

SHASS MOUNTAIN PEAT LANDSLIDE

Factual Report



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Prepared by:

Prepared for:

RPS

Lyr 2,
IDA Business & Technology Park,
Mervue
Galway,
H91 H9CK

Working Group under Ministers Supervision

Department of Culture, Heritage and the Gaeltacht,
23 Kildare Street, Dublin, D02 TD30

Dublin | Cork | Galway | Sligo
rpsgroup.com

RPS Group Limited, registered in Ireland No. 91911
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The Registered office of each of the above companies is West Pier
Business Campus, Dun Laoghaire, Co. Dublin, A96 N6T7



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Appendix A Aquatic Ecology References:

- Diffagher River Water Quality Chemistry
- Lough Allen Water Quality Data
- Field Survey Macroinvertebrate Fauna

1 INTRODUCTION

1.1 Overview

A blanket bog landslide occurred on Shass Mountain, north-east of Drumkeeran, Co. Leitrim on the 28th June 2020, approximately 1.2km upstream of the Dawn of Hope Bridge. The area affected by the peat landslide is shown in red outlined in **Figure 1-1**.

This document is a factual report on the event, a review of the catchment characteristics that may have contributed to the landslide and the aquatic ecology of the catchment before and after the event. The report also includes a risk assessment of the situation with respect to the stability of the remaining bog within the immediate slopes affected by the landslide and recommendations for short term mitigation measures and further studies required.

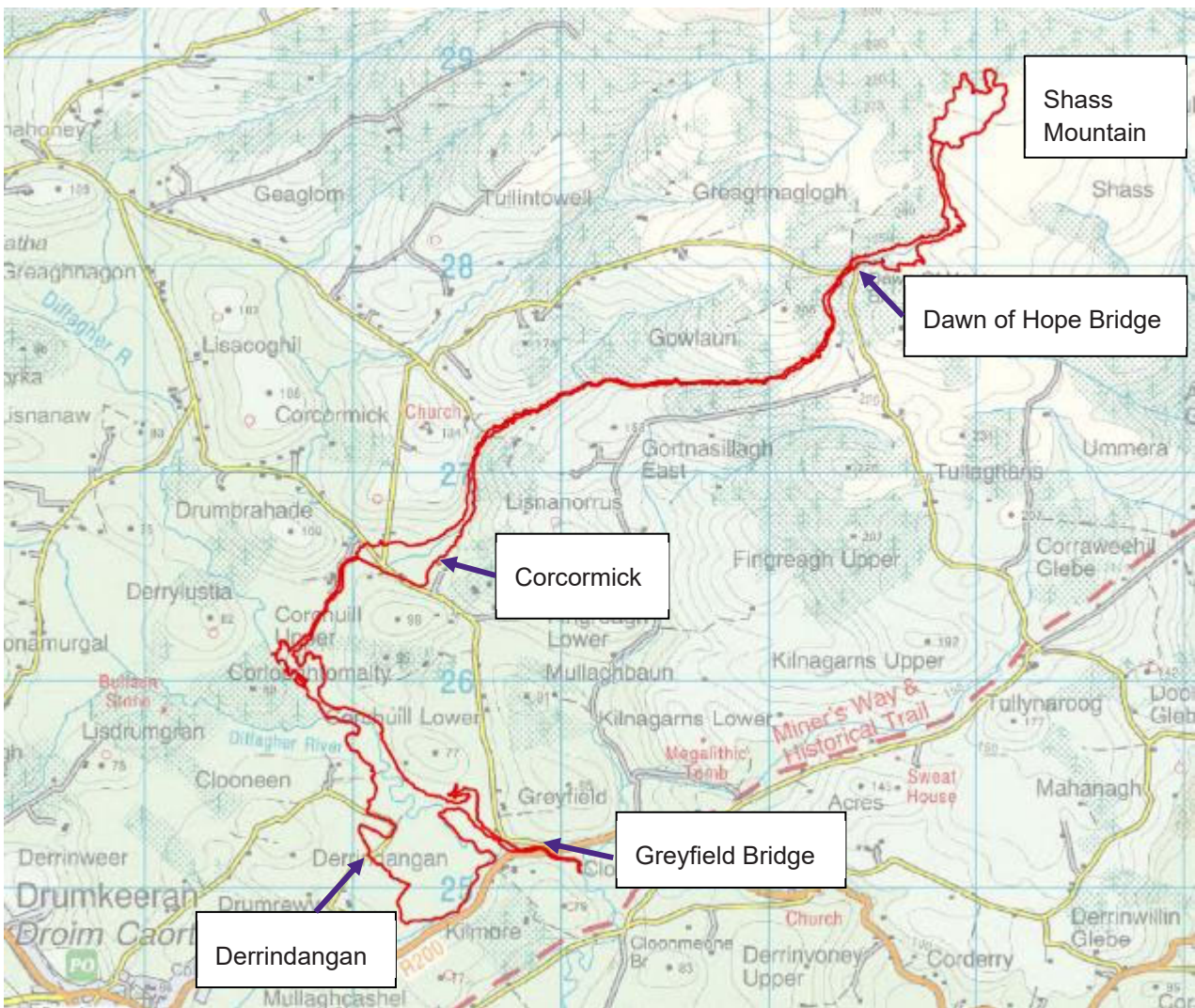


Figure 1-1 Extents of the Landslide

1.2 Developments on Shass Mountain, 1995 to Present

The OSi online mapviewer provides orthophotography imagery of Ireland and includes imagery of Shass Mountain for the years 1995, 2000, 2005, and Aerial Premium taken after 2013. **Figure 1-2** provides screenshots of the orthophotography imagery from OSi.

As is seen in the progression of the orthophotography, the main development on Shass Mountain in the period 1995 to present is the planting of forestry in 1997 (approximately outlined in red to the below image for pre-planting in 1995) which has grown over time.

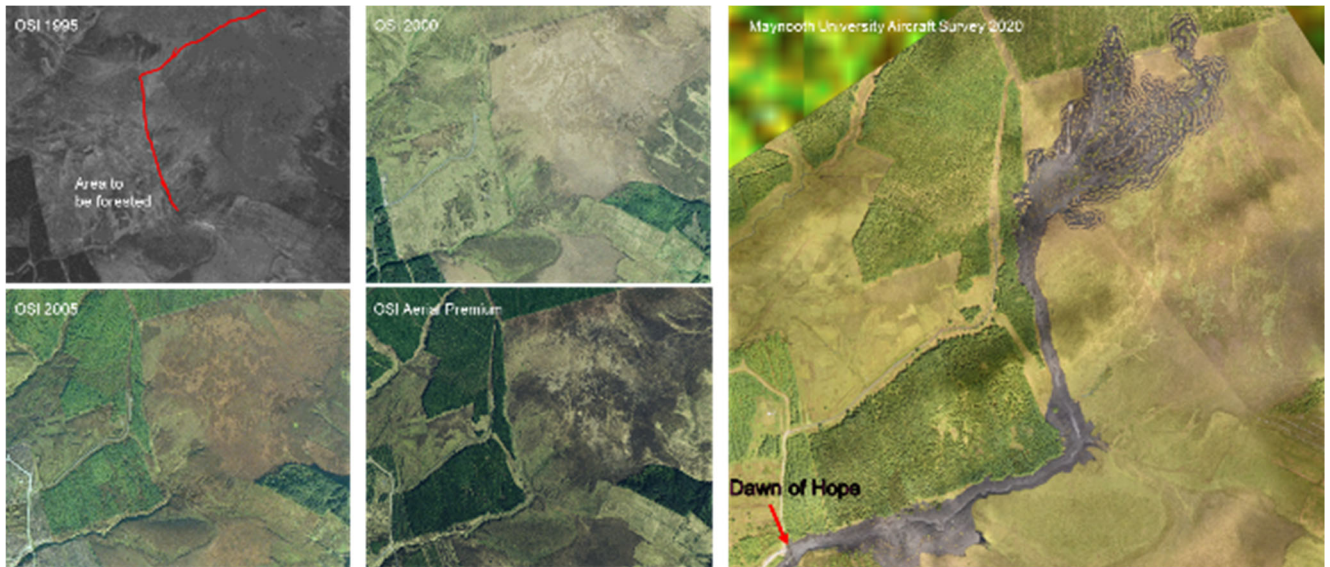


Figure 1-2 Developments on Shass Mountain, 1995 to Present

2 THE SHASS MOUNTAIN PEAT LANDSLIDE EVENT

2.1 Description of the Landslide and Lands Affected

The landslide occurred within an area blanket bog on Shass Mountain, north-east of Drumkeeran, Co. Leitrim on the 28th June 2020, approximately 1.2km to 1.4km upstream of the Dawn of Hope Bridge. The evacuated peat travelled within the existing watercourses where it resulted in flooding of the flood plain in the townlands of Corcormick and Derrindangan. The majority of the peat carried downstream of the Dawn of Hope bridge remains on these flood plains. The Diffagher River carried some peat sediment and other debris to Lough Allen, approximately 8.45km from the starting point, where it has washed up on the shoreline, e.g. at Corry Strand. The trajectory of the landslide with distances from the headscarp is shown in **Figure 2-1**.

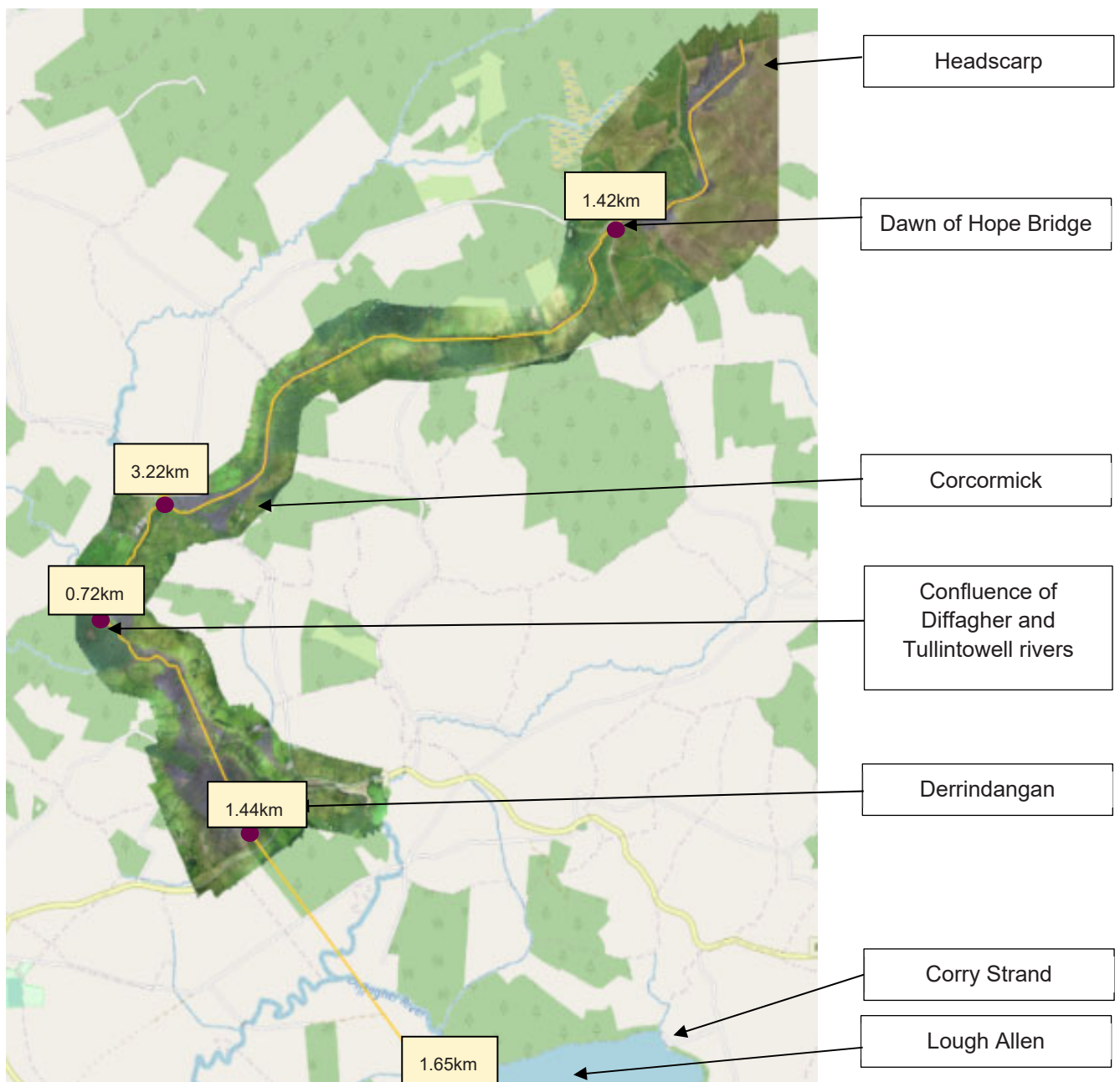


Figure 2-1 Extent of the Landslide and Sector Lengths (total = 8.45 km)

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The slide occurred after a period of prolonged dry weather followed by heavy rainfall. The landslide occurred on a moderately south sloping upland bog, approximately 1.42 km upslope from the Dawn of Hope bridge. The area of the headscarp where the initial slide occurred is approximately 0.08km², or 8 hectares, (shown in **Figure 2-2**), and is approximately 200m wide by 450m long, extending from the forestry in the northern section to the stream channel in the southwestern corner. The landslide appears to have formed within the surficial peat layer estimated to be up to 5m thick. The headscarp and the islands of peat and trees left after the landslide occurred can be seen in **Figure 2-2**.

The specific location where the landslide originated cannot be definitively stated. However, it is possible that the slide started in the area within the red dashed circle as shown in **Figure 2-2**. This hypothesis is based on the visible subsoil surface underneath the blanket bog which is a potential slip plane. The evacuation of peat from this area may have resulted in the destabilisation of the peat further upslope which is why there are islands of intact bog and standing trees within the affected area which 'floated' downslope with the peat. The subsoil layer under the blanket bog is also visible in places.

This is just one hypothesis of the timeline of the slide based on the current available information and discussion with relevant parties. To more accurately state causes of the slide, further studies would be required which have been listed in **Section 10.2**, Recommendations. This could include reviews of land-use; land-use change; drainage patterns; peat depths and properties; clay layer properties, extent and shape; and the impact of weather patterns on the landscape.

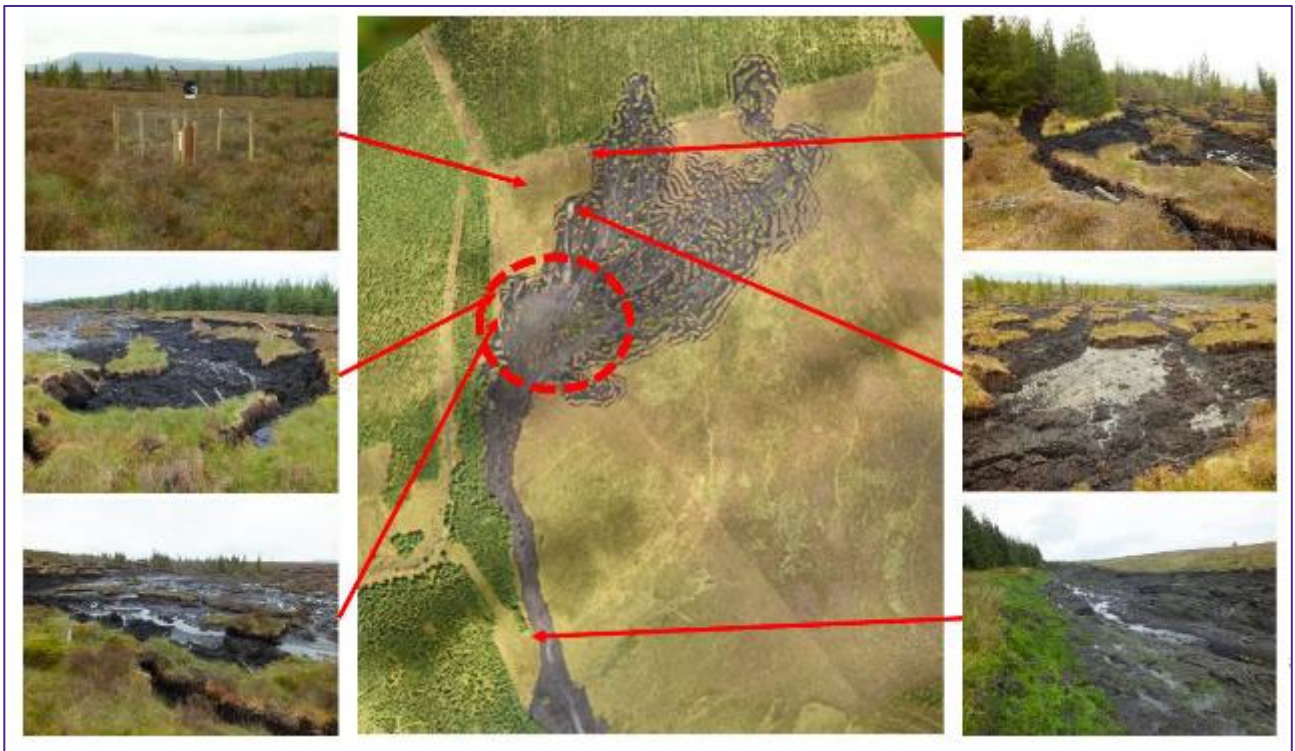


Figure 2-2 Starting Location of Landslide

Work carried out by the Irish Centre for Research in Applied Geoscience (iCRAG) shows the inferred pre-slide surface drainage pattern (**Figure 2-3**) which seems to converge on the area of the hypothesized slip area in **Figure 2-2**. The flow direction in the image is from north to south.

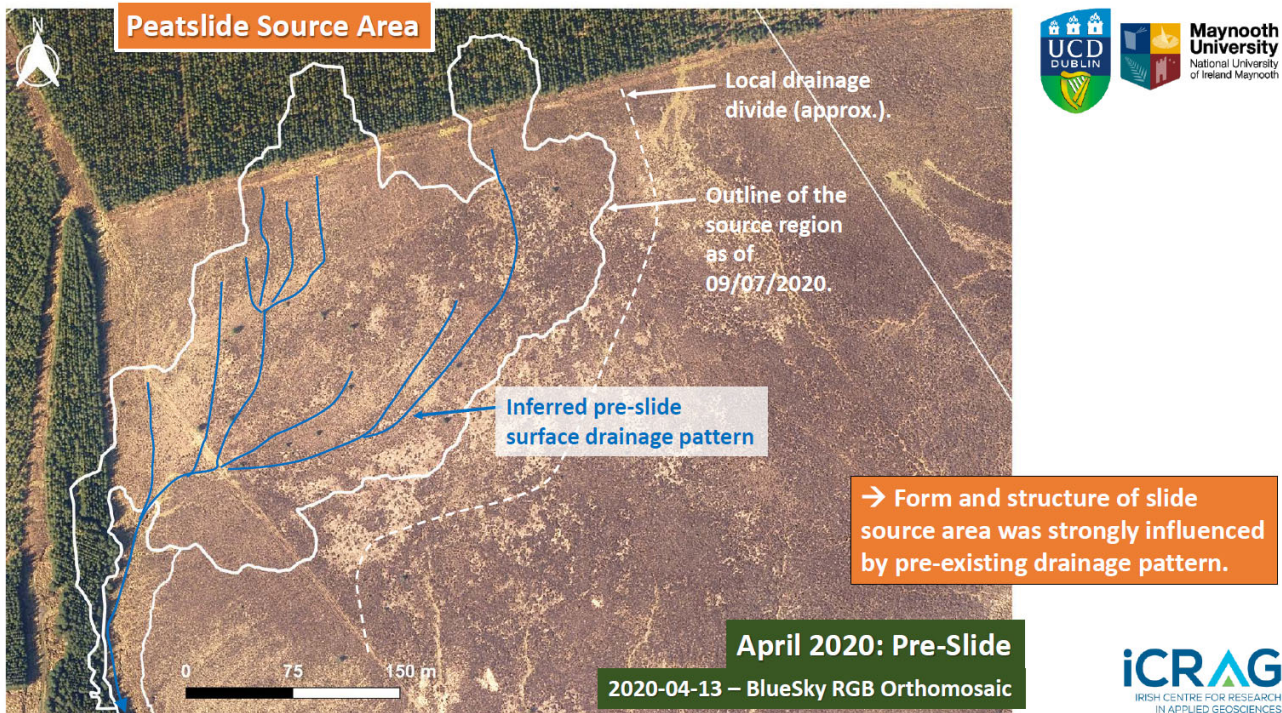


Figure 2-3 Drainage Patterns from iCRAG Research

The GSI Landslide Susceptibility Map indicates the site of landslide was in an area of land classified as having a low to moderately low susceptibility to landslide. The GSI website describes the site as follows:

‘It is primarily mapped as blanket peat on slopes of 3-10 degrees. The national map shows that the highest number of landslides recorded in this category are those of peat in the 3-6 degree range. Landslides mapped in this category account for approximately 12% of all mapped landslides. The susceptibility and the heavy rainfall on Saturday is the likely cause. The National Landslide database also shows a landslide event mapped in 2006 and listed as a bog burst.’

The contours indicate the pre-slip slope within the area likely to have initially failed was greater than 4 degrees.

Once released, the evacuated peat formed a slurry in the mountain stream, which rises north of the Dawn of Hope Bridge, and flowed downstream largely within the river channel. Debris from the slide lodged behind the Dawn of Hope Bridge, blocking it. Subsequently, the mass of peat and debris overtopped the bridge, before continuing downstream within the existing stream channel. The bridge, while damaged, remained intact. Damage to the bridge was evident with displaced stones located at the bottom of the bridge on the downstream edge.

