Research Repository UCD

Title	Irish peat slides 2006 – 2010
Authors(s)	Long, Michael (Michael M.), Jennings, Paul, Carroll, Roselyn
Publication date	2011-03-02
Publication information	Long, Michael (Michael M.), Paul Jennings, and Roselyn Carroll. "Irish Peat Slides 2006 – 2010" 8, no. 3 (March 2, 2011).
Publisher	Springer
Item record/more information	http://hdl.handle.net/10197/3097
Publisher's statement	The final publication is available at springerlink.com
Publisher's version (DOI)	10.1007/s10346-011-0254-z

Downloaded 2023-04-07T10:52:29Z

The UCD community has made this article openly available. Please share how this access benefits you. Your story matters! (@ucd_oa)

© Some rights reserved. For more information

Title of paper: Irish peat slides 2006 – 2010

Names of authors: Michael Long¹, Paul Jennings² and Roselyn Carroll³

Position / affiliation of authors:

1: Senior Lecturer, University College Dublin (UCD), Ireland

2: Director, AGECE Ltd. Consulting Engineers, Bagenalstown, County Carlow, Ireland.

3: Research student, UCD.

Contact address:

Michael Long, School of Architecture, Landscape and Civil Engineering, University
College Dublin (UCD), Newstead Building, Belfield, Dublin 4, Ireland.

Phone: +353-1-7163221

Fax: +353-1-7163297

e-mail: Mike.Long@ucd.ie

Date paper written: March 2010

Date paper revised: January 2011

Abstract: The purpose of this paper is to present a review of peat landslide events in Ireland since 2003, when two significant events occurred. Since 2003, there have been at least thirteen such events. Several of these events included more than one slide. It is also likely that there have been unrecorded slides. It seems that there is an increasing incidence of such events but they seem to occur in clusters with intervening quiet periods. These clusters coincide with periods of intense rainfall. For many slides at least two causal factors can be identified. Primarily these comprised intense rainfall but human activities such as road construction and peat cutting also contributed to the slides. Detailed geotechnical testing of the peat, including laboratory direct simple shear tests (DSS), is reported for two of the slides. Backanalysis of these two failures suggest that the mobilised strength of the material in the failure surface is similar to that measured in the DSS tests. However conventional geotechnical analyses need to be treated with caution as they fail to account for the complex interactions in the sliding surface and in particular the lubricating role of water.

Key words: peat; translational (planar); undrained shear strength; rainfall; Ireland;

Introduction

Following the major bog slides in Ireland at Pollatomish (Long and Jennings, 2006, Dykes and Warburton, 2008) and Derrybrien (Boylan et al., 2008) in 2003 there has been a renewed interest in the study of these events. Recent occurrences of these slides has been attributed to many factors but mainly to changing weather patterns (e.g. more intense short duration rain fall) and to human activities (e.g. construction in blanket bog areas). The purpose of this paper is to review what has happened since 2003 and to investigate whether there has been an increased incidence of peat slides and what are the causes of the slides. The paper will also address whether these slides could have been predicted by relatively simple geotechnical analysis. It is beyond the scope of this paper to outline a detailed geomorphologic description and assessment of the slides. The paper seeks to assess overall factors and trends only.

General review

A database of all landslides in Ireland is maintained by the Geological Survey of Ireland (GSI), see www.gsi.ie. A review of all recorded peat slides is shown on Figure 1. These data are sub-divided into number of slides per century (Figure 1a), per decade since 1900 (Figure 1b) and per year since 1991 (Figure 1c).

The data per century is clearly influenced by a lack of reporting of such events but it is interesting to observe that already, in early 2011, the number of slides this century is more than 60% that of the 1900's. Data on Figure 1b will again be influenced by inconsistent recording but it shows a clear pattern of an increasing number of slides per decade. Figure 1c suggests that up until 2003 the situation was relatively stable with typically one slide occurring per year. However since 2003 the situation has been

unstable with quiet periods (i.e. no slides were recorded in 2004, 2005 and 2007) and periods where there have been several slides.

A summary of all the peat slides, which occurred since 2003, is given on Table 1. It is clear that the 2006 and 2008 events occurred in blocks in late December 2006 and in August / September 2008 respectively. On both occasions the prevailing weather conditions comprised significant rainfall leading up to the time of the slide.

