Appendix A.13.12

Geophysical Survey Report

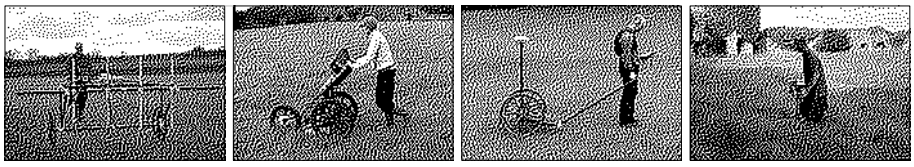
A.13.12

TARGET ARCHEAOLOGICAL GEOPHYSICS REPORT 14008

N6 GALWAY CITY TRANSPORT PROJECT BALLYBRIT TOWNLAND, CO. GALWAY

FOR IAC ON BEHALF OF ARUP/GALWAY COUNTY COUNCIL

TARGET archaeological geophysics



Ground Radar

Magnetometry

Electrical resistivity

Electromagnetic induction

TARGET GEOPHYSICS REPORT 14008

N6 GALWAY CITY TRANSPORT PROJECT, BALLYBRIT TOWNLAND, CO. GALWAY

Site Location	Archaeological geophysical survey was undertaken across lands traversing Galway Racecourse and 3 adjacent fields located in Ballybrit townland, c 2.5km north-east of Galway City. This geophysical survey was undertaken in connection with the proposed N6 Galway City Transport Project. The survey extended across 13.89ha of land situated c.1.8km east of the N17, north of the N6, west of Ballybrit Crescent and Briarhill Business Park.
NGR	533563 727698 (ITM)
Topography & Landuse	Flat and south facing pasture land with areas of tarmac and made ground.
Soils & Geology	Shallow brown earths and rendzinas (60%), grey brown podzolics (25%), gleys (10%), and peat (5%), over glacial till and limestone (Association 33).
Archaeology	Recorded monuments within the survey area may be impacted on by the proposed scheme. These are all located within Ballybrit townland, and include tower house GA082-012001 and deserted medieval settlement GA082-12002 to the west, and a large ringfort GA082-013 and house GA082-013001 (indeterminate date) to the south west. Further monuments at the periphery of the investigation area include enclosure site GA082-014 west of GA082-013, souterrain GA082-011001 to the east, children's burial ground GA082-011002 to the east, and anomalous stone group GA082-016 to the north east.
Methods	Magnetometry & targeted electromagnetic induction (quadrature) survey.

SURVEY OBJECTIVES

The aim of this geophysical survey were to:

- identify any geophysical anomalies of possible archaeological origin within the specified survey areas.
- accurately locate these anomalies and present the findings in map form.
- report on the anomalies and discuss their likely provenance and significance.
- recommend any further works likely to contribute to the mitigation of the impacts of the development on these features.

SUMMARY OF RESULTS

No responses of definite archaeological character have been recorded from the magnetometer and electromagnetic induction (quadrature) surveys undertaken across the investigation area in M1-M12 and EMI1-EMI8. The results from both surveys highlight widespread modern ferrous interference, zones of substantial magnetic disturbance, buried services, responses from recent land use and former cultivation.

Part of an enclosure or field system associated with GA082-12001/ GA082-12002 has been recorded in M7 (anomaly 15), and EMI8 (anomaly 10). This is located in the racecourse section of investigation. Further zones of archaeological potential are suggested by groups of positive linear anomalies and sub-angular responses, weak trends and zones of increased response. The most notable of these occur in M3, M4, M5, M7, M8 and M10, and electromagnetic induction (quadrature) anomalies 1, 3, 8 and 10 in EMI1, EMI6 and EMI10.

No responses clearly indicating an extension of significant remains associated with large ringfort GA082-013 have been identified in the southern region of the investigation.

PROJECT DETAILS

Client	Galway County Council
Consulting Engineers	ARUP
Project Archaeologists	IAC Ltd.
Detection License	14R0089
Author	John Nicholls MSc
Fieldwork	14th-16th and 21st-23rd July 2014
Report	26th September 2014

** This summary forms only a brief and short description of the survey results. The presentation, discussion and interpretation of the survey results are included in the main text of the report.

1 SURVEY METHODOLOGY

1.1 METHODOLOGY

This geophysical survey employed magnetometry and electromagnetic induction techniques to examine the investigation area, covering c.13.89ha of pasture land extending through Galway Racecourse and 3 adjacent fields to the south. The instrumentation and sampling strategy used for this geophysical survey are summarized below in Table 1.1.1:

Table 1.1.1 Instrumentation and sampling strategy

Instrumentation	MAG/EMI Traverse Interval	Sample Interval	Ha
Magnetometry -Bartington Grad601-6 sensor magnetometer cart system with GPS	0.5m	c.10 readings/m (14Hz)	13.89
Electromagnetic induction -EM38 MK2 cart system with GPS (vertical dipole configuration)	0,75	c.8 readings/m (10Hz)	2.26

1.2 DATA POSITIONING

A Trimble 'VRS Now' GPS working in the WGS84 coordinate system (CRS) was used to record GPS locations along each magnetometry and electromagnetic induction instrument traverse. The GPS locations from each technique were then used to position the geophysical data and a 'shift' subsequently applied for coordinate transformation to the projected ITM CRS. The procedures used for data positioning for this geophysical survey are summarized below in Table 1.2.1:

Table 1.2.1 Instrumentation and sampling strategy

No.	Positioning	Precision	GPS Traverse Interval	GPS Sample Interval	CRS
1	GPS collection	0.02-0.04m	3m	1Hz	WGS84
2	Shift from WGS84 to ITM	0.1m	0.75m	n/a	ITM

1.3 DATA PROCESSING

The procedures used for processing of the geophysical survey data are detailed below in Table 1.3.1:

Table 1.3.1 Data processing

No.	Description
1	Positioning of magnetometry & electromagnetic induction (quadrature) data in accordance with the GPS locations
2	Zero drift and median correction (magnetometry), and linear drift estimation (electromagnetic induction) to overcome discrepancies between the background values along each instrument traverse
3	Export as shapefile (magnetometry and electromagnetic induction) in vector format and XY-trace generation (magnetometry)
4	Import of all vector data to GIS

No.	Description
5	Vector to raster conversion via natural inverse distance weighted interpolation
6	Export as ESRI ARCGRID
7	Greyscale export at the optimum range for data presentation

1.4 DATA DISPLAY

This report includes location, greyscale, and interpretation diagrams for the magnetometry and electromagnetic induction (quadrature) surveys. A list of figures included for this report is provided below in Table 1.4.1.

Table 1.4.1 List of figures

Figure No.	Title	Scale
1	Survey locations, magnetometry and electromagnetic induction (quadrature)	1/5000
2	Magnetometry greyscales M1-M12	1/2500
3	Magnetometry greyscales M1-M9	1/1500
4	Magnetometry greyscales M7-M12	1/1500
5	Electromagnetic induction (quadrature) greyscales (1m vertical dipole) EMI1-EMI8	1/1500
6	Electromagnetic induction (quadrature) greyscales (0.5m vertical dipole) EMI1-EMI8	1/1500
7	Magnetometry interpretations M1-M12	1/2500
8	Magnetometry interpretations M1-M9	1/1500
9	Magnetometry interpretations M7-M12	1/1500
10	Electromagnetic induction (quadrature) interpretation (1m and 0.5m vertical dipole) EMI1-EMI8	1/1500

2 DIGITAL ARCHIVE

This report is accompanied by a digital archive comprising the raw and processed geophysical data, CAD files, GIS files (vector and raster), and report text. XY-trace display formats have also been used for interpretation of the magnetometry data, and these are included in the archive at a scale of 15 nano-Tesla (nT)/cm. The contents of the digital archive are detailed below in Table 2.1 below:

Table 2.1 Digital archive

Folder	Description	Filename(s)	File extension(s)
Data/raw magnetometry data	Magnetometry areas M1-M12 – raw data	M1-M12	XYZ
Data/raw emi quadrature data	EMI quadrature areas EMI1-EMI8 -raw data	EMI1-EMI8	XYZ
Data/processed magnetometry data	Magnetometry areas M1-M12 – processed data	M1-M12	CSV

Folder	Description	Filename(s)	File extension(s)
Data/processed emi quadrature data	EMI quadrature areas EMI1-EMI8 processed data	EMI1-EMI8	CSV
CAD	Report illustrations, figures 1-10	TAG_14008_1 to TAG_14008_5	DWG
CAD	Magnetometry interpretation M1-M12	TAG_14008_mag_interpretation	DWG
CAD	EMI quadrature interpretation EMI1-EMI8	TAG_14008_emiquad_interpretation	DWG
CAD	M1-M12_EMI1-EMI8_GPS_tracks	M1-M12_EMI1-EMI8_GPS_tracks	DWG
CAD	Report cover	FCover	DWG
GIS/Vector data - processed magnetometry data	Vector	M1_out_shft to M12_out_shft	SHP
GIS/Vector data– processed EMI quadrature data	Vector	EMIQ1_zmt to EMIQ8_zmt	SHP
GIS/Raster data – processed magnetometry data	Raster	M1_out_shft to M12_out_shft	TIFF
GIS/Raster data – processed EMI quadrature data	Raster	EMIQ1_05_zmt to EMIQ8_10_zmt	TIFF
Report	Text	TAG_14008_Ballybrit_Racecourse_Ballybrit_Co Galway_Draft_Arup_24.09.2014	MS Word
Report (with illustrations)	Portable document format	TAG_14008_Ballybrit_Racecourse_Ballybrit_Co Galway_Draft_Arup_24.09.2014	PDF

3 GENERAL CONSIDERATIONS

3.1 ACCESS & SOURCES OF MODERN INTERFERENCE

The investigation area lies within accessible, flat and south-facing pasture land interspersed with areas of made ground, post and wire fencing, and tarmac. Access across the site was generally good for the duration of the magnetometer survey with only 2 sections of the racecourse track and 2 sections of outcropping geology to the south remaining unavailable to survey. Unfortunately no arrangements for moving of cattle occupying the southern 3 fields could be negotiated for the period of electromagnetic induction survey. Consequently these fields were only examined using magnetometry. The magnetometry survey has been undertaken at a sufficiently high resolution to record significant zones of archaeological activity where present within the investigation area. The potential that some less substantial archaeological features remain unrecorded on account of access not be agreed to complete the EMI survey there should not be dismissed.

