

APPENDIX G

Geophysical survey report
**Proposed solar farm, battery storage area & substation
in Grangeford Old & Friarstown townlands, County Carlow**

Client
PRT Solar Ltd.

Detection License
23R0166

TAG Project
2023IE9

Date
April 2023

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TARGET GEOPHYSICAL SURVEY REPORT 2023IE9, PROPOSED SOLAR FARM, BATTERY STORAGE AREA & SUBSTATION IN GRANGEFORD OLD & FRIARSTOWN TOWNLANDS, COUNTY CARLOW

PROJECT BACKGROUND

Geophysical survey was undertaken in connection with a proposed solar farm, battery storage and substation development in the townlands of Grangeford Old and Friarstown, Co. Carlow, c.1.9km SW of Killybeg. Encompassing c.25ha of arable land the geophysical investigation extended over 3 separate areas situated N of the R725, c.4.5km NW of Tullow and c.3km E of the M9 Motorway. A total 25.25ha of high-resolution recorded magnetometry was completed within these 3 areas examining all lands available at the time of fieldwork.

Two solar farm developments have already been permitted at the Proposed Site.

1. Carlow County Council Ref No. 16/325– Granted and Expired
2. Carlow County Council PR 21/23 , An Bord Pleanála ABP P.Ref 309987-21 – Granted

However, the Proposed Development will supersede the previous permitted solar developments.

Further solar farm developments, granted and at further information stage, are also situated in close proximity (Carlow County Council P. Refs: 1946, 2138 and 22149).

This geophysical survey was commissioned by PRT Solar Ltd and forms part of the pre-planning archaeological assessment being undertaken by the applicant prior to proposed development. Due to time constraints and availability, the geophysical survey focused on areas in which the substation and battery storage will be placed along with an area along the eastern boundary that does not fall under permitted solar farm development. The entire area relating to granted solar farm development Carlow Council PR 21/23, An Bord Pleanála ABP P.Ref 309987-21, currently remains unavailable to geophysical investigation due to unsuitable terrain.

The aims of this geophysical survey were:

- to identify geophysical anomalies of possible archaeological origin within the investigation areas
- accurately locate these anomalies and present the findings in graphical format
- describe the anomalies and discuss their likely provenance in a written report

ITM central coordinates: 680955 675501

Townlands: Grangeford Old & Friarstown

County: Carlow

Landuse: Grass & tillage

Landscape, soils, geology

The site lies 79-92m above mean sea level within an undulating agricultural landscape used predominantly for cereal cultivation. Soils of the locality comprise of fine loamy drift of the Elton (1000c) association with river alluvium (5RIV) to the SW. Bedrock (100k) consists of Tullow Type 2 equigranular granite, typically pale, fine to coarse grained (Irish National Soils Map, 1:250,000k, V1b, 2014; Geological Survey of Ireland Spatial Resources, Public Data Viewer Series).

Archaeology

The area of archaeological constraint associated with burial ground RMP CW008-020 borders the site of proposed development. Castle CW008-032 and burial ground CW008-022 also lie immediately to the S beyond the R725, with further RMPs also present in a 1km radius. The following extract from the National Monuments Service SMR database provides summary details of all RMPs within c.1km of the site boundary:

SMR No.	Class	Townland	East	North
CW008-018001	Enclosure	Friarstown	680152	676473
CW008-018002	Castle - tower house	Friarstown	680157	676480
CW008-019	Ritual site - holy well	Baunogephure	681213	676400
CW008-020	Burial ground	Grangeford Old	680786	675298
CW008-022	Burial ground	Grangeford Old	681253	675139
CW008-023	Earthwork	Rathbaun	681906	675664
CW008-032	Castle - unclassified	Grangeford	681254	675054
CW008-053	Bullaun stone	Friarstown	680183	676469
CW008-054	Moated site	Friarstown	680103	676429
CW008-093	Ring-ditch	Aghwater	679645	674526
CW008-094	Ring-ditch	Aghwater	679677	674512
CW008-095	Enclosure	Aghwater	679850	674491
CW008-096	Ring-ditch	Aghwater	679876	674645
CW008-097	Enclosure	Aghwater	679865	674692

Fieldwork18th - 20th March 2023**Geophysical technique**

High-resolution recorded magnetometry (fluxgate gradiometry)

Report issue17th April 2023**Author**

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Detection license no.

