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Mapping Thickness of Raised Peat Bog Deposits Using GPR

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SUMMARY

The Irish Midlands have a unique landscape resulting from the retreat of the last ice age and subsequent post glacial deposition, forming extensive areas of raised peat bog. These natural resources have been used extensively for the supply of energy from domestic peat cutting to the generation of electricity on a large scale. In order to manage these vast areas there is a need for an accurate method to assess the remaining reserves and to aid future production planning. To achieve this a LIDAR survey was carried out to provide elevation data over the entire infrastructure, and accurate peat thickness data is required for approximately 35,000Ha of production bog.

GPR was used to provide this thickness information and the accuracy of the data was confirmed by peat probing. The survey showed three distinct GPR signatures associated with the presence of the three main sub-peat soils, namely gravels, plastic clays and shell marls, as well as from internal peat layers. This paper describes the work carried out at Blackwater Bog, an area of 1,890Ha of raised bog east of the River Shannon in County Offaly and presents examples of the different GPR responses.

Introduction

There are two main types of peat bog that account for approximately 14% of Irelands' land area. Blanket bogs are found in the western half of the country and mountainous areas where the annual rainfall exceeds 1200mm, and typically form extensive carpets of peat thickness between 2m and 5m. Whereas raised bogs are found mainly in the midlands where rainfall is less than 1200mm and have developed from lake basins, and typically have peat thicknesses between 4m and 10m.

Following the retreat of the glaciers at the end of the last ice age, 10,000 years ago, the midlands of Ireland were left with a landscape dominated by areas of poorly drained calcareous boulder clay. Lakes formed in the depressions and became overgrown by vegetation and later infilled by fen peat. This build up derived from mainly minerotrophic plants (reliant on groundwater for nutrients) caused the upper layer of vegetation to become cut off from their mineral rich water source and led to their replacement by more ombrotrophic vegetation types reliant on only rainfall for their nutrient source. This build up of vegetation, and peat development, resulted in the raising of the bog surface, in some cases by over 10m, giving the name to the "raised" peat bogs which form such an important part of the geography of the midlands of Ireland.

Bord Na Mona has been commercially extracting milled peat for energy generation since 1946. In 2008 a LIDAR survey of their entire bog infrastructure was commissioned. This work involved the mapping of 69,000Ha as part of the peat resource assessment project. In order to complete this assessment there was a need for accurate peat thickness information on the entire 35,000Ha of production bogs.

GPR surveys to map peat thickness are currently being carried out by APEX Geoservices Limited. This paper represents the work carried out to determine peat thickness for the Blackwater Bog as part of this overall resource calculation.

Blackwater Bog

The Blackwater Bog represents the largest single area of production peat bog within the Blackwater and Boora Group. The peat from these bogs is currently used to feed the Shannonbridge Power Station.

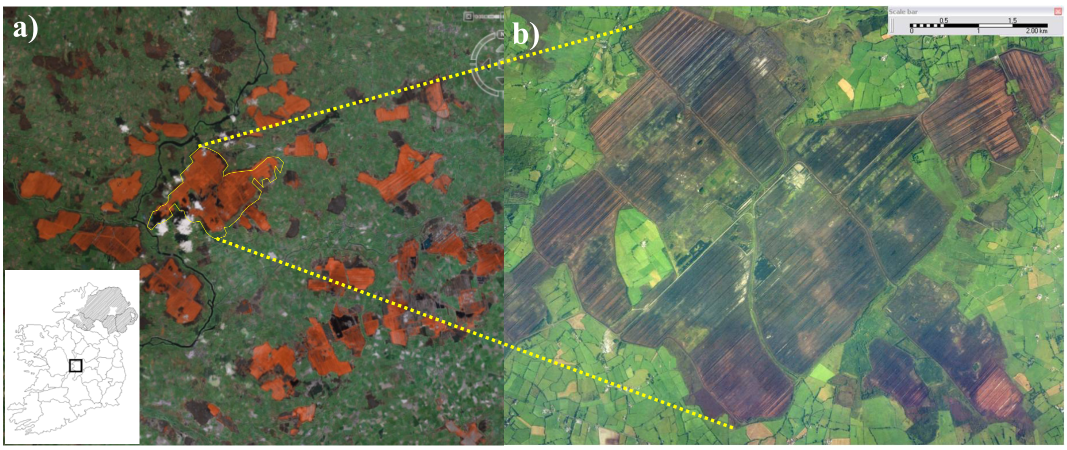


Figure 1: Location map of survey area: a) overview showing production bogs in red, b) detailed aerial photograph of Blackwater Bog.