3.2 SOURCES OF MODERN INTERFERENCE

The racecourse section of investigation contains numerous modern sources of magnetic interference, including several concrete outbuildings, freight storage containers, portacabins, wire mesh fencing, and 1 area of made ground west of survey centre. Several manhole covers associated with drainage and buried services also extend across the investigation area, demonstrating that the study area is likely to have been exposed to substantial landscaping in recent years.

The fields to the south of the racecourse are bordered by a large business park to the east/north east, a telecommunications mast and wire mesh fencing to the north west, 1 landscaped field to the west, and the N6 to the south. One electricity pylon in the eastern field contributed large-scale magnetic disturbance and caused severe disruption to connection to the GPS network during fieldwork. The potential that this interference may have masked anomalies of archaeological significance should not be dismissed.

The results from both the magnetometry and electromagnetic induction (quadrature) surveys contain numerous small-scale ferrous responses. These are frequently encountered using these two geophysical techniques and often the result of modern metallic debris contained within the topsoil. Large-scale areas of ferrous response and magnetic disturbance are also evident across the investigation area in both data sets. The potential that this interference may have masked anomalies of archaeological significance should not be dismissed.

4 MAGNETOMETRY RESULTS

4.1 M1-M9

The results from M1-M9 across the racecourse section of survey demonstrate widespread interference from modern surfaces, with few responses of archaeological potential apparent. This interference is visible as large and small-scale regions of ferrous response, as well as substantial zones of magnetic disturbance. These sources of modern interference derive from perimeter fences, existing buildings, areas of made ground and buried services.

Across M1-M9 the magnetometry results also display the effects of more recent land use within the racecourse, including cultivation on various alignments and probable former boundaries.

Areas of potential archaeological significance are evident in the magnetometry results from M1-M9. These include isolated positive anomalies in M2-M6, and more notable anomalies 6, 8 and 12 in M3, M4 and M5. Anomaly group 6 to the south east in M3 may represent a possible fulacht fiadh site or a group of pit type features. Rectilinear response 8 and an adjacent positive to the south west in M4 may also be significant, suggesting a possible enclosure ditch and pit. Positive anomalies and zones of increased response 12 at survey centre in M5 potentially indicate the plough damaged remains of a group of pit type features and linear remains. Interpretation is cautious for all these responses considering the degree of modern interference across the site. None of these responses display definitive archaeological characteristics.

One linear response 15 to the south in M7 and an adjacent weak linear trend may represent parts of an enclosure or field system associated with GA082-12001/GA082-12002. These weak responses are aligned parallel to former cultivation and their interpretation therefore remains uncertain.

Across M8-M9 further responses of archaeological potential are indicated. These are mainly visible as clusters of small-scale positives and poorly defined linear anomalies. The most notable of these include responses 16-18 in M8, and 20-22 in M9. Anomaly grouping 16 corresponds to a section of slightly elevated ground, and could indicate a concentration of potential linear and pit type features.

Interpretation of many of the responses highlighted from magnetometer survey across M1-M9 remains cautious. Widespread interference across this section of the study area has complicated interpretation. Many of the responses highlighted as being of potential interest are small-scale, poorly defined and situated in close proximity to modern sources of interference. The potential that some of these anomalies derive from modern ferrous material, buried services, recent land use or localised variations in soil morphology should not be dismissed.

Responses of potential interest recorded from survey across M1-M9 are summarised below in Table 4.1.1:

Table 4.1.1 Significant anomalies highlighted in M1-M9

Anomaly(s)	Area	Location (approx)	Description	Significance	Suggested origin
n/a	M1	n/a	No anomalies of definite or potential archaeological interest	n/a	n/a
1-3	M2	W, NW and at survey centre	Isolated positives	Potential	Possible pit remains, alternatively modern ferrous or responses from natural
4	M2	E	Weak curving linear anomalies	Limited	? former field boundaries / land divisions
5	M2	W/SW of survey centre	Weak linear trends	Limited	? former field boundaries, cultivation or effect of recent land use

Anomaly(s)	Area	Location (approx)	Description	Significance	Suggested origin
6	M3	SE	Group of small and linear positive responses	Potential	Possible fulacht fiadh or pit remains
7	M3	NW	Weak parallel linear trends	Limited	? former boundary, cultivation or effect of recent land use
8	M4	SW	Rectilinear response and adjacent positive anomaly	Potential	Possible enclosure ditch and pit type feature
9	M4	NE to SW	Weak linear trends (mainly parallel)	Limited	Possible water supply(s) or effect of recent land use
10	M4	S	Weak linear anomaly	Limited	? former field boundary
11	M5	NE	Line of small positive responses	Potential	Possible pit or linear remains, alternatively modern ferrous or responses from natural
12	M5	SE of survey centre	Zones of increased response and discrete positive anomalies	Potential	Possible plough damaged pit or linear remains
13	M5	SW of survey centre	Rectangular arrangement of weak trends	Limited	Probable recent land use
14	M6	SE of survey centre	Discrete positive anomaly	Questionable	Possible pit, alternatively modern ferrous or natural
15	M7	S	Linear anomaly and weak trend	Potential	Possible part of enclosure or field system associated with GA082-12001/ GA082-12002
16	M8	NE	Zone of increased response, discrete positive anomalies and outlying trends	Potential	Possible pit and associated linear remains
17	M8	E	Weak linear response	Potential	Possible ditch
18	M8	SW	Positive linear response	Potential	Possible ditch
19	M8	SW	Parallel weak linear trends	Limited	Probable recent land use, cultivation or drainage
20	M9	NE	Discrete positive response and weak linear trends	Potential	Possible pit or natural/former land use
21	M9	SW	Discrete positive linear and small-scale anomalies	Potential	Possible pit/linear remains, alternatively modern ferrous or natural
22	M9	SW	Discrete positive anomalies overlying zone of increased response	Potential	Possible pit and eroded remains

