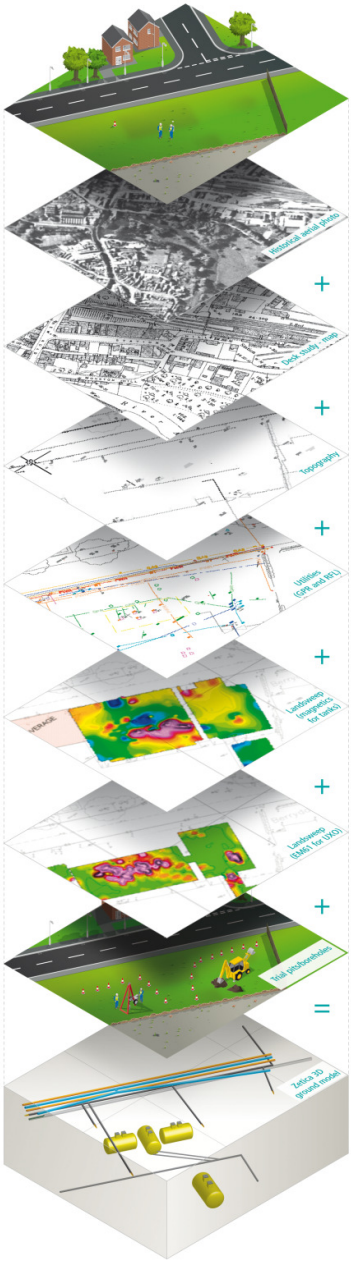


groundcheck

Location: Dalgety Bay, Dunfermline

Client: AMEC

Ref: P3191-11-R1-A

Date: 17th February 2012

SUMMARY REPORT

Location: Dalgety Bay, Dunfermline
Client: AMEC
Contact: Guy Hitchins
Reference: P3191-11-R1-A

1. INTRODUCTION

Scope	AMEC ('the Client') commissioned Zetica Ltd to undertake a GroundCheck® geophysical survey over accessible areas within 'the Site' at Dalgety Bay, Dunfermline.	
Site Location	 © Crown Copyright 2005. Reproduced by permission of Ordnance Survey	
	Figure 1: Site location plan	Scale: NTS
Aims	To determine the lateral and, where possible, vertical extents of a region of suspected Made Ground.	

2. METHODOLOGY

Summary of techniques

The survey utilised four techniques comprising:-

- Frequency-domain electromagnetic (FEM) profiling to map any changes in ground conductivity relating to the suspected Made Ground.
- Electrical resistivity imaging (ERI) to map any changes in ground conductivity in cross-section.
- Magnetic profiling to detect buried any ferrous metal within the suspected Made Ground.
- GPR to image any tipping faces or natural rock outcrops within the soils.

Useful Links

http://www.zetica.com/methods/index.htm

Summary of survey design

Technique	Configuration	Line spacing	Station interval
FEM	Vertical electromagnetic dipole.	2m	2m
ERI	64 channel Wenner α array	NA	1.5m electrode spacing
Magnetometry	Dual sensor, vertical gradient mode	1m	10Hz sampling rate, nominal 0.15m sampling interval
GPR	Dual channel system: 250MHz and 700MHz antennas	1m	~3cm

Limitations

The following clarifies some of the limitations relevant to the survey:-

- GPR depth of detection is strongly dependent on the material properties of the ground. GPR signal can be attenuated by conductive soils and scattered by in-ground objects (clutter) resulting in reduced detection depths.
- Magnetometry detection depths are strongly dependent on object size – a large ferrous object will be detectable at a greater depth than a smaller ferrous object.
- Magnetometry, TDEM and FEM methods can be detrimentally affected by surface metallic objects such as vehicles, reinforced concrete or walls and above ground pipe work.

3. DATA

Data Presentation

The GroundCheck® survey results are presented as an interpretative CAD drawing and plots of the geophysical data. These are referenced below and discussed further in Section 4.

Reference	Title
Figure 1	Site location plan
Figure 2	Example radargrams from the south of the Site
Figure 3	Example radargrams from the north of the Site
Figure 4	Example ERI data
Figure 5	FEM data overlaid on historical mapping
P3191-11-DWG01-A	Map of apparent ground conductivity
P3191-11-DWG02-A	Map of vertical magnetic gradient
P3191-11-DWG03-A	Summary interpretation plan

Data Quality

The quality of the data across the site was typically excellent.

