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Eddleston Water Floodplain Project: Data Report

Climate Change Programme

Open Report OR/12/059

BRITISH GEOLOGICAL SURVEY

CLIMATE CHANGE PROGRAMME

OPEN REPORT OR/12/059

Eddleston Water Floodplain Project: Data Report

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Summary

This report describes work done to characterise the shallow (Quaternary) subsurface environment (geology, hydrogeology and soil hydrology) of a new environmental experimental site at Eddleston, Scottish Borders, and presents the data that were gathered during an extensive and detailed investigation of the experimental site. These data form the basis for an in depth interpretation and characterisation of the geology, hydrogeology and soil hydrology of the site, which will be presented separately.

The Eddleston experimental site was set up as part of the wider Eddleston Water Project, which aims to reduce the impact of flooding in and downstream of Eddleston. A key objective of the experimental site is to improve understanding of the role of groundwater in floodplain environments and in flooding, and of how groundwater interacts with climate, rivers and soils.

The following activities have been carried out and are reported here:

- The geology of the site has been characterised by geological re-surveying, trial pitting, geophysical surveying, drilling, and the development of a three dimensional geological model.
- The hydraulic properties of the Quaternary aquifer beneath the floodplain have been characterised by test pumping.
- Soil permeability in areas of different land use across the site has been established, and areas of completely saturated soil identified.
- The hydraulic properties of the shallow (<2m) deposits beneath the wetland area have been characterised by test pumping.
- Equipment has been installed to enable long term monitoring of soil moisture, groundwater levels and groundwater temperature.

1 Introduction

The Eddleston Water, a tributary of the River Tweed in the Scottish Borders (Figure 1), has been selected as a demonstration catchment by the Scottish Government for promoting Natural Flood Management. Over time, the course of the Eddleston Water has been extensively altered, and changes in land management have also altered how the land drains. Together, these changes have led to an increased risk of flooding in the village of Eddleston and the downstream town of Peebles, and have damaged the river itself, leading to reduced water course length and habitat loss.

The geological, soil and hydrogeological characterisation work described in this report was done as part of a wider project, the Eddleston Water Project[1], which aims to reduce the impact of flooding in and downstream of Eddleston. The wider Eddleston Water Project is being delivered by the Tweed Forum and the University of Dundee on behalf of SEPA, with additional partners including the British Geological Survey (BGS). Following a detailed survey[2], the Eddleston Water Project has developed a river restoration strategy to reduce the risk of flooding of Eddleston and Peebles and to restore natural habitats. Various activities are being carried out as part of the project, by the University of Dundee, Tweed Forum, BGS and others, including the installation of a weather station and streamflow gauging and monitoring in the Eddleston Water catchment. These activities will be reported on separately by the leaders of each work package.

A key aim of the river restoration strategy was to establish good scientific data on baseline hydrological and hydrogeological conditions in an experimental site along one section of the Eddleston Water floodplain. Funding for BGS to coordinate and carry out this baseline characterisation was provided jointly by the Scottish Government and SEPA. Additional support was provided by BGS to provide supplementary geological data for the wider Eddleston Water catchment and to maintain links with work being carried out by other partner organisations, including helping to supervise a post-doctoral researcher at the University of Dundee to work on the project.

A key objective of the work at the new Eddleston experimental site is to improve understanding of the role of groundwater in floodplain environments and in flooding, and of how groundwater interacts with climate, rivers and soils. The experimental infrastructure means we will also be able to monitor hydrological changes that occur as river restoration methods are implemented.

The experimental site selected is part of Darnhall Mains Farm, adjacent to the village of Eddleston. It is approximately 0.2 km^2 (approximately 400m by 500m) and covers most of the width of the Eddleston Water floodplain on both sides of the river (Figure 1). It is farmland, with landuse encompassing mixed livestock farming on improved grassland, arable farming (crops include sileage and oilseed rape), established forest shelter belts, and a riverbank belt of unimproved grassland.

The BGS characterisation work has been done under the banner of a BGS project titled the Eddleston Water Floodplain Project. This work has been carried out in partnership with the University of Dundee. It has focused on geological and hydrogeological (including soil permeability) characterisation of the trial site. The following activities have been carried out. Unless otherwise specified, all activities have focussed on the Darnhall Mains Farm site:

1. Geological surveying at two scales: a catchment-wide survey of the Eddleston catchment, and detailed surveying of the Darnhall Mains Farm site
2. Geophysical surveying
3. Trial pitting

[1] http://www.sepa.org.uk/flooding/flood_risk_management/working_with_nature/the_eddleston_water_project.aspx
[2] http://www.dundee.ac.uk/geography/research/documents.htm

4. Borehole drilling and piezometer installation
5. Development of a 3D geological model
6. Hydraulic testing of piezometers
7. Soil permeability surveying and soil moisture monitoring

This report provides brief details of each of the above activities and presents the relevant collected data and/or outputs. **The report does not provide any interpretation of the collected data and information, or hydrogeological conceptualisation, but is intended as a record of data collection activities and the collected data, to support future research.**

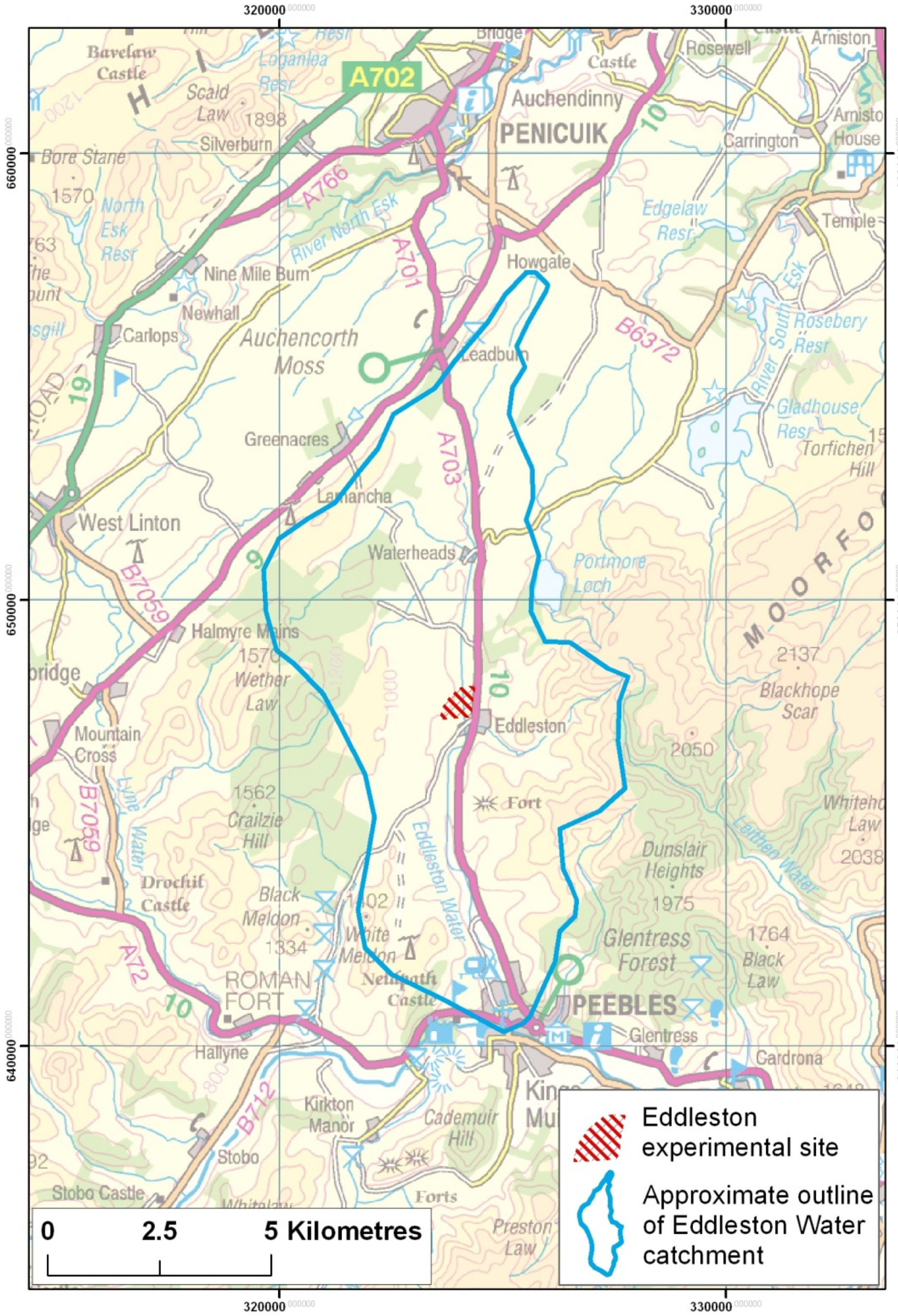


Figure 1 **Location of the Eddleston Water Floodplain Project**

2 Geological surveying

Geological re-surveying in the Eddleston catchment during this project has been carried out at two levels of detail. At the new experimental site, detailed geological surveying was carried out to support the development of a three dimensional geological model of the superficial deposits (Quaternary) geology of the site (Section 2.1). This detailed work was complemented by a separate project to rapidly re-survey the geology of the whole of the Eddleston Water catchment, which was funded and carried out by BGS (Section 2.2).

2.1 DETAILED GEOLOGICAL SURVEYING AT THE EDDLESTON EXPERIMENTAL SITE

Detailed surveying at the Eddleston experimental site was carried out by a BGS geologist (J E Merritt) over two days in July 2010. The survey methodology was based on BGS standards, using the BGS ruggedized SIGMA[3]-Mobile tablet PC and ArcGIS and Access database derived in house software. The main activities were collecting auger hole data to investigate the shallow geology (to approximately 1.2m depth), and logging exposed geological sections in river cliffs along the banks of the Eddleston Water as it flows through the site. Auger data were collected from both the floodplain and the adjacent western hill slope, using a standard metal rod auger capable of penetrating to a maximum depth of 2 metres. A total of 42 holes was augered, distributed as evenly as possible across the survey area (Figure 2). Auger penetration was poor on the hill slope above the floodplain, due to the nature of the underlying head deposits. Penetration in the floodplain was better, allowing augering down to a maximum of about 1.2m. Alluvial gravel was the main hindrance to penetration. The auger holes were all infillled immediately after they were examined.

As well as information on changes in geology with depth across the survey area, the auger hole data and observations of breaks of slope made during detailed mapping helped to accurately delineate the geological boundary of the alluvium, feeding into the larger scale map of the whole Eddleston Water catchment.

[3] SIGMA: System for Integrated Geoscience MApping. For more information see http://www.bgs.ac.uk/research/sigma/home.html

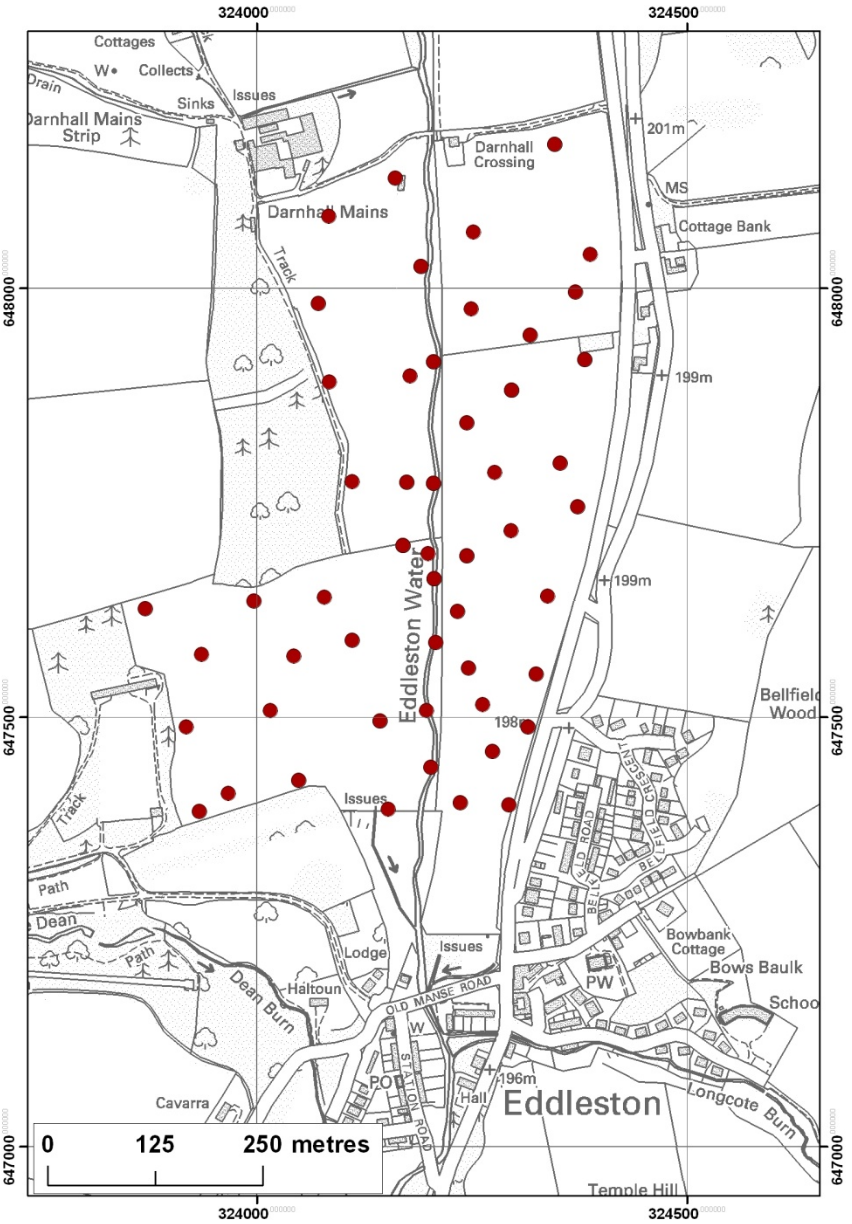


Figure 2 Location of auger holes made during detailed geological surveying at the Eddleston experimental site

2.2 GEOLOGICAL RE-SURVEYING OF THE EDDLESTON WATER CATCHMENT

A rapid geological resurvey of the catchment of the Eddleston Water, from its source near Penicuik to its confluence with the River Tweed at Pebbles, was undertaken by a BGS geologist (C A Auton) in the late summer and early autumn of 2010. The main aim of the survey was to revise the interpretation of the geology of the area in terms of the nature, distribution and thickness of the glacial, post-glacial and man-made (artificial) deposits; and to improve understanding of the evolution of catchment morphology over the past 25,000 years since the last glaciation covered the area.

The revision survey, which was conducted at 1: 10 000 scale, covered an area of 679.5 km^2. Pre-baseline geological and topographical datasets for the catchment were used to populate ArcGIS- and Access database-derived in-house software packages. Field surveying was done using a ruggedized BGS SIGMA-Mobile tablet PC, loaded with the pre-existing datasets.

The datasets used included Ordnance Survey topographical maps; BGS 6 inch 'County series' and BGS 1: 10 000 scale 'National Grid' geological maps; borehole, site investigation and mineral assessment drilling records; Digital Terrain Models derived from NextMap (© InterMap Technologies); airborne LiDAR surveys; and georectified monoscopic and stereoscopic digital colour aerial photography.

A preliminary geological interpretation of the catchment was undertaken using the pre-existing datasets, within a BGS customised ArcGIS-derived map making (SIGMA-desktop) package. This allowed digitising of geological and morphological features, at true scale, using stereoscopic aerial photography visualised in 3D, using SOCETSET™ V5.4.1 software linked to the SIGMA desktop project.

These digitally interpreted data were then loaded onto the SIGMA tablet PC and together with the baseline datasets formed the template upon which the rapid reconnaissance field survey of the catchment was undertaken in September 2010. The field survey involved ground-truthing the interpreted data and included conventional feature and outcrop mapping, augering, and the logging and photography of natural and pre-existing manmade exposures.

Upon completion of the ground-truthing, the field and remotely sensed data were reintegrated in SIGMA desk top, and the resulting ArcGIS shape files and Access databases compiled into a digital geological map and attributed ArcGIS project by BGS cartographic staff.

The new map of the superficial deposits of the Eddleston Water catchment is illustrated in Figure 3. It is available to partners within the Eddleston Water Project consortium to use within the Eddleston Water Project, and will be available to customers outside this project to purchase as a printed hard copy at 1:25,000 scale; a digital pdf file at the same scale; or to licence as GIS-enabled digital files. For more information please contact the BGS Sales Desk.

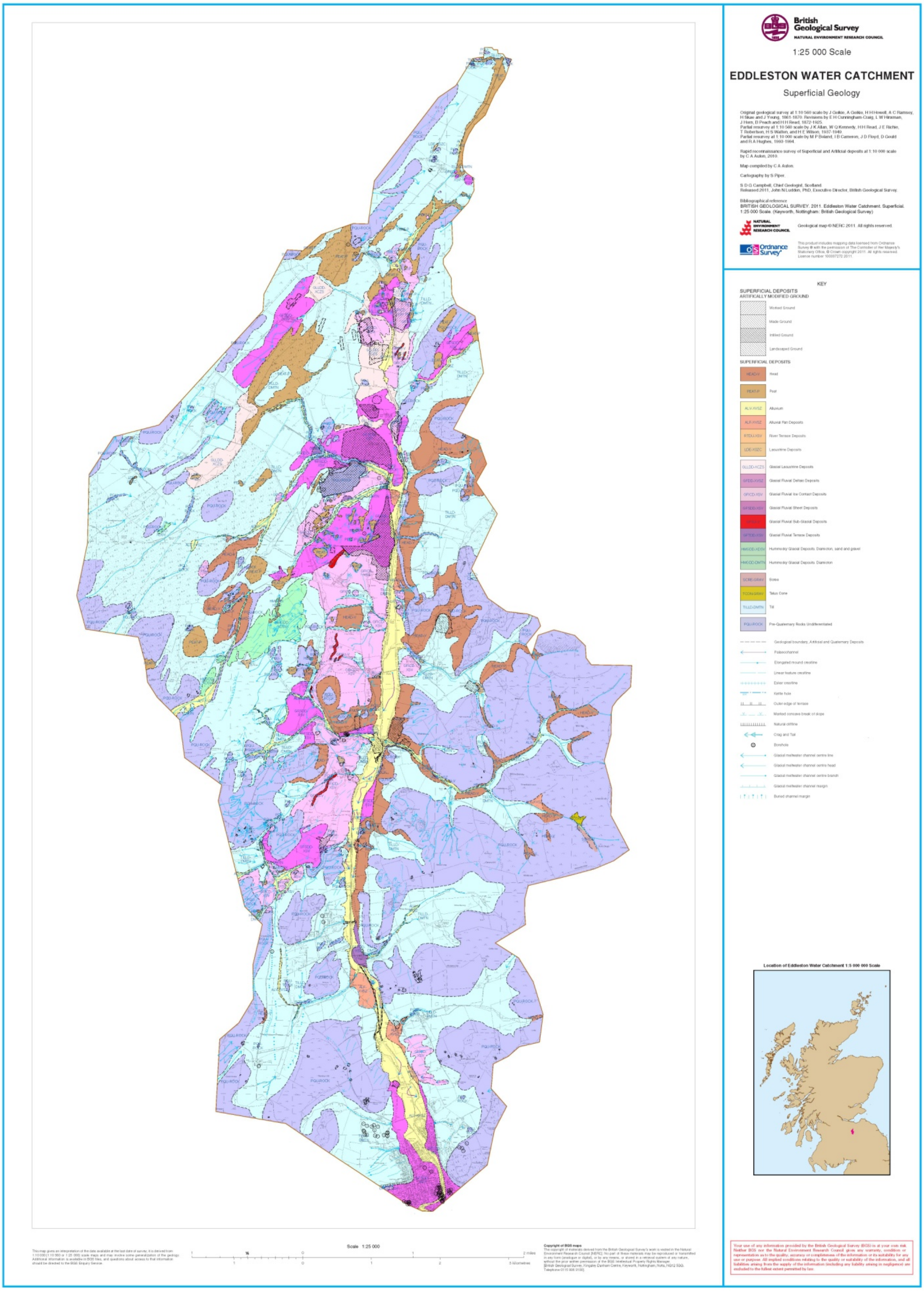


Figure 3 New map of the superficial geology of the Eddleston Water catchment

3 Geophysical surveying

Near-surface geophysical surveying at the Eddleston site was carried out in a single field campaign by BGS geophysicists (O Kuras, M G Raines, J C White and A L Weller) between 9 August and 12 August 2010. Three popular surveying methods were used: Electromagnetic Induction (EM, also referred to as ground conductivity mapping); 2D Electrical Resistivity Tomography (ERT); and Ground Penetrating Radar (GPR). This combination of electrical and electromagnetic (EM) techniques is a common application in investigations of shallow Quaternary deposits, and has been used successfully in a variety of recent BGS projects.

A summary of the nominal surface coverage (number of survey lines run for each method) is presented in Table 1. The locations of the survey lines are shown in Figure 4. The geophysical results are presented in Appendix 1.

Table 1 Summary of geophysical survey lines

Geophysical method	Number of survey lines
EM	39 (33 on a regular grid east of the river)
ERT	5
GPR	29 (19 on a regular grid east of the river)

3.1 ELECTROMAGNETIC INDUCTION

Ground conductivity mapping was undertaken with a DUALEM instrument in DUALEM-4 (4m long boom) configuration. The instrument operates by inductive coupling between pairs of electromagnetic coils, thus eliminating the need for contact with the ground. In order to maximise areal coverage and spatial resolution, the system was mounted on a non-metallic cart and pushed/pulled along linear survey profiles at moderate speed (Figure 5).

A DUALEM dual-geometry array (coils in horizontal co-planar and perpendicular configurations) simultaneously measures electrical conductivity and susceptibility of the subsurface to two distinct nominal depths, typically 2.5m and 5m. Multiple measurements therefore enable the estimation of the conductivity, susceptibility and thickness in a layered earth.

Raw data collected on a regular pattern of parallel survey lines to the East of the river were processed and gridded to produce image maps of resistivity (reciprocal of conductivity) for a shallow and a deep configuration.

3.2 ELECTRICAL RESISTIVITY TOMOGRAPHY

ERT surveys involve making a large number of four-point electrical resistance measurements (consisting of a current and a potential dipole) using computer-controlled automated measurement systems and multi-electrode arrays. These data are used to produce 2D and 3D models of subsurface electrical property distributions, from which subsurface structure and property variations can be identified. ERT surveys are entirely scalable, and can be used to cover areas ranging from a few square meters to many hectares. In order to generate images from the field measurements, data inversion is undertaken, where the aim is to calculate a resistivity model that satisfies the observed data. A starting model is produced, e.g. a homogeneous half-space, for which a response is calculated and compared to the measured data. The starting model is then modified in such a way as to reduce the differences between the model response and the measured data. This process continues iteratively until acceptable convergence between the modelled and measured data is achieved, which implies that the goodness of fit between model and observations falls below a pre-set threshold or the change calculated for consecutive iterations becomes insignificant.

2D ERT surveys at Eddleston were undertaken using an AGI SuperSting resistivity meter connected to a linear array of 64 stainless steel electrodes with regular inter-electrode spacings of between 2 m and 5 m, depending on the desired profile length and spatial resolution. Geometry details for the five ERT profiles established are shown in Table 2. Data were collected using a dipole-dipole array geometry with the characteristics n=1...8 and a=1...6. Reciprocal data were collected to aid the assessment of measurement errors. Smoothness-constrained least-squares inversion with topographic corrections was then applied to all datasets, resulting in 2D cross-sectional models of subsurface resistivity.

Table 2 Geometry of ERT survey lines

Profile	Length	Electrodes	Spacing
A	315 m	64	5 m
B	252 m	64	4 m
C	381 m	128 (roll-along survey)	3 m
D	477 m	160 (roll-along survey)	3 m
E	126 m	64	2 m

3.3 GROUND PENETRATING RADAR

Ground penetrating radar (GPR) measurements are used to characterise the structure and stratigraphy of near-surface geology. It is a geophysical imaging technique in which short pulses of high-frequency electromagnetic energy (EM) ~ 10 – 1500 MHz are emitted into the ground from a transmitting antenna. As these pulses propagate through the surface, a portion of the EM energy is reflected back to the surface when changes in the electromagnetic properties of the sediment are encountered (Davis and Annan, 1989). A profile of the sub-surface is created by continuously recording the variations in the reflection travel time. However, these reflections may result from either geologic structures or anomalous features in the subsurface, such as field drains, water/gas pipes etc.

GPR profiling was undertaken using a Mala Geoscience RAMAC/GPR system with a 100 MHz shielded antenna (Figure 6) and pulled along the ground over linear survey profiles (Figure 4). The 100 MHz antenna was considered to be a good compromise between depth of investigation and vertical bed resolution. Data were collected on alternate EM lines (every 40m on the regular grid) including all the ERT survey lines. This resulted in a total of 19 traverses east of the river (plotted west to east) with a further 10 measured to the west (Table 1). Individual GPR sections are plotted in Appendix A1.3, and a summary interpretation is presented in Tables 10 and 11.

The GPR data were processed and plotted using standard procedures (e.g., Annan, 1993) using pulse EKKO^{TM} 1V (version 4) software. A DTM was used to correct for topography and the results are plotted in section form as two way travel time against position. Time-to-depth conversions are shown on the profiles by assuming the electromagnetic wave propagation velocity of 0.1 m/ns, typical for the sands and gravels. This resulted in an observable signal penetration of approximately 5m. The data are plotted in wiggle trace mode showing the actual waveform where the positive amplitudes are filled in.

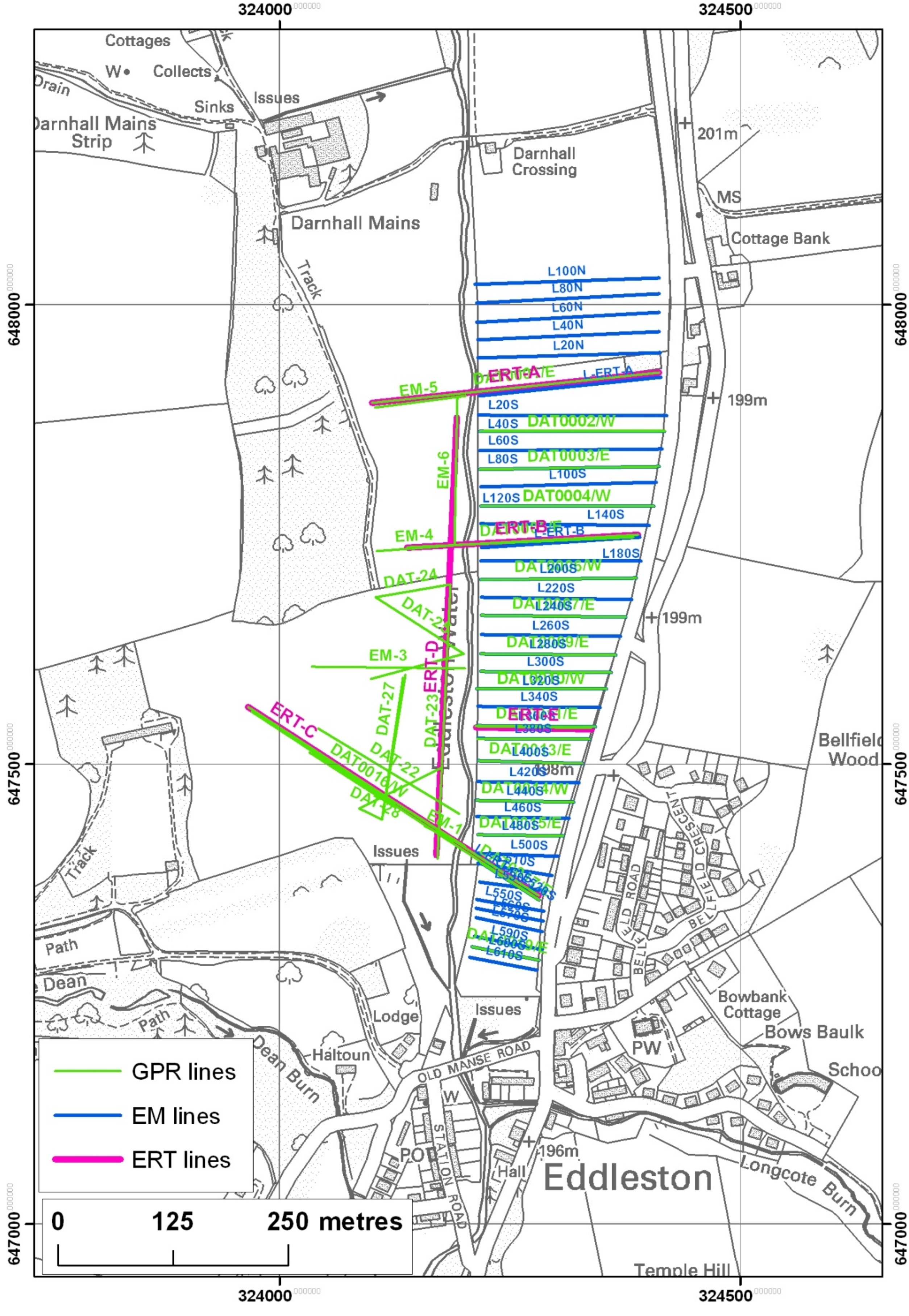


Figure 4 Location of geophysical survey lines

Figure 5 DUALEM - 4 Conductivity Meter

Figure 6 RAMAC - GPR 100 MHz Shielded Antenna

4 Trial pits

Eleven trial pits were dug across the Eddleston site between 16 and 18 August 2010, supervised, logged and sampled where appropriate by a BGS engineering geologist. The trial pits were between 1.10 and 3.85 m deep. All were filled in immediately after investigation stopped.