23R0166

Client

PRT Solar Ltd.

Consultants

Malone O'Regan Environmental Ltd.

1 SURVEY METHODOLOGY

1.1 Methodology

1.1.1 Geophysical survey was conducted in 3 areas within the boundaries of the proposed development, completing a total 25.25ha of high-resolution recorded magnetometry, examining all lands available at the time of fieldwork.

1.1.2 The survey employed an advanced multichannel fluxgate gradiometer system combined with cm precision GPS, recording magnetometer (fluxgate gradiometer) and GPS data simultaneously at rates of 50Hz and 1Hz respectively. The geophysical data were acquired along parallel instrument traverses 3.64m in width, with the instrumentation installed in 'tow configuration' for use with an ATV.

1.2 Instrumentation

1.2.1 The following table provides a summary of the survey methodology and geophysical instrumentation employed during the course of this work:

Technique	Sensor spacing	Sample rate	Instrumentation	Sensitivity/precision	No. of data recorded
Magnetometry (fluxgate gradiometry)	0.28m	50Hz	Multi-channel fluxgate gradiometer	<75pT/√Hz @ 1Hz (650mm baseline)	1,087,756
GPS	3.92m	1Hz	Trimble R10 (VRS)	<0.1m	28,291

1.2.2 The instrumentation and software employed for this geophysical survey were configured to apply a spatial resolution of c.60-80 magnetometer measurements per m². This spatial resolution meets with ease the 'Level 3 – Characterisation' EAC Guidelines for geophysical survey in archaeology (Schmidt et al, 2016).

1.3 Data processing

1.3.1 Post-fieldwork the geophysical data were processed as follows:

Process	Description
i	Positioning of geophysical data based on real-time GPS measurements (WGS84 geodetic CRS)
ii	Zero median transect processing for multi-sensor magnetometer data collected along parallel transects
iii	Transformation from WGS84 geodetic coordinate system to ITM (IRENET95) projected CRS
iv	Gridding (ordinary kriging)
v	Export of greyscale images georeferenced in ITM (IRENET95) projected CRS

1.3.2 To maintain the integrity of the processed geophysical data, and its close correlation with the original raw on-site measurements, no further processing, filtering or 'smoothing' of the data was undertaken following steps i-v.

1.4 Data display

1.4.1 Figure 1 presents the location of the proposed development to the N of the R725, with RMPs in the surrounding landscape indicated (scale 1:15,000).

1.4.2 Figure 2 presents a summary greyscale of the results from geophysical survey in areas 1-3 at a scale of 1:3000, with 1:1500 scale greyscales for each survey area presented in figures 3-6.

1.4.3 Figure 7 presents a summary interpretation of the results from geophysical survey at a scale of 1:3000, with 1:1500 scale interpretation diagrams for areas 1-3 presented in figures 8-11. Numbers included on figures 8-11 refer to notable anomalies recorded from this geophysical survey, and these are discussed in the results section of this report.

2 GENERAL CONSIDERATIONS

2.1 Ground conditions & access

2.1.1 Ground conditions at the site varied according to the type of cultivation present at the time of fieldwork, areas 1-2 under maize stubble causing some minor difficulty during data collection, with area 3 under grass over which fieldwork was completed without issue. Inaccessible terrain to the NE and NW in areas 2-3 was excluded from survey, these areas occupied by heaps of manure ready for the next cultivation phase.

2.1.2 The following table details the ground conditions, landuse and hectares completed during the course of this geophysical survey:

Area	Description of terrain	Landuse	Ha
1	North section of large sub-rectangular, level and poorly drained field occupied by maize stubble with farm access to SE.	Arable (maize stubble)	1.2
2	Large SW facing sub-rectangular arable field occupied by maize stubble with impeded drainage to the SW, manure to the NE, eroded field boundary NW-W, and R725 S-SE.	Arable (maize stubble)	9.4
3	Part of large undulating sub-rectangular grass field descending gently to NW towards farm access, and more steeply to SE towards the R725.	Pasture	14.9

2.2 Modern interference

2.2.1 The results from areas 1-3 at the site of the proposed solar farm, battery storage area and substation highlight an abundance of small-scale ferrous throughout. These responses are a common occurrence in magnetometer data, and relate mostly to modern metallic debris contained in the topsoil.