4.2 M10-M12

The results from M10-M12 across the southern portion of investigation demonstrate widespread interference from probable near surface geology, 1 buried service, an electricity pylon, a telecommunications mast, and modern ferrous sources to the N, NW, E, and S. Responses of archaeological potential apparent in M10-M12 are generally small-scale, poorly defined and situated in close proximity to areas of probable near surface geological interference and modern ferrous sources. Interpretation of these anomalies remains cautious.

Effects of recent land use evident across the results from M10-M12 include various alignments of former cultivation, mainly in M10-M11, and one suspected former boundary in M10.

A rectangular pattern of positive responses (23) with adjacent positives and zone of increased response (24) are visible to the south in M10, suggesting possible enclosure and pit remains, or the site of a possible building. A further group of pit remains are indicated by anomaly grouping 25 to the

north. Interpretation of anomalies 23-25 is cautious as they may in part derive from a former boundary (26) traversing M10 to the south.

Further groups of small-scale positives and linear responses are indicated in M11 to the north east (27), with a broader scatter of small-scale positives to the south, perhaps deriving from near surface geological/soil variations. The magnetometry results from M12 similarly display isolated positives (35-36), though less in number, with diffuse linear/sub-angular anomalies (37) also present. An archaeological source for these anomalies cannot be entirely discounted. However, no patterns of definite archaeological character indicated, and significantly no clear evidence for features associated with GA082-013 are visible in the results.

Responses of potential interest recorded from survey across M10-M12 are summarised below in Table 4.2.1:

Table 4.2.1 Significant anomalies highlighted in M10-M12

Anomaly(s)	Area	Location (approx)	Description	Significance	Suggested origin
23	M10	SE of survey centre	Rectangular pattern of positive anomalies and outlying positives	Potential	Possible enclosure and pit remains, or former building
24	M10	S	Zone of increased response	Potential	Possible eroded archaeological remains
25	M10	NW	Positive anomalies and adjacent weak trends	Potential	Possible pit and linear remains (? former field boundary)
26	M10	S	NE/SW Linear anomaly	Limited	? former field boundary
27	M11	NE	Small-scale positives	Questionable	Possible pit/linear features, alternatively modern ferrous or natural
28	M11	W	Small-scale positive	Questionable	Possible pit, alternatively modern ferrous or natural
29	M11	SW	Small-scale positives and zone of increased response overlying cultivation	Questionable	Possible pit/linear features, alternatively modern ferrous or natural
30-31	M11	E/SE	Small-scale positives	Questionable	Possible pit/linear remains
32-34	M11	NE, SE and SW of survey centre	Weak adjoining trends	Limited	Natural or recent land use
35-36	M12	NE and NW of survey centre	Small-scale positives	Questionable	Possible pit/linear remains, alternatively modern ferrous or natural
37	M12	S of survey centre	NE/SW aligned weak linear trends	Limited	Natural, recent land use or former field boundary

5 ELECTROMAGNETIC INDUCTION (QUADRATURE) RESULTS

Generally, the electromagnetic induction (quadrature) survey results show good correlation with the magnetometry, highlighting patterns of former cultivation, probable former field boundaries, buried services, and responses from modern ferrous material. No definite zones of archaeological response are indicated by the electromagnetic induction (quadrature) survey results. However, several anomalies of archaeological potential have been identified, some of which correspond to responses of archaeological potential highlighted by the magnetometry.

The most notable responses highlighted by the electromagnetic induction (quadrature) survey include a pair of weak curving trends (1) at survey centre in EMI1, curving weak linear trends (3) to the west in EMI3 and to the north east in EMI6 (8), and a weak linear trend (10) to the south in EMI8. Responses 8 and 10 correspond to magnetometer anomalies 15 and 16 in M7 and M8. 10 may represent part of an enclosure or field system associated with GA082-12001/GA082-12002

Table 5. 1 Significant anomalies highlighted in EMI1-EMI8

Anomaly(s)	Area	Location (approx)	Description	Significance	Suggested origin
1	EMI1	Survey centre	Weak curvilinear trends	Potential	Possible curvilinear remains
2	EMI1	SE	Linear response	Limited	? former field boundary
n/a	EMI2	n/a	No anomalies of definite or potential archaeological interest	n/a	n/a
3	EMI3	W of survey centre	Weak curvilinear trend	Potential	Possible linear feature or natural
4	EMI3	S to NE	Weak linear trend	Limited	Possible water supply or effect of recent land use
5	EMI3	E to W	Weak linear trend	Limited	Likely response from instrumentation
6	EMI4	E	Linear response	Limited	? former field boundary
7	EMI5	E	Weak linear trends	Limited	Natural or recent land use
8	EMI6	NE	Weak curvilinear trends	Potential	Possible linear remains
9	EMI7	W	Weak linear trend	Limited	Natural or recent land use
10	EMI8	SW	Weak linear trend	Potential	Possible part of enclosure or field system associated with GA082-12001/ GA082-12002

.

