations that will need managing such as site flooding.

Monitoring of site aftercare practices is also recommended. For example, if sites after construction are not managed to fully revegetate as part of reinstatement, there is the risk of long-term soil release. This is particularly true in peaty areas, as was found in the site visits.

No significant impacts on soils or geology from transmission projects were found during site visits. This is probably because line routes are already carefully planned to avoid sensitive areas.

It is recommended that route planning also avoids areas with soft/fine soils because these are weaker and harder to construct on. They also tend to have a higher risk of soil release.

Effective route planning can positively deliver for the environment by avoiding the more sensitive and weaker areas of ground. This also delivers on a technical capacity.

This study provides a factual basis for the development of evidence-based ecology guidelines, including soils, for transmission projects in Ireland. The purpose of the guidelines is to ensure a consistent approach to EIA topics at all stages of the development of transmission projects.

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1 INTRODUCTION

1.1 THE SCOPE OF THIS PROJECT

In April 2012, EirGrid published the *Grid25 Implementation Programme 2011-2016*, and its associated Strategic Environmental Assessment (SEA).

The SEA identified a number of Environmental Mitigation Measures envisaged to prevent, reduce and, as fully as possible, offset any significant adverse impacts on the environment of implementing the Implementation Programme (IP).

Environmental Mitigation Measure (EMM) 3 concerns *Preparation of Evidence-Based Environmental Guidelines*. These are intended to comprise a series of authoritative studies examining the actual effects of the construction and existence of transmission infrastructure in Ireland. The studies would thereby provide benchmarks to facilitate the robust preparation of projects with an evidence-based understanding of likely environmental impact.

Three types of studies are envisaged under EMM3:

- **Environmental Benchmarking Studies**: to determine the actual effect, in respect of a number of environmental topics, of the construction and existence of transmission projects in a representative range of Irish environmental conditions – typical, non-standard, and worst-case. The studies, while authoritative, are conceived as an ongoing body of work that can be continuously updated to take account of new information and/or developments in understanding arising from practice and research;

- **Evidence-based Environmental Design Guidelines:** deriving from the factual basis and evidence contained in the initial Benchmarking Studies, these will provide practical guidance to practitioners and consultants in the planning and design of transmission infrastructure from the perspective of a particular environmental topic. These might comprise new guidelines, or the updating of existing guidelines;

- **Guidelines on EIA for Transmission Projects in Ireland:** Accompanying, or incorporated into the Design Guidelines, these are intended to provide an agreed and authoritative format for the preparation of EIA for transmission projects in Ireland, again in respect of particular environmental topics.

This study is one of the Environmental Benchmarking Studies – to determine the actual effect of the construction and existence of transmission infrastructure in Ireland on its receiving environment.

1.2 THE AIMS OF THIS STUDY

The overall aim of this Evidence-Based Environmental Study has been to determine the impacts, if any, of high voltage transmission projects on soils and geology.

To do this, available literature on transmission projects and other linear type developments has been investigated. Sources of information on soil release processes such as peat failure, landslides and erosion are provided. In doing so, an understanding of how varying soils act under different circumstances is provided.

In order to investigate the actual impacts and effects from transmission infrastructure, a case study was developed. The case study selected a number of transmission line project sites to visit and assess at a pre, during and post-construction phase. Using geomorphological mapping and sequential survey techniques, any visual impacts on soils and geology were assessed.

Mitigation used at the sites was also recorded and how effective these are at reducing potential impacts assessed.

The findings of this study will be used to further develop EirGrid's best practice Ecology Guidelines for transmission projects.

1.3 THE TRANSMISSION NETWORK, SOILS AND GEOLOGY

Electricity supply is an essential service in Ireland's economy. The transmission system is a meshed network of 400kV, 220 kV and 110 kV high voltage lines, cables and substations, and plays a vital role in the supply of electricity[1].

The development of the transmission network is the responsibility of EirGrid, the Transmission System Operator (TSO), under statutory instrument 445 (2000)[2]. EirGrid is committed to delivering quality connection, transmission and market services to its customers, and to developing the transmission grid infrastructure required to support the development of Ireland's economy.

Grid development requires a careful balance between meeting the technical requirement for a project, the costs of that project, and the environmental impact of that project.

[1] Transmission Development Plan 2008-2012 EirGrid
[2] Statutory Instrument 445 (2000), entitled European Communities (Internal Market in Electricity Regulations, 2000)

The Electricity Supply Board (ESB), as the Transmission Asset Owner (TAO), is charged with constructing the transmission assets as specified by the TSO. ESB also has the role of Distribution System Operator (DSO) with which the TSO coordinates planning and development requirements.

An overview of the primary types of transmission infrastructure, including an outline of construction methodology is set out in **Appendix F** of this study.

EirGrid is committed to its role as the TSO in Ireland and to ensuring that transmission development is undertaken in an environmentally sensitive manner. This includes protection of soils and geology.

The potential impact of transmission infrastructure development on soil and geology relate primarily to the movement of soil during the construction phase of projects. Excavations for structures moves soils but even the presence of machinery and workers on a site can trigger soil movements/release. This may occur in areas with weak ground conditions i.e. peatlands, or areas with finer soils and more prone to erosion. The impact is localised pollution of waterbodies.

Mitigation can be taken to avoid or reduce soil release from sites but depending on the soil and geology of an area, impacts such as erosion may continue, even after construction has completed. Typical measures include silt fences, sediment traps and ponds.

It is preferable to plan routes to avoid sensitive areas such as peatlands and areas of fine grained soils. Therefore careful route planning is recommended to avoid impacts from occurring in the first place. Monitoring is also recommended to check that mitigation is effective.

This report should be read in conjunction with the Water Quality & Aquatic Ecology EBS report as the two reports are linked in terms of impacts, effects and mitigation.

1.4 THE STUDY LAYOUT

The study begins with a literature review on the impact of high voltage transmission infrastructure on soils and geology (Section 2). Research from other linear type developments is also referred to.

Following this, an investigation of construction and operation techniques, and a review of mitigation and current best practice guidance for transmission projects are presented (Sections 3 & 4).

The latter half of the study provides details of site assessments carried out at a number of selected transmission line project sites during the various stages of development (Sections 5 & 6).

Results from the assessments are reviewed (Section 7). As a result of the case study, conclusions and recommendations are then also provided (Section 8).

2 LITERATURE REVIEW

2.1 OVERVIEW

A literature review was undertaken to examine published information in relation to soil release or soil movement resulting in siltation or sedimentation, particularly with reference to high voltage transmission projects.

The review highlighted that peer reviewed literature is extremely limited on the implications of high voltage transmission projects or any other linear type infrastructure, on soil release.

The following sources of information were referred to during the literature review process, and while some were used to identify areas sensitive soils, they are not considered part of the review itself, as they do not give information on soil release and siltation/sedimentation:

- Information on Quaternary Geology
  - Geological Survey of Ireland MapViewer (www.gsi.ie/mapping.htm)
  - Teagasc National Soils Database (erc.epa.ie/nsdb)
  - CORINE Land Cover Database (gis.epa.ie/envision)
- Information on Bedrock Geology
  - Geological Survey of Ireland MapViewer (www.gsi.ie/mapping.htm)

The literature however indicates that construction is the most critical period in terms of soil release, especially erosion, due to exposure of soils, and peat instability where the peat may be at risk of overloading, failure and release.

To date, there is no legislation which is specific to the protection of soil resources. However, there is currently an EU Soil Thematic Strategy on the protection of soil which included a proposal for a Soil Framework Directive. This proposed Framework contains common principles for protecting soils across the EU (EirGrid, 2012) but was withdrawn in 2014. The EU Seventh Environment Action Programme recognises that soil degradation and erosion are important challenges. It refers to the need for soil protection and remediation of contaminated sites as one of its guiding principles for 2020.

There are various reference documents and best practice guidance which EirGrid refer to in relation to the construction of high voltage transmission lines, which outline current methods of protection of soils from failure or release and subsequent deposition in water bodies. These include CIRIA guidance (CIRIA, 2006 & CIRIA, 2010) relating to linear construction projects, and Inland Fisheries Ireland (IFI) guidance in relation to potential siltation from construction activities. There is some international best practice guidance for the construction of high voltage transmission lines, with reference to

“International Best Practices for Assessing and Reducing the Environmental Impacts of High-Voltage Transmission Lines” compiled by Williams (2003), and publications and papers from the International Council on Large Electric Systems (CIGRÉ). Reference should also be made to the following available information, which is further referred to in Section 4.0:

- GRID25 Implementation Programme (IP) 2011-2016 (EirGrid 2012)
- Environmental Report of the SEA accompanying the Grid25 Implementation Programme (EirGrid 2012)
- Environmental Appraisal Report of the Transmission Development Plan 2012-2022
- Ecology Guidelines for Electricity Transmission Projects: A Standard Approach to Ecological Impact Assessment of High Voltage Transmission Projects.

A negative impact of high voltage transmission projects on soils and geology which results in siltation and sedimentation is soil movement due to shear failure, erosion or wash-out of fines during construction and to a much lesser extent during operation and maintenance of projects. Where this occurs soil particles can be transported by gravity, wind or water into sensitive receptors. Water bodies are one of the main receptors that can be adversely affected by siltation and sedimentation from soil particles, negatively affecting water quality and aquatic ecology.

While the focus of this study is on the impacts on soils and geology due to soil release and siltation/sedimentation, other minor localised impacts can occur also, that may have an effect on the quaternary geology and in-situ soils. These include contamination of soil due to particular construction activities, visual impacts on in-situ soils due to the level of reinstatement carried out, and impacts to landowners/farmers particularly on cattle grazing and crop harvesting. Current construction practices are such however, that these issues are negligible and/or short-term impacts, and it is considered that they do not cause permanent detrimental effects on the affected areas, particularly in relation to the construction/maintenance of overhead power lines.

This study is intrinsically linked with the Water Quality & Aquatic Ecology Evidence-Based study. Reference is made in Section 7.0 to the results and findings of this study, particularly where there is overlap of selected sites between each study, to ascertain the quantitative degree of impact, if any, on water receptors.

The Joint Research Centre report (2012) identifies the link between soil release and the Water Framework Directive (WFD) and recommends that an effective soil protection policy, or Soils Framework Directive, cannot neglect the WFD.

2.2 SOIL RELEASE PROCESSES

2.2.1 Shear Failure

Shear failure occurs when the shear stresses between soil particles are such that they slide or roll past each other causing instability and movement of soil masses. At failure, the shear stresses along the failure plane reach the internal shear strength of the soil (Craig, 2004). This will usually occur when the soil is loaded too heavily resulting in bearing failure or is too steeply exposed in an excavation and the cohesion and friction between particles cannot keep the slope stable. Generally when a structure is to be constructed on a particular soil, the soil design parameters will be determined based on in-situ shear strength parameters under the correct test conditions which should mimic the conditions expected on site.

Weaker soft soils such as peat or soft silts are much more susceptible to failure and movement and would have a much lower shear strength than other firmer, stiffer soils and coarser material. Figure 2.1 illustrates the potential shear failure planes in soils. These are the planes of weakness through which the soil would fail through being overloaded.

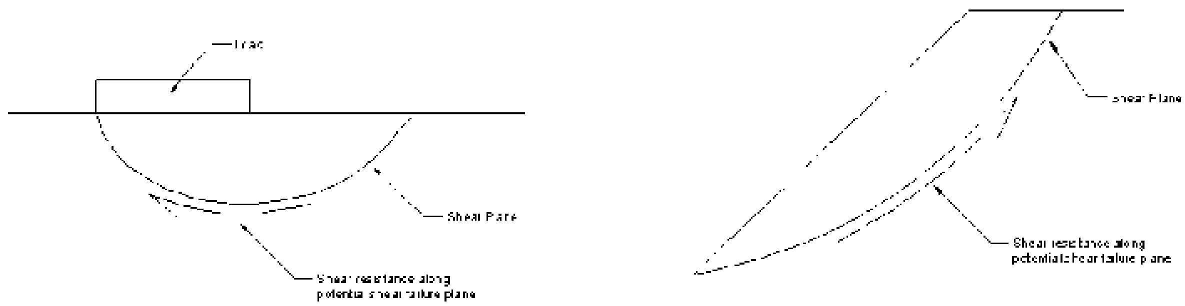


Figure 2.1 Soil Shear Failure – Potential Failure Planes

Floating roads are generally constructed for high voltage transmission projects to provide access to structure locations, however excavations for access roads may be required at times depending on site conditions. Foundations may be required to cater for the installation of structure bases or other ancillary structures. The Joint Research Centre report (2012), reports that changes in the shape of a slope, due to construction, can result in failure or landslides.

Creighton (2006) stated that typical “mineral” (i.e. non-organic) soils in Ireland are predominately glacially-derived and are generally a mixture of finer clay and silt and coarser sand and gravel with cobbles and boulders. Pure clay soils are rarely encountered in Ireland (Creighton 2006). Generally these glacial soils have high angles of shearing resistance, typically 30º to 35º and high undrained shear strength, making it possible to cut very steep slopes. This would correspond to a typical bearing capacity of up to about 250kN/m^2. However Creighton (2006) stated that in the case of a slope, this is the case only in the short term as they will eventually fail due to the dissipation of soil suction forces or internal erosion.

Current design standards, Eurocode 7 (2009), set out the requirements for soil testing, including classification and strength testing, both in-situ and laboratory. The codes also outline how to establish the characteristic parameters for soils based on available test data as well as establishing design values to be used in each appropriate design case. These codes contain national annexes which give further country specific guidance on testing and design, and where detailed design is being carried out it is this guidance that facilitates an appropriate geotechnical design in each specific country. These codes are referred to for any geotechnical design required for transmission related infrastructure.

Hughes *et al* (2007) indicated that shear failure of slopes can occur after construction, based on a case study of a slope in stiff overconsolidated lodgement till in Co. Down, Ireland due to strain softening, weathering, dissipation of negative excess pore water pressures and effects of prolonged periods of wet weather. This soil type would be typical of the glacial tills present across Ireland. Creighton (2006) indicated that water can also destabilise slopes where water seeps from an exposed face, as is the case where there is a sand layer in an exposed face of glacial till resulting in softening of the face and reduction in shear strengths of the soils in the face. Perry (1989) when studying the effects of climate change also acknowledged the implications of water on slopes. Perry (1989) stated in his study of UK geotechnical infrastructure that three times as many slopes are likely to fail if preventative measures are not taken into account for pore water effects, especially due to climate change.

Hughes *et al* (2007) identified that when designing slopes in glacial tills, the long term strength parameters should be taken into account. The literature also illustrates the need to take surface and ground water into account when designing slopes in glacial tills both from the point of view of design parameters and drainage.

Peat is naturally much weaker than mineral soils having undrained shear strengths as low as <5kPa. Where it has been attempted to test peat under drained conditions, angles of shearing resistance as low as 21^{o} (with cohesion in some cases), (Hebib 2001, and Warburton *et al* 2004) have been reported. In comparison to mineral soils these values are considered quite low, and in combination with peat's highly compressible nature and very high moisture content, are therefore much more likely to fail rapidly. The methods of failure between peats and other soils are similar however peat, as stated above, can fail much faster and also has pre-existing features which predispose it to more rapid failure.

MacCulloch (2006) tabulates failure mechanisms of peat based on a study by Warburton *et al* (2004) on slides in Ireland and the UK and include shear failure by loading, buoyancy effect, liquefaction, surface rupture and margin rupture.

Peat failures in particular, have become a topic of research in more recent times in light of peat slides that have occurred in Ireland, with a significant increase in infrastructural development within peatlands, especially upper peatland areas.

Dykes (2008) stated that peat mass movements are relatively common geomorphological phenomena in the uplands of Ireland and parts of northern Britain. There are 127 landslides recorded in the Geological Survey of Ireland (GSI) national database of landslides (Creighton 2006). Over 60 of these have peat as the principle material type. The majority of these are from historically published sources, with several more recent events which have been recorded. A pilot study carried out by GSI in the Breifne uplands in the north west of Ireland in 2005 recorded over 700 historic events over a "county size" area, pointing to the fact that nationwide there are probably many thousands of unrecorded events. This study also identified that 230 were attributed to peat slides (Creighton, 2006). This would still appear to fall far short of the true number of landslide events which have occurred in Ireland, as the British Geological Survey landslide database holds over 10,000 events for Britain alone. Over 630,000 landslides are currently held in national databases in Europe, although there is no data on the total area affected by landslides in Europe (Joint Research Centre, 2012).

The GSI database (Creighton 2006) displays an increase in the number of events occurring in the 20th century. This may reflect better record keeping and reporting, but may also indicate an increase in the frequency of landslide events in response to climatic changes (increased magnitude and frequency rainfall events) as well as development encroaching further into peatlands.

A number of failures have been noted on slope angles greater than 20^{o}, however these may be associated more with soil rather than within thin peat cover. Peat typically forms on slopes up to 20-25^{o} but localised thin deposits may be found on slopes as steep as 32-37^{o}.

The Scottish Executive (2006) has reported that the great majority of failures in Scotland, Wales and England are peat slides and tend to occur in shallow peat (less than 1.0m depth) on steeper slopes between 5^{o}-15^{o}, and bog bursts tend to occur in deeper peat (more than1.5m) on shallow slopes between 2^{o}-10^{o} where deeper peat deposits are more likely to be encountered. Reports of bog burst failures are generally restricted to Ireland and Northern Ireland. Based on a literature review Warburton et al, (2004) states that slides in the north Pennines occurred on slope angles between 4^{o}-24^{o}. Analysis of this data would suggest that the modal and mean slope angle for failure are very close, being 9^{o} and 10^{o} respectively. Evidence of landslides occurring in bedrock indicates that they tend to occur on slopes steeper than the modal slope angle (the angle that occurs most often on a slope) (Clarke and Burbank, 2010). While this is not an indication of the behaviour of landslides in peat and sensitive soils, it is interesting to note that the mean slope angle is greater than the modal angle in this case, which supports this theory. It must also be noted that the majority of these failures occurred either at the peat substrate interface or within the sub-soil clay with only one failing within the peat mass.

An analysis of the Bréifne peat failures and data presented by Jennings (2005) would suggest the majority of failures occur between 3^{o} and 12^{o}. Boylan *et al* (2008) has reported that the vast majority of failures in Ireland occurred between 4^{o} and 8^{o}. At steeper inclinations peat would not develop to a great thickness; and at lower inclinations whilst peat thickness may be greater, the destabilising down slope forces are not sufficient to initiate failure (Jennings, 2005).

Table 2.1 illustrates the various predictors of peat failures and their probability of contributing to peat movement (adapted from MacCulloch 2006).

Table 2.1 Contributory Factors to Peat Failure (adapted from MacCulloch, 2006)

Contributory Factor	Method of Assessment	Value/Indicator	Probability of Contributing to Peat Movement	Control Measure Required
Moisture Content	Experience or if available laboratory results	0-500%	Negligible	No
		500-1000%	Unlikely	No
		1000-1500%	Probable	Yes
		1500-2000%	Likely	Yes
		2000-2500%	Very Likely	Yes
Peat Depth	Measured using peat probes, ground radar, Trial Pits	0- 0.5 metres	Negligible	No
		0.5 – 1.0 metres	Unlikely	No
		1.0 – 1.5 metres	Probable	Yes
		1.5 – 2.0 metres	Likely	Yes
		2.0+ metres	Very Likely	Yes
Slope Angle	Indicative from probing, or ground radar, measure when peat excavated.	0-3 degrees	Negligible	No
		4-9 degrees	Unlikely	Yes
		10-15 degrees	Probable	Yes
		16-20 degrees	Likely	Yes
		20+ degrees	Very Likely	Yes
Cracking (tension and compression)	Visual. Very subjective, also linked to depth of cracks. It also unlikely that cracking would exceed 20% of road corridor length	No Evidence	Negligible	No
		0-5% Road Length or Other works	Unlikely	No
		5-10% Road Length or Other works	Probable	Yes
		10-15% Road Lengths or Other works	Likely	Yes
		15-20% Road Lengths or Other works	Very Likely	Yes
Underground Hydrology (Pipes/Channels)	Visual. Very difficult to evaluate, but evidence may exist in the form of exit/entrances to underground channels Collapsed ceilings of pipes may be evident	None Evident	Negligible	No
		Few	Unlikely	No
		Frequent	Probable	Yes
		Many	Likely	Yes
		Continuous/Significant	Very Likely	Yes
Surface Hydrology (Gully Channels, Hags and pool systems, wet flushes, water courses)	Visual. Interpretation may be necessary due to weather conditions at time of survey	None Evident	Negligible	No
		Few	Unlikely	No
		Frequent	Probable	Yes
		Many	Likely	Yes
		Continuous/Significant	Very Likely	Yes
Evidence of Previous Slips	Visual survey. No evidence would be no slips. Significant many small or one large slip.	None Evident	Negligible	No
		Few	Unlikely	No
		Frequent	Probable	Yes
		Many	Likely	Yes
		Continuous/Significant	Very Likely	Yes
Weather	This can be evaluated from weather records for the area. Research from Ireland has shown that most slides occur during a period of high rainfall following a dry period.	Previous Very Dry Period in excess of 5yrs	Negligible	No
		Previous Very Dry Period within 4-5yrs	Unlikely	No
		Previous Very Dry Period within 3-4yrs	Probable	Yes
		Previous Very Dry Period within 2-3yrs	Likely	Yes
		Previous Very Dry Period within 1-2yrs	Very Likely	Yes

There are many natural features which predispose peat to rapid shear failure, including the presence of relic failures, cracking or slumping, topography, altitude, slope, subsurface drainage or other detrimental drainage regimes, or the presence of weaker shear planes in a soil body. These natural features present in peat indicate the sensitive nature of peat in relation to shear failure and movement.

Anthropogenic effects such as loading, unfavourable drainage regimes, changes in land use, excavations undermining the peat mass or rapid ground accelerations can trigger non-natural peat slides.

Table 2.2 below shows a selection of peat failure events that have occurred in Ireland, including the impact they caused on their surrounding environment.

Table 2.2 Selected Peat Failure Events

Landslide Event	Location	Date	Impact
Derrybrien Failure	Derrybrien, Gort, Co. Galway.	16th October 2003	Multiple failures occurred due to construction activities at a wind farm development. Fish stocks and landscape devastated. **450,000m^3** of peat moved.
Pollatomish Failure	Dooncarton Mountain, Pollatomish, Co. Mayo.	19th September 2003	Considerable damage to roads, bridges and property during intense rainfall. Caused the evacuation of over 40 families from their homes. Damage was estimated at €10m.
Seven Bog Slides	Slieveanorra Mountain, Cushendall, Co. Antrim.	1st August 1980	1.6km long flow, up to 137m wide and 12m deep after torrential rain. Some property damage.
Knocknageeha Failure	Knocknageeha Bog, Rathmore, Co. Kerry.	28th December 1896	Considerable damage to property and some loss of life Movement of debris up to 22km.

A study of some more recent peat slides (Boylan 2008, Lindsay and Bragg 2004, Jennings 2005) indicated that loading of the peat and infiltration of water through surface cracks into the underlying peat initiated failures. In some cases the loading occurred in areas which were already weakened by forestry or cutting of the top stronger vegetated peat layer, which generally would have the most strength from the connectivity of the organic fibres. Some natural failures have occurred during or after heavy rainfall periods where water has infiltrated into the lower peat layers. The most notorious natural failure in Ireland was the Pollatomish Failure on Dooncarton Mountain in Co. Mayo in 2003. This was on steep slopes between 11 and 28^o.

Water accounts for >90% of the peat mass and the rapidity of peat land sliding and the mobility of debris is increased by the presence of water (DOE, 1996). During transport rapid remoulding of the peat may result in liquefaction of the peat mass within which solid rafts of peat may be contained making it more likely for peat to travel a greater distance before coming to a halt.

When peat stays relatively intact as a raft or in blocks as in the case of slides they are relatively limited in the distance that they travel. However, following the initial failure peat breaks down rapidly into slurry which can behave as a viscous fluid. In this state the peat may travel many kilometres from the failure source. Debris from the Knocknageeha Failure of 1896 in Co. Kerry, was recorded 22km from the failure source. The Slieveanorra Failure in Co. Antrim created a flow 1.6km long by 137m wide with a maximum depth of 12m (Hobbs, 1986). In the case of the Derrybrien Failure in Co. Galway it was found up to 23km from the source (Lindsay & Bragg, 2004). Very often this is due to the peat debris becoming confined within a drainage channel where it is mixed and diluted by any water that may be present which further increases its mobility (Boylan *et al*, 2008).

However the distance to which a peat failure may run depends on a large number of factors such as available water, proximity to drainage lines, slope gradient and length, peat thickness and failure volume. Little has been studied with regard to peat failure distances, however Boylan *et al* (2008) has presented the following relationship between peat volume versus run-out distance in Figure 2.2. This is not a definitive assessment but may provide an indicative trend.

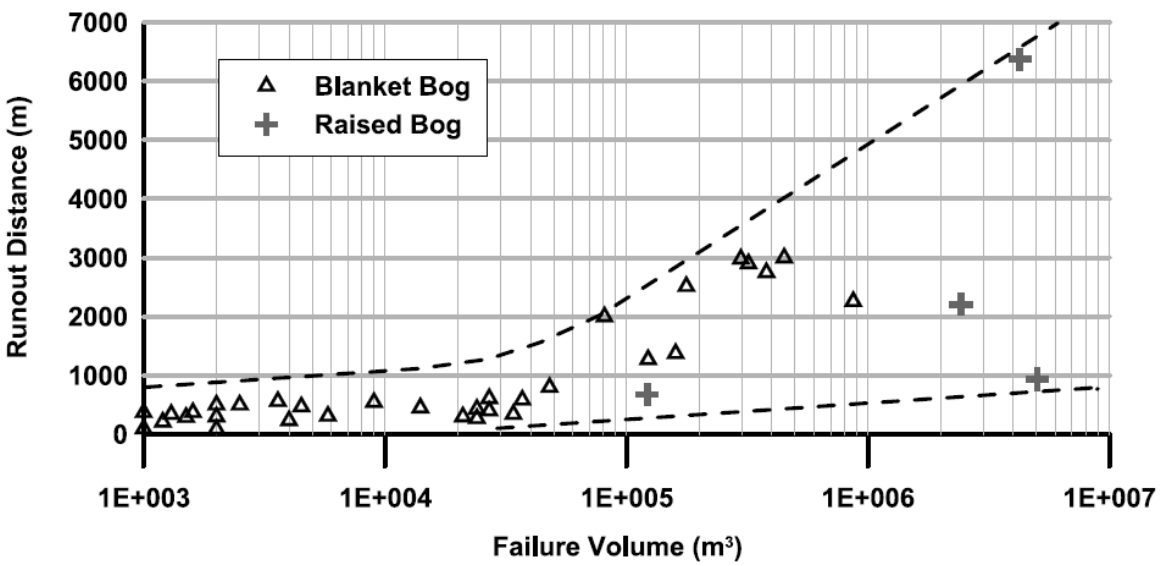


Figure 2.2 Relationship between peat run-out distance vs. failure volume for landslide events. (Boylan et al, 2008)

2.2.2 Erosion

Erosion is the wearing away of the land surface by water and wind primarily due to inappropriate land management, deforestation, overgrazing, forest lines and construction activities (Joint Research Centre, 2012). Figure 2.3 illustrates the general large scale soil erodibility potential across Europe and illustrates that Ireland falls in the middle of the rates illustrated in the map.