The locations and depths of the trial pits are summarised in Table 3 and the locations of the trial pits are illustrated in Figure 7. Detailed logs of each pit are presented in Appendix 2.

Table 3 Summary of trial pit locations and depths

Trial pit identifier	Easting	Northing	Elevation (m OD)	Depth (m)
TP1	324228.1	647391.7	195.99	2.30
TP2	324150.7	647438.3	195.96	3.30
TP3	324056	647503.1	207.17	1.10
TP4	323947.4	647500.7	230.03	1.40
TP5	323854.7	647631	243.37	2.33
TP6	324078.4	647643.3	211.22	2.00
TP7	324229.1	647741.1	197.9	2.40
TP8	324157.7	647738	200.44	1.60
TP9	324382.9	647922.7	198.59	3.00
TP10	324274.9	647927.5	198.76	1.90
TP11	324101.4	647991.6	212.63	3.85

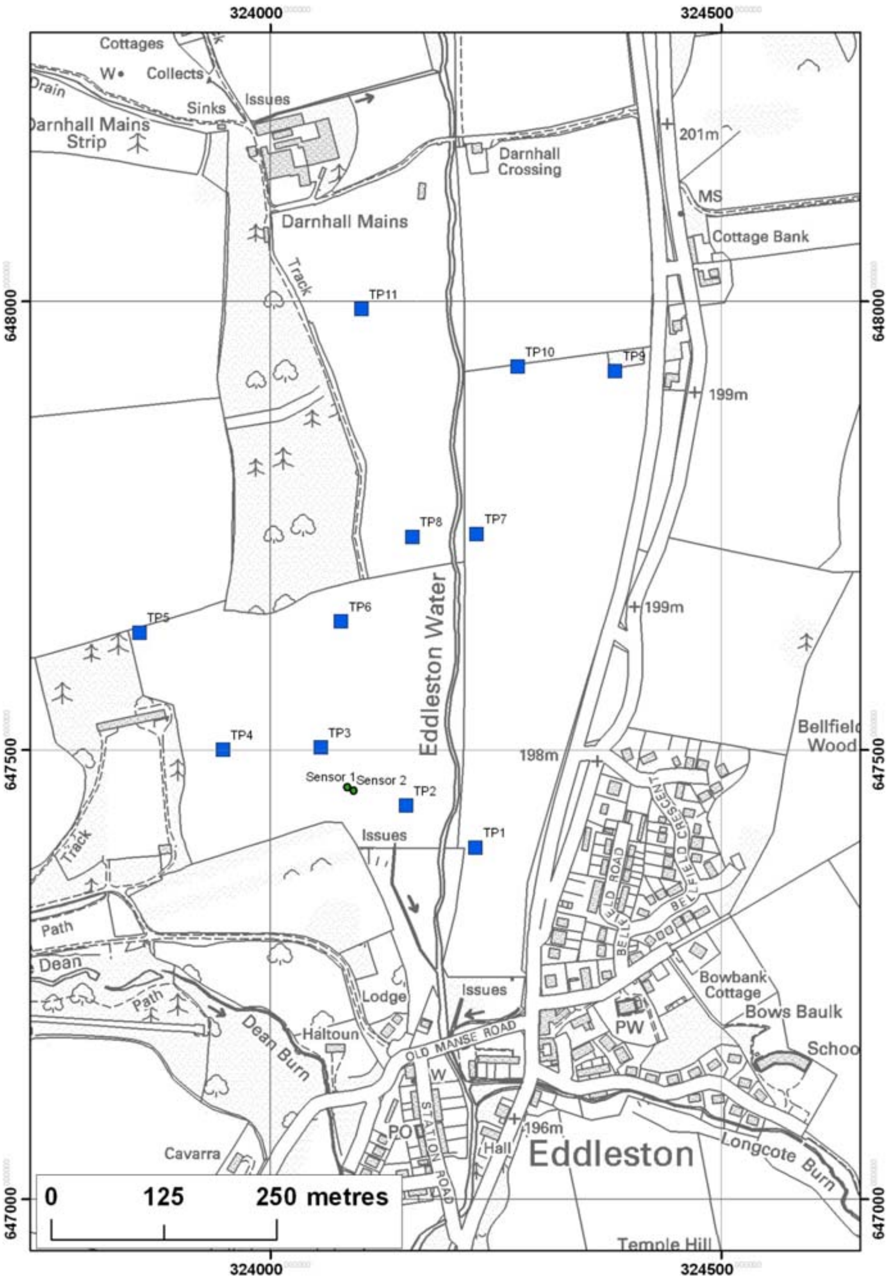


Figure 7 Location of trial pits dug at the Eddleston experimental site

5 Drilling boreholes and installing floodplain piezometers

Borehole drilling and piezometer installation at the Eddleston site are described, and lithological and construction logs are presented here. The installation and details of shallower, smaller piezometers in a wetland part of the trial site are described in Section 7. The results of hydraulic testing on the floodplain piezometers are presented in Section 8.

Borehole drilling was contracted to Groundwater Monitoring and Drilling Ltd. All the boreholes were drilled with a shell and auger (percussion) rig, in order to maximise geological sample recovery and therefore the amount and quality of geological data collected. Drilling was carried out between 28 April and 13 May 2011.

Nine boreholes were drilled, and installed with a total of 11 piezometers (two of the boreholes each have two nested piezometers at different depths). The piezometers are in pairs with one shallower (typically 4 to 5 m but occasionally less than 2m deep) and one deeper (typically 7 to 8 m deep) piezometer at each location. At one location there is a triplet of piezometers. All of the boreholes are completed in Quaternary deposits.

A further nine smaller, shallower piezometers were installed in a wetland area in one part of the trial site, in three triplets. These are described in Section 7.

Each borehole was given a drilling identifier. Subsequently, each piezometer was given a separate identifier to reflect the positioning of the piezometers in pairs (or in one case a triplet).

A summary of the boreholes drilled and piezometers installed is presented in Table 4. The locations of the boreholes and piezometers is shown in Figure 8. Detailed geological and construction logs for the boreholes are presented in Appendix 3.

Table 4 Summary of boreholes drilled and floodplain piezometers installed

Temporary borehole (drilling) identifier	Piezometer identifier	Easting	Northing	Borehole depth (m)	Depth of base of screened section (m)	Length of screened section (m)	Geology of screened section
EDS1	EDS1A	324105	647407	5.31	4.56	0.76	Sandy alluvial or glaciofluvial gravel
EDS2	EDS1B	324102	647403	1.65	1.6	0.35	Peat
EDS4	EDS2A	324149	647416	7.61	6.59	0.76	Very sandy gravel
EDS3	EDS2B	324161	647399	4.2	3.92	0.6	Very sandy gravel
EDS5	EDS3A	324193	647711	8.58	8.09	0.76	Sandy gravel
EDS6	EDS3B	324190	647707	4.75	3.75	0.76	Sandy gravel
EDS5	EDS3C	324193	647711	1.58	0.98	0.65	Sandy gravel
EDS7	EDS4A	324290	647521	8.02	7.01	0.76	Sandy gravel
EDS8	EDS4B	324284	647522	5.04	4.04	0.76	Very sandy gravel
EDS9	EDS5A	324236	647523	13.07	12.07	0.8	Gravel
EDS9	EDS5B	324236	647523	4.7	4.00	0.76	Sandy alluvial or glaciofluvial gravel

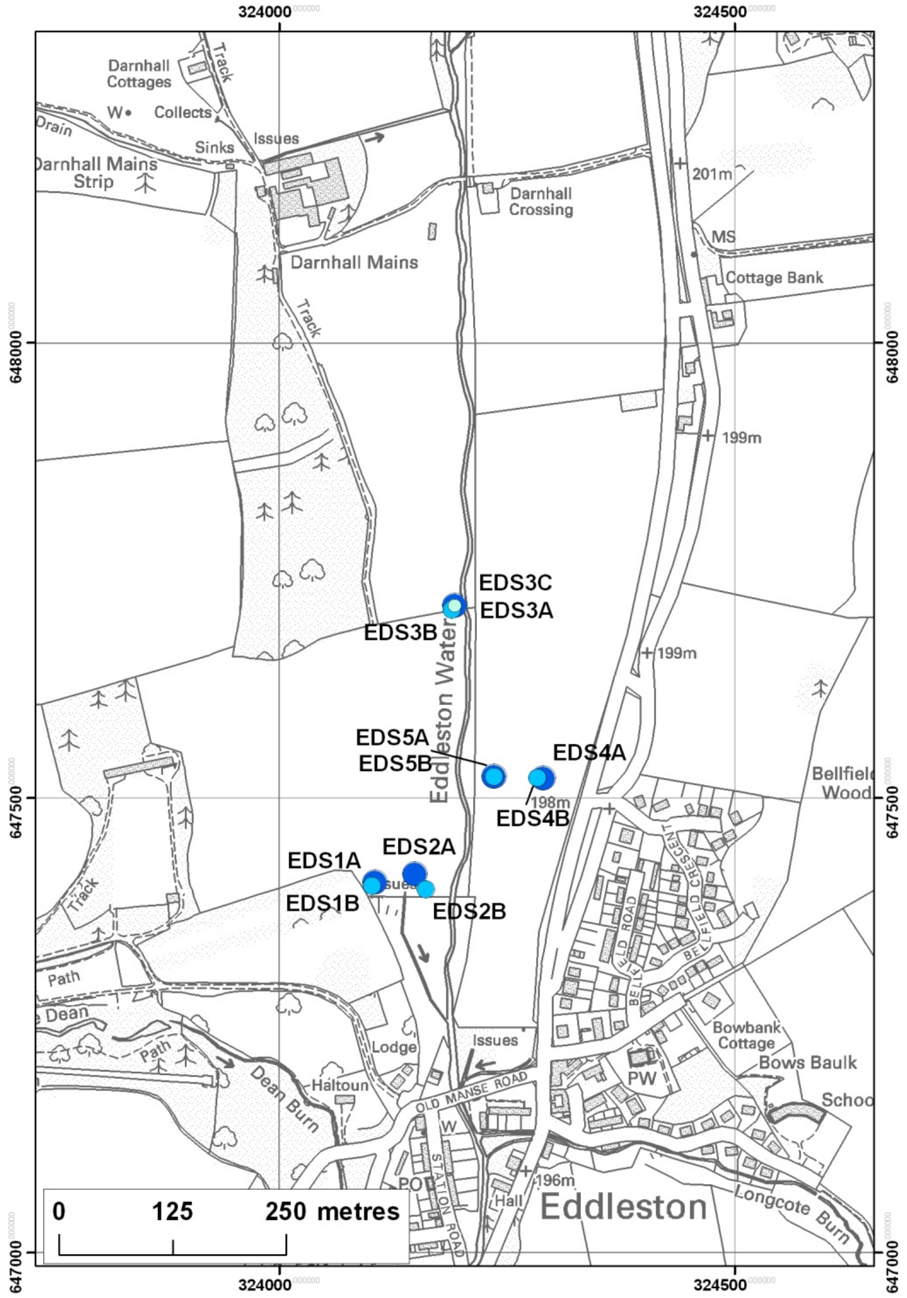


Figure 8 Location of piezometers in the Eddleston Water Floodplain Project area

6 Development of a 3D geological model

The new geological survey data from the site (Section 2) were combined with trial pit (Section 4) and borehole logs (Section 5) and geophysical survey results (Section 3) to develop a detailed three dimensional geological model of the Eddleston site.

The digital data were processed, prepared and imported into the GSI3D [4] geological modelling software. All the available borehole, trial pit, auger hole and geophysical data were considered during the geological interpretation and creation of the 3D model. Additionally, the model uses a digital terrain model (DTM) as the upper surface of the model, which was derived from high resolution Lidar data provided by Scottish Borders Council.

The key technique for geological interpretation was the creation of geological cross sections showing the spatial relationships between the different geological units. A generalised geological cross section was devised to best fit the geological deposits observed and recorded in the surveying/data collection phase. Cross sections were also constructed to coincide with geophysical lines (Section 3), and some extra sections were created to help with model constraint and calculation. The lines of all the cross sections used in the construction of the 3D model are shown in Figure 9.

Once the data were interpreted, there was a checking phase based on interrogating a fence diagram comprising all the constructed cross sections. Geological ‘envelopes’ marking the three dimensional extents of each geological unit were then defined. Final model calculation was done by triangulation of nodes from correlated geological units in cross section lines, geological envelopes and the DTM, with several iterative phases to get the best possible calculation.

Once completed, the model was exported to the BGS Lithoframe viewer (a model viewing and interrogation package) and to 3D PDF. Examples of these outputs are given in Figure 10. The exported model in the BGS Lithoframe viewer will be available to partners within the Eddleston Water Project consortium to use within the Eddleston Water Project. The 3D PDF will be published on the BGS website for public access.

[4] For more information on GSI3D see http://www.bgs.ac.uk/services/3dgeology/researchDevelopment.html

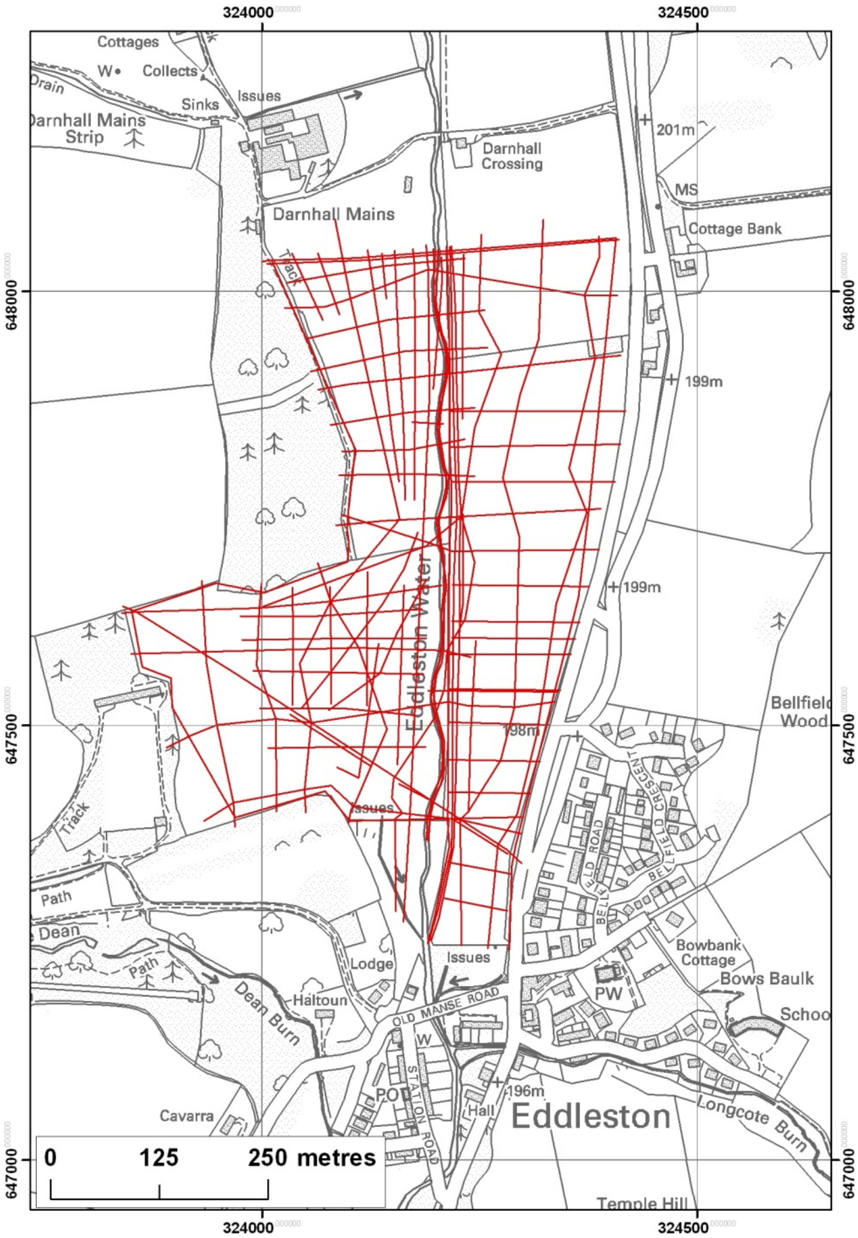


Figure 9 Lines of the geological cross sections drawn up during the construction of the 3D geological model

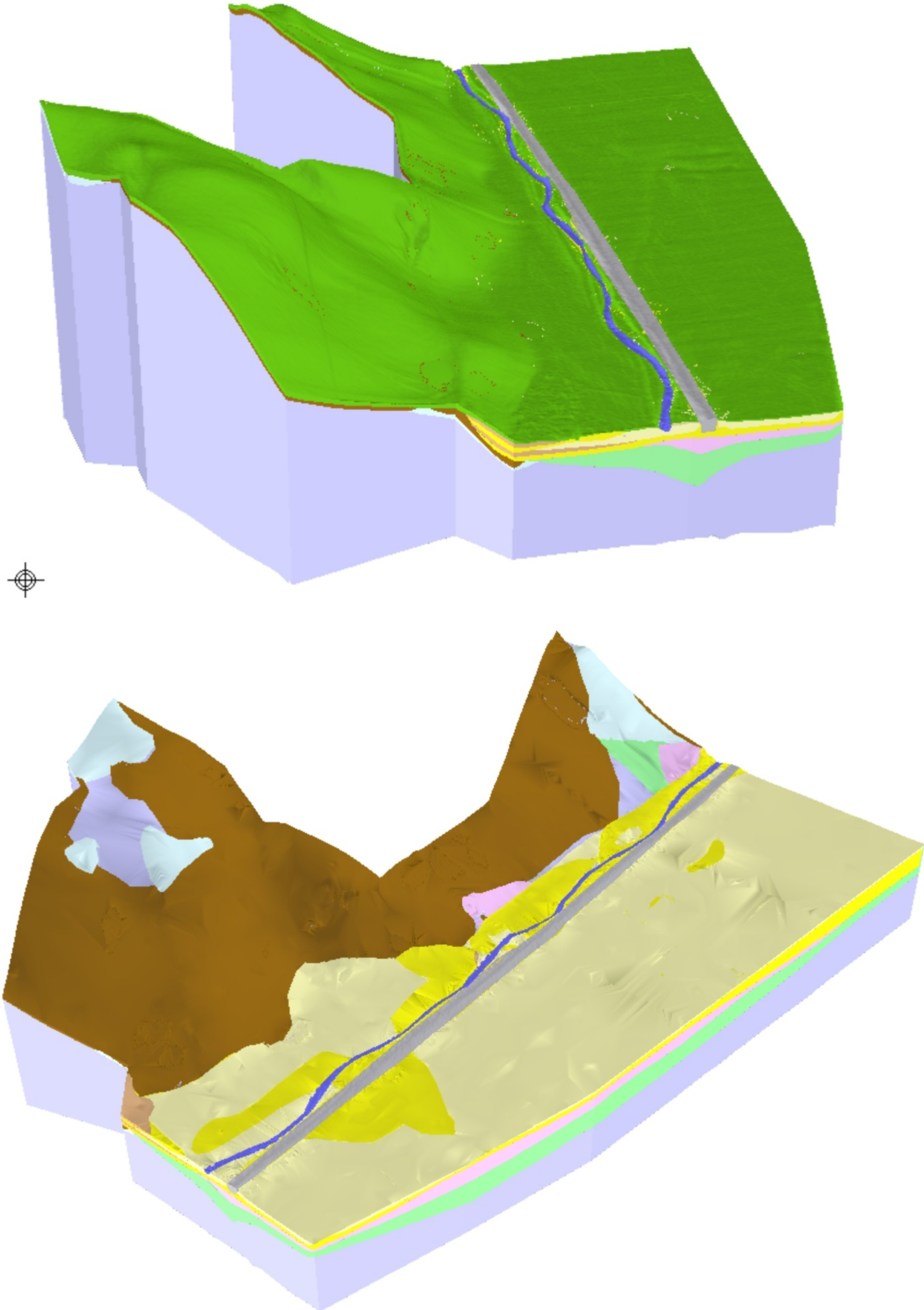


Figure 10 Examples of outputs from the 3D geological model of the Eddleston experimental site: (top) view from southwest across site; (bottom) view from southeast across site with soil layer removed to show underlying superficial deposits

7 Installation of shallow wetland piezometers

In April 2011, three groups each of three shallow piezometers (a total of nine piezometers) were installed in a wetland area within the Eddleston experimental site (Figure 11), with the aim of increasing understanding of the hydrology of the wetland area. In each piezometer group, there is one ‘deep’ piezometer installed to a maximum depth of between 1.5 and 2 m below ground level (mbgl); one ‘shallow’ piezometer at a depth of between 0.5 to 0.6 mbgl and one surface piezometer which measures the water level above ground. Summary details of the piezometers are given in Table 5.

The piezometers were installed by hand using a 50mm diameter Dutch auger. PVC screen of 32mm internal diameter with 1mm slots was used, cut to the required lengths (screen lengths are shown in Table 5). Plain PVC casing, also of 32mm diameter, was used for the rest of the piezometer lengths. The piezometers were sealed at the bottom with 40 to 50 mm long sumps. Washed sand, 1 mm in diameter, was packed around the piezometer screen and bentonite pellets were packed to about 50 mm from the ground surface. The soil taken out of the augered hole was then packed above the bentonite.

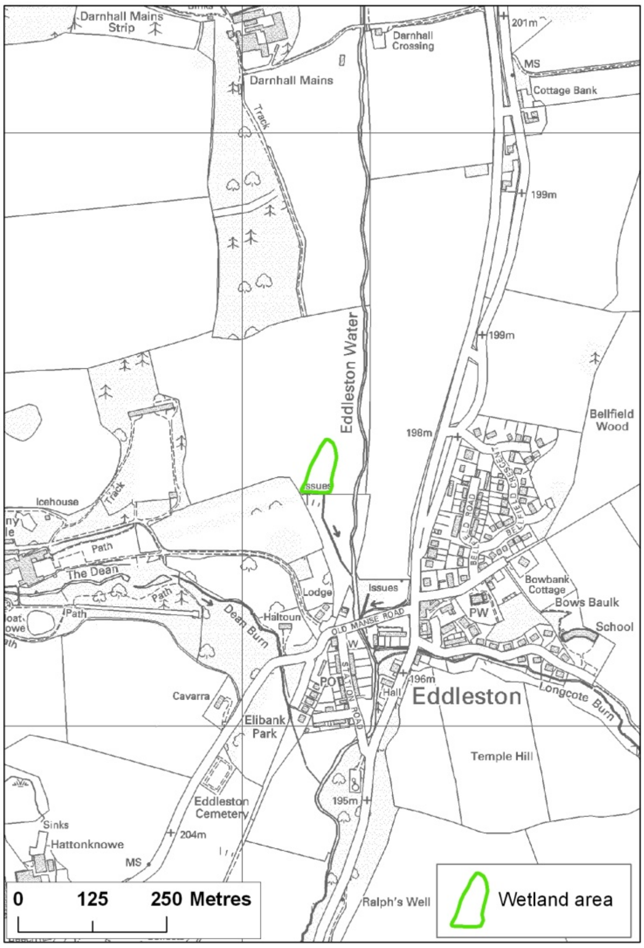


Figure 11 Location of wetland area in Eddleston experimental site

Table 5 Summary of wetland piezometers installed

Temporary installation identifier	Piezometer identifier	Easting	Northing	Piezometer depth (m)	Depth of base of screened section (m)	Length of screened section (m)	Geology of screened section
EB1	EB1A	324143	647419	1.85	1.8	0.85	Silt to coarse sand
EB2	EB1B	324143	647419	0.56	0.51	0.16	Peat
EB3	EB1S	324142	647419	0.58	Tbc[1]	Tbc	Ground surface of wetland
EB4	EB2A	324120	647439	1.20	1.15	0.25	Sandy silt to medium coarse gravel
EB5	EB2B	324120	647440	0.54	0.49	0.13	Peat
EB6	EB2S	324120	647440	0.59	Tbc	Tbc	Ground surface of wetland
EB7	EB3A	324141	647449	1.84	1.72	0.85	Sandy silt with some fine gravel
EB8	EB3B	324142	647449	0.55	0.51	0.16	Mainly silt with some peat
EB9	EB3S	324142	647448	0.59	Tbc	Tbc	Ground surface of wetland

[1]To be confirmed

8 Hydraulic testing of floodplain piezometers

Ten of the eleven floodplain piezometers were tested to establish the hydraulic properties of the geological units below the floodplain and begin to develop a conceptual model of the floodplain aquifer(s). The tests were done between 25 and 29 July 2011, and for each piezometer a constant rate test was run for between 80 and 360 minutes. For the higher yielding piezometers, a suction pump with a capacity of approximately 2 litres/second (l/s) was used; for the lower yielding piezometers, an electrical Whale pump with a capacity of approximately 0.14 l/s (12 m^3/day) was used. Table 6 shows a summary of the test pumping results. Transmissivity values calculated from pumping borehole drawdown and recovery data, and from observation borehole data where relevant, and from these a 'preferred transmissivity' value representing the most probable best estimate has been defined.

Table 6 Summary of test pumping results from floodplain piezometers

Piezo-meter	Test date	Rest water level (mbgl) [1]	Average test yield (m^3/d)	Pump	Test length (min)	% recovery at end test	Maximum drawdown (m)	Specific capacity (m^3/d/m)	T draw-down phase (m^2/day)	T recovery phase (m^2/day)	T observation borehole (m^2/day)	Preferred transmissivity (m^2/day)
EDS1A	25/07/2011	-0.03	159	Suction	300	93.4	0.182	873.63	400	1000	485 (drawdown) 1800 (recovery)	1000
EDS1B	26/07/2011	0	12	Whale	0.5	99.7	0.74	16.22		2		<10
EDS2A	26/07/2011	0.3	13.5	Whale	80	95	0.1	135.00		220		220
EDS2B	26/07/2011	0.47	11.8	Whale	95	98.9	1.03	11.46	35	30-55		50
EDS3A	26/07/2011	0.74	1478	Suction	300	95.8	0.49	3016.33	415			415
EDS3B	29/07/2011	1.0	132	Suction	300	94.9	0.76	173.68	340	450	380; 835 (both drawdown)	400
EDS4A	27/07/2011	0.55	12.6	Whale	100	97.2	0.137	91.97	400	370		400
EDS4B	29/07/2011	0.51	12.3	Whale	105	91.9	0.15	82.00	100	240		200
EDS5A	28/07/2011	0.865	11.5	Whale	100	100	0.24	47.92				
EDS5B	27/07/2011	0.675	171	Suction	360	94.4	1.245	137.35	160	290		250

[1] With pump installed

9 Hydraulic testing of wetland piezometers

Pumping tests were carried out on the wetland piezometers between 26 May and 29 May 2011. Because of the low permeability of the wetland deposits in which the piezometers are installed, a low flow Solinst variable peristaltic pump was used, with a flow rate of between 40 ml/min and 3.5 l/min. Two pumping methods were used:

1) A rapid recovery method, where the piezometer was pumped dry and the time taken for the water level in the piezometer to recover to rest level was measured, and
2) A constant yield test, where the piezometer was pumped constantly for at least one hour, and the water level in the piezometer measured throughout the pumping and the following recovery period until it recovered to rest level.

The constant yield method was only used for EB2A, as this piezometer had a higher yield than the other piezometers. All other piezometers were pumped dry even at very low pumping rates.

Transmissivity values were calculated using a numerical flow model (Barker 1988). A summary of the results of the pumping tests is given in Table 7.