The GPR survey data achieved an estimated detection depth of approximately 2m across the majority of the Site. This figure is derived from the average two-way travel time (TWTT) to the 'noise floor' (the time-depth at which the amplitude of noise exceeds that of the signal) of approximately 65ns, and an estimated signal velocity through the near-surface materials of 60mm/ns. The signal velocity was determined using the hyperbolic curve-fitting method applied to selected anomalies observed within the datasets.

The FEM and magnetic data were typically of excellent quality but were affected by surface metal (e.g. boats and trolleys) in the northern part of the site.

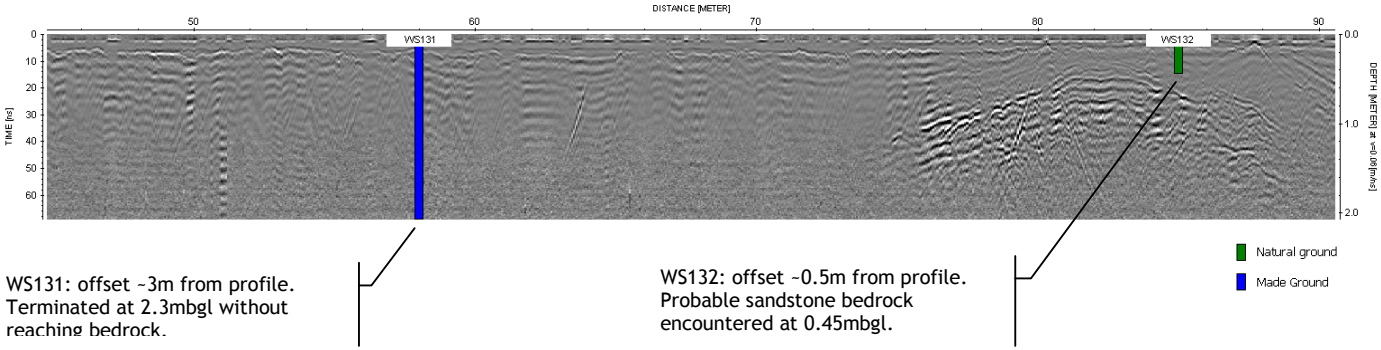
The ERI data showed excellent repeatability but the modelling of the data was influenced by the shallow buried metal present on the site. This is discussed further in Section 4.

Example GPR data from the south of the site, together with information from nearby boreholes.

The profile locations are included on Zetica drawing P3191-11-A-DWG03.

The borehole information is taken from the Client supplied land quality assesment report.

Profile A-A'



Profile B-B'

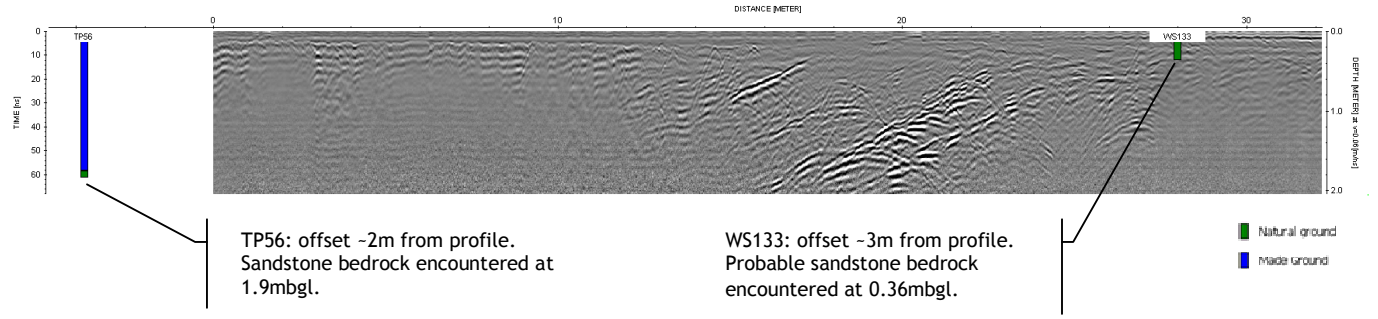
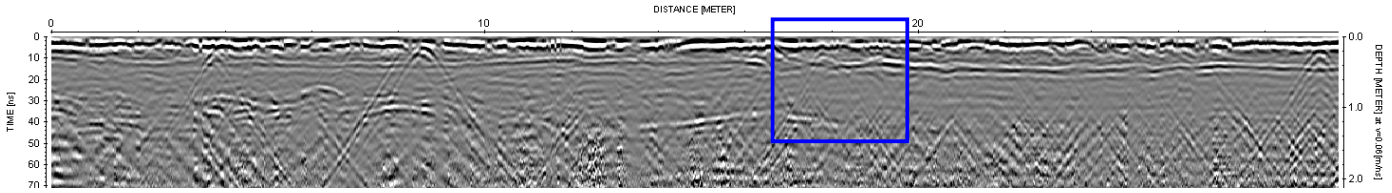