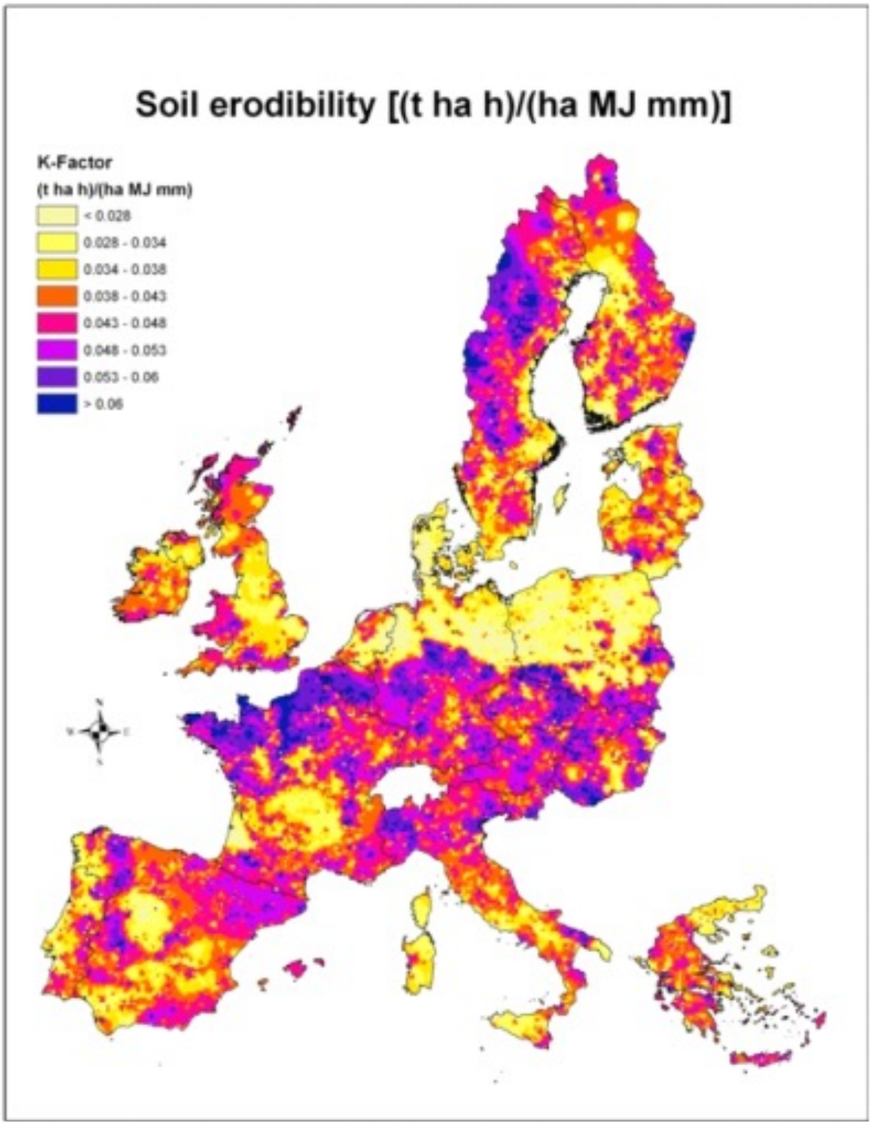


Figure 2.3 Soil Erodibility Across Europe (after Joint Research Centre, 2012)

Erosion is a two-phase process consisting of the detachment of individual soil particles from the soil mass and their transport by erosive agents such as running water and wind (Morgan 2005), along erosion paths that can be of a concentrated width or of a more significant width. When sufficient energy is no longer available to transport the particles, a third phase, deposition occurs. The severity of erosion depends upon the quantity of material supplied by detachment over time and the capacity of the eroding agents to transport it (Morgan 2005). High voltage transmission projects would generally expose the soils during construction and for a period after, prior to re-vegetation, and it is this area only that would be exposed to accelerated erosion.

The main factors influencing erosion are rainfall, erodibility of soil, slope and plant cover (Morgan 2005). Erosion rates are very sensitive to climate, land use, soil texture, slope, vegetation cover and rainfall patterns, as well as to detailed conservation practices at field level (Joint Research Centre, 2012).

Disturbance of soil, for example by being trampled or exposed during construction and maintenance/operation of infrastructure, can loosen the soil so that it is more easily removed (Morgan 2005). Compaction reduces the capacity of soil to store and conduct water, makes it less permeable for plant roots and increases the risk of soil loss by water erosion (Joint Research Centre, 2012). Some soils are naturally more susceptible to loss by erosion but this loss can be accelerated by many activities including construction activity (Cooke and Doornkamp, 1990) where soils are exposed to the elements and their cover element, such as a vegetated layer, is removed. Soil particles with a mean particle size of 0.125mm require minimal energy to detach them and mean soil particles between 0.063 and 0.2550mm are the most vulnerable to detachment by rain splash. Coarser soils are resistant to detachment because of the weight of larger particles and finer soils are resistant because of the adhesion or chemical bonding forces that link the mineral comprising the clay particles. Overall silt loams, loams, fine sands and sandy loams are the most detachable (Morgan 2005). For mixed particle sizes, the finer particles are protected by the coarser ones and therefore the shear velocity required must first remove the larger particles (Morgan 2005).

Gyssels *et al* (2005) stated that vegetation controls soil erosion rates significantly, and that the decrease of water erosion rates with increasing vegetation cover is exponential. The canopy cover and root sections of vegetation both have a positive impact on erosion (Gyssels *et al* 2005).

Cooke and Doornkamp (1990) state that soil loss is greatly reduced if protected by vegetation with the type of vegetation cover influencing the degree of protection. Cooke and Doornkamp (1990) also state that vegetation cover is perhaps the greatest deterrent to soil erosion. The Joint Research Centre Report (2012) reports that just over 7% of cultivated land (arable and permanent cropland), while in comparison only 2% of permanent grassland and pasture, is estimated to suffer from moderate to severe erosion in the EU-24 (excluding Cyprus, Greece and Malta). This also demonstrates the importance of vegetation cover as a method to combat soil erosion.

Therefore the most at risk time for high voltage transmission projects from erosion impact is when the site is stripped of vegetation for construction and in the period prior to demobilisation from site prior to re-vegetation.

The Joint Research Centre Report (2012) reports that approximately 105 million hectares (16% of Europe's total land mass excluding Russia) and 42 million hectares (6% of Europe's total land mass excluding Russia) have been affected by water and wind erosion respectively, although no reference to the contribution of high voltage transmission lines is quoted.

Swift (1984) showed that placement of a depth of crushed rock on a forest track reduced sediment production by 70% from the unsurfaced condition over a 5-month period. Tyner *et al* (2011) in their review of construction site best management practices for erosion control found that all methods commonly applied at sites which relied on surface cover for erosion control, exhibited average soil loss ratios (SLR) from 0.21 to 0.38, indicating erosion reductions of 62% to 79% from what would be expected for bare loose soil. Tyner *et al* (2011) identified the variability of test methods to determine the data but recognised the effect of a cover on the soil on reducing erosion.

This kind of cover however cannot always be guaranteed during construction and so there is still a risk of soil release due to erosion. Temporary measures can be utilised to control siltation and sedimentation during the "worst case" periods which will occur during construction and prior to revegetation. Morgan (2005) suggests the following temporary measures;

- Silt fences to trap sediment and prevent it leaving the slope. (Figure 2.4)
- Burlap rolls and straw bales, however these are not considered to be the most effective due to being easily destroyed by cattle or degradation. (Figure 2.5)
- Sedimentation ponds to trap suspended particles contained in runoff and prevent them from leaving site. (Figure 2.6)

Figure 2.4 Example of a silt fence preventing sediment release into ditch/channel

Figure 2.5 Example of straw bales and burlap rolls being used to prevent siltation of river

Figure 2.6 Sedimentation pond being used to allow settlement of suspended particles as part of the surface water management of a construction site

2.2.3 Soil Release in Karst Areas

The main mechanism for soil release from karst environments is due to water movement within karst features. Fine soils accumulate in karst voids that have been formed from the dissolution of bedrock. Construction activities which concentrate flows towards karst features can result in fine soils being washed out of voids into surface water bodies or downwards into deeper karst features (White, 1988).

Fine soil wash out from voids below the surface can cause collapse of soils on the surface and increase the amount of fine soils that can potentially be moved due to water pressure.

Fine soil movement can also occur over swallow holes or sinkholes in the karst landscape. Removal of vegetation and soil release from these areas can lead to the formation of cover collapse sinkholes, as soil is transported downward or laterally. The downward erosion of covering sediment is known as ravelling and can be accelerated by anthropogenic activities such as pumping or construction (Mullan, 2003).

Mahler and Lynch (1999) stated that karst aquifers are capable of transporting and discharging large quantities of suspended sediment, which can have an important impact on water quality. Concentrations of suspended sediment peaked 14–16 hours after rainfall, and the bulk of the sediment (approximately 1 metric ton in response to each storm) discharged within 24 hours after rainfall. A storm may replicate greater flows through the karst feature if this occurred during construction with the risk of sediment transport and discharge into water courses.

Mahler *et al* (1998) had previously undertaken testing of mass transport of fines through karst aquifers. Micron-size montmorillonite particles were injected into the system and captured and tested at retrieval at the outfall. The aim was a test of the tracer but it indicated the likely transport method of fine particles in a karst aquifer. Under normal flow conditions, the time of arrival and peak concentration of the tracer were similar to, or preceded that of a conservative water tracer. Under low flow conditions, the particle tracer was not detected, suggesting that in low flow the sediment settles out of suspension and goes into storage. Therefore it is expected that if greater flows are directed through karst features this may result in mobilisation of fine particles and transport to sensitive water bodies.

Karst or relatively pure, coarse limestone is extensively developed in many areas of Ireland, which are underlain by limestone bedrock. Karst generally includes landscapes where distinctive landforms, both above and below ground, result in the dissolution of bedrock (and subsequent infill with sediments). Karst areas can be ‘active’ (mainly in the south and west of the country) or ‘inactive’ (mainly in the east of the country). Areas of active karst are those where the groundwater system is considered to be active within the karst features, i.e. transporting water through the underground conduits. Areas of inactive karst are those considered not to contain active groundwater systems.

Construction and drainage activities in karst areas can have severe adverse impacts. Many solution features may be full of air, water or soil and any changes to the hydrology or hydrogeology of an area can result in the remobilisation of groundwater causing subsurface erosion and washout of in-filled cavities. This can lead to subsidence and often rapid collapse of the ground surface. This clearly poses significant risk to any foundation or development sited in the immediate vicinity. Best practice would be that both the karst database and geological maps held by the GSI should be reviewed prior to any development in limestone areas.

2.3 GEOMORPHOLOGICAL MAPPING AS THE PRIMARY METHOD OF IDENTIFYING SOIL RELEASE

Geomorphological mapping is a tool used by geographers, environmental scientists and engineers, to map the morphology of a landform. Geomorphological mapping can include information on slope genesis, karst features, slope angles, vegetation, erosion features, landslides and gullies, among others.

In this study, geomorphological mapping is used as the main assessment tool to develop a qualitative assessment of the impacts of construction activities from power lines on sensitive soil areas. This method of assessment is regarded as one of the main tools to be used when carrying out geotechnical assessments of sensitive sites in term of soil release and stability.

Dykes (2008) carried out a geomorphological mapping exercise of a number of Irish peat landslides. He stated geomorphological mapping can be an invaluable tool for the interpretation of landforms at almost any spatial scale and that much of the recently enhanced understanding of mass failures in peat deposits, published in several recent reviews, had been obtained through detailed analysis of the geomorphological maps produced from his field surveys.

Dykes (2008) concluded that creating geomorphological maps from field sketches provides highly satisfactory results in identifying high risk areas in terms of landslide susceptibility, particularly if selected features are geo-referenced using a hand-held GPS. Geo-referenced features can be used with software packages such as ArcGIS to build landslide risk profiles for sites, thus aiding the selection of suitable routes/locations to avoid high risk areas.

Williams and Morgan (1976 in Morgan 2005) present geomorphological mapping for erosion as a way of identifying and understanding erosion. Three types of erosion surveys exist; static, sequential and dynamic (Morgan 2005). Static surveys consist of mapping the sheet wash, rills and gullies in an area (Jones and Keech 1966 in Morgan 2005). Sequential surveys evaluate change by comparing the results of static surveys undertaken at different times (Keech 1969 in Morgan 2005). Dynamic surveys map both the erosion features and the factors influencing them and seek to establish relationships between the two i.e. by comparing geomorphological maps for different stages of a construction project (pre, during, and post construction). The influence of certain factors and their ability to aggravate particular erosion features identified through site surveys will become evident. Direct relationships can then be developed between each factor and its influence on particular erosion features based on how aggravated the feature has become over time. For example, the influence of a spoil heap on a nearby erosion gully can be mapped through different points in time, and a comparison developed.

Figure 2.7 illustrates a typical example of a geomorphological map taken at a particular instance in time. It is through the preparation of these maps for different stages, and their comparison that can lead to relationships being developed between features and factors affecting them. Thus the findings of such an assessment, while of a qualitative nature, can be determined to a confident degree of accuracy

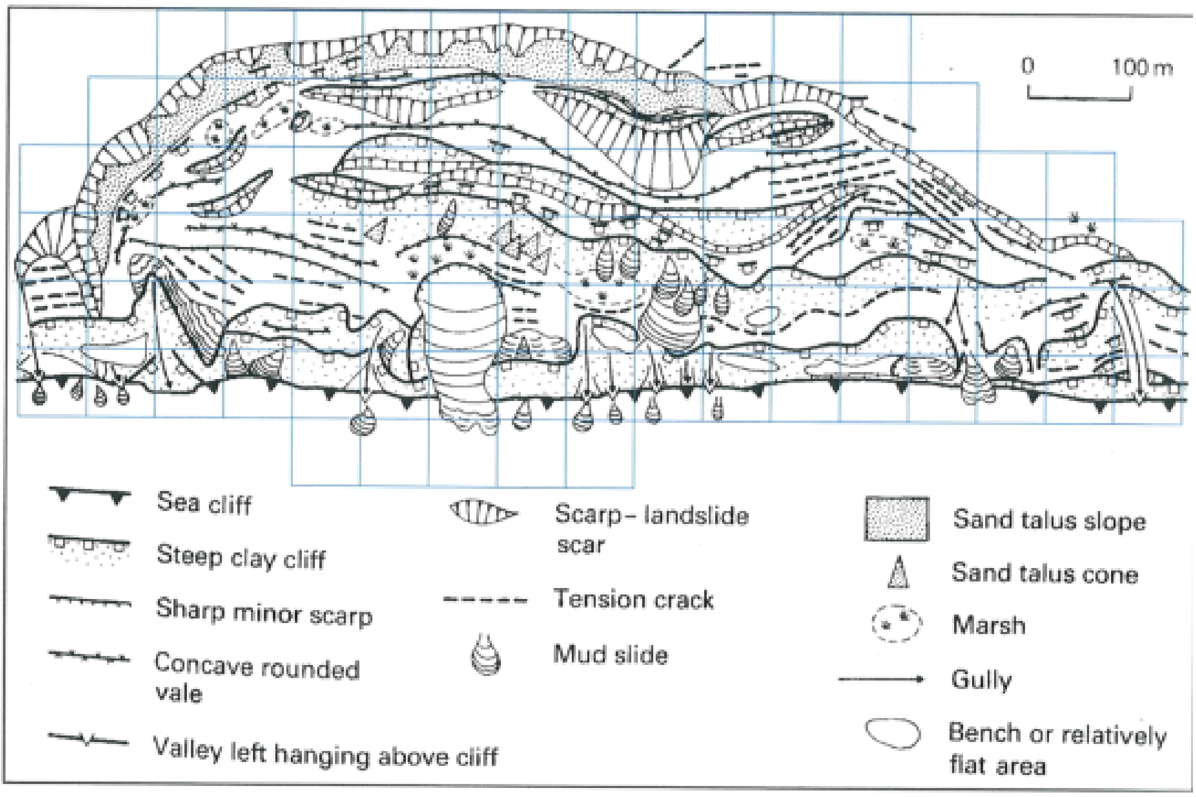


Figure 2.7 Example of Geomorphological Mapping (Brunsden 1969)

3 CONSTRUCTION/OPERATION/MAINTENANCE TECHNIQUES FOR TRANSMISSION PROJECTS

3.1 GENERAL

It is necessary to examine the typical construction techniques of high voltage transmission lines in order to put in context the temporary and permanent works required to facilitate construction and the level of disturbance required to erect structures. As stated earlier in the study, construction is expected to be the most at risk period. Besides this being the time when the heaviest loads will be in place around the structures in the form of construction plant, it is also the time when temporary access and excavation works will be required and hence the time of greatest disturbance to the surrounding area.

3.2 TYPES OF STRUCTURES

The structure types used for high voltage transmission lines depend on the voltage of the line and configuration of conductors. In Ireland transmission lines operate at 110kV, 220kV and 400kV. Support structures for 110kV are double wooden pole sets for straight sections and steel lattice towers for directional changes; for 220kV and 400kV lines, support structures are all steel towers with varying configurations depending on the requirements.

Transmission tower design has developed over the last 70 years from the early double wood pole lines, still in operation today for 110kV lines, to steel lattice tower and monopole designs.

For all new projects, efficient and optimally designed tower types are examined and tested prior to wide scale use, where the main feature of these towers is to reduce visual impact. Therefore the above ground configurations are continually being developed, but the principles of foundations are similar for conventional wooden pole and steel lattice configurations. Developments in monopole designs however will require modified foundation types, which must be examined during their development in the context of their impact on soils and geology. Until emergent designs become apparent and approved for use however, this study will concentrate on the conventional structures currently in use. The changes to steel structures have taken the form of lower towers, lower number of steel struts in the structures and varying shapes and sizes.

The spacing between towers will generally depend on the topography and altitude however average spacings are outlined in Tables 3.1 to 3.3 in the following sections.

The foundations of each structure can vary in number and in size depending on the type, size and height of a structure. The general requirements are outlined in Tables 3.1 to 3.3.

Construction techniques are similar for 110kV, 220kV and 400kV, in terms of the installation of foundations and the erection of towers/pole sets i.e. excavator required to excavate up to 4no.

individual footings in close proximity, foundations installed using conventional techniques (with temporary shuttering as required), towers/pole sets lifted and secured in place with the aid of a crane, and cables installed using a stringing machine at changes of direction or one end of a run. For all voltage ranges, the extent of temporary access required is similar, as the type and size of plant required will not vary greatly, and the layout and type of foundations (i.e. the shape of the footprint) in each case does not vary dramatically. While the sizes of foundations will vary across the three voltages, due to the fundamental similarities in construction methods used throughout, the main difference in impact for each size would be the varying degree of excavated material required to be stored on site, and how this might influence soil release and siltation/sedimentation for the different voltage ranges. Estimates of material to be excavated for each size are given in Tables 3.1 to 3.3.

3.2.1 110kV Lines

110kV lines are the most common type of transmission line on the Irish National Grid, and new lines of various lengths at this voltage are continually being planned. A 110kV line requires that the overhead line conductors be supported on a combination of lattice steel towers and double wood pole sets. The steel lattice towers are required where the line changes direction (angle towers) or terminates. The average span between these poles for a line of this type is approximately 250m but the actual span achievable depends on local topography. For double circuit 110kV lines, the overhead line conductors are supported exclusively on steel lattice structures.

The excavation required for each wooden pole is typically 1.5-2m x 3m x 2.3m deep. No concrete foundations are required for wooden pole sets in normal ground conditions (installation time approximately two per day) however a sleeper is installed attached across the base of both poles, buried for added stability. In sensitive areas, particularly in soft ground such as peat, the depth of excavation may need to extend further to a suitable bearing stratum such as the underlying mineral soil or rock. As natural materials are used in the backfill of such pole sets (granular fills etc.), the only potential impact in sensitive areas is due to the additional material being excavated and how it is being stored during construction.

Concrete foundations are required for all steel towers (base installation time approximately one week) and four excavations of approximately 2.5m x 2.5m x 3m deep is the normal requirement. Concrete used within the foundations is the only foreign material expected during construction, and its impact on the surrounding soil is expected to be negligible. As it is one of the most widely used and tested products in the construction industry, it has a proven track record in terms of minimal impact on surrounding soils. As for wooden pole sets, the amount of excavated material may be greater in sensitive areas in order to achieve a suitable bearing stratum, and it is how this additional material is managed on site that may impact soils and geology through soil release.

Table 3.1 summarises the key features of 110kV structures and Figure 3.1 illustrates typical structures currently in use in Ireland on 110kV transmission lines.

Table 3.1 110kV – Key Design Features

Key Design Features (Double Wooden Pole Sets)	**Range**
Height range	16m to 23m (incl. buried depth normally 2.3m)
Pole centres	5m
Number of foundations	2
Average span	250m (dependent on topography)
Estimated volume of material to be excavated and stored (incl. temporary excavation)	15 to 25m^3 per double pole set
Key Design Features (Lattice Steel Angle Towers / Terminal Towers)	**Range**
Height range	18m to 24m
Maximum width at ground level	4m to 9.8m
Leg Spacing	5m
Height range	18m to 24m
Average span	At changes of direction and terminals. 250m for double circuit (dependent on topography)
Number of foundations	4
Foundation Size	2.5m x 2.5m x 3m min. depth
Estimated volume of material to be excavated and stored (incl. temporary excavation)	100 to 150m^3 per tower

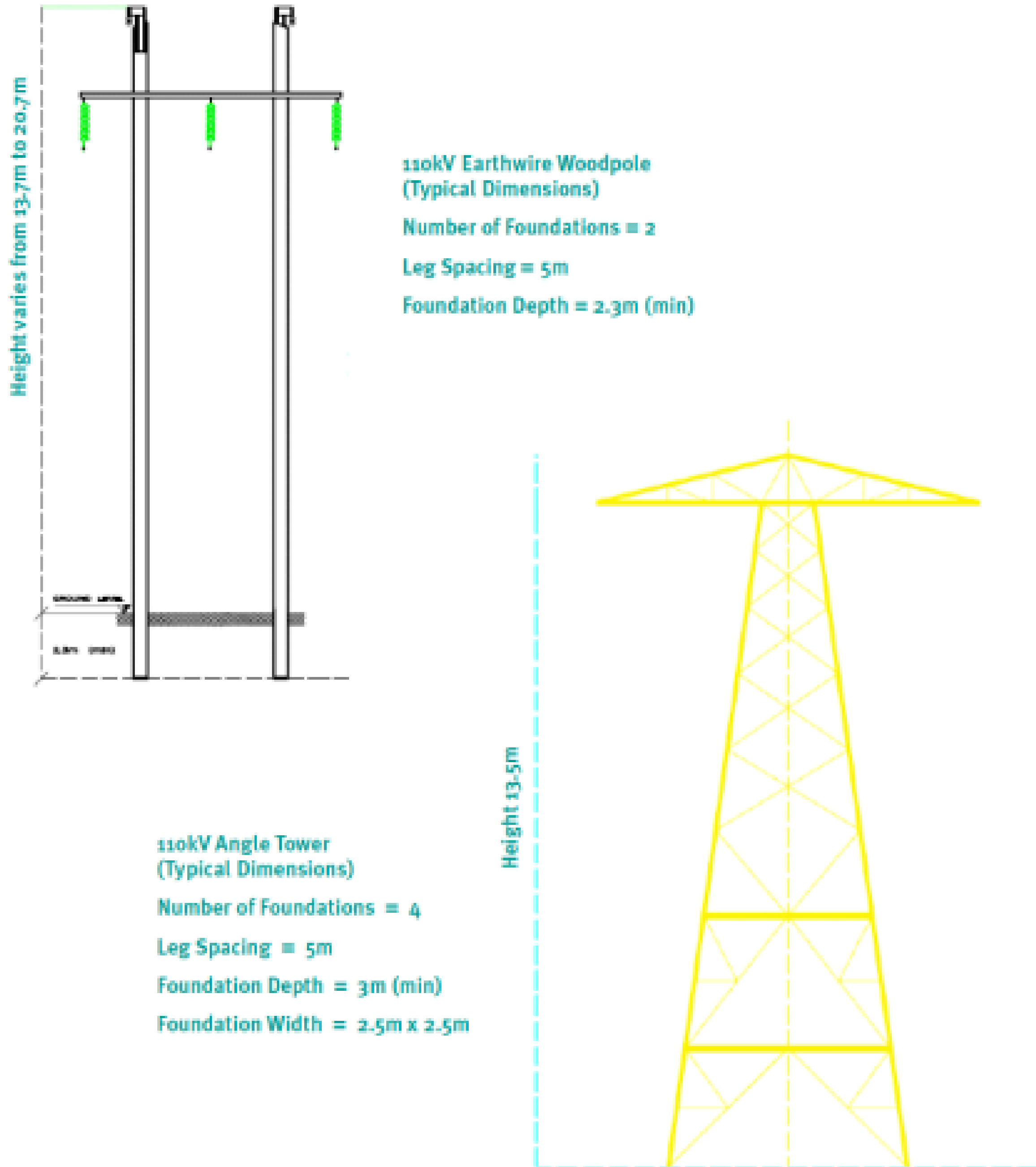


Figure 3.1 110kV Structures – Typical Dimensions (after EirGrid, Ecology Guidelines for Electricity Transmission Projects)

In addition to the excavation required at the pole set, where ground conditions dictate, further excavation is required for stay lines where more marginal soils such as peats or soft silts/clays are encountered. Four excavations, 2m x 2m x up to 1.8–2m deep, may be excavated at a distance from the pole set. The depth of the excavations depends on the extent of the bad ground. The location of the stay trenches are worked out using the following formula:

Pole height (m) – 4m / half the distance (m) from the pole set = distance (m) of the stay line trench

Where much deeper marginal ground is encountered, where a steel tower is proposed, piling may be required to transfer loads created by the structure safely into the underlying competent ground.

The location of stay lines and the installation of piles tend to expand the area of disturbance associated with erecting a pole set.

3.2.2 220kV Lines

A 220kV line requires that the overhead line conductors be supported exclusively on lattice steel towers. The average span on a line of this type is 320m but this is dependent on local topography.