2006 slides

General

All of the slides during this period occurred in mid to late December. Rainfall data (courtesy of Met Éireann) for the gauges closest to the three slide locations is shown on Figure 2. It can be seen that all the slides were preceded by a period of significant rainfall with daily amounts well in excess of the long term average values. Daily falls of in excess of 25 mm occurred at all three locations with one incidence of 100 mm occurring at Delphi Lodge near Bengorm.

Gleniff (Slide No. 122 on GSI landslides database)

This slide occurred at the upper end of a small valley along the Gleniff Horseshoe Road in County Sligo. The area is a relatively isolated upland valley on the eastern slopes of Benwiskin Mountain at an elevation of about 200 mOD and comprises un-forested blanket bog with an average slope of about 10°. Local reports (Irish Times of 15/12/06, Irish Independent of 15/12/06) suggest that water trapped in a hollow, swollen by the heavy rain burst its banks precipitating the slide. The length of the slide was some 100 m and the valley road was blocked over a 300 m length.

Clare Island (Slide No. 127 on GSI landslides database)

This relatively large event occurred on the south side of Clare Island in Clew Bay, Co. Mayo and involved a slide on the steep slopes of Knockmore Mountain at about 450 mOD (The Mayo News March 7th 2007), see Figure 3. According to local reports a similar slide occurred on the north side of Knockmore Mountain in 2000 and a major slide also occurred in the 1940's. Slide debris ran into a reservoir and blocked the source of the local water supply.

Bengorm (Slide No. 123 on GSI landslides database)

Some two weeks after the Clare Island and Gleniff events, a similar slide to that at Clare Island occurred at Bengorm, near Leenaun, about 25 km to the south east of Clare Island, see Figure 4a. The upper elevation of the slide at about 400 mOD was similar to that at Clare Island. As can be seen on Figure 4b, slide debris came to rest at the back windows of a local house and also blocked the R335 road from Leenaun to Aasleagh falls. Following a period of intense rainfall in July 2007, this slide was partly re-activated and a combination of flooding and the landslide destroyed a bridge on the N59 Clifden to Galway road (RTE News, 19/7/07)

The nature of these two slides, i.e. removal of relatively thin cover of peat on steep mountainside by high intensity rainfall is similar to the large scale event at Pollatomish in 2003.

2008 slides

These slides are described in detail by Dykes and Jennings (2011). Similar to the 2006 events a period of very heavy prolonged rainfall preceded the slides see Figure 5. Rainfall was well above the long term daily average at both the Manorhamilton (north of slide

area) and Riverstown (south of slide area) weather stations. On 13/8/2008, when four of the events took place, the daily rainfall was recorded as 51.2 mm and 36.7 mm at Manorhamilton and Riverside respectively. Although there was comparatively low rainfall in the days leading up to the Ballincollig Hill slide on 22/8/08, the preceding weeks had been extremely wet with daily rainfall of up to 49 mm recorded. Although local rainfall amounts were low during the seven day period leading up to the Garvagh Glebe North failure on 23/9/2008, intense rainfall was recorded in the period seven to fourteen days prior to the slide.

Seltan (Slide No. 140 on GSI landslides database)

This comparatively small slide occurred at an elevation of about 300 mOD on the west side of a track adjacent to forestry. The slope is generally east facing at an angle of about 10°.

Corrie Mountain (Not currently on GSI landslides database)

This relatively large slide occurred immediately north east of Tullynahaw wind farm (and the peak of Corrie Mountain) at an elevation of about 400 mOD, see Figure 6. There is no evidence to suggest that the wind farm construction activities were the cause of the failure. The failure involved a separation at the interface of the peat and mineral soil (Figure 6a). At the interface there was an intermittent line of seepage (Figure 6b). Debris from the slide entered and was subsequently transported downhill by a small stream.

