Appendix 7-6 – Peat Stability Risk Assessment

Drehid Waste Management Facility – Further Development

Planning Stage Peat Stability Risk Assessment

PRODUCED BY
Ciaran Reilly BE PhD CEng MIEI RoGEP (Specialist)

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Report prepared for:
TOBIN Consulting Engineers,
Block 10-4,
Blanchardstown Corporate Park,
Dublin 15,
Ireland.

Report prepared by:
Ciaran Reilly & Associates
Consulting Geotechnical Engineers,
Maynooth,
Co. Kildare,
Ireland.

Note on status flags and revision codes:

Status	Description	Revision Code
Work in Progress (Non-Contractual)		
S0	Work In Progress	P01.01, etc
Shared (Non-Contractual)		
S1	Suitable for Coordination. The file is available to be 'shared' and used by other disciplines as a background for their information.	P01, P02, etc
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A1, A2, A3, etc	Approved and accepted as stage complete (C= Contractual/Complete)	C01, C02, etc
B1, B2, B3, etc.	Partially signed-off: with minor comments from the Client. All minor comments should be indicated by the insertion of a cloud and a statement of 'in abeyance' until the comment is resolved, then re-submitted for full authorization.	P01.01, etc
Published for AIM Acceptance		
CR	As Construction Record documentation, PDF, Models etc	C01, C02, etc

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1. Executive Summary

Ciaran Reilly & Associates has been instructed by TOBIN Consulting Engineers (TOBIN) on behalf of Bord na Móna to carry out a planning stage peat stability risk assessment (PSRA) as part of the environmental impact assessment for a proposed extension of the existing Drehid Waste Management Facility (WMF). The proposed extension provides for additional landfill infrastructure, a new Municipal Solid Waste (MSW) processing facility, additional composting infrastructure, a new soils, stones and construction and demolition rubble processing facility and increased throughput of waste to the existing compost facility.

The site is within the Timahoe South Bog (TSB) peatland, which has been extensively harvested for peat by Bord na Móna (BnaM) in the past. There were no recorded peat landslide events within TSB and the GSI landslide susceptibility is "low" for the entire proposed development site.

The PSRA was carried out in accordance with the document "Peat Landslide Hazard and Risk Assessments, Best Practice Guide for Proposed Electricity Generation Developments – Second edition" (Scottish Government, 2017). The report sets out the methodology used to assess the peat stability risk, the activities undertaken, and the results of the peat stability assessment. The report should be read along with Chapter 7 – "Soils, Geology and Hydrogeology" of the "Drehid Waste Management Facility – Further Development" Environmental Impact Assessment Report (EIAR) and its appendices.

The site topography is generally flat, ranging from 81.5 to 88.1mOD. LiDAR digital terrain model data were obtained and interrogated to provide a generalised ground profile for peat stability assessment. The generalised ground profile slopes at a gentle angle of 0.55°. The site terrain, being largely flat, limits the potential for and the scale of peat slide and debris runout distances.

Desk study information indicates the site is underlain by cutover raised peat. Based on recent and historic ground investigation data, peat depth was characterised as 3.65m or less across the proposed development site. Drained and undrained peat strength parameters and a value for unit weight were derived based on comparable experience.

A qualitative risk assessment carried out found that the construction of berms is initially a "medium" risk activity, but once common place mitigations are applied, a "low" risk rating is appropriate. The development is assigned a "low" risk rating overall. Deterministic stability assessments indicate that the materials are considered to be stable in the short (undrained) and long (drained) term, including under the influence of extreme weather events, hence justifying the "low" hazard rankings assigned. It is concluded that the site is suitable for the proposed waste management development.

Good practice indicates that common-place mitigation measures are applied during the detailed design of the project to further control the risk. Best practice guidance regarding the management of peat stability must be inherent in the construction phase of the project.

2. Introduction

Ciaran Reilly & Associates has been instructed by TOBIN Consulting Engineers (TOBIN) on behalf of Bord na Móna to carry out a planning stage peat stability risk assessment (PSRA) as part of the environmental impact assessment for a proposed extension of the existing Drehid Waste Management Facility (WMF). The proposed extension provides for additional landfill infrastructure, a new Municipal Solid Waste (MSW) processing facility, additional composting infrastructure, a new soils, stones and construction and demolition rubble processing facility and increased throughput of waste to the existing compost facility.

The site is within the Timahoe South Bog (TSB) peatland, which has been extensively harvested for peat by Bord na Móna (BnaM) in the past, and is adjacent the existing Drehid Waste Management Facility. The proposed development is in the townlands of Coolcarrigan, Kilkeaskin, and Drummond, Co. Kildare.

This report sets out the methodology used to assess the peat stability risk, the activities undertaken and the results of the peat stability assessment. This report should be read along with Chapter 7 – "Soils, Geology and Hydrogeology" of the "Drehid Waste Management Facility – Further Development" Environmental Impact Assessment Report (EIAR) and its appendices.

2.1. Description of the Development

The development will consist of an extension of the existing Drehid WMF to provide for the acceptance of up to 440,000 TPA of non-hazardous waste material, comprising:

- Increase in acceptance of non-hazardous household, commercial & industrial and C&D waste at the existing landfill from the currently permitted disposal quantity of 120,000 TPA to 250,000 TPA until the permitted void space in the existing landfill is filled and no later than the currently permitted end date of 2028;
- Development of extended landfill footprint of approximately 35.75 ha to accommodate the landfilling of 250,000 TPA of non-hazardous household, commercial & industrial and C&D waste for a period of 25 years to commence once the existing landfill void space is filled. The new landfill will have a maximum height of approximately 32 m above ground level (115.75 mAOD);
- Provision, as part of the extended landfill infrastructure, for 30,000 TPA of contingency disposal capacity for non-hazardous waste, to be activated by the Planning Authority only as an emergency measure, for a period of 25 years;
- Development of a new Processing Facility, for the recovery of 70,000 TPA of inert soil & stones and C&D waste (rubble) and use of same for engineering and construction purposes within the site, including as engineering material in the landfill;
- Increase in acceptance of waste at the existing Composting Facility from 25,000 TPA to 35,000 TPA and removal of the restriction on the operating life of the Composting Facility contained in Condition 2(2) of ABP Ref. No. PL.09.212059;
- Extension to, and reconfiguration of, the existing Composting Facility to provide for a new MSW Processing and Composting Facility with an additional capacity of 55,000 TPA (giving a combined total for the MSW Processing and Composting Facility of

90,000 TPA), allowing for the combined facility to accept both MSW and other organic wastes;
- Construction of a new odour abatement system at the existing Composting Facility including two emissions stacks to a height of 17 m above ground level;
- Construction of a new odour abatement system as part of the new MSW Processing and Composting Facility including two emissions stacks to a height of 17 m above ground level;
- Development of a new Maintenance Building with staff welfare facility, office, storage and a laboratory;
- Installation of a new bunded fuel storage area to the rear of the new Processing Facility for the recovery of soil & stones and C&D waste (rubble);
- Construction of two new permanent surface water lagoons and one new construction stage surface water lagoon;
- Construction of a new integrated constructed wetland (ICW) area comprising five ponds;
- Car-parking provision for operational staff;
- Landscaping and screening berms; and
- All associated infrastructure and utility works necessary to facilitate the proposed development and the restoration of the facility following the cessation of waste acceptance.