Approximately 2.6km downstream of the Dawn of Hope Bridge, the peat spread out over a flat area of land in the townland of Corcormick. The peat impacted on a number of local roads and before re-joining the local watercourses and flowing south.

Beyond Corcormick, the stream joins the Tullintowell stream and flows onward to the confluence with the Diffagher River, approximately 1km downstream from Corcormick. A little further downstream, a further flood plain is encountered in the townlands of Corchuill Lower and Derrindangan, just north of the R200 road.

2.2 Estimated Areas and Volumes

For the purposes of this report it is assumed that the main constituent of the peat material mobilised and deposited in the event is water.

Preliminary estimations of affected areas based on visual observations and desktop measurements on the area of the landslide are illustrated in **Figure 2-4** and summarised below:

- Approximate area of lands affected by the landslide over the 7km length including stream and river channels, forestry, agricultural land, etc. – 553,000 m² (55.3ha).

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- Approximate area of evacuated / slipped land – 119,000 m² (11.9 ha). This is the area north of the Dawn of Hope Bridge.
- Approximate area in which debris has been deposited – 434,000 m² (43.4 ha) from the Dawn of Hope Bridge to Derrindangan.

The main deposition of peat material occurred in the townlands of Corcormick, Corcuhill Lower and Derrindangan.

- Approximately 70,000m² (7 ha) of land was directly impacted in Corcormick. Assuming an average of 0.8m of peat material was deposited in this area, then the volume of peat material within the flood plain at Corcormick equates to 56,000m³ (56,000 tonnes).
- Approximately 260,000m² (26 ha) of land was directly impacted in Corcuhill Lower/ Derrindangan. Assuming an average of 0.4m of peat slurry was deposited in this area, then the volume of peat material within the flood plain at Derrindangan equates to 104,000m³ (104,000 tonnes).

The combined volumes of material deposited at Corcormick and Corcuhill Lower/ Derrindangan is 160,000m³ (160,000 tonnes).

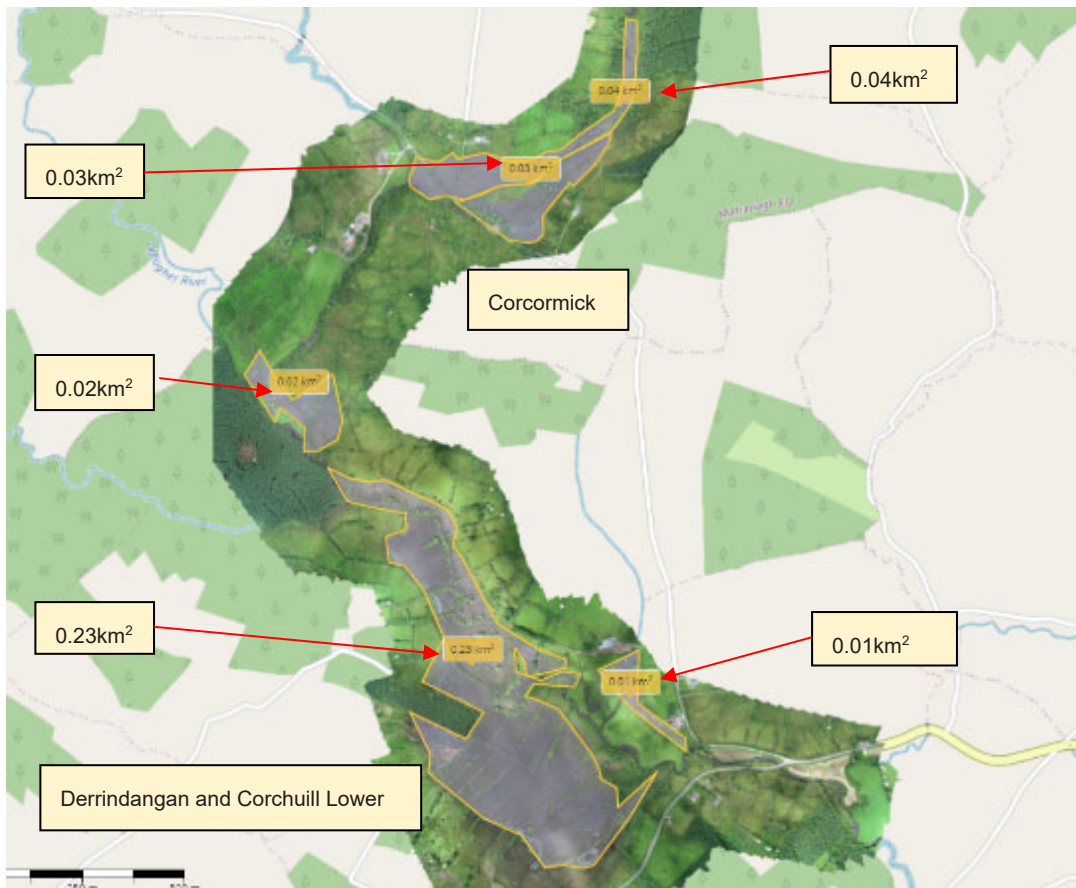


Figure 2-4 Inundated areas in the townlands of Corcormick (north) and Corcuhill Lower and Derrindangan

2.3 Consultations with Relevant Bodies

Consultation has taken place with several bodies list below with notes provided in **Table 2.1**.

- Leitrim County Council (LCC);
- Department of Agriculture, Food and the Marine (DAFM);

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- National Parks and Wildlife Service (NPWS);
- Inland Fisheries Ireland (IFI);
- Irish Farmers Association (IFA);
- Teagasc;
- Geological Survey of Ireland (GSI);
- Environmental Protection Agency (EPA);
- Local Authorities Water Programme (LAWPRO) and the Catchment Assessment Team; and
- 3rd Level Education Inst. (UCD/ Maynooth/ Trinity and Queen's University Belfast).

Table 2.1 Summary of Consultations

Relevant Body	Summary of Consultation
LCC	Project management role by LCC of the overall project. Access to data provided and coordination of steering group.
DAFM	Contact provided for the Forestry Service. Requested information on forestry planation upslope of landslide headscarp. Document and maps received on area of lands affected.
NPWS	Discussion on restoration of peat and lessons learnt from the Corrib Gas Project.
IFI	Discussion on actions from previous slides and actions to be taken at this site.
IFA	IFA interested in what happened and why to prevent repeat occurrences. Interested in pilot scheme to provide alternative to farmers to use peatlands for carbon sequestration or similar as opposed to forestry planting or agriculture. Local farmers requesting works to provide drainage to land.
Teagasc	Discussion environmental value of land with possibilities for results based argi-environmental scheme.
GSI	Requested hourly data from Met Eireann and carried out check for LiDAR survey pre-slide. Directed to Landslide Susceptibility mapping and online landslide database.
EPA	EPA will provide access to background water quality monitoring data and any other assistance required.
LAWPRO and Catchment Assessment Team	Lough Allen is a Priority Area for Action (PAA) but not the rivers which connect to the lough. No sampling will take place at these sites until summer 2021 and the area may be carried through to the next cycle. Catchment Assessment Team assess pressures in wider area and feed this to the relevant body with actions or recommendations for improvement. These are then assessed by the EPA.
3 rd Level Education Inst. (UCD/ Maynooth/ Trinity and Queen's University Belfast)	Provision of surveys including LiDAR post-slide, orthomosaic photography and drone footage. Installation of piezometers and samples taken for analysis. Provision of academic papers and useful discussion on historical slide events and the potential mechanisms of this slide. Discussion on restoration of peatlands and prevention of sediment transport in long term scenario.

3 PEAT LANDSLIDES

3.1 Types of Peat Landslides

There are six types of peat landslides or mass movements described in the literature:

1. Bog burst (flow failure in raised bogs)
2. Bog flow (flow failure in blanket bogs)
3. Bog slide (shear failure and sliding of blanket bogs)
4. Peat slide (shear failure at the peat and mineral layer interface in blanket bogs)
5. Peaty-debris slide (shear failure within the mineral substrate beneath blanket bogs)
6. Peat flow (natural failures including flow failure by head loading)

In the above “peat” refers to any partly decomposed or undecomposed plant material and “bog” refers to an accumulation of peat.

The peat landslide on Shass Mountain appears to have been predominantly a bog flow / bog slide event where the semiliquid basal peat activated in the headscarp and flowed downhill.

The landslide event on Shass Mountain presents all of the typical elements of a bog flow/ bog slide event (illustrated in **Figure 3-1**), which are:

1. Hypothesized source zone where the failure started;
2. Peat debris zone containing debris, peat blocks and mounds;
3. Zone of tension cracks and fissures in the adjacent peat mass; and
4. Downslope run-out zone, which stretches from above the head scarp on Shass Mountain above the Dawn Hope bridge to the R200 at Derrindangan, approximately 6.6km.

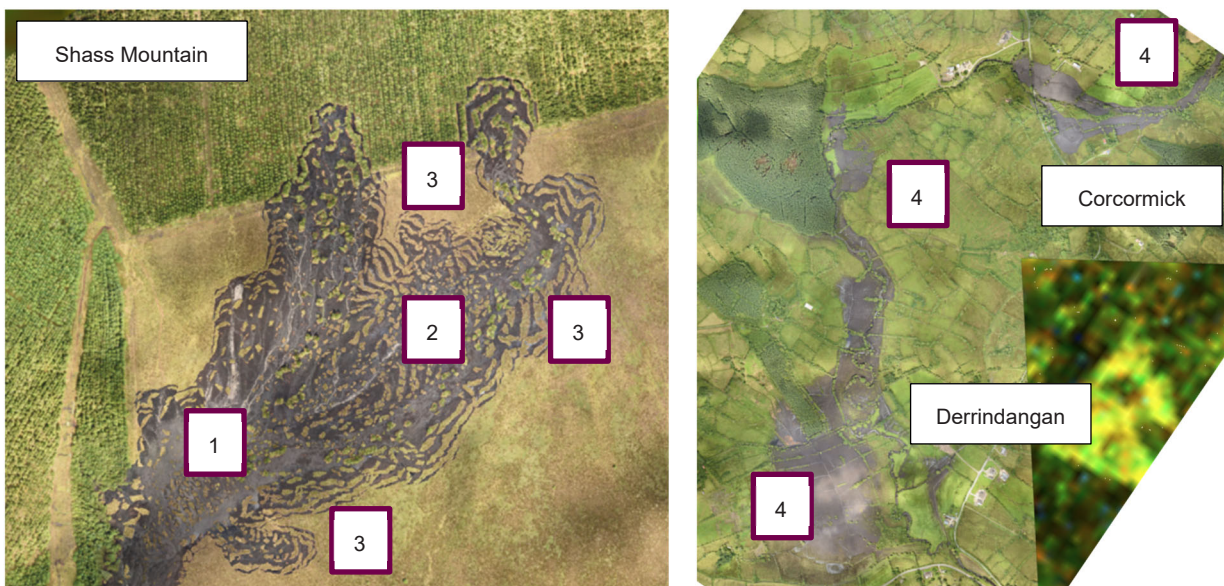


Figure 3-1 Elements of the Bog Flow/ Bog Slide on Shass Mountain Event

3.2 Historical Peat Slide Events

Numerous peat slippage events have occurred in Ireland and the UK over the last few decades. This section highlights some of these events while looking at the site dependent and site independent causes that may have triggered them.

Site dependent causes include land use, peat depth, slope angle, slope morphology, hydrogeology and the interface of the peat and underlying stratum.

Site independent causes include intense rainfall events, the appearance of tension cracks due to dry weather, loading due to construction, excavation or peat cutting and historical land uses.

Details of each slippage are provided in **Table 3.1**, including their location, length, volume, slope and contributing factors, where known. Most of the information has been gathered from the GSI Landslide Susceptibility Map, academic papers and newspaper articles.

Weather was the major contributing factor to many of the peat slippage events discussed in **Table 3.1**. The sites of most events were subjected to prolonged spells of rainfall in the weeks or months prior to the event or were subjected to intense localised showers just before the event. Many of these slides took place in the latter months of the year, i.e. August to December, correlating to the likelihood for increased rainfall events after dry summer periods.

After prolonged rainfall, the unit weight of peat can increase significantly. If the area has experienced extended dry spells and warm weather, tension cracks can appear in the peat mass as it becomes desiccated. These cracks can expose the underlying substrate and can increase the chances of shear failure occurring at the peat-rock interface, particularly if the underlying rock is impermeable or has low permeability. After intense showers, the pressure in the water in the peat can increase rapidly, increasing the likelihood of peat slide.

Another factor that contributes to landslides is the angle of the slope surface, with steeper slopes being more susceptible to slippage. However, the events discussed in **Table 3.1** show that the range for peat slippages can occur on slopes with angles as low as 3° right up to 60°.

Some of the events summarised in **Table 3.1** were caused by human interactions.

The Derrybrien landslide in 2003 that was caused by excavation works for a wind turbine foundation. This landslide initiated as the foundation was being constructed in a zone of particularly weak peat. This zone was also acting as a natural drainage channel.

The Kerry Bogslides at Ballincollig-Maghanknockane in 2008 were caused by turf cutting practices. The top metre of the turf was cut into vertical strips, effectively creating tensions cracks that allowed rain water to enter. The Kerry Bogslides were aggravated by inclement weather in the weeks before the event.

The extent of the peat slide depends on a number of factors including the site's topography, the type of material evacuated (peat, peat-debris mix etc.), weather conditions in the weeks or months up to and at the time of the event, the catchment slope / flow paths and obstructions in the landslide's path. The peat slides discussed in **Table 3.1** range from 300m to more than 3,000m in length. The volume of displaced material ranged from 190m³ up to 450,000m³.

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Table 3.1 Historical Peat Slide Events

Event Location	Date	Slide Length	Displaced Volume	Slope (°)	Contributing Factor(s)	Other Comment
Derrybrien, Co Galway	16/10/2003 29/10/2003	2,450m	450,000m ³	<10°	Windfarm construction activity Zone of weak peat Natural drainage channel Heavy rainfall prior to 2 nd movement	750m x 270m rupture Low permeability underlying rock.
Pollatomish, Co. Mayo	19/09/2003	N/A	200,000m ³	30°-60°	80mm rainfall in 2-hour period Prolonged warm weather periods in preceding summer months	41 nr. distinct slippages Highly impermeable bedrock Same date as the Shetland Islands event.
Ballincollog-Maghanknockane, Co. Kerry	22/08/2008 23/08/2008	+3,000m	130,000m ³	3°	Heavy rainfall in weeks before event Turf cutting practices.	N/A
Straduff, Co. Sligo	18/10/1984	350m	81,000m ³	3-5°	Evidence of recent burning thus reducing the vegetation cover. Dry summer and then over average rainfall in October. Presence of clay rich drift created slip plane.	Month of October experienced 25% more than average rainfall. 25.9mm of rain fell three days previous to the event.
Yellow River, Co. Leitrim	29/06/1986	150m-500m	35,000m ³	6°-12°	Heavy rainfall during thunderstorms.	2 nr. flows (western and eastern) Weeks preceding the flood were relatively dry. Rainfall on 27 th may have met the soil moisture deficit.
Drumkeeran, Co. Leitrim	c. 2006	333m	N/A	3°	Unknown.	No other information known.
Gowlaunrevagh, Co. Leitrim	23/09/2008	N/A	N/A	N/A	Separation at interface of peat and mineral soil Wedge of bog became dislodged during construction of a road on a windfarm extension development.	10km south-west of the Dawn of Hope bridge. No heavy rainfall in the days prior to event.
Slieveanorra, Co. Antrim	25/08/2020	N/A	N/A		Storm Francis weather event.	Slippage in 2004 after 50mm rainfall in 6 hours. 2,500m ³ slippage in 1980 after 47-97mm rainfall in 45 mins.
Derrysallagh, Co. Sligo	13/08/2008	N/A	N/A	17°	Heavy rainfall – 38.7mm on 13 th August.	5 nr. distinct slippages. 35,000m ³ slippage at another time in 2008. 29,000m ³ slippage event in 1945.
Aasleagh Falls,	31/12/2006	N/A	N/A	N/A	Intense rainfall.	Slide reactivated in July 2007.

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Event Location	Date	Slide Length	Displaced Volume	Slope (°)	Contributing Factor(s)	Other Comment
Co. Mayo						
Clare Island, Co. Mayo	14/12/2006	N/A	N/A	N/A	Heavy rainfall.	
Gleniff, Co. Sligo	14/12/2006			10°	Water trapped in a hollow burst its banks after six weeks of heavy rainfall.	15m high mudbank blocked 300m section of road.
Cuilcagh, Co. Fermanagh	21/08/1992 22/08/1992	300m	9,100m ³	N/A	80mm rain recorded in the days prior to event.	75m (L) x 42m (W) rupture.
Carrowmaculla, Co. Fermanagh	25/11/1979	N/A	20,000m ³	N/A	Heavy rainfall in months preceding event.	100m (W) x 2m (D) rupture.
Glen Docherty, Scotland	08/2015	N/A	190m ³ (89m ³ peat)	33°	Heavy rainfall in months preceding event Localised cloudburst.	22m (L) x 9m (W) rupture.
Teesdale, England	06/07/1963	N/A	4,000m ³ and 1880m ³	9°-17°	Heavy rainfall in June and early July 1963. Saturated peat mass and slope of valley sides.	Slide occurred on each side of the valley.
Shetland Islands, Scotland	19/09/2003	N/A	23,000 - 59,000m ³	4°	Extreme rainfall	Multiple events occurred throughout islands. Same date as the Pollatomish event.

4 WEATHER DATA

4.1 Weather Forecast Prior to the Event

A Raidió Teilifís Éireann (RTÉ) weather report from Friday 26th June 2020 forecast that wet weather would be experienced across the north west of Ireland from the 26th to the 28th June. This was due to a low-pressure system sitting just north of Ireland causing bands of organised spells of rain across Connacht and Ulster with some localised thunderstorm activity across the north west.

A yellow rainfall warning was issued for Donegal, Leitrim, Mayo and Sligo on the 26th June with the RTÉ report anticipating 40-60mm of rain in these counties. This would increase the risk of spot flooding or flash flooding in higher terrain areas.

4.2 Weather Information Sources

For this report, weather data was obtained from four official Met Éireann and six third-party weather observing stations. The weather data obtained from the official Met Éireann weather observing stations included information on hourly, daily and monthly temperatures and rainfall levels. Only rainfall data was obtained from the third-party weather stations. All weather data was taken from:

- Met Éireann website (Link - <https://www.met.ie/climate/available-data/monthly-data>) or
- data.gov.ie website (Link - <https://data.gov.ie/>).

The closest official Met Éireann weather observing station is located at Markree Castle, Co. Sligo, around 24.7km west of the Dawn of Hope Bridge. The closest third-party weather station is situated 13.4km north of the Dawn of Hope bridge at Manorhamilton, Co. Leitrim.

4.3 Met Éireann Weather Observing Stations

The locations of the four nearest Met Éireann weather observing station are contained in **Table 4.1**. Total monthly rainfall data was obtained from four official Met Éireann Weather Observing Stations for the period from the 1st January 2017 to 13th September 2020. Daily and hourly weather data was obtained for the four official Met Éireann Weather Observing Stations. The mean total rainfall for 1981-2010 was also obtained to allow a comparison to be made.

Table 4.1 Nearest Met Éireann Weather Observing Stations

Weather Station	Location	Northing	Easting	Distance to Dawn of Hope bridge
Markree AWS	Co. Sligo	54.175 N	-8.456 W	24.7km west
Finner AWS	Co. Donegal	54.4939N	-8.2431W	34.1km north
Ballyhaise AWS	Co. Cavan	53.9424N	-8.3269W	53.1km east
Mount Dillon AWS	Co. Roscommon	53.727 N	-7.981 W	53.7km south

4.4 Third-Party Weather Observing Stations

Six third-party weather observing stations were identified within close proximity to the site of the landslide as summarised in **Table 4.2**. Monthly and daily weather data was also been obtained for these sites.

Table 4.2 Third-party Weather Station Information

Weather Station	Location	Northing	Easting	Distance to Dawn of Hope bridge
Manorhamilton (Amorset)	Co. Leitrim	54.307 N	-8.182 W	13.4km north
Dromahair (Market Street)	Co. Leitrim	54.232 N	-8.297 W	14.2km west

Weather Station	Location	Northing	Easting	Distance to Dawn of Hope bridge
Drumshanbo	Co. Leitrim	54.061 N	-8.061 W	15.7km south
Cuilcagh Mountains	Co. Cavan	54.166 N	-7.801 W	19.0km east
Aughnasheelan (Miskawn)	Co. Leitrim	54.085 N	-7.869 W	19.2km south-east
Keshcarrigan G.S.	Co. Leitrim	54.018 N	-7.942 W	22.4km south

4.5 Weather Observing Stations Summary

Figure 4-1 shows the daily rainfall recorded at the four Met Éireann and six third-party weather observing stations.

