Foel Fach Wind Farm Limited.

Foel Fach Wind Farm – Environmental Statement Volume III

Appendix 8.4: Geophysical Survey Report: Foel Fach Wind Farm, UAV Magnetometer Survey Test Area

Project Reference: 664094

DECEMBER 2025

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FFMD25

FOEL FACH WIND FARM

GEOPHYSICAL SURVEY (UAV MAGNETOMETER SURVEY)

commissioned by RSK Environment
on behalf of Foel Fach Wind Farm Limited

November 2025

HEADLAND ARCHAEOLOGY

REGISTERED ORGANISATION CIfA

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This report adheres to the quality standard of ISO 9001:2015

PROJECT INFO:

HA Project Code **FFMD25** / HA Report No **2025-137** / NGR **SH 93854 41299** / Community **Llandderfel** / Local Authority **Gwynedd Council** / Fieldwork Date **29.04.2025 & 14.07.2025 – 27/08/2025**

PROJECT TEAM:

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Approved by **Sam Harrison** .....

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an RSK company

REGISTERED ORGANISATION CIfA

PROJECT SUMMARY

Headland Archaeology (UK) Ltd was commissioned by Foel Fach Wind Farm Limited (the Applicant) to undertake a geophysical (magnetometer) survey at the proposed location of Foel Fach Wind Farm, Glan-Yr-Afon (the Site). The results of this and two previous geophysical surveys will inform future archaeological strategy, if required.

Due to the steep terrain and uneven ground conditions conventional hand-carried or quad-bike towed magnetometer survey could not be carried out. A feasibility unmanned aerial vehicle (UAV - drone) borne magnetometer survey was therefore carried out and the successful completion of this was followed by additional drone survey along some of the routes of proposed access tracks, compound areas and turbine locations for the wind farm, following approval of the methodology by Heneb: The Trust for Welsh Archaeology. Some of the proposed survey areas could not be surveyed due to unsuitable weather conditions and data quality was sometimes inconsistent due to variable wind speed; these factors all demonstrating the potential problems of carrying out an aerial survey in an upland environment. Although drone-borne surveys are not currently considered in archaeological geophysical prospection best practice and guidance documents, the survey parameters adhered to current standards required for archaeological geophysical prospection.

Despite the challenging circumstances the survey has identified numerous anomalies although these are almost all due to geological variation and extant landscape features and boundaries. A few linear and discrete anomalies of uncertain origin have also been recorded although in all instances geological, agricultural or modern causes are considered more likely than an archaeological origin. The detection of these weakly enhanced magnetic anomalies however suggests that there was likely sufficient magnetic contrast, for the detection of potential archaeological features, if present notwithstanding the limitations of magnetometer survey to identify the certain types, sizes, and periods of archaeological features as described in the report text. No anomalies of archaeological potential have been recorded by the survey.

Despite the variable data quality, the survey has demonstrated that under favourable conditions drone-borne magnetometer surveys can provide reasonable results. Clearly, resolution of weaker anomalies will be more difficult with an air-borne survey but in circumstances where conventional survey would be unsafe or logistically impractical a drone survey offers a potential solution.

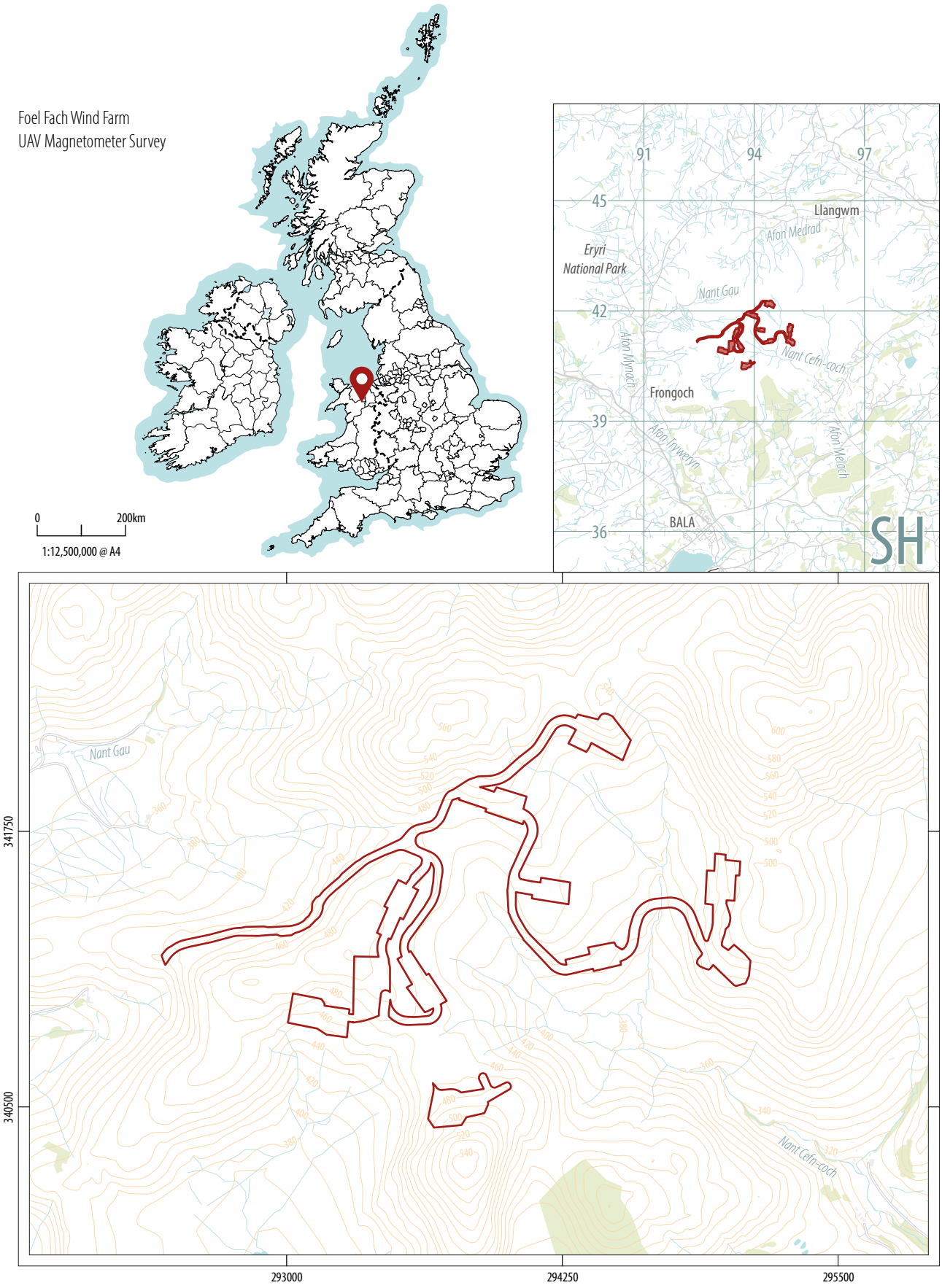
CRYNODEB

Cafodd Headland Archaeology (UK) Ltd ei gomisiynu gan Foel Fach Wind Farm Limited (yr Ymgeisydd) i ymgymryd arolwg geoffisegol (magnetomedr) ar tir oddi fewn i ddatblygiad arfaethedig Fferm Gwynt Foel Fach, Glan-Yr-Afon. Gall y caluniadau hyn cyfarwyddo strategaeth archeolegol yn y dyfodol.

Oherwydd y tir serth ac amodau tir anwastad ni ellid gyflawni arolwg magnetomedr confensiynol gyda llaw neu beic cwad. Felly, cyflawnwyd arolwg magnetomedr gyda cerbyd awyr di-griw (unmanned aerial vehicle (UAV) – drôn). Yn dilyn cwblwhad llwyddianus yr arolwg hwn, cafodd arolwg drôn ychwanegol ei gyflawni ar hyd rhai o llwybrau y traciau mynediad arfeathedig, ardaloedd compwnd a lleoliadau tyrbinau ar gyfer y fferm gwynt, yn dilyn cymeradwyaeth y methodoleg gan Heneb; Ymddieriedolaeth Archaeoleg Cymru. Ni ellid arolygu rhai o'r ardaeloedd arolwg arfaethedig oherwydd amodau tywydd anaddas, a weithiau roedd ansawdd y data yn anghyson; wnaeth y ffactorau hyn arddangos problemau posibl o ran cyflawni arolwg awyr o fewn amgylchedd ucheldirol. Er nad yw arolygion gyda drôn yn cael eu ystyried o fewn dogfennau canllawiau arfer gorau archwiliad geoffisegol archeolegol ar hyn o bryd, cadawodd paramedrau yr arolwg i safonau cyfredol sydd yn ofynnol ar gyfer archwiliad geoffisegol archaeolegol.

CONTENTS

LIST OF ILLUSTRATIONS



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ILLUS 1 Site location

FOEL FACH WIND FARM

GEOPHYSICAL SURVEY (UAV MAGNETOMETER SURVEY)

1 INTRODUCTION

Headland Archaeology (UK) Ltd was commissioned by Foel Fach Wind Farm Limited (the Applicant) to undertake a geophysical (magnetometer) survey on land for the proposed Foel Fach Wind Farm, Glan-Yr-Afon (Illus 1). Two previous geophysical surveys covering access tracks and a temporary compound area (Headland 2025a & Headland 2025b) have already been completed. The results of these previous surveys and the current survey may also inform future archaeological strategy, if required.

The scheme of work was undertaken in accordance with the requirements of the Planning Policy Wales 2024 (Edition 12, Ch.6 The Historic Environment) and with the Written Scheme of Investigation for Geophysical Survey (WSI) (Headland Archaeology 2025).

This survey was undertaken with drone-mounted survey equipment, a delivery system not currently recognised in guidance and best practice documents but which was undertaken in line with standards and guidance laid down in the European Archaeological Council's guideline publication, EAC Guidelines for the Use of Geophysics in Archaeology (Europae Archaeologia Consilium 2020) and the Chartered Institute for Archaeologists' (CIfA) Standard and Guidance for Archaeological Geophysical Survey (CIfA 2020).

The survey was carried out in two phases. A feasibility survey was carried out on April 29th but due to a co-ordinate transformation error the test area (a section of proposed access track) was incorrectly positioned immediately west of its intended location, although within the wider Site boundary. The correctly positioned survey corridor was re-flown on July 7th and July 8th, 2025 (Phase 1).

Following the successful completion of the feasibility survey a report was produced and submitted to Heneb: The Trust for Welsh Archaeology. Following approval of the report by Jenny Emmet, National Lead: Planning at Heneb, Phase 2 of the survey was carried out in August 2025. The geophysical survey area (Illus 2 - GSA) covered the proposed hard infrastructure comprising the areas of proposed wind turbines, associated infrastructure and tracks and including a buffer zone.

1.1 SITE LOCATION, TOPOGRAPHY AND LAND-USE

The feasibility geophysical survey area (FGSA) covered two proposed sections of access trackway (Illus 2) across areas of upland pasture centred at NGR SH 293737, 341761 and SH 293640, 340703 respectively. These two areas were selected as suitable locations to ascertain the effectiveness of a drone-mounted survey over the same geological, pedological and topographic conditions as prevail across the wider Site. The two survey areas are located on Pen y Bwlch Gwyn, east of Glan-Yr-Afon.

The unsurveyed areas within the GSA (see Illus 3) could not be surveyed due to poor weather (high and variable wind speeds) leading to missing the weather widow.

All the GSA comprised upland pasture which is undulating and steep in places ranging between 527 metres (m) Above Ordnance Datum (AOD) and 418m AOD.

1.2 GEOLOGY AND SOILS

The underlying bedrock across the GSA primarily consists of a complex and irregular spread of mudstone of the Ceiswyn Formation and siltstone of the Glyn Gower Siltstones Member. Both bedrocks are sedimentary in nature and formed during the Ordovician period. Small outcrops of igneous tuff (Cefn Gwyn Tuff) and limestone of the

Rhiwlas Limestone Member are mapped in the immediate vicinity of the GSA though none directly within it.

Sedimentary till superficial deposits formed between 116 and 11.8 thousand years ago during the Quaternary period are mapped across the central and southern parts of the GSA (NERC 2025).

The soils are very acidic upland loams with a wet, peaty surface, classified in the Soilscape 16 Association (Cranfield University 2025).

2 ARCHAEOLOGICAL BACKGROUND

The following has been abstracted from an Archaeological Desk Based and Stage 1 Setting Assessment (Headland Archaeology 2025) produced for the proposed scheme. It should be noted that the information below relates to the wider site boundary and not specifically to the areas evaluated by the current survey.

This assessment has identified 44 non-designated historic assets within the Site: forty-three in the WAT HER and an unrecorded linear feature that likely represents a boundary marker of unknown date identified by analysis of LiDAR data and satellite imagery and confirmed during a field visit.

Two non-designated historic assets recorded by WAT HER date to the prehistoric period: a grass covered cairn on the summit of Garnedd Fawr and north-eastern site boundary (WAT HER PRN 3258), and a hut circle located in the centre-east of the site (WAT HER PRN 15611), which has been suggested as a possible medieval or post-medieval livestock shelter.

WAT HER records two non-designated historic assets that date to the medieval period in the centre-west of the site associated with the former township of Llaethgwm (WAT HER PRN 9896), and a possible former hermitage (WAT HER 3259).

Most of the non-designated historic assets recorded by WAT HER and the linear feature, either date to the post-medieval period or are of an unknown origin, representing 90% of the non-designated historic assets identified within the site boundary. They are largely agricultural in character and include farms, outbuildings, outfarms, sheepfolds or shelters, and enclosures. Small-scale industrial and extraction activity has also been identified including a pond, a sluice, peat cuttings, mines and quarries and gravel pits, while small infrastructure features such as boundary markers, trackways, and a dam have also been recorded.

It is considered that there is a medium potential for unknown buried archaeological remains of low (local) importance to be present within the Site dating to the Bronze Age. Two non-designated historic assets possibly date to this period, while there is considered to be a low potential for earlier prehistoric activity as glacial and interglacial cycles would have caused changes in the climatic and environmental changes that probably meant that the site and surrounding landscape was inhospitable for human activity for certain periods of time.

