Geophysics report for Wyre Archaeology
Bull Brook, Bilsborrow

Survey Personnel

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Dates

Fieldwork:	22 February & 2 March 2023
Report:	14 April 2023

NGR	SD 50947 40183
W3W	pickup.revisit.knowledge
Location	The site is located in Bilsborrow between Bull Brook, Lancaster Canal and Myerscough Hall Drive in the grounds of the Gabrysch household.
Survey Methods	Electromagnetic inductance (EMI); ground penetrating radar (GPR).
Study Area	0.5 ha.

Aims

To identify any evidence of a former (Roman) road traversing Bull Brook at the site; to assess presence of any subsurface archaeological features within the area planned for installation of a storage unit for Wyre Archaeology.

Summary of results

The geophysical surveys did not provide any evidence that a road traversed the site. The presence of channel like features running parallel to the brook were observed, suggesting a possible former route of the brook. No evidence of archaeological features in the area proposed for the storage unit was observed.

Method

Georeferencing: All GPR survey grid positioning was carried out using a Trimble R8 GNSS system in RTK survey mode. The geophysical survey areas are georeferenced relative to the British National Grid. Five semi-permanent pegs were installed at the site and surveyed to British National Grid, allowing easy geo-referencing of any future surveys/investigations at the site.

EMI: GF Instruments MiniExplorer CMD using in horizontal coplanar mode. Survey conducted in 'roaming' (not grid) mode, sampling on average 1.2 measurements per m^2. Technical details in Appendix A.

GPR: MALA ProEx 250MHz antenna. 0.4m line separation. Technical details in Appendix B.

Data Processing

EMI: No filtering applied. Nearest neighbour interpolation onto regular grid.

GPR: Radar velocity estimated from hyperbola matching in *ReflexW*. *GPRPy* used for GPR data processing: time-zero correction, survey length correction, dewow, power-law gain. *GPRPy* used to generate 3D model in vts format for viewing in *ParaView*.

Survey conditions

Site cover: grass with brambles around edges of survey area. Evidence of mole activity over much of the site. Topography is relatively flat at the site. Weather conditions: dry.

1. Site description and context

1.1 The survey was prompted by observations of the presence of a cluster of dressed stone adjacent to Bull Brook (see Figure 1). It had been suggested that this may be associated with a Roman road (known to pass through Bilsborrow).

1.2 The EMI survey was conducted over the entire field (see Figure 1) in order to assess variation in electrical conductivity of the ground. GPR surveys (see Figure 1) were carried out in two plots: A (50m x 25m) and B (20m x 10m). Plot A was selected to target the area close to the dressed stones. Plot B was selected to investigate ground conditions in the area of the planned storage unit.

1.3 The average elevation of the top of the brook stones is 18.6maOD. The average elevation of the ground surface in GPR plot A is 19.8maOD, i.e. a 1.2m elevation difference.

1.4 Figure 2 shows a photograph of part of the survey area, illustrating ground cover at the time of the survey.

2. EMI survey results

2.1 The EMI survey (e.g. Figure 3) show relatively weak variation in subsurface electrical conductivity (EC), although there are two noticeable features: (1) the western area of the plot has a higher EC, likely associated with finer textured soils and greater water retention; (2) the lower EC in the east of the plot appears to show a NE-SW orientation.

2.2 The presence of buried road stones should be evident from relatively low EC values. There is no evidence of such features in the expected orientation (N-S) of a road.

3. GPR survey results

3.1 Figure 4 shows the X-Y orientations used for plotting the processed GPR data as horizontal slices in subsequent figures.

3.2 Figure 5 shows selected horizontal slices for GPR plot A. A road feature would be evident from significant reflection strength (shown as a darker colour in the plots). No such feature is present in the data.

3.3 At shallow depths (0.4m and 0.5m) some NE-SW orientated banding is evident in the GPR volume slices. This is likely to be a result of historic ploughing activity at the site.

3.4 At 0.7m and 0.8m a zone of weak reflection can be seen (also running ENE-WSW). This feature appears of natural origin and from inspection of individual vertical slices (e.g. Figure 6), a channel structure is apparent.

3.5 Figure 7 shows selected horizontal slices for GPR plot B. A linear feature running WNW-ESE is clearly seen. Two additional GPR surveys running orthogonal to the main (3D) survey reveal the hyperbolic reflection pattern characteristic of a buried pipe (Figure 8).

3.6 The only other features evident from the GPR data in plot B is the sharp contrast in reflection in an ENE-WSW orientation in horizontal slices at depth >0.8m. Interestingly, this aligns with the channel feature noted in plot A. Figure 9 shows a composite image of slices from plots A and B, illustrating the alignment of this feature.