6 CONCLUSIONS

6.1 The results from magnetometer survey in M1-M12 and electromagnetic induction (quadrature) survey in EMI1-EMI8 detail no responses of definite archaeological character. No evidence for extensive archaeological settlement, substantial enclosure remains or large concentrations of archaeological activity have been recorded. Weak linear responses to the south in M7/EMI8 reflect the most significant and likely archaeological responses recorded from this survey, suggesting part of an enclosure or field system associated with GA082-12001/ GA082-12002.

6.2 Further responses of archaeological potential are indicated by the results from this survey, including anomalies 6, 8, 12, 16, 17, and 23 in magnetometry areas M3, M4, M5, M7, M8 and M10, and electromagnetic induction (quadrature) anomalies 1, 3, 8 and 10 in EMI1, EMI6 and EMI10.

6.3 No responses clearly indicating an extension of significant remains associated with large ringfort GA082-013 have been identified in the southern region of the investigation area. Many of the responses in this location are expected to represent variations caused by modern ferrous interference, former landuse and natural soil/geological variation.

6.4 It is recommended that the results from this geophysical survey be verified by *pre-development archaeological testing*. *Pre-development archaeological testing* can be defined as 'a limited programme... of intrusive fieldwork which determines the presence or absence of archaeological features, structures, deposits, artefacts or ecofacts within a specified area or site on land or underwater. If such archaeological remains are present archaeological test excavation defines their character and extent and relative quality,' (IFA 2008).

6.5 The results from this geophysical survey suggest that the majority of responses recorded across the investigation area are of limited archaeological potential, and generally indicate effects of recent landuse, modern disturbance and/or natural soil/geological variation. On this basis it is reasonable to suggest that a systematic program of *pre-development archaeological testing* across the project area would be sufficient to examine the majority, though not necessarily all, of the responses highlighted from this survey, including those suggested as being of potential interest, and further anomalies highlighted as questionable or limited potential.

Table 6. 1 Anomalies recommended for further investigation

Magnetometry anomaly(s)	Magnetometry area	Recommendation
1, 3, 5	M2	Pre-development archaeological testing
6	M3	Pre-development archaeological testing
8, 9	M4	Pre-development archaeological testing
11, 12, 13	M5	Pre-development archaeological testing
15	M7	Pre-development archaeological testing
16, 17, 18	M8	Pre-development archaeological testing
20, 22	M9	Pre-development archaeological testing
23, 24	M10	Pre-development archaeological testing
27, 28, 29, 30	M11	Pre-development archaeological testing
35, 37	M12	Pre-development archaeological testing

Electromagnetic induction (quadrature) anomaly(s)	Electromagnetic induction (quadrature) area	Recommendation
1	EMI1	Pre-development archaeological testing
3	EMI3	Pre-development archaeological testing
8	EMI6	Pre-development archaeological testing
10	EMI8	Pre-development archaeological testing

REFERENCES

Archaeological Survey of Ireland (ASI), Archaeological Survey Database, National Monuments Service.

Bartington Instruments, Operation Manual for Grad601 Single Axis Magnetic Gradiometers (OM1800).

Bonsall .J, Gaffney C. and Armit I., 2014, Preparing for the Future: A reappraisal of archaeo-geophysical surveying on Irish National Road Schemes 2001-2010. University of Bradford.

David, A., Linford, N., & Linford, P., 2008, Geophysical survey in archaeological field evaluation, Research & Professional Guideline, No. 1 (2nd edition).

Institute of Field Archaeologists. 2008. The use of geophysical techniques in archaeological evaluations. Institute of Field Archaeologists Paper No. 6.

IFA (2008), Institute For Archaeologists, Standard and Guidance For Archaeological Field Evaluation.

GRASS Development Team, 2013, Geographic Resources Analysis Support System (GRASS) Software, Version 6.4.3, Open Source Geospatial Foundation.

National Soil Survey of Ireland (1980), General Soil Map 2nd edition, 1:575000, An Foras Taluntais.

QGIS Development Team, 2014. QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.osgeo.org

Schmidt, A. 2014. Geophysical data in archaeology: Guide to good practice http://ads.ahds.ac.uk/project/goodguides/geophys/

LIST OF FIGURES

APPENDIX 1: TECHNICAL INFORMATION ON INSTRUMENTATION AND DISPLAY

INSTRUMENTATION

GPR/Ground Penetrating Radar (GSSI SIR-3000): GPR systems comprise a configuration/data acquisition unit, a transmitting/receiving antenna (250-500mhz), and a cart with an odometer or integrated GPS. The technique is used for identifying remains of buried foundations, structures and cavities. GPR systems transmit a continuous electromagnetic wave of energy into the ground and record reflections of that energy as it interacts with the stratigraphy and structures below the surface. Data is acquired along parallel transects, 0.5m or 1m apart, and recorded as a function of the elapsed time for the energy wave to travel from transmitter to reflector and back to the surface. The strength of reflections recorded from GPR survey is proportional to the conductive and dielectric properties of the buried objects with which the transmitted energy is incident.