Derrysallagh (Slide No. 129 on GSI landslides database)

This event occurred in the late evening of 13/8/08 and comprised five separate slides, which were located within 500 m of one another. The slides took place on east side of Kilronan Mountain upslope of the Arigna to Glen road. The hillside slopes relatively

steeply at an angle of about 17° and has a maximum elevation of about 370 mOD. Debris from the slide blocked the road over lengths of up to 100 m and trapped an elderly resident in his home (The Irish Times 15/8/08, Roscommon Herald 20/8/08)

Geevagh (Not currently on GSI landslides database)

This slide originated at about 400 mOD on the slopes of Carrane Hill. Again it involved a relatively large body of peat. Debris from the slide inundated a sports pitch and the associated buildings causing an estimated €200,000 of damage (Irish Times 15/8/08, Roscommon Herald 20/8/08). This area has a history of slides and the same sports pitch had been very similarly damaged in a slide in 1984 (Alexander et al., 1986).

Garvagh Glebe North (Slide No. 133 on GSI landslides database)

This slide occurred at approximately 4:40pm on 23/9/08, when a wedge of bog became dislodged during construction of a road on a wind farm development (e.g. Leitrim Observer 1/10/08). The slide originated at an elevation of about 300 m OD on a north east facing slope. There was no heavy rainfall recorded in the week leading up to the slide, but intense rainfall occurred in the period preceding this, see Figure 5. Some minor roads were blocked by the slide and efforts were required to save fish. Some small dams and ponds were constructed to arrest the slide and to provide a habitat for the fish.

Kilronan Mountain (Slide No. 141 on GSI landslides database)

Although this slide or series of slides is known to have occurred in 2008, the exact date is unknown. Little detail is available except that there were several slides originating at an elevation of about 300 mOD on a north east facing slope on the southern part of the same mountain as the Derrysallagh slides of 13/8/08.

Ballinacollig Hill (Slide No. 130 on GSI landslides database)

This slide is described in some more detail as it will be used for geotechnical backanalysis later in the paper. The bog slide occurred on 22/8/08 with main movements on this day and the next following a period of heavy intense rainfall, see Figure 5. For example 49 mm of rain was recorded at Tralee weather station on 10/8/08. Prior to the slide this area had been used for turf cutting to provide peat for domestic consumption. It would seem that the peat had been cut mechanically using a “sausage” machine which extracts peat from about 1 m depth through vertical slits (Figure 7a). This technique effectively slices the upper metre of peat into strips. During the slide the peat peeled away in slices corresponding to the slits (Figure 7b). An existing access road to the area had been re-stoned and construction was proceeding on new access road to north-east, which was a continuation of the older road when the slide occurred, see Figure 7c. According to reports in *The Kerryman* of 29/8/08, locals reported “a ripple effect on the bog” prior to the main sliding action.

The head of slide was at an elevation of about 300 mOD and it then continued progressively downhill to the north-east towards a small river. The slope angle is approximately 3° . Inspection of the shear surface was difficult for safety reasons but at one location it was observed about 200 mm above base of peat and not at the peat / mineral soil interface, though the situation for the whole slide is likely to have been complex.

Before reaching the river, which was at distance of some 450 m, the width of the slide was approximately 30 m with peat depths of about 3 m. Much of the movement seems to have occurred from the base of the mass. There was a clear reduction in the ground level

by about 1 m in the area adjacent to the slide. Intact blocks of peat reinforced by roots and vegetation remained though they were displaced down hill.

Subsequently the slide mass mixed with the water in the river and was transported downstream. Damage was caused to the wing walls of a bridge which was overtopped by peaty debris (Figure 7d). The debris line extending into the forest on both sides can be seen on the photograph. Minor damage was caused to local roads and infrastructure, including phone lines and residents were trapped for some time and there were reports of fish kills. Several small dams were constructed and the slide was subsequently arrested some 3 km from the slide scarp.

2009 Slides

Glencolumcille (Slide No. 152 on GSI landslides database)

Similar to the 2006 and 2008 events a period of very heavy prolonged rainfall preceded the Glencolumcille slide on 23/8/2009, see Figure 8. Significant daily rainfall occurred at both Kilcar (south of site) and Bruckless (south west of site), with for example 24.5 mm being recorded at Bruckless the day before the slide occurred.

A minor road, east of the slide area, was blocked off by peat about 1.5 m deep (Irish Times of 25/08/09). According to the Irish Times 20 families were cut off. Nobody was injured though there were reports of a motorist having just passed along the road minutes before the slide.

