

Ballydonagh Solar Farm
Kiltormer, Co. Galway

Archaeological Geophysical Survey

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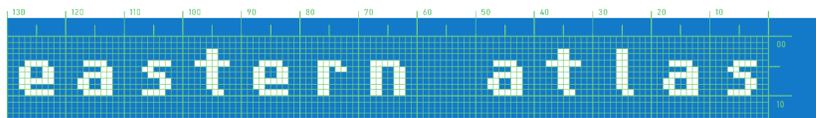
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Subsurface Geophysical Investigations

EXECUTIVE SUMMARY

1. Minorex Geophysics Ltd. (MGX) carried out an archaeological geophysical survey consisting of magnetic gradiometry for the proposed Ballydonagh Solar Farm. The survey area consisted of agricultural fields with a combined size of 81ha. The archaeological consultants are Neo Environmental Ltd. and the developer is Renewable Energy Systems Ltd.
2. The survey was carried out between the 25th October and the 9th November 2022 under detection device consent No 22R0338 issued by the National Monuments Survey of the Department of Housing, Local Government and Heritage.
3. The main objectives of the survey were to determine archaeological features and deposits and to recommend targets for direct archaeological testing or for avoiding construction.
4. The methodology consisted of a magnetic gradiometry surface survey using a LEA-MAX system with 10 Eastern Atlas sensors pulled by an ATV. The spacing between adjacent sensors is 50 cm and the measuring points are 5 to 10 cm apart along each survey line. All points are accurately positioned using RTK-GNSS in the Irish Transverse Mercator (ITM) coordinate system.
5. The results are greyscale image in 256 shades with black/white as +/- 100nT, +/- 20nT and as +/- 5nT. The magnetic gradient data with the +/- 5nT data range is displayed on Maps 2a to 2e. The AutoCAD drawings also contain the greyscale images with the +/- 100nT and +/- 20nT range.
6. The interpretation is displayed on Maps 3a to 3g and the interpretation strategy is explained in detail in this report.
7. One archaeological feature was marked (green) on the maps and this is consistent with the recorded monument GA099-061 (described as a ringfort or possible rath).
8. Seven areas with possible archaeological features (cyan) were identified and it is recommended to test these or avoid construction here. They are generally clusters of weak anomalies. They could also have a non-archaeological cause like agriculture or tree boles, until they get directly tested the cause is uncertain.
9. 19 historical boundaries (yellow) correlating with OSI historical maps were identified.
10. The survey found many underground drains or former field boundaries (blue). Most of these are drains for field improvement as can be seen by the parallel and fishbone alignment of many lines.
11. Targeted testing can be done very efficiently as it is possible to pinpoint the locations with coordinates from this report on site.
12. Areas with archaeological potential can be also avoided during the planning or construction phase of the solar farm.

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1. INTRODUCTION

1.1 Background

Minerex Geophysics Ltd. (MGX) carried out an archaeological geophysical survey consisting of magnetic gradiometry for the proposed Ballydonagh Solar Farm. The survey area is 81ha in size and consists of agricultural fields that are proposed for a solar farm. The development is being proposed by Renewable Energy Systems Ltd. and the main archaeological consultant for the project is Neo Environmental Ltd.

The survey was carried out under the National Monuments Survey Permit No 22R0338 of the Department of Housing, Local Government and Heritage under the National Monuments Acts (1930 – 2014).

The fieldwork was carried out between the 25th October and the 9th November 2022.

The purpose of the survey is to mitigate the risk of the development damaging archaeological deposits and features. This survey is an indirect, non-destructive survey and any interpreted archaeological features may not necessarily prove to be of archaeological origin.

Light orange numbers on the drawings are field numbers allocated by Neo Environmental Ltd. They are placed such that they do not obscure magnetic anomalies.

1.2 Objectives

The main objectives of the geophysical survey were:

- To determine archaeological features and deposits
- To identify unknown archaeological sites
- To recommend targets for direct archaeological testing

1.3 Site Description

The survey area (Map 1) is agricultural land mainly used for pasture. The land is flat with some slight elevation undulations.

Some ground was very wet and in Field 3 there was an area with standing water.

In Field 30 there is a recorded monument and the area stands visibly out by topography and vegetation as an elliptical area with a south to north large axis of 70m length.

