APPENDIX 4-5

APEX CABLE ROUTE GEOPHYSICAL INVESTIGATION REPORT

AGP19176_01

Report on the Geophysical Investigation At The Coole Grid Route, Co. Westmeath for Statkraft Ireland Limited

October 2019

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PROJECT NUMBER	AGP19176		
AUTHOR	**CHECKED**	**REPORT STATUS**	**DATE**
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CONTENTS

1. EXECUTIVE SUMMARY

APEX Geophysics Limited was requested by Statkraft Ireland Limited to carry out a geophysical investigation for the proposed Coole Grid cable route, Co. Westmeath to map the presence and thickness of the peat along the proposed grid route.

The geophysical investigation comprising of Ground Penetrating Radar (GPR) profiling was carried out along the regional road extending for c. 15Km from the town of Multyfarnham in the south, through the village of Coole to the Longford/Westmeath border in the North.

The survey was carried out on the 17th and 18th September and the 3rd and 4th October 2019.

Several GPR antenna frequencies were employed to maximize the resolution\depth of the GPR signal.

Soft ground probing was carried out along the route to identify/confirm areas of soft ground\peat. Thirteen Russian Cores were targeted in areas of peat to determine its thickness and to identify underlying materials. The coring information was correlated with the GPR data to assist in the interpretation of the GPR profiles.

The peat thickness recorded in the Russian cores ranges from 0.82m to 5.62m. The material underlying the peat was predominantly soft white SHELL MARL with two occurrences of soft grey CLAY.

Four sections of peat were resolved in the GPR data ranging from 0.285m to 5.34m depth below the road surface with a maximum thickness of 4.34m at chainage 3027m.

The results of the investigation are presented in a series of figures and tables shown in Appendices B and Appendix C.

The findings of the geophysical investigation should be reviewed following any further intrusive investigations.

2. INTRODUCTION

APEX Geophysics Limited was requested by Statkraft Ireland Limited to carry out a geophysical investigation for the proposed Coole Grid cable route, Co. Westmeath to investigate the presence and thickness of the peat along the proposed cable route.

2.1 Survey Objectives

The objectives of the investigation are to:

- Determine the presence of peat under the road,
- Provide information on the thickness of the peat.

2.2 Site Background

The investigation was carried out along the regional road extending for c. 15Km from the town of Multyfarnham in the south, through the village of Coole to the Longford/Westmeath border in the North (Fig. 2.1). The elevation of the regional road ranges from 59 mOD – 99 mOD.

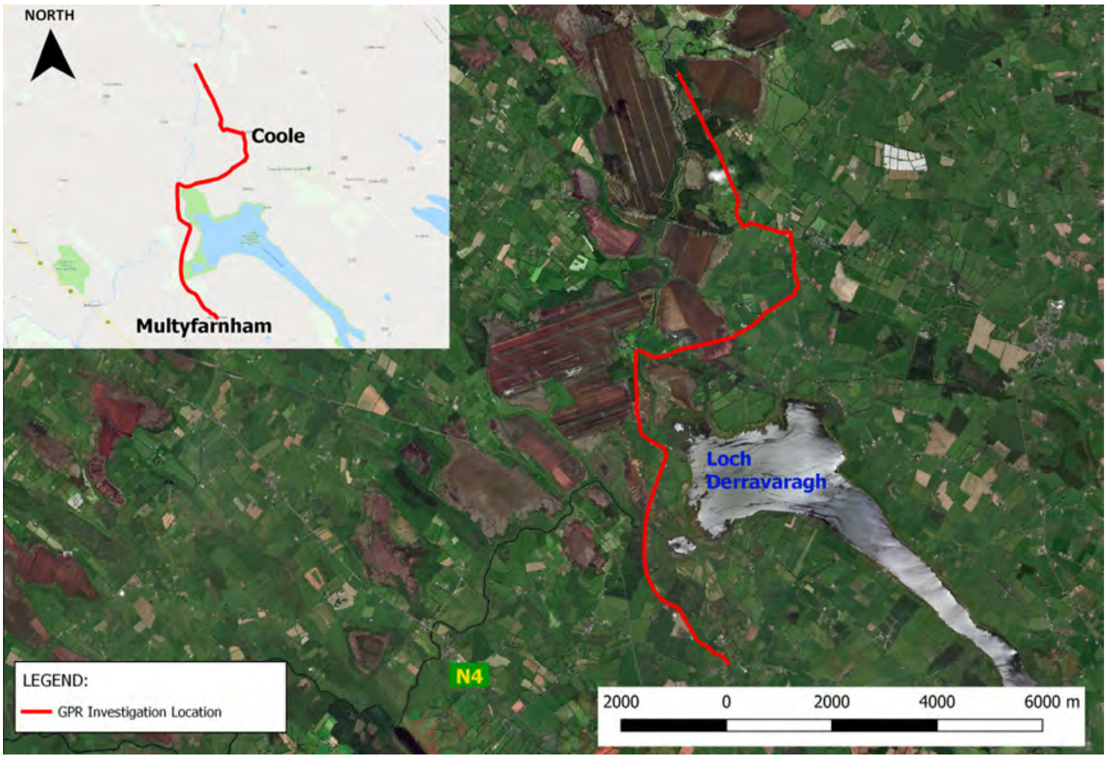

Fig 2.1: Investigation location.