The total waste intake of 440,000 TPA described above includes 30,000 TPA contingency capacity provided following pre-application consultation with the Regional Waste Officers at the Regional Waste Management Planning Office (RWMPO). This contingency capacity will not be utilised by the Applicant under normal operations and will only be activated in strict circumstances by Kildare County Council (KCC) in consultation with the RWMPOs and the EPA.

2.2. Statement of authority

Ciaran Reilly & Associates is a specialist geotechnical engineering practice delivering a range of consultancy services to the private and public sectors across Ireland and the UK. Ciaran Reilly & Associates was established in 2016 and is based in Co. Kildare.

This report was prepared by Dr Ciaran Reilly. Dr Reilly (BE, PhD, PGDip, CEng, MIEI, Registered Ground Engineering Specialist (UK RoGEP)) is a geotechnical engineer with over 15 years' experience in civil and geotechnical engineering consultancy, contracting, and research. He worked for several years in industry before completing his PhD in Trinity College Dublin in 2014. Since then, he has undertaken a diverse range of environmental impact assessment and engineering design projects as senior engineer and more recently as director of Ciaran Reilly & Associates.

Dr Reilly is familiar with the Drehid Waste Management Facility, having undertaken annual slope stability assessments of the existing facility in 2020, 2021, 2022, and 2023.

2.3. Peat Failures

Peat landslides represent one end of a spectrum of natural processes of peat degradation. They have potential to cause fatalities, injury and damage to infrastructure and farmland. They also have the potential to cause significant damage to peatland habitats.

Excavations works on construction sites can induce slope failures due to the low basal strength in peat, even in relatively flat sites. These peat failures induced by excavations can extend significantly beyond the excavations, likely due to seepage forces caused by intentional or accidental drainage of the peat.

The potential for peat failure at this site is examined with respect to waste management facility construction and associated activity.

2.4. Methodology

The evaluation of the peat stability at the site was carried out in accordance with the document "Peat Landslide Hazard and Risk Assessments, Best Practice Guide for Proposed Electricity Generation Developments – Second edition" (Scottish Government, 2017). The geotechnical and peat stability assessment at the site included the following activities:

- Desk Study,
- Site reconnaissance,
- Review of ground investigation carried out at the site,
- Review of digital terrain model data,
- Peat stability assessment using a qualitative approach, and
- Peat stability assessment using a deterministic approach.

The risk assessment approach is discussed in detail in Section 5.

3. Ground Investigation

3.1. Desk study

A desk study was undertaken to collate and review background information in advance of the site survey. The desk study involved the following:

- Examination of the Geological Survey of Ireland (GSI) datasets pertaining to geology, landslide susceptibility, and the GSI borehole database,
- Examination of Environmental Protection Agency (EPA) data, and
- Preparation of site maps and suitable field sheets for the site survey.

The desk study information obtained is referenced below. Following the desk study and the site survey, geological maps were generated in GIS and are included in Chapter 7 - Soils, Geology and Hydrogeology of the main EIAR. The full extent of the ground investigation information available is included in the Soils, Geology and Hydrogeology chapter of the main EIAR.

Publicly available sources of mapping, aerial photography and satellite imagery were consulted to establish the expected ground conditions, topography, and condition of the site in the past. The following sources were referred to:

- Ordnance Survey historical mapping,
- Geological Survey of Ireland mapping,
- EPA mapping,
- Publicly available satellite photography (Google Maps & Bing Maps), and
- Site specific LiDAR digital terrain model data.

3.2. Field work

Site surveys relating to the soil and geological environment and ground investigations were undertaken between 2006 and 2023. These surveys included:

- Site walkovers by Ciaran Reilly & Associates staff in February 2022 and February 2023 to review the ground conditions and assess the topography and geomorphology,
- 9 nr trial pits undertaken by VESI Environmental Ltd. in June and November 2022 to assist with the design of the proposed Integrated Constructed Wetland.
- 55 nr new boreholes completed by CDM Smith to supplement the 32 nr boreholes and more than 130 nr trial pits that were drilled and excavated as part of past investigations (as presented in the 2017 EIAR).
- Geophysical surveys that were conducted in 2002 and 2016 in support of the 2017 EIAR (Apex, 2016), as well as a peat probe survey that was conducted in 2006 (BRG, 2006).

The logs and records of the investigations can be found in Appendix 7-1 to the Soils, Geology and Hydrogeology chapter of the main EIAR. The locations of investigations and depths of peat recorded are summarised in drawing P22009_DR001 included as Appendix 1 of this report. The data from the ground investigations and the observations made during the walkover survey are used to prepare the Peat Stability Risk Register included as Appendix 3 of this report.

Peat probing was not carried out as it was determined that sufficient data existed from the CDM Smith borehole campaign, in addition to the data from the 2017 EIAR, to carry out the Peat Stability Risk Assessment.

4. Detailed Site Assessment

4.1. Site Topography and Geomorphology

The site topography and geomorphology are discussed in detail in the Soils, Geology and Hydrogeology Chapter of the EIAR and reference is made to that chapter herein.

The Proposed Development area is situated entirely within TSB. TSB covers a total area of approximately 17.07 km^2 and ranges in elevation between approximately 81 and 90 mOD. The bog is surrounded by gentle hills that reach maximum elevations of 116 mOD in the townland of Hodgestown to the east and 142 mOD in Carbury to the west. TSB is surrounded by agricultural lands to the west, south and east, with a scattered rural pattern of farms and residential dwellings along local roads. TSB transitions north across a gentle topographic saddle where the bog becomes referred to as Timahoe North Bog (TNB).

The proposed site covers a total area of 85 hectares and ranges in elevation between approximately 81.5 and 88.1mOD. The topography of the proposed site is in general flat. A typical view of the proposed site is shown in Figure 1.Figure 1 - Typical view of proposed site (existing Composting Facility building appears in right background)

Figure 1 - Typical view of proposed site (existing Composting Facility building appears in right background)

Several man-made drains cut through the site, draining typically to the southwest. An example of one such drain is shown in Figure 2.

Figure 2 - Drain through proposed site.

For the purposes of the peat stability risk assessment, an overall view was taken on the topography of the site and individual drainage features were not assessed. LiDAR digital terrain model data were obtained and interrogated to provide a generalised ground profile for peat stability assessment. The generalised ground profile slopes at a gentle angle of 0.55°. The site terrain, being largely flat, limits the potential for and the scale of peat slide and debris runout distances.