3.7 Figure 10 shows the same GPR slices as in Figure 9, with a background map from OpenStreetMap. Interestingly, OpenStreetMap shows an incorrect upstream position of the Bull Brook, however this aligns perfectly with the interpreted channel feature. Furthermore, the current alignment of Bull Brook appears to be linear and does not follow a course that naturally aligns with the downstream reach (beyond Myerscough Hall Drive), suggesting that the brook may have been realigned at some stage. A hypothesis that follows is that the observed channel feature is the original course of the brook. If this is the case then the archaeological significance of the dressed stone cluster in the present-day brook is questionable.

4. Conclusions

4.1 The EMI and GPR surveys carried out have not revealed any features of archaeological significance at the site.

4.2 GPR surveys in plot A show evidence of a subsurface channel-like feature. This may be a paleochannel but could indicate the original course of Bull Brook. If the latter is correct then the archaeological significance of the dressed stone cluster in the present-day brook is questionable.

Appendix A. Technical information: Electromagnetic induction (EMI).

Instrumentation: GF Instruments MiniExplorer CMD.

The MiniExplorer consists of a transmitter coil and three receiver coils, each at different spacing (0.32m, 0.71m, 1.18m) from the transmitter. The instrument can be operated in horizontal coplanar or vertical coplanar mode (the two modes result in different depth-sensitivity patterns). For the surveys conducted at Bull Brook, the horizontal coplanar mode was used, resulting in a depth of investigation of 0.5m, 1.0m and 1.8m for the three receiver coils. It is important to note that the measurements are integral measures of subsurface properties; the nominal depth of investigation represents a depth over which 70% of the signal is sensitive to. Consequently, each measurement is an *apparent* value.

The instrument measures in-phase and quadrature components of the secondary magnetic field induced by the transmitter coil. The quadrature component is directly related to the electrical conductivity of the subsurface. The SI units of electrical conductivity are S/m (siemens per metre), although values are commonly reported (as here) in mS/m. 1mS/m is equivalent to a resistivity of 1000Ωm. The in-phase component is related to magnetic susceptibility. Minimal variation in the in-phase component was noted (any significant variation is typically due to the presence of ferrous materials).

As the instrument works with an induced field, the measurements are contactless. Furthermore, they are rapid, allowing easy coverage of relatively large area. For the surveys at Bull Brook measurements were recorded every 0.5s in a 'roaming' mode, using a Trimble Pro 6 GNSS antenna attached to the control unit. The average measurement sampling was 1.2 measurements per m^2. The survey duration was approximately 50 mins.

The measured range of apparent EC for the 0.5m, 1.0m and 1.8m nominal depths of investigation are shown in Table A1. There is little variation between apparent EC values over the three depths of investigation; the only clear contrast is the slightly lower apparent EC for the intermediate depth.

Table A1: Range of apparent EC measurements for the three receiver coils

	Coil 1	**Coil 2**	**Coil 3**
Coil separation	0.32m	0.71m	1.18m
Depth of investigation	0.5m	1.0m	1.8m
Minimum recorded	3.13mS/m	1.11mS/m	4.32mS/m
Maximum recorded	14.42mS/m	9.01mS/m	11.21mS/m
Median recorded	6.84mS/m	5.44mS/m	6.62mS/m

Appendix B. Technical information: Ground Penetrating Radar (GPR).

Instrumentation: MALA ProEx unit with 250MHz shielded antenna.

The shielded GPR system typically operates in reflection mode: a transmitter antenna provides a pulse of high frequency electromagnetic energy and a receiver antenna records signals travelling directly from the transmitter and from reflections in the subsurface. Surveys are conducted along transects using an odometer to trigger measurements. After laying out a survey grid, survey lines were positioned every 0.4m and transects run in parallel. Sampling along each transect was 2cm. Data were recorded over an 85ns time window. The odometer recorded distance for each transect is compared to the known survey length (25m for plot A; 20m for plot B) and corrections made, when necessary, to adjust the recorded position, assuming a linear drift. Such errors can occur due to odometer wheel slippage on wet ground, but are typically of the order of a few percent.