There is quite a lot of vegetation present which either appears in large and wide field boundaries or as island-type areas within fields. Some cut-off vegetation heaps were left in some fields.

Field 16 contains a small quarry and there are spoil heaps to the south with some steep slopes.

There are quite a lot of metal items lying around the fields and there are several overhead power lines.

In Fields 4, 6, 7 and 8 there are many linear spoil heaps with steep slopes along drains that were created when the drains were dug out.

Field 26 had many rushes, reeds and shrub vegetation towards the center.

1.4 Archaeology

In the Record of Monuments and Places (RMP) there is one recorded monument within the survey area, GA099-061, described as a ringfort or possible rath.

There are many recorded monuments near the survey area but outside of it. These are indicated on the maps. Most of them are described as ringforts – raths. There is also an enclosure (GA099-023), field system (GA099-174001), monumental structure (GA099-025) and 18th/19th century house (GA099-063).

The historical information on field boundaries was taken from the Ordnance Survey of Ireland (OSI) historic maps. They are referred to in the interpretation where relevant to the survey results.

1.5 Geology

The overburden consists of glacial tills derived from limestones

The bedrock geology consists of the Lucan Formation, described as dark limestone and shale.

The geological strata are suitable for the magnetic gradiometry method.

1.6 Report

This report contains the results and interpretation of the archaeological geophysical survey. Maps are included to illustrate the results of the survey. More detailed descriptions of the geophysical methods and measurements can be found in Clark et al. (1990), David et al. (1995), English Heritage (2008) and Bonsall et al. (2014).

The interpretative nature and the non-invasive survey methods must be taken into account when considering the results of this survey and Minerex Geophysics Limited cannot give any guarantees regarding the subsurface present, despite using appropriate procedures to conduct, interpret and present the data.

2. GEOPHYSICAL SURVEY

2.1 Methodology

The magnetic gradiometry methodology was proposed during the tender phase. The survey areas are indicated on the maps by the orange outline.

The survey areas included the fields where future solar panels are proposed and one future access track in the NE.

2.2 Magnetic Gradiometry

The methodology consisted of conducting a large-scale magnetic gradiometry survey using the flexible and mobile LEA-MAX (Eastern Atlas) system. The system consists of a flexible array of 10 Fluxgate-Foerster gradiometer probes (FEREX 4.032 Con 650) towed by an ATV. The distance between each of the ten gradiometer probes is 50 cm, the row spacing of the measuring points between 5 and 10 cm, depending on the speed. The positioning was realised with the help of an RTK-GNSS.

The measured and stored value is the difference in the vertical magnetic field and the value in nT (Nanotesla) between the sensors. If the value is positive then the lower sensor has a higher magnetic field than the upper sensor. The vertical sensor separation is 0.65m.

The prospection of the survey areas is done by driving parallel profiles at 5 m intervals. Data is recorded by meandering measurements in only one direction and the zero level of probes and recording device (digitiser LEA-D2) is defined before the measurements. For measurement and evaluation, the software EAL is used (proprietary development for the magnetic measurement system LEA).

Unprocessed raw data are in binary format, they are matched with the GNSS position data and transmitted as data in ASCII format. The individual steps of data processing (e.g. despiking, destriping, desloping) are described in the report and differentiated in the interpretation of archaeologically induced anomalies.

The results of the magnetometer prospection are output as GeoTiff as well as in PNG in at least three dynamics for the vertical difference of the Z-component (vertical gradient) of the magnetic field in the projection ETRS 89 UTM Zone 29, EPSG: 25829.

The visualisation of the data is done in greyscale images with 256 greyscales from white to black stored in Tiff format.

The positioning of the geophysical data is done by RTK (real time kinematic) using two dual frequency GNSS receivers as base and rover. The rover is permanently fixed to the mobile sensor array. The relative accuracy of the RTK positioning is ± 5 cm.



Photo 1: Magnetic Gradiometer with 10 sensors front view



Photo 2: Magnetic Gradiometer with 10 sensors back view



Photo 3: Magnetic Gradiometer with 10 sensors top view

2.3 Site Work

Data acquisition was carried out between the 25th October and the 9th November 2022. Weather conditions were favourable throughout the acquisition period. During some heavy rain the survey was suspended. Health and safety standards were adhered to at all times.