4.2. Local bedrock geology

Geological Survey of Ireland bedrock mapping shows that the site is underlain by Waulsortian Limestone, a massively bedded, pale to dark grey limestone which incorporates skeletal debris and dark grey carbonate mud. Bedrock geology mapping is provided as Figure 7-6 of the Soils, Geology and Hydrogeology chapter.

4.3. Local soils and subsoils

Geological Survey Ireland mapping shows the site as underlain by cut over raised peat, as shown in Figure 3 and Figure 7-4 and Figure 7-5 of the Soils, Geology and Hydrogeology chapter. The raised peat has formed in a hollow in the surrounding glacial till derived from limestone (boulder clay) with local instances of gravel, alluvium, and lacustrine sediment deposition.

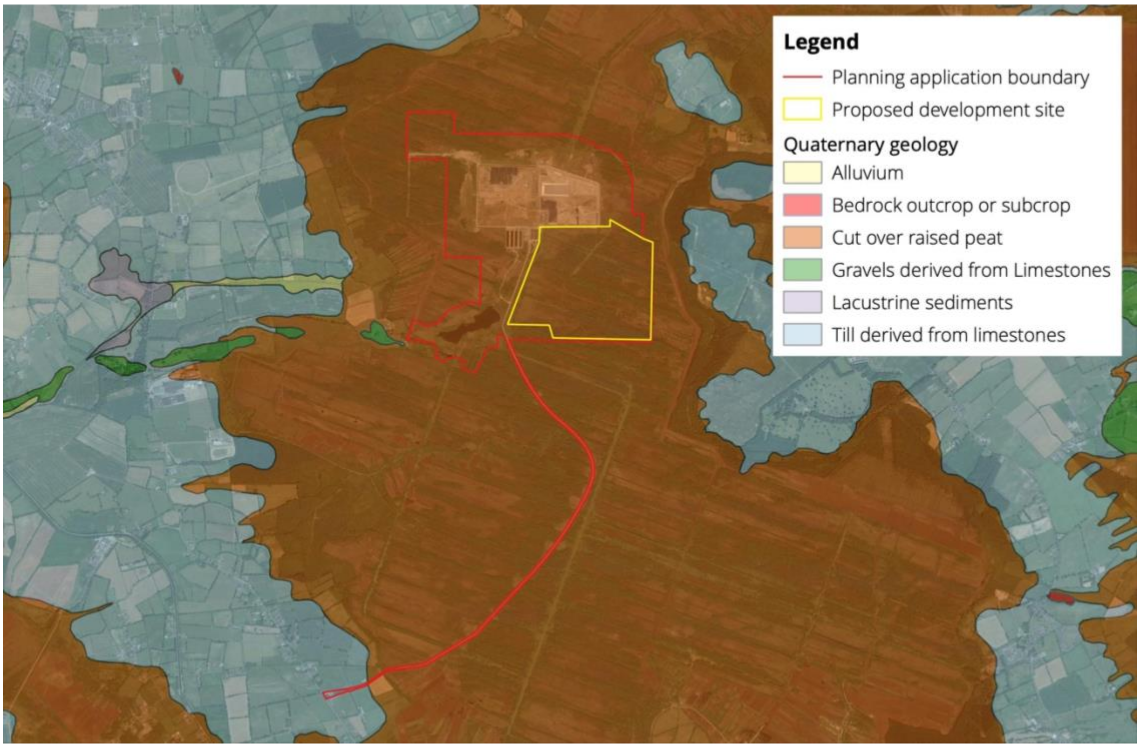

Figure 3 - Quaternary geology

In places, the peat has been stripped back entirely and the underlying glacial till is exposed. A typical example is shown in Figure 4.

Figure 4 - Exposed glacial till at drain location

4.4. Water courses

Mapping, aerial photography, and satellite imagery available via the Geohive (2023) services were consulted. Ordnance Survey 6-inch and 25 inch (Geohive, 2023) shows the area as peatland with a drainage feature, on a similar alignment to the present day Cushaling River, draining the site to the southwest. The 6-inch first edition mapping is reproduced as Figure 5.

Figure 5 - Ordnance Survey 6" first edition mapping showing drainage feature with similar alignment to present-day Cushaling River draining the proposed site (outlined in red) to the southwest.

The site is crossed by a network of artificial drains which in the past served to facilitate BnM's peat extraction activity. The drains can be up to 4 m deep and 4 m wide, extending through both peat and subsoils. Typical examples of these drains are shown in Figure 2 and Figure 4. The landfill expansion area currently forms a drained mosaic of young birch and scrub woodland with dry heath, as shown in Figure 1. We understand peat extraction from the site ceased in the early to mid 1980s. Aerial photography from 1995, 1999-2003, 2004-2006, and 2005-2012 shows the site lying idle with most of the described artificial ditches in place. More recent (2013 to present) aerial photography and satellite imagery shows the site largely as configured today, with the Drehid WMF in place, as shown in Figure 6 and Figure 7.

Figure 7 shows a more recent diversion drain feature (highlighted by yellow arrows) constructed to divert existing flows around Phase 9 and 10. A new north-south oriented drain to the east of the expanded landfill footprint will be constructed to lead bog drainage water around the landfill expansion area and maintain the hydrology of the site. This is shown in Figure 7-31 of the Soils, Geology and Hydrogeology chapter of the main EIAR.

Figure 6 - Aerial image from MapGenie Digital Globe (Geohive, 2023) showing proposed site outlined in red and existing Phases 1 to 8 under construction.

Figure 7 - MapGenie (2013- 2018) satellite image (Geohive, 2023) showing proposed site outlined in red and existing Phases 1 to 8 undergoing filling and capping and Phases 9 and 10 under construction. Diversion drain shown by yellow arrows.

The site is in the Figile (Cushaling River) subbasin of the Barrow catchment. The formal river network, excluding artificial drains, in the vicinity of the site is shown in Figure 8. Proximity to a water course is used to assess the risk of peat stability at individual infrastructure elements in Section 5 of this report.