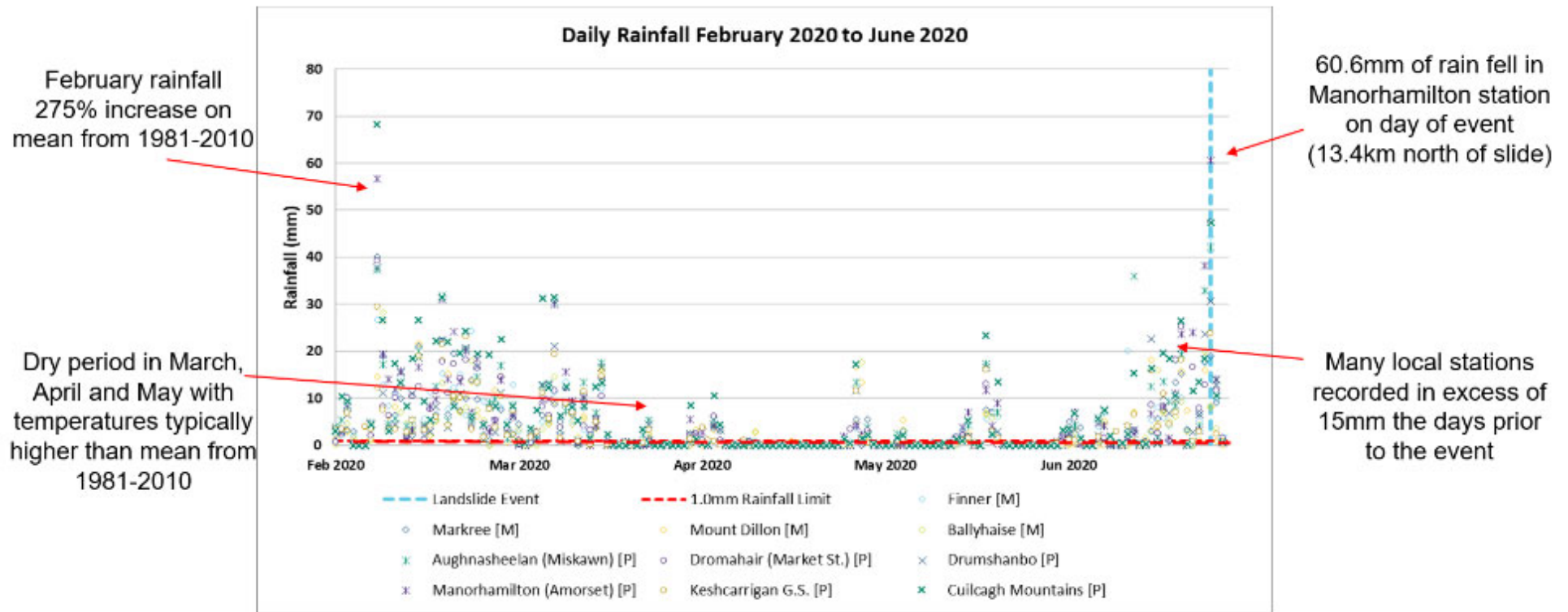
February 2020 was a particularly wet month with all weather stations recording well above average rainfall. In February, Markree AWS recorded a 262% increase on the mean total rainfall for 1981-2010 with 240mm of rain falling. Similarly, Ballyhaise and Mount Dillon experienced greater than 290%, with 213mm and 225mm falling respectively.

Relatively dry spells were recorded at all weather stations throughout the months of March, April and May, with 66 days recording 1.0mm of rain or less at both the Finner Camp and Mount Dillon stations, 68 days at Ballyhaise and 92 days at Markree. Met Éireann describes days with 1.0mm of rainfall or more as 'Wet Days'. The horizontal dashed red line on **Figure 4-1** indicates the 1.0mm limit. It can clearly be seen that there are many days in March, April, May and June that have less than 1.0mm of rainfall at all ten observations sites. The months of March, April and May also saw above average temperatures.

The relatively 'dry' period seen between March and May was followed by a particularly wet June, with all weather stations recording rainfalls greatly in excess of their 30-year average. Particularly heavy rainfall events were experienced on the 23rd, 25th, 27th and 28th June 2020. **Table 4.3** highlights the rainfall figures recorded at the third-party weather stations, along with the total June and average June rainfalls. The Manorhamilton (Amorset) station, the nearest station to the Dawn of Hope bridge, experienced almost 61mm of rainfall on the day of the event, while 101.7mm of rain fell in the week leading up to the event.

Table 4.3 Rainfall in June 2020

Weather Station	June Total 2020 (mm)	June Average 1981-2010 (mm)	Cumulative Rainfall for 21 st – 27 th June (mm)	Rainfall on Dates in June Preceding the Peat Landslide (mm)			
				23 rd	25 th	27 th	28 th
Manorhamilton (Amorset)	218.2	88.9	101.7	23.6	24	38.2	60.6
Dromahair (Market Street)	179.0	84.5	81.9	25.2	16.7	12.8	47.5
Drumshanbo	171.1	80.2	70.3	20.6	2.7	23.6	30.7
Cuilcagh Mountains	243.5	99.1	99.1	26.4	11.5	18.5	47.3
Aughnasheelan (Miskawn)	220.4	90.2	74.6	19.4	0.7	32.8	42.1
Keshcarrigan G.S.	129.5	74.5	51.8	18.1	0.8	18.5	23.8



Note: [M] denotes Met Éireann Weather Observing Station; [P] denotes Private (Third-Party) Weather Observing Station

Figure 4-1 Daily rainfall data for February-June 2020¹

¹ Note: [M] denotes Met Éireann Weather Observing Station; [P] denotes Private (Third-Party) Weather Observing Station

5 CATCHMENT CHARACTERISTICS

5.1 Review of Available Information

5.1.1 General

A desktop review of available data was carried out to broadly determine the characteristics and sensitivities of the surrounding environment. Geographic Information Systems (GIS) software was used to map key environmental features and designations in the area where the landslide occurred.

In order to classify the landscape and topography of the area surrounding the landslide event, a variety of GIS datasets were cross-referenced and examined. 1:50,000 scale Discovery Series Mapping provided by Ordnance Survey Ireland (OSi) was used, in the first instance, to identify local roads, settlements, amenities, features and topography. The landslide event visibly encroaches on three local roads (including the Dawn of Hope bridge) as per the OSi Discovery Series mapping. The landslide event terminates just short of the R200, which is a regional road that traverses the Leitrim/Cavan border and, provides connectivity between the village of Drumkeeran and the N87 national route south of Swanlibar.

Overall, the OSi Discovery Series mapping gives context to the landslide event environment. The local area can be characterised as rural, with the village of Drumkeeran in the southwest representing the largest settlement in the vicinity. The source of the landslide is located on Shass Mountain. There are also several watercourses in the area, with the Diffagher River experiencing the most significant effects of the landslide event. Each of these features are discussed individually in greater detail below.

5.1.2 Bedrock

An assessment of the geology within the area of the landslide was carried out using available GIS datasets from the GSI. At the location of the landslide headscarp the bedrock geology mapping indicates dark grey silty sideritic shale. The bedrock changes to shale and minor turbiditic sandstone through the central part of the affected area. The lower reaches of the landslide affected area, around Derrindangan, is in bedrock comprised of grey/black shale with minor limestone.

5.1.3 Soils

CORINE (Co-ORdinated INformation on the Environment) Land Cover 2018, EPA (Environmental Protection Agency) soils and 10 metre contour mapping were used to determine the main landscape features within the catchment. Regarding topography, the terrain is mountainous and is characterised by a significant fall in elevation from an altitude from the landslide headscarp of approximately 280 m O.D. to its termination point approximately 50 m O.D.

According to the CORINE and EPA soils datasets, the terrain on the mountainside where the landslide began is comprised of blanket peat, transitioning to coniferous forest and woodland scrub further downslope. The land encompassing the lower half of the landslide area is predominantly agricultural, characterised by shallower topography compared to the headscarp area. The soils are also indicative of such, with much of the landslide inundation zone comprising alluvium-rich soils (influence of the Diffagher River) and evidence of cut soils at the landslide's termination point (agriculture).

5.1.4 Environment

Regarding designated and protected sites, there are several Natural and Proposed Natural Heritage Areas (NHA; pNHA) in the wider environment of the landslide. However, the landslide headscarp is located within the indicative boundaries of a Special Area of Conservation (SAC), namely Boleybrack Mountain SAC (Site Code: 002032). A description of Boleybrack Mountain SAC and potential effects of the landslide event are detailed in **Section 5.5** of this report.

There are also several watercourses in the catchment. The unnamed mountain stream from the headscarp to the townland of Corcormick 5km downstream was the channel within which the peat travelled. The stream then joins the Tullintowell stream which subsequently flow into the Diffagher River. The Diffagher River is the main named watercourse in the catchment and was significantly impacted by the released peat material and

debris associated with the landslide. The Diffagher River converges with the Owengar River just south of the landslide termination point and then flows into Lough Allen.

5.1.5 Landslide Susceptibility

Two historical landslide events (pre 2006) have been recorded in the area to the north of Lough Allen, according to the GSI 's database. One event is recorded as being comprised of earth material, which occurred in Drumlin terrain at Tullynarroog, south of the current landslide's headscarp. The other event occurred close to the location of this current landslide on Shass Mountain and was noted to be comprised of peat also. This landslide occurred on the opposite side of the mountain to the current slide.

The GSI landslide susceptibility mapping was also consulted. The mapping suggests that most of the area where the landslide occurs is considered to be an area of moderately low susceptibility with one area identified as moderately high susceptibility just south of the landslide inundation zone. This area of moderately high susceptibility is close to the area where the bulk of the bog flow/ bog slide occurred.

5.2 Surveys Undertaken Post-event

Surveys and monitoring installations have been established post the landslide event including:

- A GPR (ground penetration radar) survey by the Irish Centre for research and applied geophysics – iCrag at University College Dublin. This GPR survey was carried out by APEX for iCrag on the week of the 17th August 2020;
- Aerial photography and drone footage (taken 9th July 2020) giving satellite imagery and LiDAR surveys by the National Centre for Geocomputation at Maynooth University;
- Piezometers and data loggers were installed by UCD on 16th September 2020 to measure pore pressure in the peat. The team also took Russian auger samples for water content and box tests for testing permeability; and
- The installation of a weather station by Trinity College Dublin. The station consists of a small monitoring station and weatherproof box, with the latter containing the data logger for storing the data. The weather station itself monitors rain, wind, temperature, humidity, UV and solar index.

5.3 Peat

Site specific information available which has been reviewed as part of the study includes:

- Peat base elevation and thickness maps based on GPR undertaken around the perimeter of the existing landslide. This data was provided by Mike Long (UCD, 2020);
- 2 no. borehole logs from Russian auger holes drilled adjacent to the landslide headscarp, also provided by Mike Long (UCD, 2020).

The GPR information indicates the depth of peat around landslide headscarp varies between 1 m and 5.5 m. The peat thickness from the Russian auger holes was consistent with the GPR results showing variable depths of peat between 2.8 m and 4.2 m. The depths are slightly thicker than high level Ireland Peatland Map (prepared and published by the National Soil Survey, 1978) which indicates 1 to 2 m of peat. The logs indicate the peat is very variable, with degree of decomposition generally increasing with depth and fibre content decreasing with depth. Based on the existing information, the parameters are likely to be typical for peat studied at other Irish upland blanket bog sites.

A number of papers are publicly available on peat strength. A paper *Peat slope failure in Ireland* provides a study of existing information including peat strength. The paper reports that historical peat failures in blanket bog areas around Ireland for peat depths of between 1 and 4 m typically occur where slope angles are between 4° and 8°. The paper further reports that effective friction angles (ϕ') for peat as regularly being reported from less than 18° to as high as 58°, and that apparent cohesion values (c') having equally scattered ranges. However cohesion values were typically higher at low friction angles' and conversely lower for high friction angles. The paper reports that undrained shear strength in fibrous peat can vary from 20 kPa to below 4 kPa and has been shown to vary with several factors, such as degree of humification, water content and depth.

5.4 Forestry

The area upslope of the headscarp of the landslide is currently forested with a mixture of largely Sitka Spruce and Lodgepole Pine with small areas of Japanese Larch, Alder and Birch. This area was planted in 1996 under licence from the Forestry Service and was therefore approximately 24 years old at the time of the slide. No management is known to have occurred on the site since it was planted, i.e. the trees were not thinned or there was no active management of drainage.

For the establishment of the forestry at afforestation stage the area was drained with a series of mounds and furrows which connected to an external collector drain on the perimeter of the forested area. These drains could act as vertical pathways into the blanket bog. It was noted on a site visit after the event that the perimeter drain on the forestry edge has largely revegetated with sphagnum moss (**Figure 5-1**) and potentially transports reduced volumes of water since the time of planting. It has also been noted in the literature of the potential for cracking in the peat beneath forestry plantations allowing water to penetrate vertically into the lower peat layers. Evidence of this was not noted on the site walkover but should be considered in further detail at the Stage 2 report.



Figure 5-1 Perimeter drain revegetated with sphagnum moss on the edge of the forestry at Shass Mountain

5.5 Protected Sites

The landslide started in the south west of Boleybrack Mountain Special Area of Conservation (SAC) (Site Code: 002032), shown in **Figure 5-2** in red outline. Boleybrack Mountain SAC comprises an extensive upland plateau situated to the north of Lough Allen in Co. Leitrim. The SAC is bounded on the north and south by forestry plantations, and on the west by the Scardan River. The site is dominated by active mountain blanket bog and wet heath, with small oligotrophic/ dystrophic lakes scattered throughout. The site also contains low rocky cliffs, areas of dry heath and a variety of grassland types, including heathy grassland dominated by Purple Moor-grass (*Molinia caerulea*), upland acid grassland, orchid-rich meadows and wet, rushy pastures.

The site is of considerable conservation importance for the various habitats listed on Annex I of the E.U. Habitats Directive that it supports, in particular the good examples of mountain blanket bog and wet heath. The examples of these habitats on the site are among the best remaining in the northern half of the country. The presence of a number of rare plant species and of a variety of bird species adds to the conservation significance of the site (NPWS, 2013)².

This SAC supports the following Qualifying Interests:

- Natural dystrophic lakes and ponds [3160];
- Northern Atlantic wet heaths with *Erica tetralix* [4010];
- European dry heaths [4030];
- *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinia caerulea*) [6410]; and
- Blanket bogs (* if active bog) [7130].

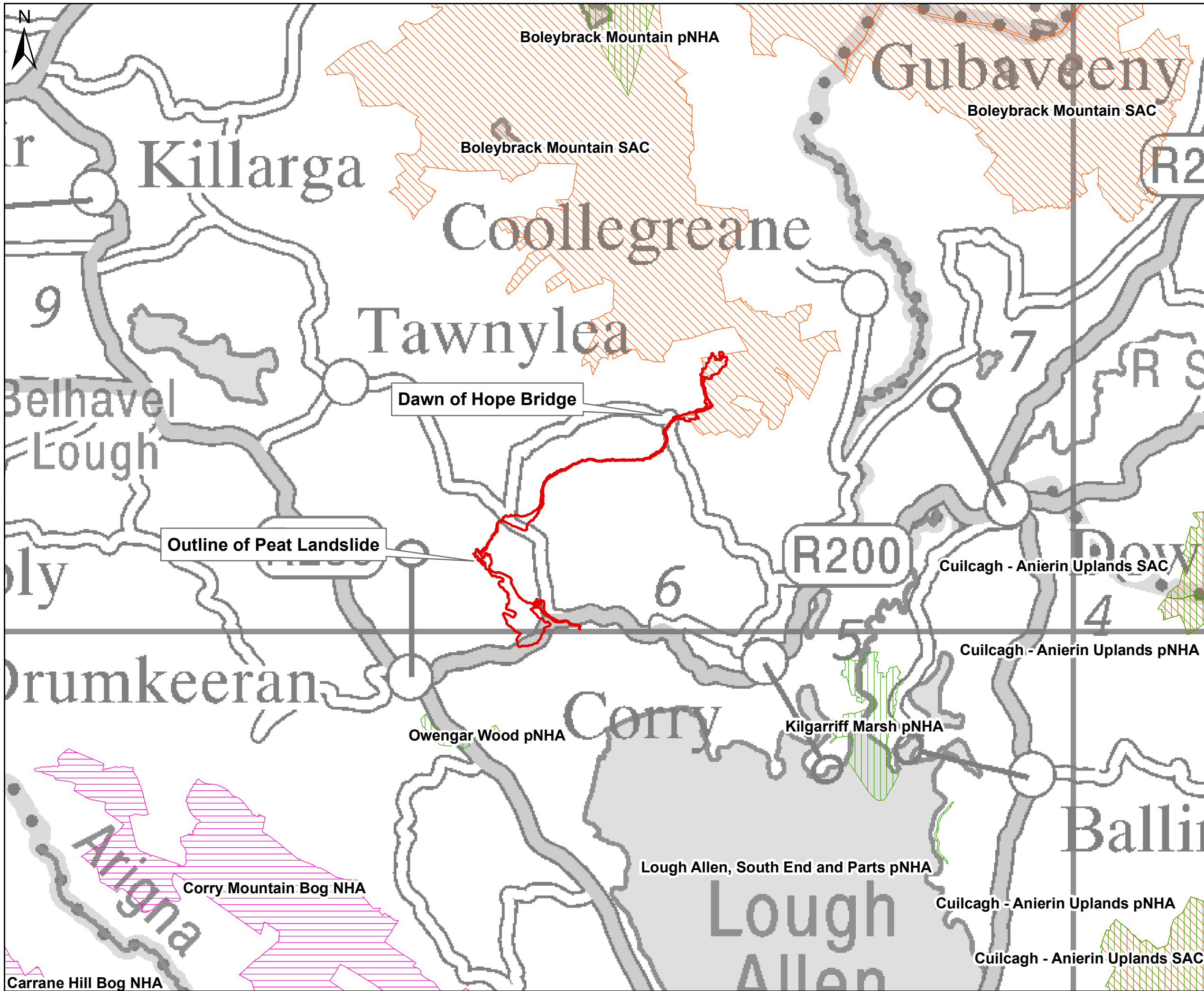
No detailed habitat survey is available for the SAC. In the absence of habitat mapping, a review of the aerial photography and the site specific conservation objectives document for Boleybrack mountain SAC³ (NPWS ,

² <https://www.npws.ie/sites/default/files/protected-sites/synopsis/SY002032.pdf>

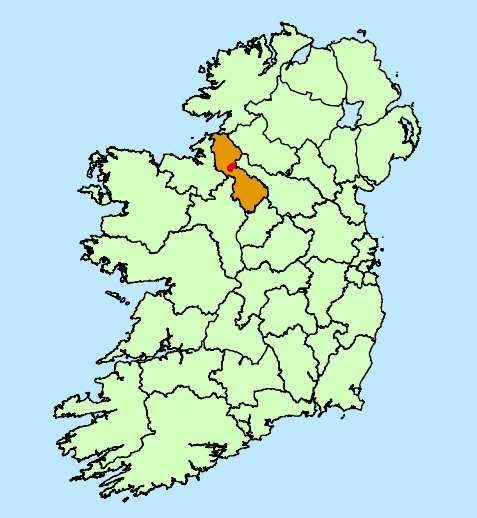
³ https://www.npws.ie/sites/default/files/protected-sites/conservation_objectives/CO002032.pdf

FACTUAL REPORT

Rev. 1 2016) was conducted to determine the habitats present within the area, prior to the landslide. There are no lakes or ponds, molinia meadows or dry heaths within the area of the landslide. Therefore, the qualifying interests of Natural dystrophic lakes and ponds [3160], European dry heaths [4030] and Molinia meadows on calcareous, peaty or clayey-silt-laden soils (*Molinia caerulea*) [6410] are excluded from this assessment.



- Legend**
- Outline of Peat Landslide
 - Natural Heritage Area (NHA)
 - Proposed Natural Heritage Area (pNHA)
 - Special Area of Conservation (SAC)
 - Special Protection Area (SPA)



Client
 **Comhairle Chontae Liatroma**
 Leitrim County Council

Project
Shass Mountain Landslide

Title
Protected Sites in the Vicinity of Shass Mountain and Lough Allen

Figure 5-2

 RPS
 Lyrr 2,
 IDA Business & Technology Park,
 Mervue,
 Co. Galway,
 Ireland.
 Tel: +353 (0)91 400 200
 Email: ireland@rpsgroup.com
 Web Page: rpsgroup.com/ireland

Issue Details	
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Table 5.1 below outlines the cover of the relevant qualifying interests within the SAC and **Table 5.2** outlines the potential threats and pressures to Boleybrack Mountain SAC.

The conservation objectives applicable to the qualifying habitats of Boleybrack Mountain SAC within the zone of influence of the landslide, include the following:

- To restore the favourable conservation conditions of Northern Atlantic wet heaths with *Erica tetralix* in Boleybrack Mountain SAC; and
- To restore the favourable conservation condition of Blanket bogs in Boleybrack Mountain SAC.

The relevant targets for Northern Atlantic wet heaths with *Erica tetralix* include the following:

- Habitat area stable or increasing, subject to natural processes;
- No decline, subject to natural processes;
- Cover of disturbed bare ground less than 10%; and
- Area showing signs of drainage from heavy trampling, tracking or ditches less than 10%.

Relevant targets for blanket bogs include the following:

- Habitat area is stable or increasing, subject to natural processes;
- No decline, subject to natural processes;
- Cover of disturbed bare ground less than 10%; and
- Less than 5% of the greater bog mosaic comprises erosion gullies and eroded areas.

In addition, there is indirect hydrological connectivity between the landslide and the Lough Forbes Complex SAC (Site Code: 001818) and Ballykenny-Fisherstown Bog SPA (Site Code: 004101) which are located 66.5km downstream of the landslide. The landslide entered the Diffagher River which flows into Lough Allen where it meets the River Shannon. The River Shannon is designated as part of both the Lough Forbes Complex SAC and Ballykenny-Fisherstown Bog SPA. These two sites both have potential to be impacted by the landslide. Ballykenny-Fisherstown Bog SPA had one Qualifying Interest:

- Greenland White-fronted Goose (*Anser albifrons flavirostris*) [A395].

The Lough Forbes Complex SAC has the following Qualifying interests:

- Natural eutrophic lakes with Magnopotamion or Hydrocharition - type vegetation [3150];
- Active raised bogs [7110];
- Degraded raised bogs still capable of natural regeneration [7120];
- Depressions on peat substrates of the Rhynchosporion [7150]; and
- Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion*, *Alnion incanae*, *Salicion albae*) [91E0].