A major contributory factor to the slide was the peat cutting in the area (similar to the slide which occurred in Ballincollig Hill). The lines of peat cutting basically delineated the extent and shape of the slide. Again peat was being cut mechanically using a “sausage” machine. The interface between the upper sliced peat and the lower

undisturbed peat at about 1 m is clearly visible in Figure 9a. Figures 9b and 9c show the delineation of the slide mass by the slicing on the southern and northern flanks of slide respectively. North of the slide the peat had been consolidated by traffic on an access road and by previously cut peat piled in reeks. An existing ditch also controls the southern limit of the slide. South of this area the peat has also been cut and the ground is hummocky. Furthermore the head of the failure also corresponded with the upper limit of machining where there are cross slopes cuts. Peat had also been removed from the toe of the slide adjacent to the road, thus removing any support in this zone.

The slide was clearly initiated towards the top of the slope at an elevation of about 160 mOD and occurred in a generally east to north-east facing slope where the slope angle is approximately 5° at the head of the slide but increases to about 7° before levelling off adjacent to the road. It then advanced progressively downhill. The overall slide length is about 350 m. However only the top 225 m or so of the overall length was involved in the actual failure. Below the break in the slope at the 130 m OD contour the failed mass from upslope slid over the intact ground) forming 2 lobes of peat at the end of the slide (Figure 9d). Both of these lobes traversed the minor road. In the failed area the slide is approximately 30 m wide and increases to about 120 m at the bottom.

The peat is up to 2 m deep but more typically 1.5 m deep (Figure 9a). Failure was at the interface between the base of the peat and the underlying mineral soil (Figure 9e). This mineral soil is no more than a few cm thick and comprises firm brown organic silty clay with root fragments. It is not continuous and bedrock outcrops at the base of the slide in several locations. The mineral soil is reminiscent of the “hardpan” at the

Pollatomish site (Long and Jennings, 2006). The failure surface is therefore complex and thus does not easily lend itself to numerical modelling.

Slieve Bloom (Slide No. 155 on GSI landslides database)

The exact data of this slide is unknown but it is thought to have occurred in 2009. The event can be described as a bog flow according to Dykes and Wharburton (2007) and involved approximately 20,000 m³ of material (Personal communication from Dr. A.P. Dykes). The slide is immediately to the east of a much older slide. At least two other events are recorded in this area in the GSI database.

2010 Slide

Slieve Rushen (Slide No. 156 on GSI landslides database)

Again the exact data of this slide is unknown but it is thought to have occurred in either early 2010 or late 2009. This event, which involved some 33,000 m³ of material, can be described as a bog slide according to Dykes and Warburton (2007) (Personal communication from Dr. A.P. Dykes). The slide is also near three other events which are recorded in the GSI database.

Overview of causal factors

In a review of the causal factors of peat slides (Boylan et al., 2008) suggest the most important causal factors are:

- intense rainfall,
- loading of peat surface,
- excavation,
- morphology,
- geomorphology,

- hydrology and
- geology.

Causal factors associated with the peat slides described in this paper have been summarised on Table 2. It can be seen that intense rainfall is associated with all the slides. However generally an additional causal factor is also involved. For example in two cases slicing of peat by turf cutting was a factor and in two other cases wind farm access road construction was taking place adjacent to the slide location. Three of the slides occurred in relatively steep ground and a break in the slope was present in one case. Poor drainage was a factor in at least one of the slides. It is clear that the occurrence of intense rainfall is of greatest importance. However the reasons for the occurrence of the slides are complex and are most likely to be due to a number of overlapping factors.

Failure surface - general observations

The failure surface in the peat slides, where the peat is comparatively thick and the slope angle is relatively shallow and where the causal factors are a combination of rainfall and other issues tend to be moderately deep and they tend to “seek out” the base of the peat or the top of the underlying strata.

In contrast slides on steeper hillsides with thin peat cover is thin (The Geological Survey of Ireland, www.gsi.ie, define peat areas as being those where the peat thickness is greater than 0.5 m) and where the causal factor is intense rainfall the failures tend to be well within the underlying mineral soil or weathered rock. An example is the slides which occurred at Croaghmoyle Mountain, Co. Mayo on 2 July 2009, following intense rainfall, see Figure 10a. About 60 mm of rainfall was recorded nearby at Newport Co.