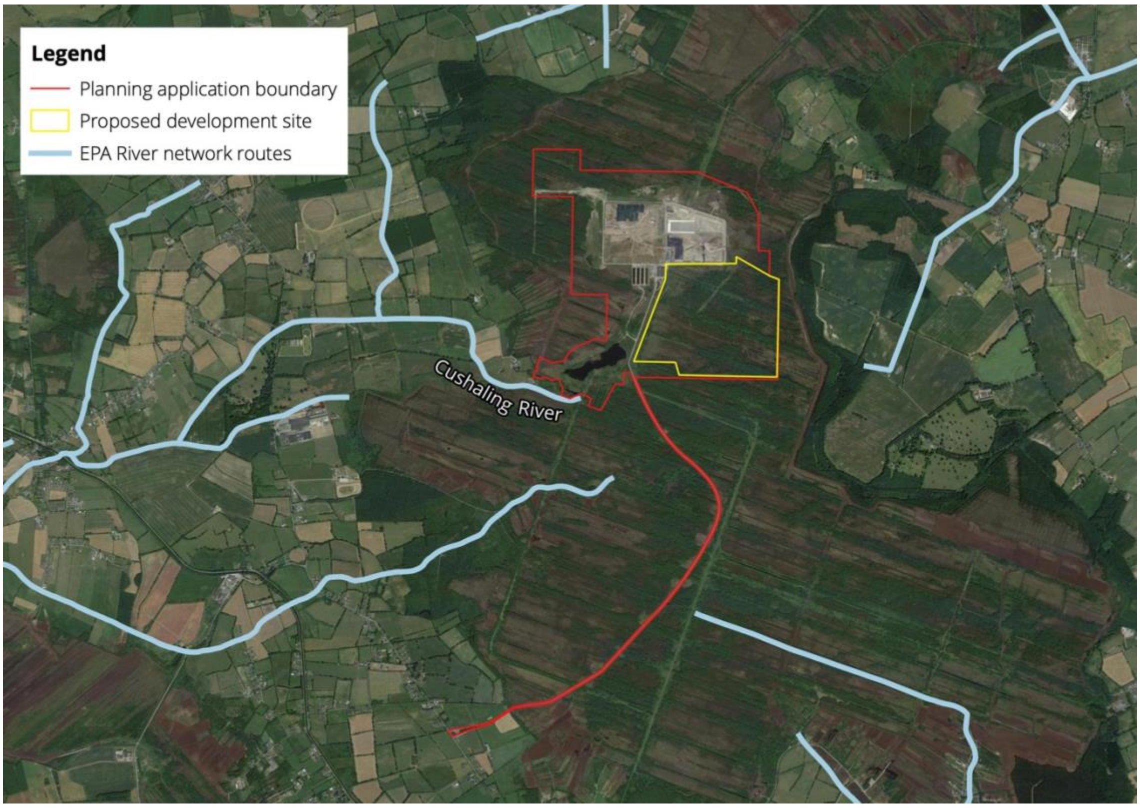

Figure 8 - River network (EPA)

4.5. Previous failures

A review of the landslide information on the GSI Irish Landslides Database indicated that the nearest recorded landslides occurred approximately 8.0 km southeast of the site (GSI_LS06-0325, in 1839) and approximately 18.0 km west of the site (GSI_LS03-0064, in 1916, and at the same location GSI_LS03-0068, in 1989). All three recorded landslides were associated with the Grand Canal and involved failures of the canal embankment in peatland areas. A map of these events is provided in Figure 9.

No evidence of historic peat failure was identified during the site walkover.

Figure 9 – Mapped landslide events (Source: GSI National Landslide Susceptibility Mapping, 2021)

4.6. Landslide susceptibility

Figure 10 shows the mapped landslide susceptibility for the site based on GSI mapping. Landslide susceptibility at the site is mapped by GSI as "Low". The mapping considers topographic slope, soil type and concentration/dispersion of overland flow. Peat can be mobilised when disturbed, but given the flat topography, there are no identified, specific geohazards within the planned expansion area. There are also no incidents of peat slides within Timahoe Bog in the past.

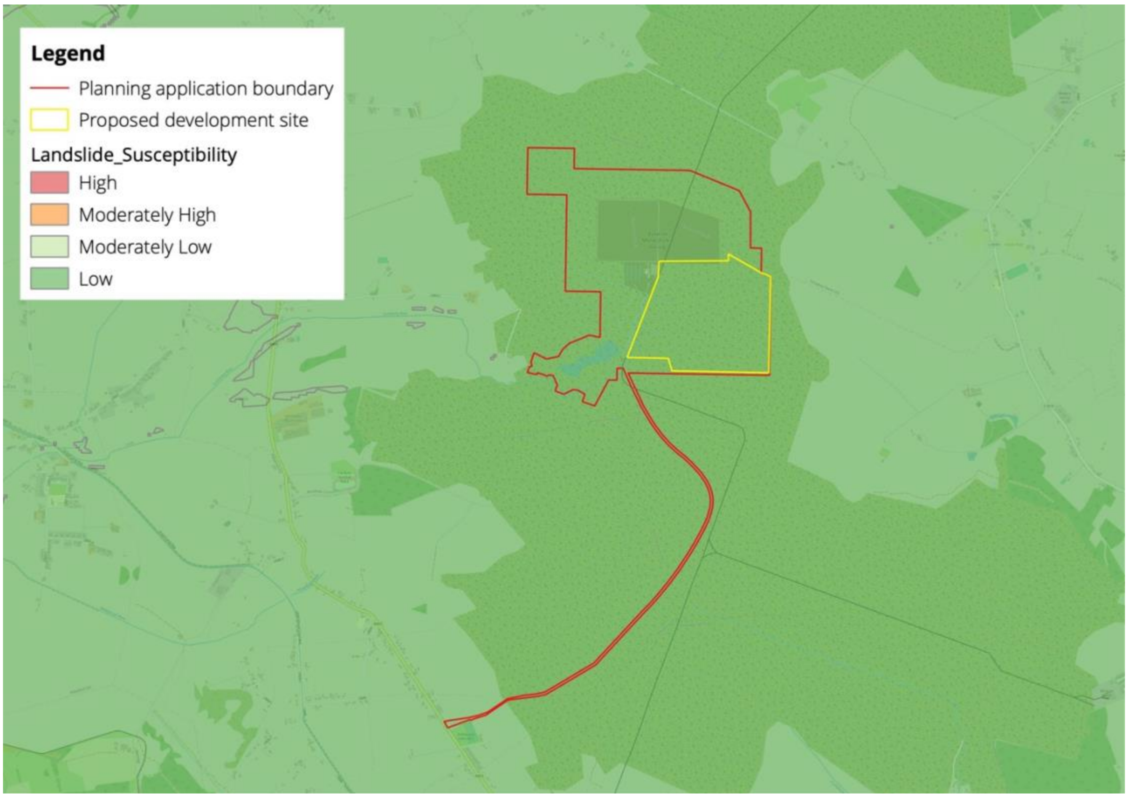

Figure 10 - Landslide susceptibility (Source: GSI National Landslide Susceptibility Mapping, 2021)

It should be noted that the GSI risk assessment is an initial indicative view which is useful to highlight areas for further assessment and is taken account of to assess the risk of peat stability at individual infrastructure elements in Section 5 of this report. Further, the GSI risk assessment only accounts for the current site topographic and hydrological conditions. The development of waste management infrastructure can alter these parameters in the temporary and/or permanent case.

4.7. Ground Investigation

Several phases of ground investigation (GI) of the development area were carried out as outlined in the main EIAR. These investigations confirmed the general geology indicated in the geological mapping. The GI indicated that the site is generally covered in shallow peat which overlies glacial till ("boulder clay") and limestone bedrock. Locations of the recent site-specific ground investigations are shown in Appendix 1. The GI data is used in Section 5 and Section 6 of this report to carry out a location-specific geotechnical risk assessment. The relevant ground investigation reports and data are presented in Appendix 7-1 to the Soils, Geology and Hydrogeology chapter of the main EIAR.