Garnedd Fawr cairn (WAT HER PRN 3258) is of archaeological interest of medium (regional) importance. The significance of the cairn largely lies in its evidential value, as there is a potential for buried human remains to be preserved. There is a bias towards cairns surviving in upland locations, as these areas remain largely undeveloped. However, WAT HER describes Garnedd Fawr cairn as being a mutilated and grass covered that has been subsequently repurposed as a marker, with a boundary stone inscribed with 'LLANFOR' on its south side and 'LLANGWM' on its north, set within a hollow in the cairn, while fencing and fence posts further illustrates that the cairn now functions as a marker between these two parishes. However, Wales as whole is a good area to analyse the concept of 'ritual landscape', which is as much of a research priority as the understanding the extensive evidence of settlement activity, with Garnedd Fawr cairn likely contributing to a wider Bronze Age ritual and funerary landscape.

Similarly, Llandderfel hut circle (WAT HER PRN 15611), either as a prehistoric feature or as a medieval to post medieval, is of archaeological interest of low (local) to medium (regional) importance, as there is no firm dating evidence, while more assessment is required to establish its chronology and the chronological sequence for individual non-defended settlement from the Bronze Age.

Single and dispersed groups of roundhouses are generally found at higher altitudes, representing a functionally complementary component of the economic regime, perhaps seasonally used for hunting or for high summer pastures. One thousand roundhouse settlements have been recorded within the region, with many single roundhouses occurring above the 200m contour, while larger, enclosed and nucleated settlements are more likely found at altitudes lower than 200m. This suggest a differentiation between settlement types due to altitude is likely for economic, social or functional distinctions rather than chronology, while possible associated upland field systems have not received sufficient detailed analysis.

There is considered to be a low potential for Romano-British activity to be present within the site boundary. Activity from this period was focused on the strategically significant Afon Dyfrdwy valley, where Roman forts and road were constructed to control the lower valley and routeway.

Medieval activity has also been identified within the Site. It is deemed that there is a low to medium potential for further unknown buried archaeological remains of low (local) importance from this period. Although the medieval township of Llaethgwm (llaytcoum) is recorded within the site boundary by documentary evidence (WAT HER PRN 9896). It is suggested by this assessment that this township more likely relates to Llaithgwm Farm, although this is an often-stated assumption and further confirmation would be required. Few excavations of medieval settlements have been undertaken, meaning that they are less well understood and recognised on the ground, as there has been a tendency to over rely on map and documentary evidence alone. Therefore, if correct and the township is located within the site boundary it would be of archaeological and historical interest of low (local) importance as evidence for an element that influenced the formation of the rural medieval landscape. A determined effort to understand and

recorded the medieval landscape is at the forefront of current archaeological research.

The former site of Eglwys Ann (WAT HER PRN 3259) has been suggested as the possible location of a hermitage due to its concealed location and the fact that the ground surrounding it is too wet and marshy for agriculture. There is no specific documentary evidence that refers to the hermitage but if correct, any buried remains relating to the hermitage would be of archaeological and historical interest of low (local) importance which could shed new light upon the medieval landscape, while knowledge of the archaeology of pilgrimage routes, holy wells and relics is poorly understood.

Even though a possible medieval settlement and hermitage have been identified it is more than likely that any further unknown buried archaeological remains would be agricultural in character and of low (local) importance.

The agricultural character of the landscape continued into the post-medieval period. As previously stated, the largest amount of non-designated historic assets within the site boundary date to the post-medieval period and relate to a range of agricultural features. These aid in characterising and illustrating this landscape but are also invaluable in identifying the variety in the post-medieval landscapes.

Post-medieval small-scale extraction activity has also been recorded with six peat cuttings, two quarries and an aluminous earth mine and turf works. These all help characterise the former post-medieval landscape although the Gwynedd slate and metalliferous mining industries are both reasonably well-known.

A linear feature has also been identified through LiDAR and satellite imagery analysis and ground truthed during the site visit. This is of an unknown origin but as the feature is not depicted on historical maps and due to its linearity is suggested to be of a more recent provenance and likely a former boundary marker of low (local) importance, similarly, characterising the landscape within the site boundary.

Two previous hand-carried magnetometer surveys (Headland 2025a and 2025b) identified various anomalies of natural and modern anthropogenic origin indicating the survey methodology and site were suitable for the detection of possible buried archaeological remains, notwithstanding the general limitations of magnetometer survey to identify certain types, sizes, and period of archaeological features particularly over the prevailing geologies.

3 AIMS, METHODOLOGY & PRESENTATION

3.1 AIMS AND OBJECTIVES

The principal aim of the geophysical survey was to gather information to establish the presence/absence, character, and extent of any archaeological remains within the Site. This would enable an assessment to be made of the impact of the proposed development on any sub-surface archaeological remains if present, and thereby inform any further investigation strategies, as appropriate.

The specific archaeological objectives of the UAV geophysical survey were:

- to assess the suitability of the technique over upland landscape within the Site where conventional magnetometer survey is unsuitable;
- to provide information about the nature and possible interpretation of any magnetic anomalies identified;
- to therefore determine the likely presence/absence and extent of any buried archaeological features; and
- to prepare a report summarising the results of the survey.

3.2 METHODOLOGY

Magnetic survey methods rely on the ability of a variety of instruments to measure very small magnetic fields associated with buried archaeological remains. A feature such as a ditch, pit or kiln can act like a small magnet, or series of magnets, that produce distortions (anomalies) in the earth's magnetic field. In mapping these slight variations detailed plans of sites can be obtained, as buried features often produce reasonably characteristic anomaly shapes and strengths (Gaffney & Gater 2003). Further information on soil magnetism and the interpretation of magnetic anomalies is provided in Annex 1.

Magnetometry is the most widely used geophysical survey technique in archaeology as it can quickly evaluate large areas and, under favourable conditions, identify a wide range of archaeological features including infilled cut features such as large pits, gullies and ditches, hearths, and areas of burning, and kilns and brick structures. It is therefore good at locating settlements of all periods, prehistoric field systems and enclosures, and areas of industrial or modern activity, amongst others. It is less successful in identifying smaller features such as post-holes and small pits (except when using a non-standard sampling interval), unenclosed (prehistoric) settlement sites and graves or burial grounds. However, magnetometry is by far the single most useful technique and was assessed as the best non-intrusive evaluation tool for this site.

The survey utilised a Sensys MagDrone with five 3-axis sensors employing UgCS True Terrain Following (TTF) radar in conjunction with a DJI M350 Drone. The sensors on the MagDrone were mounted 0.5 m apart and were flown at 2.5 m intervals. Data was collected at 200 Hertz (Hz) and resampled to 0.1 m. The drone was flown at a height of 1m above ground level (AGL) with the MagDrone sensors at 0.75 m AGL.

The path of the drone was pre-planned using UgCS software with the required height AGL pre-programmed into the flightpath. Readings were stored on the MagDrone and processed to filter out the noise from the drone using MagDroneDataTool (Sensys GMbH).

Anomaly GeoSurvey v1.12.3 (Lichenstone Geoscience) and QGIS v.3.28.5 software was used to process and present the data respectively.

3.3 DATA PRESENTATION & TECHNICAL DETAIL

A general site location plan is shown in Illus 1 at a scale of 1:25,000. The location of the FGSA and GSA is shown in Illus 2 at a scale of 1:10,000. Illus 3 and Illus 4 are overviews of the fully processed data and interpretation respectively. Fully processed (greyscale) magnetometer data, minimally processed (XY trace plot) data and interpretative plans are shown on Illus 5 to Illus 16 inclusive, by Sector, at a scale of 1:2,500.

Technical information on the equipment used, data processing and magnetic survey methodology is given in Annex 1. Annex 2 details the survey location information. Annex 3 describes the composition and location of the site archive. Data processing details are presented in Annex 4. A copy of the OASIS entry (Online Access to the Index of Archaeological Investigations) is reproduced in Annex 5.

Despite using new technologies not currently accounted for in best practice and guidance documents, the survey parameters did adhere to standards required for archaeological geophysical prospection, outlined by Europae Archaeologia Consilium (EAC 2016) and by the Chartered Institute for Archaeologists (CIfA 2020).

The Illustrations in this report have been produced following analysis of the data in 'raw' (minimally processed) and processed formats and over a range of different display levels. All illustrations are presented to display and interpret the data to best effect. The interpretations are based on the experience and knowledge of Headland Archaeology management and reporting staff.

4 RESULTS & DISCUSSION

4.1 SITE CONDITIONS, ANOMALY RESOLUTION AND INTERPRETATION

Magnetometer survey is generally recommended over any sedimentary bedrock geology, but results can be poor across mudstone geologies and variable across limestone and siltstones (English Heritage 2008; Table 4). Nevertheless, magnetometry was still the most appropriate non-intrusive geophysical technique for evaluating the GSA, taking account of the adverse ground conditions necessitating a drone survey and the limitations noted in Section 3.2 and above.

Weather conditions during the feasibility survey were generally good however high winds during the second phase of the survey prevented coverage of all areas and led to reduced data quality in some places. However, it is assessed that the reduced data quality has not detracted from the ability of the survey to have detected archaeological features, if present. Interference with the drone by red kites was also a minor problem during the feasibility survey.

The magnetic background varies across the GSA with some low magnitude broad and narrow sinuous trend anomalies and slightly enhanced discrete responses interpreted as being due to geological and pedological variation. Against this magnetic background, anomalies of agricultural, modern and geological/natural origin have been recorded. Several linear anomalies of uncertain origin have also been identified (Illus 4).

The detection of these weakly enhanced magnetic anomalies however suggests that there was likely sufficient magnetic contrast, for the detection of potential archaeological features, if present notwithstanding the limitations of magnetometer survey to identify the types, sizes, and period of archaeological features as described in Section 3.2 and keeping in mind the generally variable response to magnetometer survey across the prevailing geological conditions. The results of the survey are therefore considered to likely provide a reasonable indication of the archaeological potential of the Site.

The anomalies are discussed below according to their interpreted origin.

4.2 ANOMALIES OF FERROUS AND MODERN ORIGIN

A high magnitude discrete anomaly has been recorded in the northern section of the GSA at NGR 293651.5,341776.5 (Illus 10 - MD1). It has a magnetic signature consistent with an anthropogenic cause but there is no supporting evidence to support a more detailed interpretation.

A high magnitude linear anomaly orientated roughly north-east to south-west has been identified within the corridor section in the northern section of the GSA at NGR 293520,341692 (Illus 10 - MT1). This has been interpreted as a modern track which is visible on recent satellite imagery (Google Earth 2025).

Data artefacts can be seen manifesting as anomalous parallel linear trends and are particularly noticeable in Sector 3 (Illus 11 to Illus 13) and Sector 5 (Illus 17 to Illus 19). These data artefacts are caused by the magnetometer drone which it has not been possible to remove by post-survey processing.

4.3 ANOMALIES OF AGRICULTURAL ORIGIN

Several extant boundaries (Illus 4 - FB1 to FB5 inclusive), have been recorded by the survey, all of which are visible on satellite imagery (Google Earth 2025). These features manifest as high magnitude linear anomalies.

4.4 ANOMALIES OF GEOLOGICAL ORIGIN

Numerous anomalies of natural (geological) origin have been recorded across the GSA (Illus 5 and Illus 8). The distribution of these anomalies within the data is considered most likely due to natural, localised variations in topography and past hydrological effects and changes in the underlying bedrock geology and spreads of till superficial deposits.

A cluster of low magnitude discrete magnetic anomalies in the north of the southernmost corridor (Illus 11 to Illus 16 inclusive) where the trials were conducted, likely corresponds with a small area of limestone of the Rhiwlas Limestone Member mapped immediately south of this location. The anomalies are probably caused by soil filled fissures and depressions or pits in the limestone bedrock. Within the rest of the GSA, where till superficial deposits are mapped in the south and mudstone bedrock is more prevalent the magnetic background is more homogeneous, containing fewer discrete responses but several low magnitude sinuous trends likely resulting from topographic changes across the GSA.

4.5 ANOMALIES OF POSSIBLE OR PROBABLE ARCHAEOLOGICAL ORIGIN

No anomalies of probable or clear archaeological potential have been identified.

4.6 ANOMALIES OF UNCERTAIN ORIGIN

Several linear, curvilinear and discrete anomalies have been interpreted as of uncertain origin on the basis they cannot be confidently interpreted in any other category. They are highlighted as they generally stand-out above the natural magnetic background in their immediate vicinity. Where possible the most likely cause has been stated. In all cases an archaeological cause is considered least likely due to the absence of any other evidence to support an anthropogenic (archaeological) interpretation.

Four linear anomalies of uncertain origin have been recorded (Illus 4 - L1 to L4 inclusive). Anomaly L1 (Illus 19) in the north-east of the GSA at the location of a proposed wind turbine base and located at NGR 293391, 341869, is a faint linear anomaly orientated approximately south-west to north-east oblique to the direction of geological trends in the immediate vicinity. A geological or agricultural origin is assessed as the most likely cause.

Anomalies L2, L3 and L4 (Illus 10) are similar in response to L1 and cannot be obviously related to either geology or topography due to their general orientation differing from surrounding geological anomalies. However, an archaeological origin is again considered unlikely.

A pair of high magnitude, discrete anomalies have been recorded (Illus 4 and Illus 10 – ME1 and ME2).

ME1 is located at the western end of the survey area (Illus 7) at NGR 292484, 341211 and ME2 is located at NGR 293709, 341884 (Illus 10). The form and magnitude of the anomalies suggest a geological origin is perhaps the most likely cause.

Four other curvilinear and linear anomalies have also been identified (Illus 4 - U1 to U4 inclusive). U1 to U3 inclusive (Illus 19) comprises two curvilinear negative anomalies at the north-eastern end of the site, a very low magnitude positive response and U3 a possibly rectilinear anomaly located at NGR 294102, 341760 respectively.

U4 (Illus 7) is partial linear anomaly with two discrete low magnitude round anomalies to the east of it. A geological or agricultural cause is on balance deemed the most likely cause.

Three pit-like low magnitude responses (Illus 19 – P1) have been recorded approximately 13m north-west of U3. A relationship with the sub-rectangular feature cannot be discounted but is considered unlikely.