Table 5.1 Boleybrack Mountain SAC Habitats of Qualifying Interest within Landslide Headscarp

Habitat Code	Qualifying Habitats	Cover (ha)*	% of SAC
7130	Blanket bogs (* if active bog)	2,000	47
4010	Northern Atlantic wet heaths with <i>Erica tetralix</i>	1,400	33

*Area of habitat within SAC

Table 5.2 Potential Pressures and Threats to Boleybrack Mountain SAC

European Site	Threat Code ⁴	Threat Type	Rank ⁵	i (inside) o (outside) b (both)
Boleybrack Mountain SAC	J01.01	Burning down	M	b
	C01.03.02	Mechanical removal of peat	M	i
	C01.01.01	Sand and gravel quarries	L	i
	A04.03	Abandonment of pastoral systems, lack of grazing	M	b
	D01	Roads, paths and railroads	M	i
	C01.03.02	Mechanical removal of peat	M	i
	J02.06.02	Surface water abstractions for public water supply	L	i
	F03.02.02	Taking from nest (falcons)	M	i
	B02	Forest and plantation management and use	L	o
	C03.03	Wind energy production	M	b
	D02.02	Pipe lines	L	i
	A10	Restructuring agricultural land holding	M	o
	B	Sylviculture, forestry	H	o
	A04.02.01	Non intensive cattle grazing	M	i
	A07	Use of biocides, hormones and chemicals	M	i
	A04.03	Abandonment of pastoral systems, lack of grazing	M	i
	B01	Forest planting on open ground	M	o
	A04.01.02	Intensive sheep grazing	M	b
	I02	Problematic native species	M	i
	G01.02	Walking, horseriding and non-motorised vehicles	L	i
K03.02	Parasitism	M	i	

⁴ Threat codes sourced from Natura 2000 data form and follow reference list provided on threats, pressures and activities for European Sites <http://cdr.eionet.europa.eu/help/natura2000>

⁵ H – High, M – Medium, L - Low

6 IMPACT ON THE AQUATIC ENVIRONMENT AND LANDS

6.1 Catchment Overview

The event on Shass Mountain impacted on a tributary of the Diffagher River. This tributary brought peat down the valley to the confluence with the Diffagher River and on to Lough Allen, approximately 7km from the headscarp of the event.

The Diffagher River and tributaries drain the lands between Lough Allen and Behaval Lough, with headwaters reaching up into Boleybrack Mountains to the northeast and Corrie Mountain to the west. The Diffagher also forms the outflow from Belhavel Lough, although it is noted that Belhavel also drains to the west to the Garavogue catchment as a result of drainage works.

Aquatic ecological investigations of the Diffagher River and its tributaries were undertaken on 14th September 2020. A desk-based review of lake and river ecological and water quality data for the Diffagher River catchment and Lough Allen was also conducted. Inland Fisheries Ireland were consulted in relation to fisheries data and their involvement in response to the incident. Supporting documentation and results for this chapter are in **Appendix A**.

The principal river network in the area is shown in **Figure 6-1** alongside the locations where sampling was undertaken on 14th September 2020. Peat movement followed the path from Boleybrack Mountain SAC as follows: Dawn of Hope Stream → lower Tullintowell Stream → Diffagher River → Lough Allen. **Table 6.1** sets out the EPA waterbody codes and naming conventions for the watercourses in the area.

Table 6.1 Watercourse Names and EPA Codes

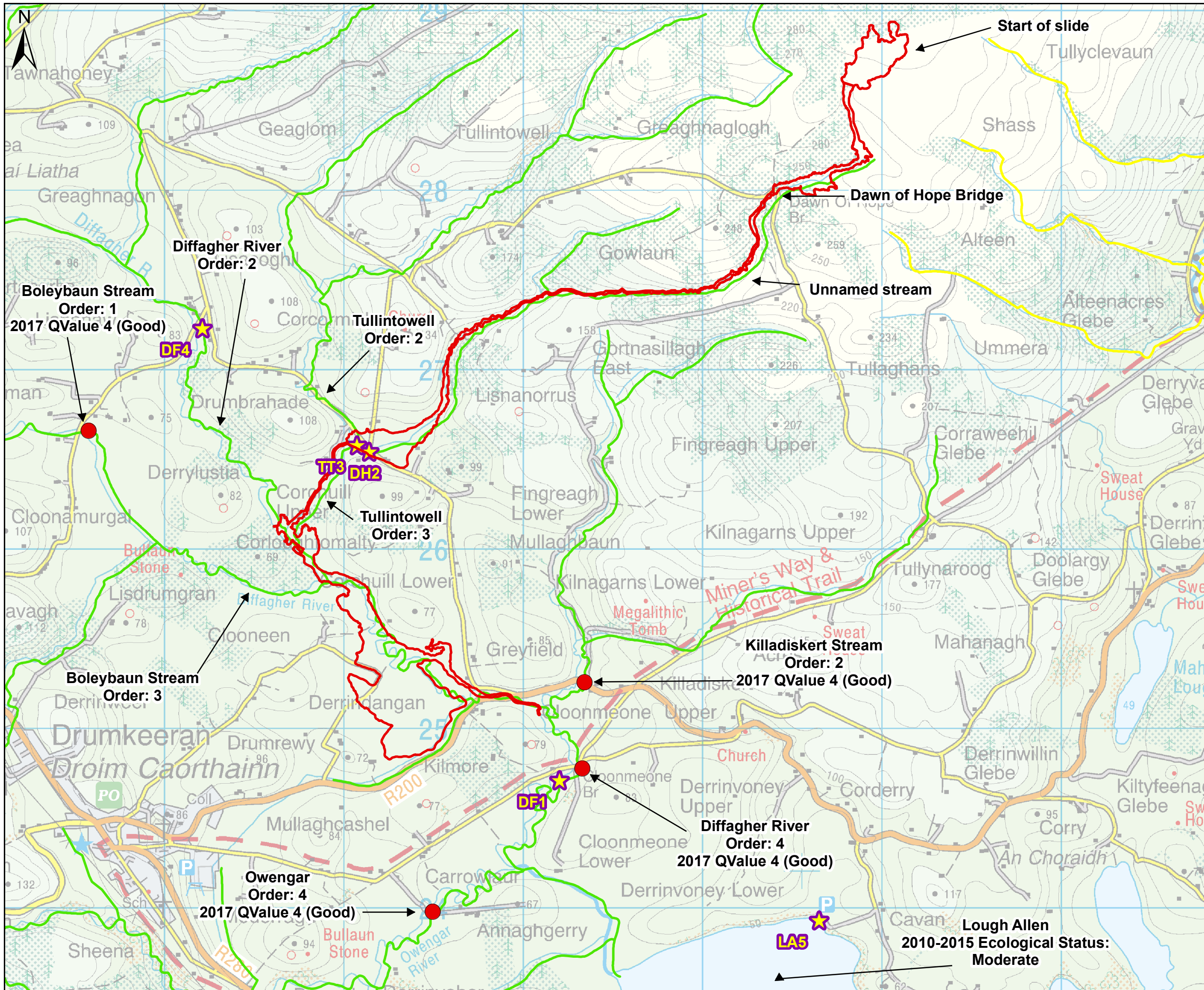
Name	EPA name	EPA Waterbody Code	EPA Code
Dawn of Hope Stream	Un-named	IE_SH_26D020200	No code
Tullintowell Stream	Tullintowell	IE_SH_26D020200	26T70
Diffagher River	Diffagher	IE_SH_26D020200	26D02
Boleybaun Stream	Boleybaun Stream	IE_SH_26D020200	26B30
Killadiskert Stream	Killadiskert Stream	IE_SH_26D020200	26K16
Owengar River	Owengar [Leitrim]	IE_SH_26O020200	26O02
Lough Allen	Allen (Lough)	IE_SH_26_716	26_716

6.2 Pre-event Water Quality

Watercourses affected by the landslide were characterised by a combination of desk and field survey. Field survey methods were all consistent with standard and published protocols. Desk-based review of existing information informs the aquatic baseline against which impact/recovery may be assessed.

A thorough desk-based search of available information on the Diffagher River and Lough Allen. Online information, plus published and unpublished data and literature were utilised.

Table 6.2 collates EPA Q-value data for the period 1992-2017 (most recent publicly available). Samples were taken by the EPA in September 2020 which will be available in the coming months. Ecological status is determined by the Q-rating. Note that Q4 'good status' is the minimum requirement to comply with surface water regulations under the WFD. The asterisk (*) in **Table 6.2** indicates there was some confounding factor or additional explanation (e.g., notable sedimentation).

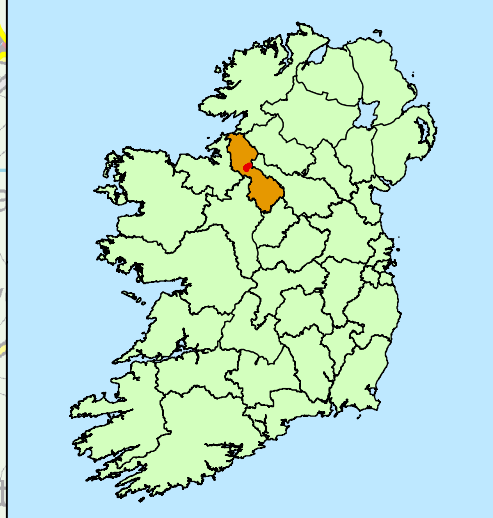


Legend

- Outline of Peat Landslide
- EPA Q Value Monitoring Stations
- ★ RPS Water Kick-Samples

EPA River Quality Status

- Good
- Moderate



Client
 **Comhairle Chontae Leitrima**
 Leitrim County Council

Project
Shass Mountain Landslide

Title
Diffagher Catchment and Field Survey Locations

Map no. **6-1**

 Lyrr 2,
 IDA Business & Technology Park,
 Mervue,
 Co. Galway,
 Ireland.
 Tel: +353 (0)91 400 200
 Email: ireland@rpsgroup.com
 Web Page: rpsgroup.com/ireland

Issue Details	
Drawn By: JG	Project No. MGE0780
Checked By: JOC	File Ref:
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Scale: 1:20,000 @ A3	Projection:
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Table 6.2 EPA Biological River Monitoring Data: Diffagher Sub-Catchment

Station Code	Station Name	River	1992	1996	1999	2002	2005	2008	2009	2011	2014	2017
26D020200	Cloonmeone Br.	Diffagher (main channel)	5	4-5	4-5	4-5	4-5	4	~	4	4	4
26B300400	Br 2 km u/s Main Chan conf	Boleybaun Stream (Trib. of Diffagher)	4-5	4-5	4-5	4	4	4	~	4-5	4	4
26K160600	Br u/s Confl with main Diffagher	Killadiskert Stream (Trib. of Diffagher)	~	4	4	4	4-5	4	~	4	4	4
26O020050	Br S Glassalt	Gowlaunrevagh (Trib. of Owengar)	~	~	~	~		1*	~	2-3	3*	3
26O020075	SE Letter	Owengar (main channel u/s Gowlaunrevagh confl.)	~	~	~	4-5	4-5	~	~	4	4	4
26O020100	Bridge at Barragh (R280)	Owengar (main channel)	4-5	4	4-5	4-5	~	~	4	4	4	4
26O020200	Bridge at Annagherry	Owengar (main channel)	5	4	3-4*	~	4	4*	~	4	4-5	4

Of particular interest from the above data is the highlighted row for the Gowlaunrevagh Stream, located in the Owengar catchment. The Gowlaunrevagh Stream, tributary of Owengar River, has been monitored since 2008 following a serious landslide incident in that catchment which occurred on 23rd September 2008. This stream was rated Q1* 'bad' status in 2008; since recovering to Q2-3 'poor' status then Q3 'poor' over the 9 years between 2008 and 2017.

The EPA record in relation to the landslide in the Owengar catchment (and Gowlaunrevagh Stream) provides an insight into the potential trajectory of water quality and habitat recovery following an event similar to the Dawn of Hope event. While the affected tributary was at Q1* 'bad' status, the Owengar main channel at Annagherry Bridge was at Q4* 'good' status. The asterisk in these cases almost certainly relates to sedimentation (peat mass) in the channel. It is noted that in the 6 years between 2011 and 2017, the affected tributary has progressed through Q2-3 to Q3 'poor' status, while the main channel sites upstream and downstream of the tributary remained at Q4/Q4-5, with 'good' status as a minimum. Provisional results from the EPA for the 2020 samples indicate that these sites continue to improve. There were fisheries and habitat rehabilitation works carried out in the Owengar since the 2008 incident which may have contributed to the recovery of the downstream situation on the Owengar main channel.

6.3 Leitrim County Council Water Quality Chemistry Data

Leitrim County Council conducted three water sampling rounds at selected locations in the Diffagher catchment in the aftermath of the event, commencing 30th June 2020, with follow up rounds on 21st July and 26th August. This report analyses key parameters that can be compared to river water quality criteria under the Surface Water Regulations (S. I. 77 of 2019).

Appendix A presents summary graphs of the data provided by Leitrim County Council for key water quality parameters for the main impacted sites moving down the catchment from the Dawn of Hope Stream at Corcormick → Diffagher River at Greyfield's Bridge → Diffagher River at Cloonmeone Bridge → Diffagher River d/s Owengar River confluence.

Each of the four impacted sites sampled was within good status criteria for Ortho-P, Ammonia, BOD and %DO and suspended solids were low by late August; two months after the event.

The water chemistry sampling data provided by Leitrim County Council shows significant improvements at selected stream and river locations in all key water quality parameters over the three months of sampling to date. Each of the four impacted sites sampled was within good status criteria for Ortho-P, Ammonia, BOD and %DO and suspended solids were low by late August; two months after the event. This is promising, but

does not mean that there will not be flushes of sediment and nutrient over the coming months (especially during winter rainfall). It is recommended this sampling continues on a regular basis, but that a range of flow types are also targeted, to include a number of high flow events, not just low flows. High flow sampling should target, in as much as possible, the peak of the hydrograph, i.e., within a few hours of heavy rain, as this is when solids and nutrients are exported in these types of spate catchments. This will provide an indication of the catchment response and runoff dynamics and may help target areas where extra rehabilitation is required over time.

6.4 Diffagher River Fisheries Data

There were no published fisheries data available for the Diffagher River. Consultation with the IFI confirms there is some electrofishing data in existence for the river, from previous works carried out, e.g., culverting. It holds good brown trout (*Salmo trutta*) stocks, but in the context of the catchment as a whole, the Diffagher main channel is less significant in terms of its trout population compared to the Owengar River, which was unaffected by this incident. The Diffagher trout population generally holds less year classes of trout (n=5) compared to the Owengar (n=7). The lower reaches of the Diffagher are fish migration routes to spawning areas higher in the catchment, one of these areas being in the Corcormick area within the Tullintowell Stream (unimpacted) and Dawn of Hope Stream (impacted). Electrofishing carried out immediately after the event revealed no fish remaining in the highly impacted Dawn of Hope Stream, but more recent electrofishing (week commencing 14th September 2020) revealed small numbers of trout have moved back up into this stream.

6.5 Lough Allen

6.5.1 Water Quality

A full set of EPA water chemistry data from Lough Allen was obtained and analysed for the years 2007-2020 to provide a baseline to examine the impact (if any) of the recent landslide on lake water quality. Key biological quality parameters investigated were: total phosphorus (TP), chlorophyll a, ammonia and water colour. These include the principal parameters used to indicate lake ecological quality in terms of habitat quality for fish and other aquatic organisms. Lake data was analysed by aggregating to the waterbody level, as per EPA WFD methods (Deakin et al., 2015), i.e., pooling annual data reported from stations located in that waterbody.

The EPA currently reports lake status as Moderate in Lough Allen based on 2010-2015 data. Lake status includes other biological quality elements, e.g., macrophytes, macroinvertebrates. The lake passed (is within good status) for chemical parameters (TP, Ammonia, DO, chlorophyll) but is apparently downgraded to moderate based on other biological quality elements (for which data was not readily available).

Aggregated annual waterbody data was analysed and assessed with respect to criteria for 'good' and 'high' status in Irish lakes for TP and Ammonia (taken from S.I. 77 of 2019) and for chlorophyll (taken from previous Surface Water Regulations - S.I. 272 of 2009). Annual means were the basis for assessment of TP in all cases. Annual mean chlorophyll was used as there were >12 samples per annum each year. Maximum values were examined in each parameter to help determine effects of the 2008 Owengar River peat slide event in the same catchment. Lough Allen is a type 4 lake (EPA data). The results are presented in

Appendix A.

As a result of the 2020 peat mass input from the Diffagher inflow into Lough Allen, the lake may be subject to a brief period of elevated water colour for up to two years arising from humic substances from the peat wash out to the lake. There may be slightly elevated TP, followed by a brief spike in chlorophyll max. (as algae respond to the additional nutrient supply). This may exacerbate the current upward trend (quality deterioration) in TP (in particular) and chlorophyll (to a lesser extent) already evident over recent years, and in the case of TP the lake may tip the good-moderate status boundary for a period of time. However, the current upward trend in these lake water quality parameters (TP, chlorophyll) may also have continued in Lough Allen without the additional input from the Dawn of Hope land slide.

6.5.2 Fish

There is no published fisheries data for Lough Allen. IFI conducted lake surveys in early 2020, but this data was not publicly available at the time of compiling this report. An IFI summary report of the 2014 WFD fish

monitoring programme stated that, using experimental hydroacoustic surveys Lough Allen has a large population of pelagic fish, dominated by pollan (*Coregonus pollan*) and juvenile perch (*Perca perca*). Pollan are a glacial relict species not found anywhere in Western Europe outside of Ireland. It is known from only five Irish lakes, including Lough Allen. Recreationally, Lough Allen is a mixed fishery, noted for its pike fishing, but also for good trout stocks (derived from numerous angling websites). There is a fish pass at the Ballintra sluice gates, but migratory fish - notably salmon - appear unable to pass this barrier, as evidenced by the absence of salmon stocks in physically suitable rivers of the upper Shannon catchment.

6.5.3 Protected Aquatic Species and Habitats

Numerous records for white-clawed crayfish occur in rivers and streams surrounding Lough Allen, but no records are for the lake itself (NBDC live maps). This does not mean this Habitats Directive (92/43/EEC) Annex II species is absent from the lake or surrounding rivers, just unrecorded.


Unspecified juvenile lampreys (ammocoetes) were previously reported from the Diffagher River (Kurz & Costello, 1999). Annex II species Brook lamprey (*Lampetra planeri*) (non-migratory) are fairly widespread throughout Ireland, and is certainly likely to occur in the Diffagher catchment. While the upper catchment streams are less conducive to the species (i.e., lack of marginal sediments), depositional, lower reaches would be ideal nursery habitat for the species. Many lamprey ammocoetes are likely to have been physically removed with the mobile peat mass.



6.6 Field Survey 14th September 2020

6.6.1 Downstream of Dawn of Hope Bridge

A field survey of the affected watercourses was undertaken on 14th September 2020. A brief description of each site is provided in **Table 6.3**. The affected watercourses were sampled in accordance with EPA protocols to determine Q-value and water quality implications. This involved taking a 2-minute, travelling kick-sample in a fast flowing (riffle) area of the river using a long-handled sampling net (250 mm width, mesh size 0.25mm). Stone washing was employed to ensure “clinging” species, e.g. leeches and gastropods, were adequately collected. The relative abundance and sensitivity of aquatic organisms to pollution was assessed at the bankside using the Q-rating system. Macroinvertebrate results for each of the sites are included in **Appendix A**.

Table 6.3 Location of Watercourse Field Surveys

Watercourse & I.D.	Description
DF4: Diffagher River – unimpacted reach. 	<p>Moderately fast flowing with a moderate gradient over substrates of small pebble, fine gravel and coarse sand with underlying soft sediments (clay and peat). Heavy layer of iron bacteria (<i>Leptothrix ochracea</i>), a heterotrophic bacterium that thrives in the presence of iron and organic matter, typical of many peat drainage areas. High water colour is likely on account of peat soils and drainage in the upstream catchment</p> <p>The stream possesses, at best, low quality fisheries habitats and is considered largely unsuitable for salmonid (trout) and lamprey spawning. May be a migration route for fish connecting Lough Allen (downstream) and Belhaval Lough (upstream).</p>
TT3: Tullintowell Stream – unimpacted reach.	<p>Moderately-high water colour, indicating some degree of water colour is natural in these upland streams.</p> <p>Macroinvertebrate fauna (Appendix A) was indicative of Q4(3-4), equating to good-moderate status.</p> <p>Overall, the faunal diversity and abundances were low, which tends to demonstrate these upland streams are not highly productive even in an unimpacted state. Habitat is highly conducive to salmonid spawning and</p>

Watercourse & I.D.	Description
	<p>nursery and this stream is likely to be an important reservoir for trout stock and breeding this winter.</p>
<p>DH2: Dawn of Hope Stream – upstream of Tullintowell Stream confluence.</p> 	<p>Visibly impacted by peat deposition on fields, high water colour and peat material deposited on stream banks.</p> <p>Sampled in the reach a short distance upstream of the local road at Corcormick, and the stream was walked upstream and downstream of the road. There was a lot of work already carried out by Leitrim County Council in association with IFI.</p> <p>Macroinvertebrate fauna (Appendix A) indicates Q3, poor status.</p> <p>Physical habitat is technically conducive to trout spawning and nursery where faster flow has scoured away excessive peat deposits, although there was deeper interstitial peat detritus, which probably compromises trout spawning success (oxygen depletion in gravels) this coming season at least.</p> <p>A series of weirs have been inserted downstream of local road to deter fish from migrating up into impacted reaches. Noted is that IFI electrofished in this reach in mid-September, with 2 trout being present (2+ year class).</p>
<p>DF1: Diffagher River – Cloonmeone Bridge</p> 	<p>Approx. 6.7km downstream of Dawn of Hope Bridge. Visibly impacted by peat mass deposition.</p> <p>A fast flowing, stony riffle section was sampled, located ca.50m downstream of Cloonmeone Bridge.</p> <p>Macroinvertebrate fauna (Appendix A) was indicative of Q3-4(3), “moderately polluted” conditions and ‘moderate-to-poor’ status.</p> <p>While the river (during average flow) appeared highly coloured, with considerable peat material deposited along the channel; in faster flows, substrates were self-cleaning by scouring away peat detritus which can give rise to suitable habitat for recolonization by a more diverse and abundant macroinvertebrate community, beneficial to fish</p>
<p>LA5: Lough Allen</p> 	<p>Lough Allen, with a surface area of 33.32km², receives inputs from a number of significant surrounding river sub-catchments, including the Arigna, the Yellow, the Diffagher and the Shannon. It is the first of the large lakes downstream of the source of the River Shannon.</p> <p>The survey site at Corry Strand (LA5) is located just over 1km directly east of the Diffagher River outflow to Lough Allen. It is an exposed shoreline of well-sorted, sand or gravel/pebble substrates backed by mature woodland.</p> <p>A deep layer of peat mass had accumulated on the shoreline, probably as a result of prevailing south-westerly wind and wave action since the event. The peat mass formed a wedge a few metres wide at the lake shore, but submerged lake substrates were generally clean beyond that with distance into the lake. Lake water was moderately coloured, and clear</p> <p>At this site, presence of a number of sensitive macroinvertebrate species (Appendix A) indicates reasonably good water quality, with habitat conditions that are suitable to support sensitive taxa.</p>

The field survey showed promising mayfly and dipteran macroinvertebrate fauna re-colonising of the stream/river substrates that had been badly affected by the landslide. This was the case even for the highly

impacted area near Corcormick. These invertebrate communities will help support recolonising fish and are the foundation of the instream food chain (fish, otters, birds). Biological sampling (Q-values) should, at a minimum, be repeated in spring and autumn of 2021 at sites sampled in this study, in order to monitor habitat and macroinvertebrate community recovery and/or ongoing impact. This can help target areas that may require additional rehabilitation measures, e.g. substrate loosening to remove trapped sediment.