Based on data presented in the 2017 EIAR, the thickness of residual peat across TSB ranges from zero (stripped peat) to 7.7 m. Near the existing WMF and landfill expansion area, and based on the additional information from newly drilled boreholes, recorded thicknesses range from zero to 3.65 m, with 3.65m of peat being identified in MW02B to the west of the proposed development site.

The glacial till is predominantly a CLAY with variable composition of silt, sand, gravel, pebbles, and cobbles. The CLAY can be significantly silty, sandy, and gravelly. The CLAY matrix ranges from soft to stiff, and plasticity ranges from low to high.

5. Peat Stability Assessment

5.1. Material properties

For the purposes of the peat stability assessment, material properties are assessed for Peat at the site. The results of the CDM Smith (2022) and VESI Environmental Ltd. (2023) investigations are used along with comparable experience to derive the required properties.

The peat is described typically as being of "very soft" consistency in the logs. Using the relationship provided in BS 5930 (1999), this corresponds to an undrained shear strength of less than 20 kPa. A conservative view is taken on this, and based on comparable experience, a characteristic undrained shear strength of 10kPa is assessed for the Peat at the site.

Based on a range of published guidance including Long (2005) and O'Kelly and Zhang (2013), the Peat was assumed to have effective stress parameter values φ' = 28° and c' = 4kPa.

A bulk weight of 10 kN/m^3 is assumed for the Peat based on comparable experience and published data (e.g., Osorio-Salas (2012), O'Kelly (2017), and Trafford and Long, 2019)).

The derived and assumed characteristic parameter values for the Peat are summarised in Table 1.

Table 1 – Characteristic parameter values

Material / Parameter	Peat
Bulk Weight (γ_k) [kN/m^3]	10
Undrained shear strength ($c_{u,k}$) [kPa]	10
Effective cohesion (c'_k)	4
Effective angle of shearing resistance (Φ'_k) [degrees]	28

5.2. Qualitative risk assessment procedure

The guidelines set out four categories of risk and recommends various mitigation / avoidance actions for each category. The categories of risk are:

1. Insignificant;
2. Significant;
3. Substantial; and
4. Serious.

The concept of risk analysis for a particular hazard presented in the guidelines referred to the publication entitled "Scottish Road Network Landslides Study" by Winter et al. (2005) and is presented as follows:

$$\text{Hazard Ranking} = \text{Hazard} \times \text{Exposure}$$

Where:

- Hazard = The likelihood of the landslide event occurring
- Exposure = The effect and consequences that the event may have

Table 2 presents the scale of the likelihood and Table 3 presents the classification of exposure ratings based on a percentage of total project cost/time. These classifications are taken from the report entitled Peat Landslide Hazard and Risk Assessments, Best Practice Guide for Proposed Electricity Generation Developments – Second edition (Scottish Government, 2017).

Table 2 – Qualitative assessment of peat landslide Hazard over the lifetime of the development (Scottish Government, 2017)

Scale	Likelihood	Probability of occurrence
5	Almost certain	> 1 in 3
4	Probable	1 in 10 – 1 in 3
3	Likely	1 in 10^2 – 1 in 10
2	Unlikely	1 in 10^7 – 1 in 10^2
1	Negligible	< 1 in 10^7

Table 3 – Qualitative assessment of peat landslide Exposure over the lifetime of the development (Scottish Government, 2017)

Scale	Exposure	Impact as % damage to (or loss of) receptor
5	Extremely high effect	> 100% of asset
4	Very high effect	10% - 100%
3	High effect	4% - 10%
2	Low effect	1% - 4%
1	Very low effect	< 1% of asset

Using Table 2 and Table 3 it is possible to assign a hazard ranking for each zone by multiplying the hazard by the exposure. This will result in a hazard ranking between 1 to 25 (Table 4). Following the result, mitigation measures can be targeted and a revised assessment, post-control measures, is carried out. An indicative list of control measures is provided in Section 8 and the Peat Stability Risk Register in Appendix 3.

Table 4 – Hazard ranking and suggested actions (Scottish Government, 2017)

Hazard Ranking	Designation	Action suggested
17-25	High	Avoid project development.
10-16	Medium	Project should not proceed unless the hazard can be avoided or mitigated without significant environmental effect, to reduce hazard ranking to low or negligible.
5-9	Low	Project may proceed pending further investigation to refine assessment and mitigate hazard through relocation or re-design.
1-4	Negligible	Project should proceed with monitoring and mitigation of peat landslide hazards as appropriate.

GSI landslide susceptibility mapping (Geological Survey of Ireland, 2021) indicates that the entire proposed development is in an area denoted as "low" landslide susceptibility, as shown in Figure 10. It should be noted that the GSI assessment only accounts for the current site topographic and hydrological conditions and is not intended to be used in isolation to determine actual onsite risk. The development of infrastructure can alter these parameters in the temporary and/or permanent case. Excavations to strip peat can be several metres deep and represent a significant alteration to the local topography in the short term. This can have a significant effect on the stability of the material local to the excavation.

Construction operations are proposed as follows:

- Prior to the construction of the landfill, all vegetation will be cleared, and the ground will be stripped of peat and topsoil. The floor of the landfill will be graded in accordance with the required formation levels prior to the development of each phase.
- Peat material will be stripped from the footprint of proposed buildings to suitable subsoil bearing material. Building foundations will be constructed and sub-base material laid for construction of the floor slab and rising walls.
- Excavated peat from the proposed development area will be reused for construction of environmental screening berms and landscaping at the facility.
- Screening berms will be 4 – 6 m in height and constructed on a phased basis with the development of the landfill. The berms will be planted with bands of native peatland tolerant woodland mix with remaining areas allowed to naturally revegetate over time, ensuring their stability.
- No peat will be removed off-site, and all peat materials excavated will be utilised within the proposed development site area.

The peat will be trimmed back to a safe angle of repose, subject to temporary works assessment on site.

The material encountered during ground investigations was generally described as "very soft". Given this, the likelihood of an excavation collapsing during construction is generally in the range "likely" to "probable" in the absence of mitigation. A non-exhaustive listing of possible proposed mitigation measures is provided in Section 8 of this report.

The significance of a collapse in terms of cost and programme is likely to be in the range "very low effect" to "extremely high effect" as the affected area due to a collapse could range from a very localised area up to a major peat slide event feeding into a watercourse.

Mitigation measures can be put in place during the construction of the scheme to reduce the likelihood of a peat failure. Possible mitigation measures include battering back of excavations to a safe angle (as determined through a slope stability assessment by a competent temporary works designer), construction of a glacial till or rock fill berm to support the peat during construction, constructing the screening berms in dry weather only and in stages with strength monitoring as the height increases, or implementation of a monitoring plan for berm stability in the long term.