Each transect dataset is processed individually in *GPRPy* using the following steps: (1) odometer correction to known survey length; (2) time-zero correction; (3) dewow (low frequency fiter); (4) time window truncation (to remove later sections of the trace where no reflections are present); (5) application of a gain function (to amplify signals at later times in the trace); (6) translation of time window to an effective depth using an appropriate velocity. In order to obtain a velocity measure, a number of transect datasets with visible hyperbolic reflections were selected for velocity analysis in *ReflexW* (*GPRPy* has this feature too but *ReflexW* has much greater flexibility and user control). The inferred velocity from such analysis was 0.055 m/ns. This is a relatively low velocity and characteristic of a very wet soil. Most of the observed hyperbolae occur at shallow depth and yet the velocity may vary with depth. Consequently the computed depths of GPR reflections but be treated with some caution. For example, a two way (i.e. from transmitter to reflector and return to receiver) of 30ns equates to a reflector depth of 0.825m (assuming a velocity of 0.055m/ns) and a depth of 1.125m (assuming a velocity of 0.075m/ns, which may be more typical of an assumed velocity). Once each transect is processed in *GPRPy*, they are combined to create an interpolated 3D volume of signal strength (higher signals equating to strong reflections). The interpolation was done on a 10cm (horizontal) x 10cm (horizontal) x 3cm (depth) grid. The resultant 3D volume was view in *ParaView*, allowing horizontal slices to be extracted. As signal weakens with depth a colour scale was uniquely assigned for each depth slice. It is, therefore, important to recognise that a colour for one slice does not necessarily equate to an equivalent signal strength on another slice.

As the topography at the survey site is relatively flat, no topographic correction was applied to the data.

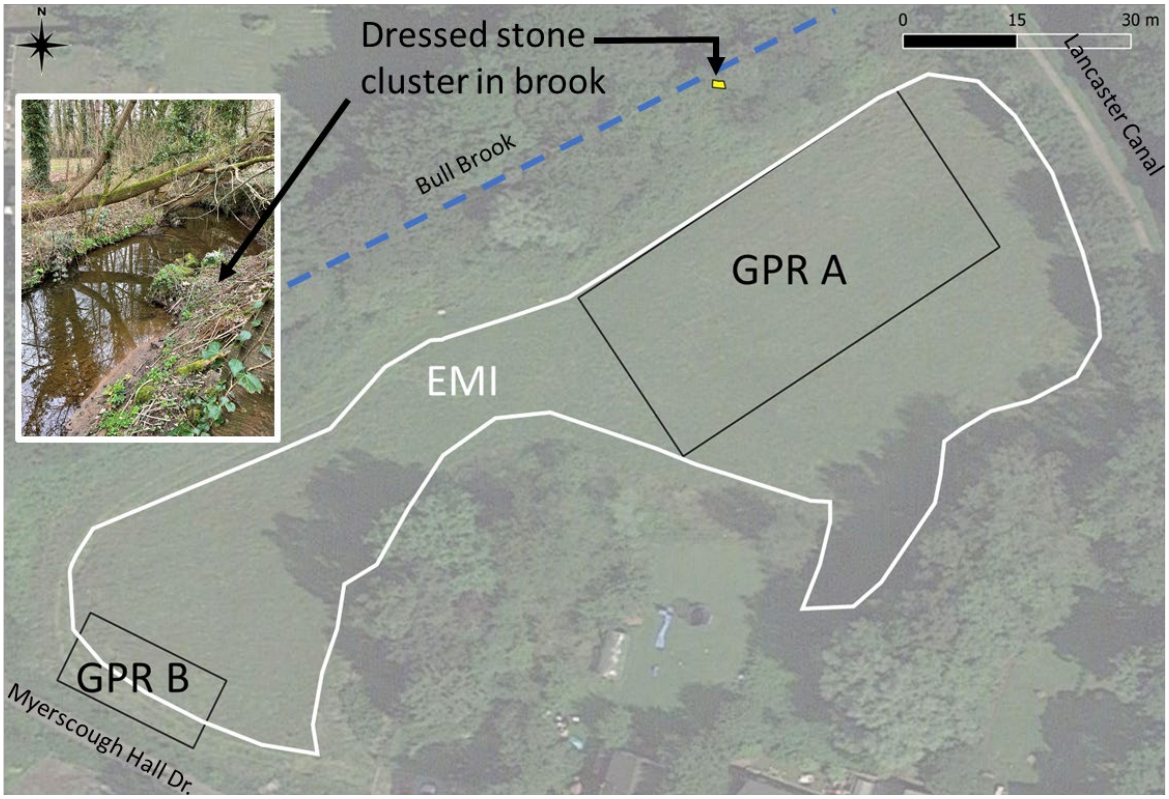

Figure 1: Survey areas for EMI and GPR, and locality of dressed stone in Bull Brook with photograph insert.

Figure 2: Photograph of site looking south west. Bull Brook is adjacent to the embankment to the right of the photograph.