2.2.2 Broad ferrous responses are also evident in the data, in proximity to existing field boundaries and trackways, farm buildings, field entrances and other modern surfaces, most notably to the NE in area 1, and SE-SW in area 3. Regions of magnetic disturbance in area 2 are also expected to be modern in origin, deriving, most likely, from recent landscaping to improve the agricultural potential/drainage quality within this part of the site.

2.3 Recent landuse & cultivation

2.3.1 Responses associated with recent landuse and cultivation include suspected land drains in area 1 and remnants of former field boundaries traversing area 2

2.3.2 Remnants of former cultivation are also indicated throughout areas 2-3.

2.3.3 The results from areas 2-3 also highlight numerous responses indicative of field system remains which predate the historic mapping. The possibility that these may in part be of archaeological significance should not be ignored.

2.4 Natural soil/geological variation

2.4.1 Natural soil/geological variations are also evident in the survey results N-NE and W-SW in area 2, and S-SE of survey centre in area 3.

3 GEOPHYSICAL SURVEY RESULTS

3.1 General overview

- 3.1.1 The results from geophysical survey in areas 1-3 at the site of the proposed solar farm, battery storage area and substation, demonstrate a quiet magnetic background in the region of $\pm 1\text{nT}$. Fluctuations in response beyond $\pm 1\text{nT}$ derive mostly from effects of recent landuse, including past cultivation, former/probable former field boundaries, and modern ferrous/magnetic disturbance. Further low contrast anomalies indicative of natural soil/geological variations have also been recorded.
- 3.1.2 Responses of definite archaeological significance are indicated by the results from this geophysical survey, and these include a small circular enclosure and 3 larger sub-circular enclosures which have been recorded in area 3 to the NW and SE-SW. Remains of an extensive former field system, likely contemporary with the enclosures identified in area 3, have also been identified.
- 3.1.3 Further responses of potential significance are indicated by the results from survey within the boundary of the proposed development. These include a curving ditch type anomaly and group of interconnecting linear responses NE of survey centre in area 2; a sub-rectangular pattern of weakly positive responses SE of survey centre in area 3; and an expansive network of interconnecting linear trends also in area 3.
- 3.1.4 Numerous further poorly defined positives and trends are indicated elsewhere by the results from this geophysical survey. These anomalies display patterns of response more commonly associated with recent landuse, natural soil geological variation and/or modern ferrous, and are, therefore, deemed to be of limited archaeological potential.

3.2 Survey results (figures 2-11)

- 3.2.1 The following table provides details of the most significant anomalies recorded during the course of this geophysical survey:

Area	Anomaly(s)	Location	Description & likely provenance
1	NA	NA	<i>No significant responses recorded</i> The results demonstrate a low level of background variation throughout with responses deriving from modern ferrous, probable land drains and weak trends recorded. The anomalies recorded are of limited archaeological interest.
2	1	NE	<i>? Archaeology</i> Curvilinear response of possible interest within c.35m of zone of notification associated with burial ground CW008-020.
2	2-3	N-NE	<i>?? Archaeology Trend</i> Interconnecting linear anomalies and trends of potential significance located in proximity to zone of notification for burial ground CW008-020.
2	4-6	NE-SW	<i>?? Field system predating historic mapping</i> Weakly magnetic linear parallel/perpendicular responses indicative of field system remains. Anomalies 4-6 may potentially be associated with burial ground CW008-020 situated to the NE beyond the perimeter of area 2.
2	7	SW	<i>?? Archaeology</i> 1 of 3 alignments of small-scale positives of unknown origin recorded SW and S of survey centre. A modern/probable recent landscaping origin is suggested.
2	8	S	<i>?? Archaeology</i> Sub-circular poorly defined positive response c.12m in diameter of potential note. The possibility that response 8 represents the weakly magnetic remains of a small ditched enclosure should not be ignored. A natural soil/geological origin should also be considered.