2.2.1 Soils

The Geological Survey of Ireland (GSI) Quaternary sediments map for the area (Fig. 2.2) indicates that the survey route is predominantly underlain by cutover raised peat. Limestone till is mapped in the south, centre and north of the survey route and sandstone and shale till is mapped in the north of the survey route. Limestone gravels are shown in the north and south of the site.

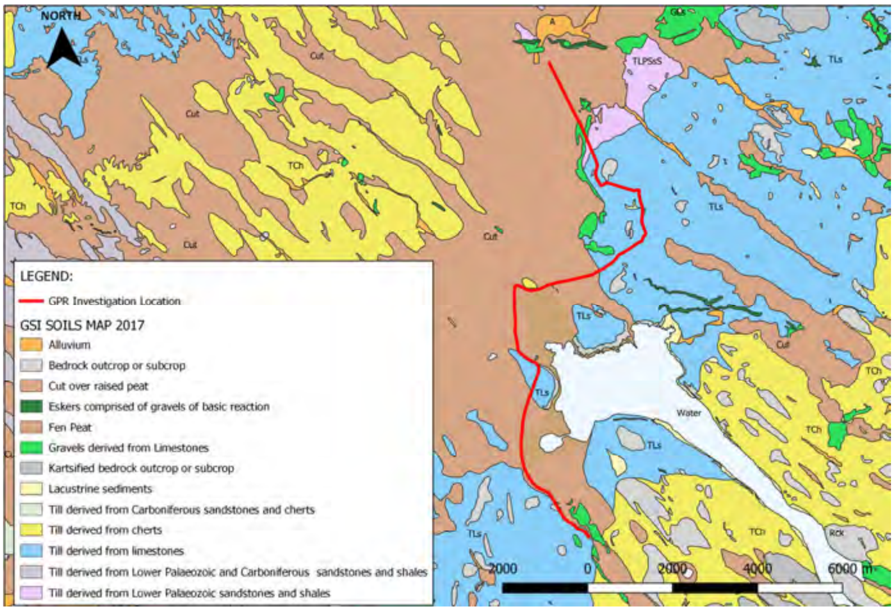

Fig 2.2: GSI Soils Map.

2.2.2 Geology

The GSI 1:100k Bedrock Geology map for the area (Figure 2.3) indicates that the survey route is predominantly underlain by dark limestone & shale (`Calp') of Lucan Formation with Mudbank limestone in the centre of the route. and cherty limestone and minor shale of the Derravaragh Cherts in the south of the survey route. Two SW-NE faults are mapped west and east of the road.

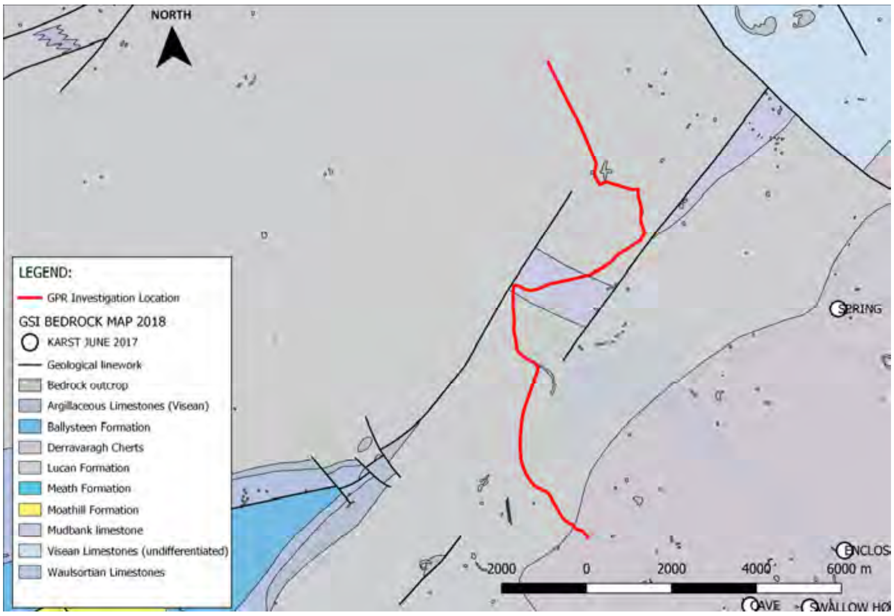

Fig 2.3: GSI Bedrock geology Map.

2.2.3 Vulnerability

The groundwater vulnerability rating for the site (Fig. 2.4) is classified as predominantly low to moderate to high, with some areas of an extreme vulnerability and rock at or near surface in the south, centre and north of the survey area.