5 CONCLUSION

Due to the steep terrain and uneven ground conditions conventional hand-carried or quad-bike towed magnetometer survey could not be carried out. A feasibility drone-borne magnetometer survey was therefore carried out. Following the successful completion of this pilot survey and the approval of the subsequent report and methodology by Heneb additional survey was carried out along some of the routes of proposed access tracks, compound areas and turbine locations for the wind farm. Some of the proposed survey area could not be surveyed due to unsuitable weather (strong and variable wind speeds) and data quality was sometimes inconsistent; these factors demonstrating the potential problems of carrying out an aerial survey in an upland environment. Although drone-borne surveys are not currently considered in archaeological geophysical prospection best practice and guidance documents, the survey parameters adhered to current standards required for archaeological geophysical prospection.

Despite the challenging circumstances the survey has identified numerous anomalies although these are almost all interpreted as being due to geological variation and extant landscape features and boundaries. A few linear and discrete anomalies of uncertain origin have also been recorded although in all instances geological, agricultural or modern causes are considered more likely than an archaeological origin. No anomalies of archaeological potential have been recorded by the survey.

Despite the variable results the survey has demonstrated that in favourable conditions drone magnetometer surveys can provide reasonable results. Clearly, resolution of weaker anomalies will be more difficult with an air-borne survey (with a flight height of 1m above ground level) but in circumstances where conventional survey would be unsafe or logistically impractical a drone survey offers a potential solution.

6 REFERENCES

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Headland Archaeology (2025b) ***Access Track and Compound, Foel Fach Wind Farm, Glan-Yr-Afon, North Wales Geophysical Survey Report*** FFWW24b

Headland Archaeology (2025) ***Foel Fach DNS Archaeological Desk-Based and Stage 1 Setting Assessment***

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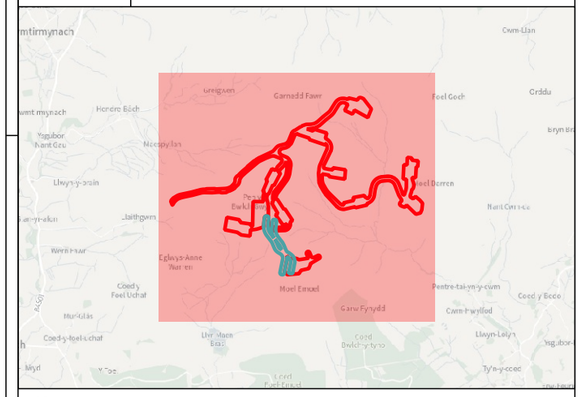

Key

- Feasibility Geophysical Survey Area
- Geophysical Survey Area
- Survey Extent

0 200 400 m

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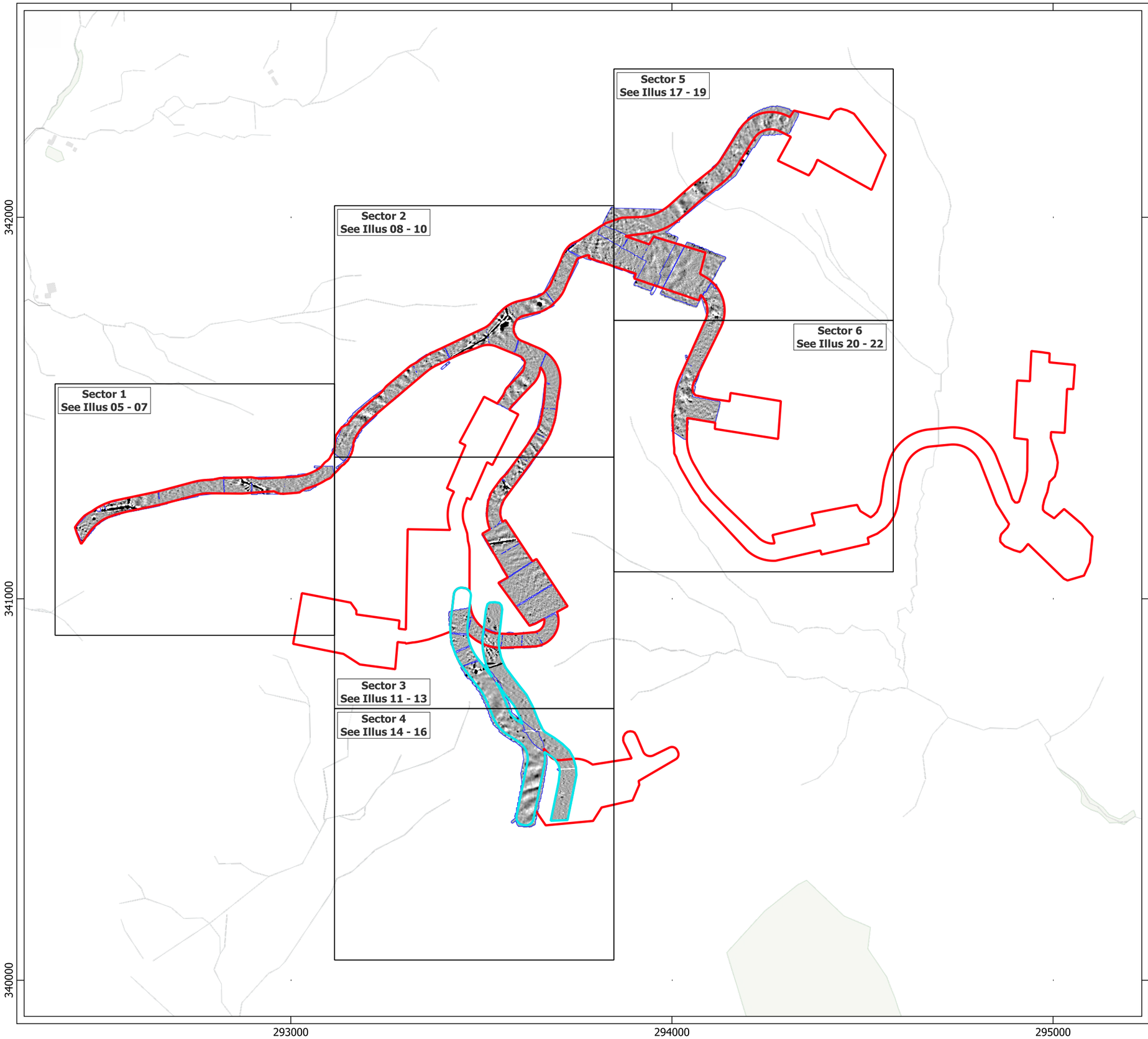
Created by:	CM
Checked by:	SH
Version:	v1.0
Date:	04/11/2025
Scale:	1:10,000 @ A3

Illus 02 - Survey location showing areas unsuitable for survey



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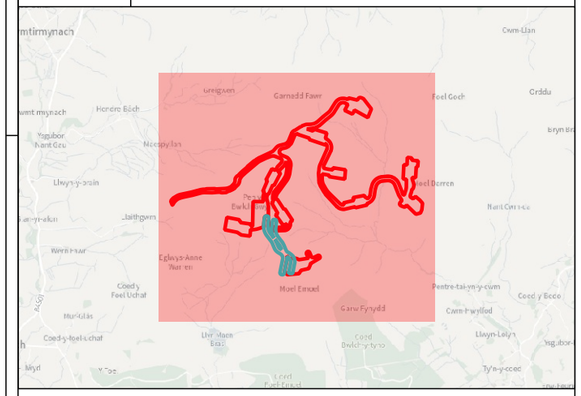


Key

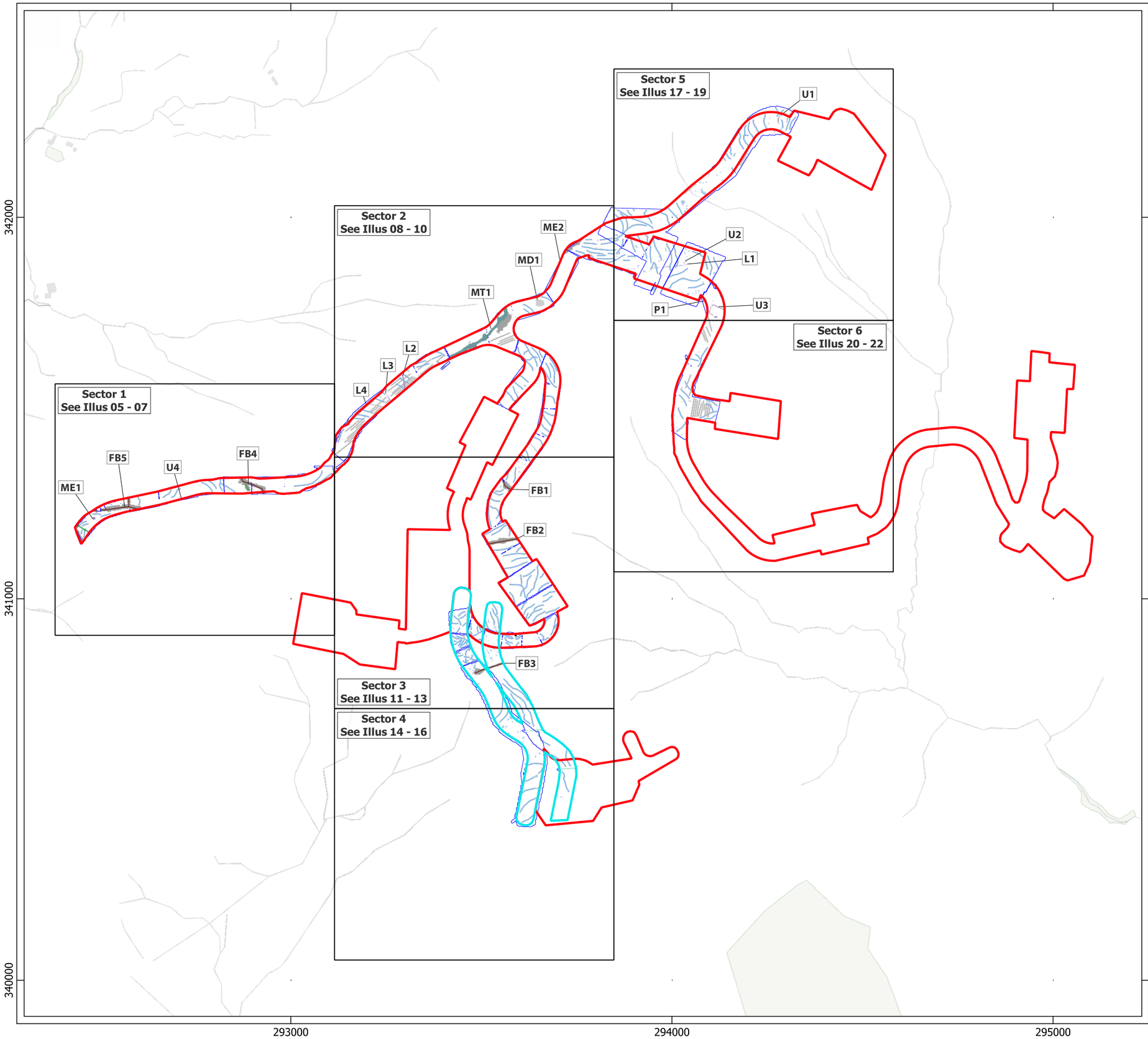
- Feasibility Geophysical Survey Area
- Geophysical Survey Area
- Survey Extent
- Area for Illus 05 - 16

+2nT
-1nT

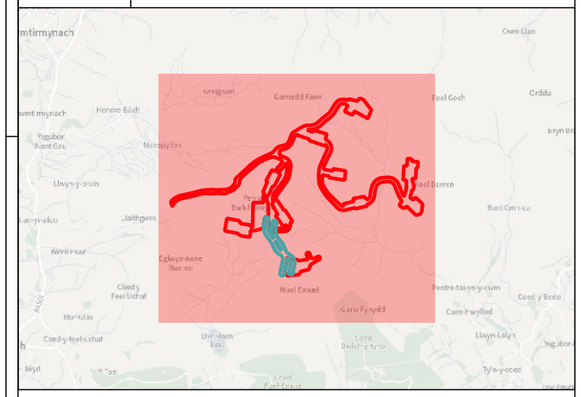
0 200 400 m

Site:	FFMD25
Created by:	CM
Checked by:	SH
Version:	v1.0
Date:	04/11/2025
Scale:	1:10,000 @ A3

Illus 03 - Greyscale plot of processed magnetometer data



HEADLAND ARCHAEOLOGY
an RSK company



Key

- Feasibility Geophysical Survey Area
- Geophysical Survey Area
- Survey Extent
- Area for Illus 05 - 16
- Ferrous Objects
- Data Artefact
- Field Boundary
- Field Drain
- Natural
- Uncertain
- Magnetic Disturbance (Above Ground)
- Magnetic Disturbance (Below Ground)
- Natural
- Uncertain
- Data Artefact
- Modern Track

	Abbreviation
FB	Field Boundary
L	Linear Trend
MD	Magnetic Disturbance
ME	Magnetic Enhancement
MT	Modern Track
P	Pit
U	Uncertain

0 200 400 m

Site:	FFMD25
Created by:	CM
Checked by:	SH
Version:	v1.0
Date:	04/11/2025
Scale:	1:10,000 @ A3

Illus 04 - Interpretation of magnetometer data

341500

341250

341000

292500

292750

293000

N

HEADLAND ARCHAEOLOGY
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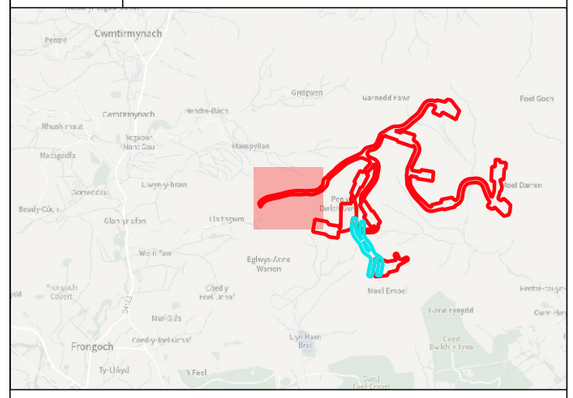