Concrete foundations are required for all steel towers. Four foundation blocks are required to be excavated, with typical dimensions of approximately 2.5m x 2.5m x 3m deep as for 110kV, but can range from 1.4m to 3.9m in diameter depending on the tower design (intermediate or angle tower, double or single circuit). Where deeper marginal ground is encountered, piling may be required to transfer loads created by the structure safely into the underlying competent ground, and this may further increase the footprint of the structure. As for 110kV, it is the storage and management of material on site, particularly any additional material excavated due to soft ground that may impact soils and geology through soil release.

Table 3.2 summarises the key features of 220kV structures and Figure 3.2 illustrates typical structures currently in use in Ireland on 220kV transmission lines.

Table 3.2 220kV - Key Design Features

Key Design Features	Range
Height range	21.1m to 37.1m
Maximum width at ground level	8m to 14m
Leg Spacing	6.3m
Average span	320m (dependent on topography)
Number of foundations	4
Foundation Size	2.5m x 2.5m x 3m min. depth (can range in diameter from 1.4m to 3.9m depending on design)
Estimated volume of material to be excavated and stored (incl. temporary excavation)	100 to 150m^3 per tower (may be greater if typical designs not used)

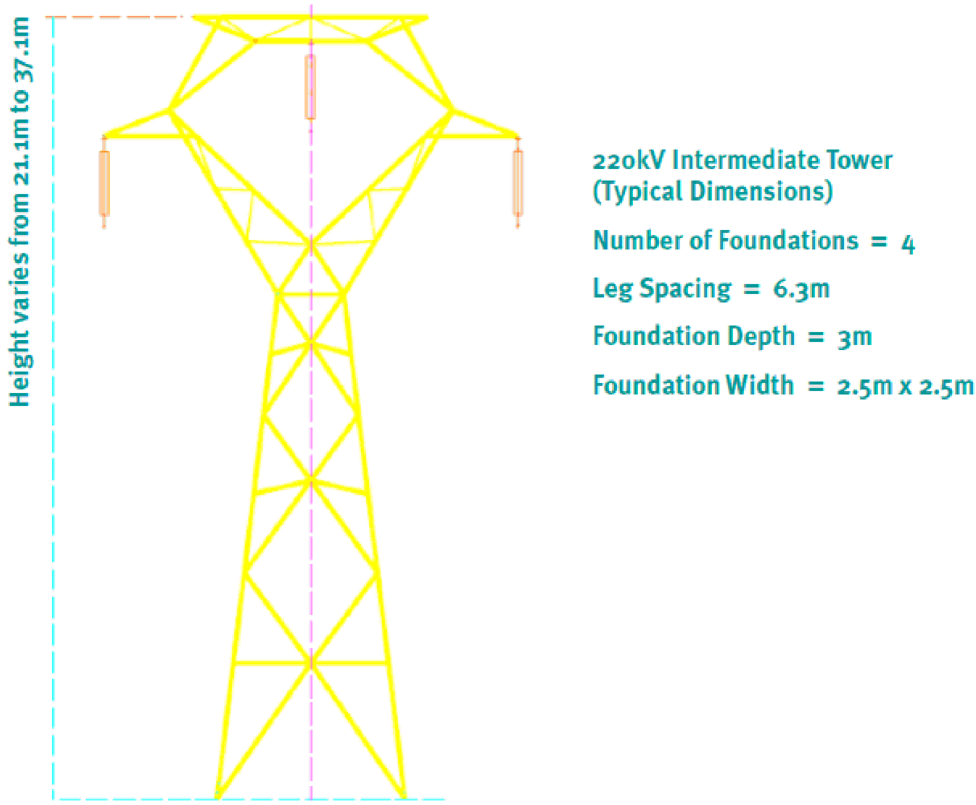


Figure 3.2 220kV Intermediate Structure – Typical Dimensions (after EirGrid, Ecology Guidelines for Electricity Transmission Projects)

3.2.3 400kV Lines

A 400kV line requires that the overhead line conductors be supported exclusively on lattice steel structures. The average span on a line of this type is 250-330m but this is dependent on local topography. Currently the use of 400kV lines is limited on the Irish National Grid, but additional lines at this voltage are planned to improve the overall functioning of the network.

Four concrete foundations are required and the excavation for each foundation pad ranges in size from 2.2m – 5.3m in diameter depending on the tower design (intermediate or angle tower, double or single circuit) with typical sizes of approximately 4.6m x 4.6m x 3.6m deep. Analysis of foundation sizes for the Meath-Tyrone 400kV Interconnector show a maximum foundation size of 2.75m x 2.75m x 2.6m depth. As with 110kV and 220kV, where deeper marginal ground is encountered, piling may be required to transfer loads created by the structure safely into the underlying competent ground, and this may further increase the footprint of the structure.

Again, it is the storage and management of material on site, particularly any additional material excavated due to soft ground that may impact soils and geology through soil release.

Table 3.3 summarises the key features of 400kV structures and Figure 3.3 illustrates typical structures currently in use in Ireland on 400kV transmission lines.

Table 3.3 400kV - Key Design Features

Key Design Features	Range
Height range	30m to 56.75m
Maximum width at ground level	12m to 16.5m
Leg Spacing	7.6m
Average span	250m to 330m (3 to 4 structures per km)
Number of foundations	4
Foundation Size	Typically 4.6m x 4.6m x 3.6m deep (can range in diameter from 2.2m to 5.3m depending on design)
Estimated volume of material to be excavated and stored (incl. temporary excavation)	350 to 450m^3 per tower

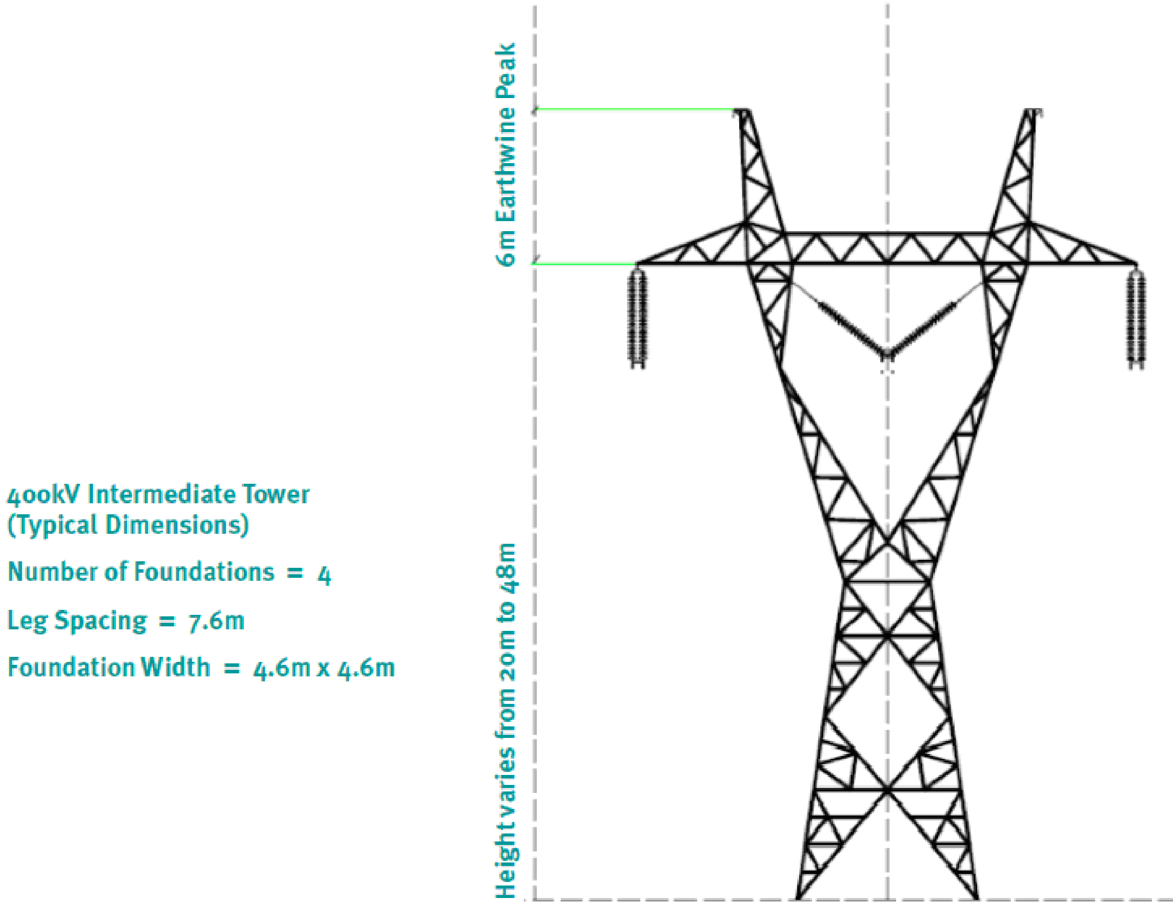


Figure 3.3 400kV Intermediate Structure – Typical Dimensions (after EirGrid, Ecology Guidelines for Electricity Transmission Projects)

3.2.4 Earth Mats

Earth mats are copper mesh mats that are installed under and around the base of steel lattice towers (angle towers at 110kV, 220kV, 400kV, and structures) where the soil resistivity is such that it can result in a Grid Potential Rise (GPR) when a fault occurs on a line, for example a lightning strike. Furthermore, certain ground conditions dictate that earth mats need to be placed at the base of pole sets (110kV).

They are used:

- In situations where there is a possibility that a fault might occur on a line or in a station and there is a potential of the earth grid to rise relative to the remote earth – Grid Potential Rise (GPR)

- When resultant 'Touch and Step' voltages have potential safety implications for the general public and staff/contractors working at a tower or in a station, for example if the area of the ground around the tower is energised and the voltage is such that it is a potential hazard to people/farm animals in the vicinity of the structure.

Earth mats are not normally installed when the towers are initially erected unless obviously required. Instead, following construction, a resistivity test is conducted along the line and structures are retrofitted at identified locations along the line. The excavation area required is not extensive but depending on soil conditions, may extend beyond the tower base by a few metres. The exact dimension of the trench depends on ground conditions.

Earth mats can be installed when towers and pole sets are initially erected if work is taking place in a sensitive environment, this way the disturbance is minimised.

3.2.5 Underground Cabling

High voltage (HV) circuits can only be laid underground using special HV cables designed specifically for underground use. The conductors in underground HV cables must be heavily insulated to avoid a short circuit between the conductor and the ground around the cable. Underground cables are sometimes used in the following circumstances, where technically feasible -

- A built-up urban area where there is no space for support structures;
- An area with a multiplicity of existing overhead power lines;
- A relatively wide expanse of deep water.

Table 3.4 shows the typical width of a cable trench at the three voltage levels, the area of the joint bays and the intervals at which they are installed.

Table 3.4 Trench Dimensions

Criteria	Trench Dimensions Width x Depth (m)	Joint Bay Dimensions Length x Width x Depth (m)	Approximate interval between joint bays (m)
110kV	0.6 x 1.25	6 x 2.5 x 2.1	700
220kV	1.1 x 1.25	6 x 2.5 x 2.1	600
400kV	1.1 x 1.25	10-25m x 2.5 x 2.1	500

Underground cabling is generally not present in more sensitive soils and so therefore has not been included as part of the study. Underground cabling requires extensive linear excavation, and within sensitive areas where the aim is to minimise impacts from power line construction, it is not considered a feasible method of installation, when compared to overhead lines. The laying of high-voltage cables in peat land is also undesirable from a technical point of view, due to the nature of that type of terrain, which can shorten the cable life. The peat land itself can also be adversely affected by the heat which builds up in the cables.

3.2.6 Substations

The majority of substation plant and equipment was installed between 1970 and 2000. Accordingly, the older stations are now approaching 40 years in service. Station-wide condition assessments are being carried out and where necessary, options for refurbishment are being developed. Stations are generally located in low-lying areas at the ends of transmission lines and connection points to other lines. They usually have permanently designed access and hardstanding. As these areas are subject to more robust detailed design, and because of the generally lower lying and controlled construction environment, it is felt that stations are not as high risk areas to soil release as along the transmission lines. Therefore stations have not formed part of the study sites.

3.2.7 Line Refurbishments

In general a transmission line requires little maintenance. It is periodically inspected to identify any unacceptable deterioration of components so that they can be replaced as necessary.

A condition assessment on a line is usually carried out when it is 35 years old. The majority of the existing transmission line grid was constructed after 1960 (EirGrid, 2010) and the majority of those lines constructed prior to 1960 have already been refurbished. There is an on-going programme of line refurbishment concentrating on the older lines. Refurbishment projects are condition based and once a line has been identified for refurbishment, consideration is given to the potential opportunity to upgrade the capacity or thermal rating of the line. Insulators and conductors are normally replaced after about 40 years and towers are painted every 15-20 years, or as necessary.

Where structures require replacement during a line upgrade or refurbishment, additional excavation may be required particularly where angle towers or structures require replacement. In general they are replaced within the footprint of the original structure. It is assumed that all the same mitigation measures would be in place during refurbishment, and best practice has improved since original erection. Line refurbishment has not been focused on as part of this study, but the same principles of new line construction would apply to line refurbishment. In that regard, the findings and recommendations of this report apply to line refurbishment also.

3.3 CONSTRUCTION SEQUENCE OF WORKS

The works required to construct a high voltage transmission line typically follow the sequence of events as outlined below:

- Prepare access
- Excavate foundation base/pole bases
- Install tower foundations
- Erect towers or wooden poles
- String conductors
- Reinstate tower/pole sites as necessary
- Remove temporary access

Access is required to all structures/pole locations for construction. Table 3.5 outlines the necessary plant required for erection of different structure types.

Table 3.5 Plant Required for Construction

Structure Type	Plant Required
Double Pole Set	Conventional delivery truck either to site of poles or to storage area Excavator Lifting arm (usually using excavator) Small ancillary Items
Tower	Conventional delivery truck either to site of tower or to storage area Excavator Lifting arm (usually using excavator) Concrete trucks Crane Small ancillary Items

Once the towers and poles have been erected the conductors are winched to/pulled from section towers. Access in and around these towers is required for conductor drums and large winches. Therefore the access arrangements to angle towers are greater than for line towers.

Access is usually along a designated route as agreed with the relevant landowner. Access road requirements vary depending on ground conditions.

Where ground conditions are considered good and excessive rutting or damage is not expected, plant will traverse existing ground. However where ground conditions are poor, for example in peat areas, bog mats or a geotextile reinforced/brush reinforced access road will be put in place overlying existing ground. Generally tracked plant is used where possible to reduce surface damage. In areas of poor ground low ground bearing, wide tracked plant, is used to reduce loading on soft ground and mitigate risk of soil failure in bearing.

Where access has occurred on existing ground any damage will be remediated by, for example rolling, rotavating and re-seeding or alternatives as deemed necessary. Where temporary access roads have been put in place, these will be removed upon completion of works.

Current practice is to erect temporary fencing around each structure to delineate the working area and to ensure the safety of members of the public and livestock. All plant remains within this area during construction and all excavated material is stored within the fenced off area. The size of the area can vary but will be dependent on the amount of material to be stored or the size of the structure to be erected. Generally this area would be smaller for pole erection. Any excavated material is stored within the working area until reinstatement occurs with any surplus material being removed off site.

During construction, the following are the activities that most affect soils and geology with respect to soil release;

- loading of the ground, which may cause bearing failure in weaker soils (Figure 3.4)
- excavation for foundations, causing the ground upslope to become unstable (Figure 3.4)
- compaction of in-situ soils, particularly along temporary access routes, making it less permeable and causing increased water run-off, increasing the level of soil release and siltation/sedimentation
- exposure of fine soils during the excavation process
- stockpiling of materials without adequate erosion control measures (Figure 3.5)

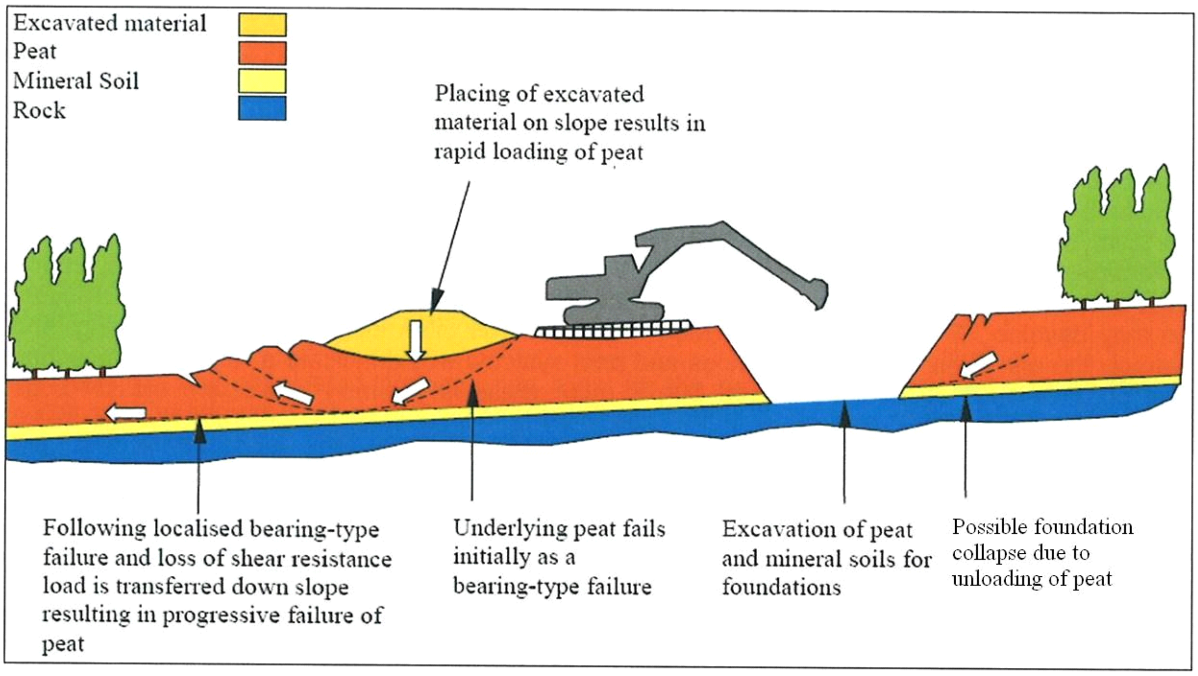


Figure 3.4 Possible failure mechanisms associated with loading and unloading peat (MacCulloch, 2006)

Figure 3.5 Inadequate erosion control measures leading to detrimental damage to adjacent stream

3.4 OPERATION / MAINTENANCE REQUIREMENTS

Upon completion of stringing and energisation of lines, access is generally only required by standard maintenance plant and personnel. These generally do not require the installation of temporary access routes, except in very poor ground conditions where temporary bog mats or access roads may be required for a short period of time. These would generally use existing access roads where possible.

4 CURRENT MITIGATION MEASURES AND BEST PRACTICE GUIDANCE

4.1 GENERAL

Based on an assessment of current mitigation measures and best practice guidance both at an Irish level as well as at International level, there are common themes running across all guidance with the ultimate aim to mitigate against negative impacts to soils and geology and subsequent negative impacts on sensitive water bodies.

The following sections outline the current guidance both in an Irish and International context, and illustrate the common goals.

4.2 IRISH CONTEXT

There are a number of bodies in Ireland that make reference to or outline best practice guidance relating to impacts on soils and geology due to construction activities. Through various publications by EirGrid, as outlined in Section 4.2.1, they cover a range of environmental mitigation measures that are considered current best practice for their projects. Guidance published by Inland Fisheries Ireland, detailed in Section 4.2.2, has become industry standard for construction activities adjacent to water courses. The Department of the Environment, Community and Local Government (DECLG) and the Irish Wind Energy Association have also published guidelines for use on wind energy projects, with specific reference to soil release, ground conditions and geology (Section 4.2.3).

4.2.1 EirGrid Guidance

Environmental considerations form part of the EirGrid strategy for Grid Development from the earliest stages of a Project. This is evident in EirGrid’s Project Development and Consultation Roadmap (Figure 4.1) which illustrates that environmental and other constraints are identified in Stage 1, the Information Gathering Stage.

Figure 4.1 EirGrid's Project Development and Consultation Roadmap

EirGrid have published a number of documents which detail environmental mitigation measures that are considered current best practice for any projects undertaken by EirGrid. These include:

- GRID25 Implementation Programme (IP) 2011-2016 (EirGrid 2012)
- Environmental Report of the Strategic Environmental Assessment (SEA) accompanying the Grid25 IP (EirGrid 2012)
- Environmental Appraisal Report of the Transmission Development Plan 2012-2022
- Ecology Guidelines *for* Electricity Transmission Projects: A Standard Approach to Ecological Impact Assessment *of* High Voltage Transmission Projects.

Key issues associated with the development of transmission lines and soils, geology, hydrology and hydrogeology have been identified within these documents, some of which relate directly to soil release. These are listed below:

- Consolidation of soils reducing permeability and increasing runoff potential
- Peat instability
- Presence of karst features
- Flooding
- Changes in local hydrology/hydrogeology

The Grid25 IP report addresses the requirement for mitigation measures to be implemented to protect the environment against long term detrimental effects. It also highlights that the SEA of the Grid25 IP identified three key objectives in relation to soils, geology, hydrology and hydrogeology as follows:

1. To prevent impacts upon the status of surface waters;

2. To prevent pollution and contamination of groundwater; and

3. To minimise effects upon the sustainable use of land, mineral resources, or soils

The first two points above are intrinsically linked with this evidence based study. While this study does not deal directly with point 3, it is recognised that the impact of such development is particularly important with regard to the sustainability of land and in-situ soils. The effect of power line construction on landowners and farmers, particularly relating to livestock and crop harvesting, needs to be considered in any mitigation measures proposed.

4.2.1.1 Mitigation Principles

Current mitigation measures which are implemented on any EirGrid project are measures developed to prevent, reduce and, as fully as possible, offset any significant adverse impacts on the environment. It is important to note that EIS's undertaken as part of the planning process for transmission projects, which are generally prepared by consultants, would also contain additional and particularly site specific mitigation measures that are beyond those specified in EirGrid documents.

Mitigation measures can be roughly divided into those that avoid effects; reduce the magnitude or extent, probability and/or severity of effects; repair effects after they have occurred, and; compensate for effects, balancing out negative impacts with other positive ones.

Below are the current mitigation principles which EirGrid refer to as part of their published documentation on the development of high voltage infrastructure projects.

Mitigation by avoidance

The best form of mitigation is avoidance through design (location of structures and routing of lines) and the ecological constraints and route assessment studies should aim to avoid areas of significant sensitivity. Where sensitive areas exist it may be possible to avoid direct impacts on the sites by the careful planning of the location and erection of structures. Figure 4.2, which is an extract from EirGrid's Ecology Guidelines *for* Electricity Transmission Projects (EirGrid, 2012), illustrates an example of constraint mapping and route selection, indicating where sensitive areas would be avoided where possible and the least constrained route identified.

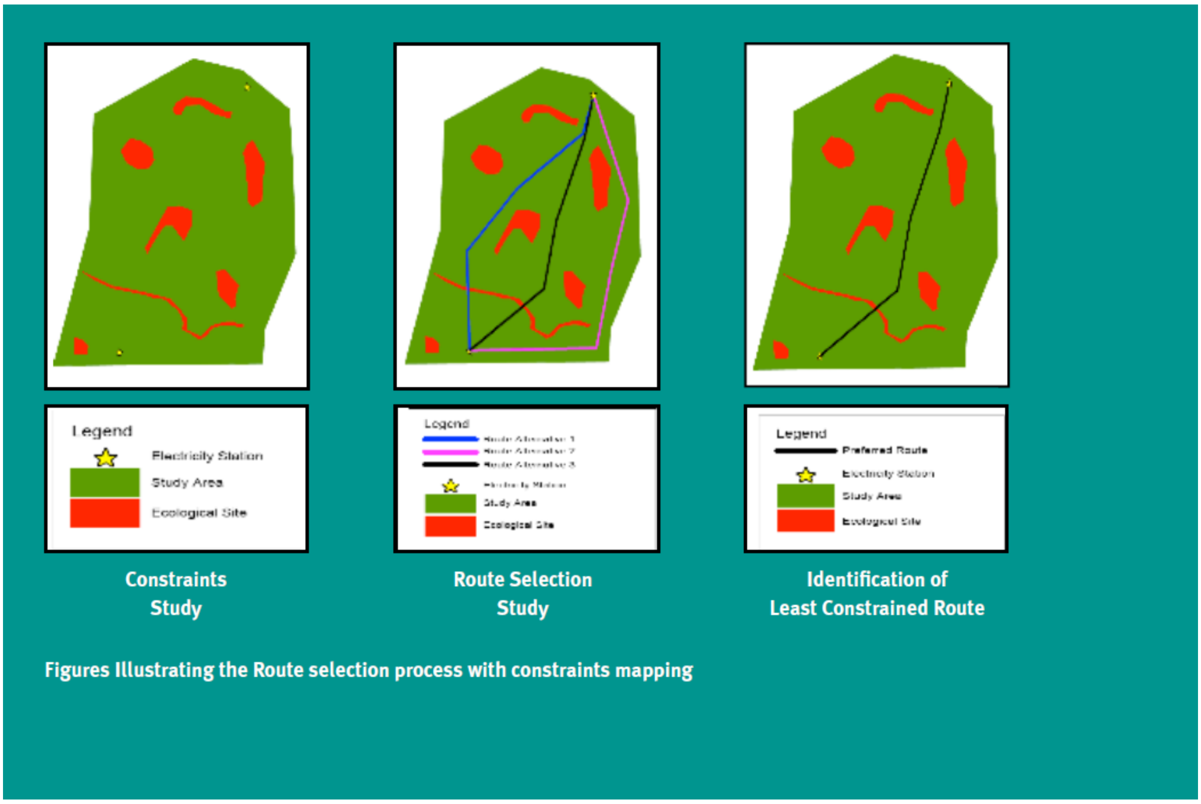


Figure 4.2 Illustration of Route Selection Process and Constraints Mapping (EirGrid, 2012)

Mitigation by reduction

Where negative impacts cannot be avoided, it may be possible to reduce impacts by reducing the area of impact or the length of time that the area is exposed to disturbance. For example, where areas of sensitive habitat need to be crossed during the construction phase, measures to reduce the impact of vehicles on wetland or bog should be considered including the use, for example, of low pressure vehicles and the laying of protective geotextile on the vegetation to be crossed.

Mitigation by remedy

Where impacts cannot be avoided or reduced, it may be possible to carry out further works to compensate for these impacts, or to restore some aspect of the natural environment to an approximation of its previous condition. This was a particular approach on the Corrib Onshore Pipeline Project which involved linear construction through a sensitive soils area. Remedial measures in this case included pre-turving a sensitive bog and coastal inlet, protection of turves during construction, replacement during reinstatement, and significant monitoring and protection for a period during the operational phase.

Mitigation measures should also take into account the operational phase of electricity transmission projects.