It is noted that the Diffagher River has a number of clean water contributions to its main channel between the Dawn of Hope Stream and Lough Allen, which will assist in natural recovery processes over time and provide clean inputs for currently migrating fish (mainly trout).

6.6.2 Upstream of Dawn of Hope Bridge

Remedial works have been undertaken at the Dawn of Hope Bridge. The structure and barrage is likely to act as a first line of defence to further excessive peat movement from Shass Mountain during the coming winter.

6.6.3 Flood Plain at Corcormick

Considerable works have been undertaken in Corcormick where peat first spilled out onto farmland along the Dawn of Hope stream. The stream is flowing freely in the recently re-excavated channel (an approximation of the original channel) and has high self-cleaning capability owing to fast riffle/run flow. This has the effect of cleaning the important pebble/gravel substrates for macroinvertebrate recolonisation, and fish feeding/spawning in the future. There has been notable regrowth of grasses on sediments, although the ground is very soft beneath. This shows that swift revegetation is likely next spring/summer, which is positive for water quality and ecology as there is demonstrated evidence that revegetation leads to significant reduction in suspended solids and sediment export to nearby stream following earthworks.

At the request of the IFI, a series of stone weirs have been installed in the Dawn of Hope Stream south of the road at Corcormick. The weirs may help divert fish migrating up into the clean gravels of the upper Tullintowell Stream rather than allowing them to attempt spawning in the Dawn of Hope Stream this coming winter season. However, these weirs should not remain in-place indefinitely.

It was noted that significant erosion has occurred of the bank of a land drain south of the road at Corcormick and at the point of the confluence of the Dawn of Hope Stream and the Tullintowell Stream. This landbank should be repaired and/or reinforced to prevent further erosion.

6.6.4 Flood Plain at Corchuill Lower and Derrindangan (north of R200)

Large volumes of peat lie on the floodplain area in the mid Diffagher catchment area, upstream of the R200 road in the townland of Derrindangan. It was not possible to access the river on foot in this area. The debris on the floodplain is likely to remain a source of leaching of BOD and nutrients to the river, but it appears from aerial imagery that there is a raised embankment along the riverbank (in part at least) that may act as a barrier to reduce export of peat mass back to the river. The soft ground conditions may make it impossible to get machinery into this area to undertake works, at least in the short-term.

6.7 Impact on Land, Property and Infrastructure

6.7.1 Impact on Land

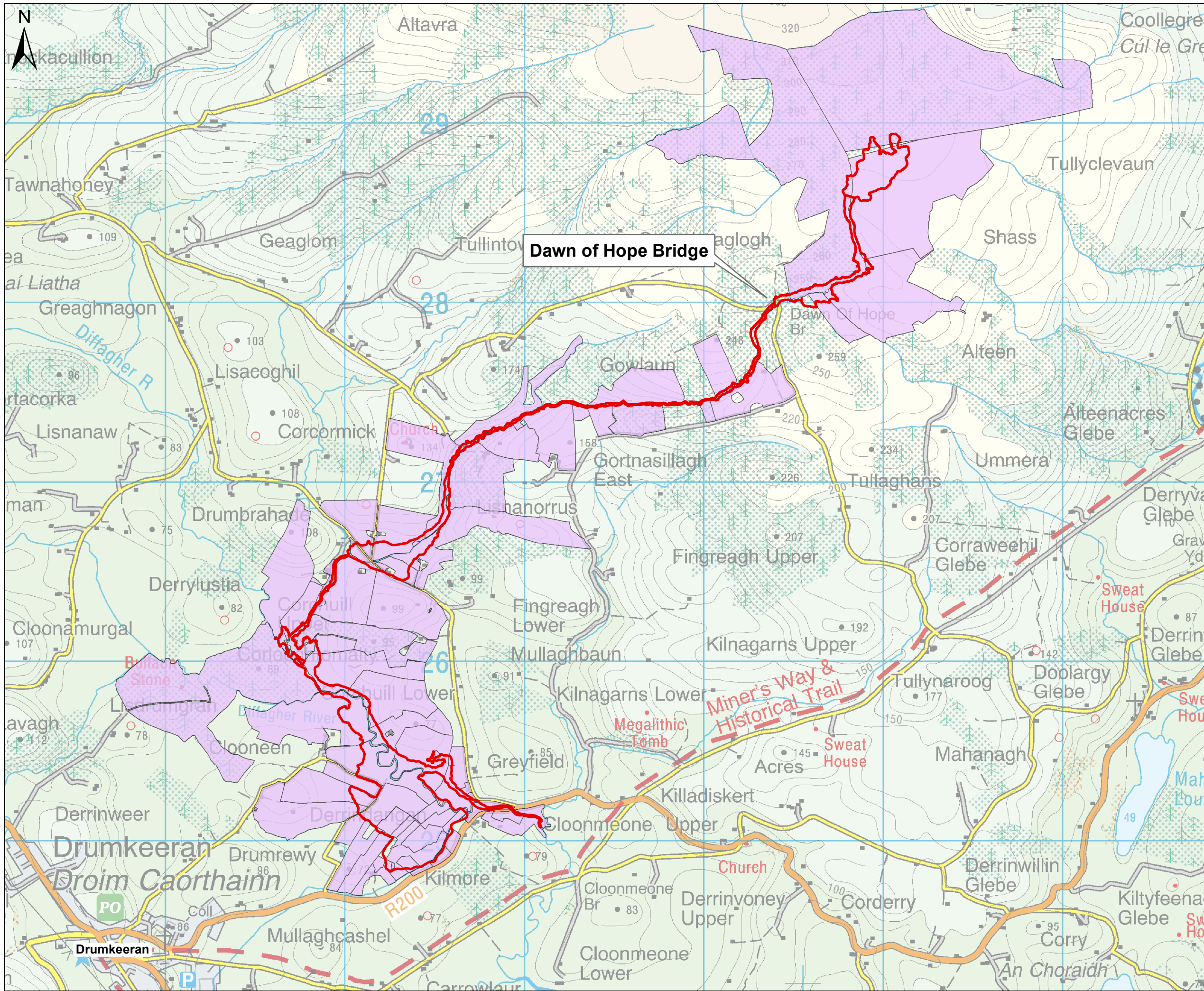
The Department of Agriculture, Food and the Marine (DAFM) has delineated the perimeter of the area impacted by the slide using sentinel satellite imagery and GPS. A list of land parcels impacted was prepared and forwarded to RPS for inclusion in this report.

Table 6.4 summarise the extent of damage for both agricultural and forestry areas prepared by DAFM. The land parcels affected are illustrated on **Figure 6-2**. No damage was observed to the south of the R200.



Table 6.4 Summary of Extent of Damage on Agricultural and Forested Land

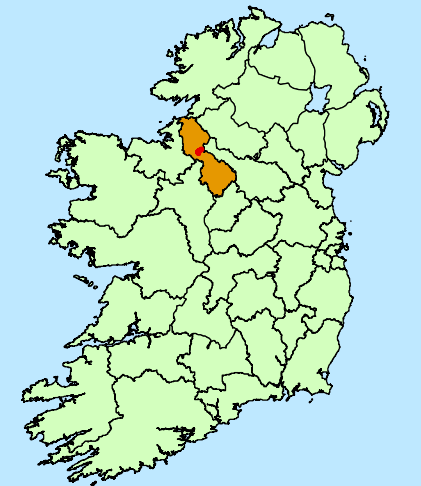
Area Impacted	Number
No of parcels with land in damaged polygons ¹	37.0
Area of agricultural land within damaged polygons (incl. SAC area)	24.1 ha
Area of SAC within damaged polygons	6.3 ha
Area of forestry within damaged polygon	12.7 ha
Gross area of damaged agricultural and forested	36.8 ha


¹Polygon refers to the outline of the mapped areas with damage.



Legend

-  Outline of Peat Landslide
-  Affected Agricultural and Forested Land



Client
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 Leitrim County Council

Project
Shass Mountain Landslide

Title
Agricultural and Forested Land Parcels

Figure 6-2



Lyrr 2,
 IDA Business & Technology Park,
 Mervue,
 Co. Galway,
 Ireland.
 Tel: +353 (0)91 400 200
 Email: ireland@rpsgroup.com
 Web Page: rpsgroup.com/ireland

Issue Details	
Drawn By: JG	Project No. MGE0780
Checked By: JOC	File Ref:
Approved By: GME	MGE0780Arc0014F01
Scale: 1:20,000 @ A3	Projection:
Date: 16/10/2020	ITM (IRENET95)

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Drone footage of the lands affected, captured by Maynooth University, has been used to create a perimeter boundary of the landslide area (shown as the red line on **Figure 6-2**). Based on the drone footage arials, the area of land inundated by peat is estimated to be 55.3 ha. This estimate differs from the DAFM figure of 36.8 ha in **Table 6.4** because it accounts for the river channel and its banks and all areas of land inundated i.e. not just agricultural and forestry land parcels.

6.7.1.1 Peat Upslope from the Dawn of Hope Bridge

An assessment has been carried out on the material trapped behind the Dawn of Hope bridge. It is not recommended to attempt to remove peat from behind the Dawn of Hope Bridge structure at this stage. Removal of the debris at this stage will only elevate suspended solids, BOD and nutrients in downstream channels during the sensitive salmonid spawning period / restricted season. This will be reviewed next spring/summer, once some settlement and further dewatering of the peat has occurred.

6.7.1.2 Peat at Corcormick and Derrindangan

Options for the treatment of the peat material on the lands at Corcormick and Derrindangan were reviewed. This included both options to leave the material in-situ to dewater and removal from the land.

As discussed in **Section 2.2** it is estimated that approximately 160,000m³ of peat, equivalent to approximately 160,000 tonnes, currently sits on the lands in these two areas. Given the water content of the peat and its capacity to flow, it is estimated that only approximately 8m³ could be transported in a single load. This is equivalent to approximately 20,000 loads required to remove the material from the affected areas. Added to this would be the physical work involved in accessing the areas where the peat has been deposited and excavating the material. This would require the installation of significant lengths of haul roads, storage areas for loading and transporting the material off-site.

There would also be a significant environmental risk associated with remobilising the peat and the release of sediment back into watercourses that are already showing some signs of recovery.

An added complexity to removal of the material would be the identification of suitable receptor sites capable of receiving the material and not causing environmental pollution. It is likely that multiple sites would have to be identified to take 160,000m³ and they would all require planning permission and environmental assessments.

The lands at Derrindangan are mostly under tree plantation. The area is largely inaccessible on machine or foot.

In conclusion, it is recommended to leave the peat insitu to dewater until spring / summer 2021 with seeding of accessible areas where possible.

6.7.2 Impact on Property

One residential property has been impacted in the Corcormick area. Peat did not enter the property but did engulf the rear area of the house, advancing as far as the back door of the property. It is understood that this property is currently uninhabited. No other residential properties were directly affected by the peat landslide.

6.7.3 Impact on Infrastructure

Works have been carried out at the Dawn of Hope bridge to secure it to retain the peat trapped upslope. This included the installation of a new bridge deck and culverts to take the flow from the river.

A number of local roads were inundated in the Corcormick area which have now by cleared by Leitrim County Council. Radharc na tSeipeal road to the east of Greyfield bridge remains inundated with peat.

7 RISK ASSESSMENT

7.1 Introduction

A preliminary risk assessment has been undertaken on the remaining bog within the 'immediate slope' affected by the landslide. The 'immediate slope' has been defined for this study as the slope within the watershed of the existing landslide starting from where the landslide meets the stream neck.

The risk assessment area is shown on **Figure 7-1** along with plans showing contours, known and assumed peat depths (**Figure 7-2**) and slope angles (**Figure 7-3**).

7.2 Methodology

A qualitative risk assessment was undertaken to assess the risk to land, property and infrastructure. The risk rating for each hazard is defined based on an assessment of likelihood and consequence for identified hazards.

A quantitative risk assessment was undertaken to assess the risk to life. The risk to life is determined based on an assessment of likelihood, and quantification of consequence to those downstream. The risk to life is then compared against acceptable and tolerable risk levels to the public defined by the UK Health & Safety Executive.

7.3 Areas

This assessment has been broken down into the following areas:

- Area A – Area in which the 28th June Landslide occurred; and
- Area B – Areas within the 'Immediate Slope' which did not slip on 28th June.

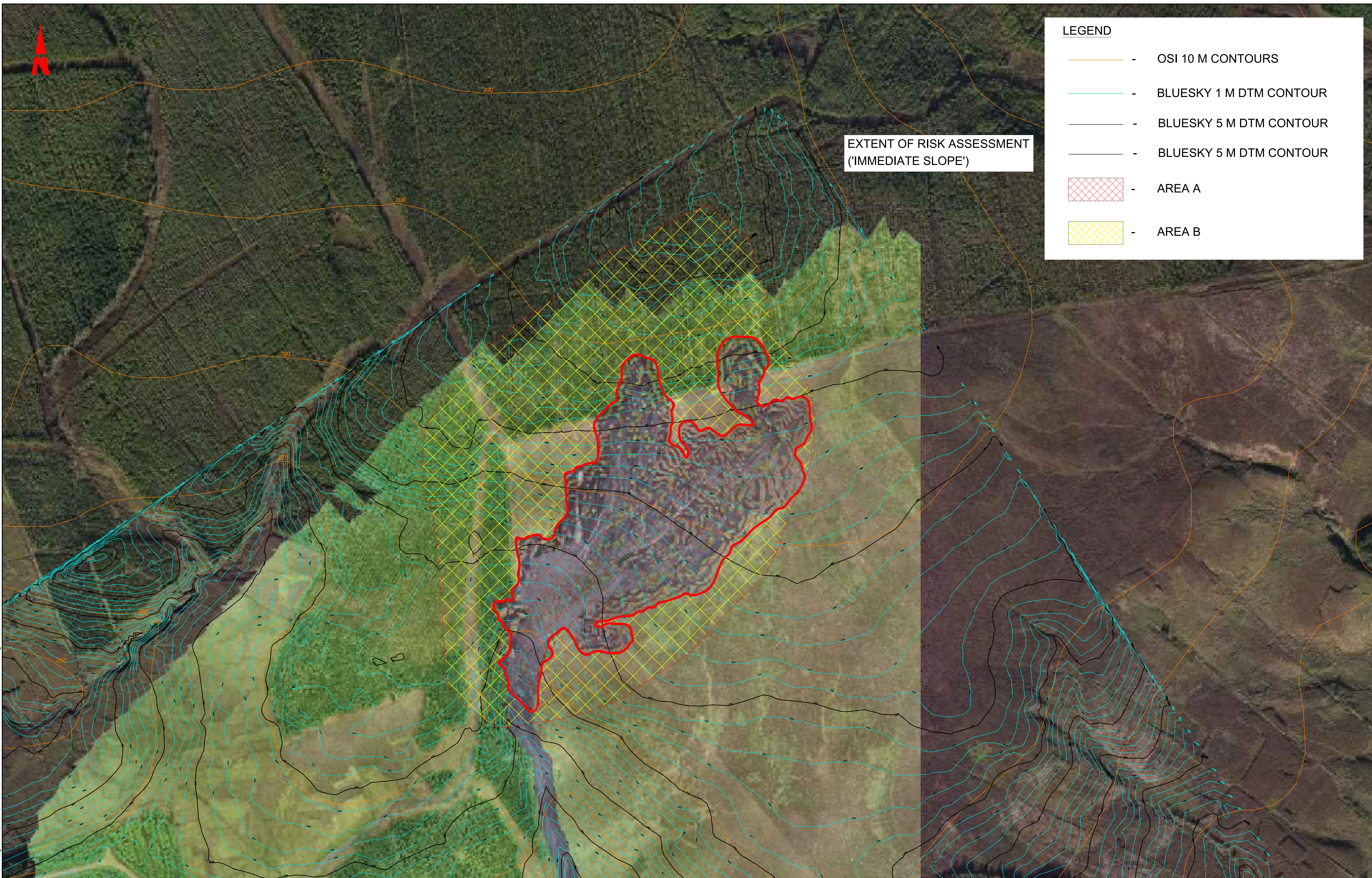
7.3.1 Area A

A review of available information indicates that the 28th June landslide principally occurred within an un-forested area assessed to have > 2 m of peat. The slope angle is principally between 1 – 4° with zones having a slope angle over 4°. *Peat slope failure in Ireland* indicated that the majority of peat landslides occur on slopes of 4 – 8° with some in slopes of 1 – 4°. The zones with a slope angle over 4° appear to generally coincide with peat depths of less than 2m. Site contours indicate that the landslide is within the principal flow path for the slope and likely collected water from the wider slope.

Area A still contains large volumes of peat with typical peat thicknesses over 2 m depth. The slope angle remains unchanged from the June 28 landslide and is principally between 1 – 4° with zones of over 4°. Due to the 28th June landslide, the area is broken up with near to no vegetation leaving the peat open to absorb rainfall and runoff. Based on these indicators, further landslides were judged to be Almost Certain (The event is expected to occur) to Likely (The event will probably occur under adverse conditions) to occur.

7.3.2 Area B

Area B appears to contain large volumes of peat with similar peat thicknesses to Area A of up to and over 2 m depth. Slope angles appear to be similar to those for across Area A with typical slope angle between 1 and 4° and zones with a slope angle over 4°. Vegetative cover generally remains across this area including Forestry in some zones. Rainfall is generally expected to runoff across Area B towards Area A rather with lower infiltration than Area A. These indicators suggesting conditions are similar to Area A before the 28th June landslide. Further landslides were therefore judged to be to Likely (The event will probably occur under adverse conditions) to Possible (The event could occur under adverse conditions) to occur.