Table 7 Summary of test pumping results from wetland piezometers

Piezo-meter	Test date	Rest water level (mbgl)[1]	Average test yield (m^3/d)	Pump	Test length (min)	Maximum drawdown (m)	Modelled transmissivity (m^2/day)
EB1A	26/06/2011	0.37	0.139	Solinst	45	0.525	0.054
EB1B	29/06/2011	0.35	1.08	Solinst	26	0.33	0.0006
EB2A	28/06/2011	0.3	0.392	Solinst	52	0.225	3.8
EB2B	26/07/2011	0.47	1.27	Solinst	40	0.27	0.0008
EB3A	26/07/2011	0.45	0.39	Solinst	13	0.945	0.0038
EB3B	29/07/2011	0.48	0.83	Solinst	24	0.88	0.0032

[1] With pump installed

10 Soil permeability surveying

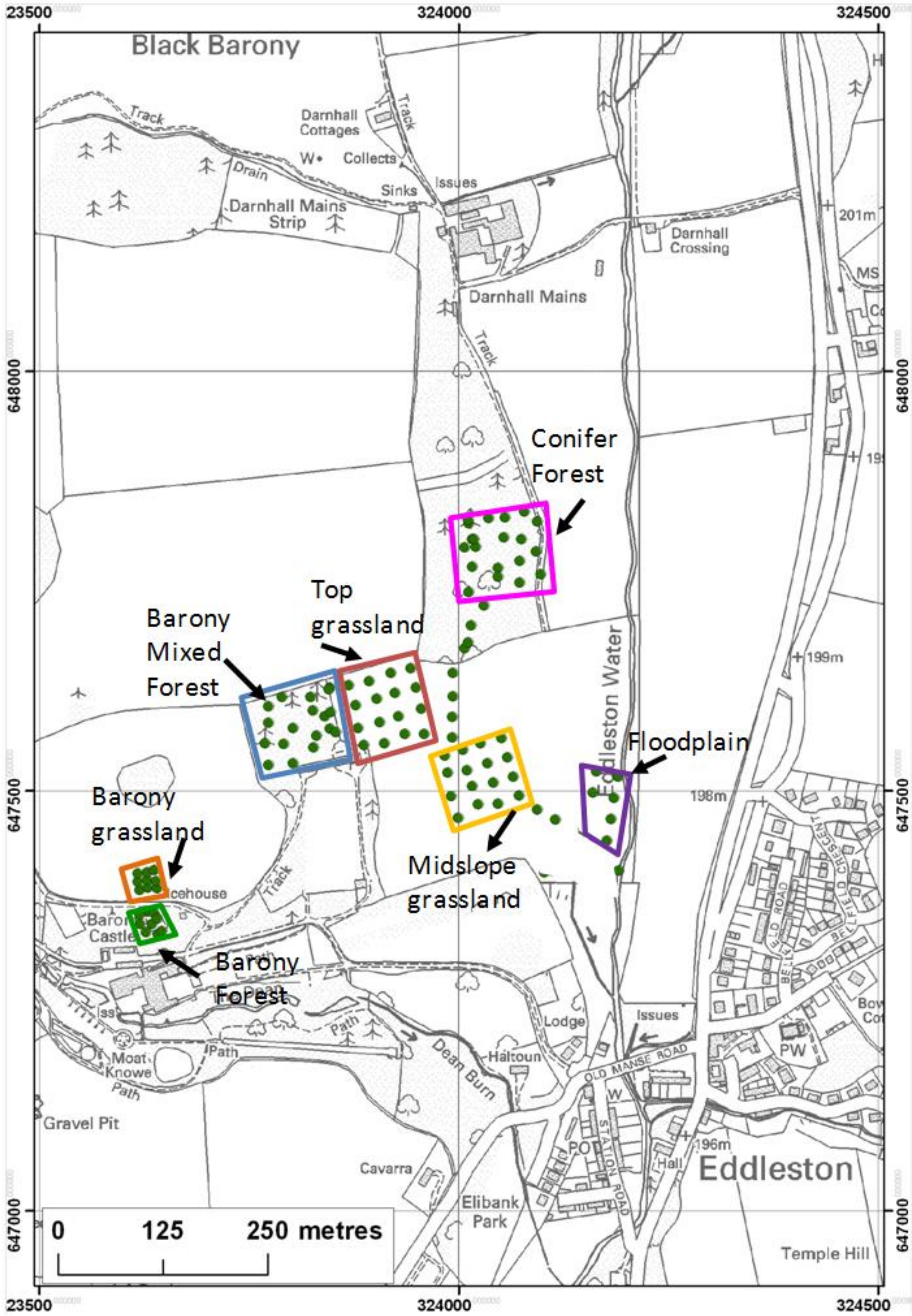
Measurements of soil permeability were made during two field campaigns. The first took place between 9 June and 18 June 2011, when point measurements were made in five areas (Table 8, Figure 12) on a grid system, with a measurement every 25 m on the grid intersections. Additional measurements were made across and down the hill slope (Figure 12). The second field campaign was done between 3 July and 08 July 2011, to measure permeability in two more areas further upslope in the experimental site (Table 8, Figure 10).

Permeability was estimated by calculating field saturated hydraulic conductivity (Kfs) from measurements using a constant head permeameter based on the Simplified Well Permeameter Procedure described by Talsma and Hallam (1980). During the first field campaign, a 5 cm diameter auger was used to auger a hole to 15 cm soil depth at each grid point intersection. The hole was wetted for 20 minutes, and the rate of falling water over time was measured from the water column of the permeameter. A falling head of 11 cm of water was used throughout all the measurements. The same procedure was used in the second field campaign, but two depths were measured instead of a single depth: one from 4-15 cm and one from 15-25 cm.

Table 8 Summary of soil permeability measurements

Field campaign	**Area**	**Number of soil permeability measurements**	**Hole depth (cm)**
1	Floodplain	7	15
	Midslope Grassland	16	
	Top Grassland	16	
	Barony Mixed Forest	15	
	Conifer Forest	16	
2	Barony Grassland	13	4-15
	Barony Old Forest	15	15-25

A summary of the results of the survey, giving measured field hydraulic conductivity (Kfs) for soil depths 4 to 15 cm in all the sample areas, and for soil depths 15-25cm for Barony Grassland and Barony Old Forest, is presented in Appendix 4. Normalised distribution curves of the data are also presented in Appendix 4.



Note: GPS-measured coordinates of sites in forest areas are still to be corrected for signal drift under the forest canopy.

Figure 12 Location of soil permeability measurements in the Eddleston experimental site

11 Survey of surface soil saturation near wetland

A survey of surface soil saturation at the bottom of the hill slope near to the wetland area (Figure 13) was done in order to map the possible routes of surface and subsurface water drainage between the slope and the wetland. The ground was walked over systematically, and every point where the ground began to squelch under foot – taken as an indicator of surface soil saturate – was located accurately using a Differential Global Positioning System (DGPS). Points where saturated ground becomes ponded with water 2 cm above ground level were also located accurately using DGPS.

Figure 13 Wetland area and area of surface soil saturation survey

12 Installing monitoring equipment

At the end of the characterisation phase of this project, we began to install monitoring equipment for ongoing, potentially long term monitoring of the water environment at the Eddleston experimental site.

12.1 SOIL MOISTURE MONITORING

Six soil moisture sensors were installed on the lower hill slope above the wetland area (Figure 9) to measure volumetric soil moisture and possible downslope throughflow of soil water (Figure 14). The sensors were *ThetaProbes* ML2x, a type of capacitance sensor, designed and produced by Delta-T. The sensors were installed in two groups, each of three sensors, spaced 10 m apart up the lower hill slope. In each group, a sensor was placed at 20 cm, 35 cm and 60 cm depth (Figure 15). Logging began on 6 October 2011.Soil moisture is measured and logged every 30 minutes using a Delta-T DL2e logger.

Figure 14 Positions of the two groups of soil moisture sensors (red dots) on the lower hill slope

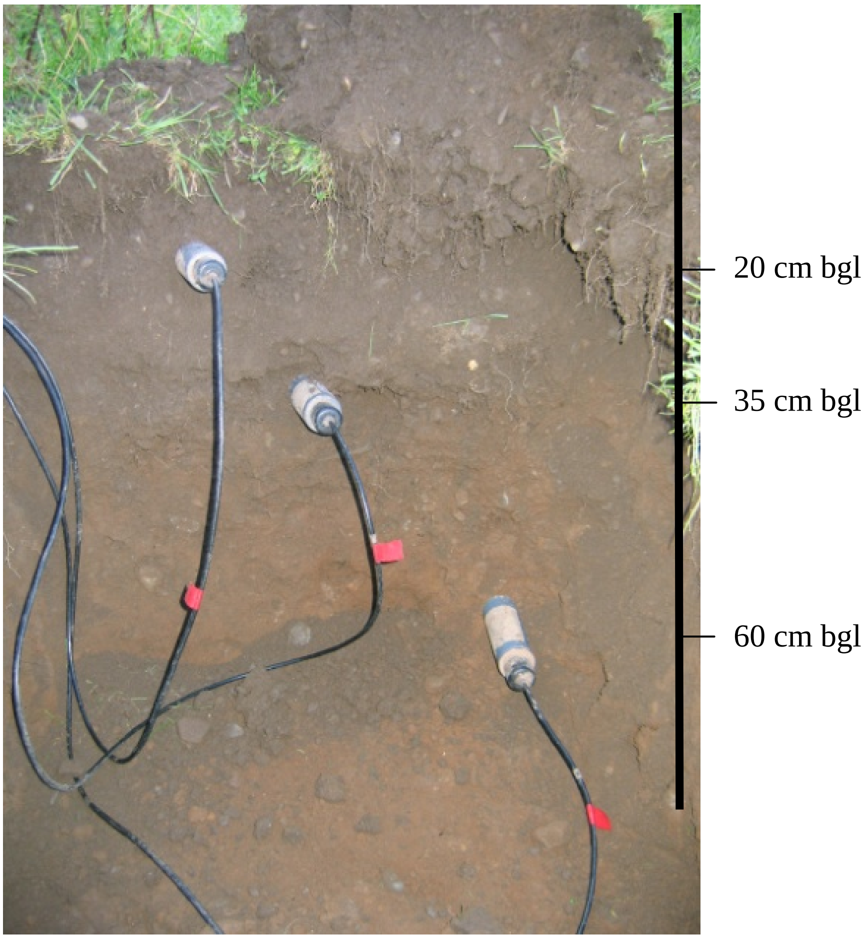


Figure 15 Soil moisture sensors installed at three depths

12.2 GROUNDWATER MONITORING

Eight groundwater level and temperature sensors have been installed in the floodplain piezometers. One of the sensors also measures groundwater conductivity. The groundwater level-temperature sensors are Aquistar PT2X Smart Pressure/Temperature Sensors and Dataloggers; the conductivity sensor is an Aquistar CT2X Conductivity Smart Sensor with pressure option. The sensors measure groundwater head pressure, and to convert this to groundwater level an Aquistar PT2X-BV Smart Barometric/Vacuum Sensor and Datalogger was installed near the Eddleston site to measure air pressure.

A summary of the installed groundwater sensors is given in Table 9.

Table 9 Summary of groundwater sensors installed in floodplain piezometers

Piezo	Sensor type	Sensor depth (mbgl)
EDS1A	PT2X	2.275
EDS1B	none	n/a
EDS2A	PT2X	3.43
EDS2B	PT2X	2.26
EDS3A	CT2X	Tbc
EDS3B	PT2X	3.61
EDS3C	none	n/a
EDS4A	none	n/a
EDS4B	PT2X	2.545
EDS5A	PT2X	7.01
EDS5B	PT2X	2.705

13 Summary

This report describes work done to characterise the shallow (Quaternary) subsurface environment (geology, hydrogeology and soil hydrology) of a new environmental experimental site at Eddleston, Scottish Borders, and presents the data that were gathered during an extensive and detailed investigation of the experimental site. These data form the basis for an in depth interpretation and characterisation of the geology, hydrogeology and soil hydrology of the site, which will be presented separately.

The following activities have been reported here:

- The geology of the site has been characterised by geological re-surveying, trial pitting, geophysical surveying, drilling, and the development of a three dimensional geological model.
- The hydraulic properties of the Quaternary aquifer beneath the floodplain have been characterised by test pumping.
- Soil permeability in areas of different land use across the site has been established, and areas of completely saturated soil identified.
- The hydraulic properties of the shallow (<2m) deposits beneath the wetland area have been characterised by test pumping.
- Equipment has been installed to enable long term monitoring of soil moisture, groundwater levels and groundwater temperature.

14 Future work

Characterisation of the physical subsurface environment at the Eddleston experimental site is only the first step in developing an improved understanding of the role groundwater plays in the Eddleston floodplain environment and in flooding events, and of how groundwater interacts with the local climate, soils and the Eddleston Water. Further characterisation work and ongoing monitoring of the hydrological and hydrogeological system is underway.

Further work is being done to characterise the groundwater and surface water chemistry and groundwater residence time across the site, and to start to investigate seasonal changes in water chemistry. This will help our understanding of surface water-groundwater interaction and the flow of water through the site.

The monitoring infrastructure already installed is being used to observe temporal and spatial variations in soil moisture, groundwater levels and groundwater temperature, and in one borehole, groundwater conductivity. These data will be used with river flow/stage and climatic data for the site, which are being gathered by the University of Dundee, to investigate surface water-groundwater interaction, the hydrological processes involved in flood events, and hydrological changes that occur due to any river restoration methods that are implemented, among other issues.

References

British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: http://geolib.bgs.ac.uk.

ANNAN A P. 1993. Practical processing of GPR data. Sensors and Software, Inc.

BARKER J A. 1988. A generalized radial flow model for hydraulic tests in fractured rock. *Water Resources Research* **24** (10), 1796–1804, doi:10.1029/WR024i010p01796

DAVIS J L AND ANNAN AP. 1989. Ground-penetrating radar for high-resolution mapping of soil and rock stratigraphy. Geophysical Prospecting 37, 531–551.

TALSMA T AND HALLAM P M. 1980. Hydraulic conductivity measurement of forest catchments. *Australian Journal of Soil Research* **18**, 139–148.

Appendix 1 Geophysical survey data

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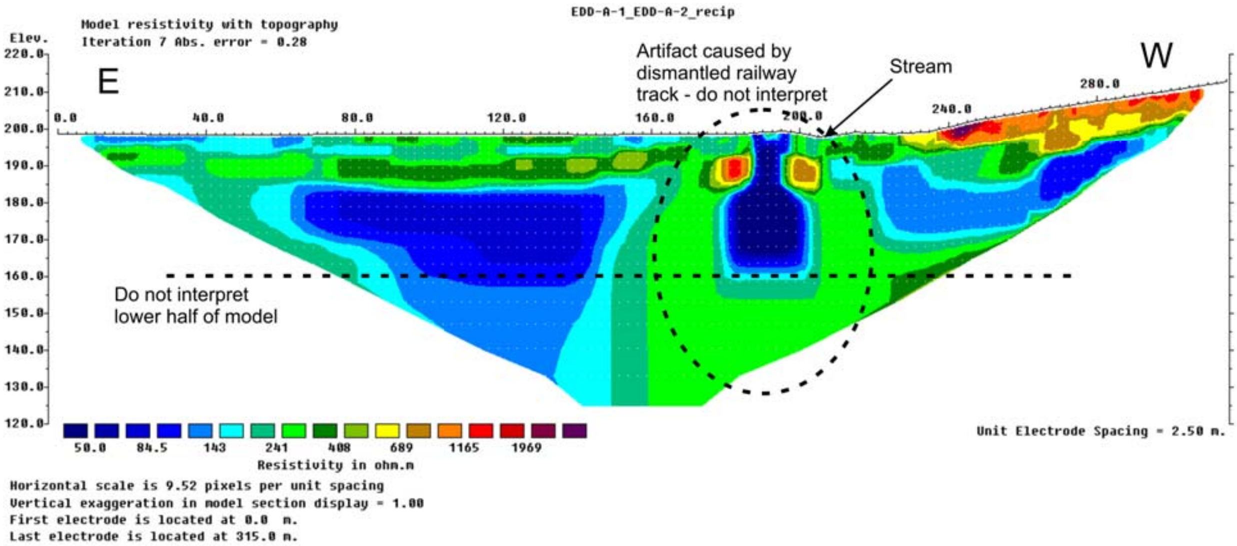

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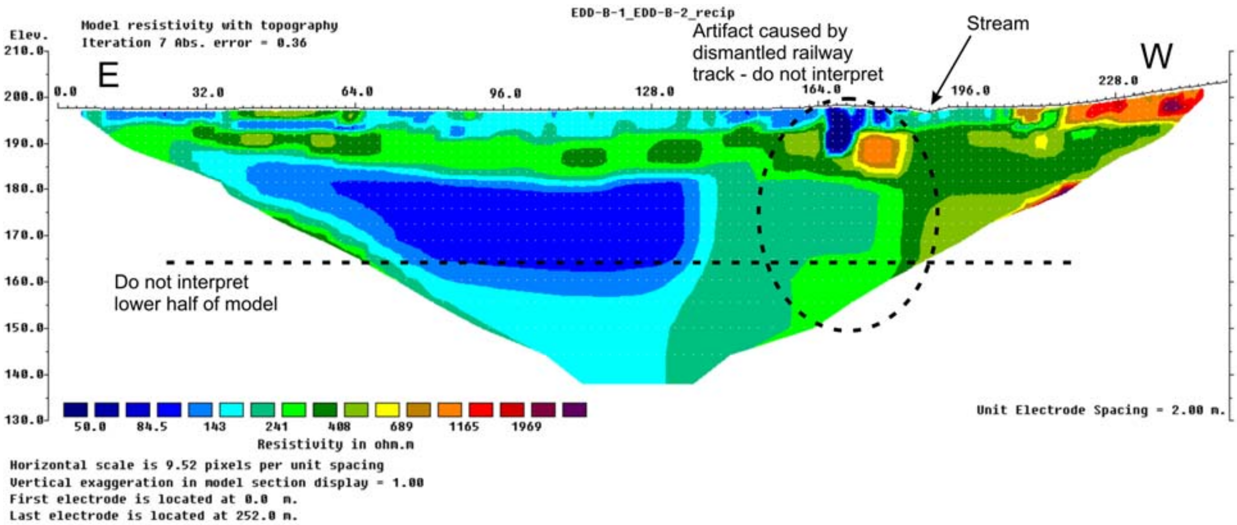

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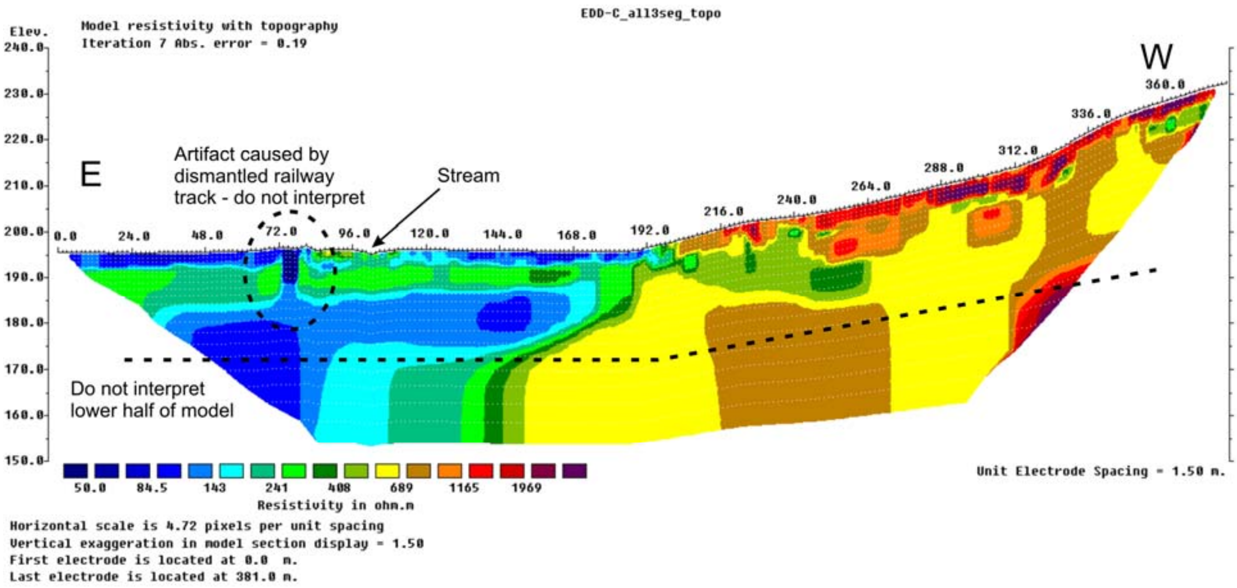

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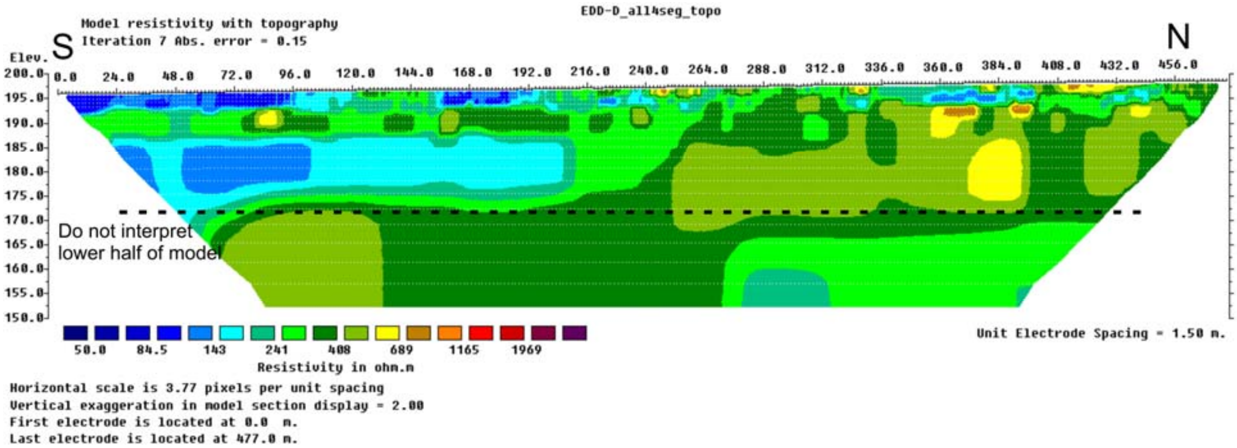

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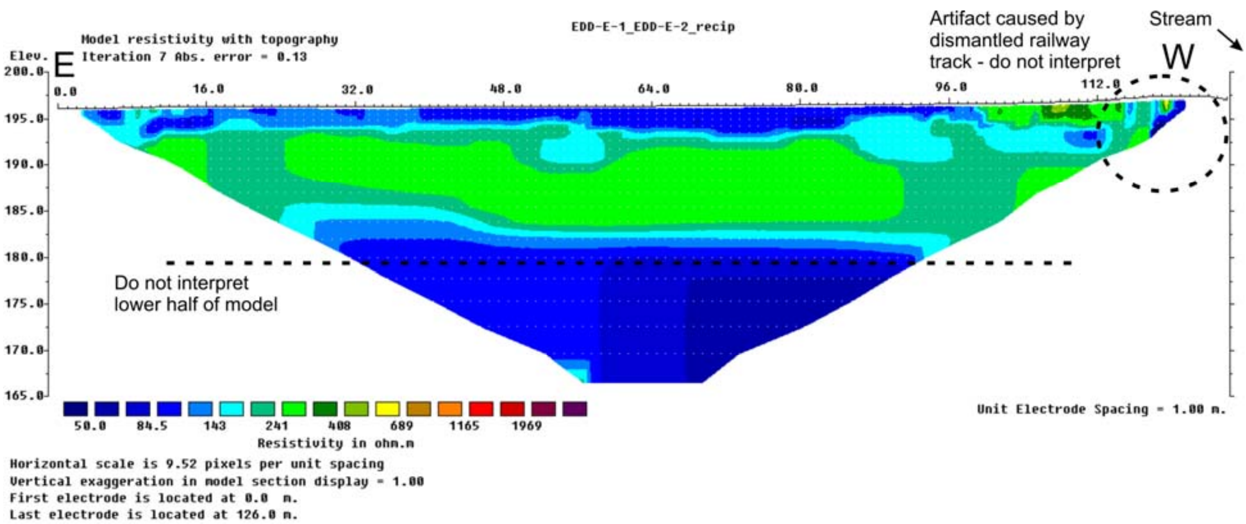

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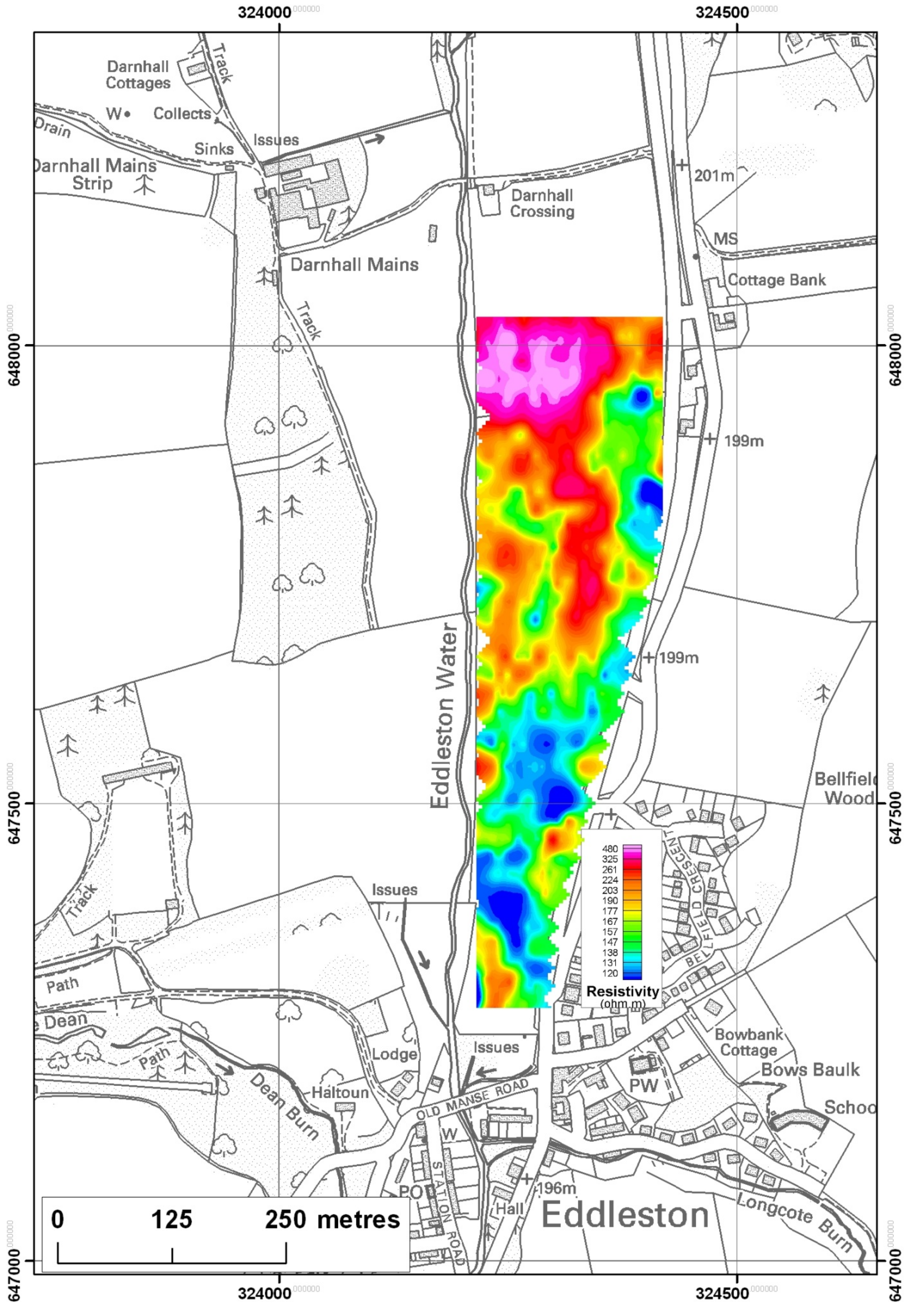

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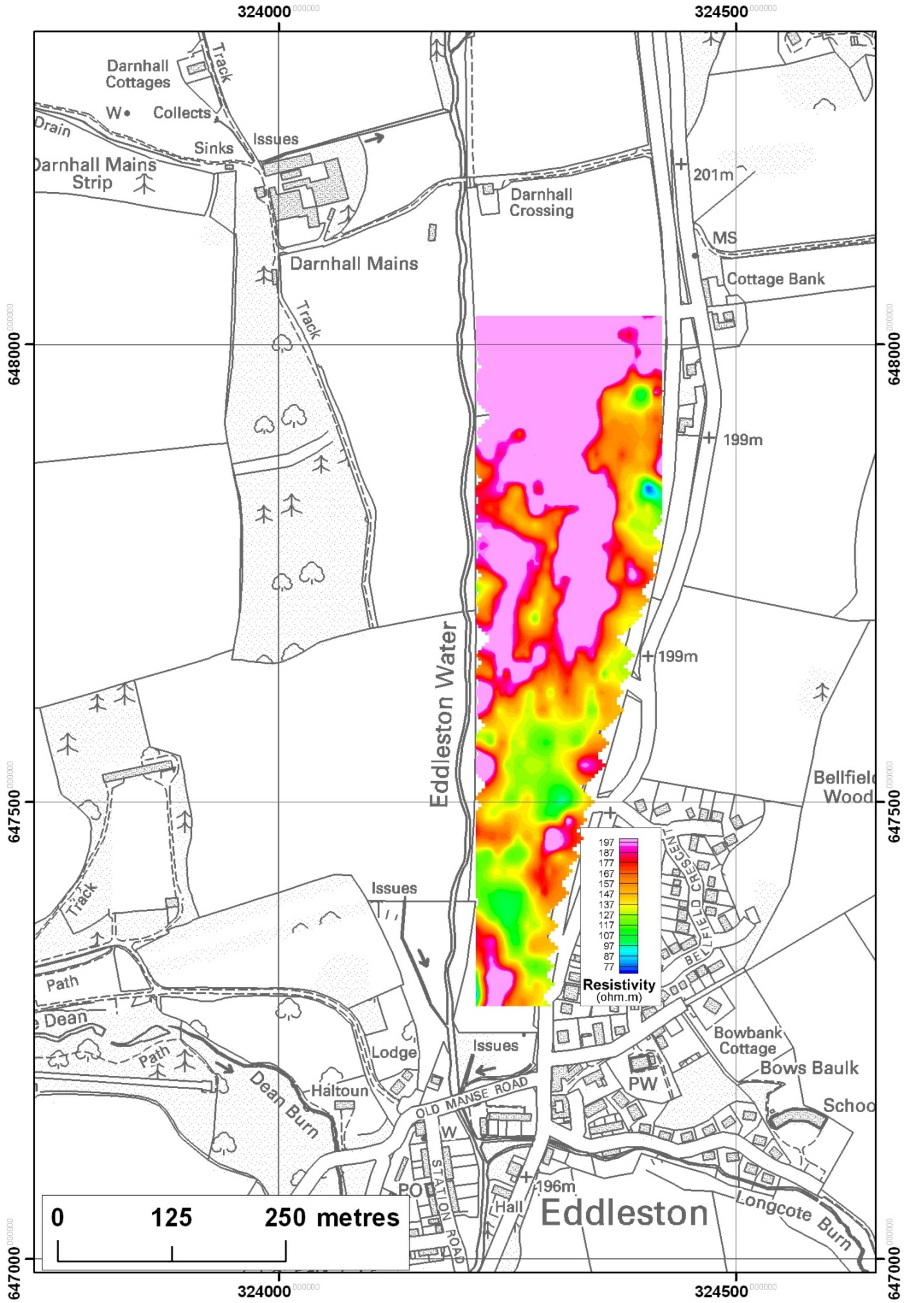