Gradiometry/Magnetometry (5 sensor Grad601 cart system with GPS): Gradiometry is the most widely applied technique in archaeological prospection, and is regularly used on sites 1-100ha in size to locate and characterize buried remains of enclosure ditches, pits, hearths, furnaces and kilns. These remains often produce magnetic contrasts above localized soil/geological variation due to enhancement from burning activity and organic enrichment of the soil during archaeological settlement. Mapping of these contrasts is undertaken using an array of either caesium or fluxgate magnetic sensors for measurement of the earth's total magnetic field or variations in its vertical component. Target uses a 5 sensor Grad601 GPS cart system to measure magnetic anomalies from buried archaeological remains in detail, collecting data along parallel lines 0.5m or 0.75m apart, at 10-12cm intervals along each line.

Electrical Resistivity (Geoscan RM15 & twin probe array): Electrical resistivity is generally used to map locations of buried structures, including foundation remains, walls, burial cairns, and existing earthworks. Using an array of electrodes mounted on a portable frame a small electrical current is passed through the ground at regular intervals via *current* emitting probes. Variations in resistance to the flow of this electrical current as it passes through the ground are measured by *potential* probes. Single or parallel twin arrays use 1 or 2 pairs of current and potential probes fixed to a mobile frame, with 1 remote *current* and 1 *potential* probe maintained stationary 20m from the survey limit. Resistivity surveys are normally conducted at 0.5m x 1m or 1m x 1m intervals.

EMI/Electromagnetic Induction (Geonics EM38-MK2 cart system with GPS): EMI is suitable for detection of buried remains including foundations, enclosures, ditches, pits, and kilns. The technique measures variations in both the electrical conductivity and magnetic susceptibility of the soil. The Geonics EM38-MK2 comprises of 1 transmitting and 2 receiving coils, providing 2 data sets from 2 depths below surface. The transmitting coil generates a time varying primary magnetic field which propagates above and below ground, generating alternating (eddy) currents within the soil and the objects it contains. These create a secondary magnetic field proportional to the rate of change of the magnetic field, which is measured by receiving coils 0.5m and 1m from the transmitting coil. Target's Geonics EM38-MK-2 cart system is used to undertake EMI survey in vertical or horizontal modes along 0.5m, 0.75m or 1m spaced lines at 10-12cm intervals along each line.

DISPLAY

Greyscale: The greyscale 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 above localized soil/geological variations.

Colour Plot: Colour plots comprising RGB values linearly interpolated between a user-specified range of values can provide further insight into the varying anomalies within a given data set. Colour plots are particularly useful for EMI data where presentation of results within a confined range of values is not always feasible with other formats.

XY Trace: XY Trace displays provide a near-perspective representation of responses recorded along each instrument traverse. The format is used mainly for locating responses from modern ferrous, but can assist in identifying magnetically strong anomalies relating to hearth, kiln and furnace remains. Ferrous anomalies can also be identified via a search of the attribute table in a GIS extracting readings beyond a specified range (e.g. where z<= -15 and where z>=15), and then combining this layer with other display formats for interpretation.

Time-slice: Radargrams collected from grid based survey or parallel transects can be compiled as a 3D volume, then re-sampled to produce a series of 2D plans at incremental depth/time offsets. A series of Time-slice displays at 25-50cm offsets permits analysis of the pattern and depth of reflections within a given GPR survey area.

Investigation area
Available for magnetometry
Targeted EM
RMP
National monument

1 Tower House GA082-012001
2 Deserted Medieval Settlement GA082-12002
3 Large Ringfort GA082-013
4 House - Indeterminate Date GA082-013001
5 Enclosure Site GA082-014
6 Souterrain GA082-11001
7 Children's Burial Ground GA082-11002
8 Anomalous Store Group GA082-016

GA082-072

M1 M2 EMI1 EMI2 EMI3 M3 M4 EMI4 M5 EMI5 M6 M7 EMI6 M8 EMI6 EMI7 M9 M10 M11 M12

8 6 & 7 1 2 3 4 5

GA082-017

GA082-015

ERRANLOUGHAUN

Project	Figure:	Figure No:	Scale:	Ref:
N6 Galway City Transport Project. Ballybrit townland, Co. Galway	Survey locators, MAG and EMI	1	1/5000 @ A3	TAG 14008

N W E S

0 m 200

TARGET archaeological geophysics

Project:	Figure:	Figure No:	Scale:	Ref:
N6 Galway City Transport Project, Ballybrit townland, Co. Galway	Magnetometry greyscales M1-M12	2	1/2500 @ A3	TAG 14008

M1

M2

M3

M4

M5

M6

M7

M8

M9

Ballybrit Castle
(in ruins)

N

W E

S

4

nT

-3

archaeological
geophysics

0 m 60

Project:	Figure:	Figure No:	Scale:	Ref:
N6 Galway City Transport Project, Ballybrit townland, Co. Galway	Magnetometry greyscales M1-M9	3	1/1500 @ A3	TAG 14008

M6

M8

M7

M9

M10

Ballybrit Castle
(In ruins)

38Kv

110Kv

38kv

M11

M12

N

W

E

S

4

nT

-3

0

m

60

archaeological geophysics

archaeological geophysics

Project:	Figure:	Figure No:	Scale:	Ref:
N6 Galway City Transport Project, Ballybrit townland, Co. Galway	Magnetometry greyscales M7-M12	4	1/1500 @ A3	TAG 14008

EMI1

EMI2

EMI3

EMI4

EMI5

EMI6

EMI7

EMI8

Ballybrit Castle
(in ruins)