LEGEND

- OSI 10 M CONTOURS
- BLUESKY 1 M DTM CONTOUR
- BLUESKY 5 M DTM CONTOUR
- BLUESKY 5 M DTM CONTOUR
- AREA A
- AREA B

EXTENT OF RISK ASSESSMENT ('IMMEDIATE SLOPE')

J:\MGE0780 - Leitrim Landslide\8.0 Drawings\DC\MGE0780-RPS-00-XX-DR-C-DG0001 Landslide Risk Assessment.dwg

Client

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Rev	Date	Drawn By	Amendment / Issue	App
P01	08.10.20	DM	DRAWING NAME UPDATED	TSC
P01.01	30.09.20	DM	REVIEW AND COMMENT	TSC

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RPS | Consulting UK & Ireland
Lyr 2, IDA Business & Technology Park
Mervue, Galway, H91 HBCK, Ireland

T +353 91 400 200
E ireland@rpsgroup.com
rpsgroup.com

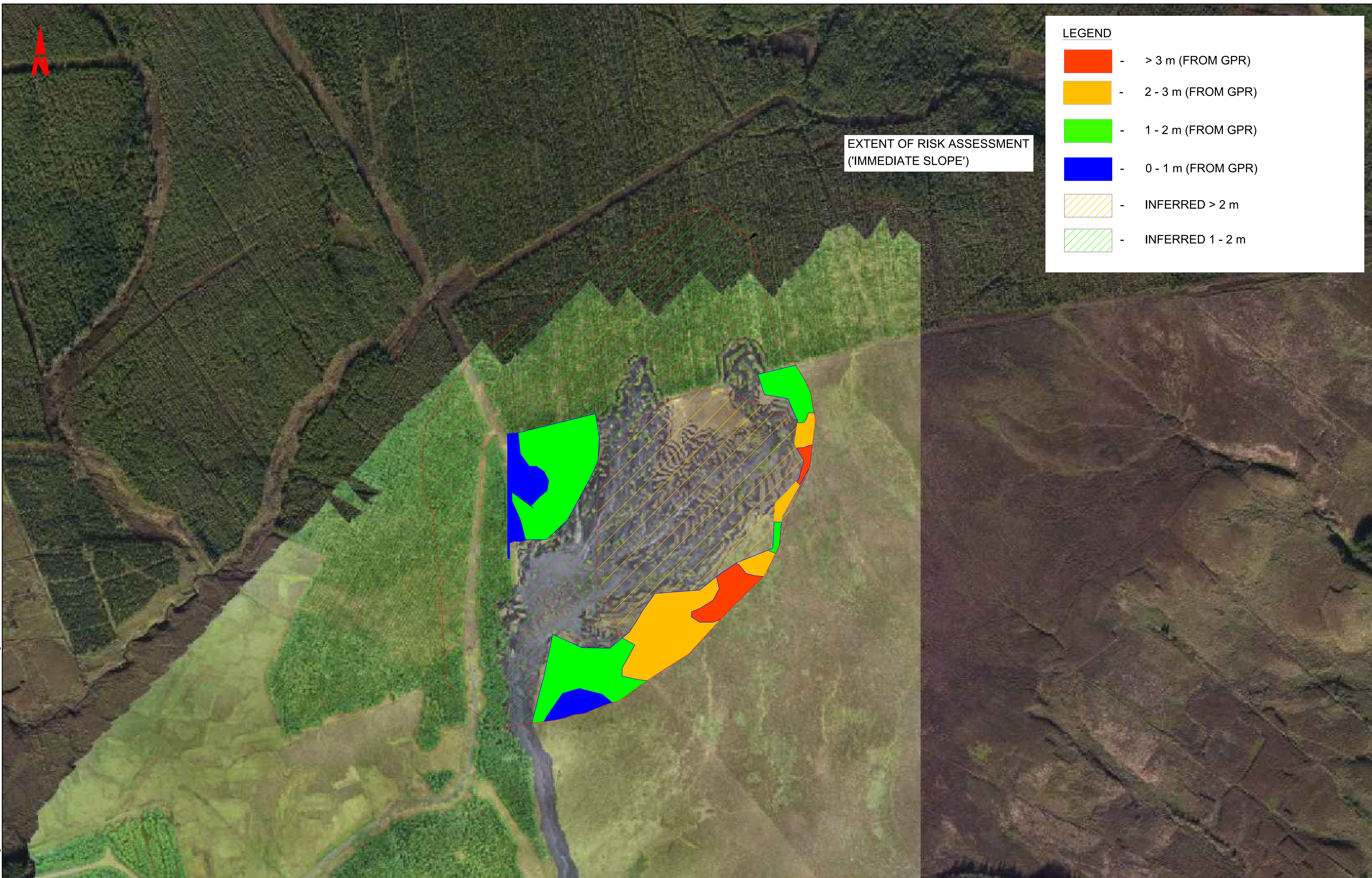
Scale	NTS @ A1 NTS @ A3	Project	Shass Mountain Landslide Drumkeerin, Co. Leitrim
Created on	28/09/2020	Title	FIGURE 7-1 RISK ASSESSMENT EXTENTS
Sheets	01 of 03	File Identifier	MGE0780-RPS-00-XX-DR-C-DG0001-01
Model File Identifier	MGE0780-RPS-00-XX-DR-C-DG0001-01	Status	S3
Rev	F01		



LEGEND

- > 3 m (FROM GPR)
- 2 - 3 m (FROM GPR)
- 1 - 2 m (FROM GPR)
- 0 - 1 m (FROM GPR)
- INFERRED > 2 m
- INFERRED 1 - 2 m

EXTENT OF RISK ASSESSMENT
(‘IMMEDIATE SLOPE’)



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Rev	Date	Dim Ck	App	Amendment / Issue
P01	08.10.20	DM TSC		DRAWING NAME UPDATED
P01.01	30.09.20	DM TSC		REVIEW AND COMMENT



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RPS | Consulting UK & Ireland
Lyr 2, IDA Business & Technology Park
Mervue, Galway, H91 HBCK, Ireland

T +353 91 400 200
E ireland@rpsgroup.com
rpsgroup.com

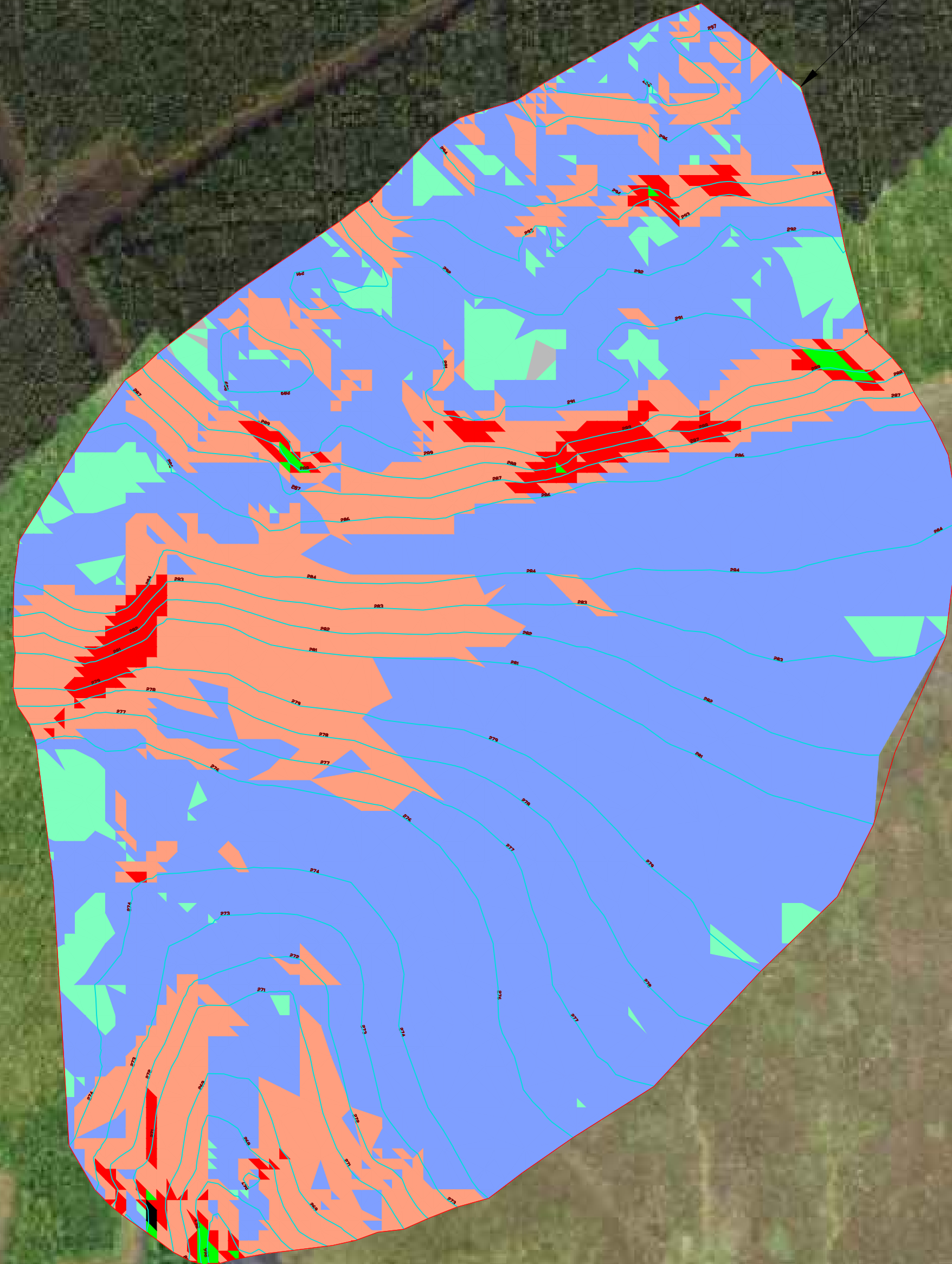
Scale	NTS @ A1 NTS @ A3	Project	Shass Mountain Landslide Drumkeerin, Co. Leitrim
Created on	28/09/2020	Title	FIGURE 7-2 APPROXIMATE PEAT DEPTHS
Sheets	02 of 03	Model File Identifier	MGE0780-RPS-00-XX-DR-C-DG0001-02
		File Identifier	MGE0780-RPS-00-XX-DR-C-DG0001-02
		Status	S3
		Rev	F01



LEGEND

- > 12°
- 8 - 12°
- 4 - 8°
- 1 - 4°
- 0 - 1°

EXTENT OF RISK ASSESSMENT
(‘IMMEDIATE SLOPE’)



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Rev	Date	Dim Chk	Amendment / Issue	App
P01	08.10.20	DM TSC	DRAWING NAME UPDATED	TSC
P01.01	30.09.20	DM TSC	REVIEW AND COMMENT	TSC



RPS | Consulting UK & Ireland
Lyr 2, IDA Business & Technology Park
Mervue, Galway, H91 HBCK, Ireland

T +353 91 400 200
E ireland@rpsgroup.com
rpsgroup.com

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MGE0780-RPS-00-XX-DR-C-DG0001-03

Scale	NTS @ A1 NTS @ A3
Created on	28/09/2020
Sheets	03 of 03

Project	Shass Mountain Landslide Drumkeerin, Co. Leitrim		
Title	FIGURE 7-3 APPROXIMATE SLOPE ANGLES OF BLANKET BOG		
File Identifier	MGE0780-RPS-00-XX-DR-C-DG0001-03	Status	S3
Rev	F01		

7.4 Risk to Land, Property and Infrastructure

Based on the results of the preliminary qualitative risk assessment, there is a high risk to land, property and infrastructure from further landslide from Area A and Area B.

7.5 Risk to Life

The risk to life to road users, those using the Dawn of Hope bridge, and those living within the potential debris zone downstream of the landslide (within areas previously affected by the 28th June landslide) was assessed to be within the 'Tolerable' range (10^{-4} - 10^{-6} / year).

8 REMEDIAL WORKS

8.1 Emergency Works

In the immediate aftermath of the peat landslide, Leitrim County Council undertook emergency works to protect property and lands downstream of the Dawn of Hope bridge.

As a priority action the Dawn of Hope bridge was buttressed to stabilise it and a new bridge deck was constructed immediately downstream of the old Dawn of Hope bridge to provide additional support and re-open the local road (**Figure 8-1**). Headwalls and drainage pipes were installed to take the upstream water flow under the road and discharge it back into the old watercourse.



Figure 8-1 Completed Remedial Works at the Dawn of Hope Bridge

In the townland of Corcormick, the watercourse was cleared of peat debris and the banks of the stream cleaned back. The local roads that were inundated were cleared, raised and repaired where necessary (**Figure 8-2**).



Figure 8-2 Completed Remedial Works at Corcormick

It is understood that approximately €1.2 million in emergency funding was provided to Leitrim County Council to enable these works to be completed.

8.2 Remedial Measures to be Completed in the Short Term

8.2.1 Works at Dawn of Hope Bridge

The outfalls of the culverts downstream of the Dawn of Hope bridge require further bank stabilisation to reduce sediment transfer to the stream (**Figure 8-3**). This could include the placement of sandbags, lean mix, and/ or rock armour around the base of the culverts and keyed into the surrounding bank back towards the road. Additional site specific measures will be identified and developed in the follow up to this report.



Figure 8-3 Eroding Banks at Culverts of Dawn of Hope Bridge

8.2.2 Measures to Protect Water Quality

The following short term water quality protection measures are required:

- Review records of rehabilitation works carried out to the Owengar catchment following 2008 landslide as some of these measures may be equally applicable to the Diffagher catchment.
- Continue water quality chemistry sampling and analysis. This should be carried out over a range of flow types to include high and low flows in the rivers and streams.
- Install an additional upstream water quality monitoring point on the Diffagher River at location DF4 shown on **Figure 6-1**.
- Accumulated peat mass on Lough Allen Corry Strand (**Figure 8-4**) shoreline should be carefully removed during dry, settled, low lake water level conditions by scraping the obvious layer / bank of peat away from the lake edge. Care is required to only remove the overlying peat layer, not the lake substrate. The work should be done in consultation with the IFI. The spoil could be placed well up the shoreline in the vegetated area away from the lake edge or removed and spread elsewhere. If left to degrade in-situ, it will contribute nutrient and BOD to the lake, potentially affecting oxygen conditions and promoting eutrophication in spring 2021. It can also currently re-suspend as lake levels rise in the winter, potentially affecting fish, e.g. pollan and possibly trout, spawning sites nearby.



Figure 8-4 Peat on Corry Strand, Lough Allen

8.2.3 Areas of Inundation in Corcormick and Derrindangan

Short-term remedial measures to be undertaken in the townlands of Corcormick and Derrindangan have been illustrated in **Figure 8-5** through to **Figure 8-7**. They include:

- Re-instating land drains and field boundaries including the planting of wetland areas to assist in re-vegetation and dewatering of the peat;
- Raising the height of local roads and providing farm access tracks; and
- Providing bunding to protect the affected house.

8.2.3.1 Reinstatement of Land Drains, Field Boundaries and Planting

Over time, the peat in these affected areas will de-water. In order to assist with this de-watering drainage channels with silt control measures should be installed across the inundated lands. The land can also be reseeded with appropriate grass species to establish growth as soon as possible to help stabilise sediment and encourage uptake of nutrient from the peat mass. The areas could be planted with wetland plants, e.g., reed canary grass (*Phalaris arundinacea*), branched burr-reed (*Sparganium erectum*), yellow flag iris (*Iris pseudocorus*), reed mace (*Typha latifolia*).

In both Corcormick and Derrindangan areas, field boundaries should be re-established and fenced where possible. Access to severed land parcels should be reinstated where feasible. Pre-slide drains should be cleared where safe to do so to allow the land to dewater. Sediment control measures such as straw bales, geotextile or stone filters should be employed to reduce sediment runoff to the Diffagher River. Silt fencing could be used where possible but this requires maintenance. Required drainage could be carried out following consultation with landowners and local Teagasc or IFA representatives.

It is likely that the inundated areas will pose a hazard to humans and livestock due to the soft ground conditions. Consideration should be given to securing those areas, providing a barrier to livestock. Warning signage should be fixed to any such fencing to advise people of the hazards.

Temporary bank and drain rock-armouring work at the confluence of the Tullintowell and Dawn of Hope Streams should be carried out in consultation with IFI, to help prevent further scouring of sediment and river bank caused by drainage from the lands to the west of the local road at Corcormick. All instream works are to be carried out in consultation with the IFI. It should be noted that the closed season for in-stream works is from 1st October through to 31st April.

Location specific measures will be further developed in the follow up to this report.

8.2.3.2 Raising Local Roads and Providing Farm Access Tracks

The local road in Corcormick will be raised by 0.5m to provide protection to the road should further material travel down the valley over the winter season.

It is proposed to construct farm access tracks along the banks of the restored river bank in the Corcormick area. This could be underlaid by geotextile, slightly raised above the level of the field and set back from the stream bank, to form a slight barrier (filter strip) between bare fields and the stream edge. From the site walkover it appears likely that this zone was a farm track prior to the event. This would likely be more

effective as a filter and buffer zone than any type of silt fencing. Banks and fields will begin to green over in the spring, leading to a significant reduction in suspended solids export once vegetation is established.

It is proposed to clean the local road at Radharc na tSeipeal and build it up with material to protect it from future flooding.

8.2.3.3 Property Protection Measures

A review of properties in the landslide zone highlights one property at risk in the Corcormick area. This property is located within the vicinity of the downstream debris and has the potential to be inundated in a future event. Measures which will reduce the consequences of failure such as construction of a series of rock weirs above the Dawn of Hope bridge and downslope bunding of the property to retain some of the landslide debris should be considered. Alternatively, the purchase of the affected property could be considered.

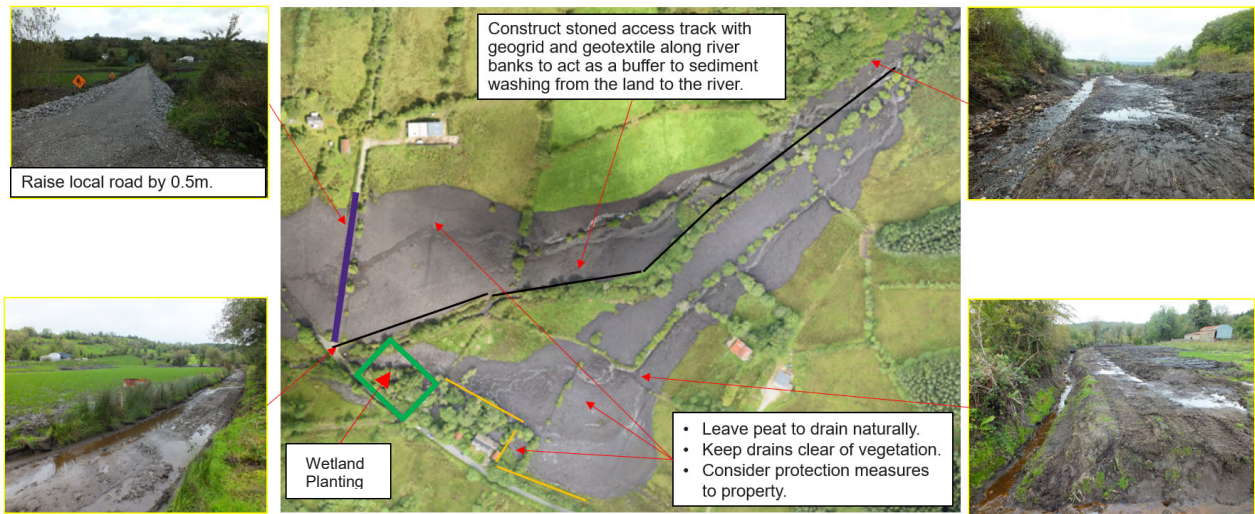


Figure 8-5 Proposed Works at Corcormick East of the Local Road

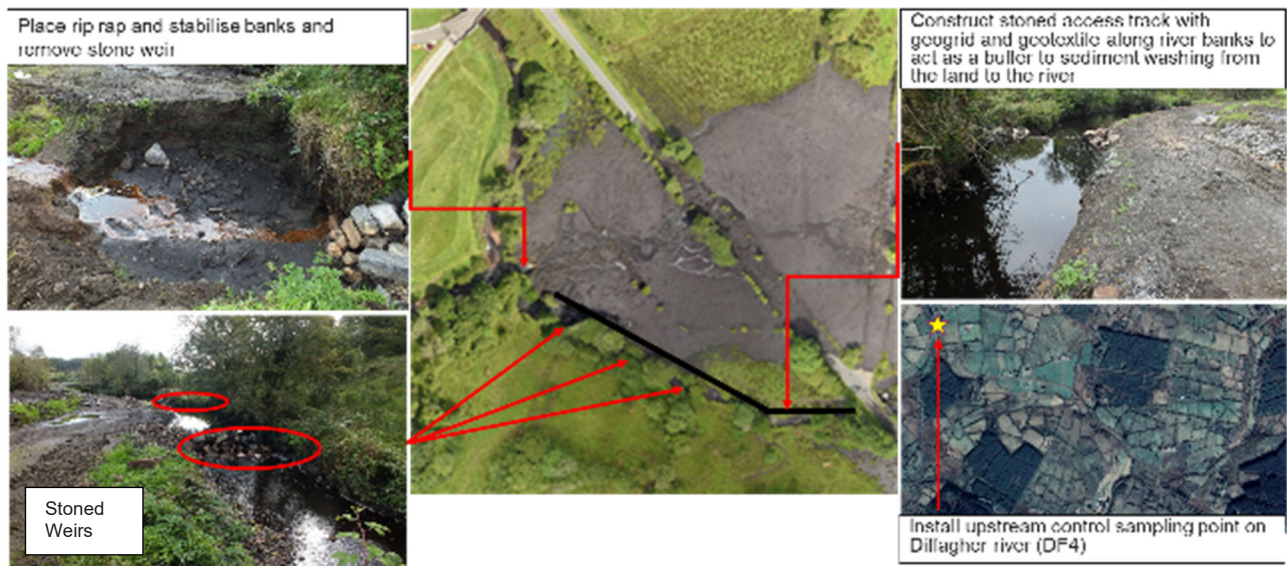


Figure 8-6 Proposed Works at Corcormick West of the Local Road



Figure 8-7 Proposed works at Radharc na tSeipeal Road

8.2.4 Geotechnical Investigations

As noted in **Section 7**, there is a high risk of further slippages in the blanket bog to the north of the Dawn of Hope bridge. It is therefore recommended that further geotechnical investigations be undertaken. The more detailed information that can be gathered about the peat and its properties, the more robust a risk assessment can be carried out.

Work is currently underway by 3rd level institutions, as mentioned in **Section 5.2**, to provide data to understand the mechanisms of the slide. This includes a GPR survey around the perimeter of the slide, piezometers and data loggers to measure pore pressure in the peat and samples for water content and box tests for testing permeability and potentially strength. Limited results to date have been generated from these investigations as the GPR surveys needs to be interpreted; the data loggers installed in the piezometers once settled; and the analysis carried out on the samples taken.

The universities should be consulted on the most appropriate site investigation techniques to determine peat properties and to maintain and utilise the equipment already installed, e.g. the weather station and piezometer network, and add to this where deemed necessary. Future investigations should include:

- A detailed ground investigation (GI) of the area to support the assumptions of the risk assessment and provide information for the development of preventative measures:
 - Shear strength analysis of peat;
 - Details investigated on mineral materials beneath peat including its extent and shape;
 - Pre-failure topography of base of peat (GPR on wider area and slipped area);
 - Drainage elements on top and beneath the peat (potential peat pipes or cracking) and site specific details of drainage within the forestry where possible; and
 - On-going monitoring.