In Fields 1, 5, 9, 10 and 11 there was no access permission given from the landowner during survey stage, although initially access was granted. The reason given was that the cattle could not be moved until a much later date.

In Field 16 is a small former overburden extraction pit located that could not be surveyed. The pit is dug into a small hill and the steeper slopes of this hill could not be surveyed.

The survey was carried out as continuously as possible with a view to obtain the best coverage. In some places dense vegetation patches and steep slopes prevented the survey. Between Fields 13, 14, 18, 19 and 20 wide overgrown field boundaries presented some surveying. In Field 30 a larger overgrown area and steep topography at the recorded monument GA099-061 prevented the survey.

There are some smaller areas within fields where the survey could not be done (e.g. Field 12 and 16).

In Field 26 it was only possible to drive the cart system around the outside periphery and not through the more overgrown center.

3. RESULTS AND INTERPRETATION

The interpretation of geophysical data was based on the known responses of geophysical measurements, typical physical parameters for subsurface features that may underlay the site, and the experience of the authors.

3.1 Magnetic Gradiometry Processing

The magnetic gradiometry data was processed as follows: Referencing to the Irish Transverse Mercator grid, filtering the raw data and displaying it as a greyscale image in 256 gradations of black and white as +/- 100nT, +/- 20nT and as +/- 5nT.

The magnetic data is shown against a white background as we did not receive Ordnance Survey base maps from the client.

The magnetic gradient data with the data range of +/- 5nT are shown in maps 2a to 2e. The AutoCAD drawings also contain the greyscale images with the range +/- 100nT and +/- 20nT. They are switched off in the viewports, but can be shown when working with the AutoCAD drawings and are part of this report, which is supplied in *.dwg format. An example for the +/- 20nT data is in Map 4 and an example for +/- 100nT on Map 5.

3.2 Magnetic Anomalies and Archaeology

Magnetic gradiometry finds small anomalies that typically indicate archaeological cuts or fills such as former ditches, pits or postholes. Postholes are very small and can only be found under optimal conditions and in conjunction with other patterns or when they form a larger pattern such as a circular array.

Thermoremanent features are burnt deposits that may indicate features such as kilns, smelting furnaces, hearths and burnt mounds.

Interpretations follow certain patterns, and linear, circular, curved, ellipsoidal and rectangular shapes are often man-made, while less organised and more random shapes are often caused by geological or hydrogeological or similar natural processes.

Cultivation furrows are often recognisable in the data, by the repeating pattern of parallel lines.

Magnetic anomalies relevant to archaeological features are typically in the range of +/- a few nanotesla (nT) and are therefore shown as grey spots, areas or lines in the images. They are generally caused by weakly magnetised material deposited in former holes or ditches in the ground surface. They cause a monopole anomaly (grey or black only little or no white) and they have an amplitude of typically between 0 to 5 nT. These are also called weak anomalies in the interpretation.

Rapid changes between white and black hues indicate strongly magnetised objects in the soil, which are mostly ferrous magnetic metal pieces (ferritic litter). These anomalies are also called magnetic dipole anomalies and they have negative and positive that can reach several hundred nT in amplitude. Many of these objects are pieces of iron that are lost in agriculture by machinery or introduced by fertiliser or fencing material.

Magnetic anomalies indicative of archaeological remains may also be caused by other processes such as building development, gardens, agriculture and construction work (e.g. foundations, pipelines and masts for overhead power lines).

Some fields have been intensively cultivated in the past through ploughing and cultivation, resulting in the destruction or scattering of possible archaeological remains within the plough depth. Therefore, the evidence and interpretations in the current survey assume a greater depth than the maximum ploughing and cultivation depth.

3.3 Interpretation

The interpretation is shown on Maps 3a to 3g, which are superimposed on the data with +/- 5nT.

There are a number of magnetic anomalies that may be of archaeological origin. The interpretation highlights these and gives a possible interpretation or reason for these anomalies. The interpretation is overlaid on the maps by the colours explained below. Not every black or grey dot indicating the source of a small magnetic anomaly is drawn in the interpretation.

Green: Anomalies highlighted in green indicate probable archaeological features or deposits in the subsurface. They may be the main targets for further investigation or may be avoided in construction. However, they may also turn out not to be of archaeological origin.