N
W E
S

4.8
mS/m
-2.9

archaeological geophysics

archaeological geophysics

0 m 60

Project:	Figure:	Figure No:	Scale:	Ref:
N6 Galway City Transport Project, Ballybrit townland, Co. Galway	Electromagnetic induction quadrature (1m vertical dipole) greyscales, EMI1-EMI8	5	1/1500 @ A3	TAG 14008

EMI1

EMI2

EMI3

EMI4

EMI5

EMI6

EMI7

EMI8

Ballybrit Castle
(in ruins)

N

W E

S

4.8

mS/m

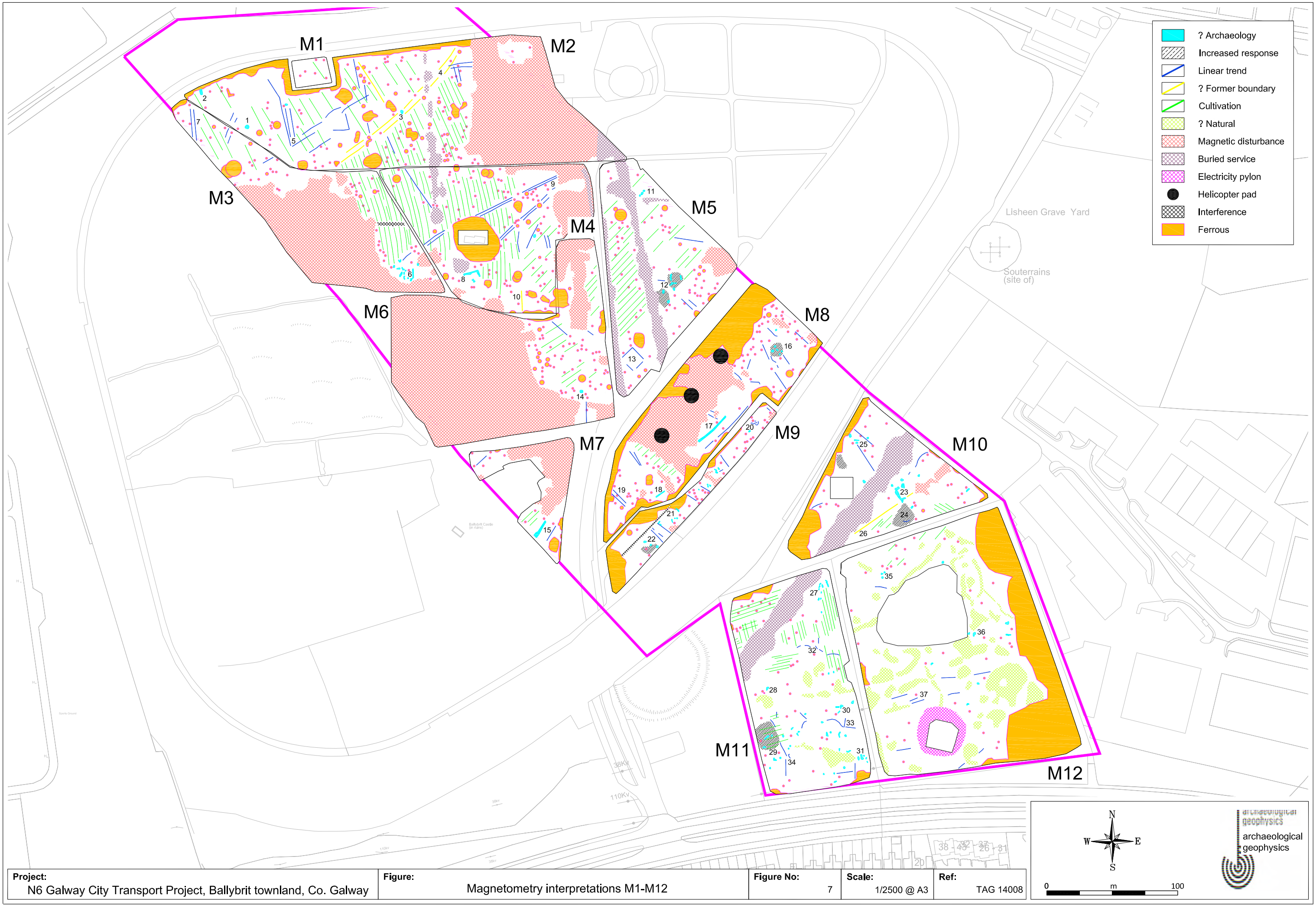
-2.9

0 m 60

archaeological geophysics

archaeological geophysics

Project:	Figure:	Figure No:	Scale:	Ref:
N6 Galway City Transport Project, Ballybrit townland, Co. Galway	EMI Quadrature (0.5m vertical dipole) greyscales	6	1/1500 @ A3	TAG 14008



Project:	Figure:	Figure No:	Scale:	Ref:
N6 Galway City Transport Project, Ballybrit townland, Co. Galway	Magnetometry interpretations M1-M12	7	1/2500 @ A3	TAG 14008

M1

M2

M3

M4

M5

M6

M7

M8

M9

? Archaeology
Increased response
Linear trend
? Former boundary
Cultivation
? Natural
Magnetic disturbance
Buried service
Electricity pylon
Helicopter pad
Interference
Ferrous