Key

Survey Extent

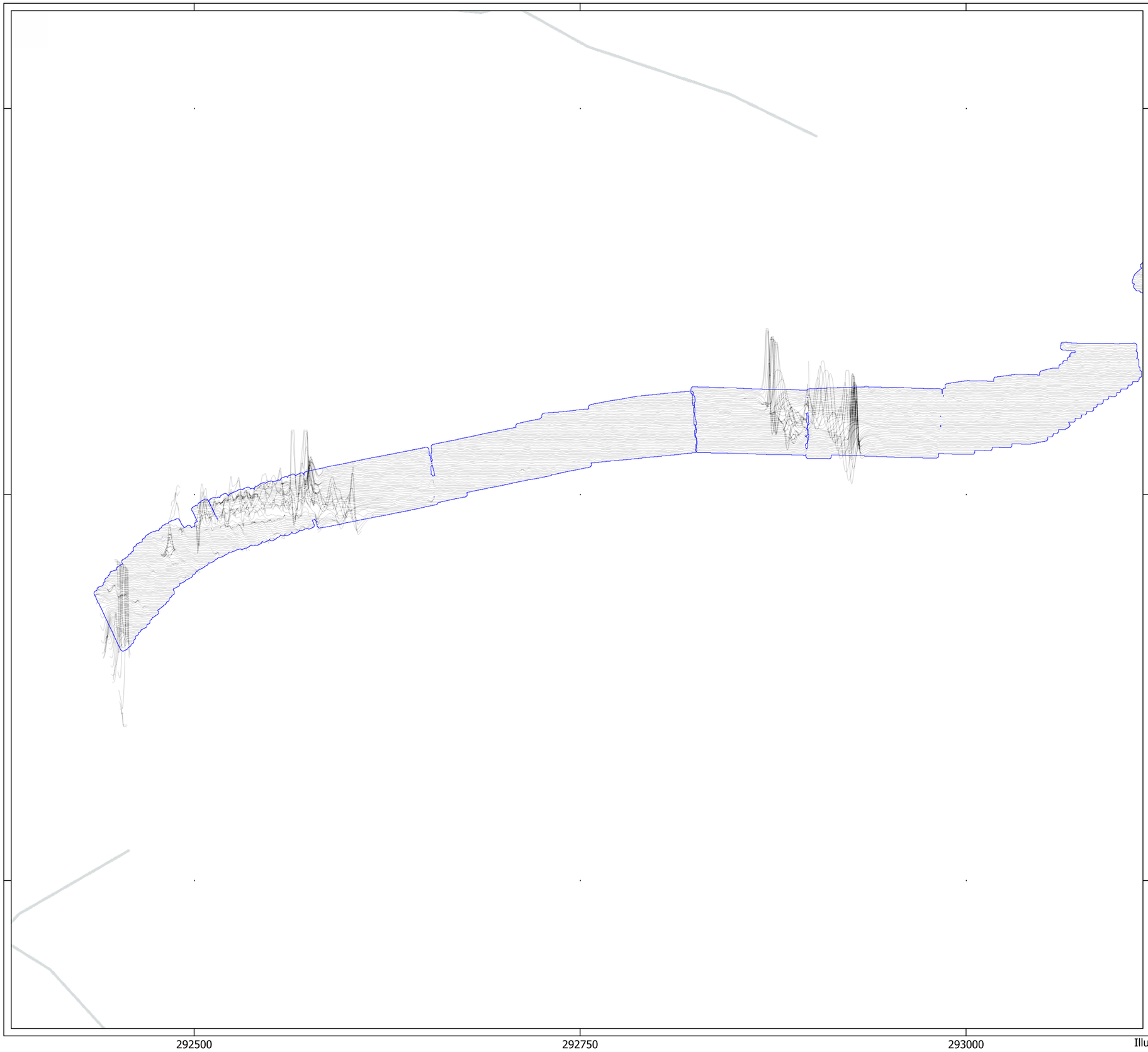
+2nT

-1nT

0 50 100 m

Site:	FFMD25
Created by:	CM
Checked by:	SH
Version:	v1.0
Date:	04/11/2025
Scale:	1:2,500 @ A3

Illus - 05 Processed greyscale magnetometer data; Sector 1



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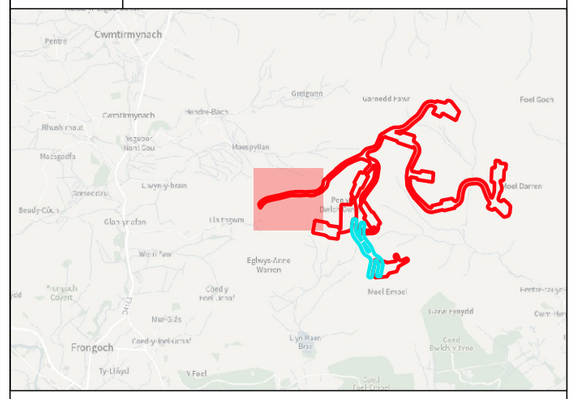
HEADLAND ARCHAEOLOGY
an RSK company



Key

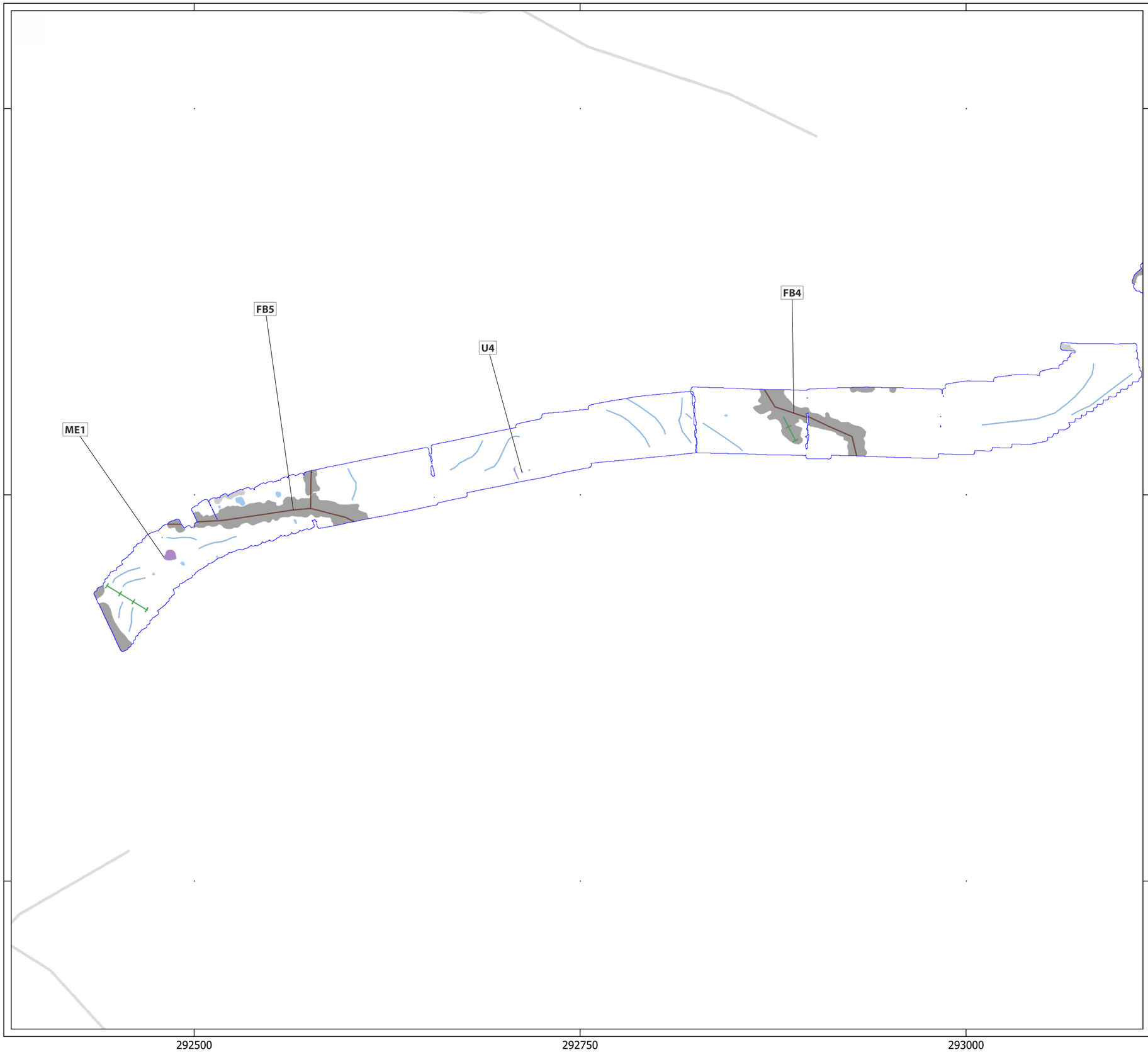
Survey Extent

XY Trace (25nT/cm)

0 50 100 m

Site:	FFMD25
Created by:	CM
Checked by:	SH
Version:	v1.0
Date:	04/11/2025
Scale:	1:2,500 @ A3

Illus - 06 XY trace plot of minimally processed magnetometer data; Sector 1



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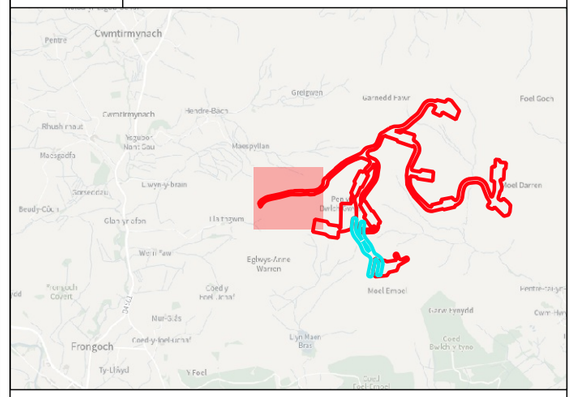
HEADLAND ARCHAEOLOGY
an RSK company



Key

- Survey Extent
- Field Boundary
- Field Drain
- Natural
- Magnetic Disturbance (Above Ground)
- Magnetic Disturbance (Below Ground)
- Natural
- Uncertain

	Abbreviation
FB	Field Boundary
ME	Magnetic Enhancement
U	Uncertain

0 50 100 m

Site:	FFMD25
Created by:	CM
Checked by:	SH
Version:	v1.0
Date:	04/11/2025
Scale:	1:2,500 @ A3

Illus - 07 Interpretation of magnetometer data; Sector 1

342000

341750

341500

293250

293500

293750

N

HEADLAND ARCHAEOLOGY
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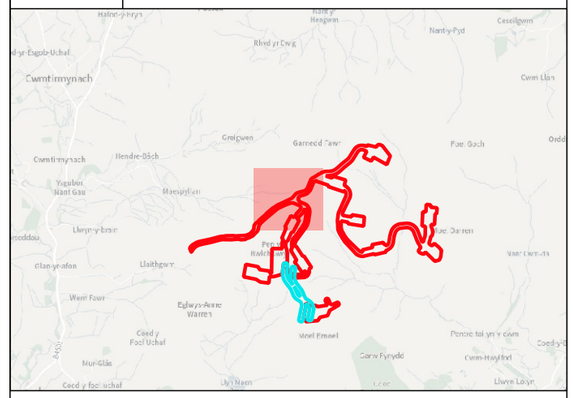


Key

Survey Extent

+2nT

-1nT

0 50 100 m

Site:	FFMD25
Created by:	CM
Checked by:	SH
Version:	v1.0
Date:	04/11/2025
Scale:	1:2,500 @ A3

Illus - 08 Processed greyscale magnetometer data; Sector 2

342000

341750

341500

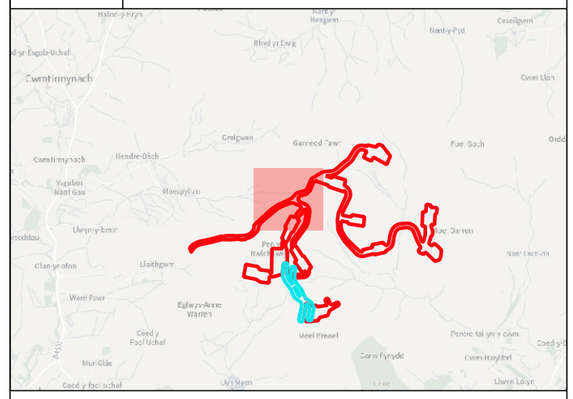
293250

293500

293750

N

HEADLAND ARCHAEOLOGY
an RSK company



Key

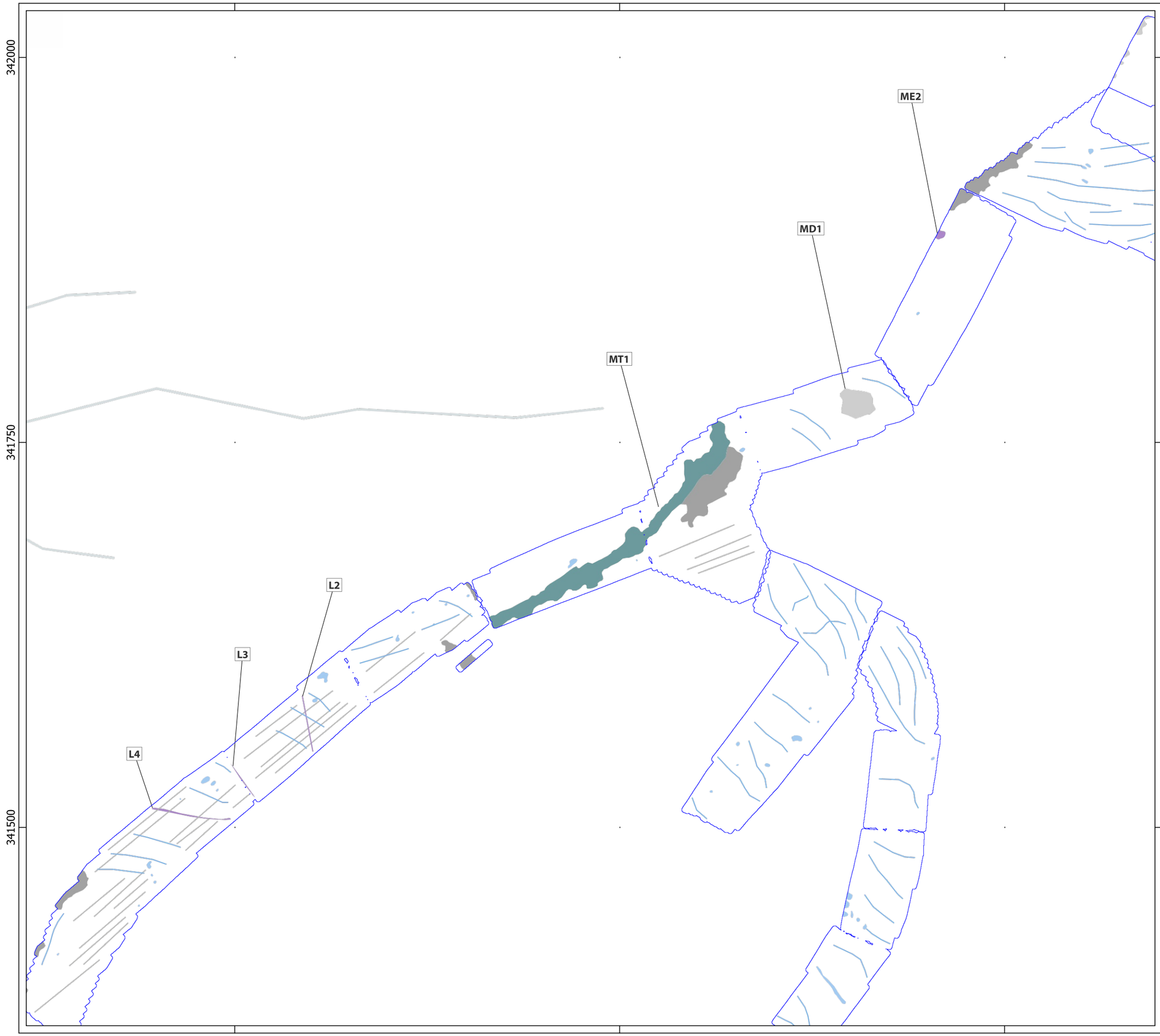
Survey Extent

XY Trace (25nT/cm)