Figure 2: Example radargrams from the south of the Site

Example GPR data from the north of the site showing a change in stratigraphy (boxed in blue).

The profile locations are included on Zetica drawing P3191-11-A-DWG03.

Profile C-C'



Profile D-D'

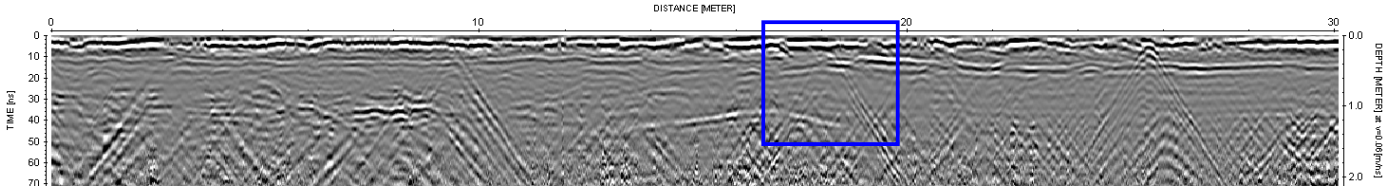


Figure 3: Example radargrams from the north of the Site

Example resistivity data from the south of the site.

The profile location is included as R-R' in Zetica drawing P3191-11-A-DWG03.