3	9	NW	<i>Archaeology</i> Small weakly magnetic circular ditched enclosure/probable ring-ditch c.9m in diameter.
3	10	SE of survey centre	<i>Archaeology</i> Weakly magnetic sub-circular ditched enclosure c.40 x 45m in diameter.
3	11	SE	<i>Archaeology</i> Weakly magnetic sub-circular enclosure c.70m x 56m in diameter, located c. 75m SE of enclosure 10.
3	12	SW	<i>Archaeology Trend</i> Weakly magnetic sub-circular enclosure c.15m in diameter, located c. 80m SW of enclosure 11.
3	13	SE	<i>? Archaeology Trend</i> Sub-rectangular pattern of weakly magnetic positives and trends highlighting potential structural/building remains, perhaps 5 x 10m in diameter in size. Interpretation is cautious: 13 lie in proximity several intersecting former boundaries and earlier field system remains.
3	14-19	SE-W of survey centre	<i>?? Field system predating historic mapping</i> Intricate network of probable early field system remains likely, in part, to be contemporary with enclosures 10-12, potentially also relating to RMPs CW008-020, CW008-022 and CW008-032.
3	20-21	SE	<i>?? Archaeology Trend</i> Linear ditch type responses, poorly defined positives and trends immediately N of the R725, in proximity to and potentially associated with CW008-022 and CW008-032 to the S.
3	22-25	NW, S of survey centre & SE	<i>Trend</i> Trends suggesting potential further field system and possible early trackways which may be associated with enclosures 10-12. A recent landuse, natural soil/geological explanation for a number of these anomalies should also be considered.

4 CONCLUSION

- 4.1 Geophysical survey at the site of the proposed solar farm, battery storage area and sub-station in Grangeford Old and Friarstown townlands has been successful in recording the location of four previously unknown ditched enclosures. These are located to the NW and SE-SW of survey centre in area 3. Remnants of suspected early field system remains are also indicated by the results, these being particularly extensive to the S in area 3 and likely contemporary with CW008-020, CW008-022 and CW008-032. Further responses of note include a curving ditch type anomaly and interconnecting linears to the NE in area 2, possible structure in area 3 and poorly defined positives/trends also in area 3 to the SE in proximity to CW008-022 and CW008-032.
- 4.2 The results from this geophysical survey also highlight responses deriving from recent landuse including former boundaries, zones of modern magnetic disturbance, land drains and modern ferrous debris, with occasional natural soil/geological variations also present.

BIBLIOGRAPHY

QGIS Development Team, 2021, QGIS Geographic Information System, Open-Source Geospatial Foundation Project <http://qgis.osgeo.org>

Schmidt A, (2002), Archaeology Data Service. Geophysical Data in Archaeology. A guide to good practice.

Schmidt A, Linford P, Linford N, David A, Gaffney C, Sarris A, and Fassbinder J, (2016), EAC Guidelines for the Use of Geophysics in Archaeology.

ONLINE RESOURCES

Archaeological Survey of Ireland SMR Database: <http://webgis.archaeology.ie/historicenvironment/>

Bing Maps: <https://www.bing.com/maps>

Geological Survey of Ireland Spatial Resources, Public Data Viewer Series:

<https://dcenr.maps.arcgis.com/apps/MapSeries/index.html?appid=a30af518e87a4c0ab2fbde2aaac3c228>

Google Maps: <https://www.google.com/maps>

Irish National Soils Map, 1:250,000k, V1b (2014). Teagasc, Cranfield University (jointly funded by the EPA STRIVE Research Programme 2007-2013 & Teagasc): <http://gis.teagasc.ie/soils/map.php>

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APPENDIX

Technical Information: magnetometry

MAGNETOMETRY

Introduction

Magnetometry represents one of a suite of geophysical techniques employed in archaeological prospection to inform invasive work such as trial trenching and excavation.

Frequently used to determine the often non-visible boundaries of archaeological remains, magnetometer surveys enable archaeologists to identify the location, form and extent of a diverse array of archaeological features no longer visible at the surface.

Buried archaeological remains successfully identified using magnetometry include sites such as enclosure systems and deserted villages, hillforts and military encampments, henges and tumuli, villa/castle foundations, ecclesiastical settlements and formal gardens.