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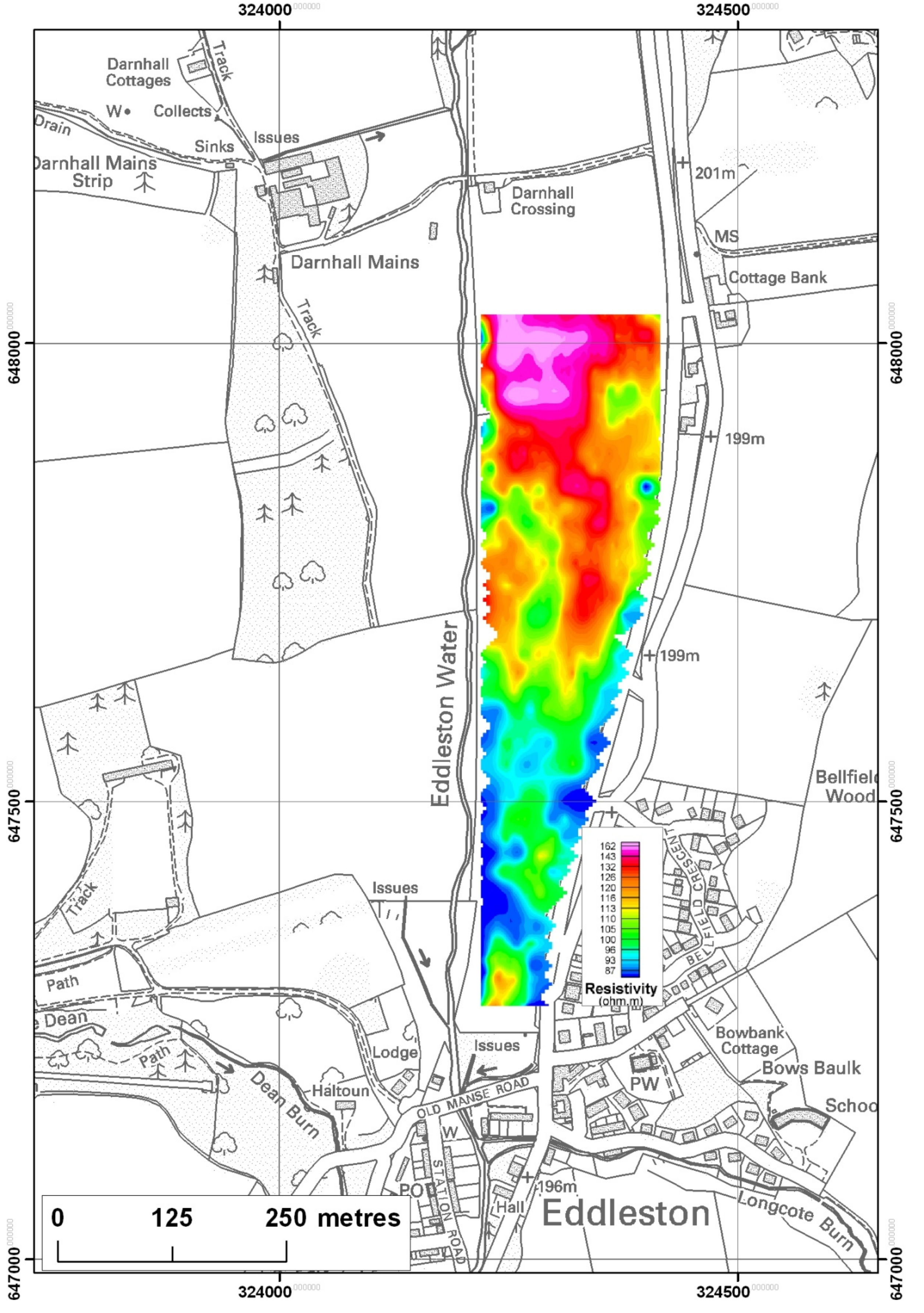

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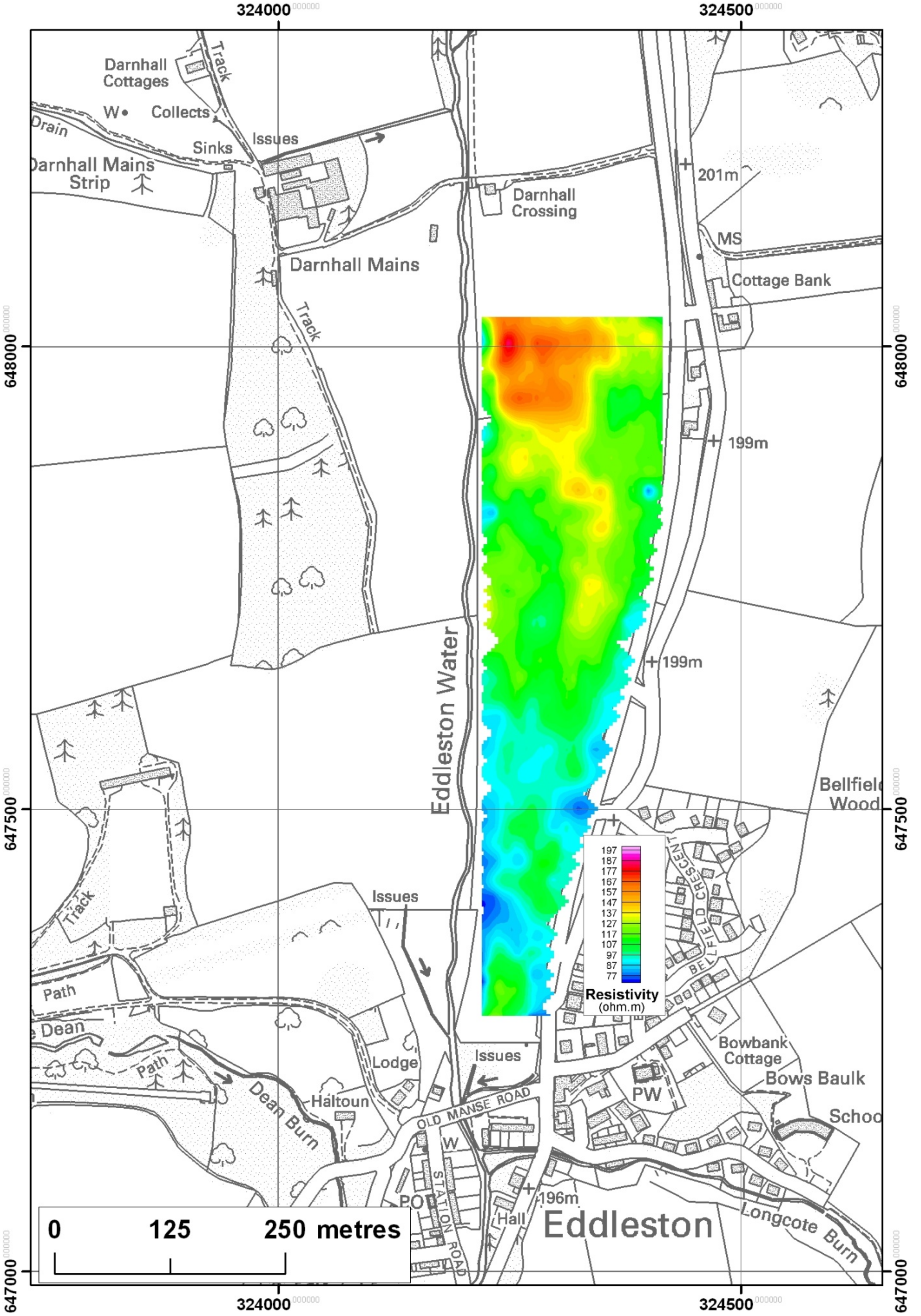

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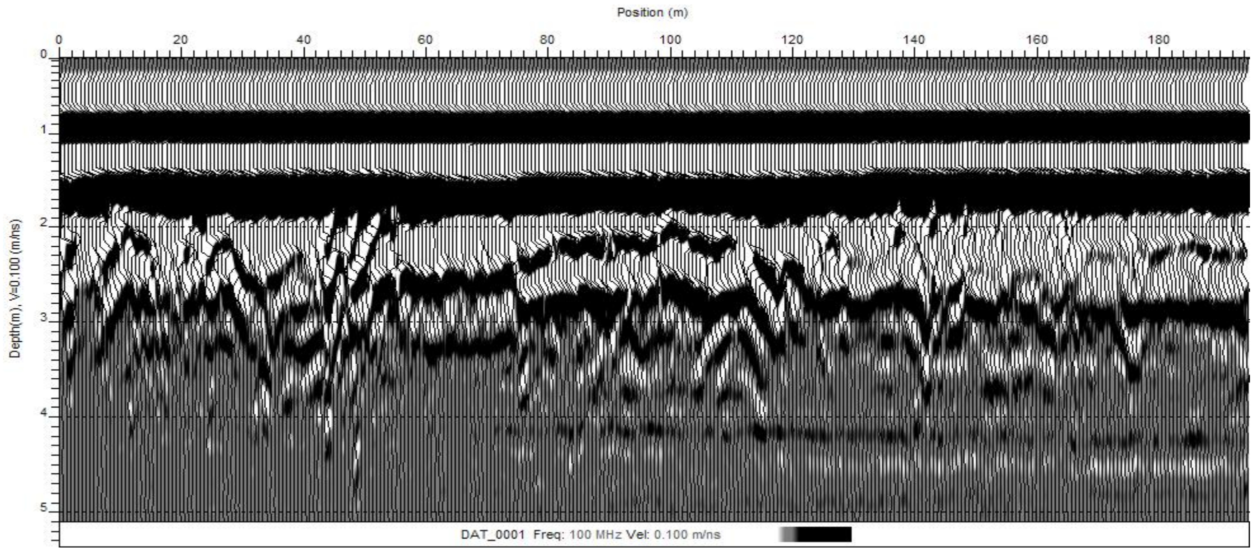
A1.3 GPR Data

A1.3.1 Data east of Eddleston Water (plotted from west to east)



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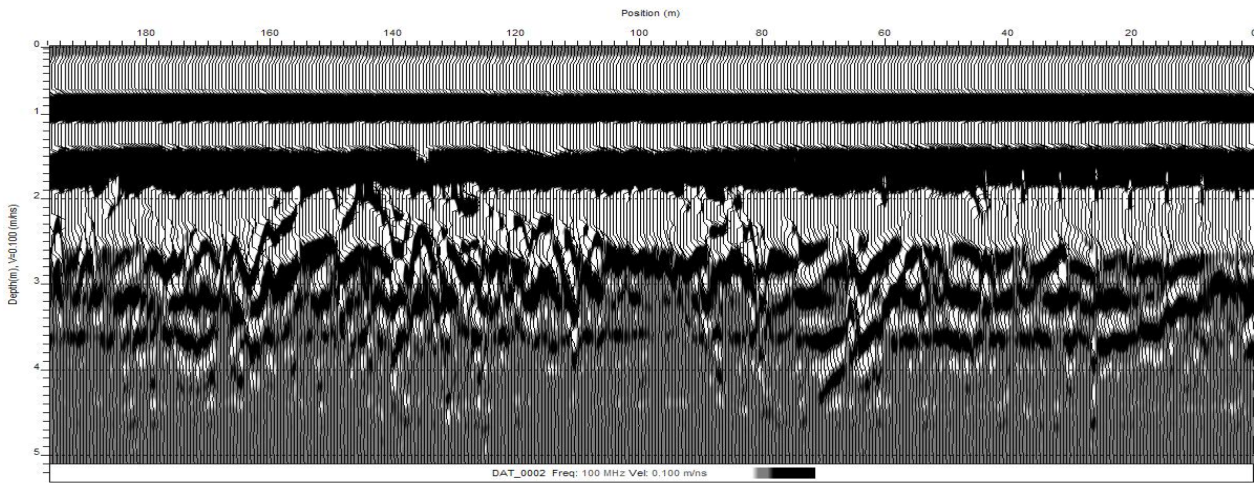

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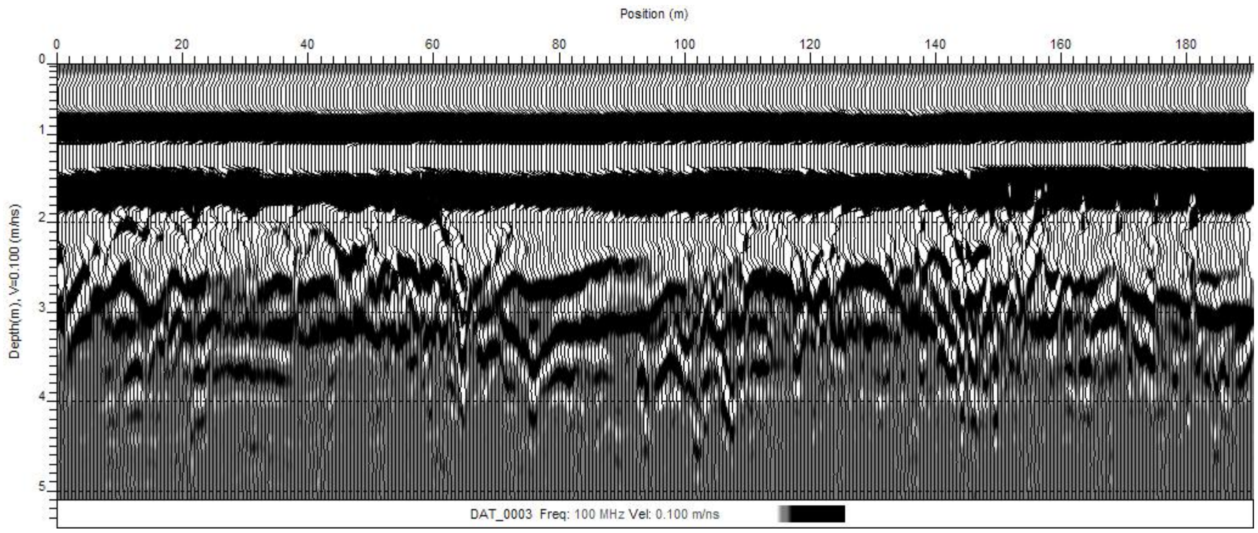

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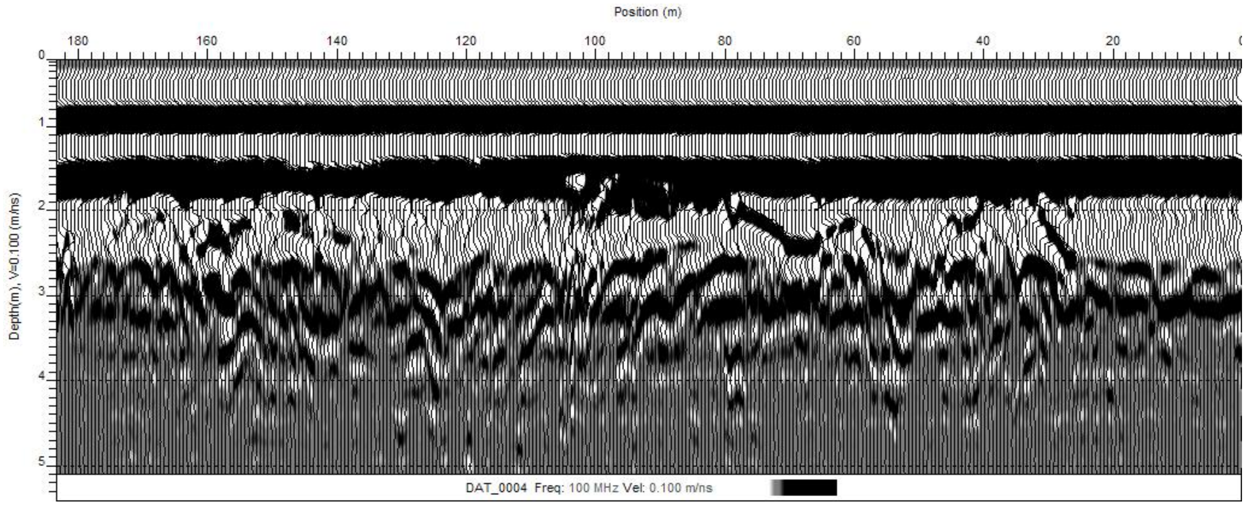

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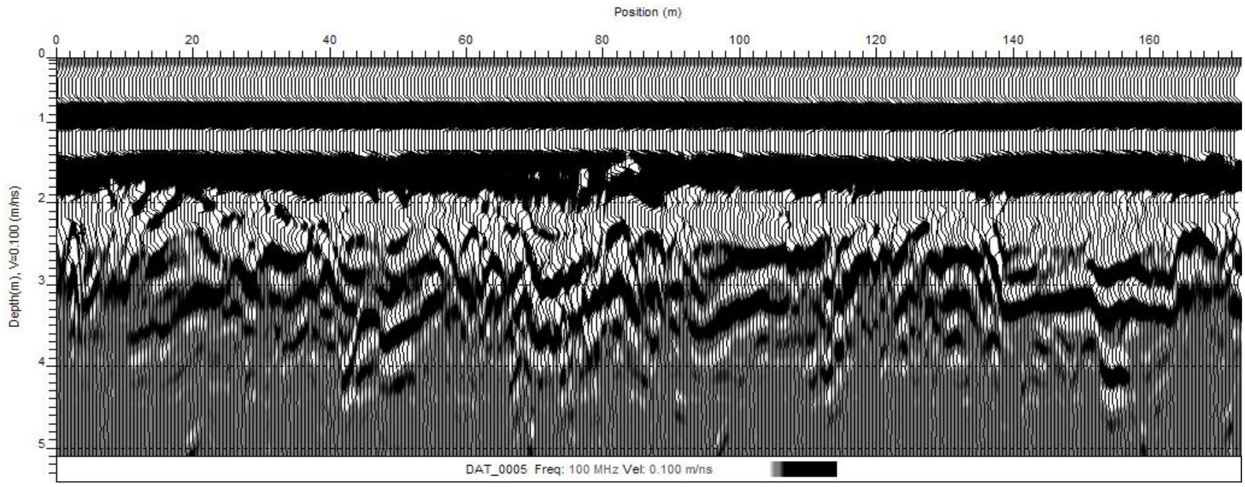

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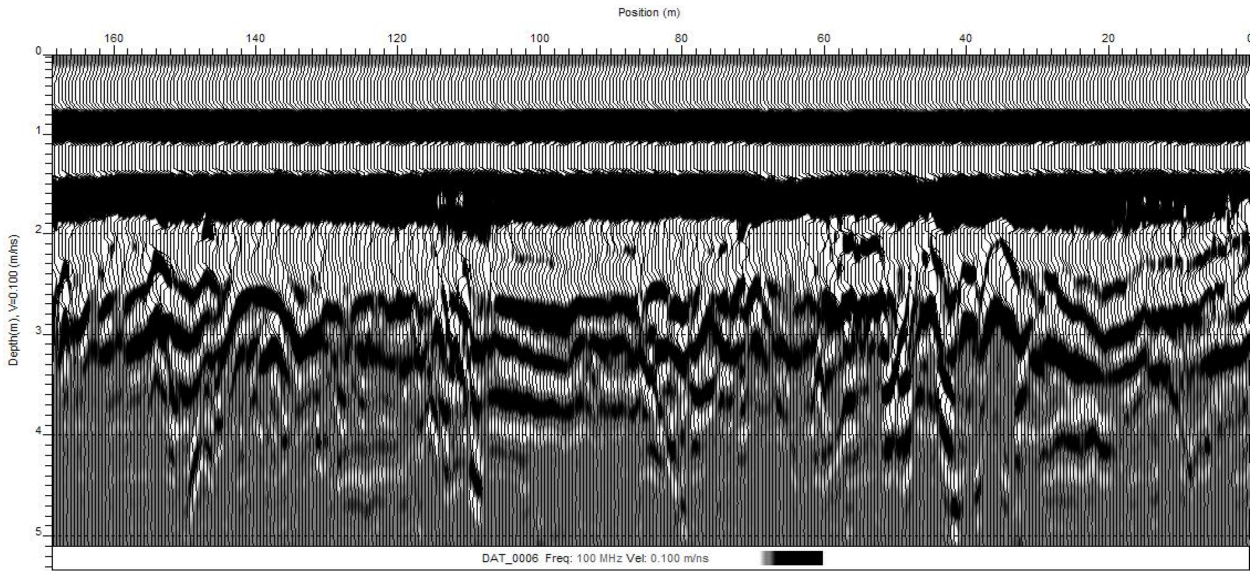

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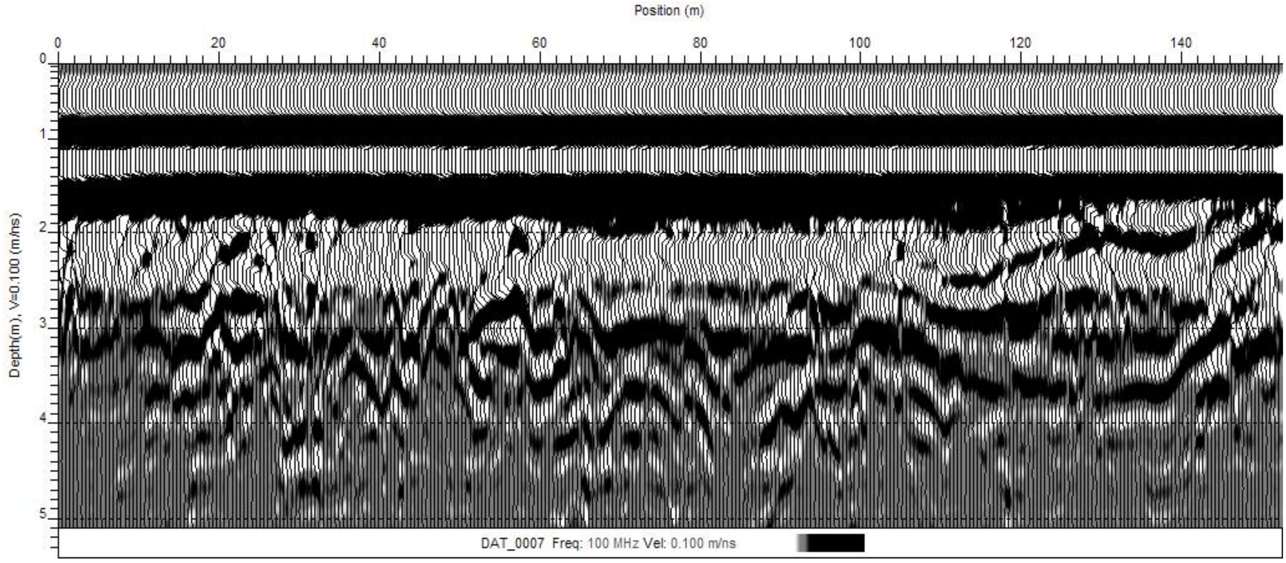

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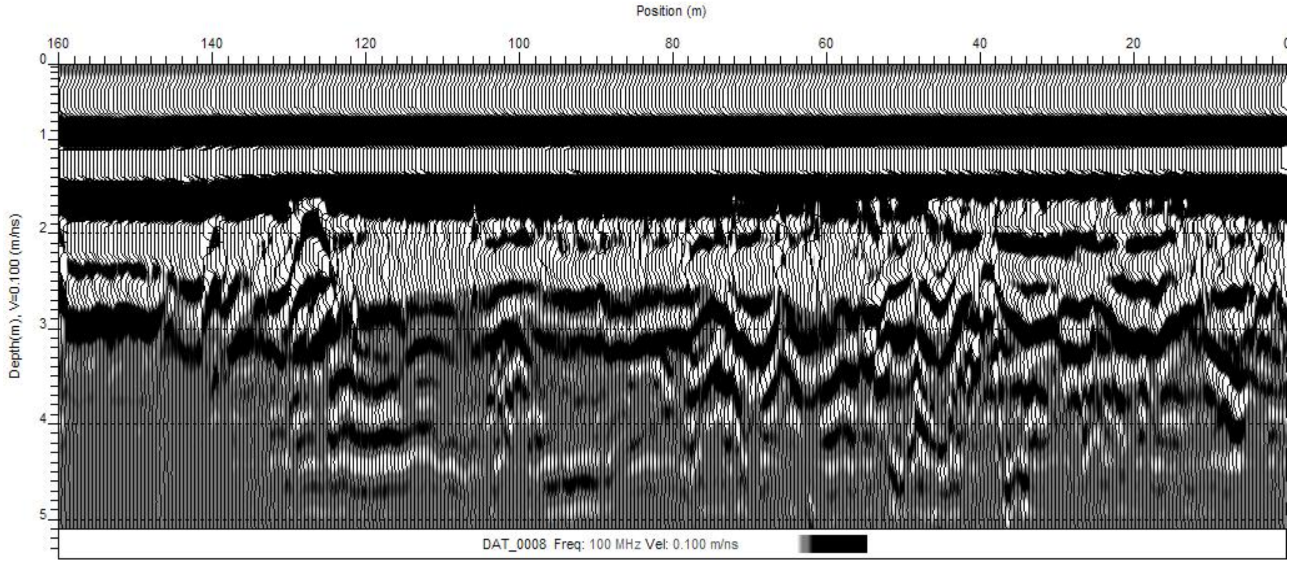

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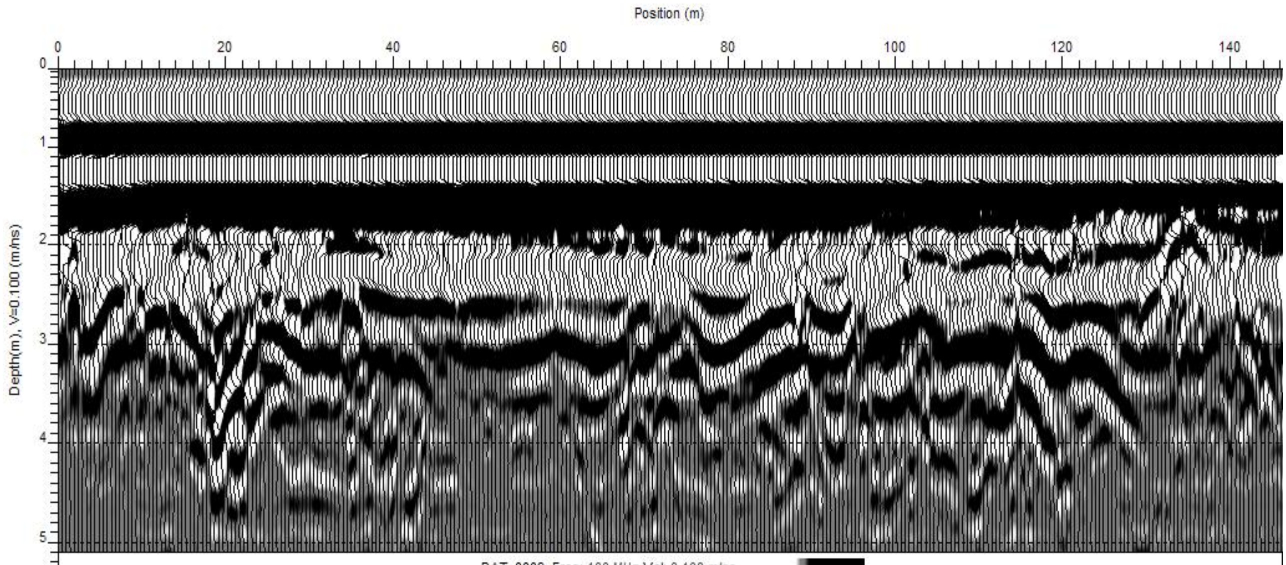

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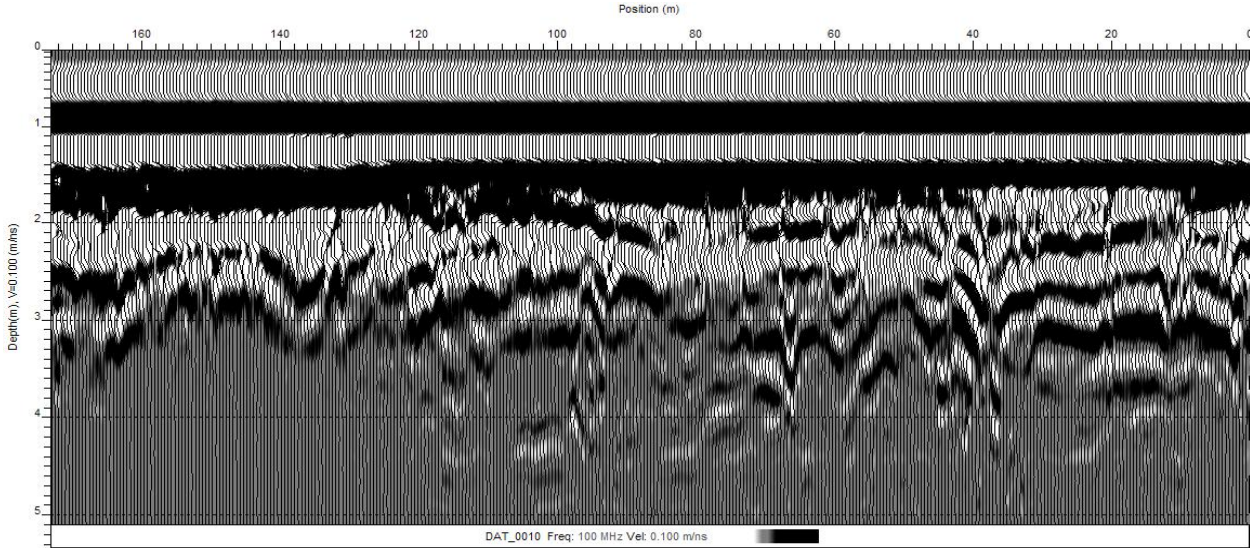