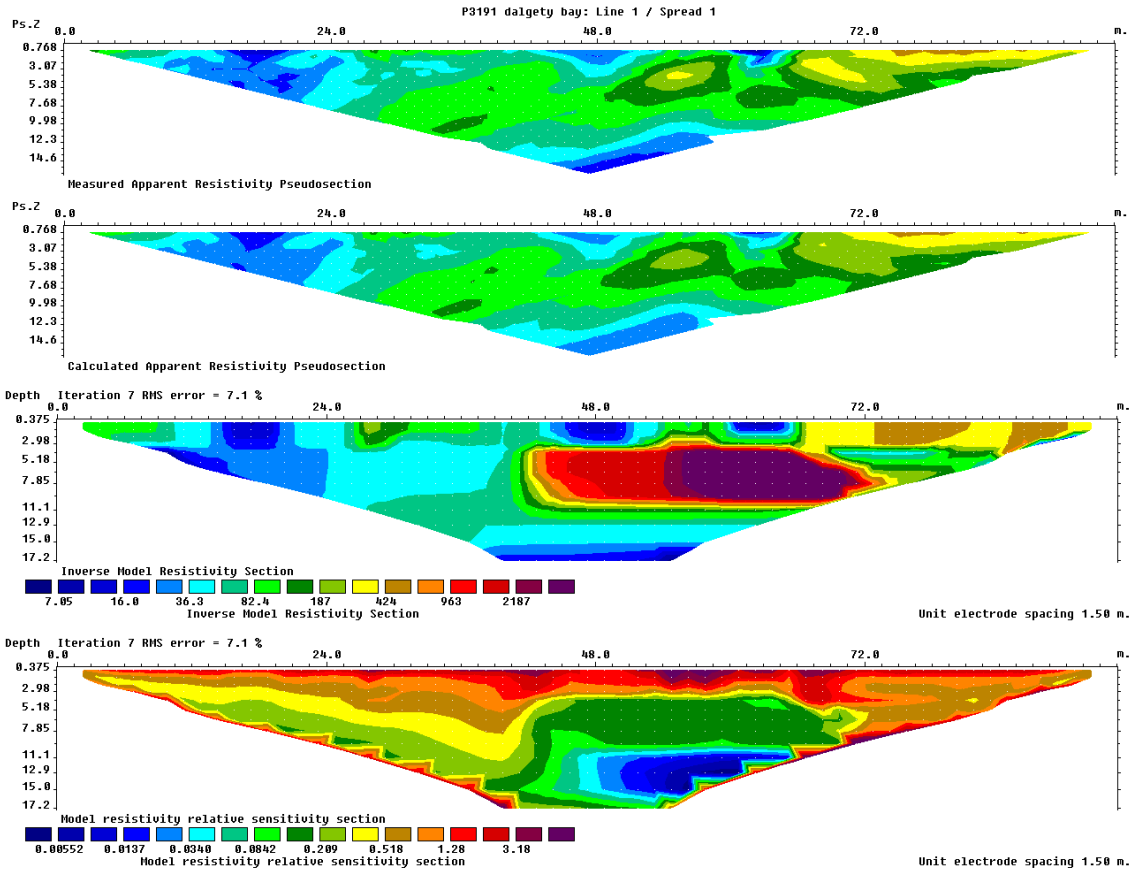


Figure 4: Example ERI data

FEM data (as shown in Zetica drawing P3191-11-DWG01-A) overlaid on the Client-supplied c. 1958 Ordnance Survey map.

Figure 5: FEM data overlaid on historical mapping

4. RESULTS

The results of the survey are summarised in Zetica drawing P3191-11-DWG03-A. The survey has successfully delineated several areas of probable Made Ground. These have been grouped into two categories according to their signature in the geophysical data.

'Zone 1' shown in DWG03 is characterised primarily by a high bulk electrical conductivity. Given the history of the site and the results of the intrusive works this likely due to an increased concentration of the incinerator waste suspected to have been deposited on the Site. 'Zone 2' shown in DWG03 is characterised by a lower electrical conductivity with a high concentration of shallow buried metal (detected in the magnetic survey). The remainder of the survey area is considered likely to comprise predominantly natural ground.

The results of the survey are consistent with the Client-provided radiological walkover survey, which shows elevated count rates within the area interpreted as Made Ground.

A more detailed discussion of the interpretation in different parts of the site follows below.

Southern area

The FEM data (see Zetica drawing P3191-11-DWG01-A) in this area shows a high conductivity anomaly ('warm' colours) to the south-east. This anomaly coincides closely with the location of a refuse tip shown in the historical mapping (see Figure 5). Borehole logs in this area show layers of ash and clinker within the Made Ground. It is therefore considered likely that this anomaly corresponds to an increased concentration of the incinerator waste suspected to have been deposited in this area. This area corresponds to 'Made Ground – Zone 1' in DWG03.

Further west the ground conductivity is lower but the magnetic data (see Zetica drawing P3191-11-DWG02-A) shows a high concentration of buried metal consistent with Made Ground. This area corresponds to 'Made Ground – Zone 2' in DWG03.

This interpretation is supported by the GPR data which shows a highly attenuated signal throughout the interpreted Made Ground (see Figure 3).

Further west, several dipping reflectors are visible in the GPR data which coincide with a decrease in the depth to bedrock observed in the boreholes (illustrated in Figure 3). These reflectors have therefore been interpreted as the top of, or beds within, the observed sandstone bedrock. In this area the GPR signal is far less attenuated, the ground conductivity is low and there is a low concentration of buried metal detected in the magnetic survey. It is therefore likely that the ground is predominantly natural in this area.

An ERI profile was also acquired in this area (see Figure 4) in order to determine the thickness of the conductive anomaly. The resulting cross section of ground resistivity is shown in the third panel in Figure 3. The results show a change from resistive to conductive to resistive ground moving west to east. This is consistent with the FEM data and provides additional confidence in the results of the survey. Unfortunately the results do not allow an estimate of the thickness of Made Ground to be made. This is primarily due to shallow buried metal affecting the sensitivity of the model at depth.