0 50 100 m

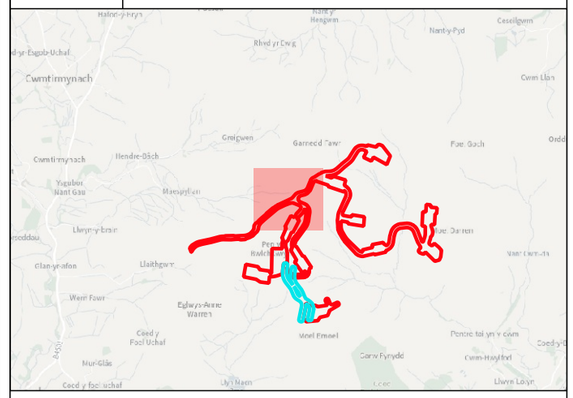
Site:	FFMD25
Created by:	CM
Checked by:	SH
Version:	v1.0
Date:	04/11/2025
Scale:	1:2,500 @ A3

Illus - 09 XY trace plot of minimally processed magnetometer data; Sector 2



N

HEADLAND ARCHAEOLOGY
an RSK company



Key

- Survey Extent
- Data Artefact
- Natural
- Uncertain
- Magnetic Disturbance (Above Ground)
- Magnetic Disturbance (Below Ground)
- Natural
- Uncertain
- Modern Track

	Abbreviation
L	Linear Trend
MD	Magnetic Disturbance
ME	Magnetic Enhancement
MT	Modern Track

0 50 100 m

Site:	FFMD25
Created by:	CM
Checked by:	SH
Version:	v1.0
Date:	04/11/2025
Scale:	1:2,500 @ A3

Illus - 10 Interpretation of magnetometer data; Sector 2

341250

341000

340750

293250

293500

293750

N

HEADLAND ARCHAEOLOGY
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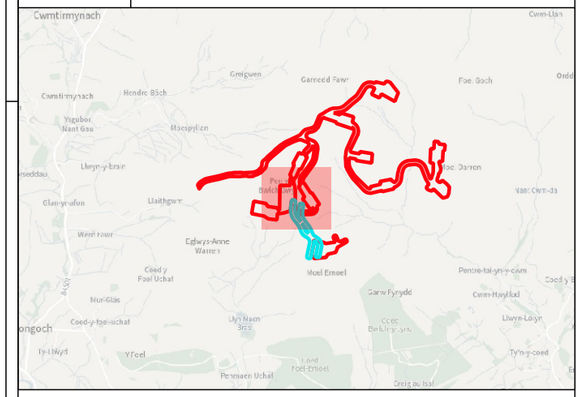


Key

Survey Extent

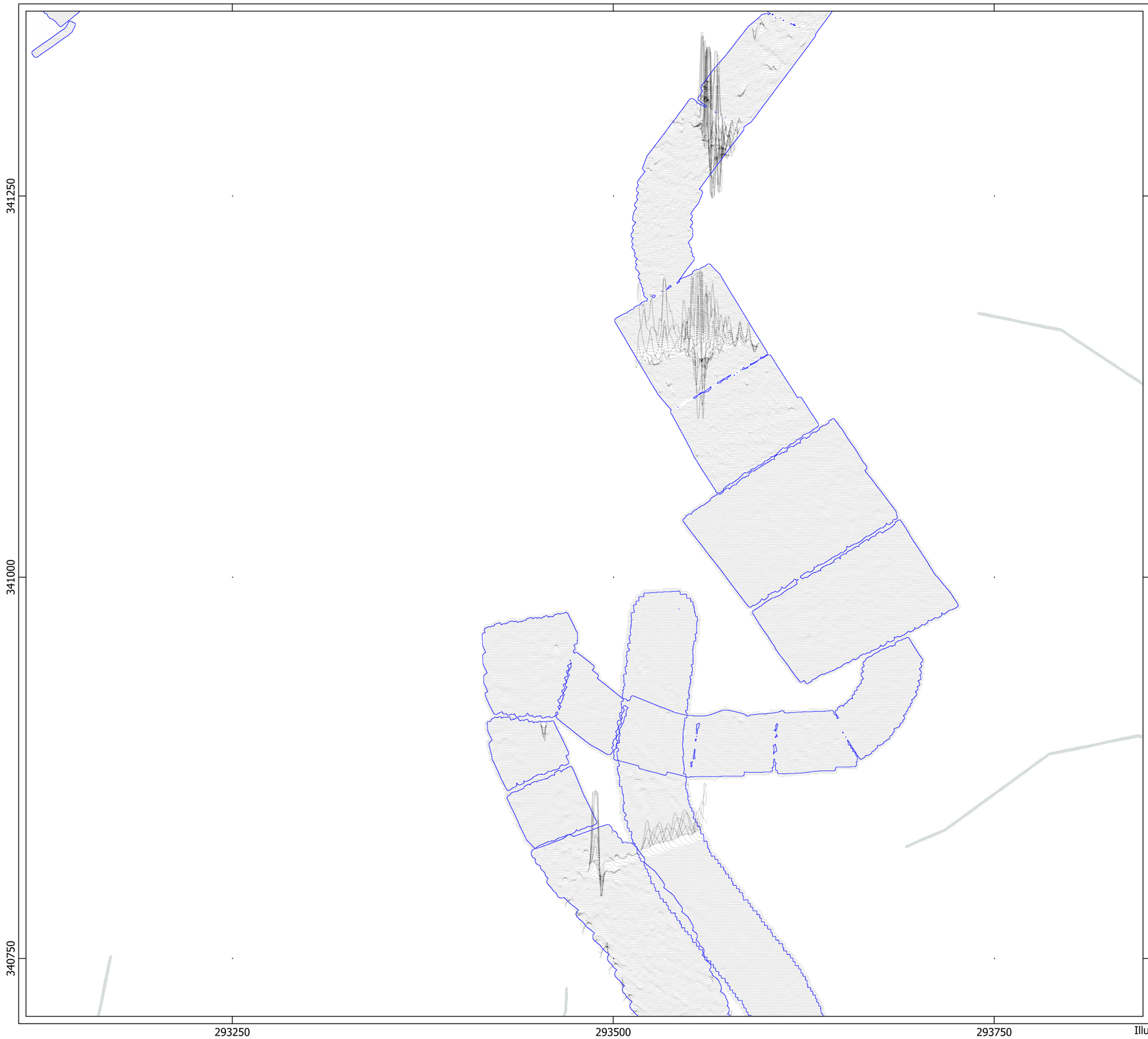
+2nT

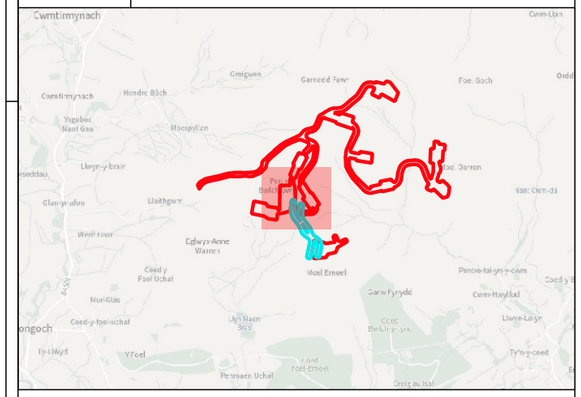
-1nT

0 50 100 m

Site:	FFMD25
Created by:	CM
Checked by:	SH
Version:	v1.0
Date:	04/11/2025
Scale:	1:2,500 @ A3

Illus - 11 Processed greyscale magnetometer data; Sector 3





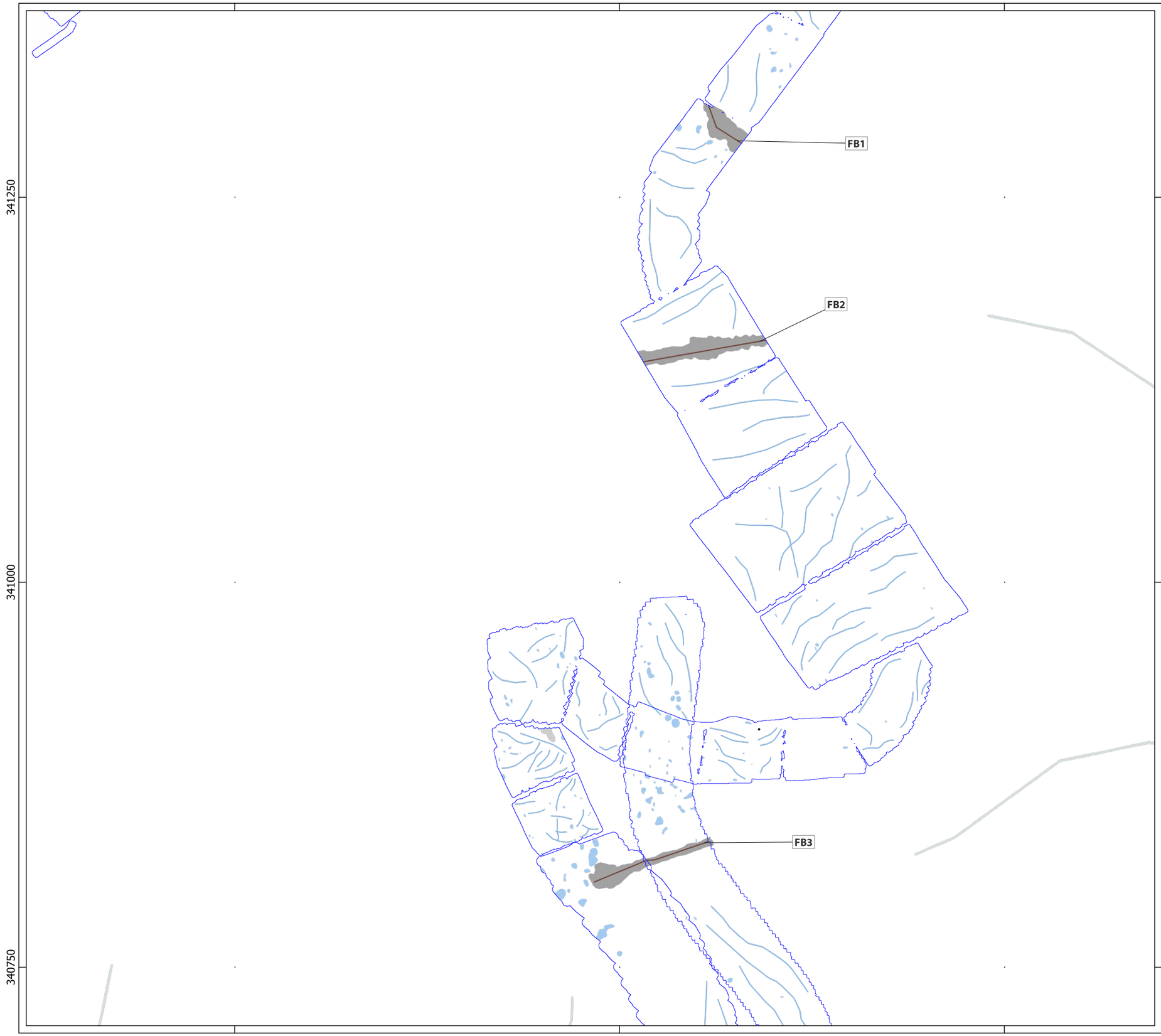
Key

- Survey Extent
- XY Trace (25nT/cm)

0 50 100 m

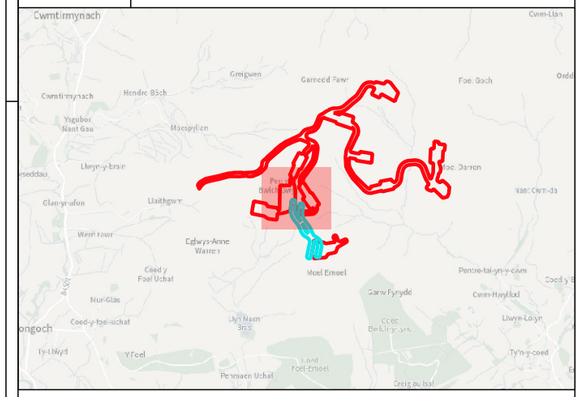
Site:	FFMD25
Created by:	CM
Checked by:	SH
Version:	v1.0
Date:	04/11/2025
Scale:	1:2,500 @ A3