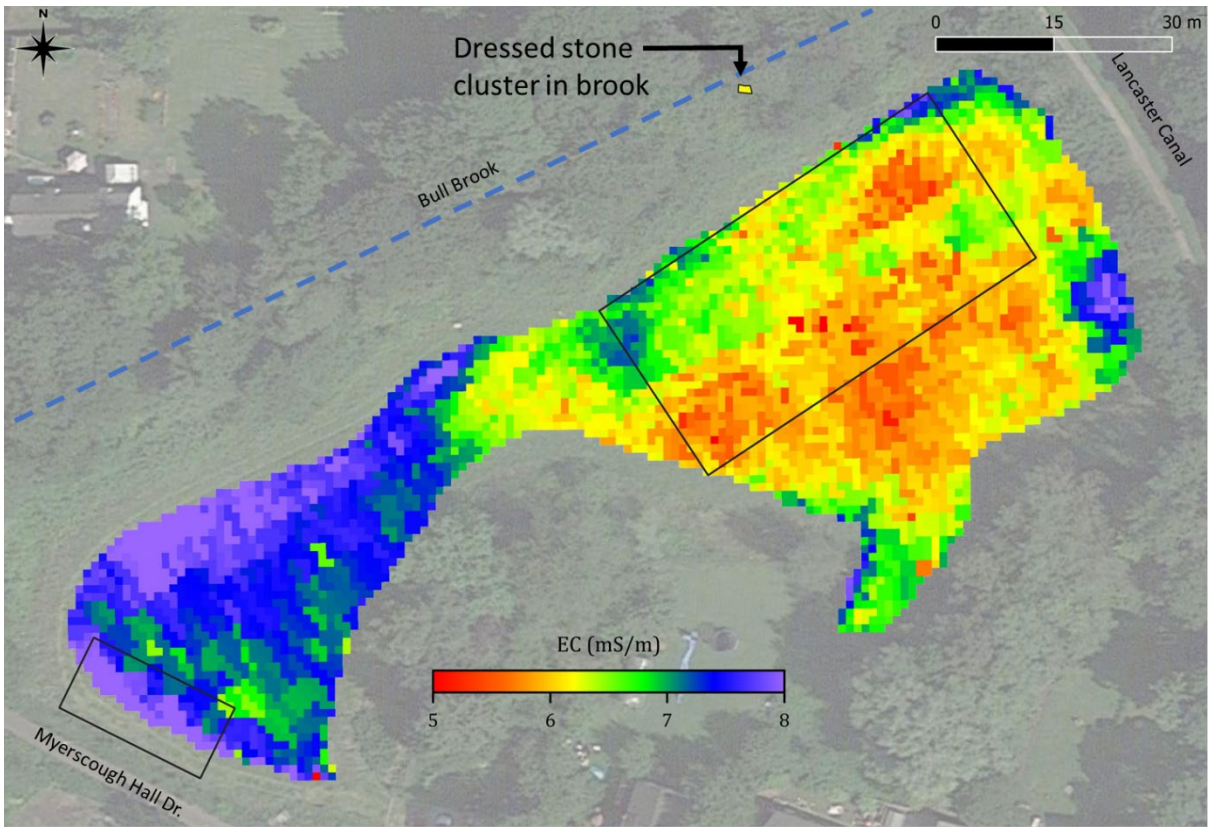

Figure 3: EMI results showing electrical conductivity (EC) for 1.18m coil separation (effective depth of investigation: 1.8m). The GPR surveys areas are marked by the two rectangles.