Mayo on the afternoon of 2 July. The peat was typically less than 0.5m deep and the mineral soil was typically less than 1.0m thick and described as brown/grey peaty slightly gravelly clay which grades into the underlying weathered rock (Figure 10b). Typical slope inclinations ranged from 21° to 44° and all the failures were shallow translational slides with the basal failure surface on weathered bedrock or bedrock and occurred at the mineral soil / weathered rock or bedrock interface. Groundwater ingress into the base of the mineral soil or top of rockhead during the heavy rainstorm event was the likely cause of the failure. Natural piping or seepage lines were evident in the headwall scar of most of the failures surfaces.

Failure surface and type of failure

The nature of the failure surface and the type of failure (Dykes and Warburton, 2007) is also summarised on Table 2. Four of the slides appear to have been “peat slides” involving failure at the interface of the peat and the underlying mineral soil. At least three slides were “bog slides” where failure occurred towards the base of the peat mass. However it is likely that in practice the conditions at the interface were complex and involved failure in the peat, at the interface between the peat and mineral soil or bedrock and even in the mineral soil itself. Therefore these slides represent cases which are not easily modelled by conventional soil mechanics stability analyses.

Characterisation of the peat

Ballinacollig Hill

Basic geotechnical properties for the Ballinacollig Hill peat are shown on Figure 11. Water content increases from about 900% at 0.8 m depth to 1200% at 1 m and stays relatively constant until 2 m before decreasing again. Bulk density value show some scatter but are

on average 1.05 Mg/m^3 . Loss on ignition values are typical for Irish peat being generally greater than 90%. Von Post and Granlund (1926) humification values are between 5.5 and 7 and show a gradual increase with depth.

Two sets of undrained shear strength values (s_u) from direct simple shear testing (DSS) are shown on Figure 11(e). DSS tests are considered to represent the mode of failure in a landslide. In order to be conservative the s_u values shown were consistently chosen at 15% shear strain. The UCD tests were carried out at a consolidation stress (σ_{vc}') of about 18 kPa (corresponding to a water table at about 1.8 m) and the Norwegian Geotechnical Institute (NGI) tests were carried out at σ_{vc}' equal to 4.5 kPa (water table about 0.5 m). The results confirm the significant dependence of available strength on consolidation stress and show that at low σ_{vc}' (i.e. high water table) the shear strength can be as low as 2.0 kPa.

Glencolumcille

A similar set of properties for the Glencolumcille site are shown on Figure 12. Here there is a clearer pattern in the properties of the peat. Water content decreases steadily from about 1350% at 0.5 m to about 750% at the base of the peat. This is mirrored by a steady increase in degree of humification from von Post H of 4 at 0.5 m to 8 at 1.9 m. Bulk density values are on average 0.96 Mg/m^3 and DSS undrained shear strength values (with approximately 19 kPa consolidation stress) are between 4.5 kPa and 7.5 kPa.

Backanalysis of slides

Ballinacollig Hill

The geotechnical data shown above can be used to backanalyse the slides using standard geotechnical approach. For a peat thickness of 3 m, a slope angle of 2.85° and undrained

shear strength (s_u) of 2.0 kPa (minimum from DSS tests), the calculated factor of safety (FOS) using a simple infinite slope calculation is 1.3. The undrained shear strength value needs to be reduced to about 1.5 kPa in order to produce a factor of safety of 1.0 compatible with failure. This low value is not unreasonable and would correspond to a DSS consolidation stress of about 3 kPa (i.e. in situ water table at 0.3 m)

This simple analysis can be criticised on the basis that the failure surface needs to be assumed and that it cannot account easily for a variable water table or for surcharge loading (e.g. construction plant in this case). However a more sophisticated approach, carried out using OASYS-SLOPE V19.0, yielded similar results. These are summarised on Table 3. Here the computer program was allowed to search for the most critical shear surface and this process resulted in the choice of a circle with very large radius, i.e. yielding a failure surface very similar to that in the infinite slope approach. Again although the calculated FOS is sensitive to the location of the water table, the s_u value and the surcharge loading, the resulting values are all greater than 1.0 and again the s_u value would need to be reduced to about 1 kPa to produce failure conditions.