Methodology

The GPR survey was carried out using a MALA 100MHz shielded antenna towed behind a quad bike with profiles collected every 4th field (60m). The GPR system was triggered by a hub mounted electronic encoder calibrated to sample at 200mm intervals and linked to RTK GPS to provide accurate positional information written directly to the trace headers. The positional accuracy of the RTK GPS data is ±20mm in both lateral position and height. The GPR monitor was mounted on the front of the quad to enable onsite QC of the data and to effectively target the placement of physical soundings. The soundings were carried out using a peat auger, sometimes known as a "Russian Sampler" where the sampler is pushed into the peat and then rotated to trap the sample in the chamber. The position of each probe was recorded as a digital mark on each profile to enable accurate relocation of the calibration data. See Figure 2 below for survey configuration.

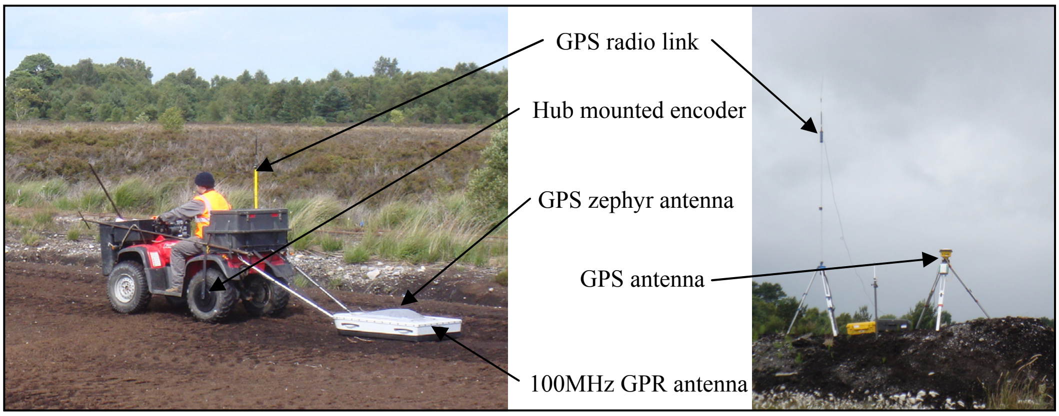


Figure 2: a) GPR survey configuration and b) GPS base station

Data acquisition was carried out by a two man team on site with one person operating the GPR and driving the quad and the second carrying out the probing. Using this method it was possible to cover between 20 and 60km per day, depending on ground conditions. A total of 315 linear km of GPR data were collected for the Blackwater Bog.