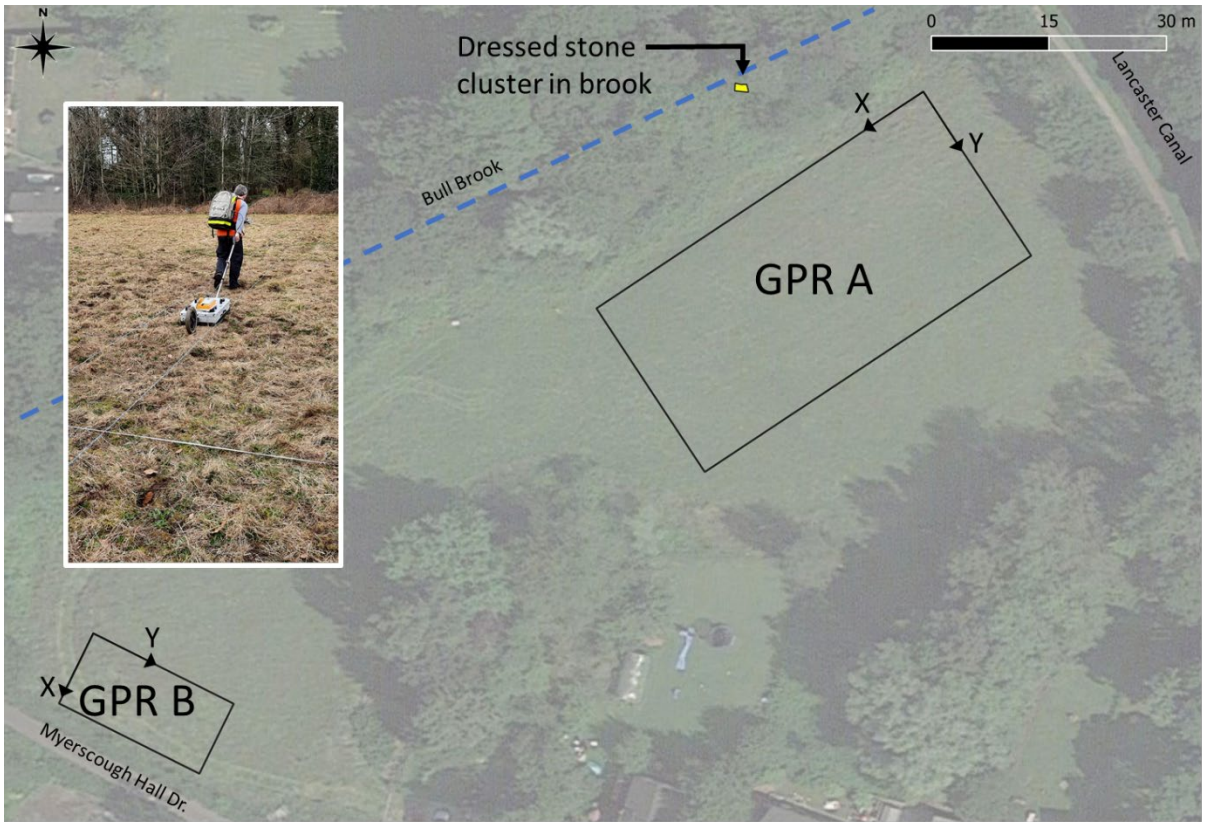

Figure 4: Orientation of GPR survey images (used in following figures) with insert photograph of data acquisition.

