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A pilot study into the feasibility of using ground-penetrating radar to determine water table depth in peatland ecosystems

Abstract

A test-case ground-penetrating radar (GPR) survey was carried out on the upland peat site on the RSPB Lake Vyrnwy Reserve in the Berwyn Special Area of Conservation (SAC), North Wales (www[1]) in order to determine whether the depth of the water table was identifiable in the reflected radar signal using a the Pulse EKKO 1000 GPR system. A preliminary investigation was carried out to decide upon the frequency to be used. Following this two fixed-offset transects were surveyed in a saturated region of the peatland. Peat soil and water table depth measurements were taken at several points along transects and the depth of the soil horizons noted. GPR failed to detect the water table so close to the surface but the contact between the organic and clay-rich soils was identifiable. GPR may thus prove more useful for estimating soil parameters such as bulk density than for estimating water table depth.

Background

Peatlands are thought to store large quantities of carbon (Bellamy et al., 2005). However drainage ditches have lead to a decrease in the rate of peat production, which requires partially saturated conditions, and erosion of the peat, both of which result in a reduced amount of carbon storage in the soil. In addition to other schemes, large sums of money are being spent on blocking the drainage ditches (“grips”), over a total area of more than 4500 in North Wales with the aim of raising the water table and reversing the erosion and carbon loss. However, raising the water table through drainage ditch blocking will change the aeration within the soil profile, resulting in altered emissions of greenhouse gasses, particularly methane which is produced by bacterial anaerobic respiration in water-logged conditions – potentially causing the soil to shift from a net carbon sink to a net source. It is therefore unclear what effect the grip-blocking will have on the net carbon balance of a peatland ecosystem. Being able to estimate the water table depth over a wide area is essential to characterising the methane flux component of the carbon balance over the whole site, particularly via process models, for which water table depth is a key parameter.

It was proposed that GPR might be used to measure water table depth rapidly and over a wide area, which is not possible using dipwells at individual point locations. As water has a much higher dielectric permittivity than air or dry soil contrasts in the water content will cause strong reflections from that interface. The water table might therefore cause a strong reflection of the radar signal in the peat sub-surface and therefore be identifiable. Measuring the GPR return time from this surface might enable a measure of the water table depth to be calculated.

A pilot study aimed at testing this hypothesis at the RSPB Lake Vyrnwy Reserve in North Wales. It was suggested that the Pulse EKKO 1000, with its broad range of frequencies might be ideal for this pilot study as whilst lower frequency systems penetrate deeper into the subsurface, the water table in a peatland ecosystem will tend to lie close to the surface.

A technique for rapidly measuring water table depth over wide areas would potentially be of great benefit for estimating methane fluxes, hydrological monitoring and for biodiversity studies.

Survey Procedure

A fixed offset survey was carried out on a 30m transect in a flat part of the peatland site (Fig. 1) which contained mainly short sedge and moss vegetation. Both the 450MHz and 900MHz antennae were used. Tests were carried out beforehand to determine the optimum system configuration and data collection parameters such as operating frequency, step size along transect, length of time window, antenna separation, orientation and trace stacking. Water table depth measurements were taken every 1m along the transect and soil cores were collected every 10m to determine the depth to the peat – clay interface, which was used to calculate the wave velocity in the soil. The location of drainage ditches was noted. GPR profiles were imported into the ReflexW software. Processing included dewow filtering, start-time adjustment and gain correction using the gain function and the data collection parameters determined in the field.

Figure 1: Map of the RSPB Lake Vyrnwy Reserve site and experimental set up (left). Coloured polygons are the control (solid line) and treated (dashed line) grip-blocked areas for each catchment. Red square shows the location of the pilot GPR study. Right panel shows site and survey operation (image N. MacBean).

Results

The 450MHz survey showed two distinct reflectors near to the top of the profile (Fig. 2). These were relatively continuous with little depth variation along the transect. A zone of strong reflections was visible further down the profile. The trend of these reflectors along-transect was the same as that of the interface between the peat and clay, confirming that this horizon corresponded to the depth of the peat. Soil depth measurements (Fig. 2) made every 10m were therefore used to determine the velocity of the wave in the soil. This was calculated to be ~0.042m/ns. The presence of an artificial drainage ditch is clearly seen in the GPR profile 15m along the transect. The distinct reflectors near the surface were compared with water table depth measurements. Although the water table depth measurements showed the water table was close to the surface it varied considerably more than these surfaces, suggesting that these horizons correspond to the bottom of the vegetation and litter layer and not to the water table depth.