Northern area

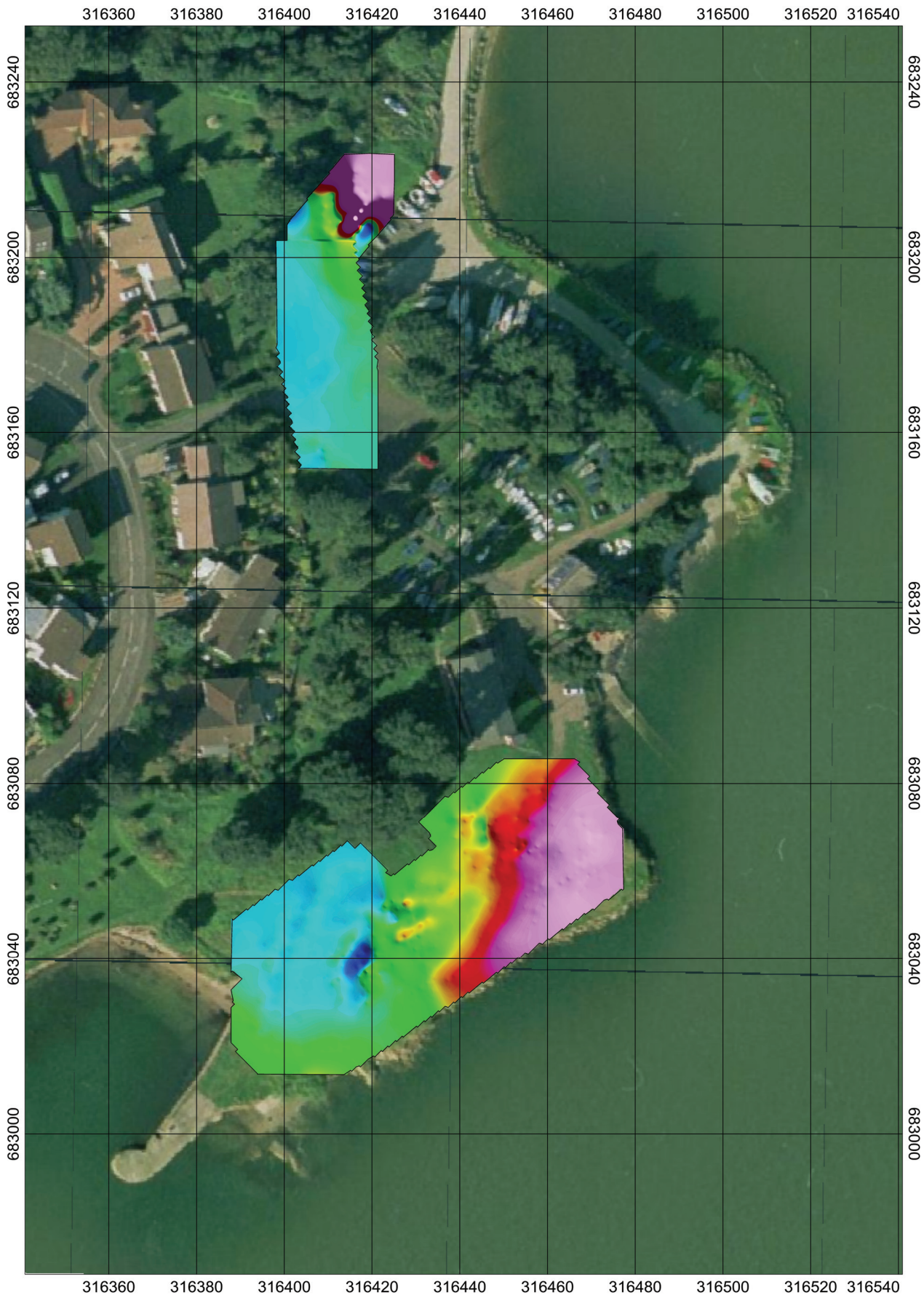
In the northern area, the FEM data again shows a high conductivity anomaly which closely coincides with a feature in the historical mapping (see Figure 5). In this case the edge of the anomaly coincides with the former coastline indicated on Ordnance Survey map. The FEM data in this area were significantly affected by the presence of boats and other metal objects on the surface so this feature must be interpreted with caution. However, the shape and character of the anomaly is difficult to explain based on the surface metal alone. Furthermore, the edge of the anomaly coincides closely with a change in stratigraphy observed in the GPR data. Finally, the boreholes within this anomaly are the only ones in this vicinity of the survey area which contain ashy Made Ground. This anomaly has therefore been interpreted as 'Made Ground – Zone 1'.

Further to the south west there is a high concentration of buried metal coinciding with Made Ground in the borehole logs. This has been interpreted as 'Made Ground – Zone 2'. The area south of this region has a lower concentration of buried metal and the borehole logs comprise mostly natural materials. This area is therefore considered likely to be predominantly natural ground. However, unlike in the southern area, the boundary between natural ground and 'Zone 2' is not corroborated by a feature in the GPR data.