4.2.1.2 Mitigation Measures

EirGrid, in their current published literature as listed in Section 4.2.1, make recommendations that within the mitigation section of an EIS or Environmental Report (ER), it should be made clear how the measures will act to avoid or reduce impacts on ecological sites / habitats / species. Evidence of how each mitigation measure will be implemented should be provided. A timeframe of when mitigation measures are to be put into practice should be outlined in terms of the project plan. A system of monitoring the effectiveness of the mitigation measures should be put in place and contingency for ineffective measures established.

Where there are significant negative effects, consideration is given in the first instance to preventing such effects or, where this is not possible for stated reasons, to lessening or offsetting those effects. It is the aim of this study to ascertain the effectiveness of current EirGrid best practice and augment and extend the requirements where necessary based on conclusions of the study.

Below are mitigation measures as outlined in the SEA of the Grid25 IP as best practice guidance in relation to soils and geology. These are general high-level mitigation measures, with project specific measures being required at a more local level, based on site specific environmental assessments. Further mitigation measures are also included in EirGrid documentation, as listed in Section 4.2.1, however those listed below are relevant to this study. EMM is a reference to EirGrid Environmental Mitigation Measure as detailed in the SEA for Grid 25 IP (EirGrid, 2012).

EMM8A Biodiversity and Flora & Fauna

EMM8A (ii) General Habitat Loss and Disturbance

- Use of bog-mats to minimise the impact of heavy machinery on vegetation and soils.
- Minimise extent of works areas.

- Re-distribute vegetation and soil stripped from the construction areas to provide a seed bank and do not re-seed with perennial ryegrass (*Lolium perenne).*
- Land within the working area will be reinstated as near as practical to its former condition.

EMM8A (iii) Bogs and Peatland areas

- Areas of deep and active peat shall be avoided where ever possible.
- Detailed peat slip risk assessments should be carried out for all proposed developments in areas where peat substrates occur.
- Construction machinery should be restricted to site roads and designated access routes. Machinery should not be allowed to access, park or travel over areas outside development construction zones.
- Peat excavated during construction activity should not be stored (temporarily or otherwise) on areas of adjacent mire habitats or near flushes or drains. Temporary storage of spoil material excavated during the construction phase developments should be stored at suitable locations away from surface watercourses.
- All spoil material excavated during the construction phase should be reinstated following the completion of the construction phase of a proposed development.
- Where disturbance of peat soils cannot be avoided, there should be some consideration given to possible re-seeding with native species to stabilise the peat and accelerate recovery of the vegetation.

EMM8B (ii) Suspended solids & sediment deposition

- Precautions shall be put in place to avoid or minimise the generation and release of sediments into all watercourses. Sediments in this instance include all soils including peat.

EMM8C Soils and Geology

EMM8C (i) Geological Features

- Site investigations shall be undertaken at intervals and specific locations along the power circuit route. This information shall be used to plan site work operations to anticipate, avoid or minimise construction impacts arising from disturbance of sub-surface conditions.
- Cut and fill operations should be avoided unless absolutely necessary.
- Route selection and lower tier assessments should consult Geological Survey of Ireland as appropriate in relation to geological heritage sites either recommended for Natural Heritage Area (NHA) or County Geological Site designation.

EMM8C (ii) Soil

- Height of stockpiles should be limited to less that 3m and storage time will be minimised.
- Material handling and reinstatement operations should follow good practice to avoid inadequate or over compaction of the materials.
- Route selection and lower tier assessments for peatland areas should consider relevant government guidelines on development in these areas as well as relevant datasets including the Geological Survey of Ireland's landslide dataset and Teagasc's subsoils dataset.

In addition to the mitigation measures outlined above, An Emergency Response Plan should be produced, in the event of a major spill or other significant discharge of polluting matter to surface waters.

4.2.2 Inland Fisheries Ireland Guidance

Inland Fisheries Ireland (IFI) have published guidelines (under the previous Eastern Regional Fisheries Board, now part of IFI) (IFI 2006), which have become an industry standard for construction works in the vicinity of watercourses. The following recommendations are considered best practice for construction and in-stream works to control or mitigate detrimental effects to waterways from sediments:

- Stockpiles should be kept to minimum size, well away from the watercourse.
- Runoff from the above should only be routed to the watercourse via suitably designed and sited settlement ponds/filter channels.
- Settlement ponds should be inspected daily and maintained regularly.
- Temporary crossings should be designed to the criteria laid down for permanent works.
- Watercourse banks should be left intact if possible. If they have to be disturbed, all practicable measures should be taken to prevent soils from entering the watercourse.

4.2.3 Wind Energy Guidance

In 2006, the Department of the Environment, Community and Local Government, DECLG (then the Department of the Environment, Heritage and Local Government, DoEHLG) prepared guidelines for the wind energy sector which offers advice to planning authorities on planning for wind energy projects (DECLG, 2006).

The Irish Wind Energy Association (IWEA) has also developed a guidelines document (IWEA, 2012) which outlines information to be supplied at planning stage in terms of ground conditions/geology. The document covers items that should be considered in the planning of wind farms in relation to soil release. These are listed below.

- Monitoring and supervision of construction phase by qualified and experienced geo-technical engineer(s) and/or by qualified and experienced ecologist(s), where deemed necessary

- Construction traffic movements, including vehicle types and routes in relation to removal of excavated material, and importation of materials, turbine parts and equipment

- Ground disturbance during construction

- Management and treatment of rock and soil excavated during construction work

- Storage and transfer of material, including use of bounded storage areas during construction and operational phases to avoid any pollution of surface or ground waters

- Impacts on surface and groundwater drainage

- Reinstatement of the site where construction works result in ground disturbance/surface damage or erosion

4.3 INTERNATIONAL CONTEXT

Williams (2003) compiled a document titled "International Best Practices for Assessing and Reducing the Environmental Impacts of High-Voltage Transmission Lines". The paper includes a discussion on internationally recognised best practices for assessing, avoiding, reducing, and mitigating the environmental impacts associated with the siting, construction, and operation of high voltage transmission lines and associated facilities such as sub-stations and converter stations.

It lists the types of environmental impacts found in transmission projects, and in terms of soil release include soil erosion resulting from removing vegetation cover, compacting soils, and cutting into banks

The paper describes measures for reducing these environmental impacts which include the following during the assessment stages and during project implementation;

- Environmental assessment and reporting at early project stage
- Alternative routings

- Field assessments of potential sites, such as in-situ testing, probing, and visual inspections
- Mitigation plans for the final route option
- Monitoring during the construction and operation of the transmission line
- Avoidance of sensitive areas
- Use of existing corridors
- Environmental mapping
- Land restoration
- Widening spans to reduce number of structures/pole sets
- Limiting construction to dry seasons or periods when the ground is completely frozen in order to minimise the effects of construction equipment on wet soils
- Providing stringent control of erosion and sedimentation when vegetation is removed
- Using helicopters for tower installation and other means of minimising road-building in remote areas

The International Council on Large Electric Systems (CIGRÉ) have produced a range of publications and papers through their working groups, relating to the construction of high voltage transmission lines, with particular reference to the working group WG B2.23, responsible for the geotechnical and structural design of foundations for overhead power lines. This group have published technical brochures, including one on the refurbishment and upgrading of foundations for overhead high voltage transmission lines (CIGRÉ, 1999). One of the main terms of reference of this working group is, "the effect of potential geotechnical influences both natural and man-made, e.g. land slips, faults, soil liquefaction, mining activities, etc., on the routing of an overhead line, and how these influences may be identified and possible means of alleviation, if it is not possible to re-route the overhead line." This working group aims to provide guidance on how to undertake geotechnical investigations for overhead power lines, and they intend to produce a guidance report indicating procedures for desk studies and intrusive inspections, etc.

5 CASE STUDY

5.1 SITE SELECTION

5.1.1 Site Types

To facilitate robust evidence based research, site based work has a key part to play. Site assessments facilitate the collation of project specific, micro-level information on impacts. It can be difficult and misleading to identify impacts from desk study assessment only. Aerial photography or mapping is not always available at different stages of a project, and over the timeline that one may require it to compare effects. Therefore field based case study assessment is a critical element in the compilation of evidence based research.

Case study sites were selected on a countrywide basis by utilising available mapping of the transmission network overlaid on soils and geological features mapping across Ireland. The study site selection process was assisted by input from EirGrid's knowledge of projects proposed for construction, under construction and recently constructed overhead lines and their terrain and ground conditions as required for this evidence based study.

The most vulnerable soil types were identified as those that are most easily released, and when released could have the most detrimental effect on water quality. These were identified through the literature review and experience with EIA, as weaker and finer soils which would be the most vulnerable to failure and/or erosion. These are namely:

- Peat
- Alluvial deposits, or fine silt/clay type glacial tills on slopes adjacent to water bodies
- Karst features, through which finer material could be washed out.

Glacial till type soil, being a mixed soils type of silt, clay, sand, gravel and interspersed cobbles and boulders, is the most prevalent soil type in Ireland. Because of its mixed nature it would not be the most sensitive soil type to erosion and movement and as it is generally a lodgement till it is found extensively on flatter land. However where on slopes adjacent to rivers or streams it can be as erosive as an alluvial deposit. Generally this soil type, on flat terrain, was chosen as a control site type.

For the purposes of this study, the sites were spilt into three soil type categories, namely:

- **Standard**
- **Non-standard, and**

- **Worst case.**

Standard sites are considered to be low lying glacial till landscapes (e.g. agricultural land, non-peat areas), as they are considered to be areas at lower risk to construction activity This was included in the study as a control type site.

Non-standard sites are considered to be areas that are at greater risk to construction activities, and include the following:

- areas where karst is present, as these are not expected countrywide across Ireland
- areas where significant clay/silt deposits exist close to water bodies (alluvium adjacent to river banks); and
- areas of flat shallow peat.

Worst case sites are those that are considered to be at greatest risk to construction activities, and include upland, steep- sloped peat environments, preferably convex sloped, with peat depths greater than 1.0m, and surface hydrological features such as streams, bog pools, hags etc. These criteria are based on MacCulloch (2006), as these relate to the thresholds at which he recommends mitigation measures to be implemented at a site where peat failure is of concern.

5.1.2 Stages of Construction at Each Site

There are three stages to any project over which effects can be measured, assessed and compared, to gain information on the actual impacts of the construction of high voltage transmission lines. These are:

- **pre-construction** to gain background knowledge
- **during construction** to ascertain immediate impacts from works, and
- **post-construction** after a state of equilibrium (revegetation, settlement, etc) would be expected to be achieved at the site.

The main question being asked is whether soil has been released because of the construction of the lines? Therefore pre, during and post-construction sites were selected so that comparisons could be made and any subtle changes or impacts identified.

However, it was not feasible within the timeframe of the study to include the same site where construction was taking place with sites post-construction (with the exception of one site), as it was established that a time frame of at least one year would be required for the post-construction impact assessment. This timeframe is based on engineering judgement relating to settlement and consolidation of soils, which according to design theories of soil mechanics, can take significant periods of time, depending on the soil type and the level of secondary consolidation that is likely to occur.

5.1.3 Study Sites

Standard, non-standard and worst-case sites (in terms of soils characteristics), comprising of pre, during and post-construction overhead line projects were determined as appropriate parameters to be assessed to facilitate a robust assessment of impacts of high voltage transmission lines on soils and geology. Five site categories were identified for assessment, each of which is examined under three phases of construction (refer to Table 5.1).

Through Client input, a series of potential sites were identified as being suitable for the various site categories to be examined, both in terms of ground conditions (some lines containing a range of ground conditions applicable to the study) and in terms of project stage.

Following the initial identification of potential study sites, they were mapped using MapInfo and ArcGIS software. Where the occurrence of the infrastructure coincided with the selected soil types and topography these were chosen as the first round of preferred sites. Soil type mapping and karst mapping from the Geological Survey of Ireland (GSI) was used in this exercise. This database identifies peat in the form of cutover, blanket and raised peat and identifies alluvium deposits as a separate layer. It also identifies various types of till and includes the parent material from which they have been derived.

The initial selection process identified a large number of potential sites. A second selection process was completed where sites were rated in terms of likely sensitivity, taking into account proximity to sensitive water bodies, as well as the likely perceived depth and extent of sensitive soil, with the top ranking sites being chosen as preferred. This second selection process, in so far as possible, took into account the study sites in the Water and Aquatic Ecology Evidence Based Study report so that sites chosen were in the proximity, preferably upstream of these study areas.

The aim of the study was to utilise the same site pre, during and post-construction in so far as possible, within the time frame of the study. As mentioned in Section 5.1.2 however, it was not feasible to include the same site where construction was taking place with sites post-construction, as it was established that a time frame of at least one year would be required for the post-construction impact assessment. It was established however that valuable conclusions could be drawn from the study sites selected, particularly given that it was observed that consistent construction practices and mitigation measures were being implemented throughout. Based on engineering judgement and experience, it is reasonable to consider that where the site types and conditions are of a similar nature, that similar impacts (if any) could be expected between pre, during, and post-construction sites, and that the assumptions and conclusions drawn would be valid in that case.

The final sites chosen for assessment are shown in Table 5.1, and are the result of several revisions, with the sites representing four separate counties. This table details the transmission project, the type of transmission infrastructure, the location, and the site reference code. The reference code relates to the locations as illustrated in Figure 5.1.

Table 5.1 Finalised Site Categories

Category No.	Project Stage	Site Name	Transmission Line	Transmission Infrastructure	Location	Site Reference	Date Energised (post construction only)
Standard Sites (low lying glacial till)							
1	Pre-Construction	Connemara IMP5 and IMP7	Connemara 110kV Line	2 no. double pole sets	Co. Galway	05L115	-
2	During Construction	Connemara IMP5 and IMP7	Connemara 110kV Line	2 no. double pole sets	Co. Galway	05L115	-
3	Post Construction	Banoge AM14 to AM16	Banoge 110kV Line	3 no. steel lattice angle towers	Co. Wexford	05L106	2012
Non-Standard 1 Sites (karst)							
4	Pre-Construction	Connemara AM44	Connemara 110kV Line	1 no. steel lattice angle tower	Co. Galway	05L113	-
5	During Construction	Connemara AM44	Connemara 110kV Line	1 no. steel lattice angle tower	Co. Galway	05L113	-
6	Post Construction	Dalton Galway ST3 to ST6	Dalton Galway 110kV Line	4 no. steel lattice angle towers	Co. Galway	05L108	2012
Non-Standard 2 Sites (silt/clay)							
7	Pre-Construction	Connemara IMP6	Connemara 110kV Line	1 no. double pole set	Co. Galway	05L115	-
8	During Construction	Banoge AM19	Banoge 110kV Line	1 no. steel lattice angle tower	Co. Wexford	05L107	-
9	Post Construction	Banoge AM19	Banoge 110kV Line	1 no. steel lattice angle tower	Co. Wexford	05L107	2012
Non-Standard 3 Sites (low lying peat)							
10	Pre-Construction	Donegal IMP176 to AM180	Donegal 110kV Line	3 no. double pole sets and 1 no. steel lattice angle tower	Co. Donegal	05L102	-
11	During Construction	Donegal IMP176 to AM180	Donegal 110kV Line	3 no. double pole sets and 1 no. steel lattice angle tower	Co. Donegal	05L102	-
12	Post Construction	Tarbert Tralee – West of Blake's Cross	Tarbert Tralee 110kV Line	2 no. steel lattice angle towers	Co. Kerry	05L112	2011
Worst Case Sites (upland steep sloped peat)							
13	Pre-Construction	Donegal ST244 to 251	Donegal 110kV Line	7 no. double pole sets	Co. Donegal	05L103	-
14	During Construction	Donegal ST244 to 251	Donegal 110kV Line	7 no. double pole sets	Co. Donegal	05L103	-
15	Post Construction	Derrybrien to Agannygal	Derrybrien to Agannygal 110kV Line	3 no. double pole sets and 1 no. steel lattice angle tower	Co. Galway	05L116	2011

Figure 5.1 Soil and Geology Study Sites

6 FIELD SURVEYS

6.1 ON-SITE METHODOLOGY

Each site was visited and all relevant features, as listed below, were noted. A site check sheet was developed as part of the project as an aid to identify all relevant information in terms of soil release. A blank example is included in Appendix A.

It should be noted that the aim of pre, during and post construction geomorphological mapping is to compare features at these different stages. Some sites will possess features prior to any works being undertaken and so therefore the study aims to identify where these types of features may have been exacerbated and/or new features created due to the works. Therefore the extent of any features is also included in the study to determine if there is potential for growth of these features due to the works.

The check sheet included in Appendix A has been developed taking into account standard features of soil release. The feature list has been amended from MacCulloch (2006) to suit the study and the relevant information included. Soil release and erosion features have been identified through the geomorphological mapping that has been developed for this study (Section 6.3).

The following list summarises the features which potentially indicate soil release or erosion and which form part of the checklist:

- Slope instability features, backscarps, soils mounds etc.
- Tension cracks
- Creep/bulging
- Gullies
- Erosion features (rills, bank erosion etc.)
- Sedimentation
- Karst features, and sediment trails from underground channels
- Movement of trees, fences, walls
- Severe rutting
- Subsidence
- Collapse

The main extent of the study was focused on a 50m buffer each side of, or around the selected electricity transmission infrastructure, to ascertain the impacts if any on soils and geology in terms of soil release. This buffer is widely used in assessing soil release features relating to various construction projects, particularly linear projects.

Mapping showing the location of the proposed or existing pole sets or towers were presented on site and annotated with notes and comments of features present that were identified as a result of soil release. Features were also photographed where applicable. Particular attention was taken of the extent of any soil release features, i.e. how far they extended from the proposed structure locations or the constructed structures on post construction sites.

6.2 GEOMORPHOLOGICAL MAPPING

6.2.1 General Terrain Mapping

In this study, geomorphological mapping is used as the main assessment tool to develop a qualitative assessment of the impacts of construction activities from power lines on sensitive soil areas. This method of assessment is regarded as one of the main tools to be used when carrying out geotechnical assessments of sensitive sites in terms of soil release and stability. The main features to be identified through geomorphological mapping are in Table 2.1 and in the list above in Section 6.2.

Geomorphological mapping is a useful tool where information is required about landforms, soils, rocks or other features created by geological or surface processes. It is used extensively as a basis for terrain assessment. Geomorphological mapping can be prepared from mapping and aerial photography however ground truthing by visiting the site is necessary to confirm assumptions gleaned from potentially older mapping or photography (Cooke and Doornkamp, 1990).

Typical features that are identified and mapped as part of a geomorphological mapping exercise include bedrock lithology, geological structures, features resulting from bedrock structure, volcanic features, superficial geology, instability features, aeolian features, coastal features, glacial features, fluvial features, karst features, man-made features and any others of relevance. Gustavsson *et al* (2006) have set out a revised list of features and their relevant mapping symbols, based on an original list set out by Cooke and Doornkamp (1990). These are included in Appendix B as a reference and have been adapted and used as the basis for the geomorphological terrain mapping.

6.2.2 Peat Mapping

Typical features identified during walkover surveys of peat areas to facilitate detailed geomorphological mapping include the following,

- Drainage characteristics and proximity of proposed works to water courses, both natural and artificial including springs, pipes and areas of saturated ground.
- Evidence of past movement such as, tilting trees and structures, failure scars, depressions and lobe features or discrepancies between field boundaries and those on past editions of Ordnance Survey (OS) maps or aerial photographs.
- Evidence of previous changes to the site by infilling, man-made embankments or tips and cuttings e.g. cutaway bog, drainage ditches, ponds, quarries, roads, railways etc.
- Slope gradients and form, such as convex and concave breaks of slope, valleys and depressions.
- Signs of movement through bulging and deformation of roadways, drainage lines and other linear features.
- Evidence of movement due to subsidence, mining or natural underground cavities such as collapsed pipes.
- Signs of distress such as desiccation cracking, fissures, hummocky ground, tension cracks etc.
- Proximity to forestry, cut over bog, burning and other ground disturbance.
- Vegetation types indicative of high water table or changes in soil type and condition.
- Identify areas of potentially unstable ground and potential slide corridors and the consequence of failure.

An example of a typical geomorphological map of a peat area where landslides occurred in 1945, 1990 and 2008 (Dykes and Jennings, 2009) is included in Appendix C.

6.2.3 Erosion Mapping

Williams and Morgan (1976) in Morgan (2005) outline a geomorphological mapping system for erosion mapping which portrays information on distribution and type of erosion, erosivity, runoff, slope length, slope steepness, slope curvature in profile and plan, relief, soil type and land use. The legend for this mapping is included in Appendix D. This type of mapping is used in this study.

6.2.4 Compiled Mapping

The chosen site categories (as outlined in Table 5.1) incorporating sites where high voltage transmission lines were planned, under construction, or operational were surveyed and assessed visually. Qualitative geomorphological mapping was prepared for each site. Mapping was prepared utilising available mapping and aerial photography as well as site data. This is the core basis of the mapping drawings prepared for the study, which are presented in Appendix E of this report. The following data sets were utilised:

- GSI Bedrock mapping
- GSI Karst mapping
- GSI Subsoils database
- OSI 1:50,000 mapping
- OSI 1:10,000 mapping
- OSI 1:5,000 mapping
- OSI 6” historical mapping
- Aerial photography (Google mapping, Bing Mapping)
- Site data

6.3 SEQUENTIAL SURVEYING AS THE METHOD OF INTERPRETING GEOMORPHOLOGICAL MAPS

Sequential surveying is used as the main method of interpreting the differences between geomorphological mapping as part of this study. Sequential surveys evaluate changes on a site by evaluating geomorphological mapping at different dates, and in the case of this study at different stages pre, during and post-construction, and comparing the results.

In the case of slope instability or erosion, changes are identified by changes in the soils cover and landform shape and the presence or absence of geomorphological features discussed in Section 6.3. These can include evidence of disturbance to existing erosion gullies, or increase in siltation and sediment deposit at particular locations during construction. Peat movement is observed through increases in tension cracks, visual evidence of tree or fence movement, or an increase in bulging of peat. Visual interpretation of water quality can be determined through the clarity of the water and if evidence of sediment trails reaching ditches/streams can be seen.

The interpretation of the differences in features identified through the 3 stages, pre, during, and post construction, is the main method of determining the impacts, if any, from overhead power line construction at the chosen sites. Particular reference is drawn to Section 5 regarding the feasibility of during construction and post construction site selection, and the engineering judgements therein.

The findings of the study are outlined in Section 7, with particular reference to the maps in Appendix E.

7 CASE STUDY RESULTS

7.1 OVERVIEW

As set out in Table 5.1 and the preceding sections, site assessments were undertaken for chosen site categories with varying ground conditions and at three construction stages to determine whether the construction of high voltage transmission line projects have had any negative impacts on soils and geology.

The assessment in this report aims to identify if negative impacts have occurred at the sites. The results of this case study are also reviewed in the context of existing evidence determined from the Literature Review in Section 2. The aim is to amass evidence based research, with the aid of available literature, to back up the assessment of impacts and their occurrence from high voltage transmission lines. This report also aims to assess the effectiveness of mitigation measures detailed in EIAs prepared by EirGrid and their consultants utilising best practice as set out in Section 4.

7.2 RESULTS

The results of the case study are based on the findings from the geomorphological maps, prepared for each of the chosen site categories, assessed as part of a sequential survey as detailed in Section 6.3. These geomorphological maps are included in Appendix E, and are an essential record by which the findings of this study can be determined. Table 7.1 outlines each of the chosen site categories and the corresponding geomorphological map references.

Table 7.1 Geomorphological Map References for Each Site Category

Category No.	Project Stage	Site Name	Transmission Line	Transmission Infrastructure	Location	Date Energised (post construction only)	Geomorphological Map Drawing Ref. (refer to Appendix E)
Standard Sites (low lying glacial till)							
1	Pre-Construction	Connemara IMP5 and IMP7	Connemara 110kV Line	2 no. double pole sets	Co. Galway	-	**MDE1020DG0001**
2	During Construction	Connemara IMP5 and IMP7	Connemara 110kV Line	2 no. double pole sets	Co. Galway	-	**MDE1020DG0002**
3	Post Construction	Banoge AM14 to AM16	Banoge 110kV Line	3 no. steel lattice angle towers	Co. Wexford	2012	**MDE1020DG0003**
Non-Standard 1 Sites (karst)							
4	Pre-Construction	Connemara AM44	Connemara 110kV Line	1 no. steel lattice angle tower	Co. Galway	-	**MDE1020DG0004**
5	During Construction	Connemara AM44	Connemara 110kV Line	1 no. steel lattice angle tower	Co. Galway	-	**MDE1020DG0005**
6	Post Construction	Dalton Galway ST3 to ST6	Dalton Galway 110kV Line	4 no. steel lattice angle towers	Co. Galway	2012	**MDE1020DG0006**
Non-Standard 2 Sites (silt/clay)							
7	Pre-Construction	Connemara IMP6	Connemara 110kV Line	1 no. double pole set	Co. Galway	-	**MDE1020DG0007**
8	During Construction	Banoge AM19	Banoge 110kV Line	1 no. steel lattice angle tower	Co. Wexford	-	**MDE1020DG0008**
9	Post Construction	Banoge AM19	Banoge 110kV Line	1 no. steel lattice angle tower	Co. Wexford	2012	**MDE1020DG0009**
Non-Standard 3 Sites (low lying peat)							
10	Pre-Construction	Donegal IMP176 to AM180	Donegal 110kV Line	3 no. double pole sets and 1 no. steel lattice angle tower	Co. Donegal	-	**MDE1020DG0010**
11	During Construction	Donegal IMP176 to AM180	Donegal 110kV Line	3 no. double pole sets and 1 no. steel lattice angle tower	Co. Donegal	-	**MDE1020DG0011**
12	Post Construction	Tarbert Tralee – West of Blake's Cross	Tarbert Tralee 110kV Line	2 no. steel lattice angle towers	Co. Kerry	2011	**MDE1020DG0012**
Worst Case Sites (upland steep sloped peat)							
13	Pre-Construction	Donegal ST244 to 251	Donegal 110kV Line	7 no. double pole sets	Co. Donegal	-	**MDE1020DG0013**
14	During Construction	Donegal ST244 to 251	Donegal 110kV Line	7 no. double pole sets	Co. Donegal	-	**MDE1020DG0014**
15	Post Construction	Derrybrien to Agannygal	Derrybrien to Agannygal 110kV Line	3 no. double pole sets and 1 no. steel lattice angle tower	Co. Galway	2011	**MDE1020DG0015**

All sites assessed have been mapped in terms of their site conditions and soil release features, if any. The mapping illustrates visually the findings of the study. The results of these findings are tabulated in Sections 7.2.1 to 7.2.5 for each site type. The tables presented in these sections summarise the site conditions at each stage of a project as well as outlining the mitigation measures employed during construction. Descriptions of each site are given in Table 7.2.