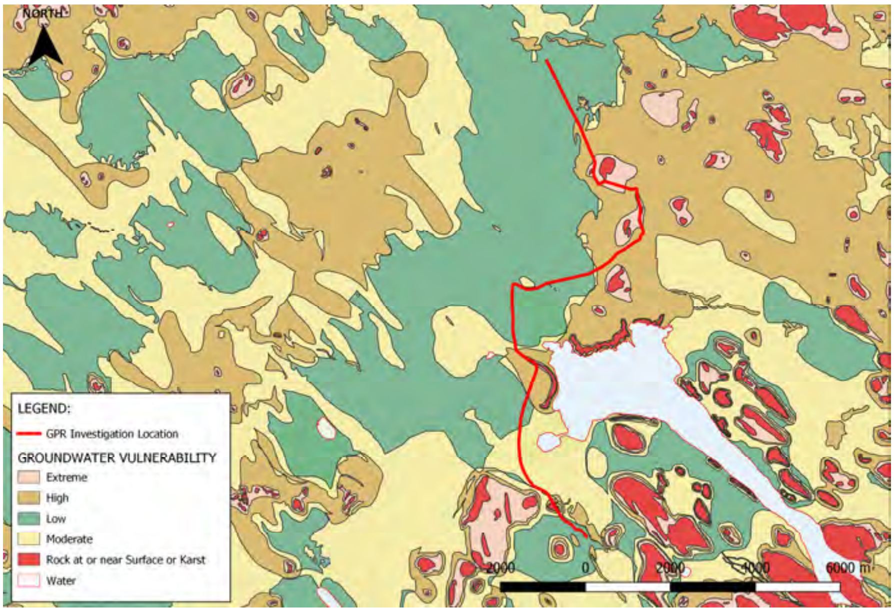

Fig 2.4: Groundwater vulnerability.

2.2.4 Historical Data

The historical 6 inch sheet for the area indicates bog deposits in the north, centre and south of the road, marked in orange (Fig. 2.5). Outcrops of dark Limestone are shown in blue on the map.

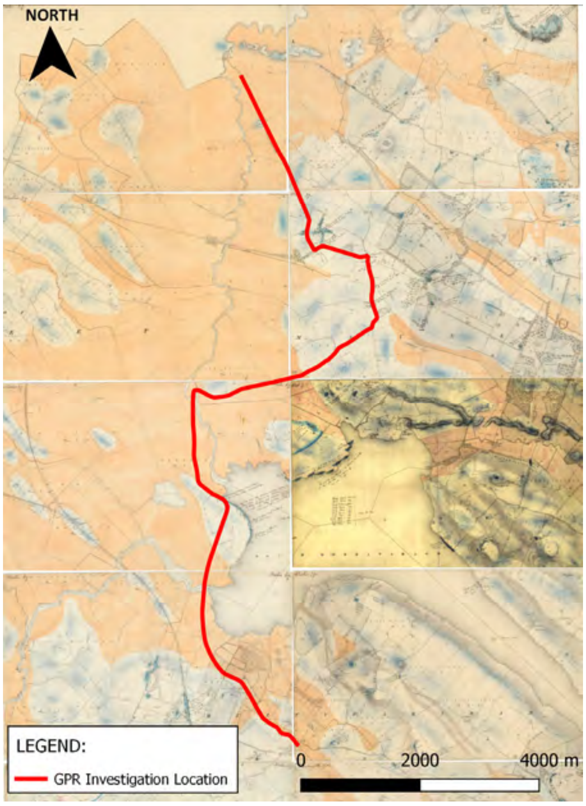

Fig 2.5: The historical 6inch map.

2.2.5 Direct Investigation Data

Thirteen Russian Cores (RS1-RS13) were targeted in areas of peat to determine the thickness of peat, the nature of the material underlying the peat and to correlate the readings to the GPR profiles (e.g. Figure 2.6).

The peat thickness recorded in the Russian cores ranges from 0.82m to 5.62m. Underlying material was predominantly soft white SHELL MARL with two occurrences of soft grey CLAY. The findings from the Russian cores are listed in Table 2.1.

Fig 2.6: Russian core showing soft white shell marl overlain by peat.

	Chainage (m)	Peat Thickness (m)	Underlying Material
RS1	2420	2.66	Soft White Shell Marl
RS2	2682	2.00	Soft White Shell Marl
RS3	3031	4.70	Unknown, Bog Oak at Base of Peat
RS4	3257	2.45	Soft White Shell Marl
RS5	3443	3.60	Soft White Shell Marl
RS6	3739	5.65	Soft White Shell Marl
RS7	3975	0.82	Soft White Shell Marl
RS8	6262	1.10	Soft White Shell Marl
RS9	8268	3.43	Soft Grey Clay
RS10	8889	2.40	Soft White Shell Marl
RS11	9050	1.60	Soft White Shell Marl
RS12	14274	0.90	Soft Grey Clay
RS13	15098	1.10	Soft Grey Clay

Table 2.1: Russian core data.

No other intrusive investigation was available at the time of producing this report. Where additional intrusive data becomes available the findings from the geophysical investigation should be reviewed accordingly.

2.3 Survey Rationale

Ground Penetrating Radar (GPR) works by sending radio waves into the ground and measuring the time of the reflected wave. Reflections occur where different material properties exist.

GPR has been used extensively in the determination of pavement construction. Pavement construction materials are generally well controlled and prove an effective target for the GPR technique providing continuous layer information which can be correlated to more intrusive core data.