The assessment process described above was applied to the site, which was treated in two parts, being general landfill development and the construction of screening berms, and is summarised in Table 5. This assessment is based on information from geological maps from GSI, the available aerial and satellite mapping, walkovers, and the site-specific ground investigation undertaken. The Peat Stability Risk Register that this summary table is derived from is presented in Appendix 3, where a detailed risk register for the assessment area is provided.

Table 5 – Peat Stability Risk Register Summary

Assessment area	**Pre-control measure risk rating**	**Post-control measure risk rating**
Landfill development	Low	Low
Berm construction	Medium	Low

Notes: Assessment based on mitigation measures suggested in Section 8 and the Peat Stability Risk Register in Appendix 3.

It is noted that while the construction of berms is initially a “medium” risk activity, once common place mitigations are applied, a “low” risk rating is appropriate. The development is assigned a “low” risk rating overall. Good practice indicates that common-place mitigation measures are applied to further control the risk. It is concluded that the site is suitable for the proposed waste management development.

6. Deterministic peat stability assessment

In addition to the qualitative assessment carried out in Section 5, a deterministic peat stability assessment was carried out based on the results of the ground investigation carried out on the site.

Stability of a peat slope is dependent on several factors working in combination. The main factors that influence peat stability are slope angle, shear strength of peat, depth of peat, pore water pressure, and loading conditions. An adverse combination of factors could potentially result in a peat slide. An adverse condition of one of the above-mentioned factors alone is unlikely to result in peat failure.

6.1. Methodology

To assess the factor of safety for a peat slide, an undrained and drained analysis has been undertaken to determine the stability of the peat slopes on site. The undrained case examines the stability in the short term, while the drained case examines the long term, including the effects of extreme weather events.

The infinite slope model (Skempton and DeLory, 1957) is used to combine these factors to determine a factor of safety for peat sliding. This model is based on a translational slide, which is a reasonable representation of the dominant mode of movement for peat failures.

The formula used to determine the factor of safety for the undrained condition is as follows (Bromhead, 1986):

$$ODF = \frac{c_{u,d}}{\gamma z \sin\beta \cos\beta}$$

Where:

ODF = Overdesign Factor (analogous to Factor of Safety, however ODF > 1.0 indicates satisfactory stability.
$c_{u,d}$ = Design value of undrained shear strength
γ = Bulk unit weight of material
z = Depth to failure plane assumed as depth of peat or soft soil
β = Slope angle

The formula used to determine the factor of safety for the drained condition is as follows (Bromhead, 1986):

$$ODF = \frac{c'_d + (\gamma z - \gamma_w h_w)\cos^2\beta \tan\phi'_d}{\gamma z \sin\beta \cos\beta}$$

Where:

ODF = Overdesign Factor (analogous to Factor of Safety, however ODF > 1.0 indicates satisfactory stability.
c'_d = Effective cohesion, assumed as
γ = Bulk unit weight of material

z = Depth to failure plane assumed as depth of peat
γ_w = Unit weight of water
h_w = Height of water table above failure plane
β = Slope angle
φ' = Effective stress friction angle

6.2. Effects of weather events

The drained loading condition applies in the long term. This condition examines the effect of the change in groundwater level because of rainfall on the stability of the peat slopes. For the drained analysis the level of the water table above the failure surface is required to calculate the factor of safety for the peat slope. To represent varying water levels within the peat slopes, a sensitivity analysis is carried out which assesses varying water level in the peat slopes i.e., water levels ranging between 0 and 100 % of the peat depth is conducted, where 0 % equates to the peat being completely dry and 100 % equates to the peat being fully saturated. By carrying out such a sensitivity analysis with varying water level in the peat slopes, the effects of intense rainfall and extreme dry events were analysed.

6.3. Results and discussion

The results of the analysis are shown in Appendix 2. The assessment takes account of:

1. Slope angle, as derived from LiDAR digital terrain model data,
2. Material strength, as derived from site-specific ground investigation and comparable experience,
3. Likely loadings during the construction period, and
4. Extreme weather events.

The calculations are formulated in accordance with Eurocode 7 (I.S. EN 1997-1), where partial factors are applied to soil strength parameters and loadings to achieve a satisfactory level of reliability in the design.

All overdesign factors (ODF) were greater than 1.0, indicating that the stability is satisfactory in both short term (undrained) and long term (drained) condition. Hence, a general “low” risk rating for peat instability is appropriate for the proposed development.

7. Summary and Conclusions

Ciaran Reilly & Associates has been instructed by TOBIN Consulting Engineers (TOBIN) on behalf of Bord na Móna to carry out a planning stage peat stability risk assessment (PSRA) as part of the environmental impact assessment for a proposed extension of the existing Drehid Waste Management Facility (WMF). The proposed extension provides for additional landfill infrastructure, a new Municipal Solid Waste (MSW) processing facility, additional composting infrastructure, a new soils, stones and construction and demolition rubble processing facility and increased throughput of waste to the existing compost facility.

The site is within the Timahoe South Bog (TSB) peatland, which has been extensively harvested for peat by Bord na Móna (BnaM) in the past. There were no recorded peat landslide events within TSB and the GSI landslide susceptibility is "low" for the entire proposed development site.

The PSRA was carried out in accordance with the document "Peat Landslide Hazard and Risk Assessments, Best Practice Guide for Proposed Electricity Generation Developments – Second edition" (Scottish Government, 2017). The report sets out the methodology used to assess the peat stability risk, the activities undertaken, and the results of the peat stability assessment. The report should be read along with Chapter 7 – "Soils, Geology and Hydrogeology" of the "Drehid Waste Management Facility – Further Development" Environmental Impact Assessment Report (EIAR) and its appendices.

Peat depth was characterised as 3.5 m or less across the proposed development site. LiDAR digital terrain model data were obtained and interrogated to provide a generalised ground profile for peat stability assessment. The generalised ground profile slopes at a gentle angle of 0.55°. The site terrain, being largely flat, limits the potential for and the scale of peat slide and debris runout distances.

While the construction of berms is initially a "medium" risk activity, once common place mitigations are applied, a "low" risk rating is appropriate. The development is assigned a "low" risk rating overall. Deterministic stability assessments indicate that the materials are considered to be stable in the short (undrained) and long (drained) term, including under the influence of extreme weather events, hence justifying the "low" hazard rankings assigned. It is concluded that the site is suitable for the proposed waste management development.

Good practice indicates that common-place mitigation measures are applied during the detailed design of the project to further control the risk. Best practice guidance regarding the management of peat stability must be inherent in the construction phase of the project and further recommendations are provided in the following section.