Cyan: These lines indicate a possible archaeological origin, but may also have other causes, such as agricultural or tree boles. There are several weak monopole anomalies occurring in clusters or groups that are marked by a cyan closed outline with irregular shape.

Yellow: Anomalies highlighted in yellow indicate a pattern consistent with the historic maps seen on the Ordnance Survey of Ireland's online map viewer (www.osi.ie). The historic maps cover the years from 1829 to 1930 in four sets of maps. The extent to which this is of archaeological potential or relevance must be assessed by the client's archaeologist.

Blue: These anomalies are almost certainly interpreted as existing subsurface drainage lines or former field boundaries or both.

Orange arrows: These symbols indicate a ploughing or cultivation pattern, with the arrows indicating the direction. Usually, one double arrow is drawn in a larger area of a cultivation pattern.

Pink G: "G" indicates a geological cause visible in the magnetic data. It can be linear or curved and has a striated and smeared appearance corresponding to the geological strata terminating shallow below the surface. The magnetic field is often caused by slight variations in the magnetic material between more or less tilted rocks. Generally, there is one 'G' placed in the centre of a pattern covering a larger area.

Red: Indicates buried magnetic metal such as former fences.

Black/White: Such dots in the maps indicate strongly magnetised objects in the ground, e.g. pieces of ferrous magnetic metal.

3.4 Recommendations

Probable or possible archaeological features in the subsurface can either be bypassed and avoided during planning and construction or investigated by targeted archaeological test excavations to determine the cause of the magnetic indication.

It is advisable to communicate with the relevant landowners first, as they may be able to recall how an area was used, whether there were permanent or temporary buildings or structures, or whether other activities took place.

Targeted trial trenching is recommended on all interpreted probable or possible archaeology where a construction project is planned. This may reveal that some of them are not archaeological in origin. It is also possible that they are physically extinct but a magnetic anomaly remains in the ground ('ghost'). In which case the survey represents the record but there are no further constraints on the construction of the site.

If archaeological remains have been found during trial excavations, the geophysical interpretation should be checked and the results may improve the interpretation.

The magnetic field is precisely mapped in the ITM system. This makes it possible to define test sections with particularly high accuracy (cm) achieving results quickly, purposefully and very efficiently.

3.5 Conclusions by Maps

All Maps: Metal items are visible in many places in the fields and also appear as strong dipole anomalies buried in several fields. Fields 3 and 31 show many underground metal anomalies in larger accumulations rather than just individual items. All magnetic indications have been excluded from the interpretation.

The most notable anomalies are parallel patterns indicating former cultivation directions. They are marked by double orange arrows. The pattern of former ridges with furrows is maintained in the magnetisation of the ground even though the raised beds are no longer visible. There are fields with cultivation pattern in two different directions.

The cultivation patterns indicate that former fields were smaller than those visible today, with the outlines of cultivation patterns indicating the former field boundaries.

Many fields contain patterns indicating field drains or former field boundaries (marked blue). Some parallel or fish bone patterns indicate underground drains. Some single blue lines can indicate former open drains or former field boundaries.

Map 3a: These fields are dominated by cultivation patterns and drainage systems (blue). In Field 3 the patterns are very strong. In Field 3 there was also some standing water where no readings could be taken, and a relatively large area with metal (red).

Several straight lines in the magnetic data could be matched with historic field boundaries visible in the OSI maps (yellow).

Some weak anomalies in Fields 2 and 6 have been interpreted as geological.

Map 3b: Field 7 shows few anomalies and only the one cultivation direction has been interpreted.

Field 8 shows an intensive pattern of drainage and former field boundaries (blue) and many cultivation patterns in smaller divisions. This shows the intensive agricultural use in the past.

Field 14 shows an intensive pattern of cultivation in the west and a drainage system (blue) in the east.

Map 3c: Field 12 indicates drainage (blue) and some cultivation directions.

In Field 13 two curvilinear anomalies (yellow) could be matched with historical field boundaries. The larger shape in the center of the field is showing the outline of a forested area in the historical OSI maps. There are several weak anomalies (cyan) inside the yellow outline that could be possible archaeology. To the east of this is a small area with an accumulation of weak anomalies that could be possible archaeology (cyan). The area of the roughly circular historical boundary and the possible archaeology (cyan) should be either archaeologically tested and assessed or avoided for construction of solar panels.