GPR has been used extensively in the determination of peat thickness in both raised bog as well as upland blanket bog and has proved to be extremely accurate. The base of the peat is normally underlain by materials with significantly different properties to the peat itself. This in turn produces a strong signal from the base of the peat enabling accurate thickness measurements to be made. Where peat has a high inorganic content (organic soil rather than pure peat) the penetration is reduced and the peat base may not be fully resolved.

Where high conductivity materials such as ash or clinker are recycled into road construction the GPR signal will be attenuated and may not penetrate sufficiently to resolve the base of peat.

As with all geophysical methods the results are based on indirect readings of the subsurface properties. The effectiveness of the proposed approach will be affected by variations in the ground properties. Further information on the detailed methodology employed in this investigation is given in **APPENDIX A**.

3. RESULTS

The investigation was carried out on the 17th and 18th September and the 3rd and 4th October, 2019. Seven GPR profiles were recorded at the chainages outlined in table 3.1. The higher GPR frequencies (providing higher resolution at shallower depths of penetration) were recorded along the entire route to image road construction material and lower GPR frequencies (providing a greater depth of penetration at a lower resolution) were recorded across areas of peat. The geophysical survey locations are plotted on Drawing AGP19176_0, Appendix C.

GPR Center Frequency	Chainage (m)	
	From:	To:
400MHz	0	15662
250MHz	0	15662
100MHz	1624	9031
	13196	15662
40MHz	2074	4067
	5482	6460
	7533	9049

Table3.1: GPR Investigation Locations.

The pavement construction and underlying peat deposits interpreted from the GPR data are presented on Drawing's AGP19176_02 to AGP19176_07, Appendix C. The longitudinal sections are vertically exaggerated x 100 for presentation purposes.

A pavement construction summary is presented in tabular format in Appendix B.

4. DISCUSSION & RECOMMENDATIONS

The GPR data was generally of good quality and the data have been interpreted as follows:

- The 250MHz and 400 MHz GPR frequencies contained sufficient detail to image the road construction materials.
- The reflections from the base of the peat were attenuated across much of the 100MHz data. This is possibly due to the presence of a highly conductive material such as ash or clinker which may form part of the pavement construction. As a result, the reflections from the base of the peat were further investigated with a 40MHz GPR frequency.
- Peat was resolved beneath four sections of the road construction with a maximum thickness of 4.34m at chainage 3027m. These areas were further investigated with Russian cores to correlate the peat depth with the GPR data.
- Where the peat thickness is minimal below the base of the subbase it is likely that there has been mixing between the overlying material and the base of the peat.
- Possible shallow bedrock has been interpreted along six sections of the survey route. The shallow bedrock presents as planar reflections from the bedding planes within the rock.

The findings of the geophysical investigation should be reviewed following any further intrusive investigations.

5. GPR Data Examples

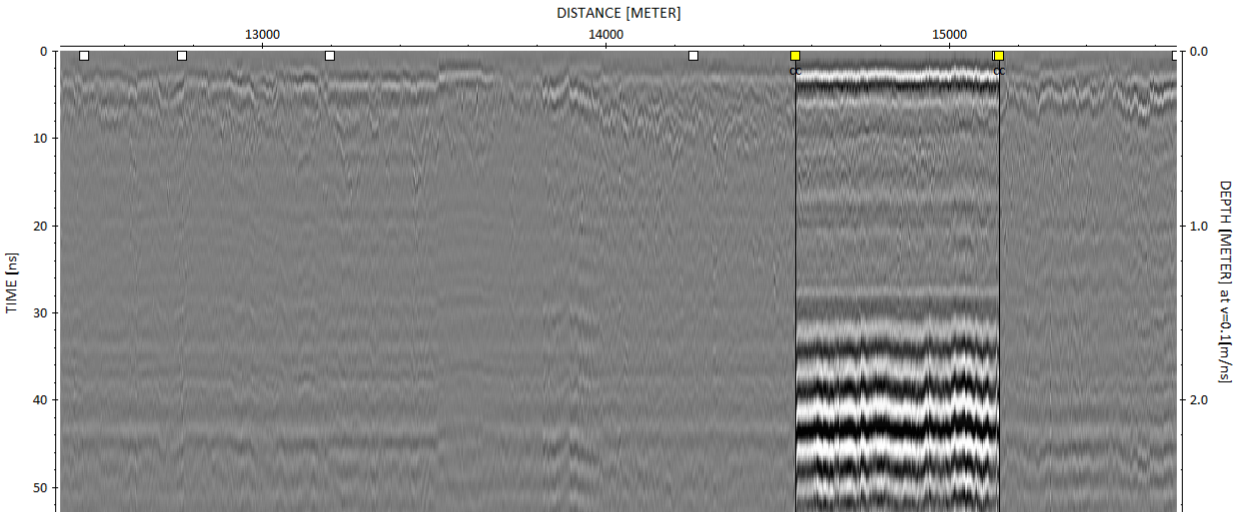

Figure 5.1: 400MHz Frequency – A high amplitude response occurring at a depth of c.0.12mbelow ground level (bgl) between chainage 14550 and 15150 indicates the presence of rebar in the pavement construction.