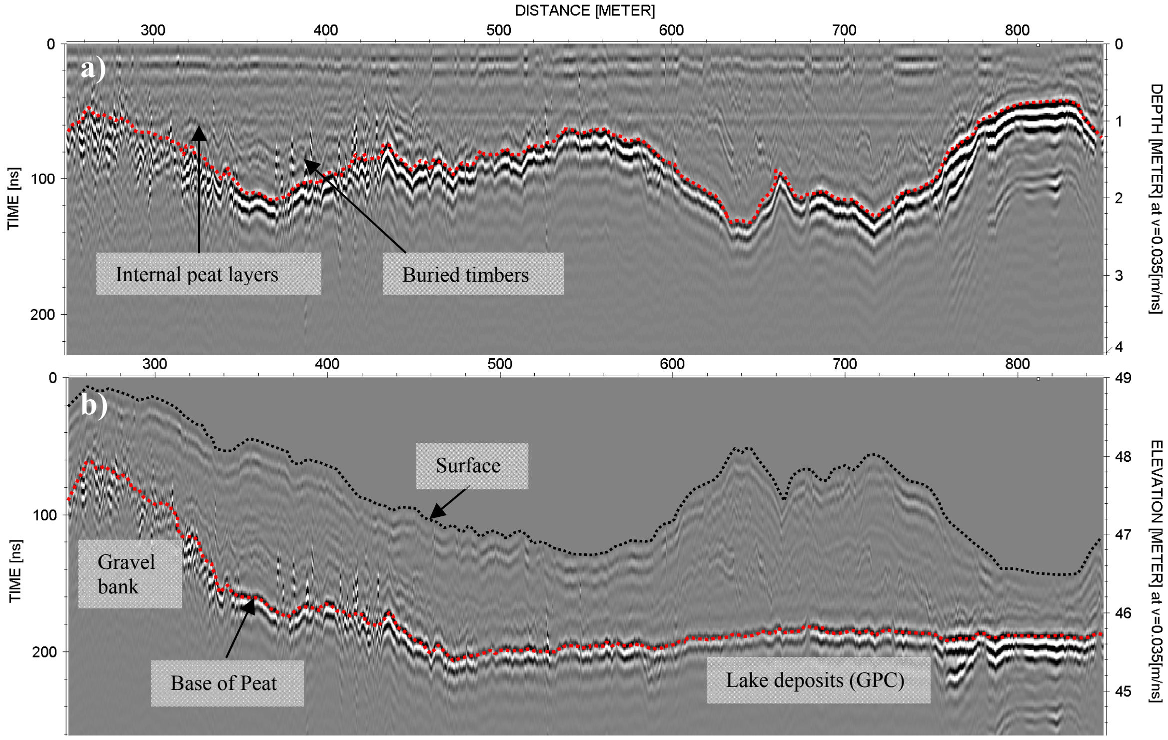
A total of 364 physical soundings were taken during the course of the Blackwater investigation. These calibration probes gave an accurate velocity determination of the peat layer of 0.035m/ns ±3%. This velocity was found to vary little with depth due to the high water content of the peat.

The data were processed using Reflex 3D software using the following sequence:

- Spatial relocation – GPS data assigned to individual trace headers (XYZ)
- Temporal relocation (T_0 correction, Dynamic Correction)
- Frequency filtering (Butterworth bandpass)
- Amplitude recovery (Exponential Y-Gain)
- Noise removal (Background removal)
- Topographic correction (Correction to MoD)

Figure 3 below shows an example processed GPR profile before and after the topographic correction. The ability to view topographically corrected data gives a much greater appreciation of the geomorphology of a site resulting in a more confident interpretation of the data.

Figure 3: Example GPR data: a) processed section b) topographically corrected



As well as the presence of hyperbolic reflections from buried timbers as annotated in Figure 3: a), internal boundaries within the peat are identified which may be due to the changes in types of vegetation associated with the different stages of raised bog development.

The known sub-peat soil types can be divided into the glacial deposits of boulder clay and gravels and the post glacial lake deposits of blue/grey plastic clays (GPC) and shell marl (SM). To assess the feasibility of using GPR to accurately determine peat thickness in different depositional settings the following test sites were chosen: Cloncreen (SM), Noggusboy (GPC, SM), Clongawny More (Gravel, GPC, SM), Garryduff (GPC, SM) and Derryarkin (Gravel).

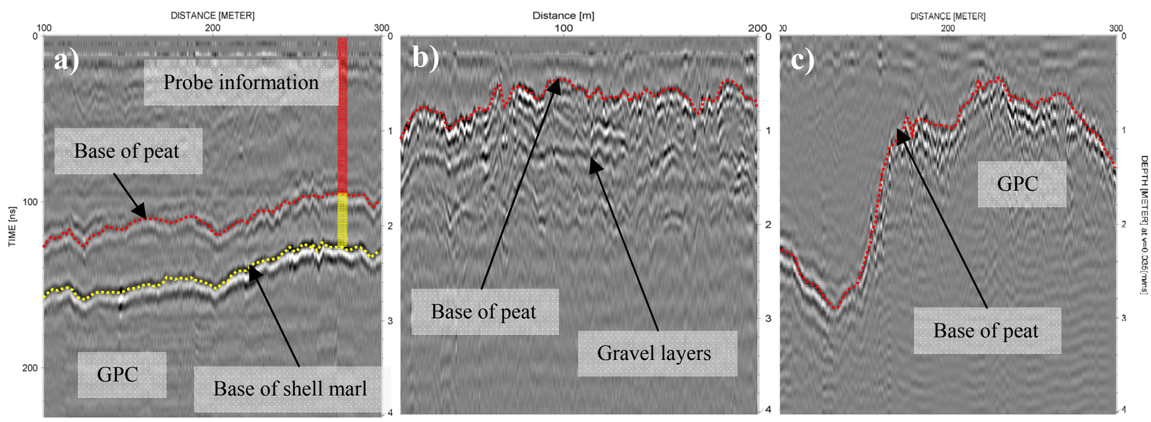


Figure 4: GPR signature from different sub-peat soil types: a) Shell marl; b) Gravel and c) GPC