Table 7.2 Site Descriptions

Ref. No.	Project Stage	Site Name	Location	Site Description
Standard Sites (low lying glacial till)				
1	Pre-Construction	Connemara IMP5 and IMP7	Co. Galway	The pole set locations are on glacial till agricultural pasture land with some scrub and rough grass. The structures are located on slightly sloping ground with slopes of between 0° and 3° approximately. The Barna Stream lies to the east and local drainage channels lie to the east of the pole sets which feed into the Barna Stream. The pole sets are located to the west of the slope crest line. The ground becomes softer towards IMP5.
2	During Construction	Connemara IMP5 and IMP7	Co. Galway	As per Site Ref. 1
3	Post Construction	Banoge AM14 to AM16	Co. Wexford	The site is located on glacial till agricultural pasture land with a small young forest plantation located adjacent to AM15. The land is flat and lies west of the M11. At the time of the visit the field within which AM14 stood was void of any significant vegetation due to being harvested of its crop a short time before the visit. Trees had been cleared to facilitate AM15 and the surrounding area was void of any significant vegetation. During construction works one access way was used and working areas were delineated around structures using posts and wire. Plant worked only within these demarcated areas. Rutting was evident around AM15. AM16 was located across a field boundary and the boundary had been removed to facilitate construction.
Non-Standard 1 Sites (karst)				
4	Pre-Construction	Connemara AM44	Co. Galway	The site is located on improved agricultural land, of peaty origin, with bedrock and boulders outcropping and significant rough grass and brush growth. The bedrock beneath the structure is Porphyritic-Megacrystic Granite, an igneous intrusion, west of the Errisbeg Townland Granite, another igneous intrusive rock. The site is within approximately 2km of the Visean Limestone Formation along the boundary of which the GSI karst database has recorded 2 no. karst features, being swallow holes. The site slopes at about 3° towards the Lough Kip River. Local drainage channels exist around the site and feed into the Lough Kip River. The Lough Kip River flows into Loch Bhaile Uí Choirc which eventually feeds into Lough Corrib, about 4.5km away
5	During Construction	Connemara AM44	Co. Galway	As per Site Ref. 4
6	Post Construction	Dalton Galway ST3 to ST6	Co. Galway	The site is located in agricultural land on till derived from limestone. The site is flat with no significant local drainage. Local industry warehouse is located south east of the structures with residential housing on both sides along the line. Cashla sub-station exists at the end of the line after ST1. The bedrock beneath the site is Visean Limestone Formation. The GSI karst database has records of some karst features in the area, including two caves and a turlough (seasonal waterbody), between about 500m and 1.2km from the site. There are also more recorded features such as caves, enclosed depressions and turloughs in the vicinity. One structure, ST3, has been cordoned off against a boundary wall with stock proof fencing. Two stockpiles of stone and rock exist outside the fencing.
Non-Standard 2 Sites (silt/clay)				
7	Pre-Construction	Connemara IMP6	Co. Galway	The site is located on fine glacial till with low vegetation such as ferns, bushes and briars. The site is located adjacent to agricultural land. The structure is located on steep ground sloping at about 12° towards a local drainage channel to the west less than 20m away from the pole set, which subsequently feeds into the Barna Stream to the east of IMP7. The channel is overgrown with reeds. The Barna Stream flows south towards the Galway Bay Complex SAC located about 600m to the south.
8	During Construction	Banoge AM19	Co. Wexford	The tower is located on glacial till derived from shale and alluvial deposits and is currently agricultural pasture land. The structure is located on ground gently sloping at about 1o, and up to about 3o at the edge of a stream which is located approximately 100m away. The stream is a tributary of the Banoge River, with the Banoge River eventually outfalling into the sea at Courtown. The outfall at Courtwon is located in Courtown Dunes And Glen pNHA. Two foundation pads are located on either side of a boundary ditch. The ditch has been reduced to approximately a metre above existing ground to facilitate erection of the tower with a section of the ditch removed also. Post and wire fencing was in place either side of the lowered ditch. During construction works, one access way was used utilising farm tracks in so far as possible, and the working area was demarcated with posts and wire around the structure. Vegetation was stripped only where excavations were undertaken for foundations and locally to form a level area for plant as necessary. Aluminium plates were put down for plant in the level areas and where access was required through removed ditch. Material excavated was stockpiled adjacent to the excavations within the working area.

Ref. No.	Project Stage	Site Name	Location	Site Description
9	Post Construction	Banoge AM19	Co. Wexford	As per Site Ref. 8
Non-Standard 3 Sites (low lying peat)				
10	Pre-Construction	Donegal IMP176 to AM180	Co. Donegal	The site is located on blanket peat. The Stracashel River runs in a north east, south west direction, north of the structures. The Stracashel River flows into the West of Ardarra/Mass Road SAC which begins about 4 – 4.5km downstream of IMP176, which then becomes and SAC and pNHA further downstream. The area between the proposed IMP176 to 178 has been improved as agricultural pasture land and as forestry. The area between the proposed IMP179 and AM180 is blanket peat with minor drainage at the periphery and some local drainage running through the site. Some sheep traverse the area but the vegetation is heather and moss as would be expected in lowlying peat areas. Peat depth probing in the area indicated depths of peat between 0.5m and 1.9m with rock outcropping particularly around IMP179 and AM180
11	During Construction	Donegal IMP176 to AM180	Co. Donegal	As per Site Ref. 10
12	Post Construction	Tarbert Tralee – West of Blake's Cross	Co. Kerry	The site is located on cutover peat, about 1 to 1.5km south of the Lower River Shannon SAC and Bunnaruddee Bog NHA, and about 3km north of Moanveanlagh Bog SAC and NHA. The Galey River (being part of the Lower River Shannon SAC) is located approximately 1km north east of the structures. Local drainage channels exist around the site which feed into the Galey River. Peat cutting has been undertaken on the site with peat footings being evident around the structure. Vegetation is generally bushes, rushes and high grass. An existing access track is in place from the local road into the peat cut areas around the structures.
Worst Case Sites (upland steep sloped peat)				
13	Pre-Construction	Donegal ST244 to 251	Co. Donegal	The site is located on blanket peat between the River Finn SAC, Meentygrannagh Bog SAC and pNHA, and Cloghernagore Bog and Glenveagh National Park SAC and pNHA. A tributary of the Cummirk River runs north east to south west along the transmission line. The Cummirk River feeds into the River Finn, which is an SAC. The peat has been improved for agricultural purposes with sheep present on site. The site slopes at about 3.5 to 4o towards the Cummirk River Tributary. The site has hummocks and hollows with vegetation of moss and grass. Some local drainage channels run downslope towards the stream. Peat depth probing in the area indicated depths of peat between 1.4m and 2.8m.
14	During Construction	Donegal ST244 to 251	Co. Donegal	As per Site Ref.13
15	Post Construction	Derrybrien to Agannygal	Co. Galway	The site is located on blanket peat in the Slieve Aughty Mountain SPA. The site is also located north and west of the Slieve Aughty Bog NHA. A tributary of the Owendalulleegh River runs along the east of the site, about 100m away. The Owendalulleegh River becomes the Derrywee River/Owendalulleegh River which flows into Lough Cutra. Lough Cutra is an SAC and pNHA. The peat has been forested over the years but is currently cleared in the vicinity of the transmission line. The site slopes towards the north and the Owendalulleegh River tributary at about 3 to 5o. There is a short steeper slope of about 45o roughly halfway along the site. There was the sound of running water in the vicinity of the slope but the area was overgrown. Some cross drains were evident along this section of line, most likely from forestry activity. Vegetation on the site is mainly moss, rushes, young intermittent evergreen trees and heather. Peat depth probing in the area indicated depths of peat between 0.75 and 3.3m. In the vicinity of the steeper slope, peat depths were between 0.1 and 0.5m. Brush was evident on the ground along the line which indicated that this was likely to have been used as a base for the access track during the works. There was also a stone area, about 5m x 5m, adjacent to one of the pole sets which was likely to have been a working area for plant. Some stone was evident around the base of the pole sets. It is likely this was used as a backfill around the cross beams used below ground for stability of the poles. At the steel lattice angle tower, peat had been excavated and the mineral soil below exposed for foundation construction. The mineral soil was still exposed in spots as the entire had not revegetated completely at the time of the site visit. Banks of peat were evident around the base of the tower. The banks are likely to be side cast peat from excavation during the construction activities and have revegetated. This site is similar to the Donegal ST244 to ST251 site, in that it is blanket peat and transitional woodland-scrub on slopes of about 5^{o}, to a site across the valley at Derrybrien Wind Farm where a significant peat failure occurred in 2003 which caused damage to fish stock in Lough Cutra and also caused blockages and damage to local infrastructure.

7.2.1 Standard Sites (low lying glacial till)

Site Name	Transmission Line	Transmission Infrastructure	Location	Project Stage	Results of Findings	Geomorphological Map Drawing (refer to Appendix E)
Connemara IMP 5 and IMP7	Connemara 110kV Line	2 no. double pole sets	Co. Galway	Pre Construction	**Soil Release Features within 50m of proposed development:** No evidence of soil release features were identified at the site before construction commenced. **Other Features of Note:** None	MDE1020DG0001
				During Construction	**Soil Release Features within 50m of proposed development:** No evidence of soil release features were identified during construction, due to mitigations in place. **Mitigation Measures in Place:** One access and egress route. Use of existing farm tracks where possible. Demarcation of working area. All plant, material and storage of spoil within working area. Spill kits readily available on site. Vegetation was stripped only where excavations were undertaken for pole set foundations. All material was used to backfill excavations and mounded up around base of poles. **Other Features of Note:** None	MDE1020DG0002
Banoge AM14 to AM16	Banoge 110kV Line	3 no. steel lattice angle towers	Co. Wexford	Post Construction (completed 2012)	**Soil Release Features within 50m of proposed development:** No evidence of further soil release features were identified after construction, highlighting that there has been no adverse impact to soils and geology due to construction at this site. **Other Features of Note:** None	MDE1020DG0003

7.2.2 Non-Standard 1 Sites (karst)

Site Name	Transmission Line	Transmission Infrastructure	Location	Project Stage	Results of Findings	Geomorphological Map Drawing (refer to Appendix E)
Connemara AM44	Connemara 110kV Line	1 no. steel lattice angle tower	Co. Galway	Pre Construction	**Soil Release Features within 50m of proposed development:** No evidence of soil release features were identified at the site before construction commenced. **Other Features of Note:** None	MDE1020DG0004
				During Construction	**Soil Release Features within 50m of proposed development:** Some evidence of material behind silt trap. Slight indications of material eroded from stockpiles, with one of the stockpiles being very close to the local drainage channel. **Mitigation Measures in Place:** Access and egress off existing local road. Stone platform on geotextile constructed as working platform. Demarcation of working area. All plant, material and storage of spoil within working area. Local drainage channel cleared and silt trap installed. Excavation for tower bases completed within a steel box to minimise excavation and minimise amount of concrete required. Amount of concrete used recorded to ascertain if any materials lost to voids. Spill kits readily available on site. **Other Features of Note:** None	MDE1020DG0005
Dalton Galway ST3 to ST6	Dalton Galway 110kV Line	4 no. steel lattice angle towers	Co. Galway	Post Construction (completed 2012)	**Soil Release Features within 50m of proposed development:** No evidence of further soil release features were identified after construction, highlighting that there has been no adverse impact to soils and geology due to construction at this site. **Other Features of Note:** One structure, ST3, has been cordoned off against a boundary wall with stock proof fencing. Two stockpiles of stone and rock exist outside the fencing.	MDE1020DG0006

7.2.3 Non-Standard 2 Sites (silt / clay)

Site Name	Transmission Line	Transmission Infrastructure	Location	Project Stage	Results of Findings	Geomorphological Map Drawing (refer to Appendix E)
Connemara IMP6	Connemara 110kV Line	1 no. double pole set	Co. Galway	Pre Construction	**Soil Release Features within 50m of proposed development:** No evidence of soil release features were identified at the site before construction commenced. **Other Features of Note:** None	MDE1020DG0007
Banoge AM19	Banoge 110kV line	1no. Steel lattice angle tower	Co. Wexford	During Construction	**Soil Release Features within 50m of proposed development:** No evidence of soil release features were identified during construction, due to mitigations in place. **Mitigation Measures in Place:** One access and egress route. Utilising existing farm tracks. Demarcation of working area. All plant, material and storage of spoil within working area. Aluminium plates where plant required a level platform. Spill kits readily available on site. **Other Features of Note:** The structure is located on ground sloping at about 1°, and up to about 3° at the edge of a stream which is located approximately 100m away. Two foundation pads are located on either side of a boundary ditch. The ditch has been reduced to approximately a metre above existing ground to facilitate erection of the tower with a section of the ditch removed also. Post and wire fencing was in place either side of the lowered ditch.	MDE1020DG0008
				Post Construction (completed 2012)	**Soil Release Features within 50m of proposed development:** No evidence of further soil release features were identified after construction, highlighting that there has been no adverse impact to soils and geology due to construction at this site. **Other Features of Note:** Both sections have been reinstated with post and wire fencing along the ditch. All excavations were reinstated and stockpiled material used or removed off site. The working area has re-vegetated except for very local areas directly beneath the structure. Some stored posts and wire remained on site.	MDE1020DG0009

7.2.4 Non-Standard 3 Sites (low lying peat)

Site Name	Transmission Line	Transmission Infrastructure	Location	Project Stage	Results of Findings	Geomorphological Map Drawing (refer to Appendix E)
Donegal IMP176 to AM180	Donegal 110kV Line	3 no. double pole sets and 1 no. steel lattice angle tower	Co. Donegal	Pre Construction	**Soil Release Features within 50m of proposed development:** Eroded sides to drainage channels and river exposing mineral soil and bedrock, were identified at the site before construction commenced. **Other Features of Note:** None	MDE1020DG0010
				During Construction	**Soil Release Features within 50m of proposed development:** Evidence of material behind silt traps. Some peat particles evident in ponded water where re-vegetation had not yet occurred. Eroded sides to drainage channels and river exposing mineral soil and bedrock. **Mitigation Measures in Place:** Silt traps. Silt fences. Environmental/access mapping for site personnel to follow. One access and egress route. Utilising existing farm tracks. Bog mats used over softer areas. Wide tracked, low ground bearing pressure plant used. Spill kits readily available on site. **Other Features of Note:** Particular access and egress routes were identified for each structure and mapped for site personnel. Farm accesses were used in so far as possible. A stone access was constructed off the local road for 40m for access to AM180 so that the required plant could reach more level ground. Site maps were prepared for site personnel which identified sensitive areas where specific measures were necessary during construction as well as indicating where silt traps and fences were to be installed.	MDE1020DG0011
Tarbert Tralee – West of Blake's Cross	Tarbert Tralee 110kV Line	2 no. steel lattice angle towers	Co. Kerry	Post Construction (completed 2011)	**Soil Release Features within 50m of proposed development:** No evidence of further soil release features were identified after construction, highlighting that there has been no adverse impact to soils and geology due to construction at this site. **Other Features of Note:** None	MDE1020DG0012

7.2.5 Worst Case Sites (upland steep sloped peat)

Site Name	Transmission Line	Transmission Infrastructure	Location	Project Stage	Results of Findings	Geomorphological Map Drawing (refer to Appendix E)
Donegal ST244 to ST251	Donegal 110kV Line	7no. Double pole sets	Co. Donegal	Pre Construction	**Soil Release Features within 50m of proposed development:** Eroded sides to drainage channels and stream exposing mineral soil and bedrock, were identified at the site before construction commenced. **Other Features of Note:** None	MDE1020DG0013
				During Construction	**Soil Release Features within 50m of proposed development:** Some damaged road edges where farm access used. Some sediment plumes on ground up to about 20m long. Evidence of finer peat material suspended in ponded water around reinstated areas. **Mitigation Measures in Place:** Silt traps. Silt fences. Environmental/access mapping for site personnel to follow. One access and egress route. Utilising existing farm tracks. Bog mats used over softer areas. Wide tracked, low ground bearing pressure plant used. Spill kits readily available on site. **Other Features of Note:** During construction, particular access and egress routes were identified for each structure and mapped for site personnel. Farm accesses were used in so far as possible. Site maps were prepared for site personnel which identified sensitive areas where specific measures were necessary during construction as well as indicating where silt traps and fences were to be installed.	MDE1020DG0014
Tarbert Tralee – West of Blake's Cross	Tarbert Tralee 110kV Line	2 no. steel lattice angle towers	Co. Kerry	Post Construction (completed 2011)	**Soil Release Features within 50m of proposed development:** No evidence of further soil release features were identified after construction, highlighting that there has been no adverse impact to soils and geology due to construction at this site. **Other Features of Note:** Some stone was evident around the base of the pole sets. It is likely this was used as a backfill around the cross beams used below ground for stability of the poles. At the steel lattice angle tower, peat had been excavated and the mineral soil below exposed for foundation construction. The mineral soil was still exposed in spots as the entire area had not revegetated completely at the time of the site visit. Banks of peat were evident around the base of the tower. The banks are likely to be side cast peat from excavation during the construction activities and have revegetated.	MDE1020DG0015

7.3 CORRELATION WITH WATER QUALITY & AQUATIC ECOLOGY STUDY

Based on quantitative data available from the Water Quality & Aquatic Ecology EBS report, there have been no long term adverse impacts to water bodies identified as a result of overhead power line construction at the selected sites.

It has been identified that some of the works during construction and control measures taken were not adequate enough, with silt curtains bypassed by pipework, and siting of structures too close to river banks during the routeing phase. This has had a localised impact, but not significant enough to cause deterioration in the morphological status, or long term effects to the status of the water bodies. Oil/diesel at two sites were also observed in nearby channels, and some elevated suspended solids where the site preparation and topsoil stripping had altered the river bank. However, upon analysis of samples taken, no long term adverse impacts were observed.

7.4 SUMMARY CONCLUSIONS ON RESULTS OF CASE STUDY

The site visits and subsequent sequential survey assessment illustrated that the majority of sites visited had no indications of major soil release. There were however some minor localised occurrences of soil release identified at 3no. sites visited for the ‘during construction’ stage, (2no. non-standard sites and the worst case site). In all cases it was evident that any sediment generated had a maximum run out of approximately 20m, and these occurrences were all during adverse weather conditions. Mitigation measures including silt traps were in place in all cases, however it is felt that minimal improvements in site practices by the contractors in these instances could have ensured that these minor occurrences would have been avoided altogether.

The sites visited post-construction had no indications of soil release due to construction activities. In most instances, revegetation has reoccurred around the structures and affected areas, with any expected settlement of backfill material having taken place, and re-grading having been carried out to bring the sites back to equilibrium with their local surroundings. There were some minor reinstatement issues noted at 3no. sites, relating to construction practices rather than soil release. These included minor stone stockpiles left at one site, and excess fencing posts and wire not removed from another site. At the worst case site, there were minor mounds of peat remaining that had not been re-graded or removed post construction, and these have since revegetated. Again, it is felt that these types of minor reinstatement issues could readily be avoided in future with minimal improvements to contractors’ site practices..

Based on the evidence gathered during the site visits, particularly between ‘during’ and ‘post’ construction stages, and given that there were no visual indicators of soil release at any sites post construction (sediment trails, silt run-off), it is deemed that construction activities relating to high voltage transmission lines do not cause detrimental long-term impacts to soils and geology, provided that adequate mitigation measures and construction practices are in place. Table 7.3 gives a summary of the impacts noted at each survey stage.

Table 7.3 Summary of Impacts from Field Surveys

Stage	No. of Sites Visited	No. of Sites with Soil Release Features Identified	Sites Affected	Soil Type	Impacts Noted
Pre Construction	5	2	Donegal IMP176 to IMP180	Non-Standard 3 (Low Lying Peat)	Eroded sides to drainage channels and river exposing mineral soil and bedrock, were identified at the site before construction commenced.
			Donegal ST244 to ST251	Worst Case (Upland Steep Sloped Peat)	Eroded sides to drainage channels and stream exposing mineral soil and bedrock, were identified at the site before construction commenced.
During Construction	5	3	Connemara AM44	Non-Standard 1 (Karst)	Some evidence of material behind silt trap.
					Slight indications of material eroded from stockpiles, with one of the stockpiles being very close to the local drainage channel.
			Donegal IMP176 to IMP180	Non-Standard 3 (Low Lying Peat)	Evidence of material behind silt traps.
					Some peat particles evident in ponded water where re-vegetation had not yet occurred.
					Eroded sides to drainage channels and river exposing mineral soil and bedrock.
			Donegal ST244 to ST251	Worst Case (Upland Steep Sloped Peat)	Some damaged road edges where farm access used.
					Some sediment plumes on ground up to about 20m long.
					Evidence of finer peat material suspended in ponded water around reinstated areas.
Post Construction	5	0			

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 EVIDENCE BASED STUDY CONCLUSIONS

8.1.1 Conclusions from Literature Review

The Soils and Geology EBS sets out to examine the qualitative effects of construction and operation of High Voltage Transmission lines on soil release.

The literature review identified the current status of published literature in relation to soil release or soil movement resulting in siltation or sedimentation, particularly with reference to High Voltage Transmission Projects.

The review highlighted that peer reviewed literature is extremely limited on the implications of High Voltage Transmission Projects on soil release or any other linear type infrastructure. However, the literature indicates that construction is the most critical period in terms of soil release, especially erosion, due to exposure of soils, and peat instability where the peat may be at risk of overloading, failure and release.

To date, there is no legislation which is specific to the protection of soil resources. However, there is currently an EU Thematic Strategy on the protection of soil which includes a proposal for a Soil Framework Directive. This proposed Framework contains common principles for protecting soils across the EU (EirGrid, 2012).

In terms of general soil stability, the literature review revealed that detailed design in accordance with the relevant standards (Eurocode 7 et al), is necessary to facilitate an appropriate design that can mitigate against failure. The detailed design must also take into account the presence of ground water and changes to slope shape due to construction.

In terms of peat stability the literature review indicated that peat is predisposed to more rapid failure due to its low strength parameters, high compressibility and high moisture contents as well as the presence of natural features such as presence of relic failures, cracking or slumping, topography, altitude, slope, subsurface drainage or other detrimental drainage regimes or the presence of weaker shear planes in a soil body. The review indicates that peat failures can occur on slopes as low as 3^{o}. Peat, when failed can also have significant run-out distances once it becomes mobile, and especially where it may enter water courses.

EirGrid guidance and mitigation measures as detailed in Section 4.2.1, include for mitigation by avoidance as part of the initial route selection process for any infrastructure. This is imperative where peat stability is of concern and should always be carried out at the early stages of a project.

In terms of soil release by erosion, the literature review revealed that the main factors influencing erosion are rainfall, erodibility of soil, slope and plant cover, with finer soils being more susceptible to detachment. Disturbance of soil and its exposure can loosen the soil so that it is more easily removed. It is concluded that construction is the most at risk time for erosion as soils are exposed through excavations and in stockpiles. Control of sediments can be gained through the use of temporary measures which either trap sediment, reduce its exposed time, or cover the exposed areas.

The control measures are also applicable to areas of karst where fine soils could be washed out and by the use of traps around the site, the sediment would be prevented from leaving the site.

8.1.2 Conclusions from Case Study

A qualitative assessment of case study sites across a range of soil types was undertaken to ascertain if soil release has occurred on the selected sites due to the construction and operation/maintenance of high voltage transmission lines. A summary of the results from the case study are detailed in Section 7.4.

The following conclusions were determined:

- Mitigations measures, that were in place at sites during construction were observed to be effective in preventing/reducing the effects of soil release at most sites, including sensitive sites. Visual evidence from site assessments highlighted that the mitigation measures have been effective with no indications of detrimental long-term impacts to soils and geology at the study sites. Refer to Table 7.3 for a summary of the impacts from the field surveys.

- Minor localised issues with soil release, generally from stockpiled material placed too close to streams, or lack of suitable revegetation, were identified at 3 of the 5 sites visited during construction. Mitigation measures including silt traps were in place in all cases, however it was felt that minimal improvements in site practices by the contractors in these instances could have ensured that these minor occurrences would have been avoided altogether.

- No visual indicators of soil release were identified at any of the ‘post construction’ sites (sediment trails, silt run-off, etc), with any expected settlement of backfill material having already taken place, and re-grading having been carried out to bring the sites back to equilibrium with their local surroundings. Therefore it is deemed that construction activities relating to high voltage transmission lines do not cause detrimental long-term impacts to soils and geology, provided that adequate mitigation measures and construction practices are in place.

- Some minor reinstatement issues were observed at 3no. 'post construction' sites, relating to construction practices rather than soil release, and with minimal improvements to contractors' site practices, it is felt that these types of minor reinstatement issues could readily be avoided in future

- Current best practice guidance utilised by EirGrid highlights the importance of careful route selection, in terms of minimising environmental impacts, and it is expected that this is a key reason for the lack of significant impacts to soils and geology, based on the study.

- Construction activities relating to high voltage transmission lines are, by their nature, less extensive and intrusive on their surrounding environment in terms of earthworks, compared to other types of linear construction (rail, roads, etc.). This is also considered an important reason for the lack of significant impacts on the soils and geology of the 'post construction' study sites.

- Line refurbishment has not been focused on as part of this study, but it is evident that the same principles of new line construction would apply to line refurbishment also, due to the similar construction methods required, particular in replacing towers and pole sets.

- The main focus of this study has been on the impact of soil release on weaker soils, particularly peat and fine soils. Given that very little evidence of adverse soil release has been identified at sensitive sites as part of the field surveys, particularly due to current mitigation practices, it is concluded that for more robust soil types (those with greater cohesive properties or heavier constituent particles) and less exposed/sensitive areas, very little soil release would be expected as a result of overhead power line construction. This is based on engineering knowledge and experience in dealing with various ground conditions and soil types, and also based on various published research and literature available on the engineering properties of soils, particularly that particle weight and cohesive properties can greatly influence how a soil mass stays intact.

- While this study takes a qualitative approach to the assessment of soil release, it is a robust method of analysis of the impacts of such features, and is one of the main tools used by engineers to determine impacts relating to soil release. Furthermore, cross referenced with the Water Quality & Aquatic Ecology EBS (Section 7.3), for which quantitative analysis of potential impacts to water bodies has been carried out, no long term adverse impacts due to soil release from overhead power line projects is indicated.

8.2 RECOMMENDATIONS

While not within the scope of this study, it may be beneficial to carry out a quantitative assessment on a project specific basis, specifically at the construction stage, to ascertain the actual level of soil release from a site, due to construction activities. If such a quantitative assessment was considered necessary as part of project specific mitigation and monitoring measures, it should incorporate sediment boxes or traps which are monitored, with the amounts of sediment generated being measured. Such a study should be targeted at ‘worst case’ site types (as defined in Section 5.1.1) and undertaken for a period of time before and after construction, so that useful background data could be gained prior to trying to assess the actual impact during the works.