Investigations may also be appropriate in the areas of Corcormick and Derridangan to determine the depth of peat in various areas across the affected lands.

8.3 Procurement Options for Short-term Remedial Measures

The short-term remedial works should be completed within the next 3 to 6 months, where feasible. These works should be considered urgent works due to the requirement to have them completed as soon as

possible to reduce the risk of further environmental impacts, particularly from sediment reaching watercourses as the weather changes for winter.

Where multiple public authorities or government departments are responsible for ensuring the delivery of the proposed short-term remedial measures, it is recommended that they collaborate to ensure coordination of the works into a single project. It is preferable that a single appointment be undertaken for consultants to undertake the detailed design and act as the project supervisor design process (PSDP) in accordance with the Safety, Health and Welfare at Work (Construction) Regulations, 2013. A single client for the purposes of the project will also have to be nominated in accordance with the Safety, Health and Welfare at Work (Construction) Regulations, 2013.

The case for procuring the construction of the short-term remedial measures through an argument of “extreme urgency”, in line with the EU procurement directive, is unlikely to be applicable at this time. However, an argument can be made that the short-term remedial measures are considered “urgent”. Therefore, the contracting authority may reduce the time limit for receipt of a tender using the open procedure to not less than 15 days from the date of the contract notice.

The most cost effective and efficient procurement option is to engage one contractor capable of undertaking all of the works or for Leitrim County Council to complete the works. The contractor shall also be responsible for taking on all duties of the project supervisor construction stage (PSCS) in accordance with the Safety, Health and Welfare at Work (Construction) Regulations, 2013.

8.4 Medium to Long Term Measures

8.4.1 North of the Dawn of Hope Bridge

In the Stage 2 report, it is intended to examine the possibility of diverting some stream flow to the north or south of the material backed up behind the bridge (area marked in purple dashed box in **Figure 8-8**) to allow the material to dewater. This would provide additional capacity behind the bridge for any further landslide material and also reduce the volume of material to be removed at a later stage.

The top layers of the material behind the bridge could also be excavated and reshaped along the riparian zone to promote drying. This process would need to be carried out while protecting the watercourse from sedimentation. This may also allow part of the eye of the bridge to be reopened and the river to return to its natural course.

It is recommended that detailed investigation, planning and implementation measures are developed and considered to reduce the high risk to land, property and infrastructure from further landslide to acceptable levels. This may include measures which will reduce the consequences of failure such as construction of a series of rock weirs and downslope bunding to catch and contain some of the landslide debris (area marked in blue dashed box in **Figure 8-8**). It should be noted since the event the peat behind the Dawn of Hope bridge has consolidated providing some capacity for further material to be contained.

Measures for water management and drainage around the headscarp above the Dawn of Hope bridge should be considered to reduce risk of further peat slide. Any such measures would need to be cognisant of the instability of the peat in this area and the risks associated with construction activities.

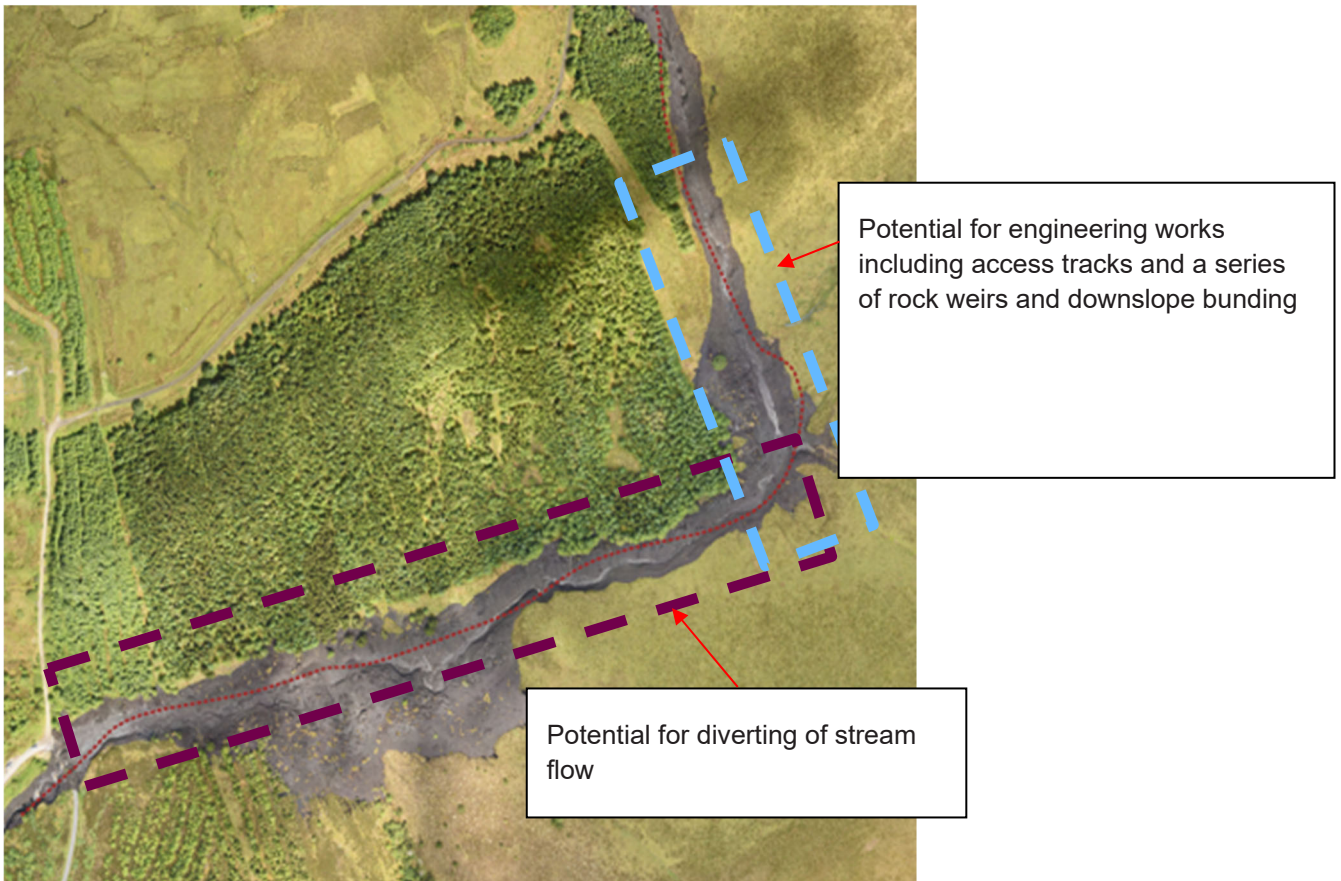


Figure 8-8 Potential dewatering and rock weirs at Dawn of Hope Bridge

8.4.2 Areas of Inundation in Corcormick and Derrindangan

The inundated areas should be re-assessed in mid-2021, to review the progress of dewatering and the status of the land. Once the status of the peat has been better understood, future works can be considered including the rehabilitation of the land and/ or the creation of nature refuges. The use of the land as a peat habitat should be considered but previous works on rehabilitation of placed peat has had limited success.

It is not recommended that the constructed weirs (marked on **Figure 8-6**) be removed from the Dawn of Hope Stream until after this current spawning season. It is the IFI's view that their presence may help divert fish migrating up into the clean gravels of the upper Tullintowell Stream rather than allowing them to attempt spawning in the Dawn of Hope Stream this coming winter season. The weirs could be removed next spring at earliest, in consultation with IFI.

8.4.3 Water Quality Measures

Biological sampling (Q-values) should be repeated in spring and autumn of 2021 at sites sampled in this study.

9 PRELIMINARY COST ESTIMATES FOR REMEDIAL MEASURES

9.1 Remedial Measures

The remedial measures described in **Section 8.2** through **Section 8.4** have been costed using a range of current rates from construction projects. The costs have been summarised into the different locations and types of works required as shown in **Table 9.1**. These figures should be treated as high level estimates and are subject to refinement at later stages of design development. Low, medium and high level estimates have been provided to account for the range of unit rates and construction values, including preliminaries, overheads and other costs that would be associated with the proposed remedial works.

Table 9.1 Preliminary Cost Estimates of Remedial Works

Item	Low	Medium	High
Geotechnical Investigation Costs			
Further geotechnical investigations above Dawn of Hope Bridge	€70,000	€100,000	€130,000
Construction Cost Estimates			
Dawn of Hope: Construction of haul road and dam/ barrage			
Construction of new access roads and dams north of the Bridge of Hope	€356,000	€436,000	€526,000
Surface water drain to dewater the peat and headwall repairs	€14,000	€18,000	€22,000
Finishing works to new Dawn of Hope Bridge	€50,000	€75,000	€100,000
Corcormick: Farm access road, drainage, rip/rap and planting			
Farm access track north of local roads (500m in length)	€31,000	€37,000	€44,000
Farm access track south of local roads (150m in length)	€10,000	€11,000	€13,000
Drainage, boundary fencing and bank stabilisation	€34,000	€38,000	€43,000
Landscaping and bund to protect house	€57,000	€110,000	€163,000
Corcormick: Road repair			
Road construction	€17,000	€19,000	€22,000
Derrindangan: Farm access road, drainage and planting			
Drainage and boundary fencing	€66,000	€74,000	€84,000
Landscaping	€150,000	€300,000	€450,000
Radharc na tSeipeal Road repair			
Local road repairs and reinstatement	€60,000	€70,000	€80,000
Corry Strand: Beach clean-up			
Excavate peat from strand and replace sand	€14,000	€16,000	€19,000
Preliminaries and Contingency	€276,000	€445,000	€663,000
Other costs including consultancy services, procurement, contract administration.	€200,000	€282,000	€395,000
Total Cost Estimate	€1,405,000	€2,031,000	€2,754,000

It should be noted that the above costs do not include for the following: planning permissions and other authorisations, landowner liaison / negotiations, stakeholder interactions, identification of remedial works packages for landowners and others, etc.

9.2 Purchase of Land / Compensation

In order to benchmark the cost of the clean-up of the peat landslide, it is beneficial to compare the costs of future remedial works against the value of the lands affected. The main areas impacted by the peat landslide fall broadly within two categories, namely, agricultural land and forestry.

The main area of agricultural land affected is in the townlands of Corcormick and Derrindangan with forestry areas impacted both upstream and downstream of the Dawn of Hope bridge. As presented in **Section 6.7**, DAFM has estimated that a total of 24.1 hectares of agricultural land and 12.7 hectares of forestry was impacted by the peat landslide.

The cost of agricultural land and forestry can vary considerably across Leitrim. In order to estimate costs a range of values have been used providing low, medium and high level estimates. **Table 9.2** presents these high level estimates were these lands available to purchase on the open market.

Table 9.2 Estimated Land Purchase Costs

Item	Description	Low*	Medium*	High*
Agricultural Land	24.1 hectares	€268,000	€327,000	€388,000
Forestry	12.7 hectares	€48,000	€95,000	€142,000
Total for Land Purchase Only		€316,000	€422,000	€530,000

***Note: These figures do not include for negotiating costs, conveyancing, solicitors' fees, etc**

9.3 Excavation of Peat and Disposal at Suitable Receptor Site

Although discounted as an option at this stage, a cost estimate on the removal of all of the peat landslide material in the townlands of Corcormick and Derrindangan can be made. The estimated cost for removing 160,000m³ of the peat landslide material would be in the order of €3 million to €4 million. This cost estimate does not include costs associated with permitting for receptor sites, planning permissions, landowner liaison, stakeholder engagement, consultancy fees, etc. This cost is not included in **Table 9.1**.

10 CONCLUSIONS AND RECOMMENDATIONS

This factual report has detailed the landslide event at Shass mountain in the context of other landslide events in Ireland and the UK. It has presented an assessment of the information available on the catchment characteristics, the weather conditions prior to the event, the environment context in the area, and a risk assessment of the area above the Dawn of Hope bridge.

10.1 Conclusions

10.1.1 The Event

The landslide occurred within an area blanket bog on Shass Mountain, north-east of Drumkeeran, Co. Leitrim on the 28th June 2020, approximately 1.2km to 1.4km upstream of the Dawn of Hope bridge. The evacuated peat travelled within the existing watercourses where it resulted in flooding of flat lands in the townlands of Corcormick and Derrindangan. The majority of the peat slurry remains on these flood plains. The Diffagher River carried some peat sediment and other debris to Lough Allen, approximately 8km from the starting point, where it has washed up on the shoreline, e.g. at Corry Strand.

10.1.2 Weather Data

The weather data presented in **Section 4** clearly demonstrates that an extreme rainfall event took place in the days preceding the peat landslide. It is likely that this rainfall contributed significantly to the conditions necessary to instigate the bog flow/ bog slide event.

10.1.3 Impact on the Aquatic Environment

A field survey of the affected watercourses was undertaken on 14th September 2020. The field survey showed promising mayfly and dipteran macroinvertebrate fauna re-colonising of the stream/river substrates that had been badly affected by the landslide. This was the case even for the highly impacted area near Corcormick. These invertebrate communities will help support recolonising fish and are the foundation of the instream food chain (fish, otters, birds).

10.1.4 Land Inundated

The area of lands affected by the event and inundated by peat is estimated to be 55.3 ha. This estimate differs from the DAFM figure of 36.8 ha because it accounts for the river channel and its banks and all areas of land inundated i.e. not just agricultural and forestry land parcels.

It is estimated that a total of 30,000m³ of peat material is being held upstream of the Dawn of Hope bridge. It is not recommended to attempt to remove peat from behind the Dawn of Hope bridge structure at this stage as it will only elevate suspended solids, BOD and nutrients in downstream channels during the sensitive salmonid spawning period / restricted season. This will be reviewed next spring/summer, once further dewatering and settlement of the peat has occurred.

Options for the treatment of the estimated 160,000m³ of peat material on the lands at Corcormick and Derrindangan were considered. Given the economic, environmental and logistical constraints surrounding moving the peat it is recommended to leave the peat insitu to dewater until next spring / summer with options for landscaping and planting to be assessed in Stage 2.

10.1.5 Risk Assessment

A preliminary risk assessment has been undertaken on the remaining bog within the 'immediate slope' affected by the landslide. Based on the results of the preliminary qualitative risk assessment, there is a high risk to land, property and infrastructure from further landslide from Area A and Area B.

The risk to life to road users, those using the Dawn of Hope bridge, and those living within the potential debris zone downstream of the landslide (within areas previously affected by the 28th June landslide) was assessed to be within the 'Tolerable' range (10⁻⁴ - 10⁻⁶ / year).

10.1.6 Remedial Works

Remedial works have been identified and classed as short term, and medium to long term works.

Short term works include:

- Placing of rock armour at the new culverts downstream of the Dawn of Hope bridge;
- Measures to protect water quality including review of information, ongoing monitoring and removal of peat from Corry Strand; and
- Remedial works at Corcormick and Derrindangan including planting and opening of drainage channels, fencing of boundaries, raising of the local roads, creation of stoned access tracks, rock armour on confluence of rivers and bunding to one property.

Medium to long term works include:

- Review of peat trapped north of the Dawn of Hope bridge and potential stream diversion and dewatering operation;
- Construction of bunding or stone weirs to prevent further peat coming downhill;
- Reviewing settled peat and continuing monitoring; and
- Remove weirs to the east of Corcormick.

10.2 Recommendations

It is recommended that the following be undertaken and prioritised for action as part of the Shass Mountain Landslide Project:

- Carry out a detailed design for the short-term remedial measures. This must include the appointment of project supervisor design process (PSDP) and notification to the HSA.
- Engage with landowners and other stakeholders to seek agreement on the short term remedial measures.
- Following completion of the detailed design, procure a works contractor or complete the works by direct labour (Leitrim County Council).
- Commence the Stage 2 report to assess in detail feasible medium to long term remedial measures, including measures at and upslope from the Dawn of Hope bridge. The Stage 2 report should include, but not be limited to, the following:
 - Design and procure a geotechnical investigation to determine the geotechnical properties at the locations affected by the peat landslide.
 - Review the impact (depth, area and ownership) and management options of the inundated lands in the Corcormick and Derrindangan areas north of Lough Allen where peat material currently sits following the slide. This review should also investigate options to deal with the peat and estimate timescales and potential results based schemes that could be employed to benefit the landowners and the environment.
 - Investigate further measures for planting of areas with deposited peat such as those in Corcormick and Derrindangan. Such planting could alleviate the high levels of BOD and nutrient leaching into the stream.
 - Carry out a Land Registry search of ownership of and mapping of all lands impacted including lands on the mountain in the slip area and lands in the valley where peat is now deposited.
 - Landowner and stakeholder engagement to scope and agree medium to long-term remedial measures.
 - Carry out a carbon assessment of the peat material now displaced by the event. This assessment should focus on the lands at Corcormick and Derrindangan where the deposited peat will continue to degrade and emit high quantities of carbon into the atmosphere. This quantity of carbon released should be calculated and potentially offset elsewhere where possible.

- Investigate works to provide and stabilise the upland slopes to prevent re-occurrence. The risk assessment in **Section 7** and the medium to long term measures in **Section 8.4** proposed options including placing rock armour to contain blanket bog on the mountain. Future engineering works will require design and supervised construction.
- Investigate options to treat the large volume of material retained by the Dawn of Hope bridge. Determine if the material should remain permanently in-situ and be allowed to dry out.
- The Stage 2 report should investigate the land uses (animal grazing etc), land-use changes (forestry etc) and drainage patterns at the headscarp to determine potential impact of changes in the landscape over time and consequences of these changes on the landslide.
- Review the impacts of the landslide on the conservation objectives, habitats and services provided by the Special Area of Conservation (SAC) and surrounding environment.
- Review records of rehabilitation works carried out to the Owengar catchment following 2008 landslide as some of these measures may be equally applicable to the Diffagher catchment.
- Develop the detail of the medium to long term measures in the next 3 – 6 months following on from the emergency response.

Appendix A Water Quality and Aquatic Survey Results

A.1 Water Quality: Diffagher River Water Chemistry Results

The following graphs illustrate water quality data provided by Leitrim County Council for key parameters for the main impacted sites moving down the catchment from the Dawn of Hope Stream at Corcormick → Diffagher River at Greyfield's Bridge → Diffagher River at Cloonmeone Bridge → Diffagher River d/s Owengar River confluence

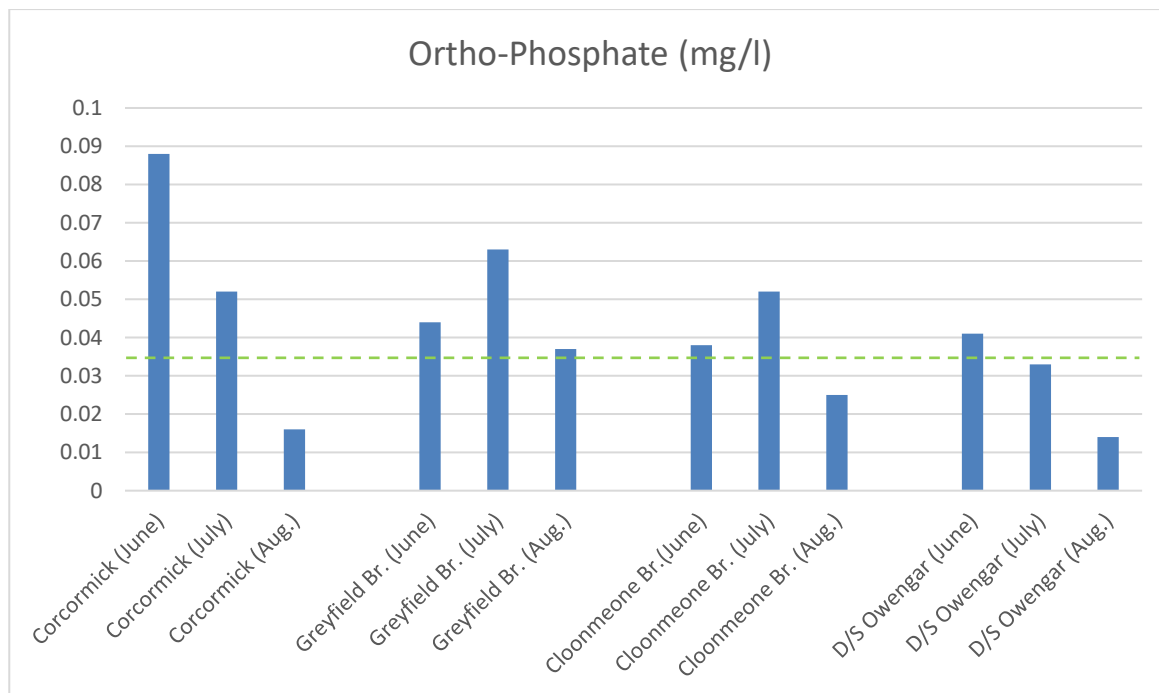
Green dashed lines mark the threshold for 'good' status under Surface Water Regulations. Waters must achieve a minimum of 'good' status under the Water Framework Directive.