Illus - 12 XY trace plot of minimally processed magnetometer data; Sector 3



N

HEADLAND ARCHAEOLOGY
an RSK company



Key

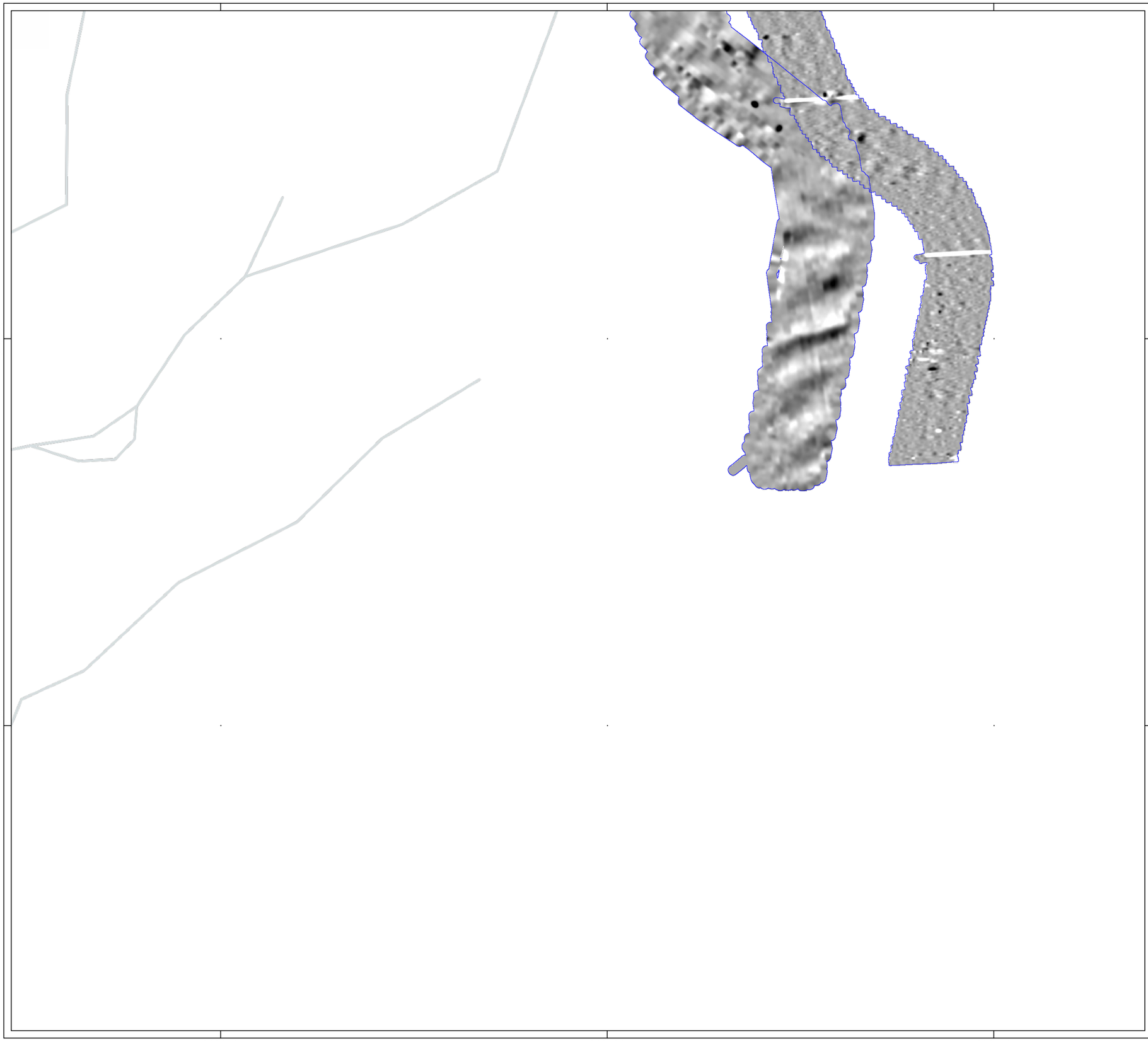
- Survey Extent
- Ferrous Objects
- Field Boundary
- Natural
- Magnetic Disturbance (Above Ground)
- Magnetic Disturbance (Below Ground)
- Natural

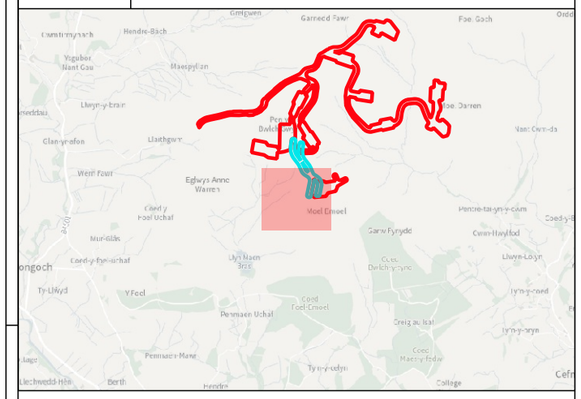
	Abbreviation
FB	Field Boundary

0 50 100 m

Site:	FFMD25
Created by:	CM
Checked by:	SH
Version:	v1.0
Date:	04/11/2025
Scale:	1:2,500 @ A3

Illus - 13 Interpretation of magnetometer data; Sector 3





Key

Survey Extent

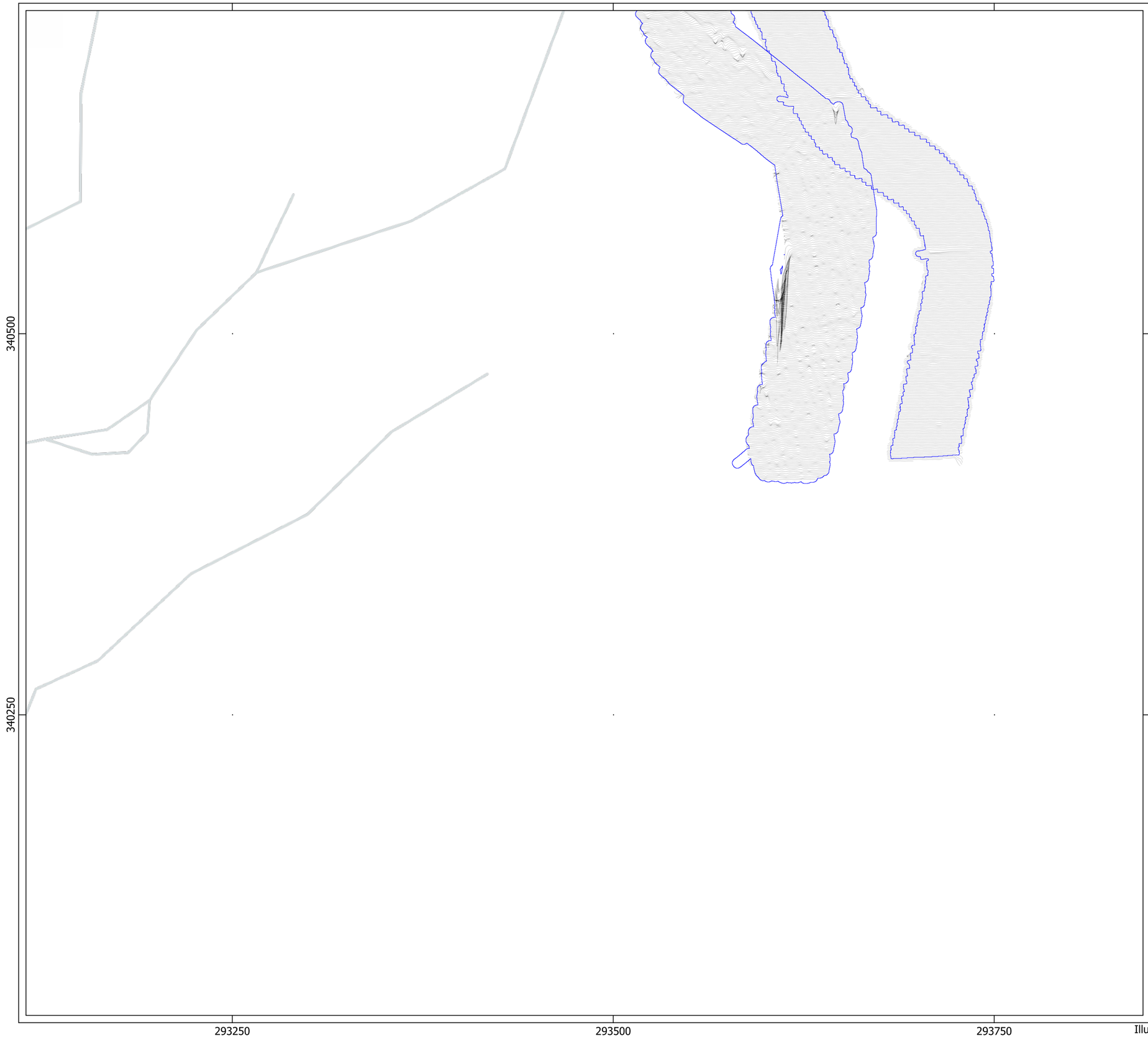
+2nT

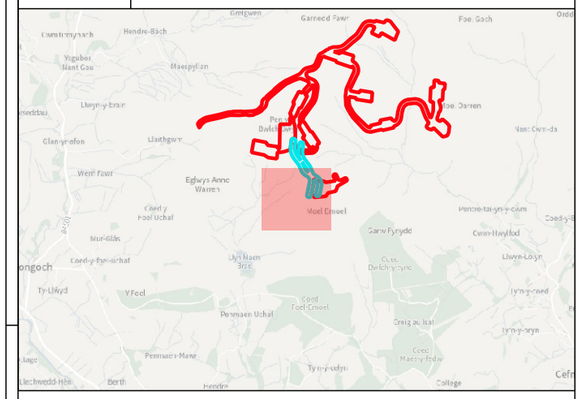
-1nT

0 50 100 m

Site:	FFMD25
Created by:	CM
Checked by:	SH
Version:	v1.0
Date:	04/11/2025
Scale:	1:2,500 @ A3

Illus - 14 Processed greyscale magnetometer data; Sector 4





Key

- Survey Extent
- XY Trace (25nT/cm)

0 50 100 m

Site:	FFMD25
Created by:	CM
Checked by:	SH
Version:	v1.0
Date:	04/11/2025
Scale:	1:2,500 @ A3

Illus - 15 XY trace plot of minimally processed magnetometer data; Sector 4

340500

340250

293250

293500

293750

N

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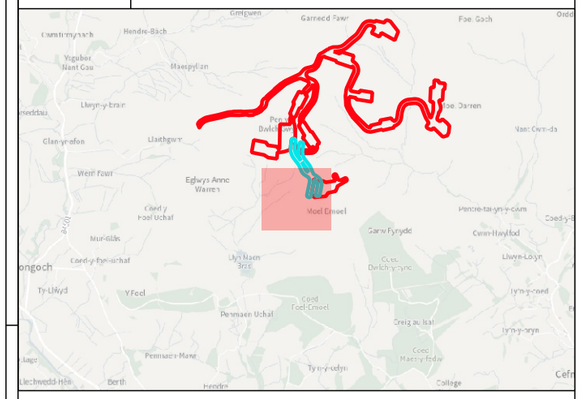


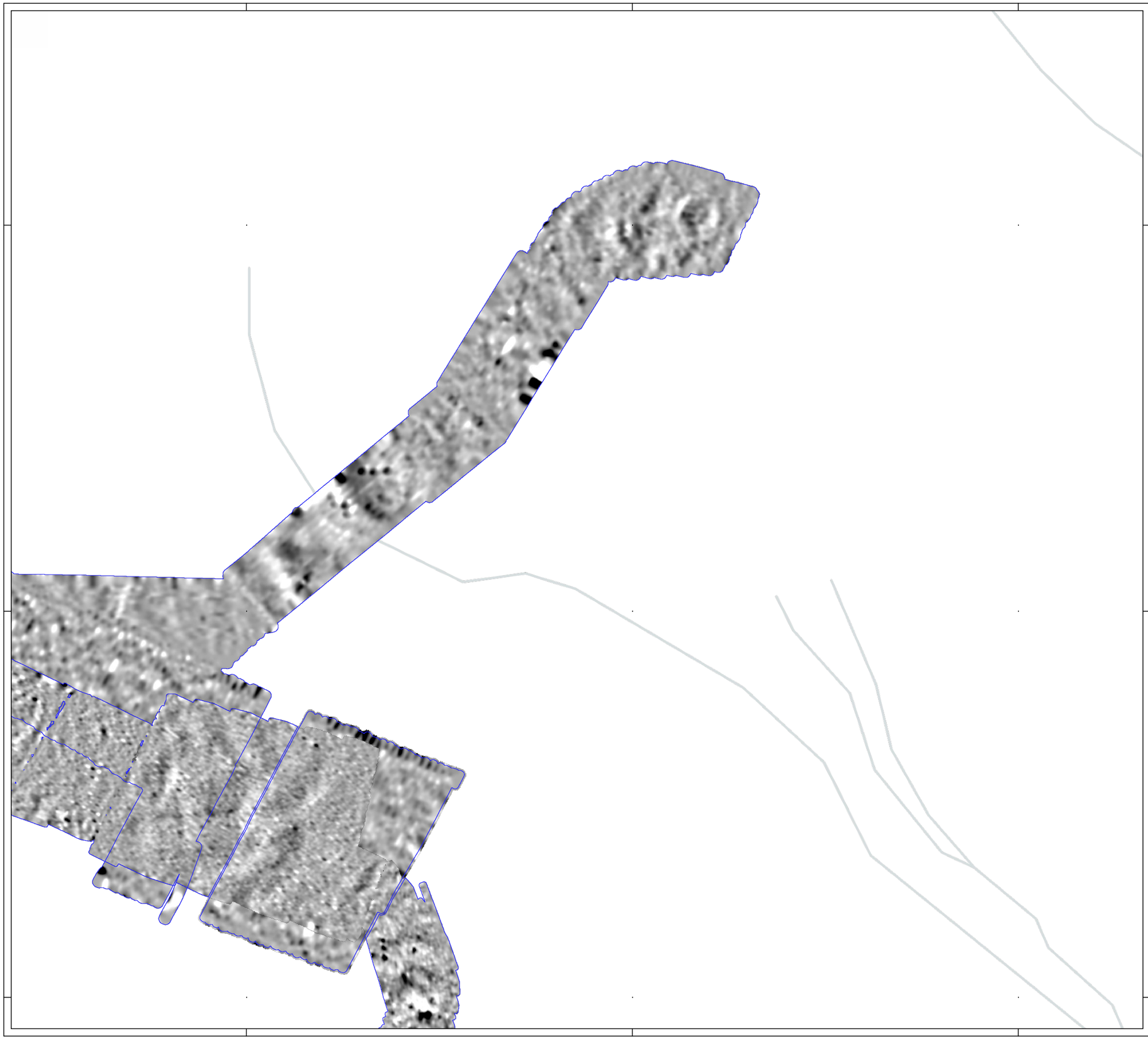
Key

- Survey Extent
- Natural
- Magnetic Disturbance (Above Ground)
- Natural
- Data Artefact