Effective route planning is a key measure to minimising the effect of high voltage transmission infrastructure on soils and geology and is a means of avoiding more sensitive and weaker areas of ground where possible, such as peat, ecologically and environmentally protected areas, exposed sites with steep slopes, karst areas, etc. This is a key consideration, not just from an environmental point of view, but also from a constructability sense, as it is much more difficult to carry out construction activities upon weaker soils with low bearing capacities. Examples of effective route planning include, avoiding exposed silt areas close to rivers/streams, attempting to avoid peat areas where possible, utilising buffers to streams at all structure locations, and spanning sensitive areas where possible. It is important that this is appropriately highlighted during the planning and development phases of all transmission projects, whether they require an EIS or not, in order to inform the decision-making process. While sensitive areas cannot always be avoided, it is evident from the field surveys that the current mitigation measures being practiced, in general, are adequate to prevent adverse impacts from soil release at such sites.

It is recommended that soils and geology, with particular reference to soil release and siltation/sedimentation, form part of any route selection, and to be considered from both an environmental perspective and a technical/constructability perspective, with a detailed report kept of the identification process of the preferred route. The main implications from bypassing this element of the assessment process would be that soil release, through siltation and sedimentation may cause detrimental impacts to sensitive water bodies and aquatic life.

With regard to areas of karst, the GSI datasets for karst and geological mapping must be reviewed prior to any development in limestone areas, as there are major risks in karst areas of sediments becoming mobilised in underground water channels, and potentially making their way to sensitive water bodies.

In terms of positioning structures at the line design stage, in the limited areas where soil release was identified, measurements carried out showed that any sediment generated had a maximum run out of approximately 20m. Therefore it is recommended that a sufficient buffer of 50m be kept at all times where possible between the structure and rivers or streams. In terms of proximity of construction work to water courses, this would be considered a typical best practice mitigation measure within engineering industry. Where a natural buffer cannot be maintained then alternative control measures must be put in place.

Where it is not possible to completely avoid peat, it is very important that all peat areas are assessed prior to construction, in terms of temporary and permanent works. All works must be designed to take into account the likely peat features which predispose it to failure, and which may be present on site. The inherent strength characteristics of the peat should also be considered. Best practice guidance recommends laying bog mats or a geotextile-reinforced/brush-reinforced access road over existing ground. Tracked plant is also recommended to be used where possible, to reduce surface damage. In areas of very poor ground, low ground bearing wide-tracked plant should be used to reduce the loading on soft ground, and mitigate the risk of soil failure in bearing.

All areas should be revegetated so that a full cover of vegetation takes hold post construction around all structures. This can be through re-seeding, turve removal and replacement, or natural revegetation, depending on the flora and fauna at the site, and any other requirements particularly at sensitive sites.

Monitoring of ground movement does not currently form part of the guidance currently in place by EirGrid. Although sensitive peat areas are generally avoided in the route selection process, these sometimes cannot be completely avoided and in these cases it is recommended that ground movement monitoring is put in place as part of a site management plan in the form of string lines and marker posts. This is also recommended for sites with fine soils where a risk of soil release has been identified during the planning process.

Due to the fact that any transmission line will traverse a variety of ground conditions it is recommended that a best practice handbook for soils is developed to illustrate the measures to be put in place during construction, depending on the ground conditions encountered. This handbook could be developed so that the same measures are utilised during operation and maintenance also, to mitigate any negative impacts. This would further improve the long term mitigation throughout all project stages.

Bibliography

Alsharif K. (2010). Construction and Stormwater Pollution: Policy, Violations, and Penalties. Land Use Policy 27(2):612-616. International Journal.

Allen J.R.L. (1992). Principles of Physical Sedimentology. Chapman & Hall. London.

Ball D. M., (2002). Assessment of the Proposed Development in relation to Soils, Peat, Bedrock, Groundwater and Surface Water and their influence on other planning issues under consideration. Report for An Bord Pleanala.

Boylan, N. (2008). The shear strength of peat (Doctoral dissertation, University College Dublin).

Boylan N., Jennings P. & Long M., (2008). Peat Slope Failures in Ireland and Stability Assessment. Reinforce Water 2008 – Engineering and Environmental Consideration in Construction over Peat. BGS, Murchison House, Edinburgh.

Brunsden, D. (1969). The moving cliffs of Black Ven. *Geographical Magazine* 41(5):372-374.

CIGRÉ (1999). SC22 WG07 Refurbishment and Upgrading of Foundations, (Brochure No. 141)

CIRIA (2006). Control of Water Pollution from Linear Construction Projects (C648, C649, & C650).

CIRIA (2010). Environmental Good Practice on Site (C692).

Clarke, B.A. & Burbank, D.W., (2010). Bedrock fracturing, threshold hillslopes, and limits to the magnitude of bedrock landslides. Earth and Planetary Science Letters: Dept. of Earth Science, University of California.

Cooke R.U. & Doornkamp J.C., (1990) Geomorphology in Environmental Management, An Introduction.

Craig, R.F. (2004). Craig's Soil Mechanics, Seventh Edition. Taylor and Francis

Creighton R., (2006). Landslides in Ireland: A Report of the Irish Landslides Working Group. Geological Survey of Ireland. Dublin.

Dargie T., (2004). Windfarm Impacts on Blanket Peat Habitats in Scotland. IEEM Renewable Conference, London.

DECLG, 2006. The Department of the Environment, Community and Local Government: Wind Energy Development Guidelines. DECLG.

DOE (1996). UK Department of Environment. Planning Policy Guidance: Development on Unstable Land: Landslides and Planning. PPG14, Annex 1.

Duff D., (1993). Holmes Principles of Physical Geology. 4th Edition. Chapman & Hall. London.

Dykes, A. P. (2008). Geomorphological maps of Irish peat landslides created using hand-held GPS. Journal of Maps, 4(1), 258-276.

ESBI (2012), Clashavoon – Dunmanway 110kV Project 110kV Overhead Line Construction Methodology.

EirGrid (2008). Environmental Impact Statement: Donegal 110kV Project. ESB International.

EirGrid (2012). Environmental Report for the Grid25 Implementation Programme 2011–2016: Strategic Environmental Assessment. EirGrid.

EirGrid (2012). Grid25 Implementation Programme (IP) 2011-2016. EirGrid.

ESB Networks (2008). Environmental Impact Statement: Connemara 110kV Project. ESB International.

Gray D. H. & Sotir R. B., (1996). Biotechnical and Soil Bioengineering Slope Stabilisation: A Practical Guide for Erosion Control. Wiley & Sons Inc. United States.

Gustavsson, M., Kolstrup, E., Seijmonsbergen, A.C. (2006). A new symbol-and-GIS based detailed geomorphological mapping system: Renewal of a scientific discipline for understanding landscape development. Department of Earth Sciences, Physical Geography, Uppsala University, Sweden

Gyssels, G., Poesen, J., Bochet, E., & Li, Y. (2005). Impact of plant roots on the resistance of soils to erosion by water: a review. Progress in Physical Geography, 29(2), 189-217.

Harbor J, (1999). Engineering geomorphology at the cutting edge of land disturbance: erosion and sediment control. Geomorphology 31, 247–263. International Journal.

Harrison E., Norris R., & Wilkinson S., (2007). The Impact of Fine Sediment Accumulation on Benthic Macroinvertebrates. Charles Stuart University. New South Wales.

Hebib, S. (2001). Experimental investigation on the stabilisation of Irish peat (Doctoral dissertation, Ph. D. thesis, 2001, University of Dublin, Trinity College).

Hobbs N.B, (1986). Mire morphology and the properties and behaviour of some British and foreign peats. Quarterly Journal of Engineering Geology and Hydrogeology 1986, v.19: p.7-80.

Hughes, D., Sivakumar, V., Glynn, D., & Clarke, G. (2007). A case study: delayed failure of a deep cutting in lodgement till. Proceedings of the Institution of Civil Engineers-Geotechnical engineering, 160(4), 193-202.

IFI (2006), Requirements for the Protection of Fisheries Habitat during Construction and Development Works at River Sites. ERFB.

IS EN 1997-1 (2005) Eurocode 7: Geotechnical Design – Part 1: General Rules (+ INA 2007)

IS EN 1997- (2007) Eurocode 7: Geotechnical Design – Part 2: Ground Investigation and Testing

IWEA, 2012. Best Practice Guidelines for the Irish Wind Energy Industry. Fehily Timoney & Co.

Jennings P., (2005). Slope Instability in Ireland with Particular Reference to Peat Failures. Presented at the IEI West Region – GSI meeting.

Join Research Network (2012). The State of Soil in Europe: A contribution of the JRC to the EEA Environment State and Outlook Report – SOER 2010. Joint Research Centre.

Lindsay R. & Bragg O., (2004). Wind Farms and Blanket Peat: The Bog Slide of 16 October 2003 at Derrybrien Co. Galway, Ireland. Report to V.P. Shields & Son. University of East London.

Long M, (2004). Review of Peat Strength, Peat Characterisation and Constitutive Modelling of Peat with Reference to Landslides. Dept. of Civil Engineering, University College Dublin.

MacCulloch F, (2006). Guidelines for the risk management of peat slips on the construction of low volume/low cost roads over peat. Forestry Civil Engineering, Forestry Commission, Scotland.

Mahler, B.J., & Lynch, F.L. (1999). Muddy waters: Temporal variation in sediment discharging from a karst spring. J. Hydrol., 214: 165-178.

Mahler, B.J., Lynch, F.L., Bennett, P.C. 1998. Mobile sediment in an urbanizing karst aquifer: implications for contaminant transport. Environ. Geol., 39:25-39.

Morgan, R.P.C., (2005), Soil erosion and Conservation.

Morgan R. P. C. & Richardson R.J., (1995). Slope Stabilization and Erosion Control. Chapman & Hall. London.

Mullan, G. (2003). Caves of County Clare and South Galway. The University of Bristol Spelaeological Society, 259pp.

Perry, J. (1989). A Survey of Slope Condition on Motorway Earthworks in England and Wales. Transport Research Laboratory, Crowthorne, 1989, Research Report RR 199.

Ryan T., Phillips H., Ramsey J, & Dempsey J., (2004) Forest Road Manual – Guidelines for the Design, Construction and Management of Forest Roads. Coford, National Council for Forest & Development.

Scottish Executive (2006). Peat Landslide Hazard and Risk Assessments. Best Practice Guide for Proposed Electricity Generation Developments. Scottish Executive.

Skempton, A.W. and Delory, F.A (1957). Stability of natural slopes in London clay. Proc. 4th International Conference on Soil Mechanics and Foundation Engineering, 2, pp 378-381.

Swift, L.W., Jr, (1984). Soil losses from roadbeds and cut and fill slopes in the Southern Appalachian Mountains. Southern Journal of Applied Forestry 8(4): 209-215.

Tyner, J.S., Yoder, D.C., Chomicki, B.J., & Tyagi, A. (2011). A review of construction site best management practices for erosion control. Trans. ASABE. 54(2):441-450.

UK Department of Environment, (1996). Development of unstable land: Landslides and Planning. UK Department of Environment Planning Policy Guidance. United Kingdom.

USEPA. (2005). Contaminated Sediment Remediation Guidance for Hazardous Waste Sites. Office of Solid Waste and Emergency Response. EPA-540-R-05-012. OSWER 9355.0-85. December.

Warburton J. Holden J. & Mills A. (2004). Hydrological Controls of surficial mass movements in peat. Earth Science Reviews 67 (2004) 139-156.

White W.B., (1988) Geomorphology and Hydrology of Karst Terrains. Oxford University Press. Oxford.

Williams, J.H., (2003), International Best Practices for Assessing and Reducing the Environmental Impacts of High-Voltage Transmission Lines, Third Workshop on Power Grid Interconnection in Northeast Asia, Vladivostok, Russia, September 30 -October 3, 2003.

Wood, P. J., & Armitage, P. D. (1997). Biological Effects of Fine Sediment in the Lotic Environment. Environmental Management 21, 203-217.

APPENDIX A

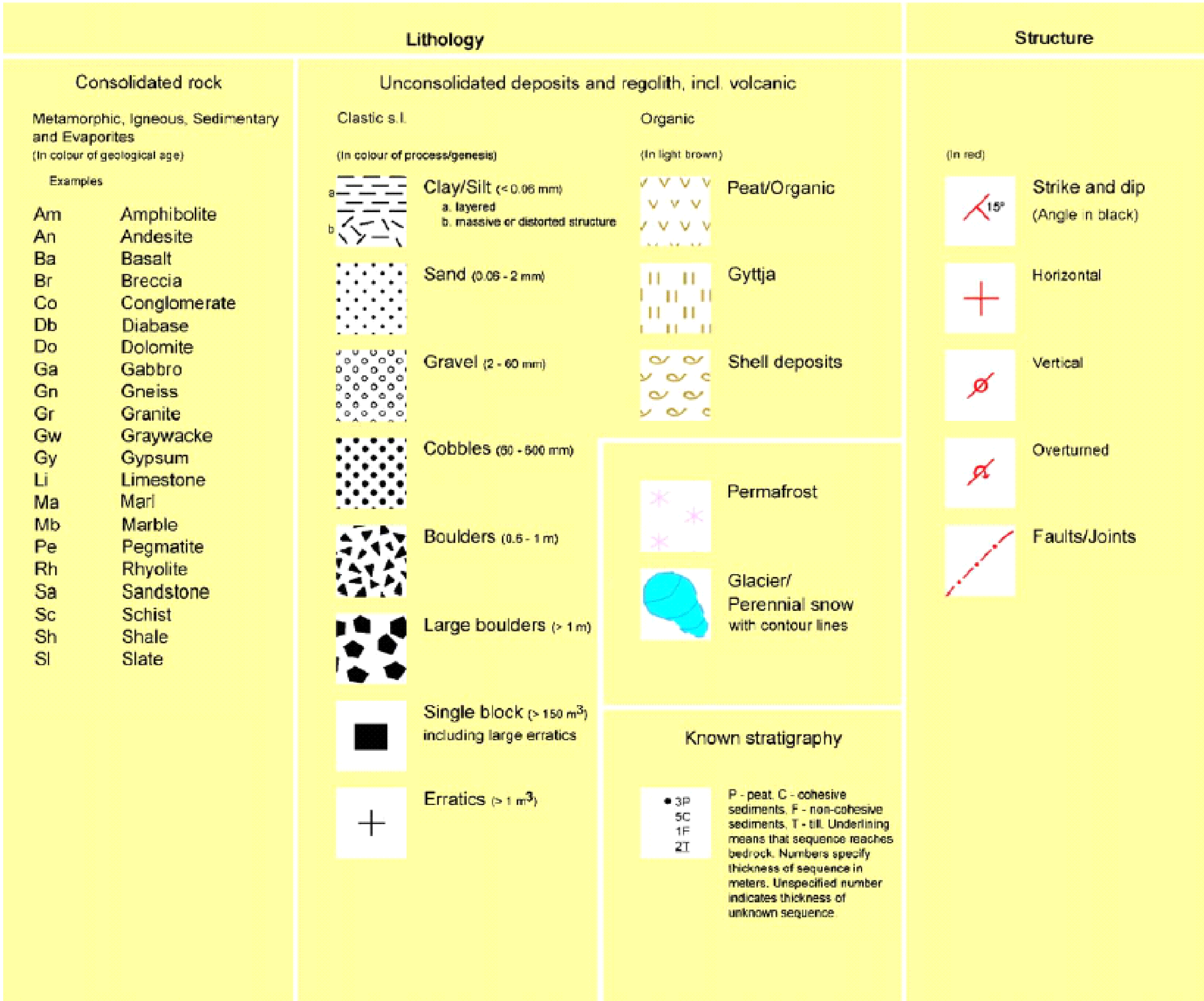
Site Visit Check Sheet Template

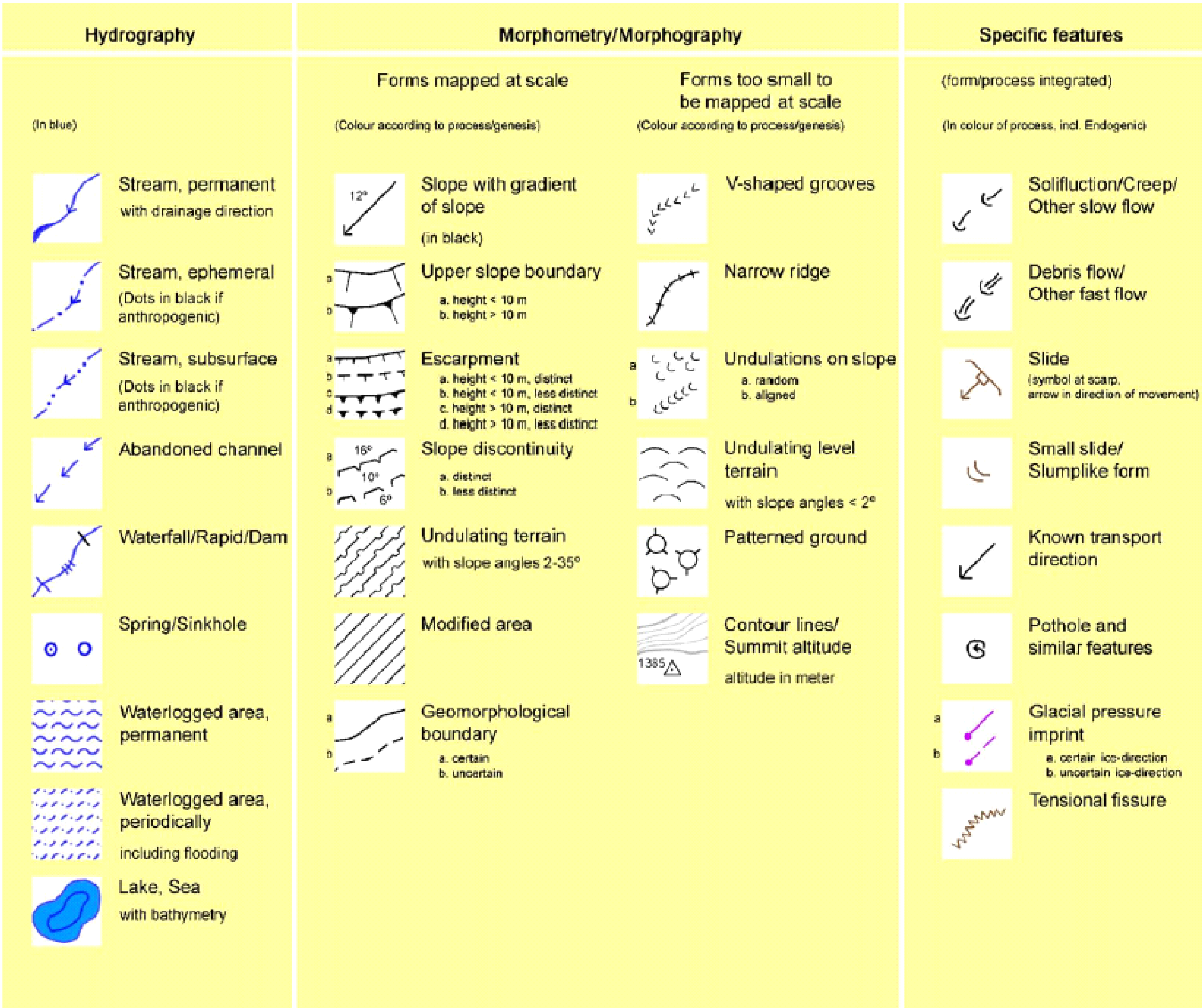
EirGrid Evidence Based Study
Soils and Geology

Site Visit Check Sheet		
Site:		
Location:		
Date:		
Weather:		
General Site Description (type of ground, vegetation, features present etc…)**:**		
Details of Current Site Operations:		
Observations (tick relevant observations and include details):		
Site Slope (steep gradients??)		
Slope Breaks		
Ground Conditions		
Subsoil		
Bedrock		
Slope Instability Features		
Tension Cracks		
Creep/Bulging		
Water Features		
Gullies		
Erosion Features (Rills, bank erosion etc..)		
Sedimentation		
Karst Features		
Man Made Features		
Saturated Ground		
Soft Ground		
Movement of Trees, Fences, Walls		
Large Peat Pipes / Springs		
Blocked Drainage		
Undermining		
Severe Rutting		
Subsidence		
Collapse		
Seepage		
Ponding		
Stockpiles		
Bog Holes		
Deep Peat		
OTHER		
Photographs of features, observations etc…. (✓ or ×)		

APPENDIX B

General Terrain Mapping Legend (after Gustavsson *et al*, 2006)

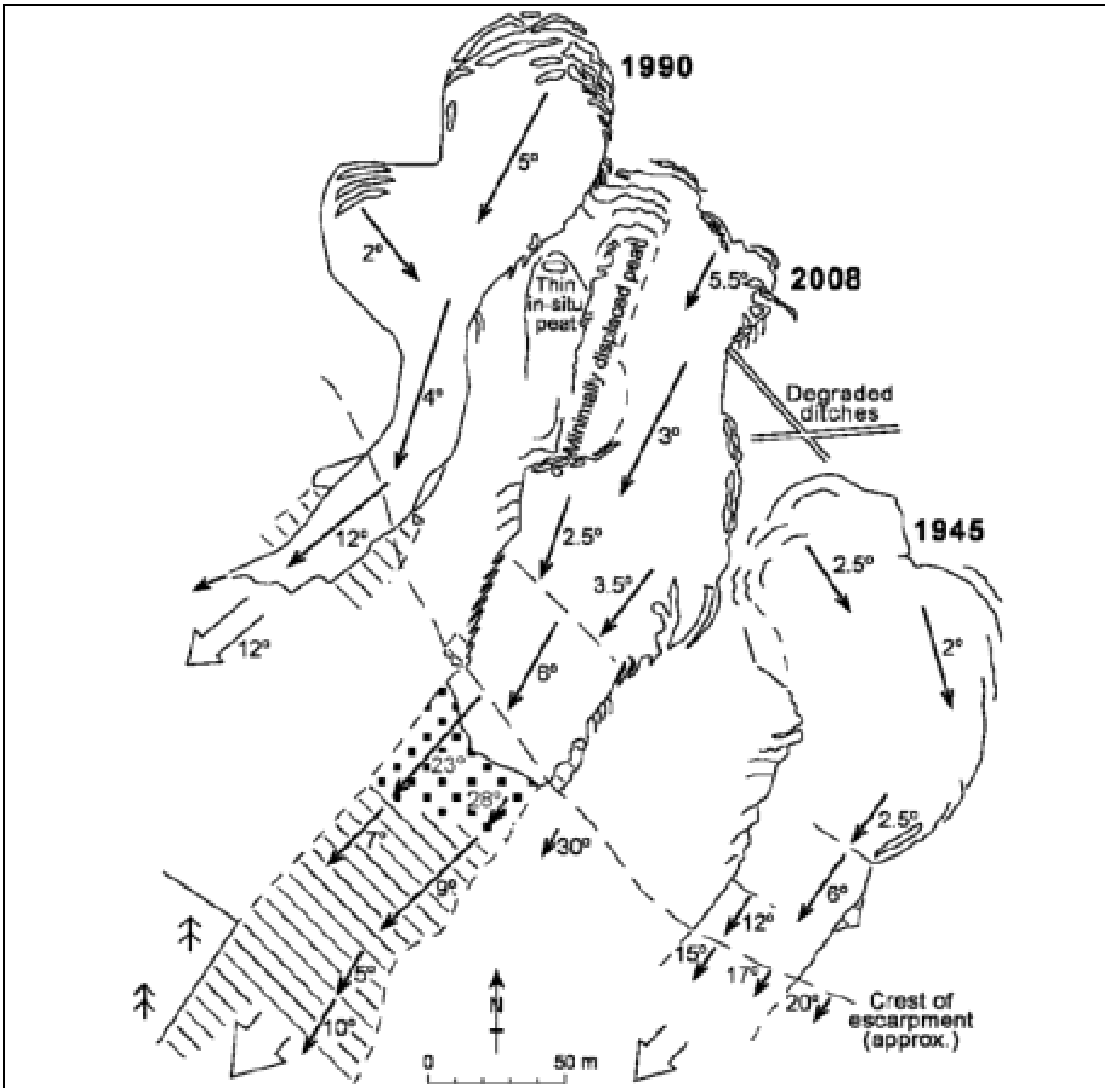

Lithology
Structure
Consolidated rock
Metamorphic, Igneous, Sedimentary and Evaporites
(In colour of geological age)
Examples
Am Amphibolite
An Andesite
Ba Basalt
Br Breccia
Co Conglomerate
Db Diabase
Do Dolomite
Ga Gabbro
Gn Gneiss
Gr Granite
Gw Graywacke
Gy Gypsum
Li Limestone
Ma Marl
Mb Marble
Pe Pegmatite
Rh Rhyolite
Sa Sandstone
Sc Schist
Sh Shale
Sl Slate
Unconsolidated deposits and regolith, incl. volcanic
Clastic s.l.
(In colour of process/genesis)
a
b
Clay/Silt (< 0.06 mm)
a. layered
b. massive or distorted structure
Sand (0.06 - 2 mm)
Gravel (2 - 60 mm)
Cobbles (60 - 600 mm)
Boulders (0.6 - 1 m)
Large boulders (> 1 m)
Single block (> 150 m³)
including large erratics
Erratics (> 1 m³)
Organic
(In light brown)
Peat/Organic
Gyttja
Shell deposits
Permafrost
Glacier/
Perennial snow
with contour lines
Known stratigraphy
• 3P
5C
1F
2T
P - peat. C - cohesive sediments. F - non-cohesive sediments. T - till. Underlining means that sequence reaches bedrock. Numbers specify thickness of sequence in meters. Unspecified number indicates thickness of unknown sequence.
(In red)
15°
Strike and dip
(Angle in black)
Horizontal
Vertical
Overturned
Faults/Joints



Hydrography
(In blue)
Stream, permanent
with drainage direction
Stream, ephemeral
(Dots in black if anthropogenic)
Stream, subsurface
(Dots in black if anthropogenic)
Abandoned channel
Waterfall/Rapid/Dam
Spring/Sinkhole
Waterlogged area, permanent
Waterlogged area, periodically
including flooding
Lake, Sea
with bathymetry
Morphometry/Morphography
Forms mapped at scale
(Colour according to process/genesis)
12°
Slope with gradient of slope
(in black)
Upper slope boundary
a. height < 10 m
b. height > 10 m
Escarpment
a. height < 10 m, distinct
b. height < 10 m, less distinct
c. height > 10 m, distinct
d. height > 10 m, less distinct
Slope discontinuity
a. distinct
b. less distinct
16°
10°
6°
Undulating terrain
with slope angles 2-35°
Modified area
Geomorphological boundary
a. certain
b. uncertain
Forms too small to be mapped at scale
(Colour according to process/genesis)
V-shaped grooves
Narrow ridge
Undulations on slope
a. random
b. aligned
Undulating level terrain
with slope angles < 2°
Patterned ground
Contour lines/ Summit altitude
altitude in meter
1385
Specific features
(form/process integrated)
(In colour of process, incl. Endogenic)
Solifluction/Creep/ Other slow flow
Debris flow/ Other fast flow
Slide
(symbol at scarp, arrow in direction of movement)
Small slide/ Slumplike form
Known transport direction
Pothole and similar features
Glacial pressure imprint
a. certain ice-direction
b. uncertain ice-direction
Tensional fissure