Glencolumcille

For this site, assuming peat thickness of 2 m and a slope angle of 5° an assumed undrained shear strength (s_u) of 0.9 kPa is required in order to produce a factor of safety of 1.0 using a simple infinite slope calculation. This value is much lower than that recorded in the DSS tests. However the DSS σ_{vc}' values were relatively high (≈ 19 kPa) and an s_u of 0.9 kPa would correspond with a consolidation stress of about 4 kPa (water table at 0.4 m) which is not unreasonable.

Conclusions

The analyses suggest the mobilised undrained shear strength values in the sliding mass were of the order of 1.0 kPa to 1.5 kPa for these two slides. These values are similar to those inferred from DSS tests at low consolidation stress (i.e. corresponding to high water table). However this finding needs to be treated with caution as this simple analytical approach is unable to model the real failure mechanism. The main uncertainty in the analyses is the nature of and the process taking place at the sliding surface, especially the interaction between the peat and underlying mineral soil and the lubricating role of water. Further work is required in order to understand these processes and to permit reliable quantification of the risk of peat slides.

Summary and conclusions

1. Thirteen recorded peat slides have taken place in the Republic of Ireland since the well documented events of 2003.
2. There is an overall trend of an increasing number of slides. However these tend to occur in groups during periods of intense rainfall.
3. Intense rainfall is associated with all of the slides. However many events have a associated second causal factor.
4. Of these the most important is human activities such as construction of access roads or peat harvesting.
5. Geotechnical characterisation of two of the slides confirms the properties of the peat to be typical of those found elsewhere in Ireland. Undrained shear strengths from direct simple shear testing of as low of 2.0 kPa were measured.
6. Backanalysis of the slides with low shear strength of the order of 0.5 to 1.5 kPa in the sliding surface produce a factor of safety of 1.0, i.e. consistent with the DSS

test results. However these conventional stability analyses need to be treated with caution as they fail to capture the complexity of the failure zone in the sliding mass and in particular the lubricating role of water.

Acknowledgements

The authors would like to thank Charise Mc Keown of the Geological Survey of Ireland for providing data from the GSI landslide database and also Dr. A.P. Dykes of Kingston University, UK for providing information on the 2009 / 2010 Slieve Bloom and Slieve Rushen slides.

Table 1. Summary of all peat slides since 2003

Date	GSI Ref. No.	Location	Easting (m)	Northing (m)
14/12/2006	122	Gleniff Horseshoe Valley, below Benwiskin Mountain, Co. Sligo	173040	347220
14/12/2006	127	Knockmore Mountain, Clare Island, Co. Mayo	66909	286108
31/12/2006	123	Bengorm Mountain, Letteras, Co. Mayo	88098	264185
13/8/2008	140	Seltan, Corrie Mountain, Drumkerrin, Co. Leitrim	187300	322500
13/8/2008	Not in GSI	Corrie Mountain, Co. Leitrim	189800	320300
13/8/2008	129	Derrysallagh, Geevagh, Co. Sligo (North side Kilronan Mountain)	187353	317035
13/8/2008	Not in GSI	Geevagh (Carrane Hill), Co. Sligo	185800	319000
23/9/2008	133	Garvagh Glebe North wind farm, Corrie Mountain, Drumkerrin, Co. Leitrim (Gowlaunreveagh in GSI database)	187100	322700
2008 Exact date unknown	141	Kilronan Mountain, Geevagh, Co. Sligo	190752	314789
22/8/2008	130	Ballincollig Hill, near Tralee Co. Kerry	91506	118566
23/8/2009	152	Glencolumcille, Co. Donegal	159500	387700

2009 Exact date unknown	155	Slieve Bloom, Co. Laois	226500	202200
2009 / 2010 Exact date unknown	156	Slieve Rushen, Co. Cavan	223200	221600