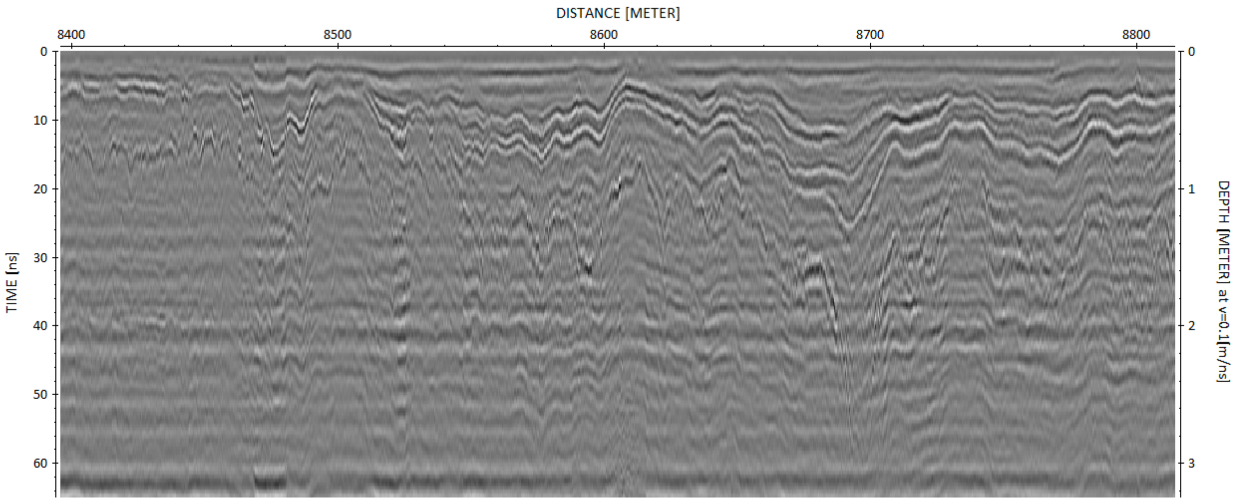

Figure 5.2: 400MHz Frequency – A series of planar reflections occurring between 0.5m to 1.5m bgl delineate layering within the pavement construction.

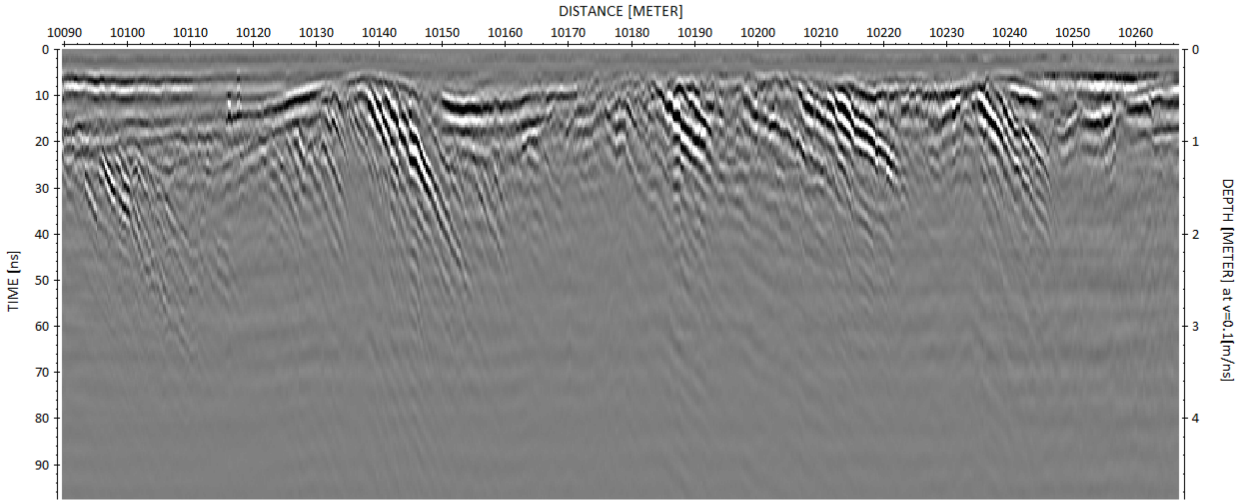

Figure 5.3: 250MHz Frequency – A series of oblique planar reflections occurring between 0.5m to 3m bgl are interpreted as been due to bedding in the underlying bedrock.