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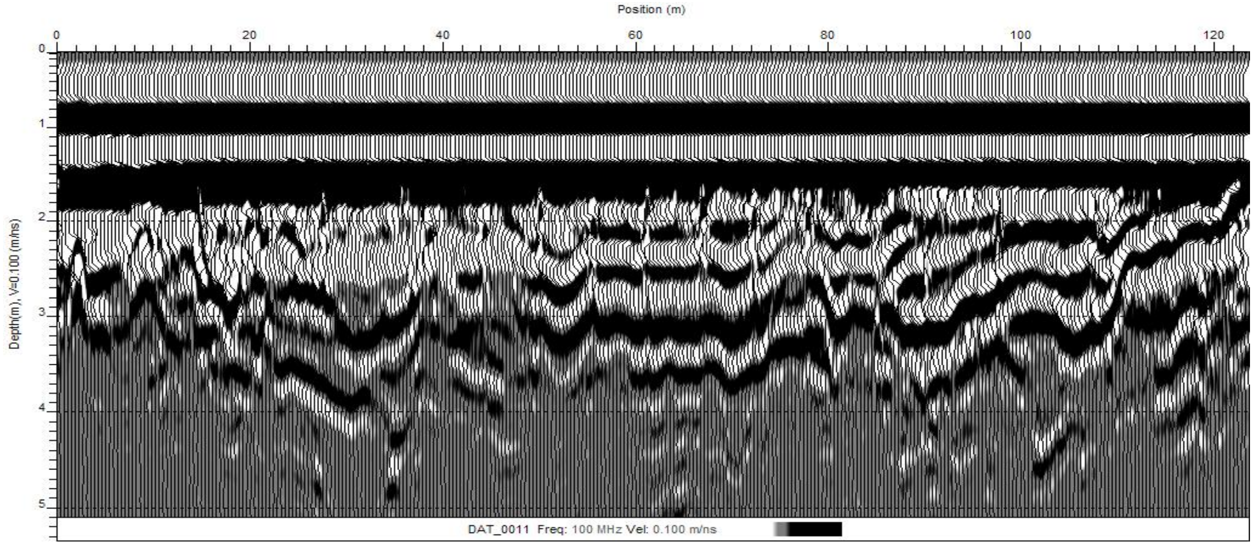

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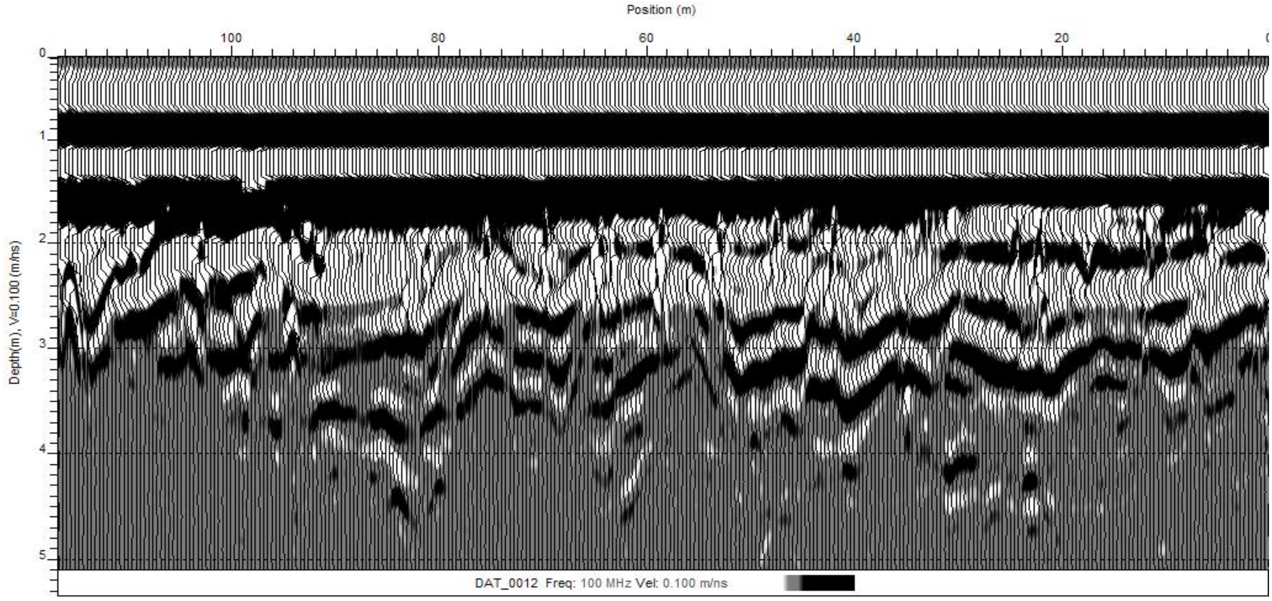

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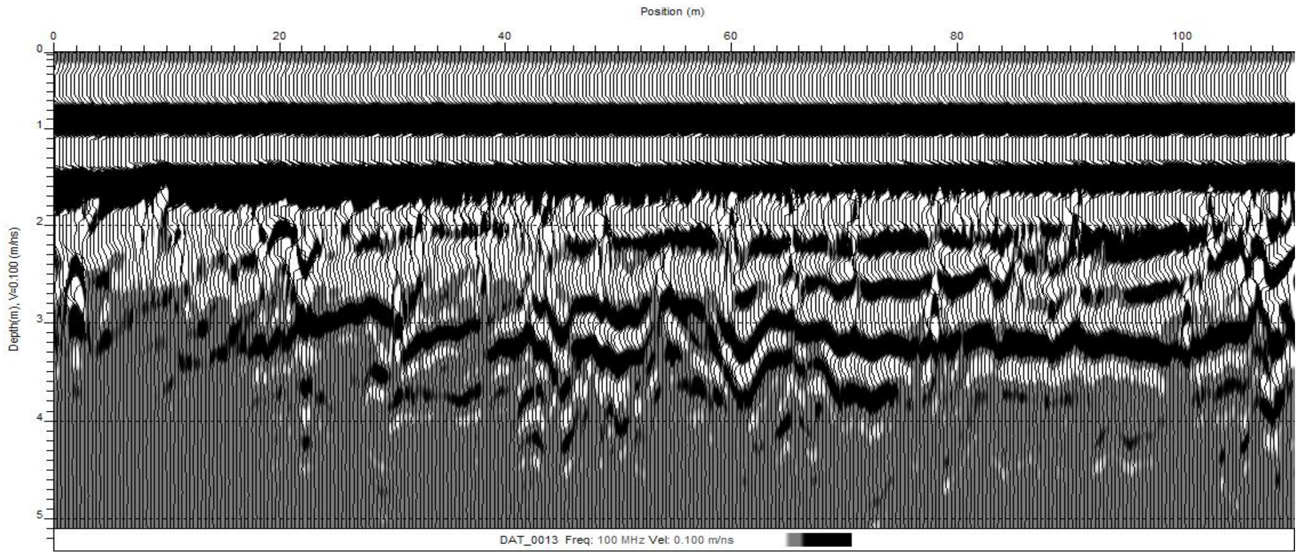

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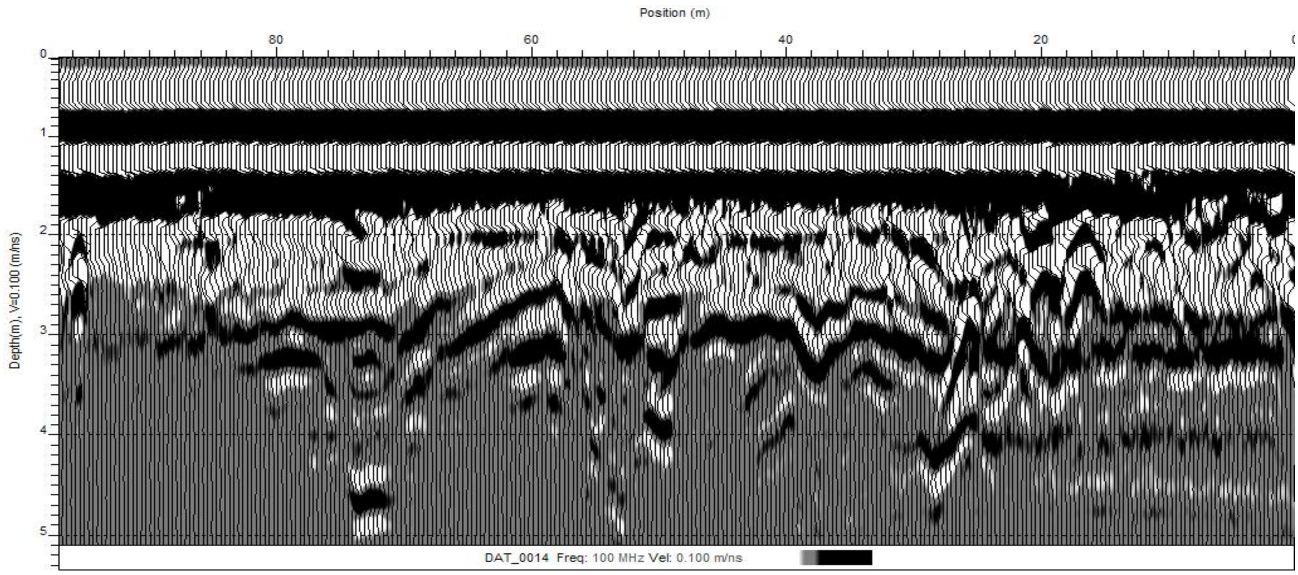

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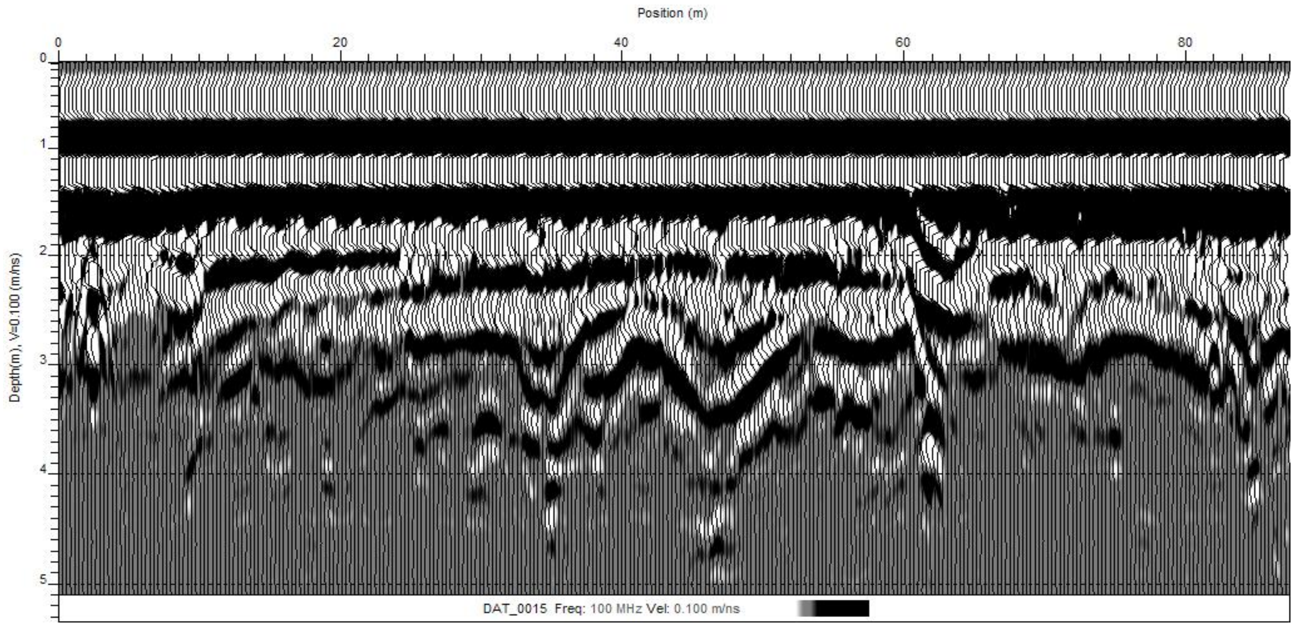

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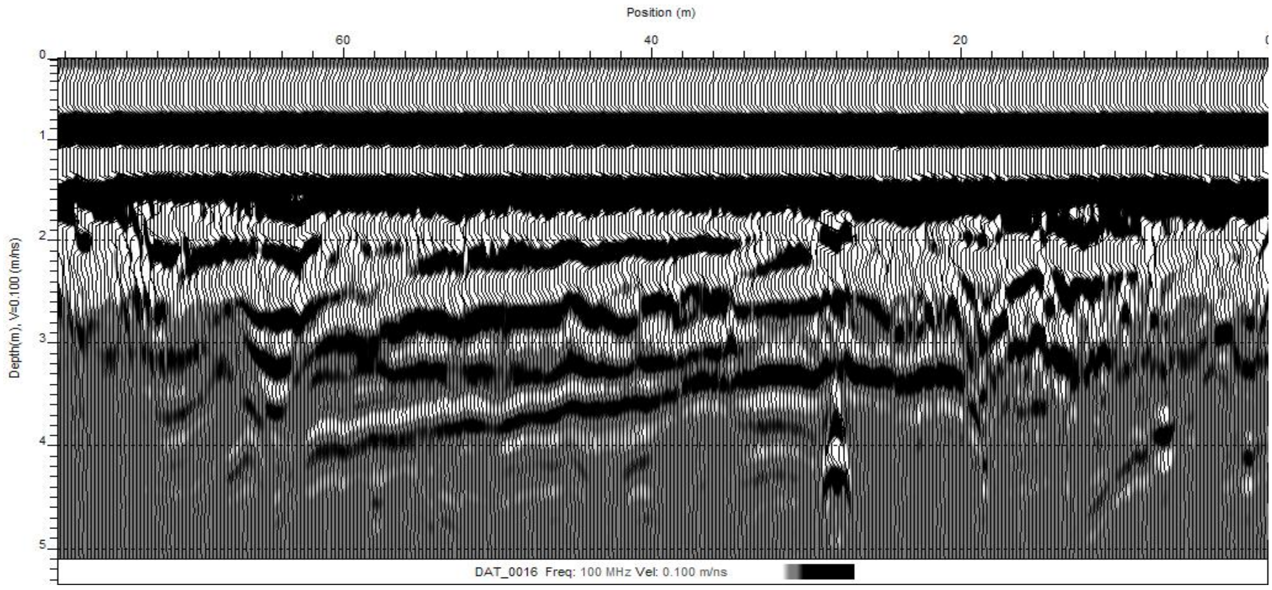

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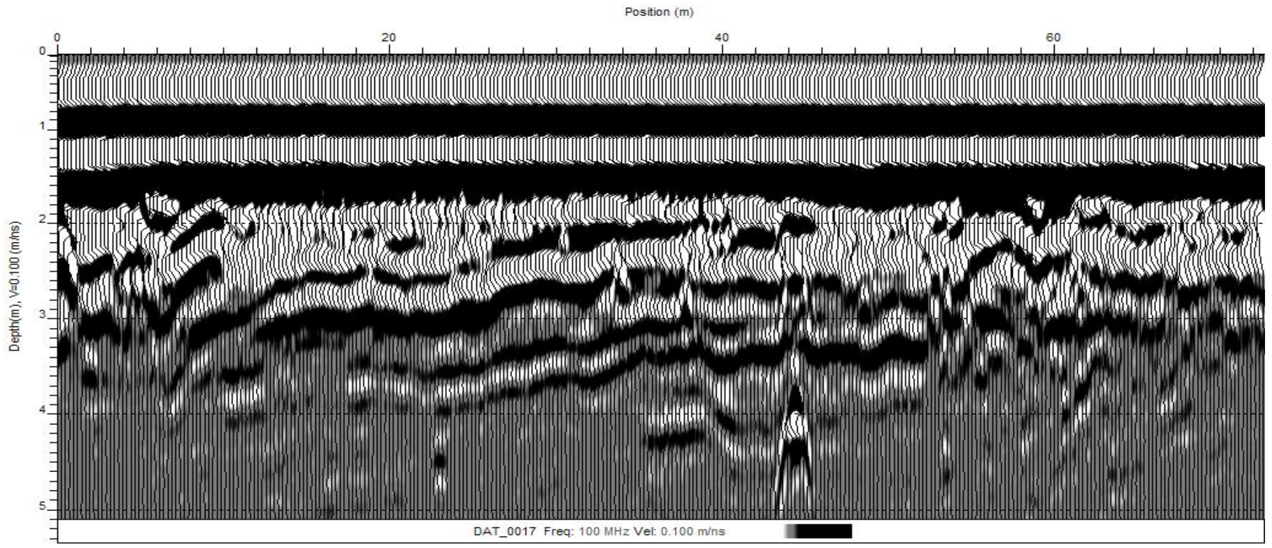

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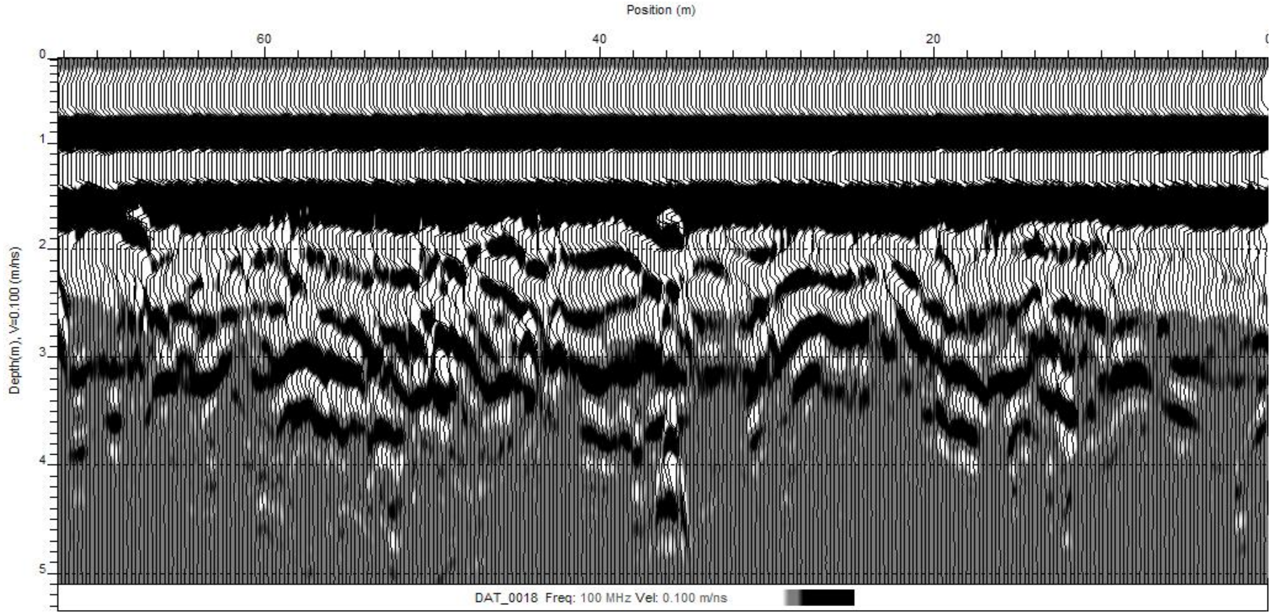

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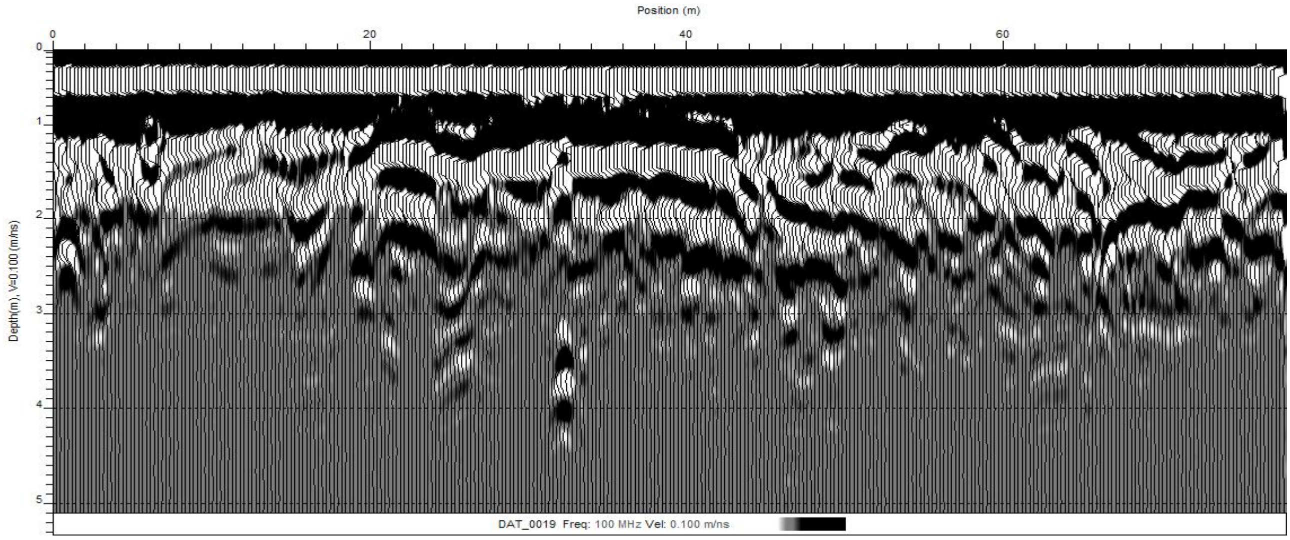
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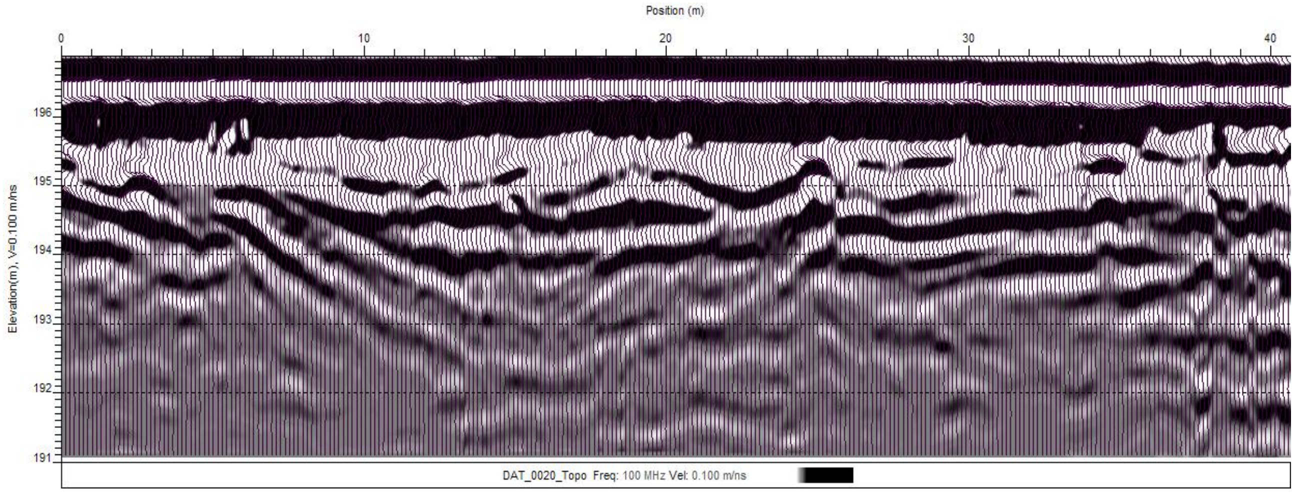
DAT_0019

A1.3.1 Data west of Eddleston Water



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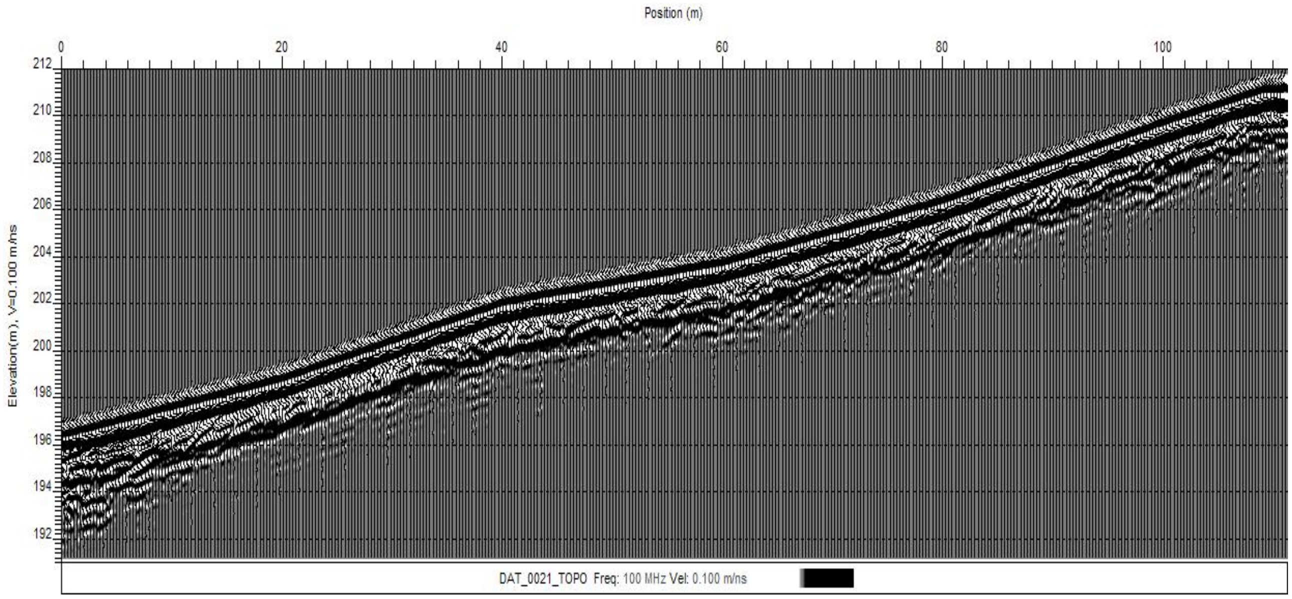

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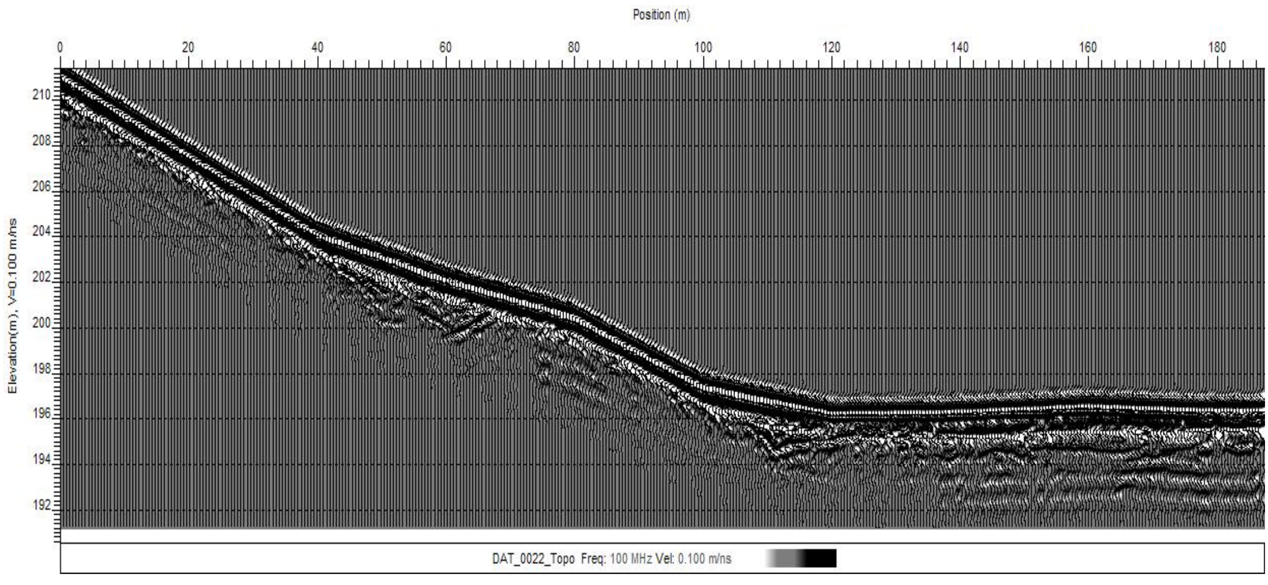

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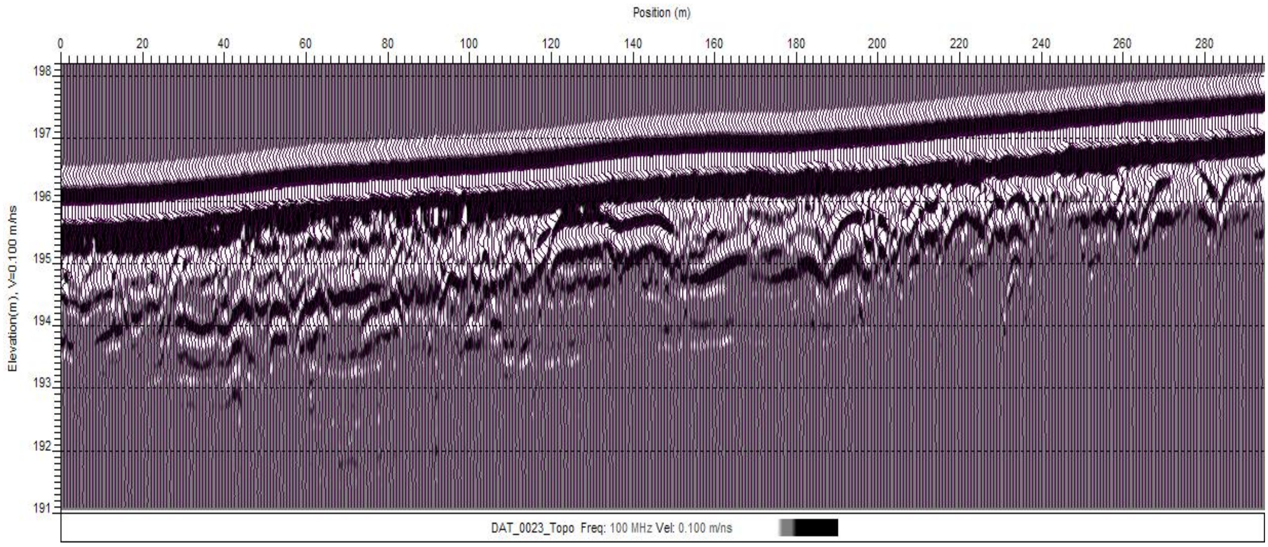