0 50 100 m

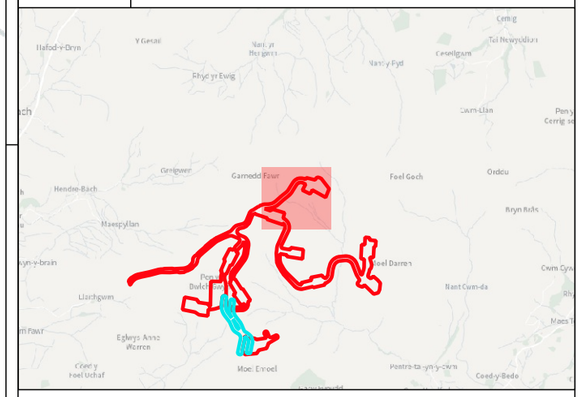
Site:	FFMD25
Created by:	CM
Checked by:	SH
Version:	v1.0
Date:	04/11/2025
Scale:	1:2,500 @ A3

Illus - 16 Interpretation of magnetometer data; Sector 4



N

HEADLAND ARCHAEOLOGY
an RSK company



Key

Survey Extent

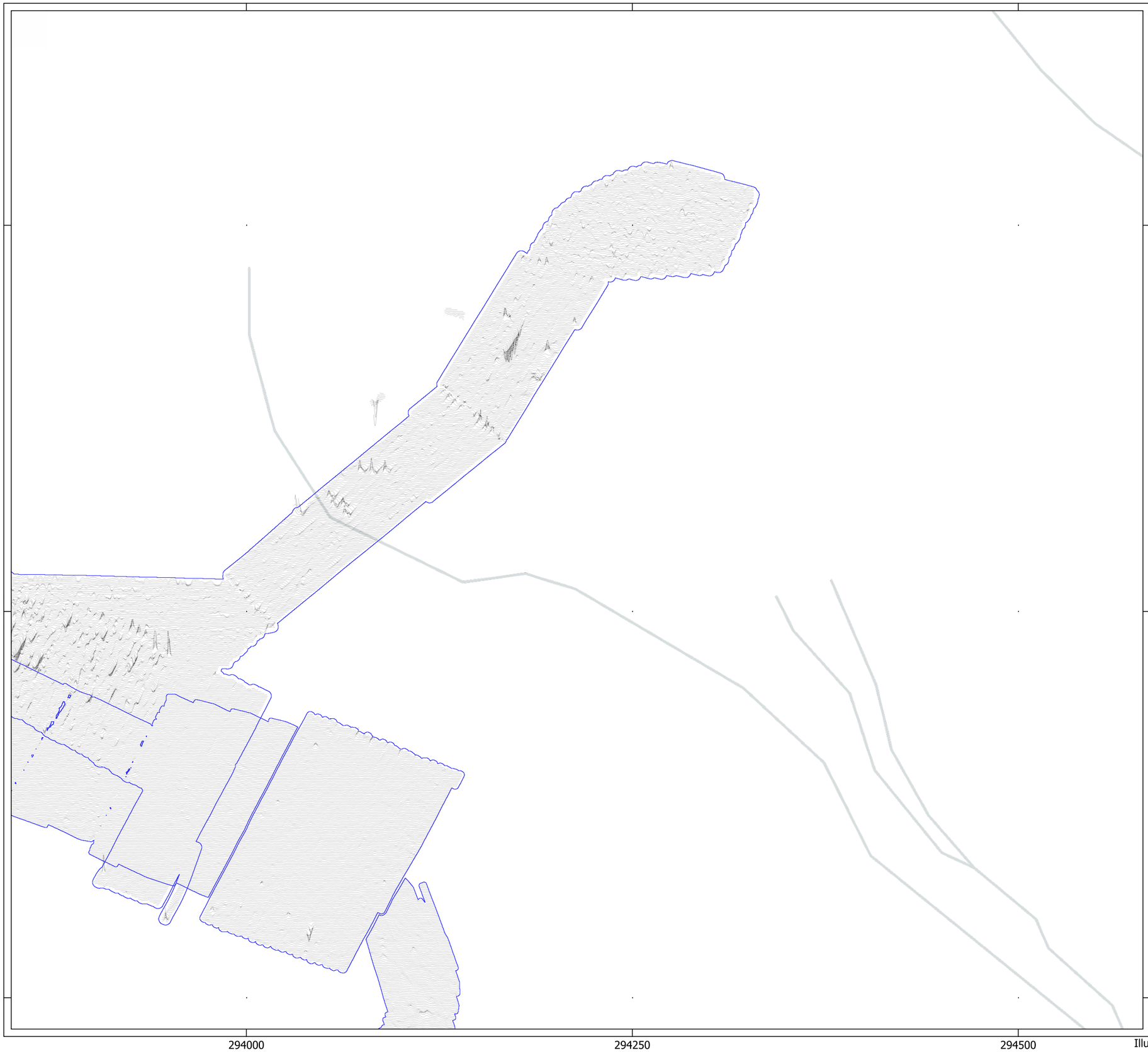
+2nT

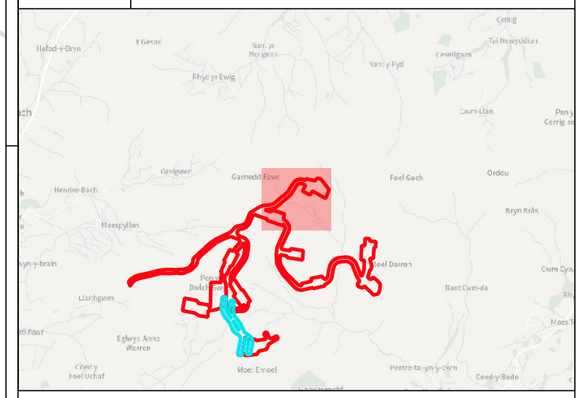
-1nT

0 50 100 m

Site:	FFMD25
Created by:	CM
Checked by:	SH
Version:	v1.0
Date:	04/11/2025
Scale:	1:2,500 @ A3

Illus - 17 Processed greyscale magnetometer data; Sector 5





Key

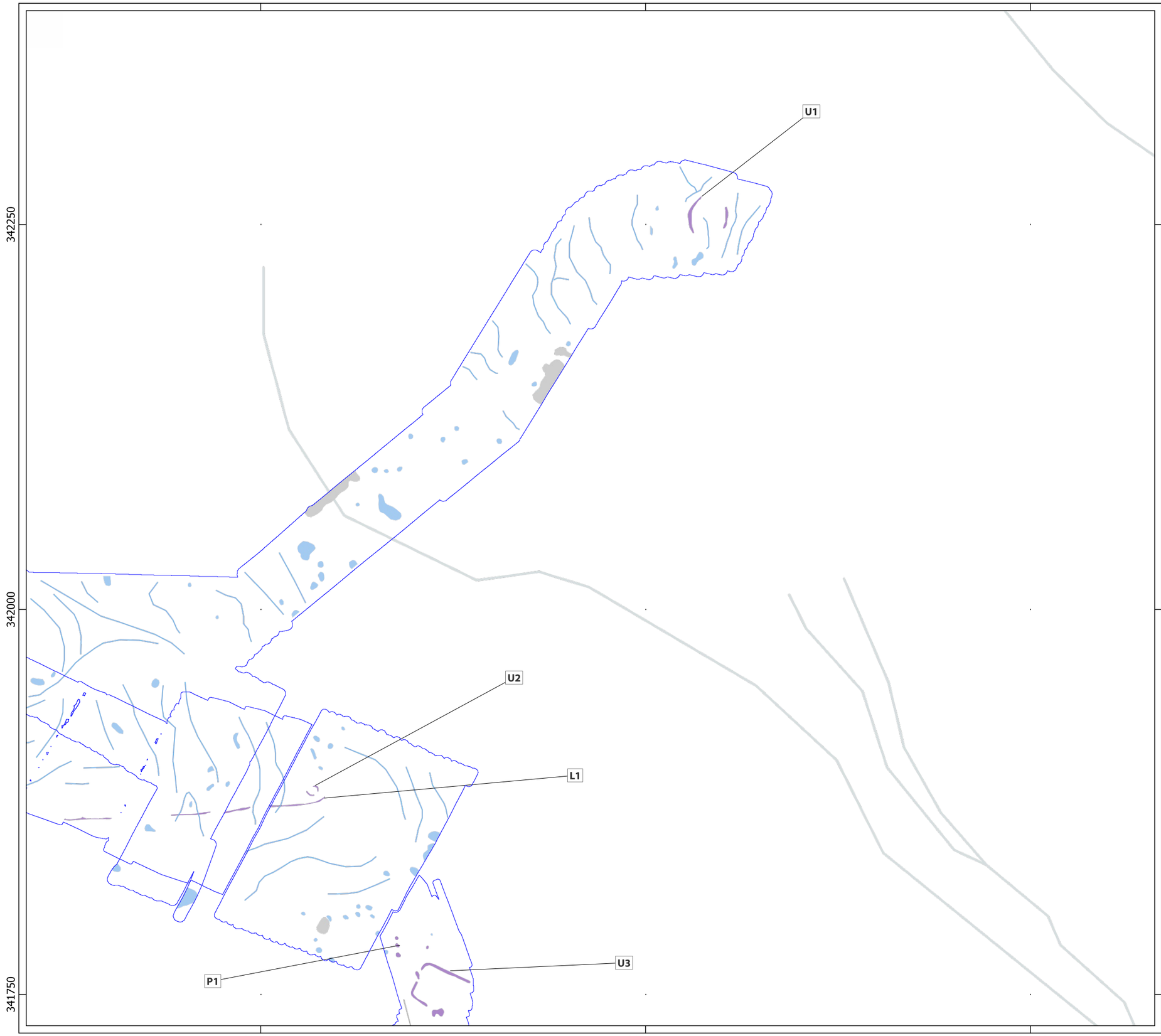
Survey Extent

XY Trace (25nT/cm)

0 50 100 m

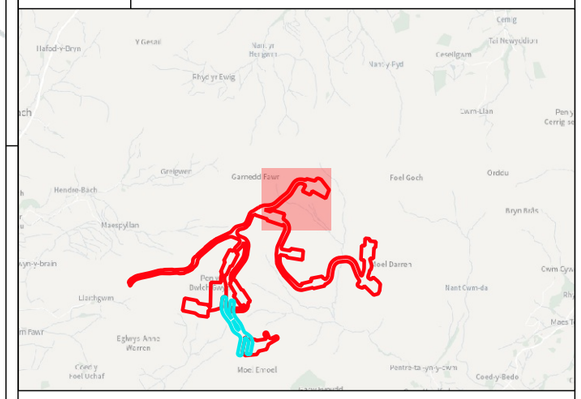
Site:	FFMD25
Created by:	CM
Checked by:	SH
Version:	v1.0
Date:	04/11/2025
Scale:	1:2,500 @ A3

Illus - 18 XY trace plot of minimally processed magnetometer data; Sector 5



N

HEADLAND ARCHAEOLOGY
an RSK company



Key

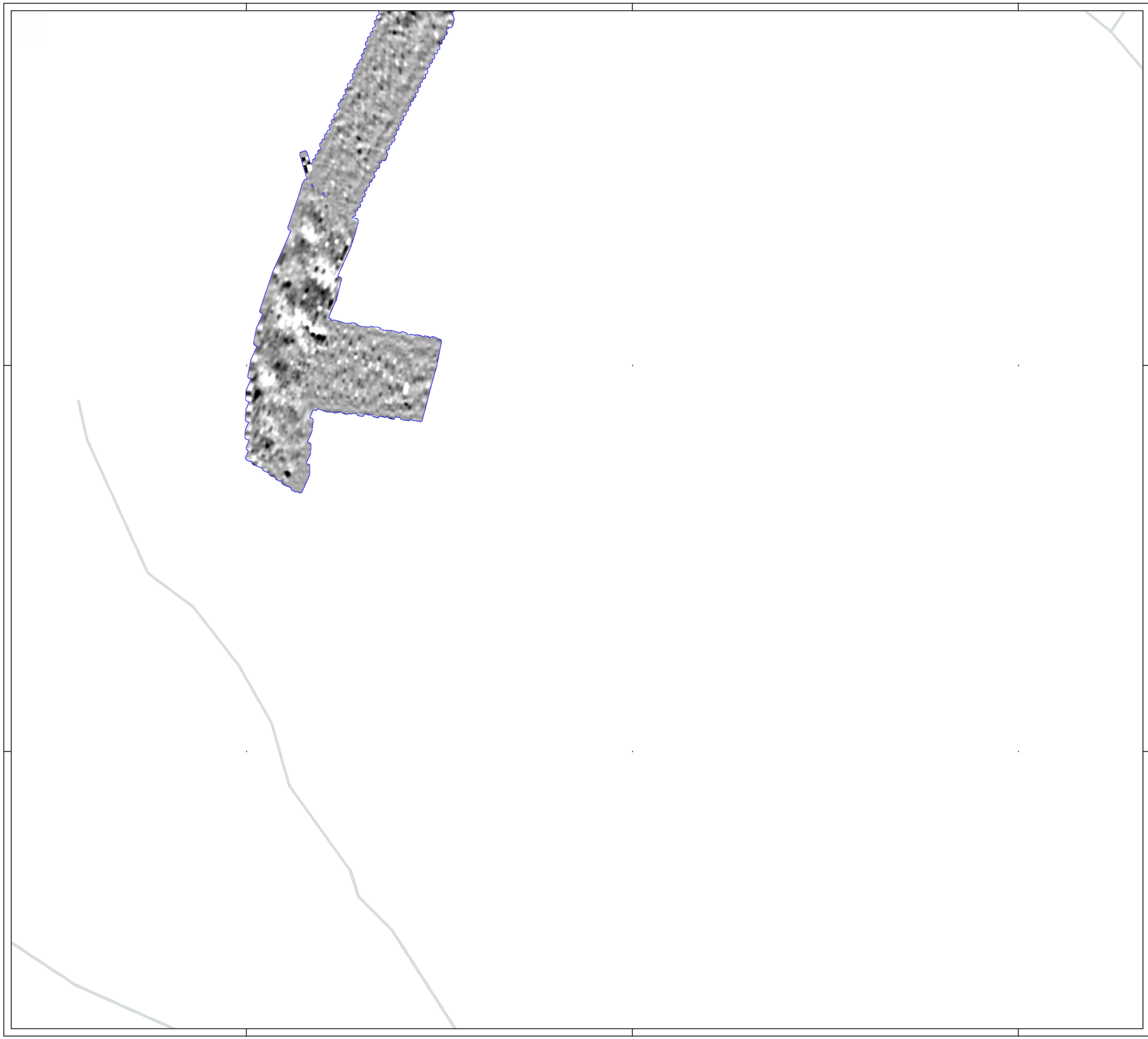
- Survey Extent
- Data Artefact
- Natural
- Magnetic Disturbance (Below Ground)
- Natural
- Uncertain