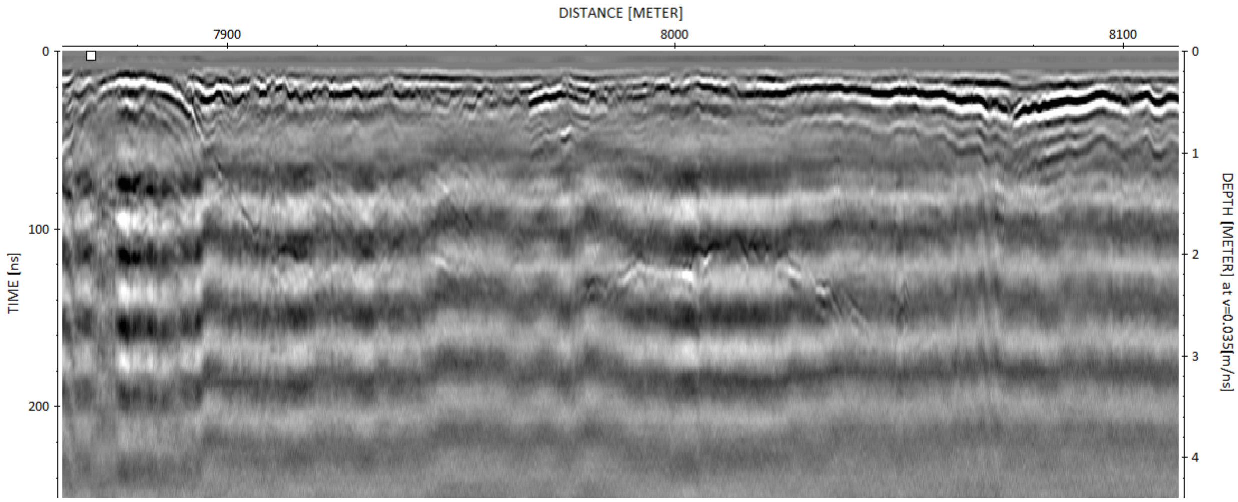

Figure 5.4: 100MHz Frequency – A planar reflection occurring between 30-150ns defines the base of peat. The signal is attenuated from chainage 8040m to 8100m beneath a section of thicker road construction. The attenuation may be due to conductive ash\clinker recycled into the roadbase.

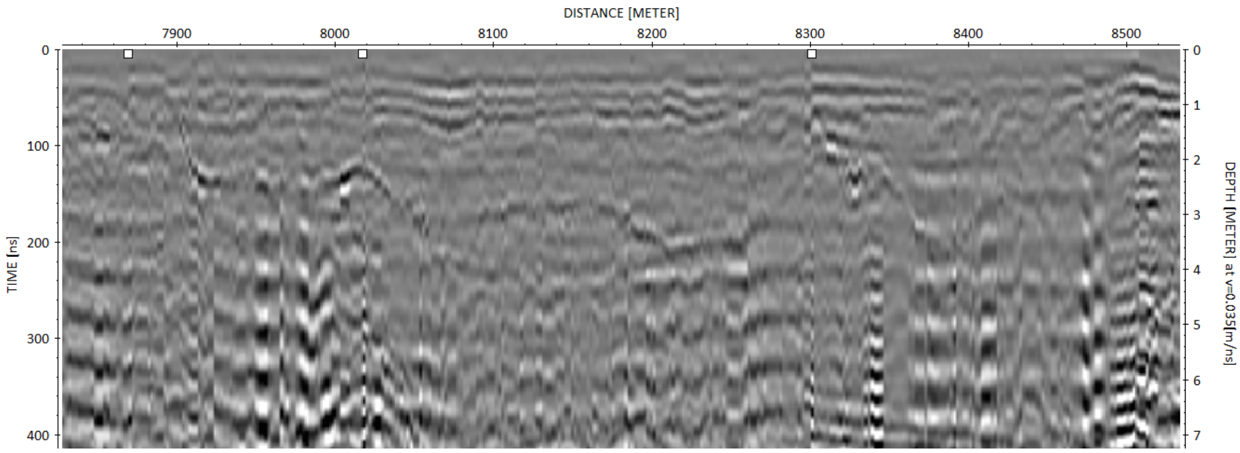

Figure 5.1: 40MHz Frequency – A planar reflection occurring between 30-200ns defines the base of peat.

APPENDIX A: DETAILED METHODOLOGY

An investigation using Ground Penetrating Radar (GPR) was commissioned to investigate the site.

Ground Penetrating Radar (GPR)

Ground penetrating radar is effective at determining the presence of layer detail within pavement construction by assessing the amplitude and phase of reflected signals from internal boundaries. The amount of reflected energy varies when there is a discontinuity caused by separation or the presence of a different material type. Changes in material type and/or the presence of discontinuities significantly alters the reflected energy.

GPR Pavement investigation is effective at resolving material boundaries (manmade or geological) but is limited in the determination of the exact nature of the boundaries. When combined with a targeted coring program any ambiguities on layer type can be resolved and an accurate longitudinal cross section can be generated.

Principles

Ground Penetrating Radar (GPR) is a reflective electro-magnetic technique that involves the transmission of high frequency radio waves (typically 100 to 1000MHz) into the ground and recording the subsequent reflections.

These pulses are transmitted with a high repetition rate as the antenna is moved along the ground and the reflected pulses build up a cross section (time series) of the sub-surface. Partial reflections of the electromagnetic pulse occur at the boundaries of materials with different dielectric properties.

By understanding the material types under investigation, specifically the electromagnetic pulse velocity, it is possible to convert the reflected time series to an accurate depth section, using:

Depth [m] = Velocity [m/ns] * Reflected Time * 0.5

The velocity and depth of penetration of the GPR signal depends on the electrical properties of the material with highly conductive materials showing a low penetration due to high absorption rates. Clay-rich and water saturated materials have a lower penetration than gravelly and dry soils. Signal penetration and resolution limits are also governed by the centre frequency of the transmitted electromagnetic pulse. High frequencies give good resolution and shallow penetration. Lower frequencies give lower resolution and deeper penetration.