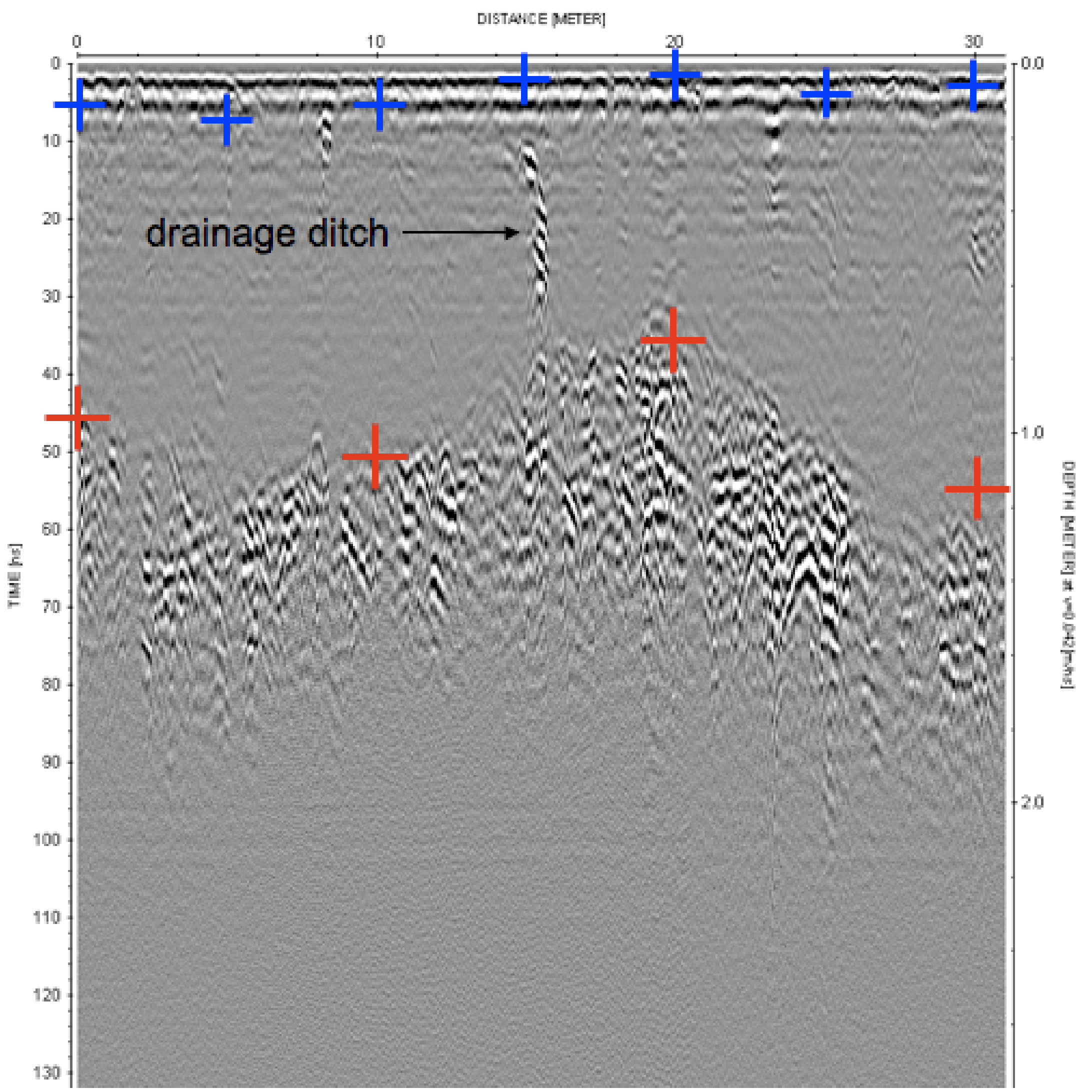

Figure 2: GPR profile along a 30m transect using the 450MHz antenna. Red crosses indicate the soil depth measurements made at the site, and blue crosses the water table depth observations.