Background to application

The basis for use of magnetometry in archaeological prospection derives from the abundance of natural iron oxides in most soils, and our ability to measure subtle variations in the magnetic properties of these iron oxides caused by human activity. Discrete variations in soil magnetism associated with buried archaeological remains derive typically from in situ burning and organic enrichment of the soil, through activities such as cooking and heating; pottery manufacture and metal working; as well as use of fired building materials such as ceramic tiles and brick. These burnt, fired and organic rich deposits create subtle magnetic contrasts visible as discrete magnetic anomalies superimposed on the earth's geomagnetic field.



1. Magnetometer survey data in greyscale format highlighting pit remains SE of an enclosure and Roman villa.



2. Burnt-fired debris uncovered during excavation of the highlighted area SE of the same enclosure and Roman villa.

Magnetometer surveys conducted in both commercial and research archaeological investigations enable determination of the location, form and extent of buried archaeological remains. Data acquired from these surveys can be quickly generated into georeferenced images and interpretation layers to inform subsequent trial trenching and excavation.

Technology

TARGET provides precise mapping and characterization of buried archaeological remains by employing an array of highly stable and sensitive fluxgate gradiometers, combined with an advanced data logging system and cm precision GPS. This state-of-the-art geophysical instrumentation, which is capable of collecting extremely dense data sets, permits detailed high-resolution survey of archaeological sites from as small as 1ha in size, to larger scale investigation of sites up to 150ha or more.

High resolution magnetometer surveys are undertaken as standard, recording data at c.5cm intervals with probe separations of 0.3m for precise measurement and characterization of buried archaeological remains. This spatial resolution meets with ease the 'Level 3 – Characterisation' EAC Guidelines recommendation for geophysical survey in archaeology (Schmidt et al, 2016).

Instrumentation is used in combination with cm precision GPS and data collected along parallel traverses with the system installed in 'tow configuration' for use with an ATV or in push mode.

Data Display

Greyscale plots are the most common format for displaying magnetometer data. This display format assigns a cell to each datum according to its location on the grid. The display of each data point is conducted at very fine increments, allowing the full range of values to be displayed within a given data set. This display method also enables the identification of discrete responses barely visible above natural 'background' magnetic variation on site.

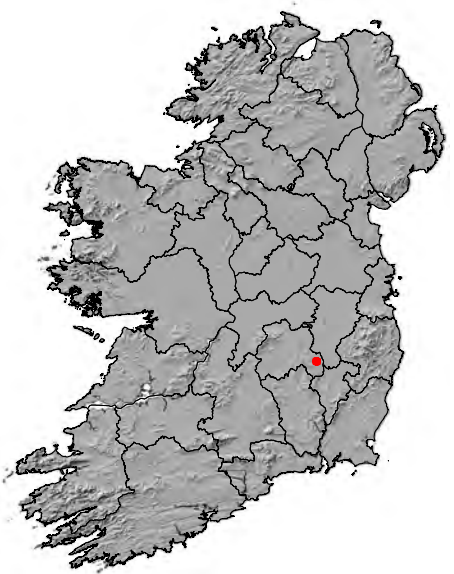
6. Greyscale from survey at the site of a deserted medieval village.



XY trace plots provide a near-perspective representation of measurements along individual lines of data recorded from each magnetometer sensor. The XY trace format is used as a conventional method for identifying responses of modern ferrous debris, and also as an aid in identifying locations of potential industrial features, such as kilns and metal working.