Reinforced concrete will often act as a barrier to GPR signals (independent of frequency) and in such cases the resolution of deeper layers of subbase / subgrade may not be possible.

Data collection

40MHz, 100MHz, 250MHz & 40MHz GPR data were collected across the specified pavement section. The use of these frequencies enable accurate resolution of the shallow, bound material layers, as well as providing good penetration into the deeper subbase and subgrade materials.

Data collection was controlled by an Electronic Distance Measuring (EDM) system linked to the hub of the survey vehicle. This enables a highly accurate, independent measuring system to be used to ensure data are collected at the specified intervals. Data were collected at 0.25m centres along the NSWP in the Southbound Lane.

Digital marks are placed on the data at predefined locations to determine the extents of the sections to be investigated.

Data processing

GPR data was collected as continuous longitudinal profiles as described above. The processing and location of subsurface features was achieved by using a proprietary processing software (ReflexWin V.8.2.2)

The following processing was applied to the data:

- Spatial relocation (data merge with surveyed positions)
- Temporal relocation (depth correction)
- Frequency band pass filtering
- Amplitude recovery gain (time dependent gain)
- Noise removal (background removal)
- Running average

Calibration

The calculation of accurate thickness measurements relies on the correlation of GPR radio wave velocity to measured material thickness. The velocity of the underlying peat material was calibrated to a series of probes taken at either side of the road to determine the depth of the peat base below the existing road surface.

Known velocities of the different materials making up the pavement construction were been used in the calculation of thickness detail.

- 0.1 m/ns Road Construction materials
- 0.035m/ns Peat

Thirty soft ground probes were taken adjacent to the road across the area investigation. Thirteen Russian samples were targeted in areas where peat were identified. The Russian samples identify the thickness of peat and the type of material underlying the peat.

Spatial Relocation

All the geophysical investigation locations were acquired using a Trimble Geo 7X high-accuracy GNSS handheld system using the settings listed below. This system allows collection of GPS data with c.20mm accuracy.

Projection:	Irish Transverse Mercator
Datum:	Ordnance
Coordinate units:	Meters
Altitude units:	Meters
Survey altitude reference:	MSL
Geoid model:	Republic of Ireland

APPENDIX B: PAVEMENT CONSTRUCTION SUMMARY TABLE

CHAINAGE		COORDINATES		ROAD CONSTRUCTION MATERIAL			PEAT MATERIAL			
start (m)	end (m)	easting ING	northing ING	min. depth (m)	max. depth (m)	avg. depth (m)	min. depth (m)	max. depth (m)	avg. depth (m)	Comments
	0	640364.083	764104.575							
0	1602	639283.526	765212.979	0.276	1.014	0.515				Section 1
1602	3278	638801.803	766700.748	0.400	2.387	0.765	0.833	5.340	2.645	Section 2 - Peat underlain by Shell Marl
3278	3355	638807.094	766777.567	0.657	1.685	0.941				Section 3 - Concrete Bridge Deck
3355	4055	638987.860	767452.176	0.437	2.231	0.779	0.664	5.140	3.676	Section 4 - Peat underlain by Shell Marl
4055	4486	639129.018	767859.410	0.268	0.491	0.341				Section 5
4486	4843	639144.495	768193.841	0.275	0.474	0.363				Section 6 - Possible Shallow Bedrock
4843	5342	638734.357	768473.072	0.331	0.836	0.504				Section 7
5342	6458	638617.150	769572.915	0.444	2.200	0.798	0.855	3.862	2.050	Section 8 - Peat underlain by Shell Marl
6458	7550	639217.202	769971.463	0.198	1.744	0.757				Section 9
7550	9119	640701.605	770443.741	0.208	3.043	0.882	0.426	4.883	2.709	Section 10 - Peat underlain by Shell Marl & Grey Clay
9119	9755	641194.058	770833.946	0.151	1.198	0.474				Section 11
9755	9851	641275.626	770884.384	0.148	0.402	0.270				Section 12 - Possible Shallow Bedrock
9851	10034	641426.158	770988.442	0.198	0.854	0.486				Section 13
10034	10240	641601.764	771095.191	0.250	0.951	0.525				Section 14 - Possible Shallow Bedrock
10240	10661	641645.686	771471.071	0.220	0.767	0.408				Section 15
10661	11017	641631.136	771822.066	0.219	0.731	0.444				Section 16 - Possible Shallow Bedrock
11017	11435	641553.443	772230.346	0.179	0.500	0.334				Section 17- Possible Shallow Bedrock
11435	11528	641541.828	772308.951	0.218	0.594	0.340				Section 18
11528	12257	640840.766	772466.270	0.211	0.489	0.319				Section 19
12257	12804	640526.050	772717.243	0.214	0.767	0.361				Section 20- Possible Shallow Bedrock
12804	13814	640256.122	773663.372	0.146	0.994	0.424				Section 21
13814	14542	639484.408	775208.405	0.103	0.608	0.338	0.285	0.792	0.547	Section 22- Peat underlain by Grey Clay
14542	15145	639661.915	774853.315	0.308	1.255	0.537	0.611	1.275	0.816	Section 23- Peat underlain by Grey Clay, Possible reinforced concrete within road construction
15145	15662	639430.310	775314.396	0.153	0.313	0.213	0.392	0.775	0.572	Section 24- Peat underlain by Grey Clay