APPENDIX C

Sample Peat Terrain Geomorphological Map (after Dykes and Jennings, 2009)


1990
5°
2°
4°
12°
12°
Thin
in-situ
peat
Minimally displaced peat
5.5°
2008
3°
Degraded
ditches
2.5°
3.5°
1945
2.5°
2°
6°
23°
28°
7°
30°
9°
2.5°
6°
12°
15°
17°
20°
Crest of
escarpment
(approx.)
5°
10°
N
0
50 m

APPENDIX D

Erosion Mapping Legend (after Williams and Morgan 1976, and Morgan, 2005)

Symbol	Feature	Colour
	Perennial water course	blue
	Seasonal water course	blue
	Crest line	brown
	Contour line	brown
	Major escarpment	brown
	Convex slope break	brown
	Concave slope break	brown
	Waterfall	blue
	Rapids	blue
	Edge of flood plain	blue
	Edge of river terrace	blue
	Back of river terrace	blue
	Swamp or marsh	blue
	Active gully	red
	Stable gully	blue
	Active rills	red
	Sheetwash/rainsplash (inter-rill erosion)	red
	River bank erosion	red
	Landslide or slump scar	red
	Landslide or slump tongue	red
	Small slides, slips	red
	Colluvial or alluvial fans	brown
	Sedimentation	brown
	Landuse boundary (landuse denoted by letter e.g. R – rubber; F – forest; P – grazing land; L – arable land.)	green
	Roads and tracks	black
	Railway	black
	Cutting	black
	Embankment	black
	Buildings	black
	Terrace	black
	Waterway	black

SLOPES

- 0–1°
- 2–3°
- 4–8°
- 9–14°
- 15–19°
- over 19°

APPENDIX E

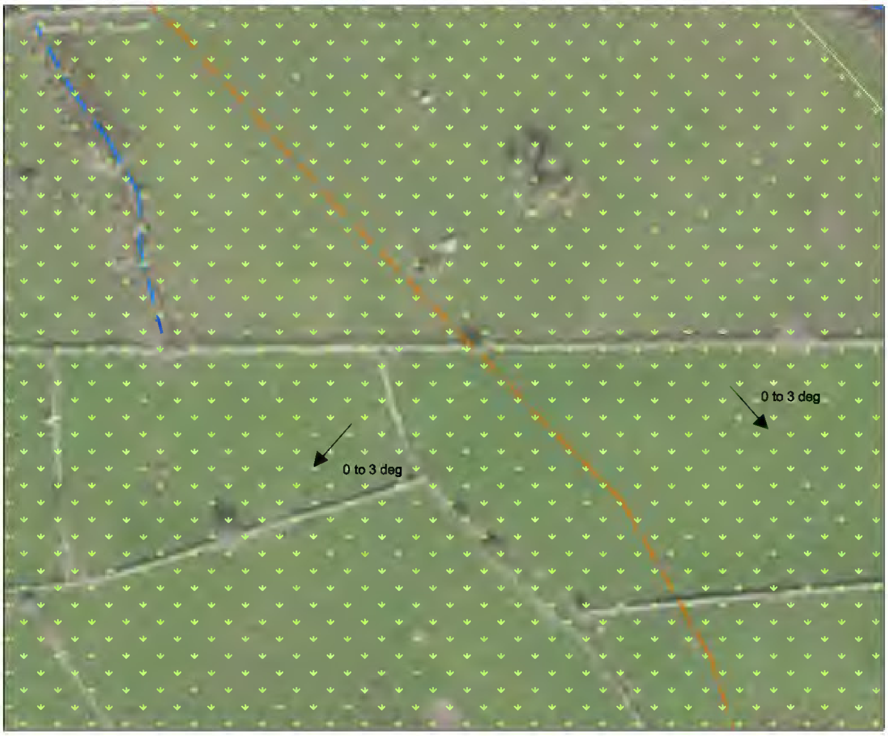
Geomorphological Map Drawings

MDE1020DG1001

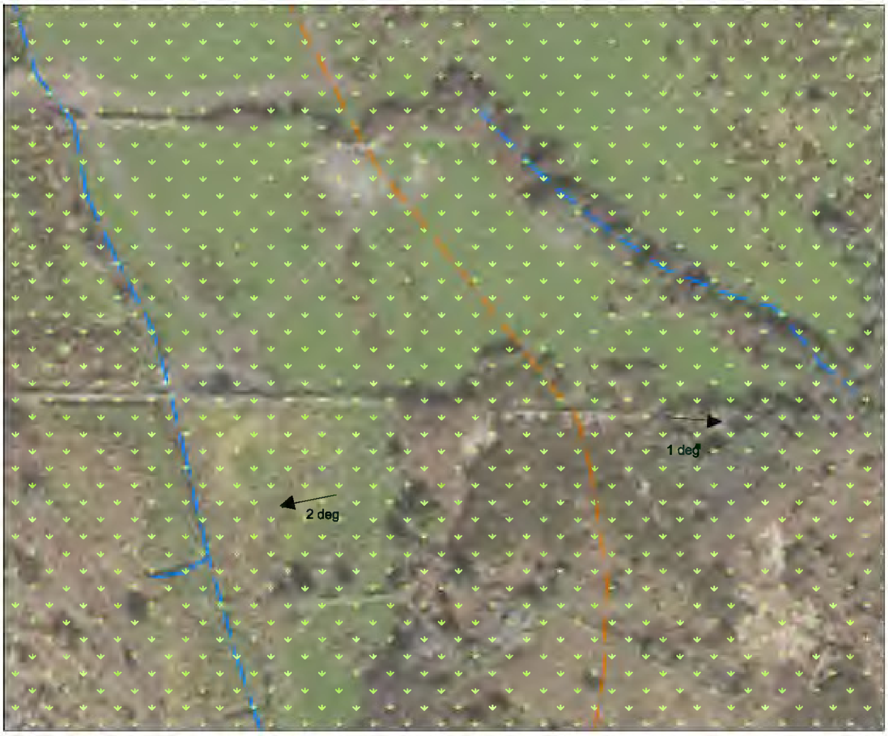
to

MDE1020DG1015

IMP7



IMP5

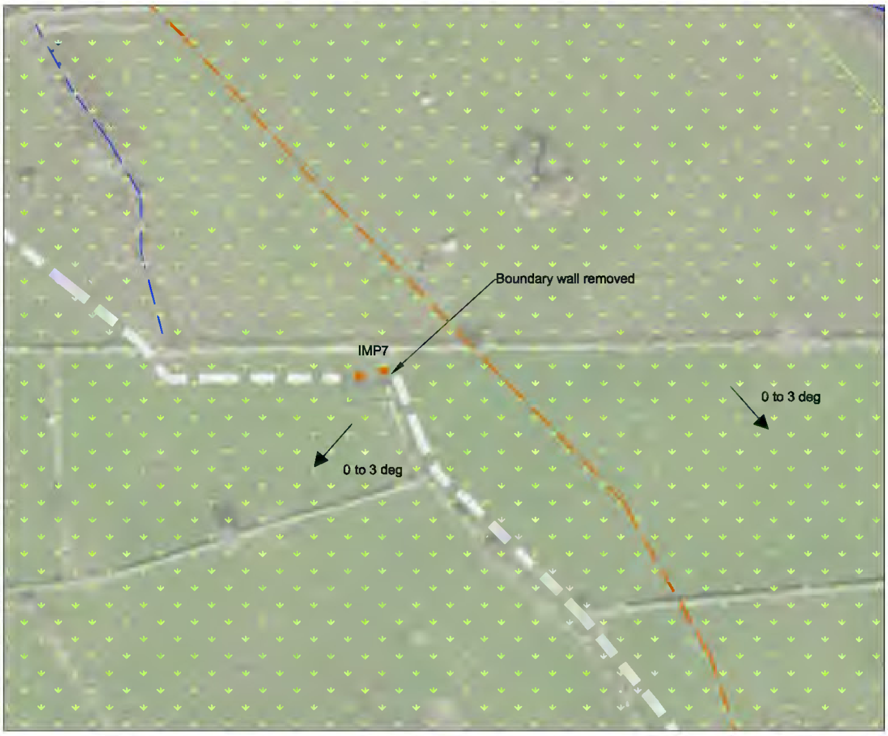


LEGEND

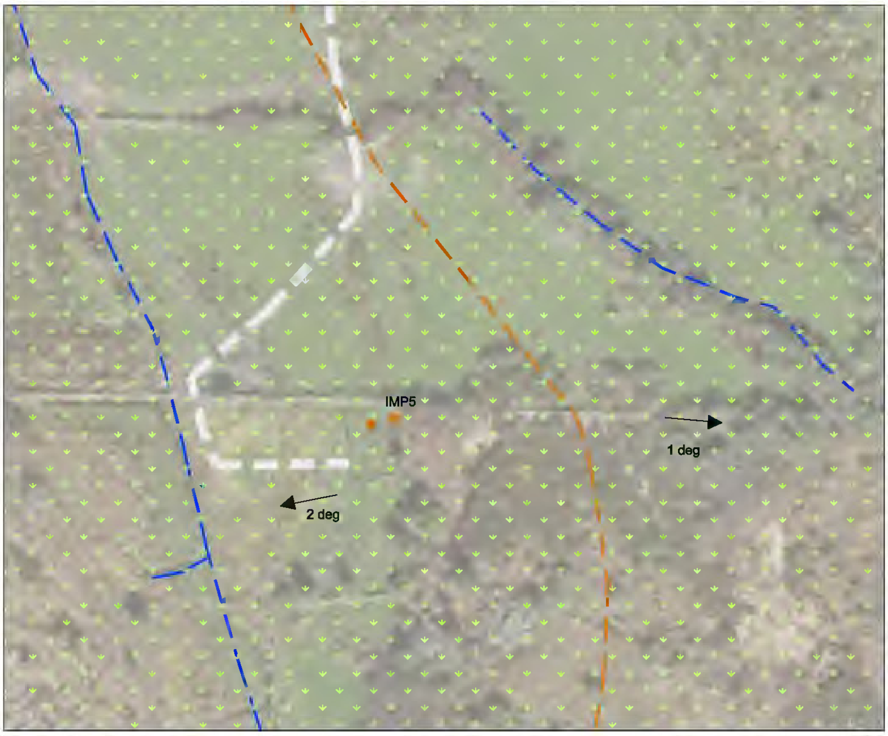
- Perennial Watercourse
- Seasonal Watercourse/local drainage channels
- Railway
- Road/Track
- Cutting
- Buildings
- 6deg Slope and Slope Direction
- Pole Set
- Steel Structure
- Crest Line
- Exposed Bedrock/Rock
- Improved Agricultural/ Reclaimed Peat
- Agricultural
- Peat/Peat Cutting
- Forestry
- Active Gully
- Stable Gully
- Active Rills
- Sheetwash/rainsplash (inter-rill erosion)
- River Bank Erosion
- Landslide or Slump Scar
- Landslide or Slump Tongue
- Small Slides, Slips
- Sedimentation
- Silt Trap
- Silt Fence
- xxx Peat Depth Probe
- Stock Proof Fence
- Stockpiles
- Temporary Fencing
- Access Route
- Bog Mats
- Hardstanding/Stone Access

Client:		Project:	Issue Details		Office Use Only	
EIRGRID	RPS	Evidence Based Studies - Soils and Geology	Drawn:	GMcl	Job No. MDE1020	
			Checked:	WO	File Ref. MDE1020DG0001	
		Title: Standard Site - Pre Construction - Connemara 110kV IMP5 and 7	Approved:	GMcl	Fig No. DG0001	Rev. D01
			Scale:	NTS		
			Date:	01/05/13		

IMP7



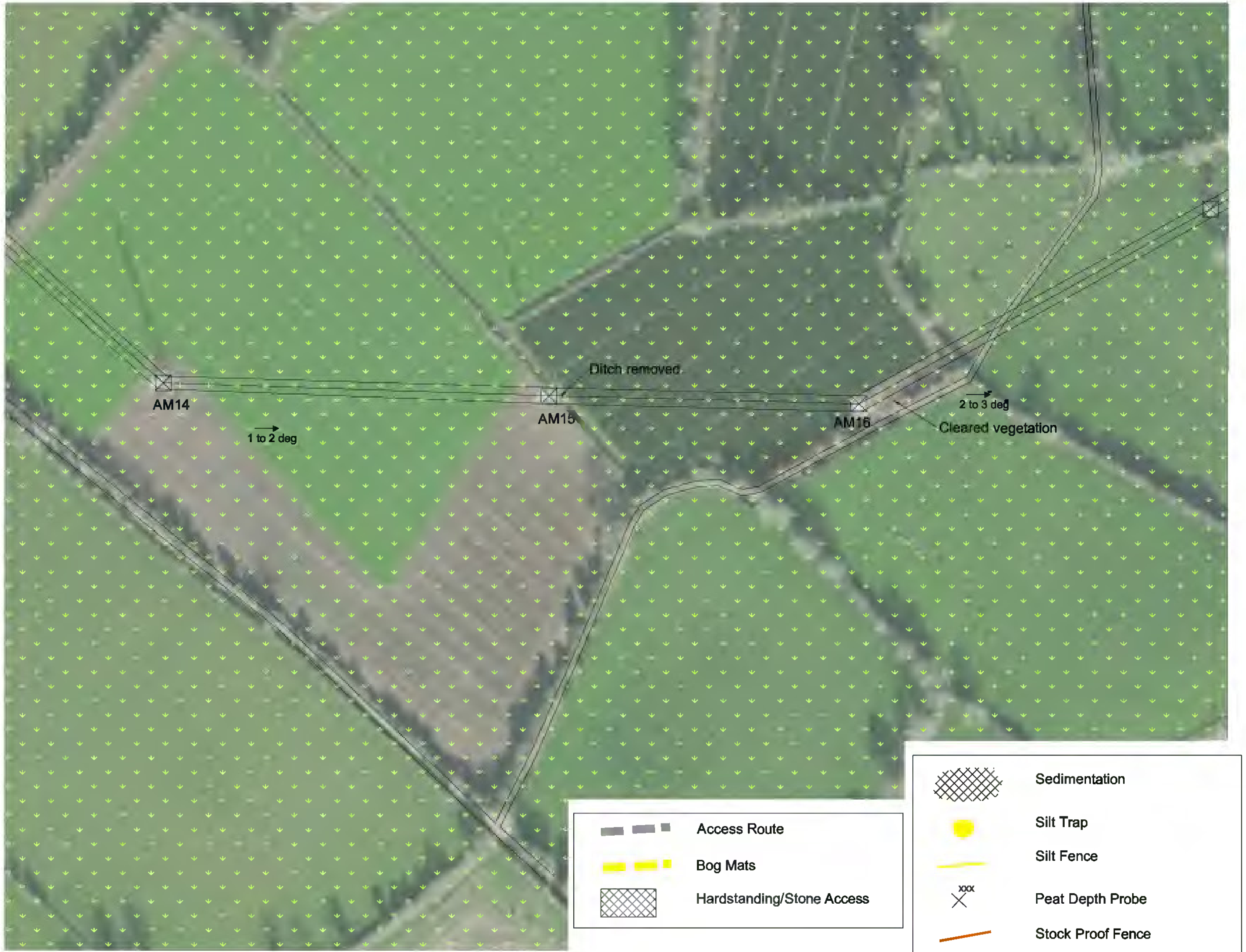
IMP5



LEGEND

- Perennial Watercourse
- Seasonal Watercourse/local drainage channels
- Railway
- Road/Track
- Cutting
- Buildings
- Slope and Slope Direction (6deg)
- Pole Set
- Steel Structure
- Crest Line
- Exposed Bedrock/Rock
- Improved Agricultural/ Reclaimed Peat
- Agricultural
- Peat/Peat Cutting
- Forestry
- Active Gully
- Stable Gully
- Active Rills
- Sheetwash/rainsplash (inter-rill erosion)
- River Bank Erosion
- Landslide or Slump Scar
- Landslide or Slump Tongue
- Small Slides, Slips
- Sedimentation
- Silt Trap
- Silt Fence
- Peat Depth Probe (xxx)
- Stock Proof Fence
- Stockpiles
- Temporary Fencing
- Access Route
- Bog Mats
- Hardstanding/Stone Access

Client: EIRGRID	RPS	Project: Evidence Based Studies - Soils and Geology	Issue Details		Office Use Only	
			Drawn:	GMcl	Job No.	MDE1020
			Checked:	WO	File Ref.	MDE1020DG0002
		Title: Standard Site - During Construction - Connemara 110kV IMP5 and 7	Approved:	GMcl	Fig No. DG0002	Rev. D01
			Scale:	NTS		
			Date:	01/05/13		



	Access Route
	Bog Mats
	Hardstanding/Stone Access

	Sedimentation
	Silt Trap
	Silt Fence
xxx	Peat Depth Probe
	Stock Proof Fence
	Stockpiles
	Temporary Fencing

LEGEND

	Perennial Watercourse
	Seasonal Watercourse/local drainage channels
	Railway
	Road/Track
	Cutting
	Buildings
6deg	Slope and Slope Direction
	Pole Set
	Steel Structure
	Crest Line
	Exposed Bedrock/Rock
	Improved Agricultural/ Reclaimed Peat
	Agricultural
	Peat/Peat Cutting
	Forestry
	Active Gully
	Stable Gully
	Active Rills
	Sheetwash/rainsplash (inter-rill erosion)
	River Bank Erosion
	Landslide or Slump Scar
	Landslide or Slump Tongue
	Small Slides, Slips

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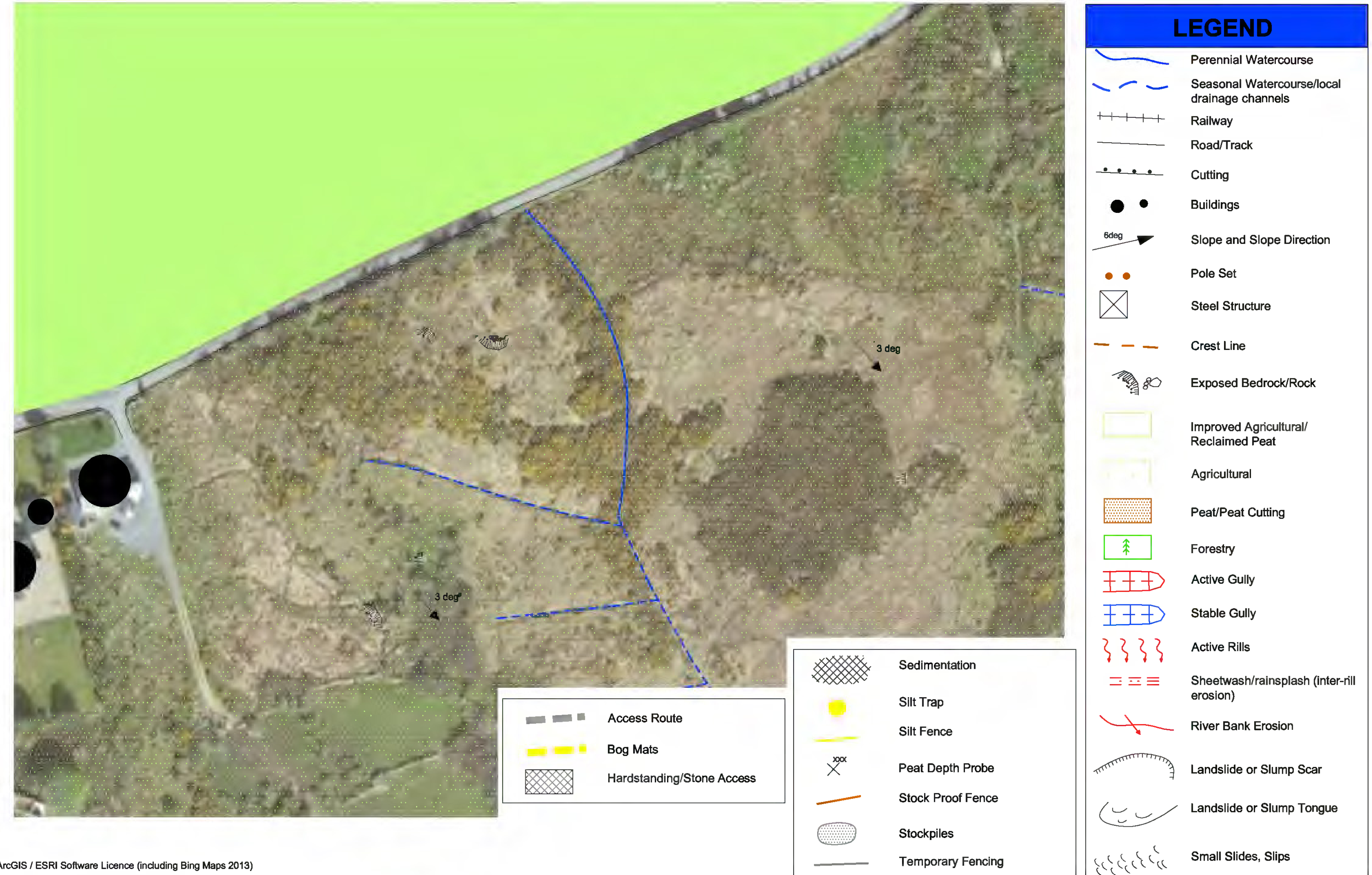
3. DO NOT SCALE, use figured dimensions only, if in doubt ask.

No.	Date	Drn. / App.	Amendment / Issue	App.
XXX	XXXX	XX / XX	XXXXXXX	XXX

Project: Evidence Based Studies - Soils and Geology

Title: Standard Site - Post Construction - Banoge 110kV AM14 to 16

Drawn by:	GMcl	Job No:	MDE1020
Checked by:	WO	File No:	MDE1020DG0003
Approved by:	GMcl	Drg. No: DG0003	Rev: D01
Scale:	NTB		
Date:	01/05/13		



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No.	Date		Amendment / Issue	App.
XXX	XXXX		XXXXXXX	XXX

Project: Evidence Based Studies - Soils and Geology

Title: Non-standard 1 Site - Pre Construction - Connemara AM44

Drawn by:	GMcI	Job No:	MDE1020
Checked by:	WO	File No:	MDE1020DG0004
Approved by:	GMcI	Drg. No: DG0004	Rev: D01
Scale:	NTS		
Date:	01/05/13		

LEGEND

- Perennial Watercourse
- Seasonal Watercourse/local drainage channels
- Railway
- Road/Track
- Cutting
- Buildings
- Slope and Slope Direction (6deg)
- Pole Set
- Steel Structure
- Crest Line
- Exposed Bedrock/Rock
- Improved Agricultural/ Reclaimed Peat
- Agricultural
- Peat/Peat Cutting
- Forestry
- Active Gully
- Stable Gully
- Active Rills
- Sheetwash/rainsplash (inter-rill erosion)
- River Bank Erosion
- Landslide or Slump Scar
- Landslide or Slump Tongue
- Small Slides, Slips

Client: EIRGRID

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No.	Date		Amendment / Issue	App.
XXX	XXXX	XX	XXXXXXX	XXX

Project: Evidence Based Studies - Soils and Geology

Title: Non-standard 1 Site - During Construction - Connemara AM44

Drawn by: GMcl	Job No: MDE1020		
Checked by: WO	File No: MDE1020DG0005		
Approved by: GMcl	Drg. No: DG0005	Rev: D01	
Scale: NTS			
Date: 01/05/13			

LEGEND

- Perennial Watercourse
- Seasonal Watercourse/local drainage channels
- Railway
- Road/Track
- Cutting
- Buildings
- Slope and Slope Direction (6deg)
- Pole Set
- Steel Structure
- Crest Line
- Exposed Bedrock/Rock
- Improved Agricultural/ Reclaimed Peat
- Agricultural
- Peat/Peat Cutting
- Forestry
- Active Gully
- Stable Gully
- Active Rills
- Sheetwash/rainsplash (inter-rill erosion)
- River Bank Erosion
- Landslide or Slump Scar
- Landslide or Slump Tongue
- Small Slides, Slips
- Sedimentation
- Silt Trap
- Silt Fence
- Peat Depth Probe (xxx)
- Stock Proof Fence
- Stockpiles
- Temporary Fencing
- Access Route
- Bog Mats
- Hardstanding/Stone Access

Client:		Project:	Issue Details		Office Use Only	
EIRGRID	RPS	Evidence Based Studies - Soils and Geology	Drawn:	GMcl	Job No.	MDE1020
			Checked:	WO	File Ref.	MDE1020DG0006
		Title: Non-standard 1 Site - Post Construction - Dalton Galway 110kV ST3 to 6	Approved:	GMcl	Fig No. DG0006	Rev. D01
			Scale:	NTS		
			Date:	01/05/13		

LEGEND

- Perennial Watercourse
- Seasonal Watercourse/local drainage channels
- Railway
- Road/Track
- Cutting
- Buildings
- 6deg Slope and Slope Direction
- Pole Set
- Steel Structure
- Crest Line
- Exposed Bedrock/Rock
- Improved Agricultural/ Reclaimed Peat
- Agricultural
- Peat/Peat Cutting
- Forestry
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- xxx Peat Depth Probe
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- Hardstanding/Stone Access

Client:	Project: Evidence Based Studies - Soils and Geology	Issue Details	Office Use Only
EIRGRID / RPS		Drawn: GMcl	Job No. MDE1020
		Checked: WO	File Ref. MDE1020DG0007
	Title: Non-standard 2 Site - Pre Construction - Connemara 110kV IMP6	Approved: GMcl	Fig No. DG0007
		Scale: NTS	Rev. D01
		Date: 01/05/13	

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No.	Date	Drawn/Chkd	Amendment / Issue	App.
XXX	XXXX	XX/XX	XXXXXXX	XXX

Project: Evidence Based Studies - Soils and Geology

Title: Non-standard 2 Site - During Construction - Banoge 110kV AM19

Drawn by:	GMcI	Job No:	MDE1020
Checked by:	WO	File No:	MDE1020DG0008
Approved by:	GMcI	Drg. No: DG0008	Rev: D01
Scale:	NTS		
Date:	01/05/13		

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No.	Date		Amendment / Issue	App.
XXX	XXXX	XX	XXXXXXX	XXX

Project: Evidence Based Studies - Soils and Geology

Title: Non-standard 2 Site - Post Construction - Banoge 110kV AM19

Drawn by:	GMcl	Job No:	MDE1020
Checked by:	WO	File No:	MDE1020DG0009
Approved by:	GMcl	Drg. No: DG0009	Rev: D01
Scale:	NTS		
Date:	01/05/13		