4. RESULTS
Northern area
It was not possible to acquire the planned ERI data in this area due to the ground conditions. Following discussions with the Client, some additional GPR data was collected along the marina to provide an alternative dataset. No significant boundaries were seen in this data, suggesting that the boundary between the 'Zone 1' and 'Zone 2' materials lies south of the marina. The marina has therefore been tentatively interpreted as 'Made Ground – Zone 1'

5. SUMMARY & RECOMMENDATIONS	
Summary	The survey has successfully delineated the lateral extents of several regions of probable Made Ground. In addition the Made Ground has been categorised according to its likely composition. The survey also mapped an interface, believed to be bedrock, at the south west of the site. It was not possible to determine the vertical extents of the Made Ground due to challenging ground conditions, in particular a high concentration of shallow buried metal.

Appendix 1	
General Notes	1. This report has been prepared in relation to the specific requirement of the contract or commission. The report should not be used by third parties without prior consultation with Zetica Ltd. Any advice, recommendations, or statements within the report should be addressed only in the context of the report as a whole. 2. The copyright for this report remains with Zetica Ltd. No part of this report may be reproduced, published or amended without prior written consent from Zetica Ltd. 3. The report refers to the conditions of the Property at the time of investigation. Zetica Ltd cannot accept liability for subsequent changes of Property conditions. 4. Zetica Ltd may have relied on externally provided information. Under no circumstances does Zetica Ltd accept responsibility for the accuracy of such information or data supplied. 5. By their nature, exploratory points, such as boreholes or trial pits, can only provide information on a relatively limited area or volume of a Property. In general, the conditions encountered may vary between exploratory points. 6. It should be noted that the detection performance is dependent on a sufficient physical (e.g. magnetic) contrast between the item for detection and host materials. Where significant noise is present (e.g. an abundance of other magnetic features in the host material), sufficient detection may not be possible. 7. Interpretation relies largely on experience of similar conditions. Site-specific conditions can create variations that may not be detectable by non-intrusive investigation techniques. It should be noted that the detail of an interpretation might vary from that identified by later intrusive investigation, although the general identification of a feature should not vary. 8. The report has been written in line with relevant guidance and legislation in use at the time of report compilation Subsequent improvement in techniques, changes in legislation, or changes in site conditions, may render parts of this report obsolete. If the report is used after such changes have occurred, or at a time in excess of 1 year of the issue date, it would be prudent to contact Zetica Ltd to reassess the report under a new contract.



Scale

10 0 10 20 30 40 50 60

(metres)

OSGB 1936 / British National Grid

Apparent Ground Conductivity
(milliSiemens/metre)

-22 5 10 16 21 25 29 34 38 43 48 56 71

Notes:

A	Base map image obtained from Microsoft Virtual Earth
B	Zetica do not accept responsibility for the accuracy of information supplied by third parties

DRAFT

Client
AMEC

Project
GroundCheck Geophysical Survey

Location
Dalgety Bay, Dunfermline

Title
Map of Apparent Ground Conductivity
(FEM quadrature response)