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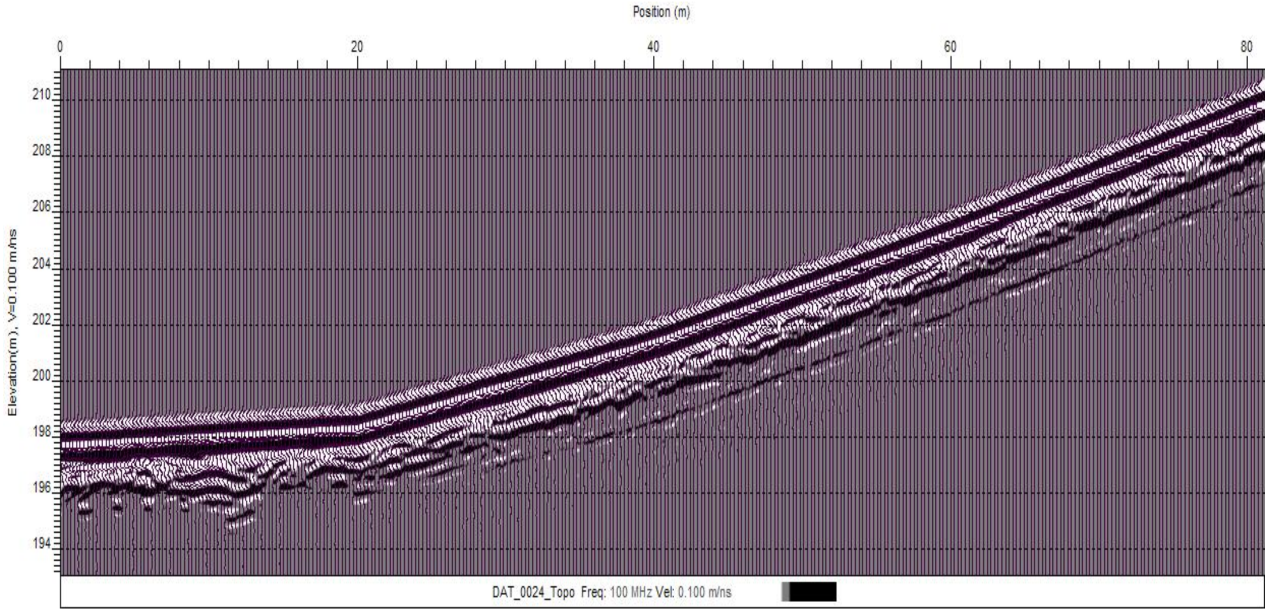

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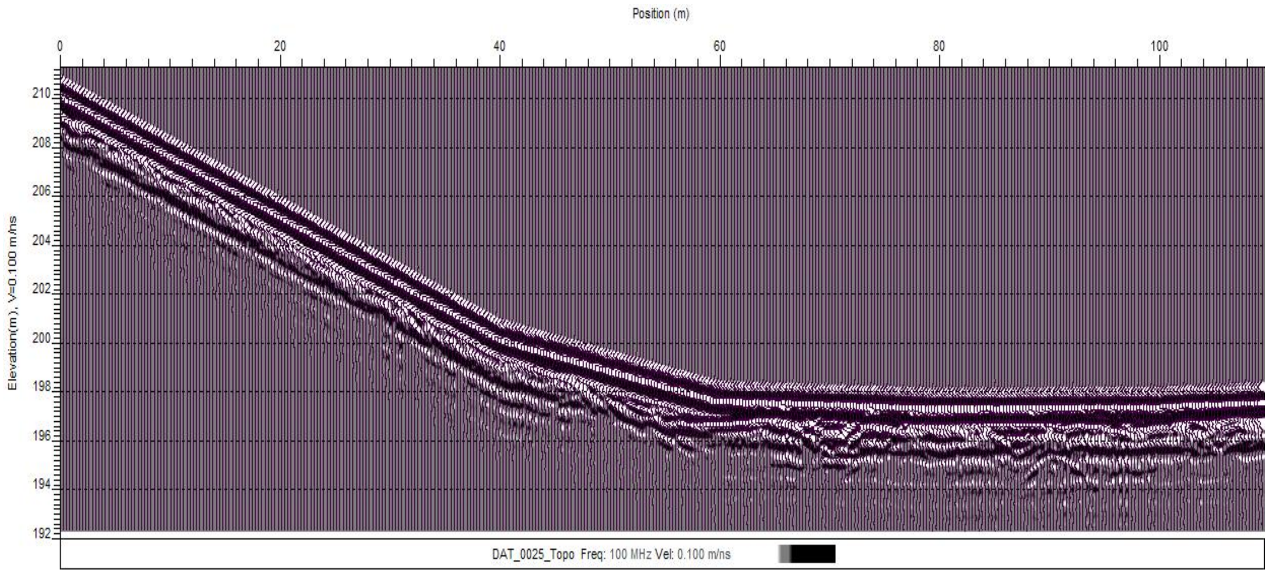

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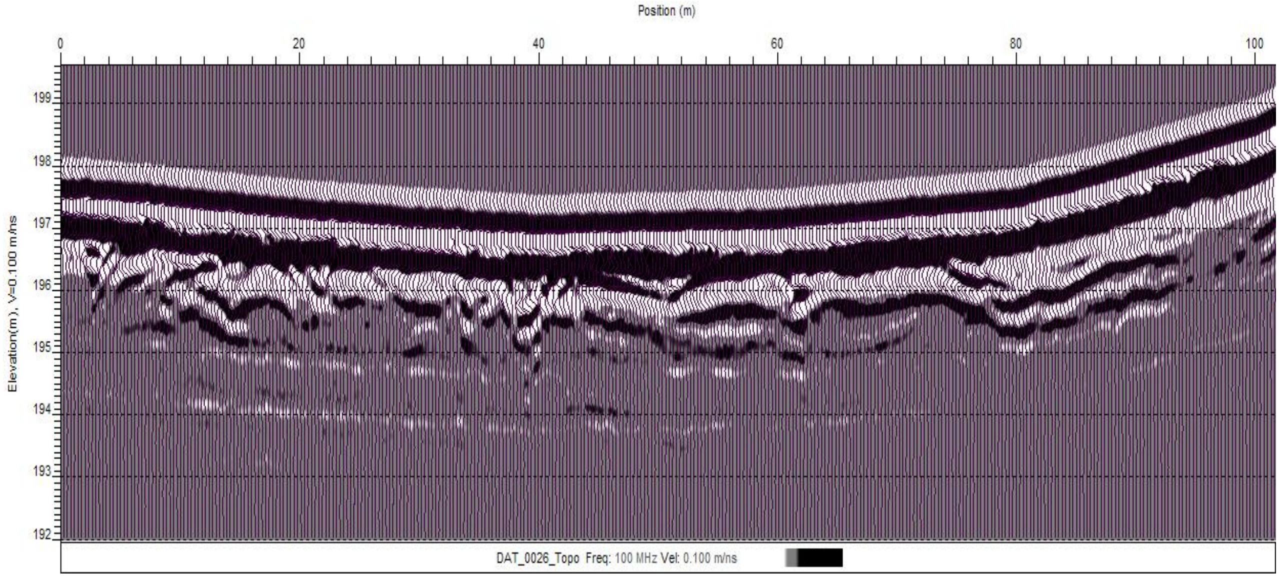

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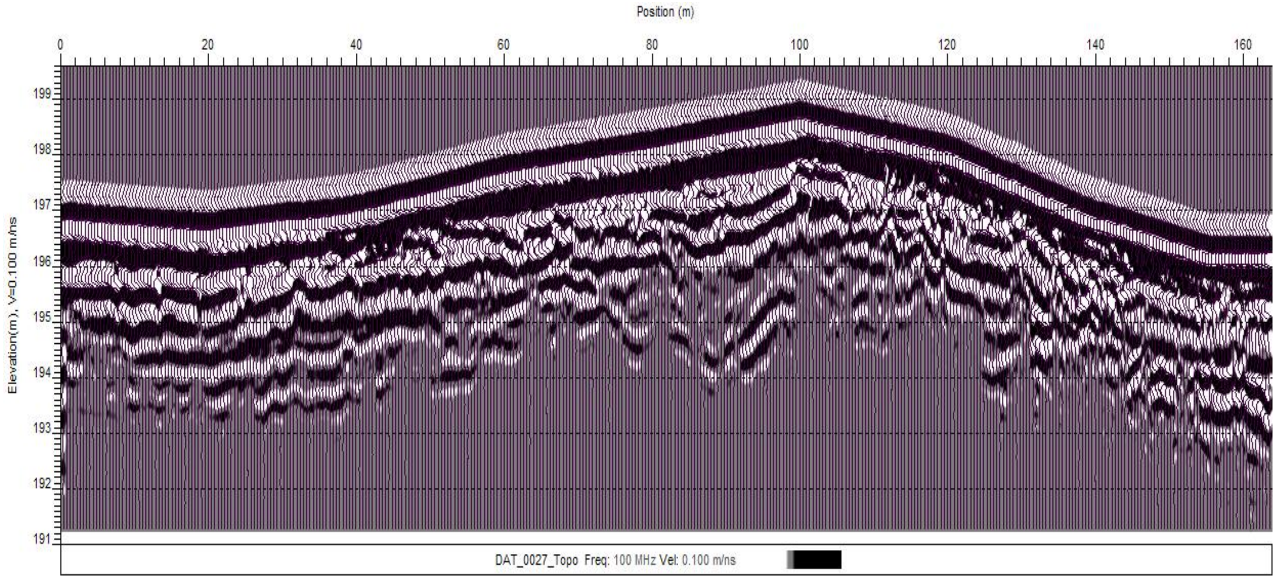

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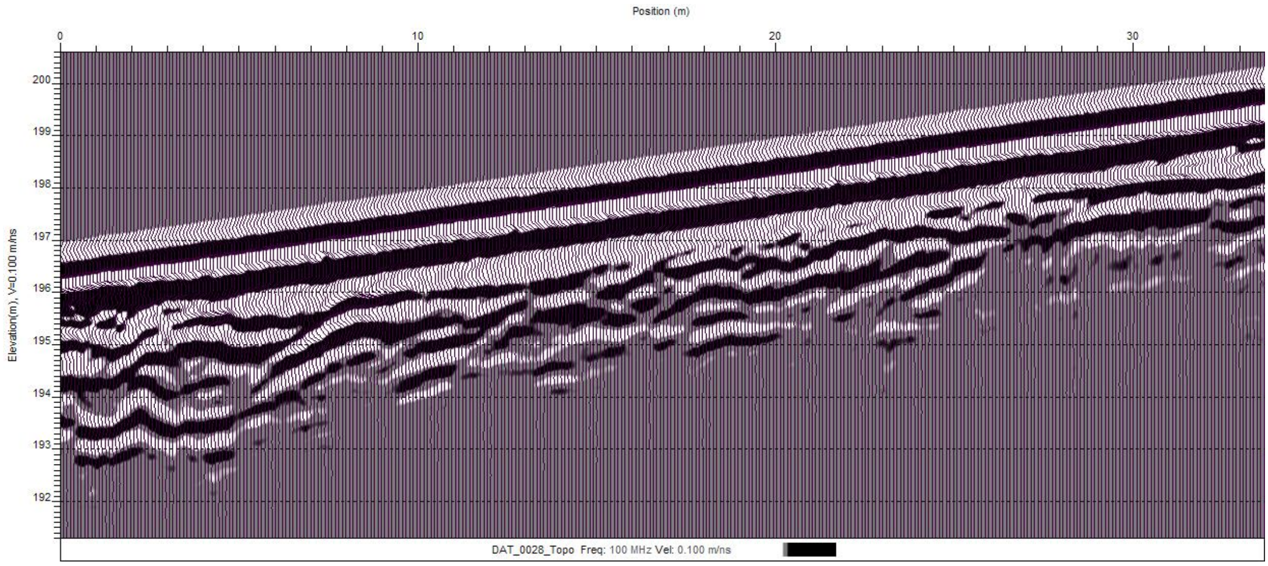

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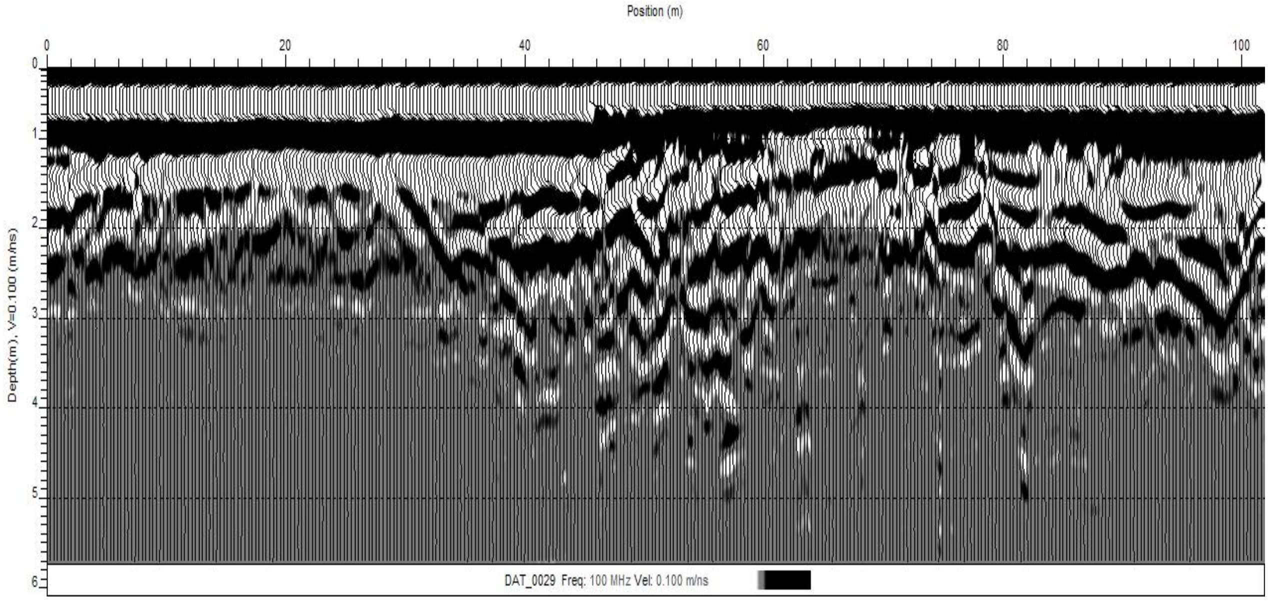
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DAT_0029

Table 100 Summary interpretation of GPR data – interpretation of field drains

GPR Traverse & Heading Direction (east or west) from Stream or Road End	EM & ERT Traverse No.	GPS Reading @ Stream/ Fence Line (All NGR square NT (36))	GPS Reading @ Road/ Fence Line (All NGR square NT (36))	Interpreted Position (m) of Field Drains in Relation to the Start Position of each GPR Traverse. (Arrow denotes East (right facing) or West (left facing) heading direction	GPR Traverse Length (m)
	L100N	24212 : 48022	24412 : 48029		
	L80N	24214 : 48002	24412 : 48012		
	L60N FIELD 1	24214 : 47981	24412 : 47992		
	L40N	24215 : 47962	24412 : 47971		
	L20N	24215 : 47942	24413 : 47948		
	L0 (Field Fence)	24216 : 47920	-		
DAT0001/E	ERT Line A	24217 : 47901	24414 : 47921	→ 138,143,148,154,160,166m	195
	L20S	24216 : 47880	24420 : 47879		
DAT0002/W	L40S	24217 : 47862	24418 : 47862	3,9,14,20,26,32,38,44m	196
	L60S	24217 : 47841	24415 : 47843		
DAT0003/E	L80S	24217 : 47821	24412 : 47824	→ 152,158,164,169,175,181m	191
	L100S	24218 : 47802	24409 : 47807		
DAT0004/W	L120S	24218 : 47781	24406 : 47781	102m	183
	L140S	24218 : 47762	24401 : 47760		
DAT0005/E	ERT Line B	24219 : 47736	24391 : 47747	→ Flat bottomed channel between 134-164m	174
	L180S FIELD 2	24218 : 47721	24392 : 47721		
DAT0006/W	L200S	24218 : 47701	24387 : 47703	← 3,9,15m	169
	L220S	24219 : 47682	24382 : 47679		
DAT0007/E	L240S	24219 : 47662	24376 : 47660	→ 118,124,132,138,144,150m	153
	L260S	24219 : 47641	24370 : 47639		
DAT0009/E	L280S	24218 : 47620	24365 : 47619	→ 102,114,121,134,140m	146
DAT0008/W	L300S	24218 : 47601	24360 : 47600	← 38,55,61,66,72,78,84,90,96,106m	160
DAT0010/W	L320S	24214 : 47582	24355 : 47582	← 8,20,30,38,50,56,62,67,73,84,90,100,104m	173
	L340S	24215 : 47563	24348 : 47562		
DAT0011/E	L360S	24215 : 47542	24343 : 47541	→ 28,38,44,50,56,62,67,72,78,98,108,120m	124
DAT0012/W	L380S (Field Fence)	As for ERT Line E		← 12,18,22,24,42,47,53,59,63,64,70,76,81,92, 102,110m	117

GPR Traverse & Heading Direction (east or west) from Stream or Road End	**EM & ERT Traverse No.**	**GPS @ Stream/ Fence Line**	**GPS @ Road/ Fence Line**	**Interpreted Position (m) of Field Drains in Relation to the Start Position of each GPR Traverse. (Arrow denotes East (right facing) or West (left facing) heading direction**	**GPR Traverse Length (m)**
	L610S	24206 : 47290	24279 : 47276		
DAT0013/E	L400S	24216 : 47504	24329 : 47501	→ 32,38,44,49,54,60,65,71,90,102	110
	L420S	24215 : 47481	24325 : 47480		
DAT0014/W	L440S	24214 : 47461	24319 : 47459	Deep Drain @ 25m	97
	L460S	24214 : 47443	24314 : 47441		
DAT0015/E	L480S FIELD 3	24215 : 47423	24308 : 47422	→ Deep Drain @ 62m	87
	L500S	24215 : 47403	24302 : 47400		
DAT0016/W	ERT Line C	24218 : 47393	24282 : 47352	Deep Drain @ 28m	79
	L510S	24215 : 47392	24296 : 47379		
DAT0017/E	L520S	-	-	→ Deep Drain @ 44m	73
	L530S	24217 : 47372	24288 : 47362		
	L550S	24214 : 47353	24287 : 47340		
DAT0018/W	L560S	-	--	← Deep Drain @ 36m	72
	L570S	24213 : 47333	24285 : 47318		
	L590S	24211 : 47313	24285 : 47298		
DAT0019/E	L600S	-	-	→ Deep Drain @ 32m	77

Table 11 Summary interpretation of GPR data – interpretation of palaeo-channels and gravel islands

GPR Interpretation of palaeo-channels and gravel islands

GPR Traverse (Corrected to all read west to east)	Gravel Island	Channel
DAT0001E	80-125m	28-80m, 125-195m
DAT0002E	146-164m	82-146m, 164-196m
DAT0003E		145-191m
DAT0004E	144-152m	0-32m, 40-80m
DAT0005E		136-174m
DAT0006E		0 - 36m
DAT0007E		105-152m
DAT0008E		0 – 38m
DAT0009E	20-40m?	114-146m
DAT0010E	92-132m	110-173m
DAT0011E		85-125m
DAT0016E		0-64m
DAT0017E		0-55m
DAT0018E	36-56m?	0-36m?
DAT0019E	20-44m	44-78m

Appendix 2 Trial pit logs

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Site: Eddleston				Trial Pit Number: **TP1**
Excavation Method: Wheeled backhoe excavator	Dimensions: 4x1m	Ground Level (mOD): 195.99	Client: Tweed Forum	Job Number: NEE4032
	Location: 324228.06 E 647391.69 N	Dates: 18/08/2010	Engineer: British Geological Survey	Sheet: 1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
					(0.40)	Firm dark grayish brown (10YR 4/2) slightly clayey slightly gravelly SILT. Gravel is fine to coarse subangular to subrounded of greywacke (TOPSOIL).		
				195.59	0.40 (0.60)	Firm to stiff brown (10YR 5/3) with strong brown (7.5YR 5/8) mottles very silty CLAY (ALLUVIUM).		
				194.99	1.00 (1.00)	Soft greenish gray (GLEY1 5/10GY) silty CLAY with very thin to thinly spaced lenses of peat from 1.3 to 2.0 m (ALLUVIUM).		
			moderate(1) at 2.00m, no rise after 20 mins.	193.99	2.00 (0.30)	Greenish gray (GLEY1 5/10GY) slightly clayey very sandy GRAVEL. Gravel is fine to coarse subangular to subrounded, occasionally rounded, of greywacke and occasional quartz and igneous (ALLUVIUM). (Continues).		▼1
				193.69	2.30	Complete at 2.30m		

Plan

Remarks

Trial pit terminated before significant undermining could occur.

Scale (approx)	Logged By	Figure No.
1:25	MRD	NEE4032.TP1

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

			Site: Eddleston	Trial Pit Number: TP2
Excavation Method: Wheeled backhoe excavator	Dimensions: 4x1 m	Ground Level (mOD): 195.96	Client: Tweed Forum	Job Number: NEE4032
	Location: 324150.96 E 647438.32 N	Dates: 16/08/2010	Engineer: British Geological Survey	Sheet: 1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
				195.76	(0.20) 0.20	Soft dark grayish brown (10YR 4/2) silty CLAY with numerous rootlets (TOPSOIL).		
0.40-0.60	U1			195.51	(0.25) 0.45	Soft dark gray (5Y 4/1) slightly silt CLAY (ALLUVIUM).		
0.60-0.80	U2			195.26	(0.25) 0.70	Spongy very dark brown (10Y 2/2) fibrous PEAT (PEAT).		
1.00-1.00 1.70-2.00	B1 W1			194.16	(1.10) 1.80	Soft dark gray (5Y 4/1) slightly silty CLAY with numerous rootlets with a 100mm thick olive brown silty clay layer at 1.27m. Coarsens downwards from 1.6m to a sandy silty CLAY (ALLUVIUM).		∇1
			slow(1) at 1.80m, rose to 2.00m in 20 mins.	193.76	(0.40) 2.20	Dark greenish gray (GLEY1 4/10GY) very clayey very sandy GRAVEL. Gravel is fine to medium subangular to subrounded of greywacke, sandstone of greywacke and occasional quartz (milky white) (ALLUVIUM).		▼1
				192.66	(1.10) 3.30	Strong brown (7.5YR 5/6) slightly silty sandy GRAVEL. Gravel is fine to coarse, subangular to rounded of greywacke and occasional quartz (milky white) (ALLUVIUM). (Continues).		
						Complete at 3.30m		

Plan

Remarks: Trial pit collapsed.

Scale (approx)	Logged By	Figure No.
1:25	MRD	NEE4032.TP2

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Site Eddleston				**Trial Pit Number** TP3
Excavation Method Wheeled backhoe excavator	**Dimensions** 4x1 m	**Ground Level (mOD)** 207.17	**Client** Tweed Forum	**Job Number** NEE4032
	Location 324056.02 E 647503.13 N	**Dates** 16/08/2010	**Engineer** British Geological Survey	**Sheet** 1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
					(0.30)	Firm very dark grayish brown (10Y 3/2) slightly sandy gravelly SILT. Gravel is fine to coarse subrounded to rounded of greywacke (TOPSOIL).		
				206.87	0.30			
0.50-0.50	B1				(0.40)	Firm dark yellowish brown (10Y 4/6) sandy gravelly SILT with some cobbles. Gravel and cobbles are subrounded to rounded of greywacke (GLACIOFLUVIAL or TILL).		
				206.47	0.70			
					(0.20)	Brown sandy silty GRAVEL (10YR 4/3). Gravel is fine to coarse and angular of greywacke (Weathered GREYWACKE).		
				206.27	0.90			
					(0.20)	Very strong dark gray (Gley1 4/N) GREYWACKE. Recovered as angular cobble and boulder-sized fragments.		
				206.07	1.10			
						Complete at 1.10m		

Plan	**Remarks** Trial pit terminated at bedrock.		
	Scale (approx) 1:25	**Logged By** MRD	**Figure No.** NEE4032.TP3

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Site	Trial Pit Number
Eddleston	TP4

Excavation Method	Dimensions	Ground Level (mOD)	Client	Job Number
Wheeled backhoe excavator	4x1 m	230.03	Tweed Forum	NEE4032
	Location	**Dates**	**Engineer**	**Sheet**
	323947.41 E 647500.72 N	17/08/2010	British Geological Survey	1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
					(0.30)	Firm brown (10YR 4/3) gravelly clayey SILT. Gravel is fine to coarse subangular to subrounded of greywacke (TOPSOIL).		
				229.73	0.30			
					(0.70)	Yellowish brown (10YR 5/8) sandy very silty GRAVEL with a little cobbles. Gravel is fine to coarse subangular to rounded of greywacke. Cobbles are rounded of greywacke (TILL or GLACIOFLUVIAL).		
				229.03	1.00			
					(0.20)	Very dark grayish brown (2.5Y 3/2) silty very sandy GRAVEL. Gravel is fine to coarse subangular to angular of greywacke (Weathered GREYWACKE).		
				228.83	1.20			
					(0.20)	Very strong very dark greenish gray (GLEY1 3/10GY) GREYWACKE recovered as angular gravel and cobble-sized fragments (GREYWACKE).		
				228.63	1.40			
						Complete at 1.40m		

Plan

Remarks

Trial pit terminated at bedrock.

Scale (approx)	Logged By	Figure No.
1:25	MRD	NEE4032.TP4

British Geological Survey NATURAL ENVIRONMENT RESEARCH COUNCIL			Site: Eddleston	Trial Pit Number: TP5
Excavation Method Wheeled backhoe excavator	**Dimensions** 4x1 m	**Ground Level (mOD)** 243.37	**Client** Tweed Forum	**Job Number** NEE4032
	Location 323854.68 E 647631 N	**Dates** 17/08/2010	**Engineer** British Geological Survey	**Sheet** 1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
				243.17	(0.20) 0.20	Soft to firm brown (10Y 4/3) slightly sandy gravelly CLAY. Gravel is fine to coarse subangular to angular of greywacke (TOPSOIL).		
1.00-1.00	B1			241.27	(1.90) 2.10	Light olive brown (2.5Y 5/4) sandy very silty GRAVEL with some cobbles and boulders. Gravel and cobbles are fine to coarse subangular to subrounded, occasionally rounded of greywacke and rare quartz. Boulders are subrounded to rounded up to 600mm (TILL).		
				241.07	(0.20) 2.30	Very strong very dark greenish gray (GLEY1 3/10GY) GREYWACKE recovered as angular gravel and cobble-sized fragments (GREYWACKE).		
						Complete at 2.30m		

Plan

Remarks

Trial pit terminated at bedrock.

Scale (approx)	Logged By	Figure No.
1:25	MRD	NEE4032.TP5

British Geological Survey NATURAL ENVIRONMENT RESEARCH COUNCIL			Site: Eddleston	Trial Pit Number: TP6
Excavation Method: Wheeled backhoe excavaor	Dimensions: 4x1 m	Ground Level (mOD): 211.22	Client: Tweed Forum	Job Number: NEE4032
	Location: 324078.44 E 647643.34 N	Dates: 16/08/2010	Engineer: British Geological Survey	Sheet: 1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
					(0.35)	Firm very dark grayish brown (10Y 3/2) sandy silty GRAVEL. Gravel is fine to coarse subangular to angular of greywacke (TOPSOIL).		
				210.87	0.35			
					(0.55)	Dark yellowish brown (10yr 4/4) sandy very silty GRAVEL with a little cobbles. Gravel and cobbles are fine to coarse subangular to angular, tabular to square of greywacke (MADE GROUND).		
				210.32	0.90			
1.10-1.10	B1				(0.40)	Light olive brown (2.5Y 5/4) sandy silty GRAVEL with a little cobbles. Gravel and cobbles are fine to coarse subangular to angular, tabular and square of greywacke (HEAD).		
				209.92	1.30			
					(0.40)	Very dark grayish brown (2.5Y 3/2) slightly silty very sandy GRAVEL with some cobbles. Gravel and cobbles are fine to coarse subangular to angular, tabular and square of greywacke (WEATHERED GREYWACKE or HEAD).		
				209.52	1.70			
					(0.30)	Very strong dark gray (GLEY1 4/N) GREYWACKE. Recovered as cobble and boulder-sized fragments (GREYWACKE).		
				209.22	2.00			
						Complete at 2.00m		

Plan

Remarks

Trial pit terminated at bedrock.