8. Recommendations

8.1. Detailed Design

The following outlines an overview of the tasks for the detailed design phase:

- Develop a design stage PSRA to include detailed descriptions of mitigations proposed.
- Mitigations to be confirmed at detailed design may include but are not limited to:
  - Detailing of monitoring regime for peat movement.
  - Identification of areas requiring site-specific temporary works design.
  - If required, specify additional site investigations inclusive of in situ testing and laboratory testing in specific risk areas on the site.
  - Confirmation of design of drainage system.
- Update the Peat Stability Risk Register.

8.2. Construction Phase:

The following outlines an overview of the tasks for the construction phase:

- Client's Geotechnical Engineer to provide a Geotechnical Induction to all contractor supervisory staff.
- Client to appoint a Site Geotechnical Supervisor to carry out supervision of site works as required. The Site Geotechnical Supervisor will be required to inspect that works are carried in accordance with the requirements of the PSRA, identifying new risks and ensuring all method statements for works are in place and certified.
- Retain a Site Geotechnical Folder which contains all the information relevant to the geotechnical aspects of the site including but not limited to Geotechnical Risk Register, Peat Stability Risk Register, site investigation information, method statements etc.
- Contractor to develop a Method Statement for the works to be carried out in each of the PSRA areas cognisant of the required mitigating measures.
- Mitigations to be implemented at construction stage may include but are not limited to:
  - Measures to maintain hydrology of area as far as possible.
  - Limiting stockpiling of materials in any specific areas.
  - Excavated material to be removed to designated peat storage areas.
  - Battering back of excavations to a safe angle (as determined through a detailed slope stability assessment by a competent temporary works designer) or construction of a glacial till or rock fill berm to support the peat during construction.
  - Constructing the screening berms in dry weather only and in stages with strength monitoring as the height increases.
  - Implement monitoring regime for peat movement.
  - Provision and management of a robust drainage system.
  - Site-specific temporary works design by competent temporary works designer.
  - If required, carry out additional site investigations inclusive of in situ testing and laboratory testing in specific risk areas on the site.

- Client's Geotechnical Engineer/Site Geotechnical Supervisor to approve the method statement.
- Contractor to provide toolbox talks and on-site supervision prior to and during the works.
- Daily sign off by supervising staff on completed works.
- Implementation of emergency plan and unforeseen event plan by the contractor.

8.3. Operation and Maintenance Phase:

The following outlines an overview of the tasks for the operation and maintenance phase:

- Communication of residual peat risk to appropriate site operatives.
- Ongoing monitoring of residual risks and maintenance if required. Such items would consist of regular inspection of screening berms for peat movement, drains to prevent blockages, and inspections of specific areas highlighted as posing a particular risk after a significant rainfall event.

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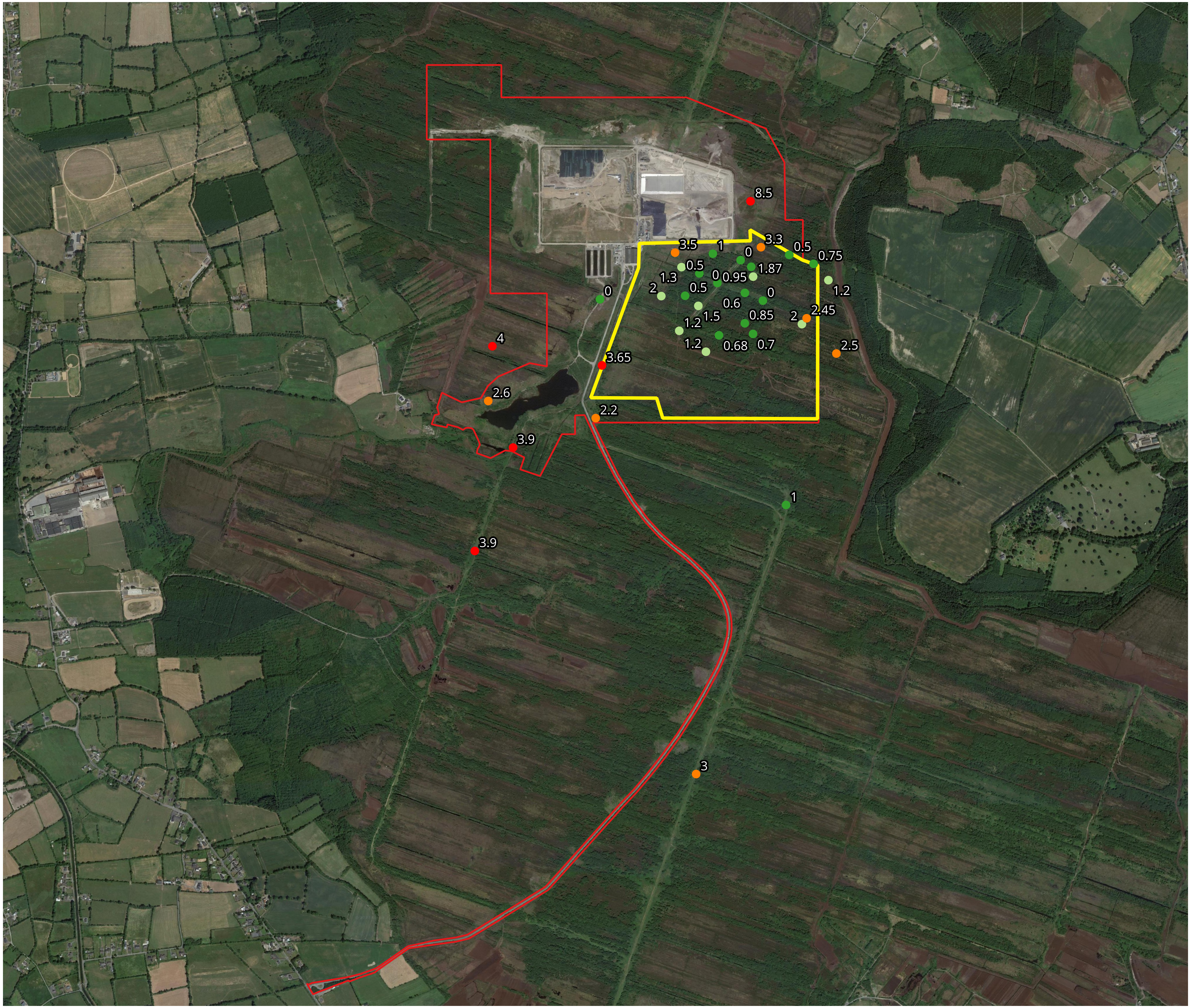
APPENDIX 1: GROUND INVESTIGATION LOCATIONS