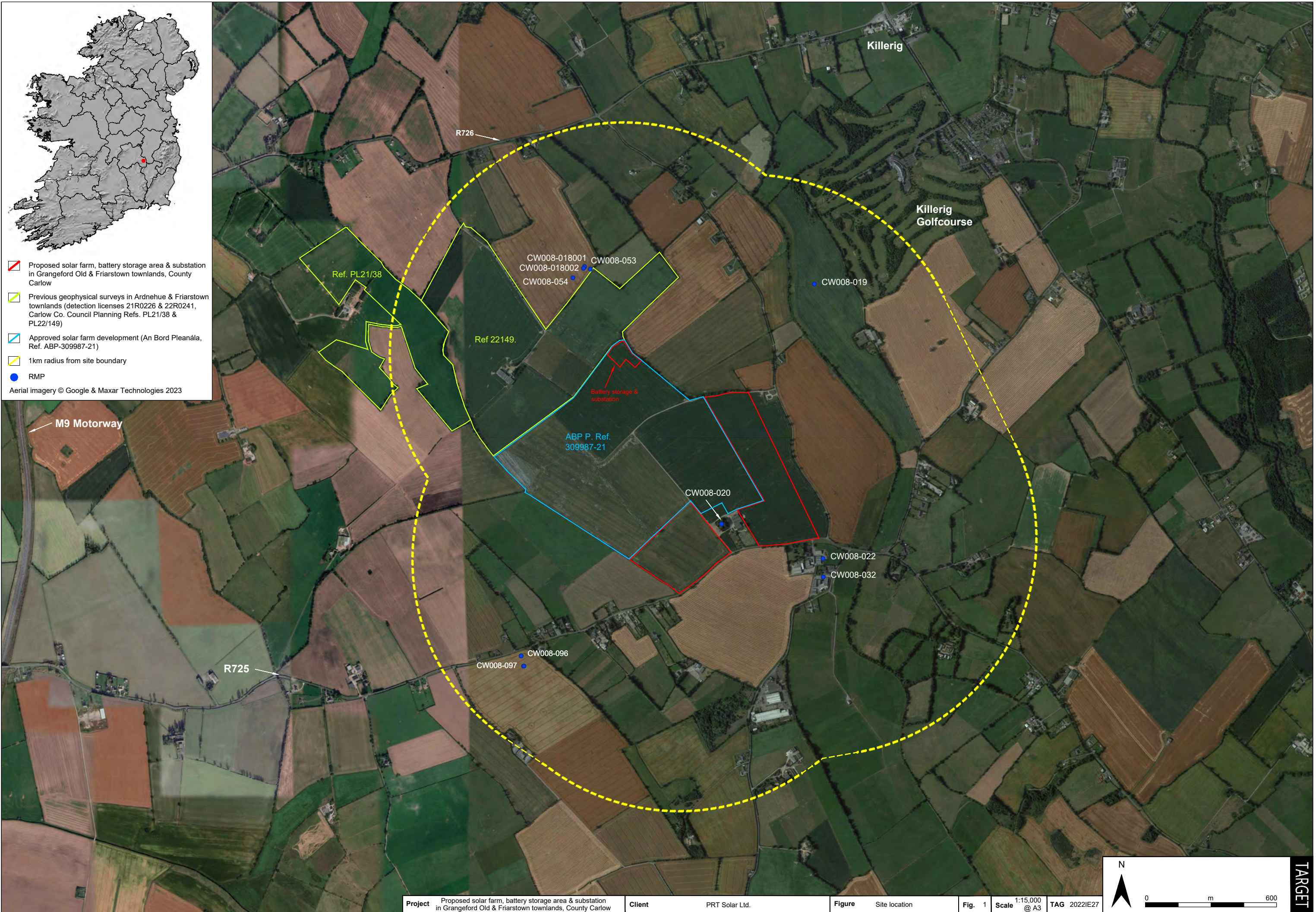
7. XY trace from survey at the site of a deserted medieval village.





-  Proposed solar farm, battery storage area & substation in Grangeford Old & Friarstown townlands, County Carlow
-  Previous geophysical surveys in Ardnehue & Friarstown townlands (detection licenses 21R0226 & 22R0241, Carlow Co. Council Planning Refs. PL21/38 & PL22/149)
-  Approved solar farm development (An Bord Pleanála, Ref. ABP-309987-21)
-  1km radius from site boundary
-  RMP

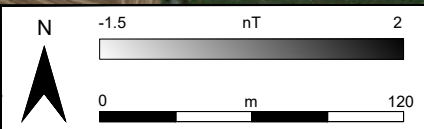
Aerial imagery © Google & Maxar Technologies 2023





Poor terrain

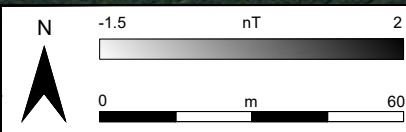
Poor terrain



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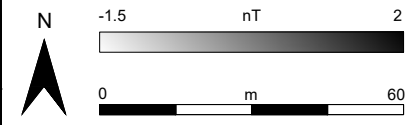