Scale (approx)	Logged By	Figure No.
1:25	MRD	NEE4032.TP6

British Geological Survey NATURAL ENVIRONMENT RESEARCH COUNCIL		Site Eddleston		Trial Pit Number TP7
Excavation Method Wheeled backhoe excavator	Dimensions 4x1 m	Ground Level (mOD) 197.90	Client Tweed Forum	Job Number NEE4032
	Location 324229.14 E 647741.12 N	Dates 18/08/2010	Engineer British Geological Survey	Sheet 1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
					(0.50)	Firm dark grayish brown (10YR 4/2) slightly clayey slightly gravelly SILT. Gravel is fine to coarse subangular to subrounded of greywacke (TOPSOIL).		
				197.40	0.50			
					(1.00)	Firm to stiff brown (10YR 5/3) with strong brown (7.5YR 5/8) mottles very silty CLAY (ALLUVIUM).		
				196.40	1.50			
1.60-1.80	U1				(0.20)	Soft greenish gray (GLEY1 5/10GY) silty CLAY with strong brown (7.5YR 5/8) mottles within top of layer and numerous rootlest at base of layer (ALLUVIUM).		
				196.20	1.70			
					(0.20)	Very dark gray (7.5YR 3/1) spongy to plastic pseudo fibrous to amorphous PEAT (PEAT).		
			moderate(1) at 1.90m, rose to 2.00m in 20 mins.	196.00	1.90			∇1 ▼1
					(0.50)	Greenish gray (GLEY1 5/10GY) slightly clayey sandy GRAVEL. Gravel is fine to coarse subangular to subrounded, occasionally rounded, of greywacke and occasional quartz and igneous (ALLUVIUM). (Continues).		
				195.50	2.40			
						Complete at 2.40m		

Plan	Remarks
	Trial pit terminated before significant undermining could occur.

Scale (approx)	Logged By	Figure No.
1:25	MRD	NEE4032.TP7

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Site	Trial Pit Number
Eddleston	TP8

Excavation Method	Dimensions	Ground Level (mOD)	Client	Job Number
Wheeled backhoe excavator	4x1 m	200.44	Tweed Forum	NEE4032
	Location	**Dates**	**Engineer**	**Sheet**
	324157.66 E 647737.95 N	17/08/2010	British Geological Survey	1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
					(0.25)	Firm dark grayish brown (10YR 3/2) slightly clayey gravelly SILT. Gravel is fine to coarse subangular to subrounded of greywacke (TOPSOIL).		
				200.19	0.25			
0.40-0.40	B1				(0.25)	Dark yellowish brown (10YR 4/6) sandy very silty GRAVEL with a little cobbles. Gravel and cobbles are fine to coarse subangular to subrounded of greywacke (TILL or GLACIOFLUVIAL)		
				199.94	0.50			
					(0.90)	Olive brown (2.5YR 4/4) sandy very silty GRAVEL with a little cobbles with a 300mm gravelly silt layer from 1.0 m. Gravel is fine to coarse angular to subrounded of greywacke (TILL).		
				199.04	1.40			
					(0.20)	Very strong very dark greenish gray (GLEY1 3/10GY) GREYWACKE recovered as gravel and cobble-sized fragments (GREYWACKE).		
				198.84	1.60			
						Complete at 1.60m		

Plan

Remarks

Trial pit terminated at bedrock.

Scale (approx)	Logged By	Figure No.
1:25	MRD	NEE4032.TP8

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Site Eddleston				**Trial Pit Number** TP9
Excavation Method Wheeled backhoe excavator	**Dimensions** 4x1 m	**Ground Level (mOD)** 198.59	**Client** Tweed Forum	**Job Number** NEE4032
	Location 324382.92 E 647922.66 N	**Dates** 18/08/2010	**Engineer** British Geological Survey	**Sheet** 1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Water
					(0.40)	Firm dark grayish brown (10YR 4/2) slightly sandy clayey SILT (TOPSOIL).	
				198.19	0.40	Firm brown (10YR 5/3) with strong brown (7.5YR 5/8) mottles slightly silty CLAY. Grades to soft greenish gray (GLEY1 5/10Y) sandy CLAY from 0.7 m (ALLUVIUM).	
0.90-0.90	B1				(0.70)		
				197.49	1.10	Dark gray (GLEY1 4/N) becoming strong brown (7.5YR 4/6) with depth slightly silty very sandy GRAVEL. Gravel is fine to coarse subangular to rounded of greywacke. Grades to greenish gray (GLEY1 5/10GY) slightly silty sandy GRAVEL with some cobbles from 1.5m. Gravel is medium to coarse subrounded to rounded of greywacke and occasional igneous (ALLUVIUM). (Continues).	
1.30-1.30	B2		slow(1) at 1.40m, rose to 1.60m in 20 mins.				▽1 ▼1
					(1.90)		
				195.59	3.00	Complete at 3.00m	

Plan

Remarks

Trial pit terminated before significant undermining could occur.

Scale (approx)	Logged By	Figure No.
1:25	MRD	NEE4032.TP9

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Site	Trial Pit Number
Eddleston	TP10

Excavation Method	Dimensions	Ground Level (mOD)	Client	Job Number
Wheeled backhoe excavator	4x1 m	198.76	Tweed Forum	NEE4032
	Location	**Dates**	**Engineer**	**Sheet**
	324274.94 E 647927.48 N	18/08/2010	British Geological Survey	1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
					(0.50)	Firm dark grayish brown (10YR 4/2) slightly sandy gravelly SILT. Gravel is fine to coarse subangular to rounded of greywacke (TOPSOIL).		
				198.26	0.50	Dark gray (GLEY1 4/N) slightly silty very sandy GRAVEL with some cobbles. Gravel is fine to coarse subangular to rounded of greywacke and occasional igneous. Cobbles are rounded of greywacke and occasional quartz (ALLUVIUM).		
			moderate(1) at 1.00m, no rise after 20 mins.		(1.20)			▼1
				197.06	1.70	Firm greenish gray (GLEY1 5/10GY) with strong brown (7.5YR 5/8) mottles CLAY (ALLUVIUM). (Continues).		
					(0.20)			
				196.86	1.90			
						Complete at 1.90m		

Plan

Remarks
Trial pit collapsed.

Scale (approx)	Logged By	Figure No.
1:25	MRD	NEE4032.TP10

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Site	Trial Pit Number
Eddleston	TP11

Excavation Method	Dimensions	Ground Level (mOD)	Client	Job Number
Wheeled backhoe excavator	4x1 m	212.63	Tweed Forum	NEE4032
	Location	**Dates**	**Engineer**	**Sheet**
	324101.39 E 647991.55 N	17/08/2010	British Geological Survey	1/1

Depth (m)	Sample / Tests	Water Depth (m)	Field Records	Level (mOD)	Depth (m) (Thickness)	Description	Legend	Water
					(0.40)	Firm dark grayish brown (10YR 3/2) slightly clayey gravelly SILT. Gravel is fine to coarse subangular to subrounded of greywacke (TOPSOIL).		
				212.23	0.40 (1.40)	Olive brown (2.5YR 4/4) sandy very silty GRAVEL with a little to some cobbles and boulders and a 300 mm silty layer at 0.6 m. Gravel is fine to coarse angular to subrounded of greywacke. Cobbles and boulders are subrounded to rounded up to 450 mm of greywacke(TILL).		
2.00-2.00	B1			210.83	1.80 (0.80)	Firm thickly laminated to thinly interbedded multicoloured light olive brown (2.5Y 5/4), yellowish brown (10YR 5/6) slightly clayey SILT and very dark brown (10YR 3/1) SAND (GLACIOLACUSTRINE).		
				210.03	2.60 (1.20)	Firm light olive brown (2.5Y 5/4) slightly clayey SILT (GLACIOLACUSTRINE).		
				208.83	3.80 (0.05)	Presumed greywacke bedrock (GREYWACKE).		
				208.78	3.85	Complete at 3.85m		

Plan

Remarks

Trial pit terminated due to spalling sides and encounter with strong strata, pressumed greywacke bedrock.

Scale (approx)	Logged By	Figure No.
1:25	MRD	NEE4032.TP11

Appendix 3 Borehole (piezometer) logs

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

BOREHOLE LOGS **DARNHALL MAINS, EDDLESTON**	**BOREHOLE No:** EDS1	**Piezometer ID:** EDS1A
	Sheets: 2	
	Grid Reference NT 24105 47407	

Equipment & Methods

Shell & Auger
300 mm diam 0-1.0 mBGL
250mm diam 1.0 – 5.40 mBGL
Dry drilled to 1.0 mBGL

Water levels Water struck at 1.0 mBGL and immediately rose to = 0.50 mBGL, 0.30 mBGL after 20 mins and 0.20 after 1 hr. Water level dropped with drilling at 1.7 mBGL but did not rise (casing at 2.0mBGL) Water struck at 2.4 mBGL and became flowing artesian WL on 19/03/11 = 0.26 m BCL /0.17mAGL WL on 20/03/11 = 0.31 m BCL/0.12 mAGL WL on 21/03/11 = 0.31 m BCL WL on 23/03/11 = 0.43 m BCL WL on 29/03/11 = 0.60 m BCL	**Datum level** Well top (WT) = 0.27mAGL Cover level (CL) = 0.43mAGL

LITHOLOGICAL LOG (Andy Dixon, Helen Bonsor)	**Date** 16/03/11-18/03/11		**Lithological Log (Clive Auton)**
Description	Thickness	Depth	Clive Auton
Dark yellowish brown (10YR6/4) stoney silty clay SOIL. Occasional subangular-angular cobbles.	0.50	0.50	SOIL
Very dark grey (10YR3/1) amorphous clayey PEAT with subangular –subrounded medium – coarse gravel and occasional cobbles.	0.50	1.00	PEAT
Dark yellowish brown (10YR3/4) fibrous PEAT with subangular – subrounded coarse gravel and cobbles. Peaty clay at 1.65 mBGL.	0.70	1.70	
Moderately decomposed PEAT with some medium-coarse gravel. 0.07m diam root. Peaty clay at base with bluish green sand patches (decomposed pebbles)	0.60	2.30	
Very gravelly CLAY, with blue-green sandy mottling.	0.10	2. 40	ALLUVIUM
Medium dense subangular sandy, coarse GRAVEL (10YR 5/4) with occasional sub-rounded cobbles	0.90	3.30	ALLUVIUM OR GLACIO-

(typically 3-5 cm diameter) and rare rounded chert clasts (typically ≤1 cm diameter). Medium grained, rounded sand grains in matrix.			FLUVIAL GRAVEL?
Medium dense poorly-moderately sorted, angular-subangular sandy, coarse GRAVEL (10YR 5/4) with occasional cobbles. Less sandy material in matrix of gravel, than in unit above. Sandy matrix coarser (~750 µm), and gravels more angular. Very rare sub-rounded pebbles of greywacke (typically 5-10 cm diameter).	1.20	4.50	
Dense, dark grey, olivine-brown greywacke angular gravel deposit. Chips and flakes of greywacke, rather than gravels and cobbles. Much less, if any, sandy matrix within gravel.	0.80	5.30	HEAD
Soft-firm greyish brown (2.5Y5/2) gravelly CLAY, with small subrounded greywacke pebbles (typically 1-3 cm diameter). Deposit is firm, and pebbles supported in-situ in matrix, but deposit is malleable and can be crumbled in hand. Very fine matrix to deposit (<180 µm).	0.10	5.40	TILL?
COMPLETION			
Protective steel casing c/w lockable lid Concrete Bentonite pellets Pack (natural) 90 mm OD x 80 mm ID pvc plain casing 90 mm OD x 80 mm ID pvc screen with 1 mm slots 90 mm OD x 80 mm ID pvc plain casing (sump)		 0.30 5.31 3.00 3.80 4.56 5.31	

Grab / bulk samples		
Sample No		
EDS1/1	0 -0.5	Bulk sample (gravel
EDS1/2	0.5-1.0	Bulk sample (peat)
EDS1/3	1.0-1.7	Bulk sample (peat)
EDS1/4	1.7-2.3	Bulk sample (peat)
EDS1/5	2.3-2.8	Bulk sample (gravel)
EDS1/6	2.8-3.3	Bulk sample (gravel)
EDS1/7	3.3-3.8	Bulk sample (gravel)
EDS1/8	3.8-4.2	Bulk sample (gravel)
EDS1/9	4.2-4.5	Bulk sample (gravel)
EDS1/10	4.5-5.0	Bulk sample (gravel)
EDS1/11	5.0-5.5	Bulk sample (gravel)

BOREHOLE LOGS DARNHALL MAINS, EDDLESTON	BOREHOLE No: EDS2	Piezometer ID: EDS1B
	Sheets: 2	
	Grid Reference NT 24102 47403	

Equipment & Methods
Shell & Auger
250 mm diam 0-1.0 mBGL
200 mm diam 1.0 – 1.50 mBGL
Dry drilled to 1.5 BGL

Water levels	Datum level
Water struck at 1.0 mBGL and immediately became flowing artesian WL on 20/03/11 = 0.39 mBCL WL on 21/03/11 = 0.41 mBCL WL on 23/03/11 = 0.50 mBCL WL on 29/03/11 = 0.68 mBCL	Well top (WT) = 0.33mAGL Cover level (CL) = 0.47mAGL

LITHOLOGICAL LOG (Andy Dixon, Helen Bonsor)	Date 19/03/11		Lithological Log (Clive Auton)
Description	Thickness	Depth	Clive Auton
Rich, dark grayish brown (10YR3/2) clayey gravel/soil. Some organic content, with organic fibres and vegetation roots. Occasional subangular greywacke cobbles.	0.50	0.50	SOIL AND/OR ALLUVIUM
Very dark (10YR2/1), fine grained clayey PEAT, with subangular greywacke pebbles (typically 1-3 cm diameter on longest axis).	0.50	1.00	PEAT
Dark reddish brown (5YR3/2) moderately decomposed fibrous PEAT. Rare subangular greywacke clasts (typically 1-3 cm diameter)	0.50	1.50	
COMPLETION			
Protective steel casing c/w lockable lid			
Concrete		0.30	
Bentonite pellets		1.00	
Pack (natural)		1.60	
90 mm OD x 80 mm ID pvc plain casing		1.25	
90 mm OD x 80 mm ID pvc screen with 1 mm slots		1.60	
90 mm OD x 80 mm ID pvc plain casing (sump)		1.65	

Grab / bulk samples

Sample No		
EDS2/1	0 -0.5	Bulk sample (gravel)
EDS2/2	0.5-1.0	Bulk sample (peat/clay)
EDS2/3	1.0-1.5	Bulk sample (peat)

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BOREHOLE LOGS DARNHALL MAINS, EDDLESTON	BOREHOLE No: EDS3	Piezometer ID: EDS2B
	Sheets: 2	
	Grid Reference NT 24161 47399	

Equipment & Methods

Shell & Auger
300 mm diam 0-1.80 mBGL
250mm diam 1.8 – 4.30 mBGL
Dry drilled to 3.10 mBGL

Water levels	Datum level
Very slight seepage at 1.3m BGL Water struck at 3.10 m BGL and rose to 2.58 mBGL immediately and to 2.40 mBGL after 20 mins (casing at 2.92 mBGL) WL on 21/03/11 (09:30) = 0.60 mBGL (casing at 4.3bmBGL) WL on 21/03/11 after completion = 0.37 mBGL WL on 23/03/11 = 0.44 mBGL WL on 29/03/11 = 0.87 mBCL WL on 30/03/11 = 1.01 mBCL	Well top (WT) = 0.35 mAGL Cover level (CL) = 0.50 mAGL

LITHOLOGICAL LOG (Andy Dixon, Nicole Archer)	Date 20/03/11		Lithological Log (Clive Auton)
Description	Thickness	Depth	
Dark greyish brown (10YR4/2) very clayey SILT. Orange mottling within silty soil and some vegetation roots	0.60	0.60	ALLUVIUM OVERBANK SILT
Bluish grey (5PB6/1) and yellowish red (5YR5/6) mottled clayey SILT. Material contains some very fine-grained (~200 µm) sandy material locally, with yellow, red mottling. SILT has blocky structure; malleable.	0.30	0.90	
Bluish grey (10B6/1) SILT. Locally contains some fine sandy material.	0.10	1.00	
Dark reddish brown (5YR3/2) moderately decomposed fibrous PEAT. Crumbly material structure when handled. Locally PEAT is clay-rich, and grayish brown in colour.	0.30	1.30	PEAT
Dark, bluish grey brown (10B6/1) SILT with some rootlets. Occasional amorphous peat patches.	0.20	1.50	ALLUVIUM
Becoming very soft bluish grey (10B5/1) CLAY. Smooth, plastic appearance to deposit.	0.80	2.30	
Very soft bluish grey (10B5/1) CLAY, containing pale yellow to grey fine (~250 µm diameter) sands	0.20	2.50	

and dark reddish black (2.5YR2.5/1) PEAT with plant material. Very occasional subrounded-subangular greywacke gravels (typically 0.5-3 cm diameter).			
Reddish black (2.5YR2.5/1) moderately – highly decomposed PEAT, with clayey bands locally. Very occasional subrounded-subangular greywacke gravels (typically 0.5-3 cm diameter).	0.20	2.70	PEAT
Medium dense bluish grey (10B5/1) very clayey sandy SILTY GRAVEL. Angular to subangular, poorly sorted material. Occasional organic matter (vegetation roots).	0.40	3.10	ALLUVIUM GRAVEL
Medium dense dark bluish/greenish grey (10B4/1) very sandy GRAVEL. Poorly sorted gravel: subangular-subrounded with some rounded mainly greywacke (gravels typically 1-4 cm diameter). Undecomposed peat clast at 4.0 mBGL, containing some medium grained sandy material within it	1.00	4.10	
Soft-firm, olive-grey, very gravelly silty CLAY. Greywacke and occasional quartz gravels (typically <1 cm diameter).	0.20	4.30	ALLUVIUM CLAY
COMPLETION			
Protective steel casing c/w lockable lid	0.3		
Concrete	0.3		
Bentonite pellets	2.70		
Pack (natural)	4.20		
90 mm OD x 80 mm ID pvc plain casing	3.32		
90 mm OD x 80 mm ID pvc screen with 1 mm slots	3.92		
90 mm OD x 80 mm ID pvc plain casing (sump)	4.20		

Grab / bulk samples		
Sample No		
EDS3/1	0-0.60	Grab sample (silt)
EDS3/2	0.6-0.90	Grab sample (silt)
EDS3/3	0.90-1.0	Grab sample (silt)
EDS3/4	1.0-1.3	Grab sample (peat)
EDS3/5	1.3-1.5	Grab sample (silt)
EDS3/6	1.5-2.3	Grab sample (clay)
EDS3/7	2.3-2.5	Grab sample (clay and peat)
EDS3/8	2.5-2.7	Grab sample (peat)
EDS3/9	2.5-3.1	Grab sample (gravel)
EDS3/10	3.1-4.1	Bulk sample (gravel)
EDS3/11	4.1-4.3	Grab sample (silt)

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BOREHOLE LOGS **DARNHALL MAINS, EDDLESTON**	**BOREHOLE No:** EDS4	**Piezometer ID:** EDS2A
	Sheets: 3	
	Grid Reference NT 24149 47416	

Equipment & Methods
Shell & Auger
300 mm diam 0-1.00 mBGL
250mm diam 1.0 – 8.00 mBGL
Dry drilled to 1.00 mBGL

Water levels	**Datum level**
Seepage at 0.80 m BGL Water struck at 1.80 m BGL and rose to 0.80 mBGL after 20 mins WL on 29/03/11 (09:30) = 0.48 mBGL (casing at 5.20bmBGL) WL on 29/03/11= 0.38 mBGL WL on 30/03/11 = 0.86 mBCL	Well top (WT) = 0.34 mAGL Cover level (CL) = 0.49 mAGL

LITHOLOGICAL LOG (Andy Dixon, Helen Bonsor)	**Date** 28-30/03/11		**Lithological Log (Clive Auton)**
Description	Thickness	Depth	
Medium-fine (~250 µm), moderately-well sorted, brown (7.5YR4/3) SOIL. Some grey silty sandy layers locally within soil.	0.20	0.20	SOIL
Grey (7.5YR5/1) clayey SILT with yellowish red (5YR5/8) mottling. Fine grained (~180 µm), homogenous, soft, smooth malleable deposit.	0.50	0.70	ALLUVIUM
Grey (N6) clayey SILT with yellowish red (5YR5/8) mottling. Some vegetation roots within SILT. Clay-rich matrix (fine-grained, homogeneous) with some silty-sandy layers/bands within the SILT.	0.30	1.00	
Dark brown (7.5YR3/2) peaty CLAY – peat layer within the SILT.	0.20	1. 20	
Soft greenish grey (5GY5/1) CLAY. Soft, homogeneous matrix and malleable deposit. No gravels or pebbles within the deposit.	1.20	2.40	
Soft very dark greenish grey (10GY3/1) CLAY with very dark brown fibrous (N2.5) PEAT at base of clay layer. High proportion of organic root matter preserved in peat.	0.30	2.70	ALLUVIUM WITH PEAT
Medium dense, dark grey-brownish (5Y4/1) clayey GRAVEL. Coarse (~250-300 µm) sand grains in clayey matrix and sub-rounded greywacke (typically 1.5-2 cm diameter, on longest axis).	0.80	3.50	ALLUVIUM GRAVEL

Deposit is soft and can be broken up by hand. Sand content in clayey matrix increasing with depth at 3.00 mBGL			
Medium dense very dark greenish grey (5BG3/1) very sandy GRAVEL. Coarse (~250-300 µm) sand grains in clayey matrix and sub-rounded to sub-angular greywacke (typically 1.5-2 cm diameter, on longest axis). Deposit is soft and can be broken up by hand.	1.00	3.90	
Dark grey (5Y4/1) clayey SILT with slightly decomposed yellowish red (5Y5/6) rounded peat clast	0.40	4.30	ALLUVIUM
As above with brown peaty material	0.10	4.40	
Medium dense olive grey (5Y4/2) very sandy gravel becoming more sandy with depth. Becoming dark greyish brown (2.5Y4/2) at 5.0, brown (10YR4/3) at 5.5 and yellowish brown (10YR4/4)	3.60	8.00	ALLUVIUM GRAVEL

COMPLETION

Protective steel casing c/w lockable lid	0.3
Concrete	0.30
Bentonite pellets	2.70
Pack (natural)	3.90
Bentonite pellets	5.20
Pack (natural)	7.61
90 mm OD x 80 mm ID pvc plain casing	5.83
90 mm OD x 80 mm ID pvc screen with 1 mm slots	6.59
90 mm OD x 80 mm ID pvc plain casing (sump)	7.61

Grab / bulk samples

Sample No		
EDS4/1	0 -0.20	Grab sample (soil)
EDS4/2	0.2-0.70	Grab sample (silt)
EDS4/3	0.70-1.0	Grab sample (silt)
EDS4/4	1.0-1.2	Grab sample (peaty clay)
EDS4/5	1.2-2.4	Grab sample (clay)
EDS4/6	2.4-2.7	Grab sample (clay & peat)
EDS4/7	2.7-3.0	Bulk sample (gravel)
EDS4/8	3.0-3.5	Bulk sample (gravel)
EDS4/9	3.5-3.9	Bulk sample (gravel)
EDS4/10	3.9-4.3	Bulk sample (silt)
EDS4/11	4.3-4.4	Grab sample (silt)
EDS4/12	4.4-5.0	Grab sample (silt)
EDS4/13	5.0-5.5	Bulk sample (gravel)
EDS4/14	5.5-6.0	Bulk sample (gravel)
EDS4/15	6.0-6.5	Bulk sample (gravel)
EDS4/16	6.5-7.0	Bulk sample (gravel)
EDS4/17	7.0-7.5	Bulk sample (gravel)
EDS4/18	7.5-8.0	Bulk sample (gravel)

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BOREHOLE LOGS **DARNHALL MAINS, EDDLESTON**	**BOREHOLE No:** EDS5	**Piezometer ID:** EDS3A and EDS3C
	Sheets: 3	
	Grid Reference NT 24193 47711	

Equipment & Methods

Shell & Auger
250mm diam.0 – 1.00 mBGL
200mm diam 1.00-8.50
Dry drilled to 2.70 mBGL

Water levels	**Datum level**
Water struck at 2.50 m BGL and rose to 2.25 mBGL after 20 mins WL on 01/04/11 = 1.41 m BGL (casing at 3.4m) WL on 02/04/11 = 1.51 mBGL (casing at 8.5m) WL on 03/04/11 = 1.25 m BGL / 1.05 mBWT WL on 04/04/11 = 1.28 mBGL /1.08 mBWT WL in shallow well = 1.07 mBWT	Well top (WT) = 0.24 mBGL Cover level (CL) = 0.04 mBGL

LITHOLOGICAL LOG (Andy Dixon, Nicole Archer)	**Date** 31/03/11-02/04/11		**Lithological Log (Clive Auton)**
Description	Thickness	Depth	
Dark brown (7.5YR3/2) stony SOIL. Sandy-silty matrix with sub-angular to sub-rounded greywacke pebbles and gravels (typically 0.5-4.0 cm diameter along longest axis).	0.40	0.40	SOIL
Dark brown (7.5YR4/2) clayey sandy GRAVEL. Matrix of deposit, clayey, with coarse (~300 m) sand/quartz grains. Greywacke gravels sub-rounded to occasionally rounded (typically <5 cm diameter).	0.50	0.90	ALLUVIUM GRAVEL
Medium dense very dark greyish brown (10YR3/2) GRAVEL, with a sandy-silty matrix. Some clay present in matrix, but less than in gravel units above. Gravels still small (<5 cm diameter) andmainly sub-rounded to sub-angular. Predominantly greywacke gravels, occasional quartz gravels.	0.50	1.40	
Dark greyish brown (2.5Y4/2) sandy-silty GRAVEL, with some clay in matrix. Mainly greywacke gravel clasts. Slightly wider range of clast size in gravels than in units above (fine-coarse; typical clast diameters 0.5-6 cm diameter), and gravel moderately sorted.	0.30	1. 70	
Soft greenish grey (5BG5/1) fine sandy, silty CLAY/SILT. Occasional blue-grey concretions, and occasional greywacke gravels in soft malleable	0.50	2.20	

CLAYEY deposit.			
Soft dark brown (7.5YR3/2) clayey decomposed PEAT. Subangular-sub rounded gravels in peat (0.2-4.0 cm diameter).	0.20	2.40	PEAT
Medium dense greenish grey ((10BG5/1) clayey sandy GRAVEL. Poorly sorted fine to coarse gravels (0.5-6 cm diameter clasts), mainly greywacke.	0.10	2.50	ALLUVIUM?
Medium dense greenish grey ((10B4/1) GRAVEL. Poorly sorted fine to coarse gravels (0.5-6 cm diameter clasts), mainly greywacke. Occasional clasts >10 cm diameter. Matrix composed of increasing proportion of medium-coarse (250-350 µm) sand with depth at 3 mbgl.	0.60	3.00	
Same as above, but increasingly wider range of clast size in gravels (0.5->10 cm diameter), predominantly of greywacke composition. Occasional chert and quartz clasts up to 1 cm diameter. Overall, GRAVEL appears slightly coarser, with more sandy matrix, and poorly sorted. Gravels are sub-rounded to sub-angular.	3.00	5.00	
Same as above, but increasingly sandy matrix (~200-250 µm typical grain size), and larger range of sub-rounded/sub-angular cobbles and gravels (diameter up to >14 cm). Gravel deposit overall, lighter hue (10YR 4/3). Gravel deposit becomes more sandy with depth.	1.00	6.00	
Brown (7.5YR5/4) SILT, with sub-rounded to sub-angular pebbles embedded in silt (0.1-2 cm diameter)	0.30	6.30	GLACIO-LACUSTRINE SILT
Dense very dark greenish grey (10Y3/1) GRAVEL. Coarse sandy to silty matrix material, with moderately/poorly sorted gravels. Gravels more angular than in gravel unit (3-6 mbgl) unit above thin silt layer, and the sub-angular gravels slightly larger (occasionally >15 cm diameter).	3.20	8.50	GLACIO-FLUVIAL GRAVEL
COMPLETION			
Flush cover			
Concrete			
165 mm OD x 155m ID plain casing	0.61		
Bentonite pellets	0.80		
Pack (1.75-4mm)	1.60		
42mmOD x 32mm ID pvc plain casing	0.98		
42mmOD x 32mm ID pvc screen with 1mm slots casing)	1.63		
42mmOD x 32mm ID pvc plain casing (sump)	1.68		
Bentonite pellets	2.70		
Spoil	4.20		
Pack (natural)	5.80		
Bentonite pellets	6.50		
Pack (natural)	8.58		
90 mm OD x 80 mm ID pvc plain casing	7.33		

90 mm OD x 80 mm ID pvc screen with 1 mm slots 90 mm OD x 80 mm ID pvc plain casing (sump)	8.09 8.58	
Grab / bulk samples		
Sample No		
EDS5/1	0 -0.4	Grab sample (soil)
EDS5/2	0.4-0.9	Bulk sample (gravel)
EDS5/3	0.9-1.4	Bulk sample (gravel)
EDS5/4	1.4-1.7	Bulk sample (gravel)
EDS5/5	1.7-2.2	Grab sample (clay)
EDS5/6	2.2-2.4	Grab sample (peat)
EDS5/7	2.4-2.5	Grab sample (gravel)
EDS5/8	2.5-3.5	Bulk sample (gravel)
EDS5/9	3.5-4.0	Bulk sample (gravel)
EDS5/10	4.0-5.0	Bulk sample (gravel)
EDS5/11	5.0-5.5	Bulk sample (gravel)
EDS5/12	5.5-6.0	Bulk sample (gravel)
EDS5/13	6.0-6.3	Grab sample (clay)
EDS5/14	6.0-6.5	Bulk sample (gravel)
EDS5/15	6.5-7.0	Bulk sample (gravel)
EDS5/16	7.0-7.5	Bulk sample (gravel)
EDS5/17	7.5-8.0	Bulk sample (gravel)
EDS5/18	8.0-8.5	Bulk sample (gravel)

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BOREHOLE LOGS DARNHALL MAINS, EDDLESTON	BOREHOLE No: EDS6	Piezometer ID: EDS3B
	Sheets: 2	
	Grid Reference NT 24190 47707	

Equipment & Methods

Shell & Auger
200mm diam 0-5.0
Dry drilled to 1.20 mBGL

Water levels	Datum level
Water struck and rose immediately to 1.21 mBGL WL = 1.02 mBWT / 1.30 mBGL on 04/04/11	Well top (WT) = 0.28 mBGL Cover level (CL) = 0.04 mBGL