P3191-11-DWG01-A

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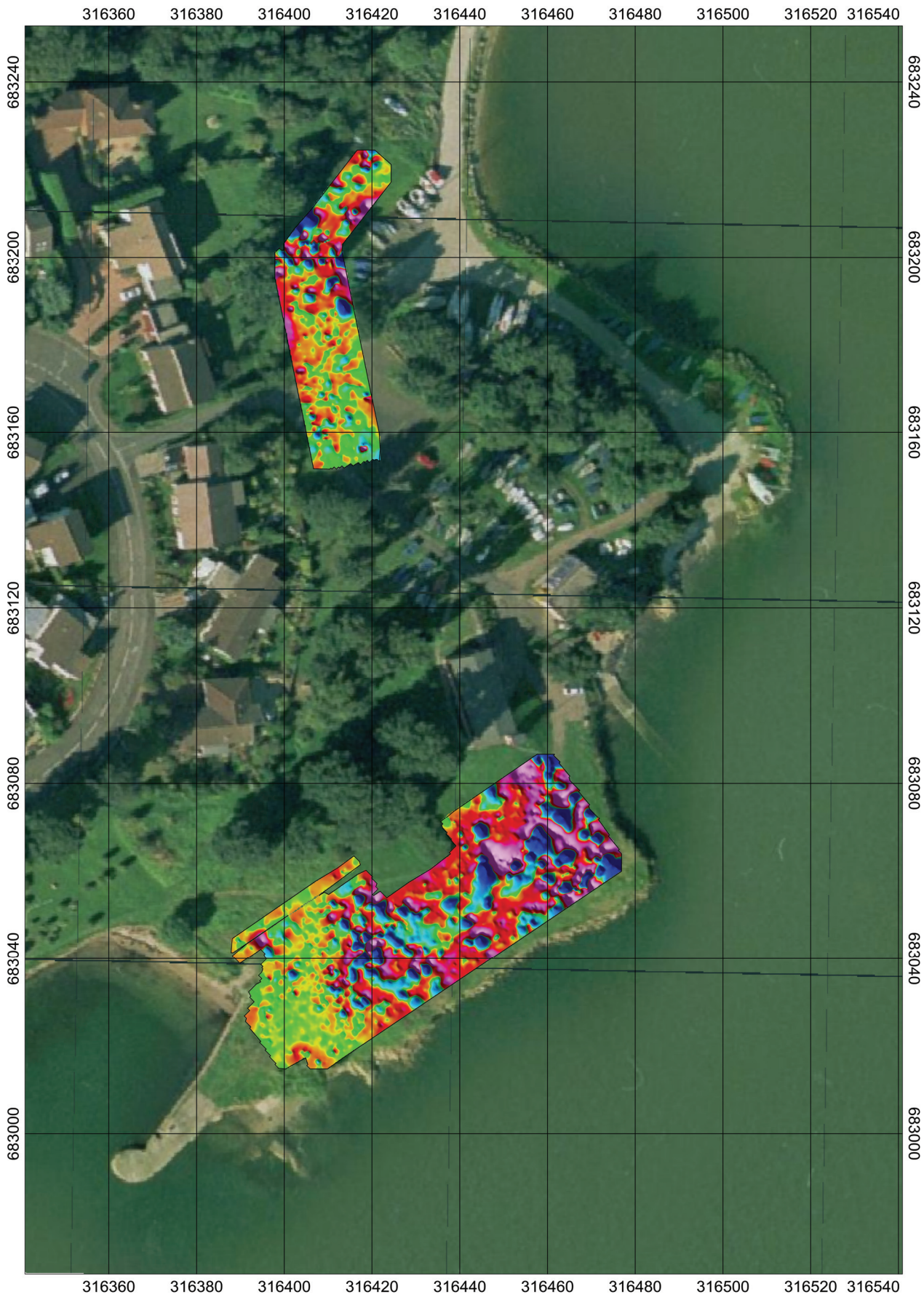
Project Ref	Scale	Drawing Ref	Rev.	Date of Issue
P3191-11	NTS	DWG01	A	09/02/2012



Scale

10 0 10 20 30 40 50 60

(metres)

OSGB 1936 / British National Grid

Vertical Magnetic Gradient

(nanoTesla/metre)

-557 -43 -11 1 3 5 8 12 20 34 52 82 162

Notes:

A	Base map image obtained from Microsoft Virtual Earth
B	Zetica do not accept responsibility for the accuracy of information supplied by third parties