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LEGEND

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Client: EIRGRID

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No.	Date	Dr. Chk.	Amendment / Issue	App.
xxx	xxxx	xx xx	xxxxxxx	xxx

Project: Evidence Based Studies - Soils and Geology

Title: Non-standard 3 Site - Pre Construction - Donegal 110kV IMP176 to AM180

Drawn by:	GMcl	Job No:	MDE1020
Checked by:	WO	File No:	MDE1020DG0010
Approved by:	GMcl	Drg. No: DG0010	Rev: D01
Scale:	NTS		
Date:	01/05/13		

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No.	Date	Dr./App.	Amendment / Issue	App.
XXX	XXXX	XX/XXX	XXXXXXX	XXX

Project: Evidence Based Studies - Soils and Geology

Title: Non-standard 3 Site - During Construction - Donegal 110kV IMP176 to AM180

Drawn by: GMcI	Job No: MDE1020		
Checked by: WO	File No: MDE1020DG0011		
Approved by: GMcI	Drg. No: DG0011	Rev: D01	
Scale: NTS			
Date: 01/05/13			

LEGEND

- Perennial Watercourse
- Seasonal Watercourse/local drainage channels
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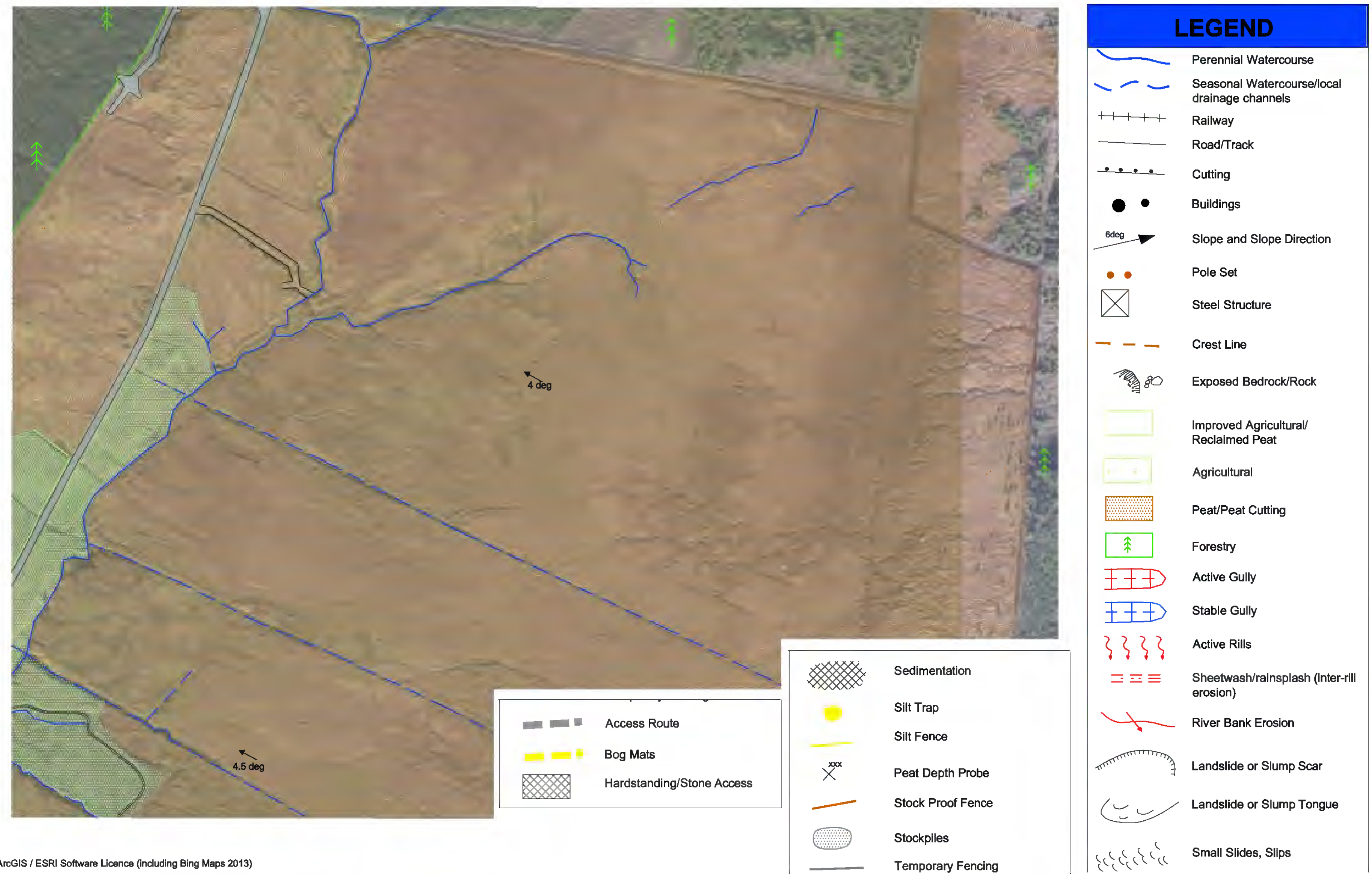
No.	Date		Amendment / Issue	App.
XXX	XXXX		XXXXXXX	XXX

Project: Evidence Based Studies - Soils and Geology

Title: Non-standard 3 Site - Post Construction - Tarbery Tralee 110kV - West of Blakes Cross

Drawn by: GMcI	Job No: MDE1020		
Checked by: WO	File No: MDE1020DG0012		
Approved by: GMcI	Drg. No:		Rev:
Scale: NTS	DG0012		D01
Date: 01/05/13			



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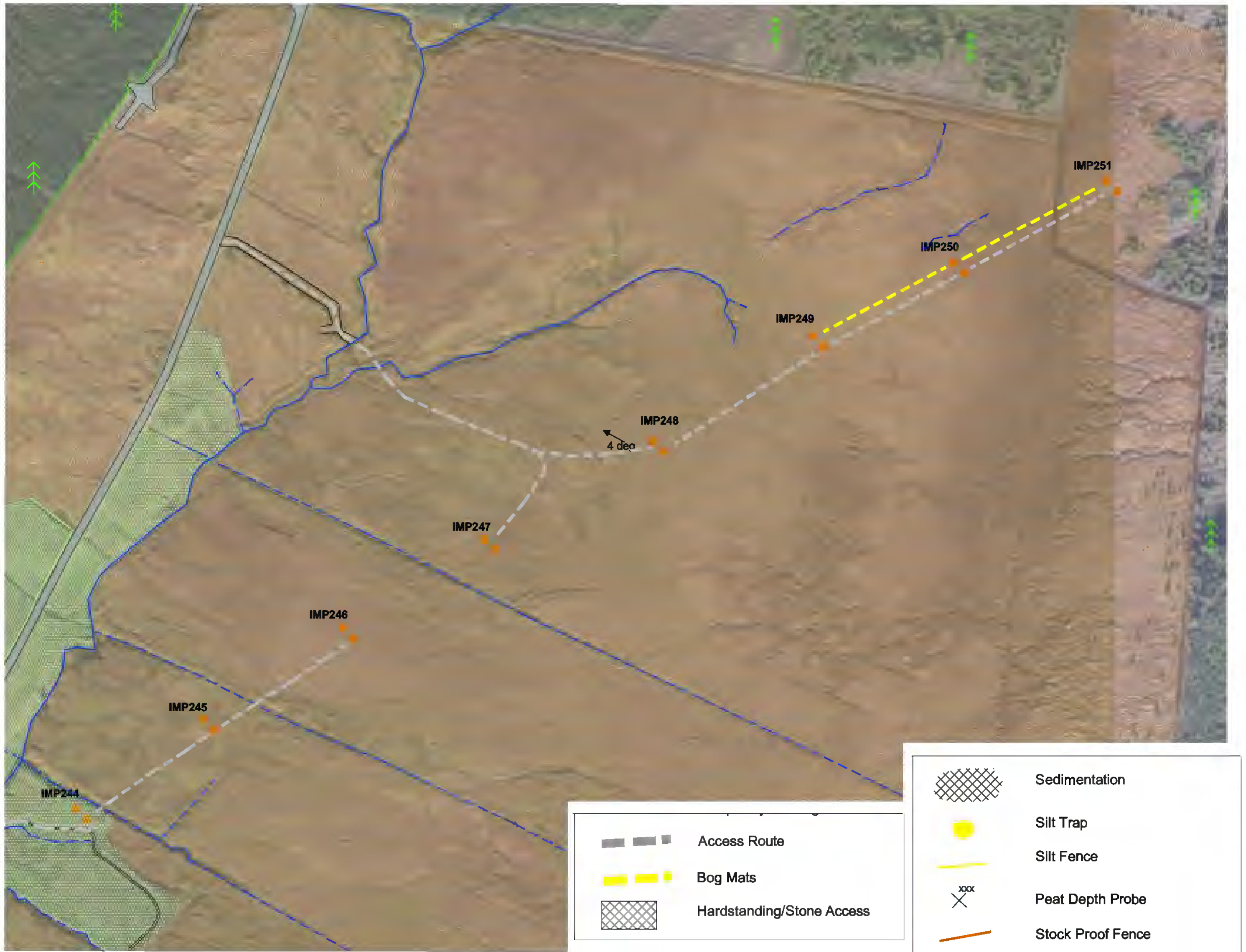
No.	Date	dr./chk.	Amendment / Issue	App.
XXX	XXXX	xx/xx	XXXXXXX	XXX

Project: Evidence Based Studies - Soils and Geology

Title: Worst Case Site - Pre Construction - Donegal 110kV ST244 to ST251

Drawn by:	GMcl	Job No:	MDE1020
Checked by:	WO	File No:	MDE1020DG0013
Approved by:	GMcl	Drg. No: DG0013	Rev: D01
Scale:	NTS		
Date:	01/05/13		



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LEGEND

- Perennial Watercourse
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- Railway
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- Buildings
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- Stockpiles
- Temporary Fencing

- Access Route
- Bog Mats
- Hardstanding/Stone Access

Client: EIRGRID

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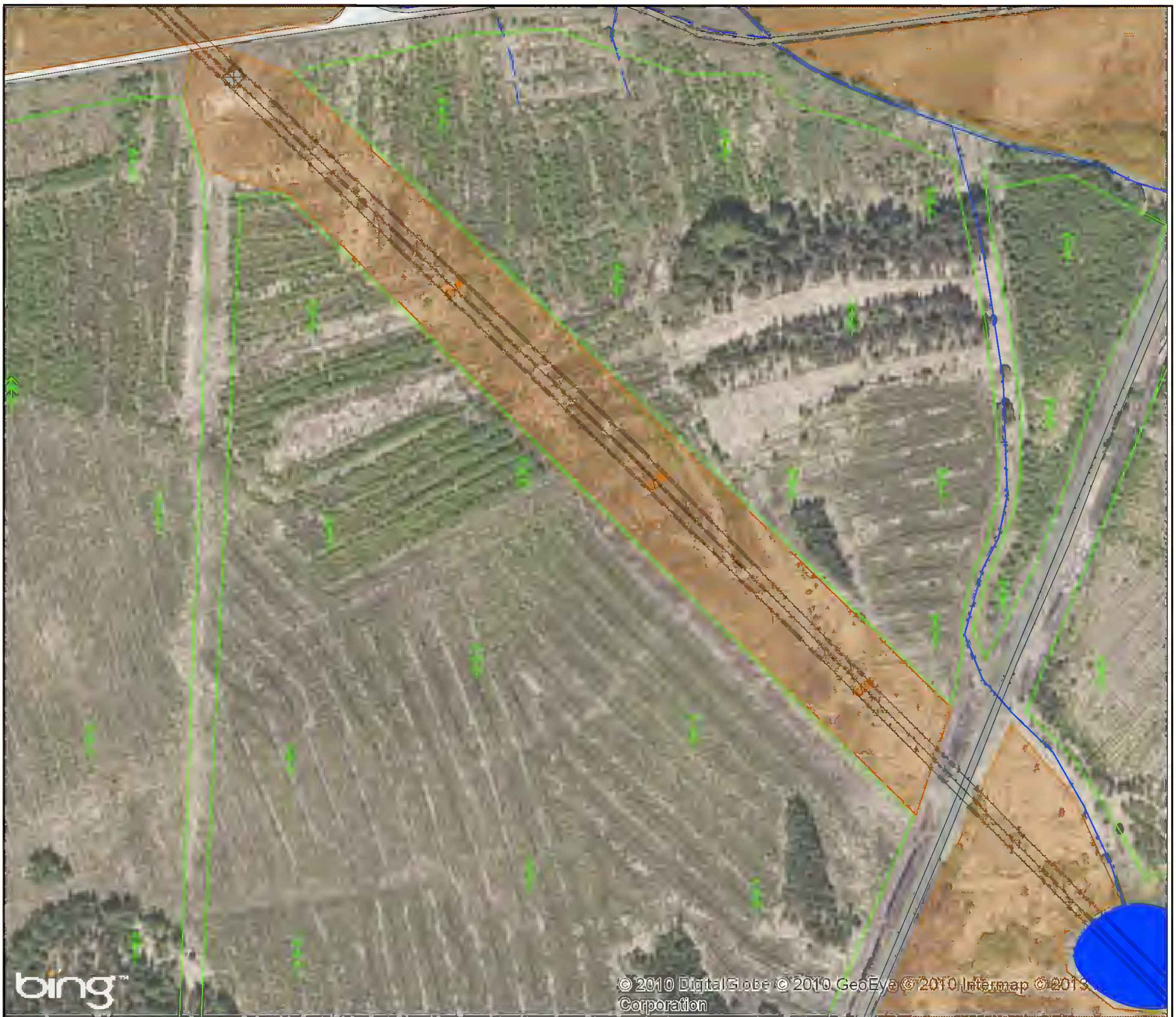
No.	Date	Drn. / App.	Amendment / Issue	App.
XXX	XXXX	XX / XX	XXXXXXX	XXX

Project: Evidence Based Studies - Soils and Geology

Title: Worst Case Site - During Construction - Donegal 110kV ST244 to ST251

Drawn by:	GMcl	Job No:	MDE1020
Checked by:	WO	File No:	MDE1020DG0014
Approved by:	GMcl	Drg. No: DG0014	Rev: D01
Scale:	NTS		
Date:	01/05/13		



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LEGEND

- Perennial Watercourse
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Client: EIRGRID	RPS	Project: Evidence Based Studies - Soils and Geology	Issue Details	Office Use Only
		Title: Worst Case Site - Post Construction - Derrybrien Agannygal 110kV	Drawn: GMcl	Job No. MDE1020
			Checked: WO	File Ref. MDE1020DG0015
			Approved: GMcl	Fig No. DG0015
			Scale: NTS	Rev. D01
			Date: 01/05/13	

APPENDIX F

OVERVIEW OF ELECTRICITY TRANSMISSION INFRASTRUCTURE, INCLUDING TYPICAL CONSTRUCTION METHODOLOGY

A1 Description of Typical Electricity Transmission Project Designs

The transmission network in Ireland comprises structures and overhead lines, underground cables and substations. When the need for a new circuit is identified in Ireland, EirGrid will consider all available solutions for the new circuit. This will include overhead line and underground cable solutions, considering both High Voltage Alternating Current (HVAC) and High Voltage Direct Current (HVDC) technology, as appropriate.

Factors which will influence the solution decision include technical, economic and environmental considerations. It is important to note that each project is different and EirGrid will determine potential technology solutions on a project-by-project basis. EirGrid will continue to keep technology developments under review and will consider new technologies as appropriate.

A1.1 Overhead Lines (OHL)

Transmission lines are generally supported on either wooden pole sets or steel lattice towers. Towers along a straight of the alignment are known as intermediate towers. Angle towers are used where a line changes direction and conductors are held under tension.

The type and height of structures required will vary according to the voltage of the overhead line, and the location and type of environment and terrain in which they are placed.

A1.2 Structure Design

For all new electricity transmission projects, efficient, appropriately placed and optimally designed structures are carefully considered and proposed. The design employed depends on the local environment, topography and technologies involved, and will vary from 110 kV, 220 kV or 400 kV, depending on the specific transmission need identified.

The spacing between structures depends on technical limitations and on the topography, particularly to ensure that conductors maintain a specific minimum clearance above the ground at all times.

Steel Lattice Tower Structures
The weight of conductors and characteristics of 220 kV and 400 kV lines require that they be supported exclusively on lattice steel structures (this also applies to angle towers along a 110 kV line). The three phases (conductors) of a circuit are carried in a horizontal plane.

Table A1: Key Design Features: Single Circuit 220 kV and 400 kV overhead line structures

Key Design Features	220 kV Indicative Range	400 kV Indicative Range
Height range	Depends on technical details of individual projects but generally between 20-40m	Depends on technical details of individual projects but generally between 20m -52m
Maximum range of width at ground level	6m to 12m	7m to 12m
Number of foundations per structure	4	4
Average span between towers	Approx. 320m (dependent on local topography)	Approx. 350 (dependent on local topography)

Example of a 400 kV intermediate tower design along the Dunstown-Moneypoint overhead line, Co Clare

Example of a 220 kV intermediate tower design along the Cashla – Flagford overhead line, Co Roscommon

Single Circuit 110 kV Overhead Lines

A 110 kV single circuit overhead line requires that conductors (and earth wires[1]) are supported on a combination of steel lattice angle towers and double wood intermediate polesets.

The average span between polesets for a 110 kV single circuit alignment is approximately 180m; however, the actual span achievable depends on local topography. Again, the three phases of the circuit are carried in a horizontal plane.

Table A2: Key Design Features of Single Circuit 110 kV overhead line support structures

Key Design Features	110 kV Indicative Range
Height range (double wood polesets)	16m to 23m (incl. buried depth normally 2.3m)
Pole centres	5m
Number of foundations	2
Height range (steel angle towers)	18m to 24m
Maximum width at ground level	4m to 9.8m
Average span	180m

Example of a typical 110kV single-circuit double wood polesets with earthwire (Co Sligo)

On an alignment there may arise a very slight change in direction, and this may necessitate, in the case of a 110 kV single-circuit line, the use of a braced wood poleset, wherein the space between the polesets is reinforced with steel members.

[1] Lines running above the conductors which protect the conductors from lightning strike.

Braced double wood poleset

Double Circuit Overhead Lines

Overhead alignments can be configured as single circuit or double circuit (two separate circuits supported on a single structure). This generally only occurs where two single circuit lines are in close proximity (for example on approach to a substation), or where space is at a premium.

Double circuit alignments, including 110 kV overhead lines, always require to be supported by lattice steel towers. The average number of structures on a line is 3-4 per km depending on topography. In addition, the structures are higher, as each circuit must be carried in a vertical plane.

Typical 110 kV double circuit structures

A1.3 Construction of Overhead Lines

Overhead line construction typically follows a standard sequence of events comprising:

- Prepare access;
- Install tower foundations/Excavation;
- Erect towers or wood poles;
- Stringing of conductors;
- Reinstate tower sites and remove temporary accesses.

Prepare Access

It is preferable to have vehicular access to every tower site for foundation excavation, concrete delivery and a crane to erect towers. With wood pole construction, (on 110 kV single circuits) a crane is not usually required, as these are normally erected with a digger using a lifting arm.

Access can take various forms and is dependent on ground conditions. In poorer conditions, more complex access works are required which can vary from the laying of bog mats, or laying temporary wooden matting, to installing crushed stone roads. Some of this work may entail removal of topsoil.

Access routes may require to be constructed for both the construction and maintenance of the transmission line, and may be temporary or permanent.

Every effort is made to cause least disturbance to landowners and local residents, and to cause the least potential environmental impact during construction. As a result, the most direct access route to a tower installation may not always be the most appropriate.

Example of a newly built access route for a transmission project, Co. Donegal

Install Tower Foundations/Excavation

Tower foundations are typically 2–4m deep with excavation carried out by mechanical excavator. Excavations are set out specifically for the type of tower and the type of foundation required for each specific site.

A larger footing may be required in the case of weak soils. Pile foundations may be required in the case of deep bog. In the case of rock being encountered at shallow depths, reduced footing size foundations may be required.

Prior to excavation, the foundations for each tower site will be securely fenced off to ensure the safety of members of the public and livestock. Tower stubs (the lower part of the tower leg) are concreted into the ground. Once the concrete has been poured and cured, the excavation is back-filled using the original material in layers. Surplus material is removed from site.

The excavation required for a wooden poleset is typically 1.5m-2m x 3m x 2.3m deep; no concrete foundations are required for polesets in normal ground conditions. Installation time is approximately two per day. The average foundation size for a braced poleset is 9.3m x 3.1m x 3.2m deep.

In addition to the excavation required for the poleset itself, where ground conditions dictate, stay lines may be required. This generally involves excavation of four trenches (approximately 2m x 2m x 1.8–2m deep) at a distance from the poleset. The installation of stay wires expands the area of disturbance associated with the erecting a poleset.

Stay lines in place, Donegal 110 kV Project

Concrete foundations are required for all steel towers. Foundation size and type is dependent on ground conditions and tower type, but is typically 4m x 4m x 3.1m for each foundation pad. The base installation time is approximately one week.

110kV angle towers at Srananagh Station with exposed substructures

For all transmission lines with earth wires, there is a requirement to install an earth ring or mat at the base of the structure to ground the structure for safety reasons. The ground around the base of structures is excavated after conductors and earthwires are in place and the earth ring is installed.

Earth ring on Donegal 110kV Project

Erect Towers or Wood Poles

Materials required for construction are transported around the site by general purpose cross country vehicles with a lifting device. Excavators are generally of the tracked type to reduce likely damage to and compaction of the ground. In addition a temporary hard standing may be required for machinery and this may require the removal of topsoil. Materials are delivered to site storage/assembly areas by conventional road transport and then transferred to sites.

Tower erection can generally commence two weeks after the foundations have been cast. Tower steelwork is usually delivered to site and assembled on site.

Installation of tower using a derrick pole at the base

Construction of wooden poleset support structure for Donegal 110 kV Project (Binbane – Letterkenny)

Stringing of conductors
Once angle towers are erected, conductor stringing can commence, installing conductors from angle tower to angle tower via the line intermediate structures. Conductor drums are set up at one end of the straight with special conductor stringing machinery, and pulled from one end to the other.

Stringing Machine

Conductor stringing equipment

Reinstate tower sites and remove temporary accesses
The disturbed ground around a tower or poleset location is made good, and all temporary access materials generally removed.

A1.4 Line Uprating and Refurbishment

In general a transmission line requires little maintenance. It is periodically inspected to identify any unacceptable deterioration of components so that they can be replaced as necessary. A more detailed condition assessment on a line is usually carried out when it is approximately 35 years old.

The majority of the existing transmission grid was constructed after 1960; the majority of those lines constructed prior to 1960 have already been refurbished. There is an on-going programme of line refurbishment concentrating on older lines.

Refurbishment projects are condition based, and once a line has been identified for refurbishment, consideration is given to the potential opportunity to upgrade its carrying capacity or thermal rating. This might involve replacing existing conductors with modern conductors which, while having effectively the same diameter, can carry significantly greater amounts of electricity.

Often the additional weight of these replacement conductors means associated replacement of support structures with stronger structures. Where structures require replacement during a line upgrade or refurbishment, additional excavation may be required particularly where angle towers or structures require replacement. In general they are replaced within the footprint of the original structure.

Insulators and conductors are normally replaced after about 40 years, and towers are painted every 15-20 years or as necessary.

A1.5 Underground Cabling (UGC)

High voltage (HV) circuits can only be laid underground using special HV cables designed specifically for underground use. The conductors in underground HV cables must be heavily insulated to avoid a short circuit between the conductor and the ground around the cable.

Table A3: Key Design Features: Underground Cabling

Key Design Features	HV Cable (typical dimensions)
Cable Trenches	c.0.6m wide-1.25m deep for a 110 kV trench, c. 1.1m wide x 1.25m deep for 220 kV and 400 kV for a single cable
Joint Bays	6m long, 2.5m wide and 1.8m deep
Excavation trench for Joint Bay	7m long, 3m wide and 2m deep
Average span between joint bays	500m–700m
Directional Drill entry and exit pits	1m x 1m x 2m

The cable is installed directly into the ground in an excavated trench. The majority of high voltage cable routes are located along public roads and open spaces. It is very unusual for a cable route to cross private open ground but this may be the case on occasion. The civil contractor will scan the ground using a cable avoidance tool (CAT), carry out a visual inspection of existing services and compare the information with the utility service records which they will have obtained from the various service providers in advance. If any previously unidentified services are discovered the site engineer will adjust the cable route accordingly.

Typical 110kV Trench Excavation (Ducts in Trefoil Formation)

The overall installation of a cable route over a large distance is broken down into sections of cable that are connected using a cable joint. Cable joints are installed in joint bays which are typically concrete structures buried underground, occurring generally every 500–700m along an alignment, and ranging in size up to 6m long, 2.5m wide and 1.8m deep.

Typical Joint Bay Construction Adjacent to Public Road

If the cable was installed directly in the ground the entire trench from joint bay to joint bay must be fully excavated. The advantage with installing cable in pre-laid ducts is that only a short section of cable trench, up to 100m is open at any time. This helps to minimise the impact on the local residents and minimise traffic impact at any given time.

Typical HV Cable Installation

Once installed, the road surface is reinstated. Where a cable route is in an open area, it is returned to agricultural/grassland use. Where a cable passes through forested land the route is not replanted with trees to prevent any damage to the cable by tree root growth.

Re-growth following underground cable construction on agricultural land

A1.6 Substations

Substations connect two or more transmission lines; they take the electricity from the transmission lines and transform high to low voltage, or vice versa. They contain various electrical equipment, including voltage switches, transformers, protection equipment, and associated lines and cabling.

The siting of a substation depends on topography; the ground must be suitable to meet technical standards. With regard to earthing requirements and soil stability, substations are usually constructed on reasonably level ground, in areas that are not liable to flooding or crossed by significant watercourses.

A substation site is normally future proofed with the capability to be extended if the need arises.

Substations can take two forms:

An Air Insulated Switchgear (AIS) substation is where the electrical equipment infrastructure is primarily installed outdoors, with the use of natural air as an insulation between circuits. This option requires a relatively large compound footprint.

Srananagh 220kV/110kV substation, Co Sligo, example of a typical outdoor AIS substation

A Gas Insulated Switchgear (GIS) substation, is where gas (Sulphur Hexafluoride – SF6) is used as the insulation between circuits. This requires the electrical equipment to be contained internally, in buildings of some 11–13m over ground. This allows for a significantly smaller substation footprint.

Both options require the associated provision of access roads off and onto the public road network and the provision of associated electrical equipment and infrastructure (including underground cables), as well as ancillary waste water treatment facilities and other site development and landscaping works. Both are therefore significant civil engineering projects.

Example of a typical indoor GIS substation, Co Limerick