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- Archaeology
- ? Archaeology
- ?? Archaeology
- ▨ Field system predating historic mapping
- ▨ Trend
- ▨ Former / ? former boundary
- ▨ Cultivation
- ▨ Natural soil/geological variation
- ▨ ? Land drain
- ▨ Magnetic disturbance
- Ferrous

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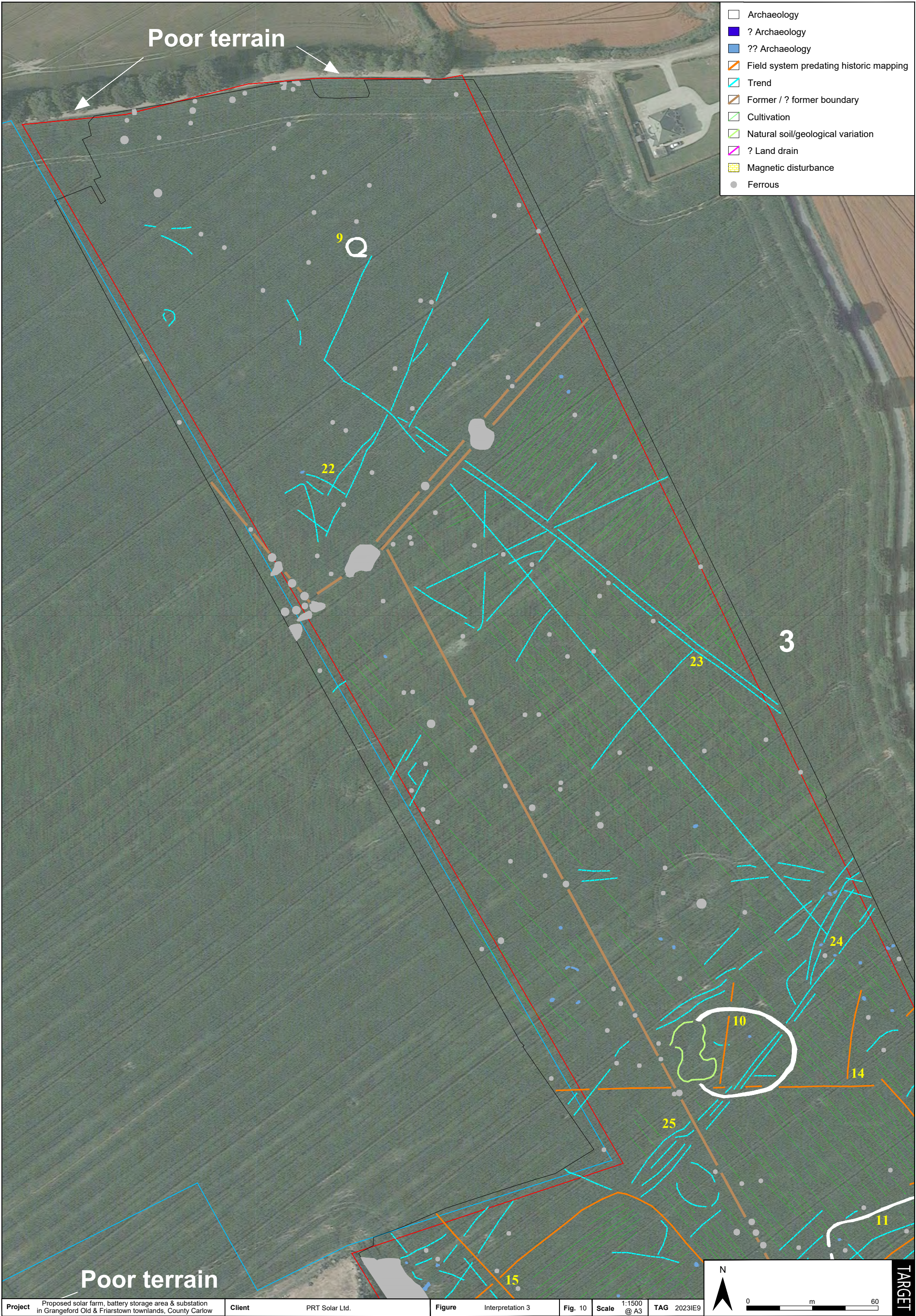
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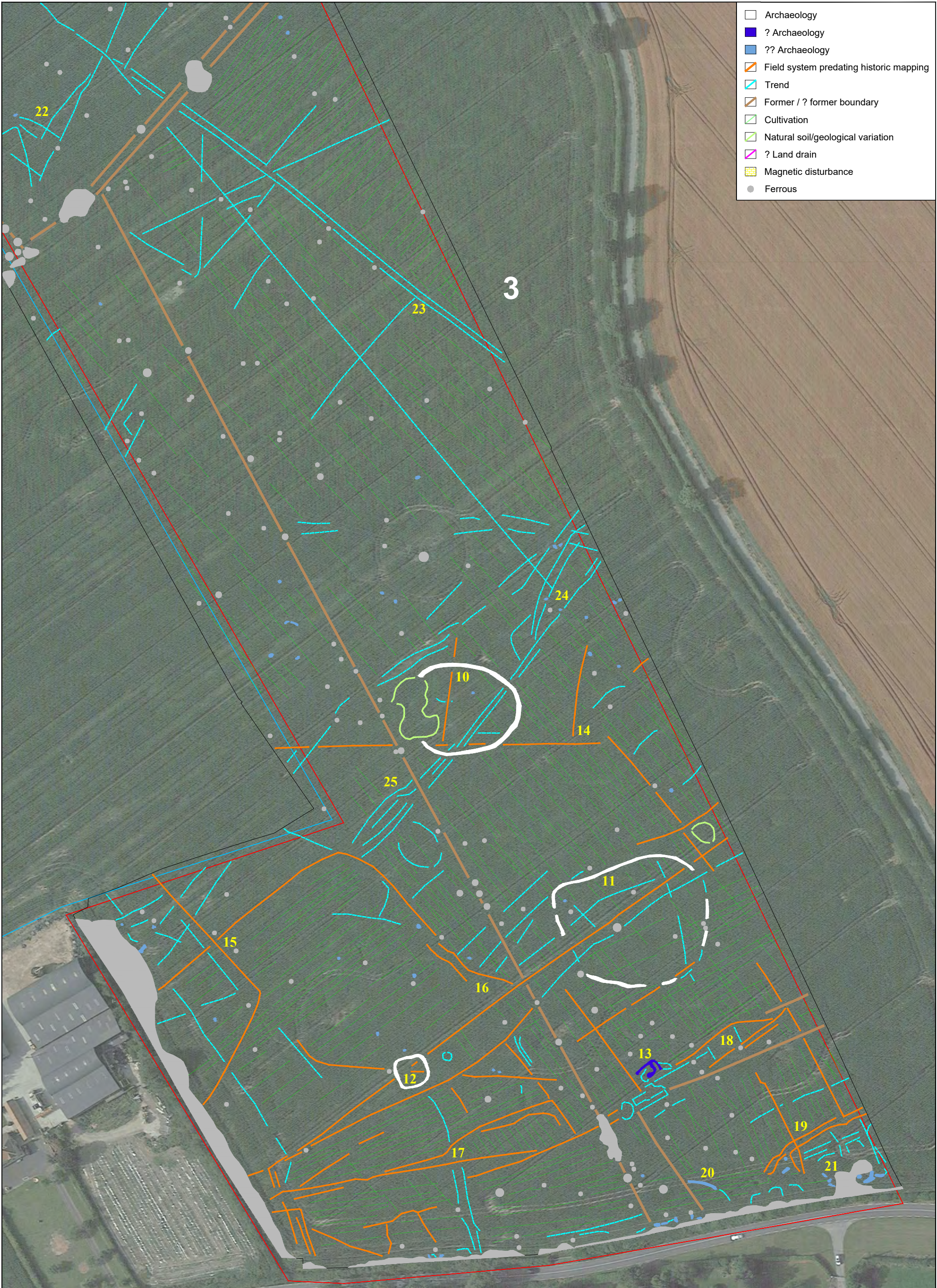
TARGET





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