The boundary between the peat and sub-peat layer has a distinct signature depending on the underlying material. Shell marl produces a smooth subtle reflection due to the nature of deposition and the comparable velocity between the two materials. Gravels (saturated) show a clear undulating reflection with internal layering within the underlying material. GPC shows a strong undulating boundary with no reflections from below due to the strong dielectric contrast.

Results

Surface plots of peat thickness calculated from GPR data were provided in XYZ format for integration into BNM GIS system. Difference plots between the RTK GPS elevations and the LIDAR data (Figure 5: a)) were used as a QC measure.

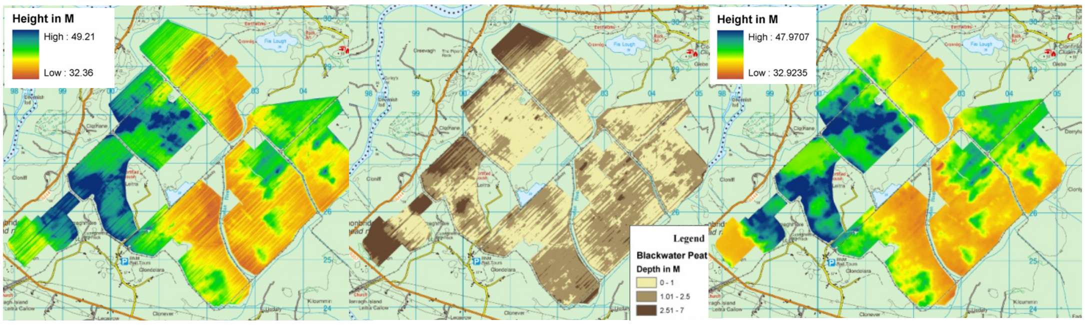


Figure 5: Output plots from GIS package: a) LIDAR surface elevation data, b) peat thickness, c) elevation of base of peat

This peat thickness data shown in Figure 5: b) was used to make accurate volume estimates of the peat resource and to draw up production plans. The areas of low elevation of the base of the peat shown in Figure 5: c) and Figure 6: below, as orange, correlate to the presence of the shell marl and follow the line of the Gowlan River which runs through the survey area.

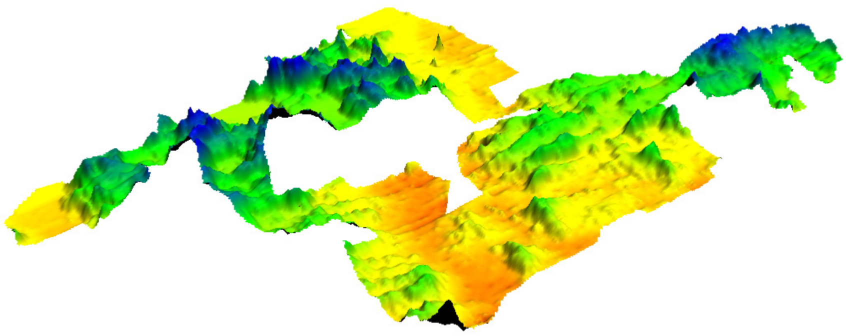


Figure 6: 3D plot of elevation of base of peat showing sub-peat topography. Areas shown as orange correlate to the areas of known shell marl below the peat.

Conclusions

The use of GPR for the assessment of peat thickness has been highly effective and has provided a level of accuracy that would not have been practically realised using other means. This data is proving to be invaluable in the future planning of the remaining peat resources of the Irish Midlands.

Although this work has been carried out as a commercial venture with the overriding objective to determine the peat thickness, it has become apparent that a great deal of information on the sub-peat soils can be determined from the GPR data. It is possible therefore to determine the type of sub-peat deposit and depositional history of an area from the assessment of the GPR response. Different reflection characteristics from within the peat layers can also provide information on the origin and composition of the peat layers.