FIGURE 1: GEOPHYSICAL LOCATIONS

SCALE 1:40,000

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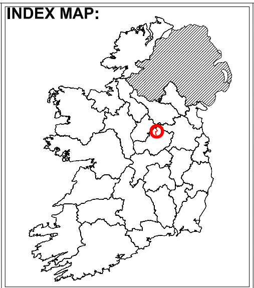
INDEX MAP:



LEGEND:

GPR Profile

GPR RECORDING LOCATIONS		
Frequency	Chainage (m)	
	From:	To:
400MHz	0	15662
250MHz	0	15662
100MHz	1621	9031
	13196	15662
40MHz	2074	4067
	5482	6480
	7533	9049

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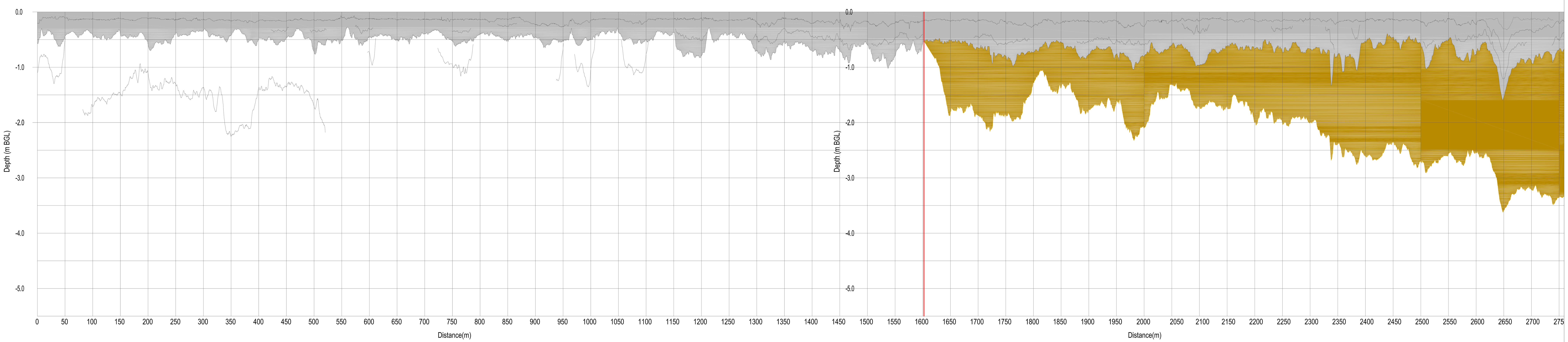
PROJECT:	COOLE GRID ROUTE GEOPHYSICAL INVESTIGATION
CLIENT.:	STATKRAFT IRELAND LIMITED
DRAWING NO:	AGP19176_01
SCALE:	AS INDICATED @ A3
DATE:	09TH-AUGUST-2019

Version:	Date:	Drawn By:	Checked:
01	09-10-2019	IS	YOC

FIGURE 1: Geophysical Locations
Scale 1:4000

FIGURE 2: Interpreted Geophysical Section
Scale Vt - 1:40, Hz - 1:4000



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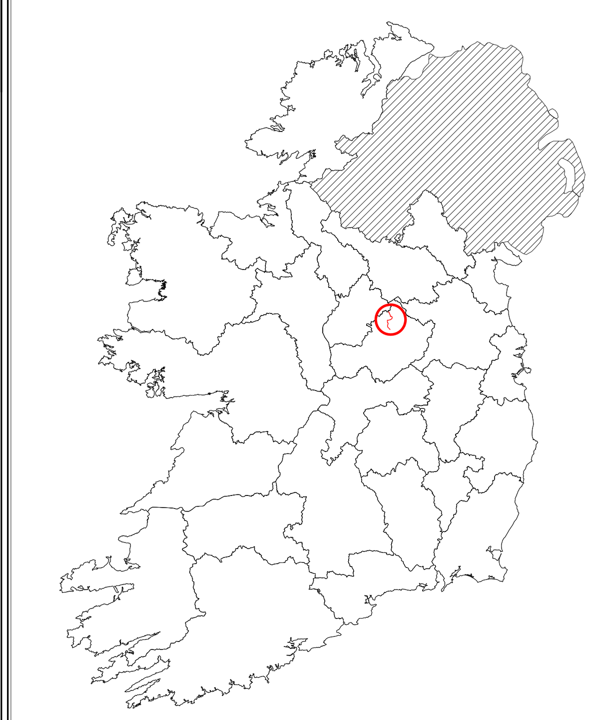

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Figure 1 key — GPR Profile

Figure 2 key — Road Construction; Internal Layering in Road Construction; Peat; Base of Peat

Unknown Layer

Construction change

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PROJECT: COOLE GRID ROUTE GEOPHYSICAL INVESTIGATION

CLIENT: STATKRAFT IRELAND LIMITED

DRAWING NUMBER: AGP19176_02

SCALE: AS SHOWN @ A1

DATE: 09TH AUGUST 2019

DRAWN: IS | CHECKED: YOC

REVISION:	DATE:	DRAWN:	CHECKED:
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