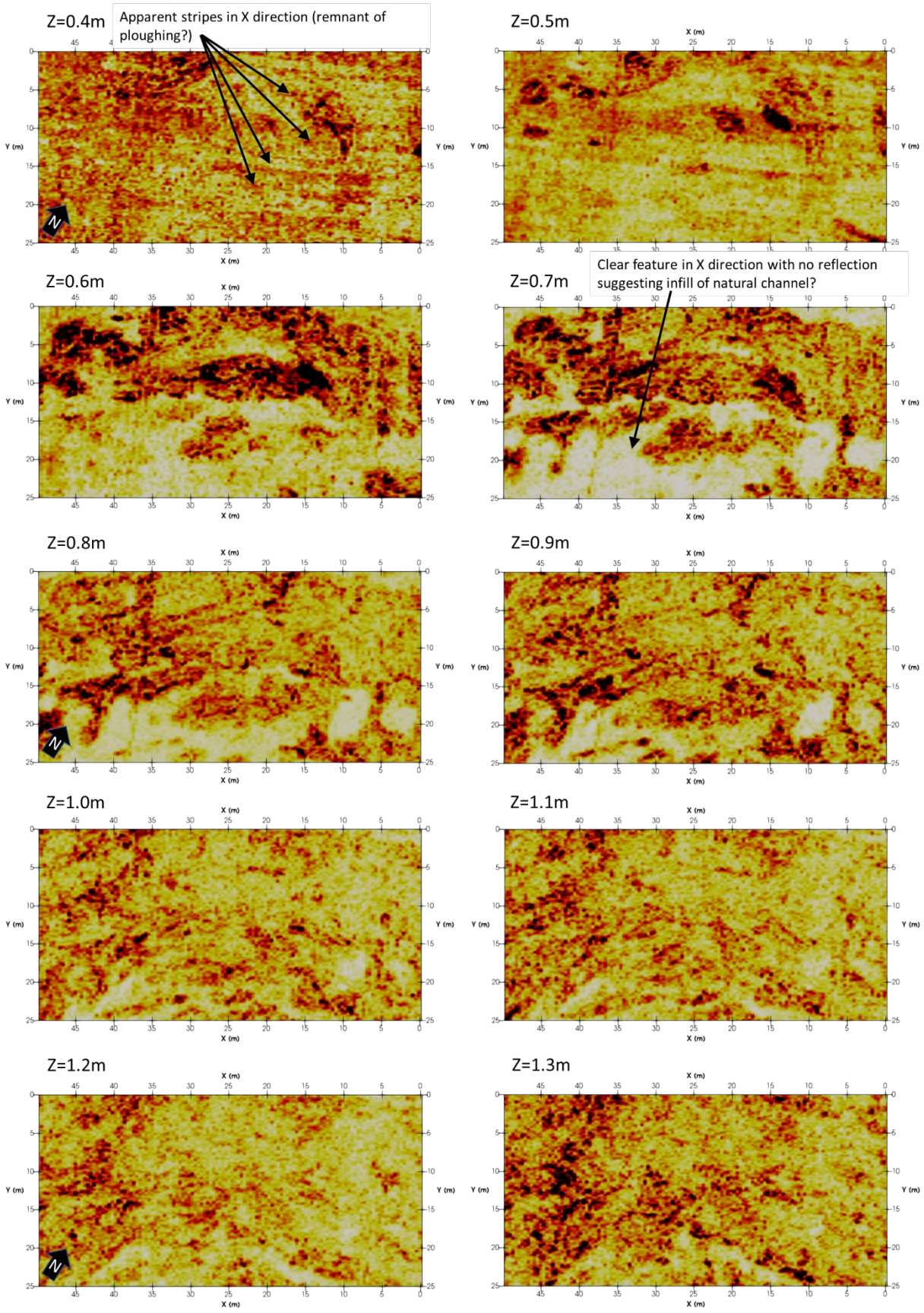

Figure 5: Horizontal slices of GPR plot A data volumes at 0.4 to 1.3m depths below ground level. Darker colours indicate GPR reflections. Light colours indicate weak reflections. See Figure 4 for orientation of X-Y plane.