Further magnetic patterns in Field 13 indicate intensive past agricultural use with cultivation direction and drainage patterns.

Field 15 has interpreted drains and former field boundaries (blue). These lines seem to show past field separations. The western part of the field is low with anomalies and the pattern there is interpreted as geology. The eastern part has a cultivation pattern.

The cultivation pattern continues east into Field 16. There is a notable topographical elevation in the north of Field 16 within signs of excavation of the overburden looking like a small sand and gravel pit. The main observation from the magnetics are two weak circular anomalies, although the circles are not fully closed (cyan). We interpret these as possible archaeology. There are three recorded monuments (ringfort – rath) to the north of the survey area, they are located on an elevated topographical ridge, and the marked two areas could in Field 16 could be also former continuations of such features.

Fields 17 and 21 show a continuation of the former field boundaries and drains (blue) from the north and are also dominated by cultivation patterns.

A historical field boundary (yellow) is identified through Fields 17 and 18. In the southeast corner of Field 18 two black monopole anomalies interrupt the cultivation pattern and they are interpreted as possible archaeology.

Field 20 has a cultivation pattern with two directions in an oval overall shape situated within an area of low magnetic values.

Map 3d:

Field 22 has three historical field boundaries matched with the OSI map. The former boundaries match with different cultivation directions, showing that the cultivation took place within the historical boundaries.

The historical boundary in the northwest of this field is accompanied by further lines forming a rectangular pattern. We interpreted this as possible archaeology and this should be tested or avoided. This are likely further historical boundaries but in how far this is archaeology has to be determined by archaeological assessment.

In the southeast part of Field 22 are two areas interpreted as possible archaeology, in each is a cluster of weaker monopole anomalies, and these should be assessed or avoided.

Field 24 indicates cultivation patterns and within it there is a small area not surveyed that is elevated and overgrown.

Map 3e: These rather low lying fields have fewer and weaker cultivation patterns than in the northern survey area, those who show at the edges of fields are in very slightly elevated locations.

There are some historical field boundaries in the southeast corner of Field 29, the two parallel lines mark the boundaries of an old road.

The center of Field 26 was too highly overgrown to be surveyed.

A band of interpreted geological anomalies runs through Field 25.

Map 3f: In Field 30 is the recorded ringfort – rath (GA099-61). This area could be only partially surveyed because of the elevated and sloping ground and some vegetation. This archaeological feature was marked by a green line and the line is following the outline of the visible area on site.

In the south of this map is a large area with strong cultivation patterns. This area is slightly raised in elevation compared to the area on the periphery with no cultivation pattern.

There are also drains and former cultivation patterns (blue).

Map 3g: There are linear magnetic anomalies matched with historical boundaries (yellow) and a former farmstead building is indicated by a rectangular shape.

Cultivation patterns change with areas of low magnetic intensity and this matches the gently undulating land with the cultivation patterns on the slightly higher ground.

There are many former drains and field boundaries (blue) in this intensively farmed area.

Notable is the large amount of strong dipole metal anomalies that are not just single objects but indicate backfilled pits and possible spreading of topsoil containing metal items.

The following table summarises the interpretation and the amount of features found:

Probable Archaeological Feature	Green	1
Possible Archaeological Features	Cyan	7 Clusters/Groups
Historical Field Boundary (OSI Map)	Yellow	19 Lines
Subsurface drainage or former field boundaries	Blue	Over 150 Lines

4. REFERENCES

1. **Bonsall, J., Gaffney, C., Armit, I., 2014.** Preparing for the future: A reappraisal of archaeo-geophysical surveying on Irish National Road Schemes 2001 – 2010, Bradford.
2. **Clark, A., Clark, O. A., 1990.** Seeing Beneath the Soil. Prospecting Methods in Archaeology, London.
3. **David, A., Linford, N., Linford, P., 1995.** Geophysical Survey in Archaeological Field Evaluation. Research and Professional Services Guideline No 1, Ancient Monuments Laboratory, English Heritage Society. David, A. (compiler), 1995.
4. **English Heritage, 2008.** Geophysical survey in archaeological field evaluation. Research professional Services Guideline No. 1. 2008.