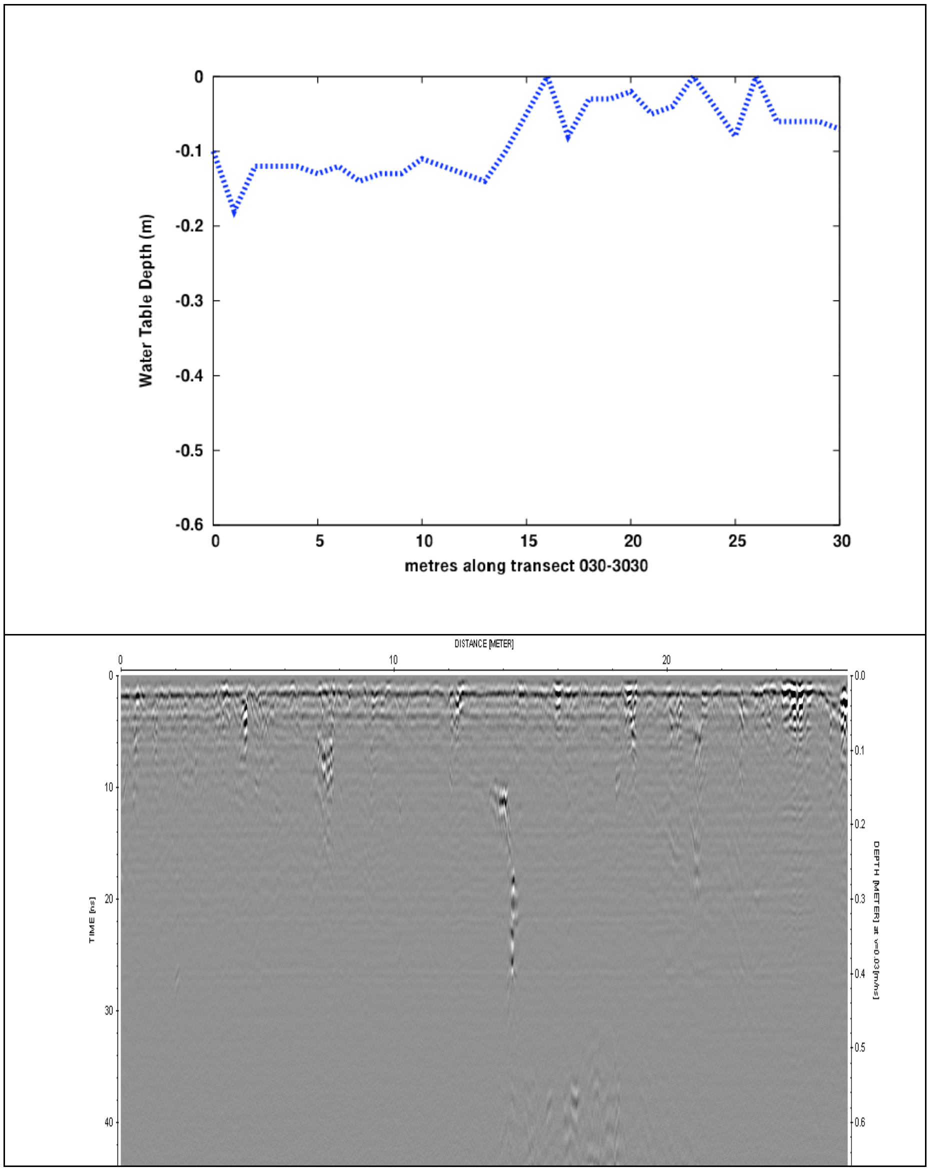

Figure 3: Water table depth measurements made every 1m along the transect (top); GPR profile along the 30m transect using the 900MHz antenna (bottom).

The 900MHz survey showed one clear reflector close to the surface at a depth of about 1cm (Fig. 3). This is likely to correspond to the interface between the vegetation and litter-peat layer below. The variability of water table depth measurements (shown alongside the GPR profile in Fig. 3) suggests this horizon does not correspond to the water table depth.

Conclusions and discussion

Unfortunately neither the 450MHz or 900MHz antennas were able to pick up the water table depth in this short pilot study. This may be because the interfaces between the vegetation and litter, and litter and soil are more distinctive than the water table depth so close to the surface. Although the water table depth can be clearly measured in a specially dug hole where it can pond, it is likely that throughout the rest of the soil profile it is not a uniform surface. However, it is clear that the depth of the peat can be detected using the 450MHz antenna. It is likely that the signal from the 900MHz antenna cannot penetrate to these depths. This is a very useful measurement in itself as peat depth is used in soil carbon stock quantification and carbon flux modeling studies and is hard to determine across a wide region. In addition, the location of artificial drainage ditches can clearly be identified using a GPR system. This is likely to be useful for land managers as often smaller/older artificial drainage ditches (up to a century old in some cases) have grown over and been lost over time.

References

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www[1] www.blanketbogswales.org