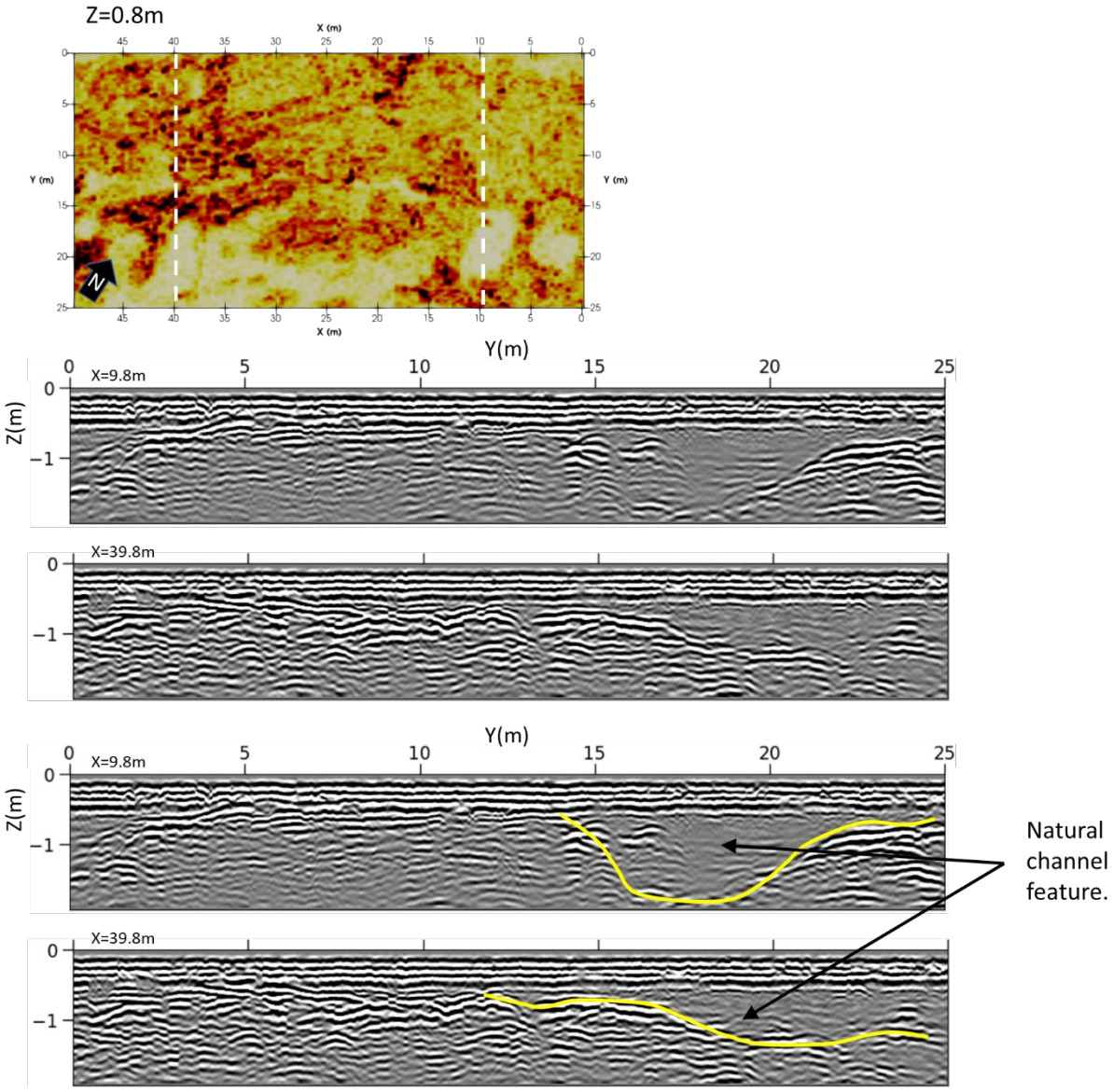

Figure 6: Illustration of channel feature in two example GPR transects from GPR plot A.

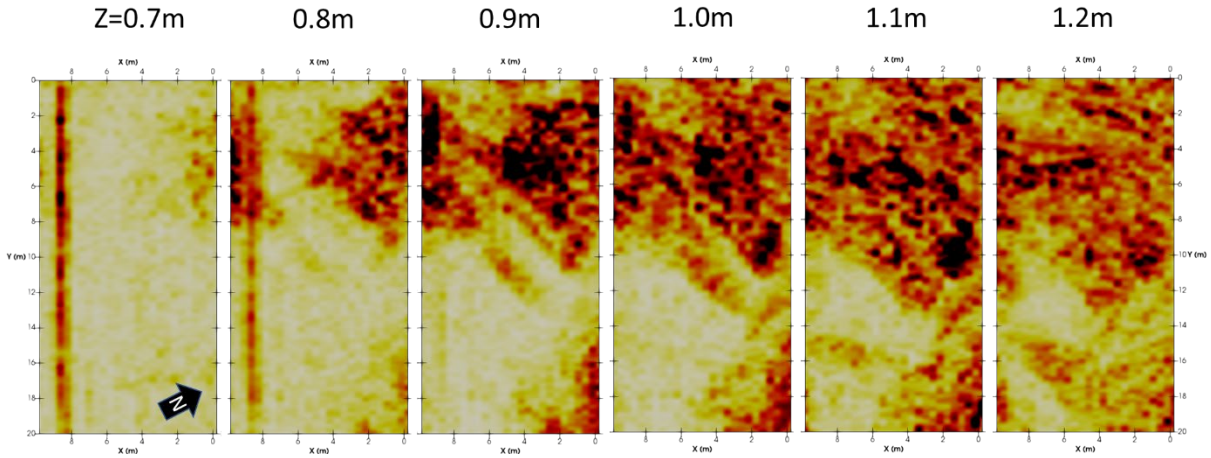

Figure 7: Horizontal slices of GPR plot B data volumes at 0.7 to 1.2m depths below ground level. Darker colours indicate GPR reflections. Light colours indicate weak reflections. See Figure 4 for orientation of X-Y plane.