Ammonia, BOD, and Suspended Solids (SS) each show a pattern of significant reduction at every site down the river system between June and August, while Dissolved Oxygen (DO) steadily increases at every site. This indicates significant improvement in water quality to within good status criteria for surface waters by late August. Suspended solids reduced from immediate post-event highs of 930-6780 mg/l down to lows of 5-47 mg/l in July and August, one and two months

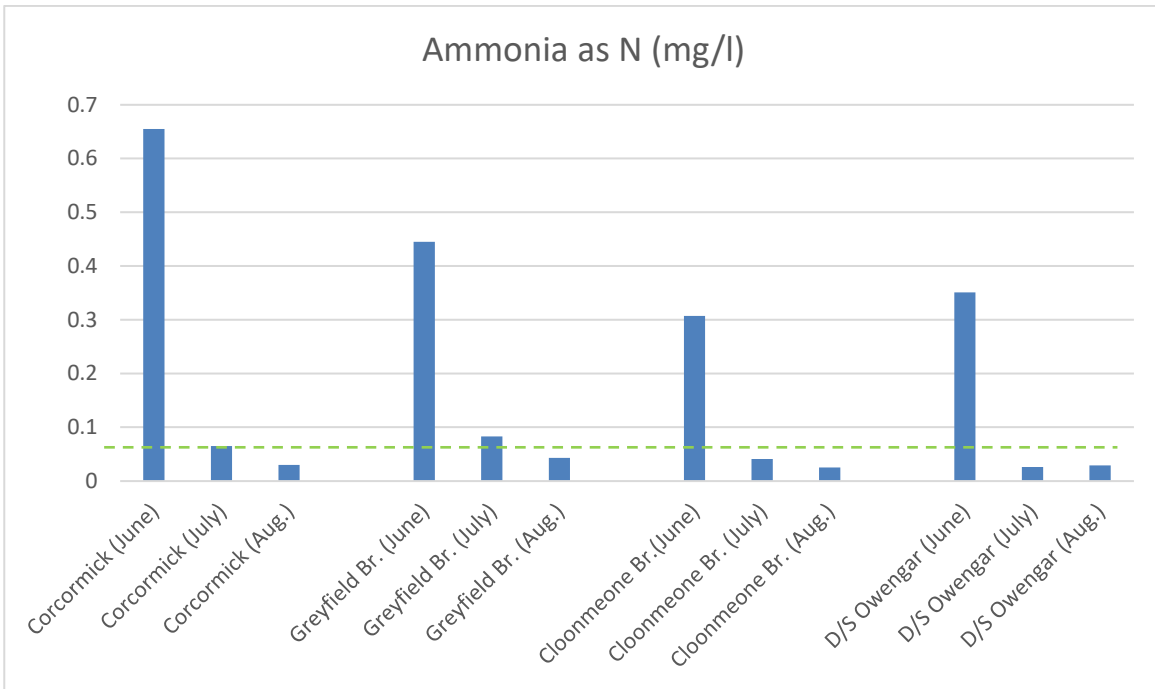
Ortho-phosphate (Ortho-P) shows a similar improvement over time, although sites in the mid-catchment (Greyfield's and Cloonmeone) recorded spikes in July (one month after the event) then reducing to Ortho-P levels within 'good' status at every site by late August (two month after the event).

Note that control sites were sampled (upstream of confluences with the impacted channel), each of these showing no significant impact from the event and no notable changes in quality indicators over the three sampling rounds.

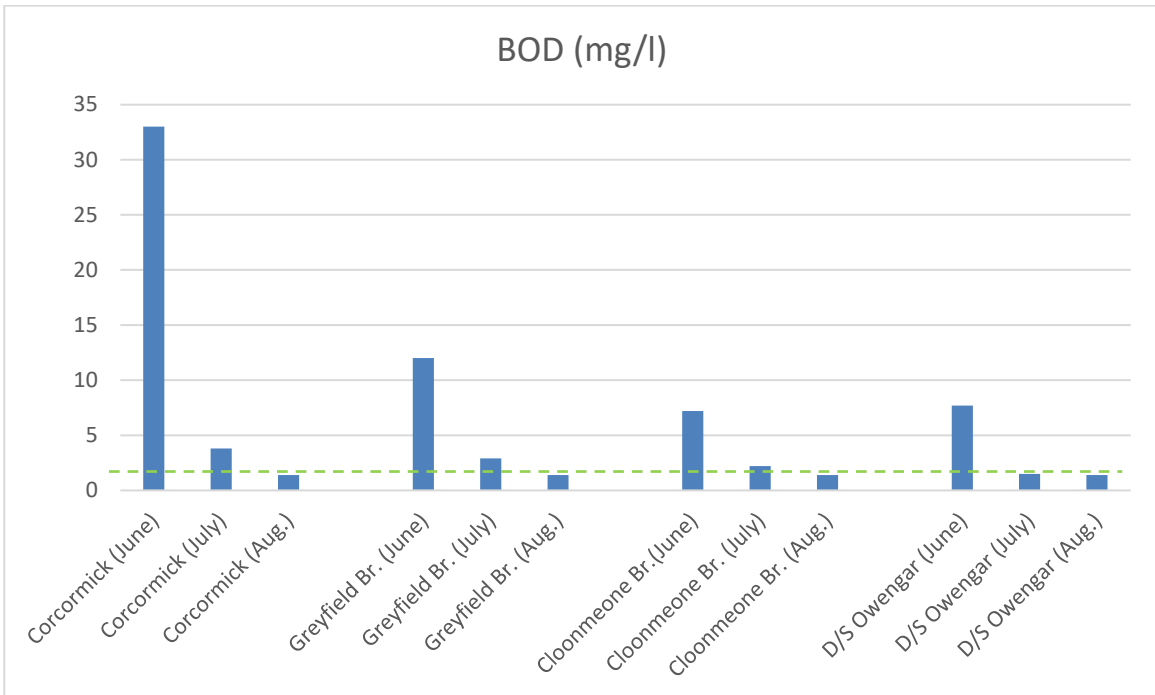
Ortho-Phosphate



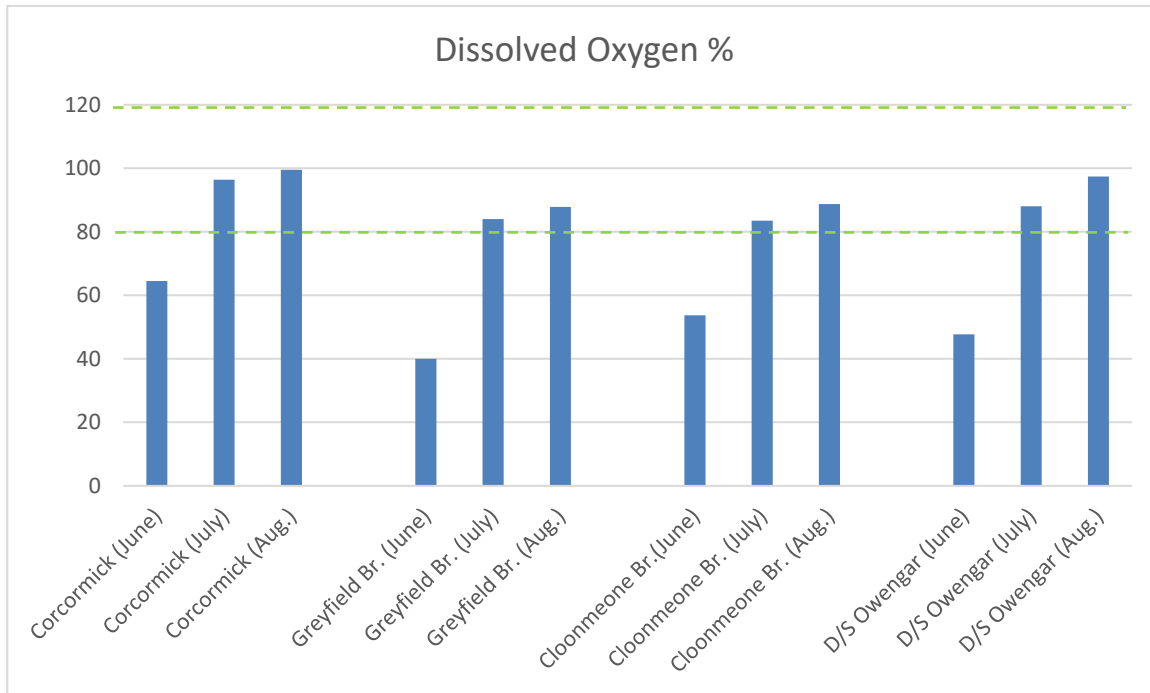
Ammonia as N



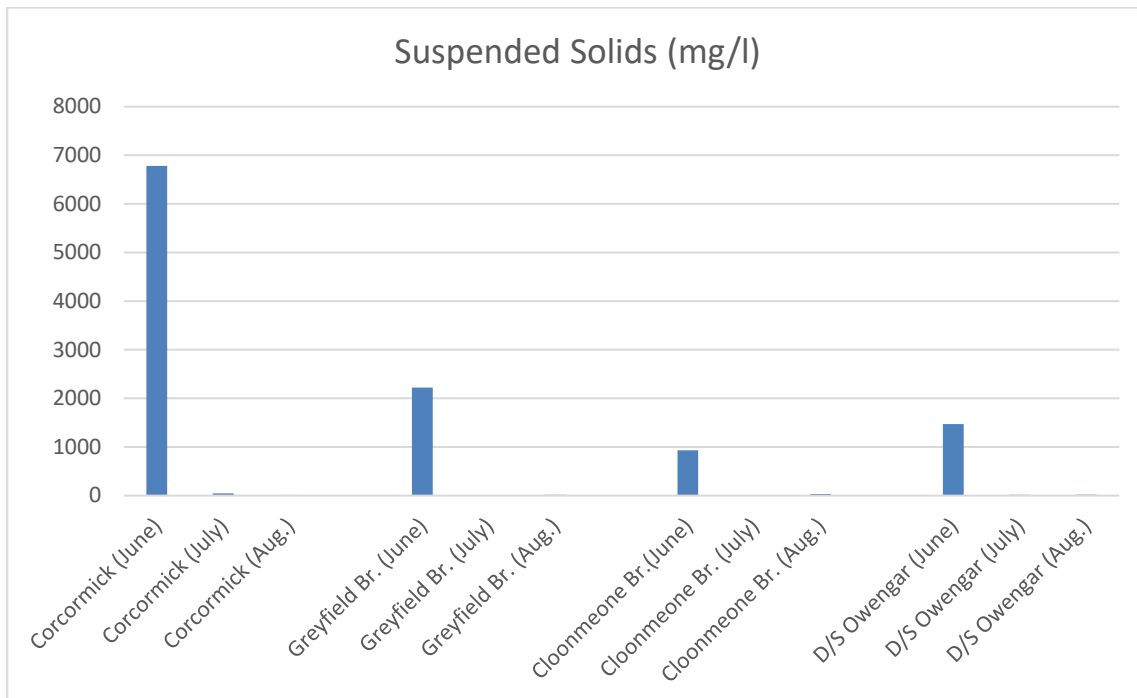
BOD



Dissolved Oxygen



Suspended Solids



A.2 Lough Allen Water Quality Data

The EPA currently reports lake status in Lough Allen as Moderate based on 2013-2018 data. Lake status includes other biological quality elements, e.g., macrophytes. The lake passed (is within good status) for chemical parameters (TP, Ammonia, DO, chlorophyll) but is apparently downgraded to moderate based on Macrophytes (plants) which is one of the biological element used to calculate lake status (for which data was not readily available).

The following graphs illustrate trends in Lough Allen annual mean and max. values for key lake water quality parameters from 2007-2020.

Green dashed lines in Figures C.1 to C.3 marks good-moderate status boundary (annual means) for lake quality, per parameter.

Note that for Figures C.1 and C.3 there are two inputs for 2008: the first for before the Owengar catchment landslide event, the second after that event. The 2008 before and after data was combined for chlorophyll as the incident occurred in late September, after the algal growing season. Any change to trends in chlorophyll would only be expected to show up in spring of 2009.

Total Phosphorous

Total-P: annual mean values 2008-2020 are all <0.025mg/l, meeting good status. A declining trend in TP (quality improvement) occurred between 2008 and 2011, but there has been an upwards trend (quality deterioration) since. A brief spike in TP max. occurred in late 2008 and in 2010, which perhaps corresponds (weakly) with a spike in chlorophyll max in 2011. It is difficult to determine if these spikes were related to inputs from the 2008 Owengar event. It's noted that similar spikes in TP max. and chlorophyll max. have also occurred in more recent years and cannot be directly linked to the 2008 Owengar event. The overall trend in mean TP was downward following the 2008 event, then steadily upwards since 2011.

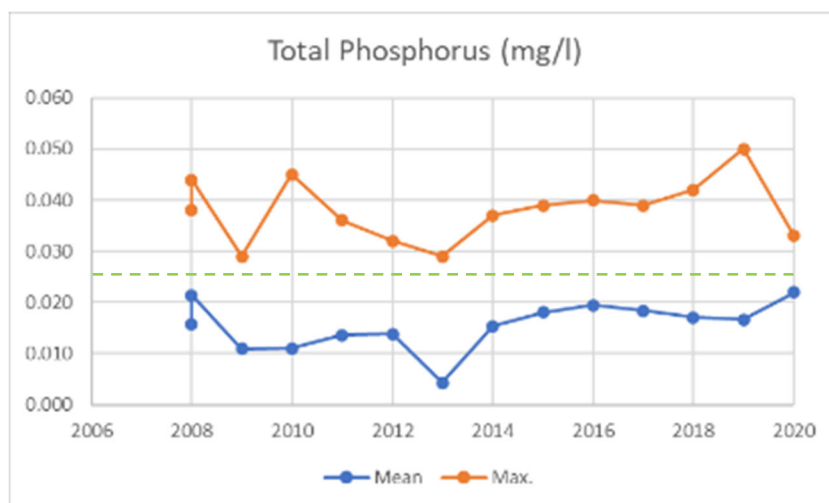


Figure C.10-1 Lough Allen: Total Phosphorous, P(mg/l), 2008-2020

Chlorophyll

Chlorophyll: annual mean values tend to show a slow but steady increase (quality deterioration) between 2008 and 2020, but remain within good status. Chlorophyll provides a useful indication of total nutrient level in the lake, with annual maximum values providing a clue into overall ecological quality. A notable spike in chl. max. occurred in 2011, in the 3rd year following the Owengar peat slide, but whether or not this was the sole cause of the spike can't be disentangled from this data. 2016 saw another spike in chlorophyll annual max. value, again the reason for that cannot be determined from the data.

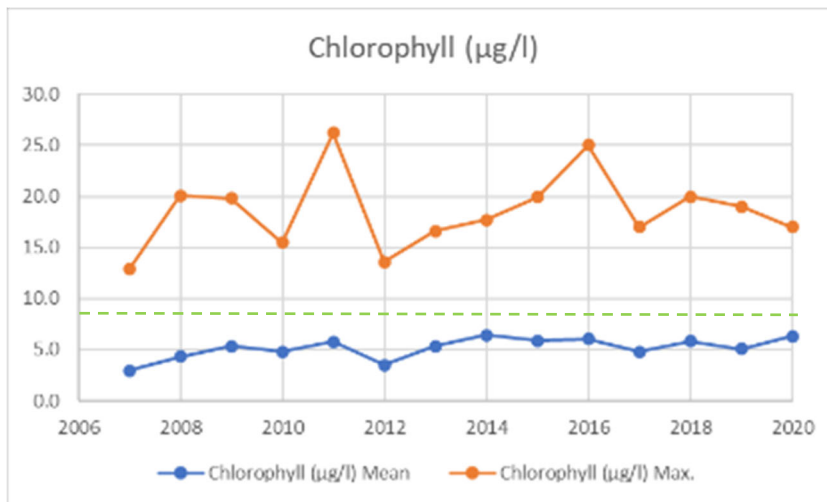


Figure C.10-2 Lough Allen: Chlorophyll a(ug/l), 2007-2020

Ammonia

Ammonia trend: annual mean values show a steady, low trend, well within good status criteria. Even the annual maximum values are within good status.

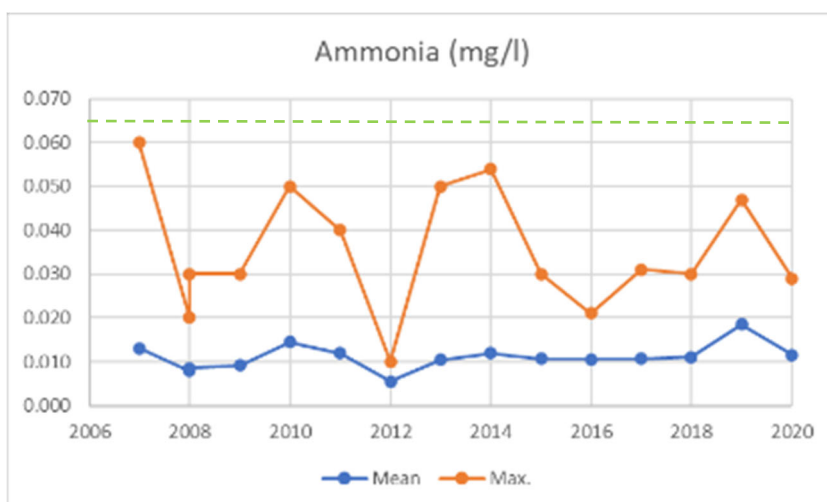


Figure C.10-3 Lough Allen: Ammonia as N (mg/l), 2007-2020

True Colour

There was a notable spike in colour following the 2008 Owengar event, remaining elevated in mean and maximum values for two years after the event (until 2010). Water colour is a good proxy for dissolved humic substances (organic carbon) present in peat runoff. Figure C.4 shows a slow decline from 2010 to 2014 in mean annual colour to a more consistent, perhaps slightly increasing level, for remaining years from 2015 through to 2020.

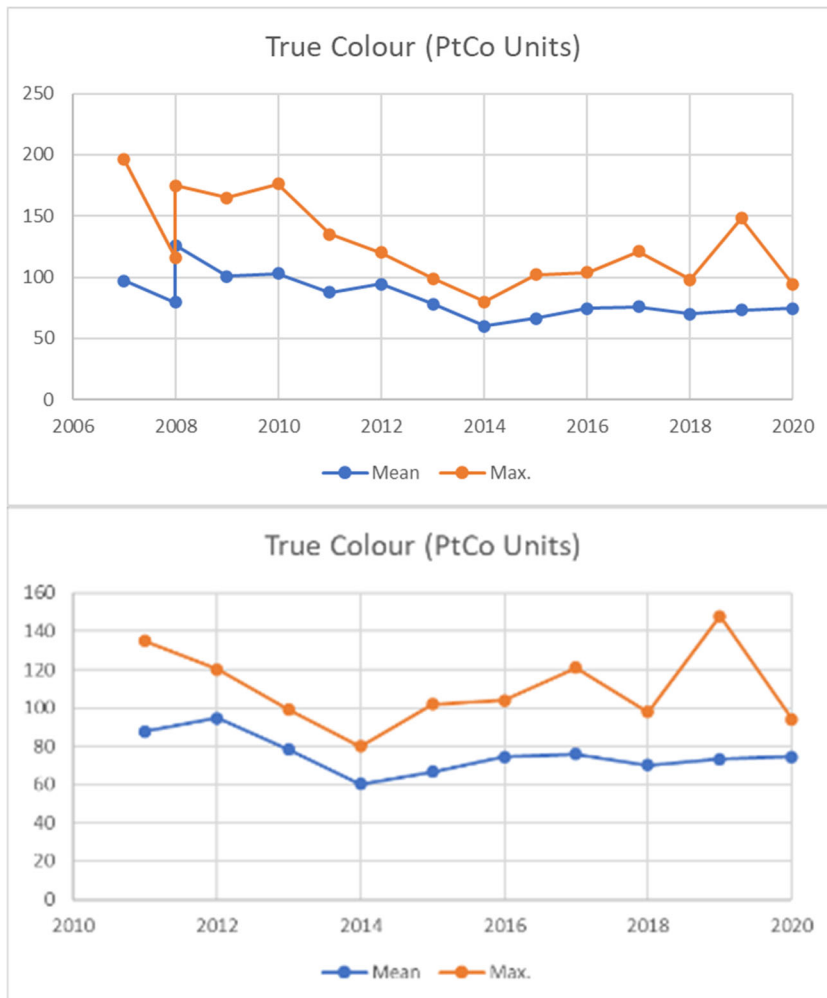


Figure C.10-4 Lough Allen: Tru Colour (PTCo units), 2011-2020

A.3 Aquatic Survey Results: Macroinvertebrate Fauna

RPS Site Code	DF4	TT3	DH2	DF1	LA5
(Leitrim CoCo site)	n/a	P026	P025	P024	P028
Waterbody	Diffagher	Tullintowel	Dawn of Hope	Diffagher	Lough Allen
X (ITM)	591133	591984	592130	593200	594604
Y (ITM)	827237	826640	826570	824754	823922
Date	14-Sep-20	14-Sep-20	14-Sep-20	14-Sep-20	14-Sep-20
Water level	Average	Average	Average	Average	Average
Taxa	EPA Qual. Cat.				
MAY FLIES (Ephemeroptera)					
<i>Ephemera danica</i>	A				5
<i>Rhithrogena semicolorata</i>	A	8		2	
<i>Heptagenia spp.</i>	A				1
Baetidae	C	11	100+	15	21
STONE FLIES (Plecoptera)					
<i>Isoperla sp.</i>	A		3		
<i>Brachyptera risi</i>	A		6		
<i>Leuctra spp.</i>	B	4	5		2
CADDIS FLIES (Trichoptera)					
<i>Lepidostoma hirtum</i>	B				1
<i>Athripsodes spp.</i>	B				3
<i>Ceraclea spp.</i>	B				2
Philopotimidae	C	1			
TRUE FLIES (Diptera)					
<i>Dicranota spp.</i>		2			
Chironomidae	C	10	15	21	25
Simuliidae	C	45	40	100+	100+
BEETLES (Coleoptera)					
Elmidae	C		6		
F/W SHRIMPS (Crustacea)					
<i>Asellus aquaticus</i>		2			
<i>Gammarus sp.</i>	C			2	25
WORMS (Annelida)					
Oligochaetae	E	30		3	6
LEECHES (Hirudinea)					
<i>Trocheta spp.</i>		2			
N-taxa	9	8	3	6	9
EPA Q Value	Q3	Q4(3-4)	Q3*	Q3-4*	n/a