LITHOLOGICAL LOG (Andy Dixon, Nicole Archer)	Date 03/04/11-04/04/11		Lithological Log (Clive Auton)
Description	Thickness	Depth	
Brown (7.5YR4/4) SOIL, with sandy-silty matrix. Few sub-angular to sub-rounded greywacke gravels (0.5-4 cm diameter)	0.70	0.70	SOIL
Brown (10YR4/3) clayey sandy GRAVEL, with silty-clay matrix. Fine, subrounded gravels (~0.1-5 cm diameter), predominantly of greywacke composition. Occasional cobbles >5 cm diameter.	0.70	1.40	ALLUVIUM GRAVEL
Medium dense olive grey (5Y4/2) sandy GRAVEL with iron coated pebbles below 1.90 mBGL Gravel: fine-coarse. Sand: coarse	1.00	2.40	
Medium dense dark yellowish brown (10YR4/4) sandy GRAVEL. Gravels: fine-coarse (0.5-6 cm diameter, poorly sorted. Predominantly of greywacke composition, but occasional chert and quartz clasts. Sandy matrix: coarse (~250-300 μm). Matrix of gravel becomes increasingly sandy with depth, and reduced clay content. Gravels become coarser – a large fraction being 3-5 cm diameter – with same mixture of clast composition (greywacke, chert, quartz).	0.50	2.90	
Medium dense dark greyish brown (2.5Y4/2) sandy GRAVEL. Less silty clayey material in this gravel, than in previous unit above. Coarse sandy matrix (~300 μm). Gravels overall slightly coarser than in unit above, with a large fraction of gravels being ~4-6 cm diameter. Gravel clasts, poorly sorted, and slightly more angular than in gravel	1.50	4.40	

unit above. Gravel clasts: greywacke, with occasional chert and quartz.			
Dense olive brown (2.5Y4/3) sandy GRAVEL. Medium-coarse sandy clay matrix (200-300 µm), with fine to medium sized gravels (0.5-5 cm diameter), and occasional cobbles (up to 11 cm diameter). A higher proportion of gravels sub-angular, than in overlying gravel units. Very poorly sorted deposit.	0.60	5.00	
COMPLETION			
Flush cover Concrete 165 mm OD x 155m ID plain casing Bentonite pellets Pack (natural) 90 mm OD x 80 mm ID pvc plain casing 90 mm OD x 80 mm ID pvc screen with 1 mm slots 90 mm OD x 80 mm ID pvc plain casing (sump)	 0.20 0.60 0.60 4.75 2.99 3.75 4.75		

Grab / bulk samples

Sample No		
EDS6/1	0 -0.7	Grab sample (soil)
EDS6/2	0.7-0.9	Bulk sample (gravel)
EDS6/3	0.9-1.4	Bulk sample (gravel)
EDS6/4	1.4-1.9	Bulk sample (gravel)
EDS6/5	1.9-2.4	Bulk sample (gravel)
EDS6/6	2.4-2.9	Bulk sample (gravel)
EDS6/7	2.9-3.4	Bulk sample (gravel)
EDS6/8	3.4-3.9	Bulk sample (gravel)
EDS6/9	3.9-4.4	Bulk sample (gravel)
EDS6/10	4.4-5.0	Bulk sample (gravel)

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BOREHOLE LOGS **DARNHALL MAINS, EDDLESTON**	**BOREHOLE No:** EDS7	**Piezometer ID:** EDS4A
	Sheets: 2	
	Grid Reference NT 24290 47521	

Equipment & Methods

Shell & Auger
250mm diam 0-2 m
200mm 2-8.1 m
Dry drilled to 2.0 mBGL

Water levels	**Datum level**
Water struck at 1.9 and rose to 0.75 mBGL after 30 mins WL = 0.59 mBGL on 04/05/11 at 09:15 WL= 0.53m BGL on 08/05/11	Well top (WT) = 0.23 mBGL 165mm casing = 0.07 mBGL Cover level (CL) = 0.04 mBGL

LITHOLOGICAL LOG (Andy Dixon, Helen Bonsor)	**Date** 03/05/11-04/05/11		**Lithological Log (Clive Auton)**
Description	Thickness	Depth	
Pale brown (7.5YR4/3) silty clayey SOIL,	0.70	0.70	SOIL
Pale brown-grey (10YR5/1) CLAY with some strong brown mottling. Soft deposit, malleable in hand. Fine grained (~200 µm)	0.50	1.20	CLAYEY ALLUVIUM
Brown- grey (5Y4/1) CLAY (slightly darker and siltier in hue than clay above). Soft deposit, malleable in hand.	0.70	1.90	
Loose dark grey (5Y4/1) clayey very sandy GRAVEL. Matrix – fine-medium grained (~200-350 µm). Gravels, predominantly greywacke, with occasional quartz and rare chert. Clast sizes: fine (0.1-0.5 cm diameter longest axis) and moderately-coarse (1-7 cm diameter clasts). All gravel clasts subangular-subrounded.	0.50	2.40	ALLUVIUM GRAVEL
Fine to coarse subangular-subrounded sandy GRAVEL - similar to unit above, but slightly more dense. Below 3.4 mbgl the greywacke gravel becomes brown coated – iron oxide coating?	1.20	3.60	
Medium dense dark grey (N4) and reddish-brown coated sandy GRAVEL. Reddish hue to gravels possibly due to iron oxide staining of greywacke. Gravels – predominantly greywacke clasts, subangular-subrounded poorly sorted (total gravel size range 0.1->12cm; typically 0.1-0.5 and 1-7 cm ranges). Sandy matrix medium-coarse grained (~250-300 µm).	1.50	5.10	GLACIO-FLUVIAL GRAVEL
Same as abpve but increasing proportion of sandy matrix, and gravel clasts overally become smaller	3.00	8.10	

(1-3 cm diameter typical)			
COMPLETION			

Flush cover	0.1	
Concrete	0.1	
165 mm OD x 155m ID plain casing	0.62	
Bentonite pellets	1.90	
Pack (1.7-4mm)	2.20	
Pack (natural)	8.02	
90 mm OD x 80 mm ID pvc plain casing	6.25	
90 mm OD x 80 mm ID pvc screen with 1 mm slots	7.01	
90 mm OD x 80 mm ID pvc plain casing (sump)	8.02	

Grab / bulk samples		
Sample No		
EDS7/1	0 -0.7	Grab sample (soil)
EDS7/2	0.7-1.2	Grab sample (clay)
EDS7/3	1.2-1.9	Grab sample (clay)
EDS7/4	1.9-2.4	Bulk sample (gravel)
EDS7/5	2.4-3.1	Bulk sample (gravel)
EDS7/6	3.1-3.6	Bulk sample (gravel)
EDS7/7	3.6-4.1	Bulk sample (gravel)
EDS7/8	4.1-4.6	Bulk sample (gravel)
EDS7/9	4.6-5.1	Bulk sample (gravel)
EDS7/10	5.1-5.6	Bulk sample (gravel)
EDS7/11	5.6-6.1	Bulk sample (gravel)
EDS7/12	6.1-6.6	Bulk sample (gravel)
EDS7/13	6.6-7.1	Bulk sample (gravel)
EDS7/14	7.1-7.6	Bulk sample (gravel)
EDS7/14	7.6-8.1	Bulk sample (gravel)

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BOREHOLE LOGS **DARNHALL MAINS, EDDLESTON**	**BOREHOLE No:** EDS8	**Piezometer ID:** EDS4B
	Sheets: 2	
	Grid Reference NT 24284 47522	

Equipment & Methods

Shell & Auger
250mm diam 0-2 m
200mm diam 2-5 m
Dry drilled to 2.0 mBGL

Water levels	**Datum level**
Water struck at 1.8 and rose to 0.70 mBGL after 30 mins RWL on completion 05/05/11 = 0.72 mBGL RWL on 08/05/11 = 0.57 mBGL	Well top (WT) = 0.30 mBGL 165mm casing = 0.12 mBGL Cover level (CL) = 0.04 mBGL

LITHOLOGICAL LOG (Andy Dixon and Helen Bonsor)	**Date** 04/05/11-05/05/11		**Lithological Log (Clive Auton)**
Description	Thickness	Depth	SOIL
Pale brown (7.5YR5/3), silty, clayey, fine (<200 µm) SOIL containing some roots; no gravels.	0.60	0.60	ALLUVIUM SILT
Pale brown-grey (2.5Y5/1) silty CLAY with some yellowish red (5YR5/6) mottling (iron oxide staining likely). Soft, malleable in hand without cracking. Very fine grained (<200 µm); no gravels.	0.60	1.20	
Greyer-pale brown (10YR4/1) CLAY. Soft, malleable deposit. Very fine grained (~<200 µm), relatively dense deposit. No gravels.	0.60	1.80	
Loose-medium dense dark grey (2.5Y4/1) clayey sandy GRAVEL. Matrix sandy, clayey – fine-medium grained (~200-350 µm). Gravels – bimodal grain size ranges: fine (0.1-0.5 cm diameter longest axis) and moderately-coarse (1-7 cm diameter clasts). All gravel clasts subangular-subrounded. Clasts predominantly greywacke, occasional quartz.	0.50	2.30	ALLUVIUM GRAVEL
Medium dense dark grey (2.5Y4/1) sandy GRAVEL. Clean gravel, with minor proportion of sandy-silty matrix – proportion of matrix to gravels ~5:95%. Sub-rounded moderately sorted gravel clasts – predominantly greywacke, but with some chert, quartz and red sandstone clasts. Gravels appear slightly more sub-rounded, rather than sub-angular, than in gravel above.	0.50	2.80	
Same as above - medium dense dark grey (N4) GRAVEL – but higher proportion of fine gravel clasts (0.1-0.5 cm diameter), and sandy matrix.	1.00	3.80	

Proportion of matrix to gravels ~20:80%.			
Same as above - medium dense dark grey (N4) GRAVEL – but increased proportion of fine gravel clasts (0.1-0.5 cm diameter), and sandy matrix. Proportion of matrix to gravels ~70:30%. Large gravel clasts (>2 cm diameter) occasional. Sandy matrix coarser (~350 µm).	0.50	4.30	
Dark grey (5Y3/1), to reddish, sandy GRAVEL with some clay below 4.8m. Reddish hue to gravels possibly due to iron oxide staining of greywacke. Gravel: mainly fine (<5 cm diameter) subangular-subrounded clasts (greywacke, chert, quartz), poorly sorted (total gravel size range 0.1->12cm; typically 0.1-5 cm). Sandy matrix medium-coarse grained (~250-300 µm).	0.70	5.00	GLACIO-FLUVIAL GRAVEL
COMPLETION			
Flush cover	0.1		
Concrete	0.1		
165 mm OD x 155m ID plain casing	0.72		
Bentonite pellets	1.80		
Pack (1.7-4mm)	1.90		
Pack (natural)	5.04		
90 mm OD x 80 mm ID pvc plain casing	3.28		
90 mm OD x 80 mm ID pvc screen with 1 mm slots	4.04		
90 mm OD x 80 mm ID pvc plain casing (sump)	5.04		

Grab / bulk samples

Sample No		
EDS8/1	0 -0.6	Grab sample (soil)
EDS8/2	0.6-1.2	Grab sample (clay)
EDS8/3	1.2-1.8	Grab sample (clay)
EDS8/4	1.9-2.3	Bulk sample (gravel)
EDS8/5	2.3-2.8	Bulk sample (gravel)
EDS8/6	2.8-3.3	Bulk sample (gravel)
EDS8/7	3.3-3.8	Bulk sample (gravel)
EDS8/8	3.8-4.3	Bulk sample (gravel)
EDS8/9	4.3-4.8	Bulk sample (gravel)

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BOREHOLE LOGS **DARNHALL MAINS, EDDLESTON**	**BOREHOLE No:** EDS9	**Piezometer ID:** EDS5A and EDS5B
	Sheets: 3	
	Grid Reference NT 24236 47523	

Equipment & Methods
Shell & Auger
300mm diam 0-1
250mm diam 1-8
200mm 8-15 mBGL
Dry drilled 0-1
Note: densities dependent on drilling diameter

Water levels	**Datum level**
RWL on 06/05/11 = 0.73 mBGL (casing and hole = 1 mBGL RWL on 07/05/11 = 0.72 (casing and hole at 8.0m) RWL on 08/05/11 = 0.97m BGL (casing at 12.0m) RWL (deep well) on 08/05/11 = 1.11m BGL (casing at 13.0m) RWL (deep well) on 08/05/11 = 1.07m BGL (casing at 7m) and inside 250mm casing =1.01 mBGL RWL (deep well) on 10/05/11 = 0.70 mBWT RWL (shallow well) on 10/05/11 = 0.68 mBWT	Deep well top (WT) = 0.30 mBGL Deep 165mm casing = 0.14 mBGL Shallow well top = 0.10 m BGL Cover level (CL) = flush

LITHOLOGICAL LOG (Andy Dixon, Helen Bonsor)	**Date** 05/04/11-		**Lithological Log (Clive Auton)**
Description	Thickness	Depth	
Pale brown (7.5YR5/3), silty SOIL. Very fine (~200 µm). Occasional small gravels.	0.60	0.60	SOIL
Dense brown (7.5YR4/2) very clayey fine sandy GRAVEL (approx. 60% gravels; 40% fine sandy-clayey matrix material).	0.50	1.10	ALLUVIUM GRAVEL
Dense dark grey-pale brown (5Y4/1), very clayey fine-coarse sandy GRAVEL. Gravel clasts (typically 1-4 cm diameter, longest axis), sub-rounded to sub-angular clasts – predominantly greywacke; rare chert.	0.70	1.80	
Medium dense very dark grey (N3) very sandy GRAVEL. Gravel clasts predominantly greywacke, with some chert, quartz and red sandstone clasts. All clasts sub-angular to sub-rounded. Approximately 40% of deposit, is composed fine gravels (~0.1-1cm diameter on longest axis), and the remainder coarse gravels (typically 1-7 cm diameter on longest axis) and sandy matrix. Proportion of coarser gravels increases slightly	2.50	4.30	

below 3.20 mbgl, and sandy matrix becomes coarser from below 2.70 mbgl.			
Dense very dark grey (N3) sandy GRAVEL with abundant brown coated pebbles. Slightly stronger bimodal size of gravels: fine (<1 cm) and coarse gravels (1-10 cm) and fine gravels comprise a higher proportion of deposit (~50:50). Gravel clasts remain sub-angular to sub-rounded and predominantly greywacke, with occasional-rare chert, and quartz. Sandy matrix (~250-300 µm).	0.60	4.90	
Reddish brown (5YR4/3 slightly humified PEAT	0.10	5.00	PEAT
Dark grey-brown (N4) clayey SILT with peaty material below 5.1m	0.40	5.40	EARLY HOLOCENE ORGANIC SILT
Grey-green (N5) SILT becoming strong brown (7.5YR5/6) below 5.7m. Smooth, malleable deposit, medium dense.	0.30	5.70	
	0.1	5.80	GLACIO-LACUSTRINE SILT
Medium dense brown (7.5Y4/3) to reddish, very sandy GRAVEL. Clean sandy gravel, with little clayey matrix material. Gravel clasts predominantly greywacke, with occasional chert, quartz and red sandstone? Some greywacke gravels have red-brown hue – iron oxide staining? Gravels sub-rounded to sub-angular, very occasionally rounded. Approx. 30% of gravels fine (~0.1-1 cm diameter); the remainder large gravels (typically 1-12 cm diameter on longest axis). Sandy matrix medium-coarse (250-350 µm). Towards base of unit (from ~8-12 mbgl) there is a lower proportion of fine gravels; higher proportion of the sandy matrix; and a similar proportion of coarse gravels. From 12-12.9 mgbl the proportion of sandy matrix increases further, at the expense of fine gravels. Proportion of medium-coarse sandy matrix to coarse gravels is: 40:60%.	3.10	8.90	GLACIO-FLUVIAL GRAVEL
Medium dense reddish brown (5RY4/2) very sandy GRAVEL. Gravel: fine-coarse subangular-subrounded Sand: fine -coarse	0.60	9.50	
Medium dense dark reddish brown (5RY3/2) very sandy GRAVEL. Gravel: fine-coarse subangular-subrounded Sand: fine -coarse	1.00	10.5	
Medium dense dark reddish brown (5RY3/2) very sandy GRAVEL. Gravel: fine-coarse subangular-subrounded Sand: fine -coarse	0.70	11.20	
Medium dense reddish grey (5YR4/2) mainly medium SAND	0.50	11.70	

Medium dense dark reddish brown (5RY3/2) very sandy GRAVEL. Gravel: fine-coarse subangular-subrounded Sand: fine -coarse	0.50	12.20	
Medium dense dark reddish brown (5RY3/2) gravelly SAND. Gravel: fine subangular-subrounded Sand: medium with fine and coarse	0.50	12.70	
Pale brown-grey (2.5YR4/2) SILT, clayey between13.7-14.3 and 14.7-15.0 m. Soft, 'sloppy' deposit, highly malleable to hand.	2.30	15.00	GLACIO-LACUSTRINE SILT

COMPLETION

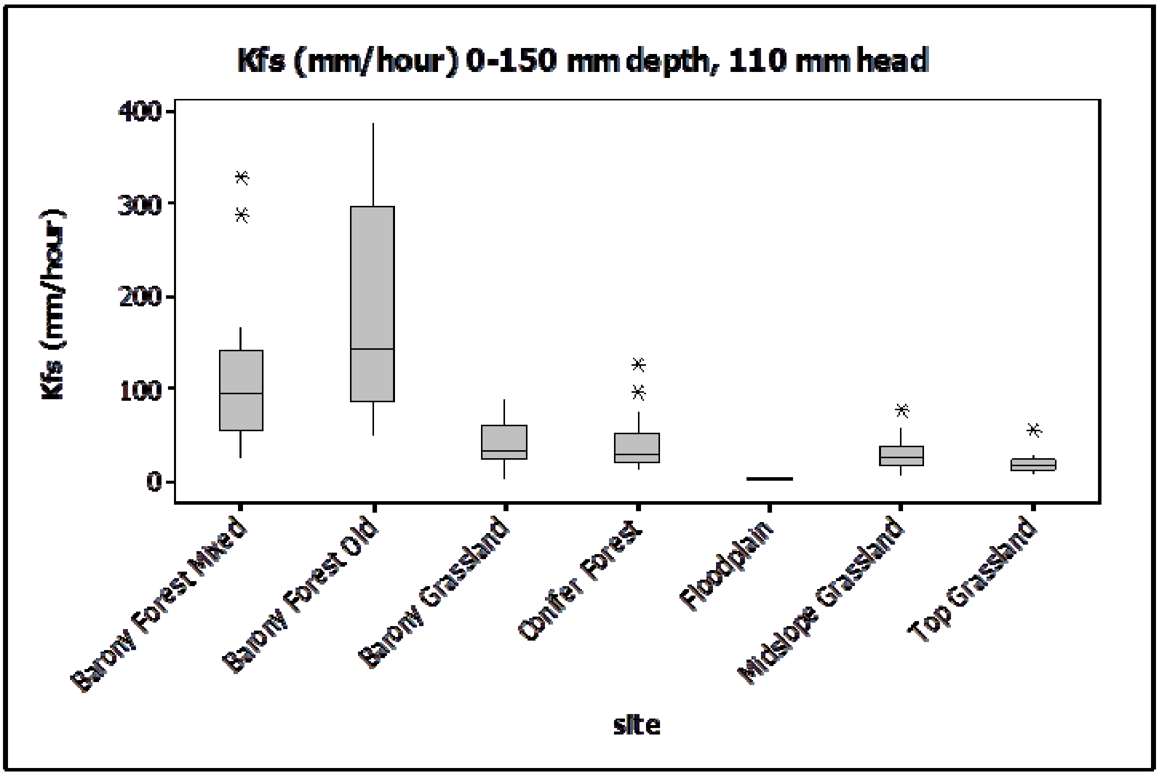
Completion	
Flush cover	0.35
Concrete	0.35
165 mm OD x 155m ID plain casing around deep well	0.64
Pack (natural)	4.90
90 mm OD x 80 mm ID pvc plain casing	3.24
90 mm OD x 80 mm ID pvc screen with 1.0 mm slots	4.00
90 mm OD x 80 mm ID pvc plain casing (sump)	4.70
Bentonite pellets	5.80
Pack (natural)	13.90
Bentonite	15.00
90 mm OD x 80 mm ID pvc plain casing	11.27
90 mm OD x 80 mm ID pvc screen with 0.5 mm slots	12.07
90 mm OD x 80 mm ID pvc plain casing (sump)	13.07

Grab / bulk samples

Sample No		
EDS9/1	0 -0.5	Grab sample (soil)
EDS9/2	0.5-1.1	Grab sample (clay)
EDS9/3	1.1-1.8	Grab sample (clay)
EDS9/4	1.8-2.2	Bulk sample (gravel)
EDS9/5	2.2-2.7	Bulk sample (gravel)
EDS9/6	2.7-3.2	Bulk sample (gravel)
EDS9/7	3.2-3.7	Bulk sample (gravel)
EDS9/8	3.7-4.3	Bulk sample (gravel)
EDS9/9	4.3-4.9	Bulk sample (gravel)
EDS9/10	4.9-5.0	Grab sample (peat)
EDS9/11	5.0-5.1	Grab sample (silt)
EDS9/12	5.1-5.4	Grab sample (silt)
EDS9/13	5.4-5.7	Grab sample (silt)
EDS9/15	5.7-5.8	Grab sample (silt)
EDS9/16	5.8-6.5	Bulk sample (gravel)
EDS9/17	6.5-6.9	Bulk sample (gravel)
EDS9/18	6.9.7.4	Bulk sample (gravel)
EDS9/19	7.4-7.9	Bulk sample (gravel)
EDS9/20	7.9-8.4	Bulk sample (gravel)
EDS9/21	8.4-8.9	Bulk sample (gravel)
EDS9/22	8.9-9.5	Bulk sample (gravel)

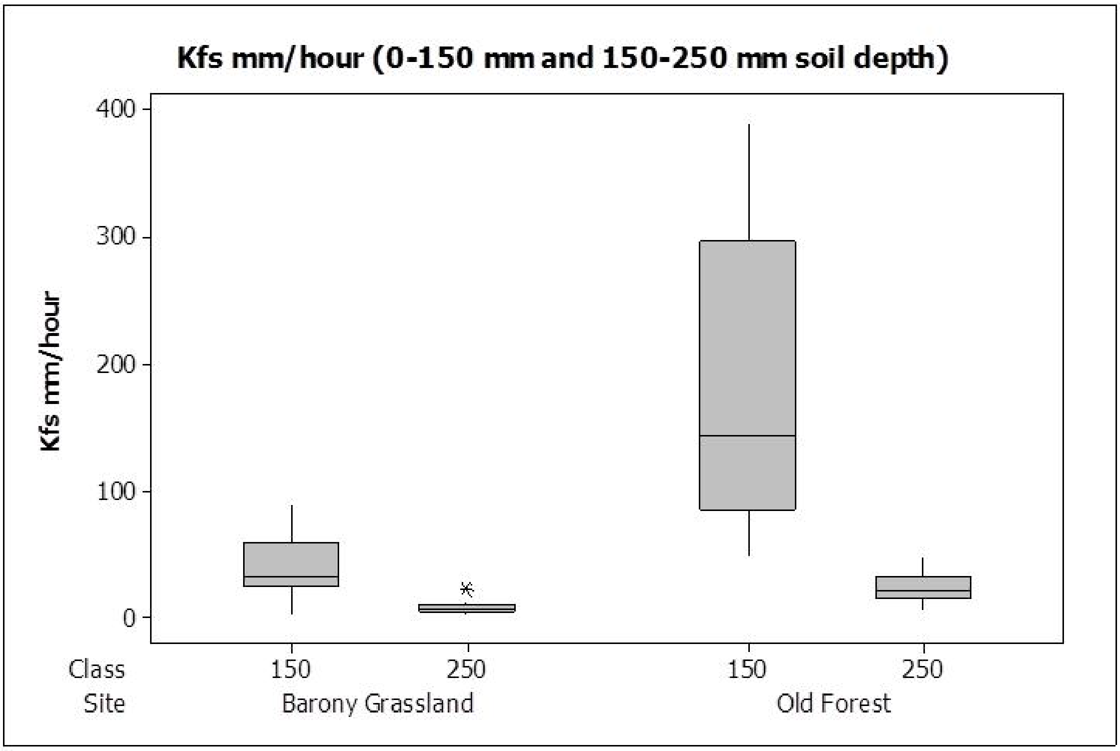
EDS9/23	9.5-10.0	Bulk sample (gravel)
EDS9/24	10.0-10.5	Bulk sample (gravel)
EDS9/25	10.5-11.2	Bulk sample (gravel)
EDS9/26	11.2-11.7	Bulk sample (sand)
EDS9/27	11.7-12.2	Bulk sample (gravel)
EDS9/28	12.2-12.7	Bulk sample (sand)
EDS9/29	12.7-13.7	Grab sample (silt) – poor recovery
EDS9/30	13.7-14.3	Bulk sample (silt)
EDS9/31	14.3-14.7	Grab sample (silt) – poor recovery
EDS9/32	14.7-15.0	Bulk sample (silt)

Appendix 4 Soil permeability data



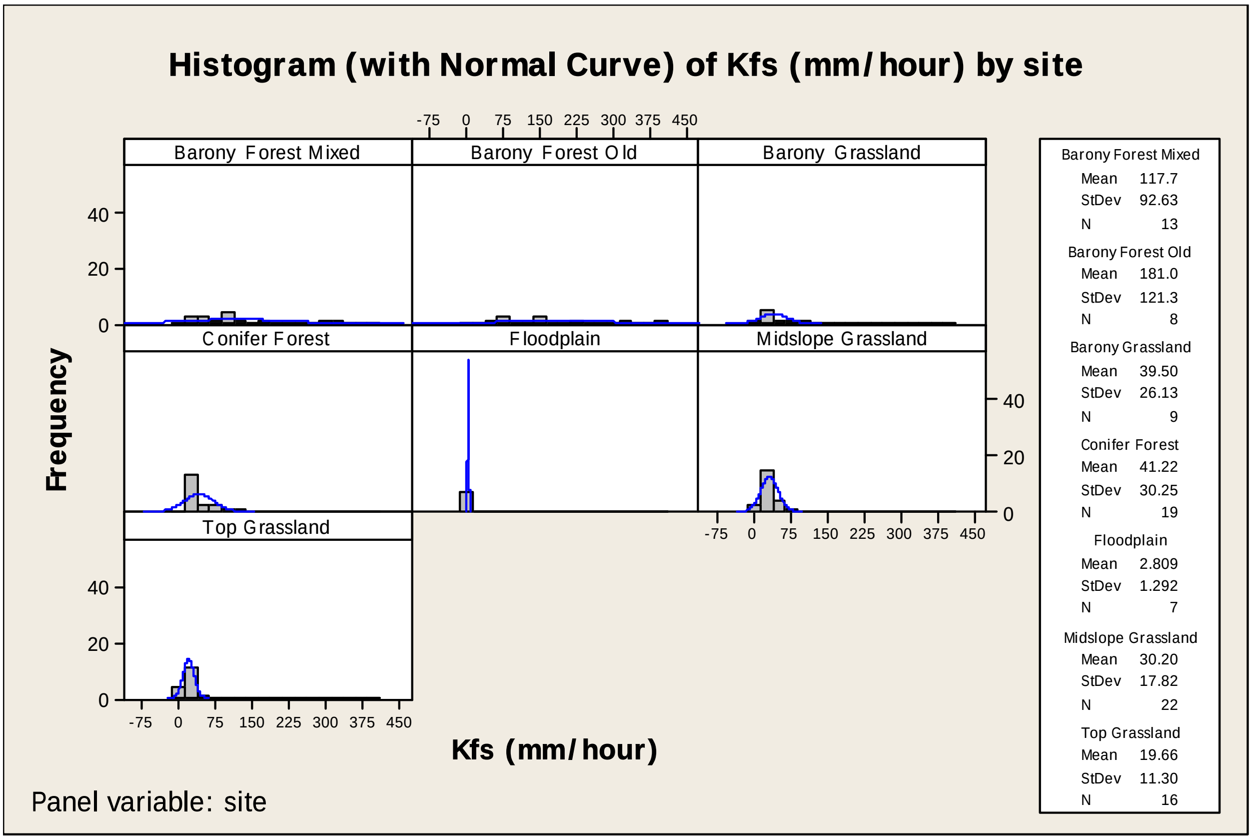
Bars show the lower and upper interquartile range for the data of each site. The middle line in each bar is the median; outliers are marked as asterisks

A8-1 Range of field hydraulic conductivity (Kfs) measurements in each sample area, in mm/hour



150 = soil depth of 40-15cm; 250 = soil depth of 15-25cm

A8-2 Range of field hydraulic conductivity (Kfs) measurements for both measured depth intervals in the Barony Grassland and Barony Old Forest sample areas



A8-3 Normal distribution curves of field hydraulic conductivity (Kfs) for each sample site for the upper soil depth (4 to 15 cm)

Table A8-1 Descriptive statistics for Ksat data for Barony Grassland and Barony Old Forest samples areas

Site	Variable	Class	Soil depth (cm)	N	N*	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
Barony Grassland	Ks mm/hour	150	4-15	9	0	39.50	8.71	26.13	3.48	23.91	32.37	59.93	87.52
		250	15-25	9	0	8.86	1.91	5.72	3.66	5.18	6.26	10.97	22.25
Barony Old Forest	Ks mm/hour	150	4-15	8	0	181.0	42.9	121.3	48.3	85.7	143.1	296.4	388.3
		250	15-25	9	0	23.67	4.22	12.65	6.78	15.30	21.76	32.14	47.63