N

Legend

- Planning application boundary
- Proposed development site

Peat depth from ground investigation

- 0.0 - 1.0
- 1.0 - 2.0
- 2.0 - 3.5
- 3.5 - 8.5

Ground investigation layout

Drehid Waste Management Facility – Further Development

Doc Nr: P22009_DR001
Rev: P01
Scale: NTS @ A3
Date: 10.03.23
Drawn: CR

0 500 1000 m

Ciaran Reilly & Associates

Consulting Geotechnical Engineers

46 Moyglare Abbey, Maynooth, Co. Kildare
M: +353 (0)86 4005110
E: ciaran@ciaranreilly.ie W: www.ciaranreilly.ie

APPENDIX 2: PEAT STABILITY CALCULATIONS

Peat stability calculations for Drehid Waste Management Facility – Further Development
Deterministic stability calculcation outputs
Undrained Case 1 and Case 2

Nr	Assessment area	Description	Relevant GI	Description	$c_{u,fv,avg}$	Vane correction	$c_{u,k}$	$c_{u,d}$	Peat depth	Slope	Surcharge	Design surcharge	Unit weight	Case 1	Case 2
					kPa		*kPa*	*kPa*	*m*	*deg*	*m*	*m*	*kN/m^3*	*ODF*	*ODF*
1	Landfill development	Cutover peat	All ground investigation (historic & recent) considered.	Peat up to 3.65m	-	0.5	10.0	7.1	3.65	0.55	1	1.3	10	20.4	15.0
2	Berm construction	Cutover peat	All ground investigation (historic & recent) considered.	Peat up to 3.65m	-	0.5	10.0	7.1	3.65	0.55	6	7.8	10	N/A	6.5

	Case 1	Case 2
Minimum	20.4	6.5
Average	20.4	10.8
Maximum	20.4	15.0

Notes:

Undrained shear strength of peat is limited to 10kPa (characteristic value) or local values if less than 10kPa.
Condition 1 relates to no surcharge loading.
Condition 2 takes account of a surcharge equivalent to fill depth of 1m of peat or typical construction traffic i.e. 10kPa.
For berm construction, slip circle analysis also undertaken.
Slope inclination (β) based on site readings and analysis of LiDAR data.
A minimum slope of 0.5 degrees has been considered.
Peat depths based on trial pits, boreholes, and peat probes at the site.

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Nr	Assessment area	Description	Relevant GI	Description	φ'_k	φ'_d	c'k	c'd	Peat depth	Water level in peat	Slope (deg)	Surcharge	Design surcharge	Unit weight	Case 1	Case 2
					deg	*deg*	*kPa*	*kPa*	*m*	*m*	*deg*	*m*	*m*	*kN/m^3*	*ODF*	*ODF*
1	Landfill development	Cutover peat	All ground investigation (historic & recent) considered.	Peat up to 3.65m	28	23.0	4.0	2.9	3.65	3.65	0.55	1	1.3	17	23.5	29.0
2	Berm construction	Cutover peat	All ground investigation (historic & recent) considered.	Peat up to 3.65m	28	23.0	4.0	2.9	3.65	3.65	0.55	6	7.8	17	N/A	37.7

	Case 1	Case 2
Minimum	23.5	29.0
Average	23.5	33.3
Maximum	23.5	37.7

Notes:

Characteristic drained shear strength of peat used.
Condition 1 relates to no surcharge loading.
Condition 2 takes account of a surcharge equivalent to fill depth of 1m of peat or typical construction traffic i.e. 10kPa.
For berm construction, slip circle analysis also undertaken.
Slope inclination (β) based on site readings and analysis of LiDAR data.
A minimum slope of 0.5 degrees has been considered.
Peat depths based on trial pits, boreholes, and peat probes at the site.

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APPENDIX 3: PEAT STABILITY RISK REGISTER

DREHID WASTE MANAGEMENT FACILITY – FURTHER DEVELOPMENT - PEAT STABILITY RISK REGISTER

Assessment area nr: 1
Location: Landfill development

Factor	Value	Pre-control measures			Post-control measures		
		Probability	Impact	Risk	Probability	Impact	Risk
Ground conditions							
Peat depth & condition	Peat up to 3.65m	4	3	**12**	3	3	**9**
Peat strength (kPa)	10	4	3	**12**	3	2	**6**
Topography							
Elevation (mOD)	81.5 to 88.1	2	3	**6**	1	2	**2**
Slope angle (deg.)	0.55	1	3	**3**	1	2	**2**
Evidence of previous slips	No	2	3	**6**	2	2	**4**
Landslide susceptibility	Low	2	3	**6**	2	2	**4**
Hydrology							
Distance from watercourse	> 750m	2	4	**8**	2	3	**6**
Evidence of surface water flow	Yes	4	4	**16**	3	3	**9**
Evidence of subsurface flow	No	1	2	**2**	1	3	**3**
Quantative assessment							
FOS - drained	23.5	1	3	**3**	1	2	**2**
FOS - undrained	15.0						
Total (pre / post control measures)			**74**			**47**	
Max possible			**250**			**250**	
Overall hazard assessment (pre / post control measures)			**7**			**5**	
Overall hazard ranking			**Low**			**Low**	

Control Measures	
1	Develop design stage Peat Stability Risk Assessment.
2	Maintain hydrology of area as far as possible.
3	Use of experienced geotechnical staff for detailed design & temporary works design.
4	Operation of monitoring regime for peat movement.
5	Engage experienced contractors and trained operatives to carry out the work.
6	Inspection regime for excavations during works.
7	Identification of areas requiring site-specific temporary works design.

Assessment area nr: 2
Location: Berm construction

Factor	Value	Pre-control measures			Post-control measures		
		Probability	Impact	Risk	Probability	Impact	Risk
Ground conditions							
Peat depth & condition	Peat up to 3.65m	4	4	**16**	3	3	**9**
Peat strength (kPa)	10	4	4	**16**	3	2	**6**
Topography							
Elevation (mOD)	81.5 to 88.1	2	3	**6**	1	2	**2**
Slope angle (deg.)	0.55	3	3	**9**	1	2	**2**
Evidence of previous slips	No	2	3	**6**	2	2	**4**
Landslide susceptibility	Low	2	3	**6**	2	2	**4**
Hydrology							
Distance from watercourse	> 750m	2	4	**8**	2	3	**6**
Evidence of surface water flow	Yes	4	4	**16**	3	3	**9**
Evidence of subsurface flow	No	1	2	**2**	1	3	**3**
Quantative assessment							
FOS - drained	1.3	4	4	**16**	3	3	**9**
FOS - undrained	1.1						
Total (pre / post control measures)		**101**			**54**		
Max possible		**250**			**250**		
Overall hazard assessment (pre / post control measures)		**10**			**5**		
Overall hazard ranking		**Medium**			**Low**		

Control Measures	
1	Develop design stage Peat Stability Risk Assessment.
2	Maintain hydrology of area as far as possible.
3	Use of experienced geotechnical staff for detailed design & temporary works design, including possible staged construction for berms.
4	Construction of berms in dry weather only.
5	Site-specific temporary works design will be required for berm construction.
6	Inspection regime for excavations & peat strength gain during works.
7	Engage experienced contractors and trained operatives to carry out the work.
8	Operation of monitoring regime for peat movement.