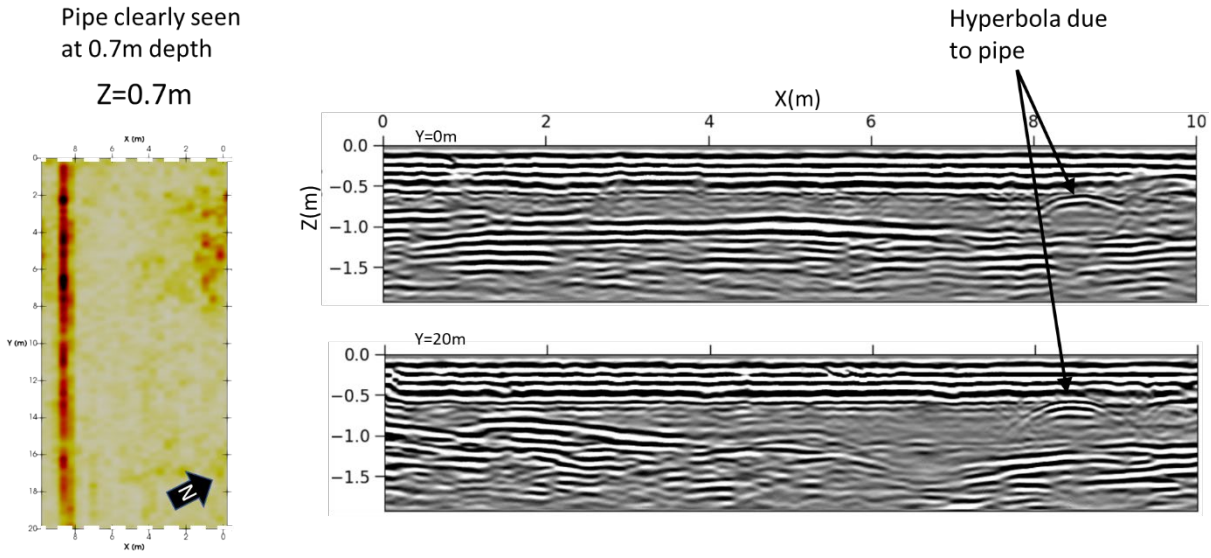

Figure 8: Example 2D presentation of GPR data from plot B from surveys running in the X direction, revealing clearly the hyperbola characteristic of a buried pipe.

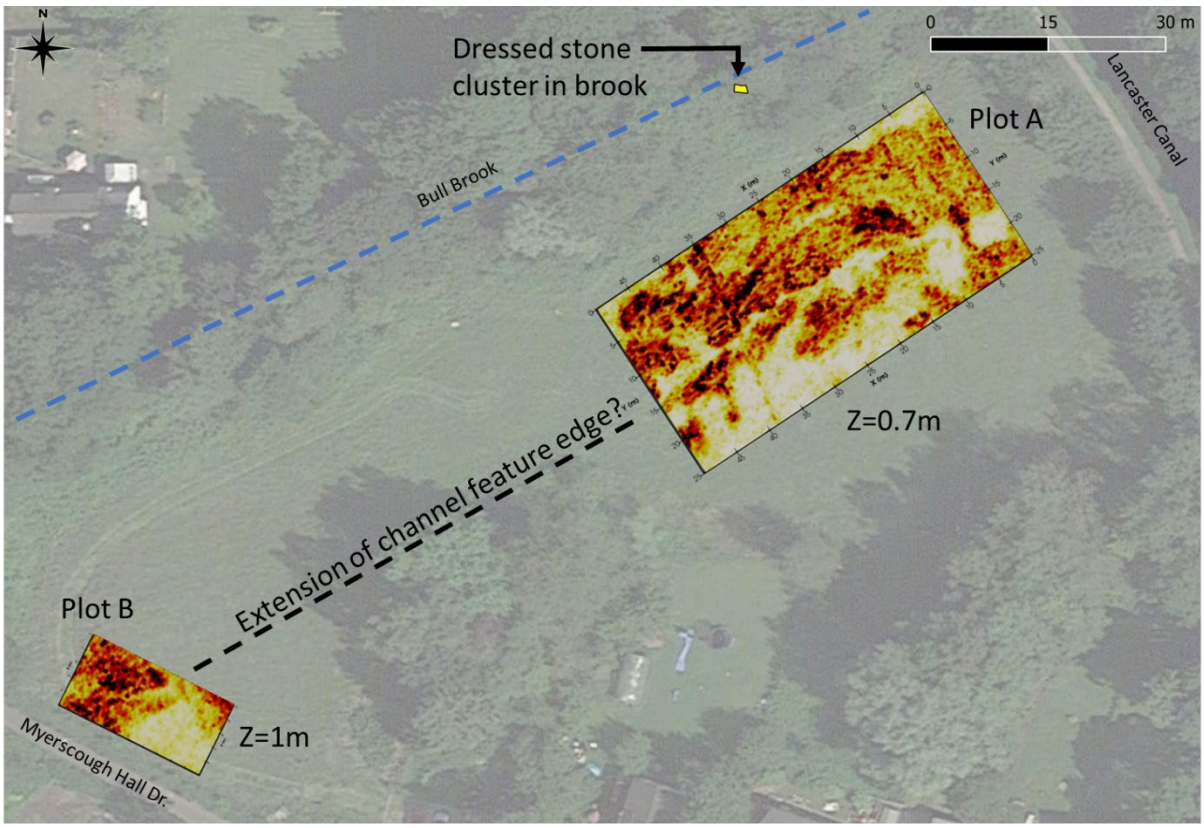

Figure 9: Example horizontal slices in GPR plots A and B to illustrate possible connectivity of channel feature across the site.

Figure 10: Re-plot of GPR horizontal slices in Figure 9 with OpenStreetMap background, showing different upstream route of Bull Brook that aligns with the observed natural channel.