Table 2. Analysis of slide causal factors

Slide	Type of failure*	Heavy rainfall	Construction activities	Turf cutting	Others	Notes and comments
Gleniff	?	✓			Poor drainage	
Clare Island	Peat slide	✓			Steep slope	
Bengorm	Peat slide	✓			Steep slope	
Seltan	?	✓				
Corrie Mnt	Peat slide	✓	See over			NE of wind farm but no evidence that construction activities were a causal factor
Derrysallagh	?	✓			Relatively steep slope	
Geevagh	Bog Slide	✓				Area has strong history of slides
Garvagh Glebe North	?	✓	✓			Failure occurred during access road construction
Kilronan Mnt.	?					Little detail available
Ballincollig Hill	Bog slide	✓	✓	✓		Failure occurred during access road construction
Glencolumcille	Peat slide	✓		✓	Break in slope below slide head	Shape of slide delineated by turf cutting
Slieve Bloom	Bog flow					
Slieve Rushen	Bog slide					

* after (Dykes and Warburton, 2007)

Table 3. Summary of slope stability analyses for Ballincollig Hill slide

Run	Water table (m)	s_u (kPa)	Surcharge Load (kPa)	Failure surface	FOS
1	1	5	0	Wedge 20 m long	≈ 10
2	1	3	0	Wedge 20 m long	6.2
3	1	2	0	Wedge 20 m long	4.1
4	Ground	3	0	Wedge 20 m long	3.7
5	Ground	3	0	Circular	3.1
7	Ground	1.5	0	Circular	1.6
6	Ground	3	10	Circular	1.2

List of figures

Fig. No.	Title	Reference
1	Number of peat slides (a) per century, (b) per decade and (c) per year	DELL/Papers/Landslides/PeatSlides2006-2009/TotalPeatSlides.grf
2	Daily rainfall for 2006 slides	DELL/Papers/Landslides/PeatSlides2006-2009/Rainfall-Late2006.grf
3	Clare Island slide	DELL/Papers/Landslides/PeatSlides06-09/MovingMountainonClareIsland.doc
4	Bengorm slide(a) general view and (b) damage to local property	DELL/M+P/PeatSlides/BenGorm/BenGormDec2006.jpg and DSCN1408.jpg
5	Daily rainfall for Autumn 2008 slides	DELL/Papers/Landslides/PeatSlides2006-2009/Rainfall-LateAutumn2008.grf
6	Corrie Mountain slide (a) general view to the north east and (b) detail at failure surface	DELL/M+P/PeatSlides/Geevagh2008/DSCN0015.jpg and DSCN0017.jpg
7	Ballincollig Hill slide (a) peat cutting by “sausage” machine, (b) peeling action of peat during slide (c) general view from head of slide and (d) peaty debris	DELL/M+P/PeatSlides/BallincolligHill/P1011187.jpg+P1011188.jpg+P1011186.jpg and P101175.jpg
8	Daily rainfall for Autumn 2009 slides	DELL/Papers/Landslides/PeatSlides2006-2009/Rainfall-LateAutumn2009.grf
9	Glencolumcille slide (a) depth of peat cutting by “sausage” machine and block sample location, (b) and (c) delineation of slide mass by cuts on southern and northern flanks (d) general view from head of slide showing two lobes and (e) failure surface	DELL/M+P/PeatSlides/Glencolumcille/P9171755.jpg, P9171748.jpg, P9171759.jpg, P9171746.jpg and P9171756.jpg

10	Slides on Croaghmoyle Mountain Co. Mayo July 2009 (a) general view b) detail on failure plane in mineral soils	DELL/M+P/PeatSlides/AGECMayo2009/DSCF0014a.jpg and DSCF0039a.jpg
11	Ballinacollig Hill – geotechnical properties of peat (a) water content, (b) bulk density, (c) loss on ignition, (d) von Post humification and (e) undrained shear strength	DELL/Labtests/BallinacolligHill/Basicandsu.grf
12	Glencolumcille – geotechnical properties of peat (a) water content, (b) bulk density, (c) von Post humification and (d) undrained shear strength	DELL/Labtests/Glencolumcille/Basicandsu.grf

Newspaper References

Gleniff slide: “Landslide of mud blocks road in Sligo”. Article by Paddy Clancy in the Irish Times, 15/12/06, Page 2.