	Abbreviation
L	Linear Trend
P	Pit
U	Uncertain

0 50 100 m

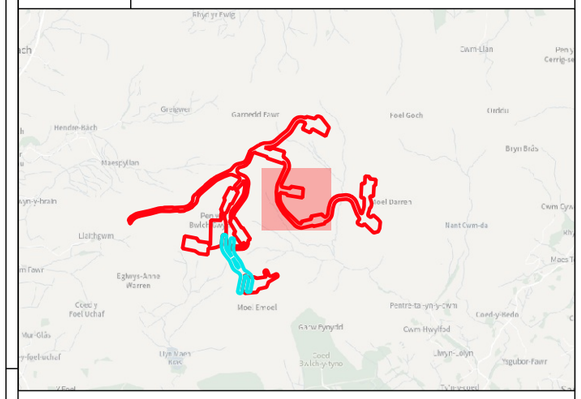
Site:	FFMD25
Created by:	CM
Checked by:	SH
Version:	v1.0
Date:	04/11/2025
Scale:	1:2,500 @ A3

Illus - 19 Interpretation of magnetometer data; Sector 5



N

HEADLAND ARCHAEOLOGY
an RSK company



Key

Survey Extent

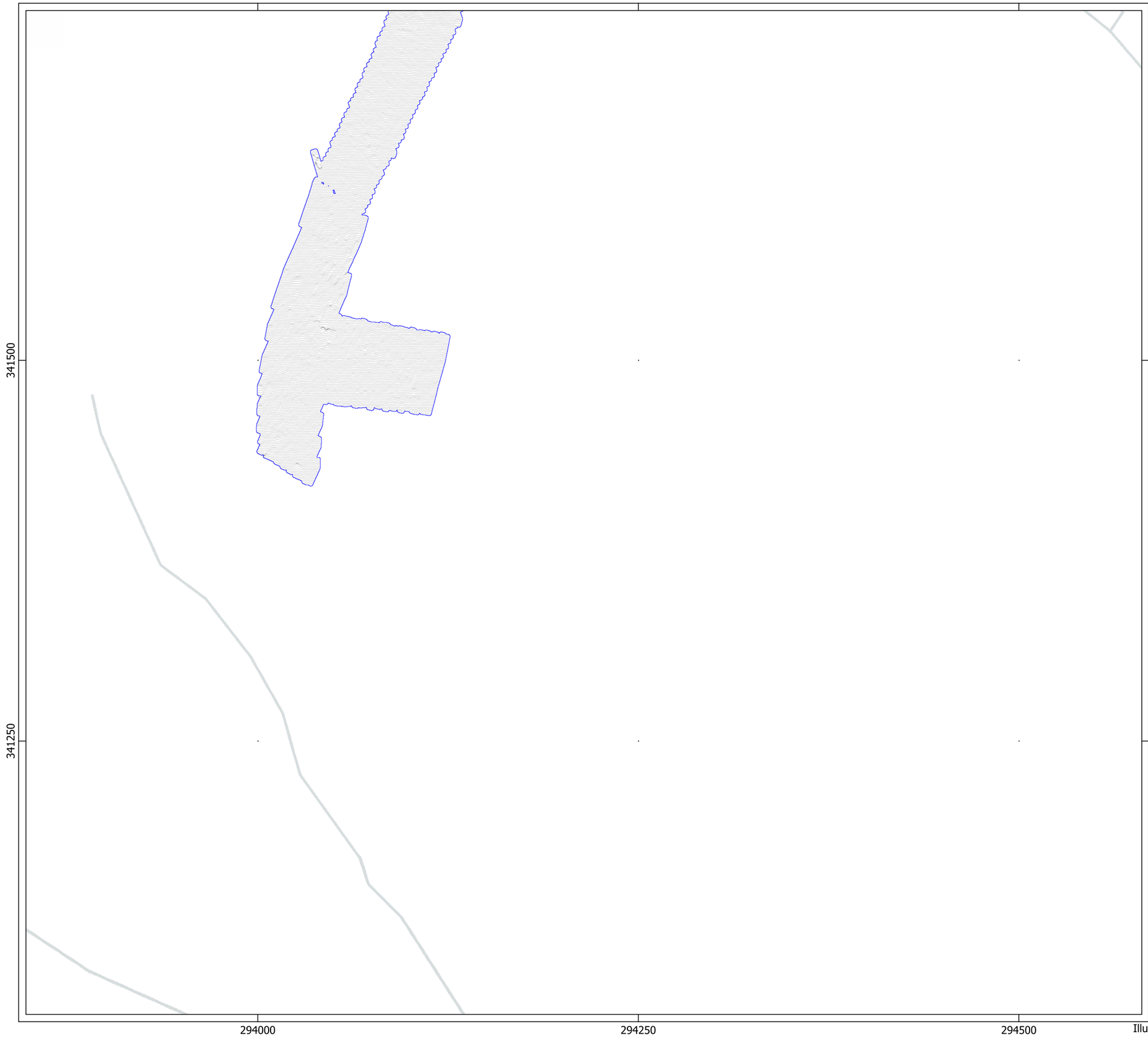
+2nT

-1nT

0 50 100 m

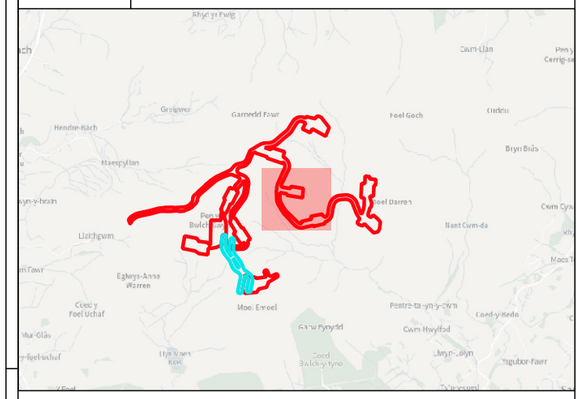
Site:	FFMD25
Created by:	CM
Checked by:	SH
Version:	v1.0
Date:	04/11/2025
Scale:	1:2,500 @ A3

Illus - 20 Processed greyscale magnetometer data; Sector 6



N

HEADLAND ARCHAEOLOGY
an RSK company



Key

- Survey Extent
- XY Trace (25nT/cm)

0 50 100 m

Site:	FFMD25
Created by:	CM
Checked by:	SH
Version:	v1.0
Date:	04/11/2025
Scale:	1:2,500 @ A3

Illus - 21 XY trace plot of minimally processed magnetometer data; Sector 6

341500

341250

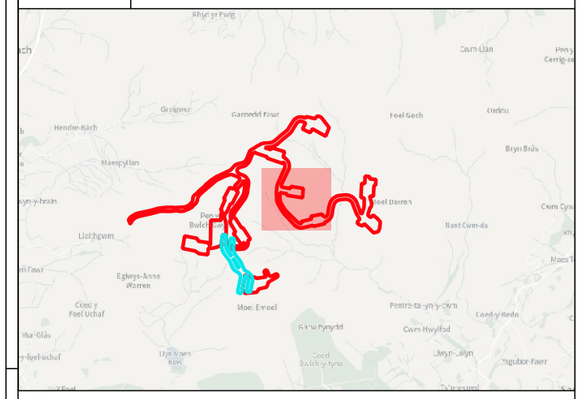
294000

294250

294500

N

HEADLAND ARCHAEOLOGY
an RSK company



Key

- Survey Extent
- Ferrous Objects
- Data Artefact
- Natural
- Magnetic Disturbance (Above Ground)
- Natural

0 50 100 m

Site:	FFMD25
Created by:	CM
Checked by:	SH
Version:	v1.0
Date:	04/11/2025
Scale:	1:2,500 @ A3

Illus - 22 Interpretation of magnetometer data; Sector 6

7 ANNEX

APPENDIX 1 MAGNETOMETER SURVEY

Magnetic susceptibility and soil magnetism

Iron makes up about 6% of the earth's crust and is mostly present in soils and rocks as minerals such as maghaemite and haematite. These minerals have a weak, measurable magnetic property termed magnetic susceptibility. Human activities can redistribute these minerals and change (enhance) others into more magnetic forms so that by measuring the magnetic susceptibility of the topsoil, areas where human occupation or settlement has occurred can be identified by virtue of the attendant increase (enhancement) in magnetic susceptibility. If the enhanced material subsequently comes to fill features, such as ditches or pits, localised isolated and linear magnetic anomalies can result whose presence can be detected by a magnetometer (fluxgate gradiometer).

In general, it is the contrast between the magnetic susceptibility of deposits filling cut features, such as ditches or pits, and the magnetic susceptibility of the topsoil, subsoil, and rock, into which these features have been cut, which causes the most recognisable responses. This is primarily because there is a tendency for magnetic ferrous compounds to become concentrated in the topsoil, thereby making it more magnetic than the subsoil or the bedrock. Linear features cut into the subsoil or geology, such as ditches, that have been silted up or have been backfilled with topsoil will therefore usually produce a positive magnetic response relative to the background soil levels. Discrete feature, such as pits, can also be detected.

The magnetic susceptibility of a soil can also be enhanced by the application of heat. This effect can lead to the detection of features such as hearths, kilns, or areas of burning.

Types of magnetic anomaly

In most instances anomalies are termed 'positive'. This means that they have a positive magnetic value relative to the magnetic background on any given site. However, some features can manifest themselves as 'negative' anomalies that, conversely, means that the response is negative relative to the mean magnetic background.

Where it is not possible to give a probable cause of an observed anomaly a '?' is appended.

It should be noted that anomalies interpreted as modern in origin might be caused by features that are present in the topsoil or upper layers of the subsoil. Removal of soil to an archaeological or natural layer can therefore remove the feature causing the anomaly.

The types of response mentioned above can be divided into five main categories that are used in the graphical interpretation of the magnetic data:

Isolated dipolar anomalies (iron spikes) These responses are typically caused by ferrous material either on the surface or in the topsoil. They cause a rapid variation in the magnetic response giving a characteristic 'spiky' trace. Although ferrous archaeological artefacts could produce this type of response, unless there is supporting evidence for an archaeological interpretation, little emphasis is normally given to such anomalies, as modern ferrous objects are common on rural sites, often being introduced into the topsoil during manuring.

Areas of magnetic disturbance These responses can have several causes often being associated with burnt material, such as slag waste or brick rubble or other strongly magnetised/fired material. Ferrous structures such as pylons, mesh or barbed wire and buried pipes can also cause the same disturbed response. A modern origin is usually assumed unless there is other supporting information.

Lightning-induced remnant magnetisation (LIRM) LIRM anomalies are thought to be caused in the near surface soil horizons by the flow of an electrical current associated with lightning strikes. These observed anomalies have a strong bipolar signal which decreases with distance from the spike point and often appear as linear or radial in shape.

Linear trend This is usually a weak or broad linear anomaly of unknown cause or date. These anomalies are often caused by agricultural activity, either ploughing or land drains being a common cause.

Areas of magnetic enhancement/positive isolated anomalies Areas of enhanced response are characterised by a general increase in the magnetic background over a localised area whilst discrete anomalies are manifest by an increased response (sometimes only visible on an XY trace plot) on two or three successive traverses. In neither instance is there the intense dipolar response characteristic exhibited by an area of magnetic disturbance or of an 'iron spike' anomaly (see above). These anomalies can be caused by infilled discrete archaeological features such as pits or post-holes or by kilns. They can also be caused by pedological variations or by natural infilled features on certain geologies. Ferrous material in the subsoil can also give a similar response. It can often therefore be very difficult to establish an anthropogenic origin without intrusive investigation or other supporting information.

Linear and curvilinear anomalies Such anomalies have a variety of origins. They may be caused by agricultural practice (recent ploughing trends, earlier ridge and furrow regimes or land drains), natural geomorphological features such as palaeochannels or by infilled archaeological ditches.

APPENDIX 2 SURVEY LOCATION INFORMATION

The magnetometer data was collected and is geo-located based on survey grade Real Time Kinetic (RTK) differential Global Positioning System (dGPS) used on a drone system. The accuracy of this dGPS equipment is better than 0.01m. The GPS system outputted in NMEA mode in real time following a preplanned flightpath to ensure full area coverage.

APPENDIX 3 GEOPHYSICAL SURVEY ARCHIVE

The geophysical archive comprises an archive disk containing the raw data in XYZ format, a raster image of each greyscale plot with associate world file, and a PDF of the report.

The project will be archived in-house in accordance with recent good practice guidelines (http://guides.archaeologydataservice.ac.uk/g2gp/Geophysics_3). The data will be stored in an indexed archive and migrated to new formats when necessary.

APPENDIX 4 DATA PROCESSING

The fluxgate data has been presented in this report in processed greyscale and minimally processed XY trace plot format.

Data collected using RTK GPS-based methods cannot be produced without minimal processing of the data. The minimally processed data has been interpolated to project the data onto a regular grid and de-striped to correct for slight variations in instrument calibration drift, heading errors and any other artificial data.

The XY data has been clipped to remove extreme values and to improve the interpretability of the data.

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