DRAFT

Client
AMEC

Project
GroundCheck Geophysical Survey

Location
Dalgety Bay, Dunfermline

Title
Map of the Vertical Magnetic Gradient

P3191-11-DWG02-A

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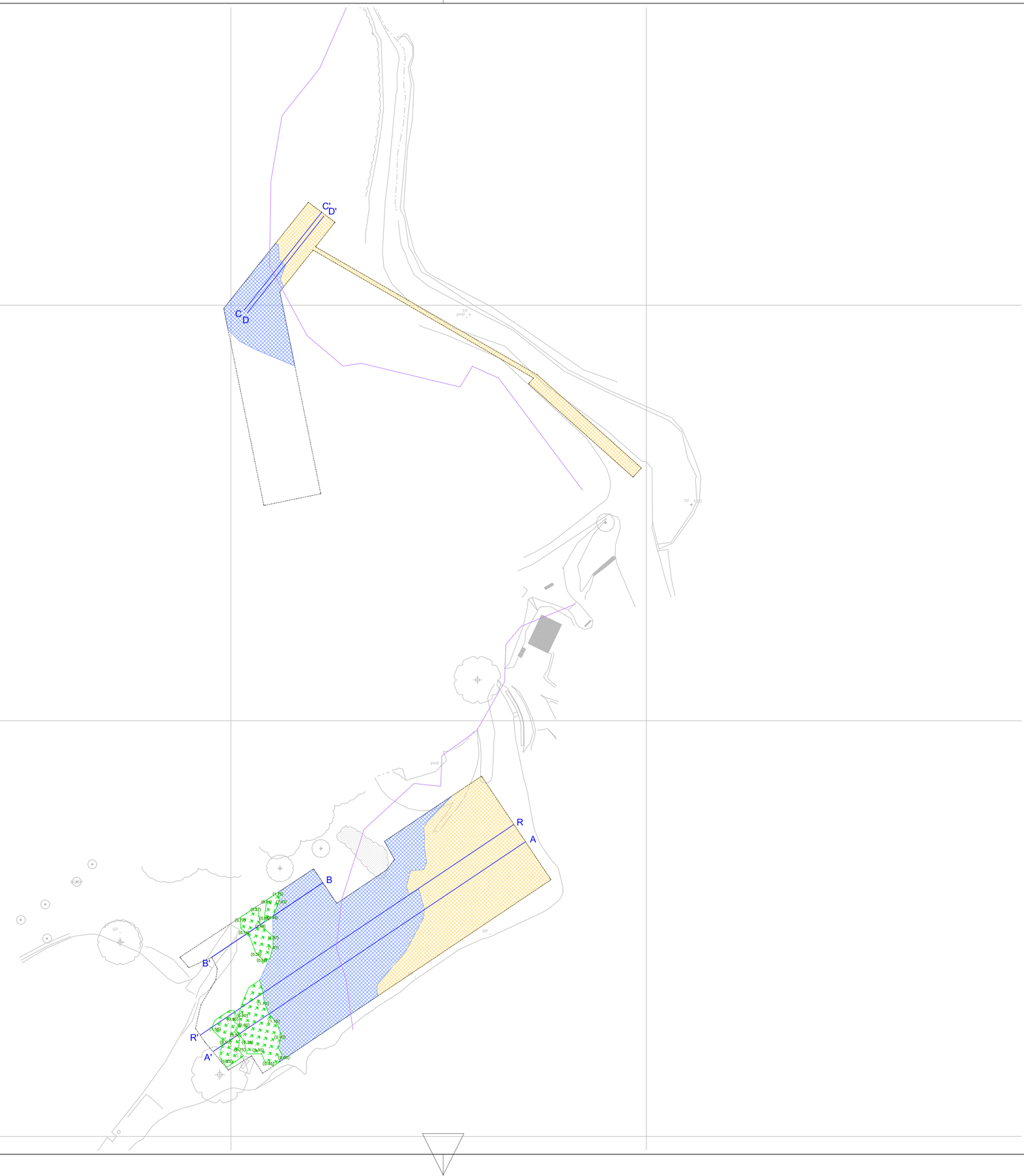
Project Ref	Scale	Drawing Ref	Rev.	Date of Issue
P3191-11	NTS	DWG02	A	09/02/2012



Notes:

A	Base map detail is based on drawings provided by the client.
B	Zetica do not accept responsibility for the accuracy of information supplied by third parties.

Legend

- Survey boundary
- Profile referenced in Zetica report P3191-11-R1-A
- Made Ground - Zone 1: Likely to contain relatively high concentrations Incinerator waste.
- Made Ground - Zone 2: Likely to contain relatively low concentrations of Incinerator waste.
- Possible bedrock Interface detected In GPR data. Arrows Indicate direction of dip. Annotations are approximate spot depths In mbgl. (1.5) (1.5) (0.5) (0.5)
- Approximate western boundary of suspected Made Ground based on Client-supplied historical maps

N

DRAFT

Client
AMEC

Location
Dalgety Bay, Dunfermline

Project
GroundCheck® Geophysical Survey

Title
Summary Interpretation Plan

Drawn by	Checked by
D White	A Eriksen

Horizontal Scale (A1)	Date of Survey	Issue Date
1:500	24-01-12 to 26-01-12	17-02-2012

zetica

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Project Code	Drawing No.	Sheet	Rev.
P3191-11	DWG03	–	A