Clare Island slide: “Moving mountains on Clare Island”. Article by Cormac Ó Cionnaith in The Mayo News 07/03/07

(http://www.mayonews.ie/index.php?option=com_content&task=view&id=1162&Itemid=38)

Bengorm slide: “Collapsed Galway bridge to be inspected”. RTE News 19/7/07 10:23 (<http://www.rte.ie>)

Derrysallagh and Geevagh slides:

“Man (80) refused rescue after landslide left him stranded. The Irish Times 15/8/08.

(<http://www.irishtimes.com/newspaper/Ireland/2008/0815/1218747922677.html>)

“Landslide leaves major damage in its wake”. The Roscommon Herald 20/8/08.

(<http://archives.tcm.ie.roscommonherald/2008/08/20/story8112.asp>)

Garvagh Glebe North slide: “Work on going at Drumkerrin landslide site as 2000 fish saved”. The Leitrim Observer 01/10/08. (<http://leitrimobserver.ie/news/work-ongoing-at-Drumkerrin-landslide.4547893.jp>)

Ballincollig Hill slide:

“Landslide leaves locals in awe at power of nature”. The Kerryman 29/08/08.

(<http://www.kerryman.ie/news/landslide-leaves-locals-in-awe-at-power-of-nature-1465170.html>)

“Locals believe windfarm is linked to bog slide disaster”. The Kerryman 29/08/08.

(<http://www.kerryman.ie/news/locals-believe-windfarm-is-linked-to-bog-slide-disaster-1465170.html>)

Glencolumcille slide: “Donegal mudslide cuts off 20 families”. The Irish Times 25/08/09

References

- ALEXANDER, R. W., COXON, P. & THORN, R. H. (1986) A bog flow at Straduff townland, County Sligo. *Proceeding of the Royal Irish Academy, B*, 86, 107-119.
- BOYLAN, N., JENNINGS, P. & LONG, M. (2008) Peat slope failure in Ireland *Quarterly Journal of Engineering Geology and Hydrogeology*, 41, 93-108.
- DYKES, A. P. & JENNINGS, P. (2011) Peat slope failures and other mass movements in western Ireland, August 2008. *Quarterly Journal of Engineering Geology*, 43, 2, May.
- DYKES, A. P. & WARBURTON, J. (2007) Mass movements in peat: a formal classification scheme. *Geomorphology*, 86, 73-93.
- DYKES, A. P. & WARBURTON, J. (2008) Failure of peat covered hillslopes at Pollatomish, Co. Mayo, Ireland: analysis of topographic and geotechnical influences *Catena*, 72, 129-145.
- LONG, M. & JENNINGS, P. (2006) Analysis of the peat slide at Pollatomish, Co. Mayo, Ireland. *Landslides*, 3, 51-61.
- VON POST, L. & GRANLUND, E. (1926) Peat resources in southern Sweden. *Sveriges geologiska undersökning, Yearbook*, 335, 1 – 127.

Figures for Irish peat slides 2006 – 2010 by Long et al.

Fig 1. Number of peat slides (a) per century, (b) per decade and (c) per year

Fig 2. Daily rainfall for 2006 slides

Fig 3. Clare Island slide

Fig 4. Bengorm slide (a) general view and (b) damage to local property (Photographs courtesy Cáitríona Douglas, National Parks and Wildlife Service)

Fig 5. Daily rainfall for Autumn 2008 slides

Fig 6. Corrie Mountain slide (a) general view to the north east and (b) detail at failure surface (Dykes and Jennings, 2011)

Fig 7. Ballincollig Hill slide (a) peat cutting by “sausage” machine, (b) peeling action of peat during slide (c) general view from head of slide and (d) peaty debris

Fig 8. Daily rainfall for Autumn 2009

Fig 9. Glencolumcille slide (a) depth of peat cutting by “sausage” machine and block sample location, (b) and (c) delineation of slide mass by cuts on southern and northern flanks (d) general view from head of slide showing two lobes and (e) failure surface

Fig 10. Slides on Croaghmoyle Mountain Co. Mayo July 2009 (a) general view (b) detail on failure plane in mineral soils

Fig. 11. Ballincollig Hill – geotechnical properties of peat (a) water content, (b) bulk density, (c) loss on ignition, (d) von Post humification and (e) undrained shear strength

Fig. 12. Glencolumcille – geotechnical properties of peat (a) water content, (b) bulk density, (c) von Post humification and (d) undrained shear strength