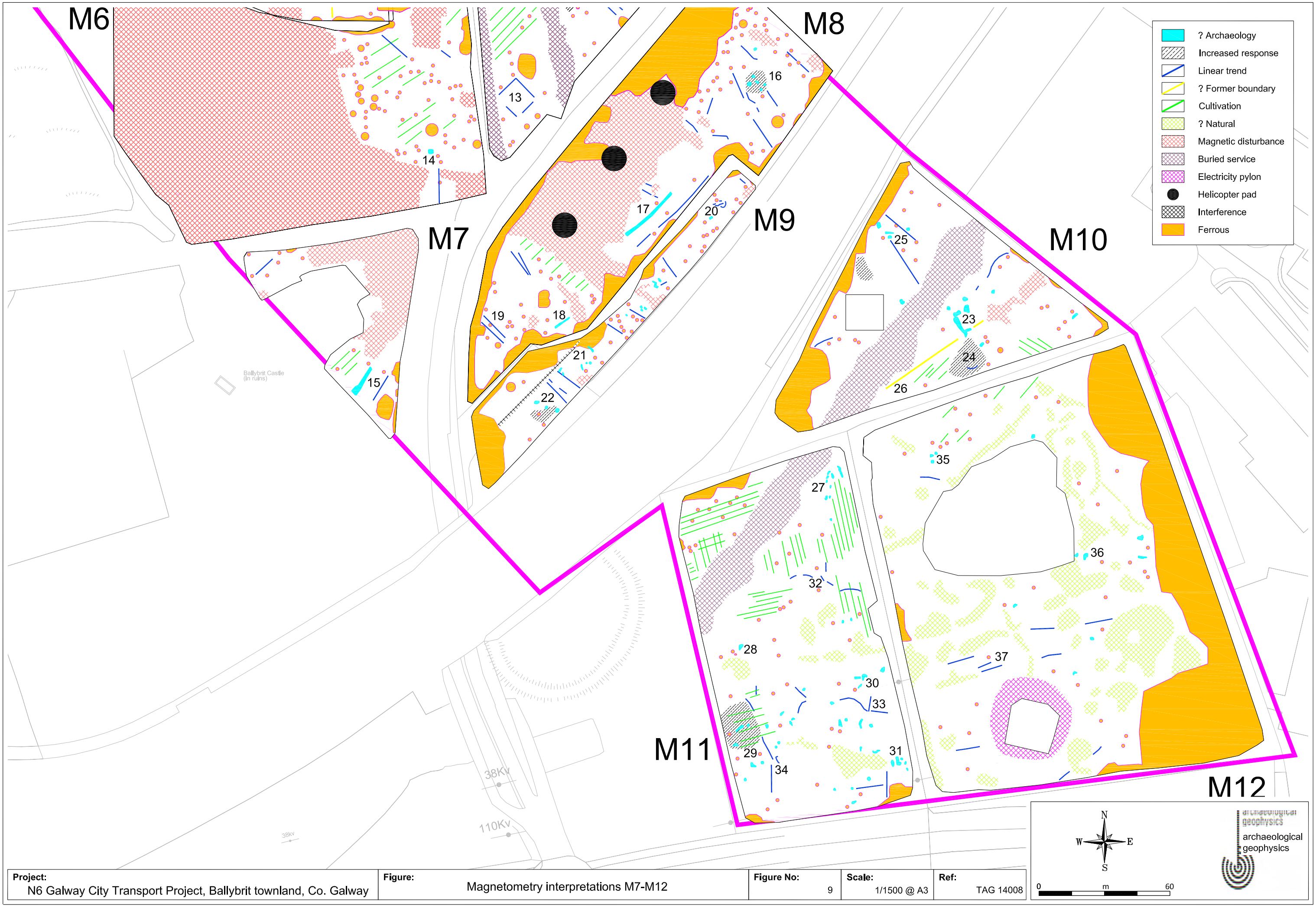
Ballybrit Castle (In ruins)

N
W
E
S

0 m 60

archaeological geophysics

Project:	Figure:	Figure No:	Scale:	Ref:
N6 Galway City Transport Project, Ballybrit townland, Co. Galway	Magnetometry interpretations M1-M9	8	1/1500 @ A3	TAG 14008



Project:	Figure:	Figure No:	Scale:	Ref:
N6 Galway City Transport Project, Ballybrit townland, Co. Galway	Magnetometry interpretations M7-M12	9	1/1500 @ A3	TAG 14008

EMI1

EMI2

EMI3

EMI4

EMI5

EMI6

EMI7

EMI8

1

2

3

4

5

6

7

8

9

10

Ballybrit Castle
(in ruins)

Linear trend

Linear trend

Cultivation

Magnetic disturbance

Buried service

Helicopter pad

Ferrous

N

W

E

S

0 m 60

archaeological geophysics

archaeological geophysics

Project:	Figuur:	Figure No:	Scale:	Ref:
N6 Galway City Transport Project, Ballybrit townland, Co. Galway	Electromagnetic induction (quadrature) interpretation (1m and 0.5m vertical dipole) EMI1-EMI8	10	1/1500 @ A3	TAG 14008

Mapping buried archaeology with geophysical methods

survey@targetgeophysics.com www.targetgeophysics.com
Leuvenstraat 43, Veltem-Beisem, 3020 Herent, Belgium, T: +32 (0)16.89.02.60, GSM: +32 (0) 483.504.280
Ireland: +353 (0)87 858 0112 UK: +44 (0)7955019047