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The Results of an Earth Resistance Survey of Echline Fields, South Queensferry.

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Report Authors: Scott Harrison, Danielle Lyons
Report Status: Draft

EXECUTIVE SUMMARY

The survey did not clearly identify any areas of clear archaeological activity, as is often expected from geophysical surveys. In this case it was predominantly due to geological conditions and site conditions not conducive to good ground contact.

However, the results do indicate several anomalies that may be significant and many more that are likely to be of Low Archaeological Significance. This meant that there were sufficient anomalies, to allow a programme of targeted trial trenching to be undertaken

The results of the trial trenching will be used to inform an updated interpretation of the geophysics, with a goal of assessing its usefulness in this case, in a more objective way.

Statement of Indemnity

Geophysical survey, both fluxgate gradiometry and resistance survey, rely on observations about the physical properties of the archaeological remains they attempt to locate. Through experience it becomes possible for geophysicists to identify archaeological features with reasonable accuracy by the physical trace these features leave behind. It must be noted however, that geophysical interpretation is an objective science and all hypotheses offered should not be treated as the unequivocal truth until tested and proven by further intrusive investigation.

CONTENTS

CLIENT DOCUMENT

Introduction

Project Summary

This document is submitted as a geophysical assessment report to Jacobs Arup in respect of the proposed Forth Replacement Crossing (hereinafter "FRC"), and in accordance with the mitigation measures recommended in the FRC Environmental Statement Chapter 14 (Cultural Heritage) wherein a programme of geophysical survey was recommended.

Between the 27th August and the 10th September 2010, Headland Archaeology (UK) Ltd. undertook an earth resistance survey on land Parcels 4 and 5 on the southern side of the landfall for the proposed FRC. This project was managed by Edward Bailey (Project Manager) and the fieldwork, data processing and reporting was overseen by Scott Harrison (Senior Geophysicist). An additional four members of staff were involved throughout the survey: Christopher Sykes (Geophysicist), Jurgen Van Wessel (Technical Services), Rob Handbidge (Surveyor) and Steven Roe (Environmental Assistant).

Scheme Summary

In December 2007, following the completion of the FRC Study (Jacobs et al., 2007) as part of the Strategic Transport Project Review (hereinafter "STPR"), the Scottish Government confirmed the intention to provide a new cable-stayed bridge to the west of the existing Forth Road Bridge. Jacobs Arup (as a joint venture) was commissioned in January 2008 to assist Transport Scotland to develop the FRC proposals, to undertake an Environmental Impact Assessment (hereinafter "EIA") and to prepare an Environmental Statement (hereinafter "ES") (Transport Scotland 2010, 30).

The cultural heritage component of the FRC EIA was carried out in 2008. The purpose of this assessment was to identify the baseline cultural heritage environment, evaluate the likely significant impacts that the proposed development would have on this environment, and provide evaluation and mitigation measures to ameliorate these impacts.

The cultural heritage baseline data for the EIA was obtained via a desk-based assessment and walkover survey undertaken in 2008 in accordance with the principles set out in DMRB Volume 11

(1993) (Archaeological Assessment Stages 1-2). Further information was also gathered during an archaeological watching brief of the Ground Investigations for the proposed scheme that was carried out during 2008 and 2009 by Jacobs Arup, Glasgow University Archaeology Research Division and Headland Archaeology Ltd in accordance with the requirements of Historic Scotland to whom the results were reported to (Transport Scotland 2010, 30).

Survey Aims and Objectives

The aims of the survey, as outlined in the tender document (Transport Scotland 2010), were to:

- to clarify the extent and layout of known and unknown buried remains within the survey area
- to disseminate the results through the deposition of a detailed report at the Monument Record of Scotland (NMRS)
- inform the invasive works.

The general objectives of the survey (Transport Scotland 2010) were to:

- ensure that no significant archaeological or palaeo-environmental remains shall be neither needlessly destroyed, nor destroyed without record;
- identify any unknown archaeological remains that may be affected by the scheme;
- enable a more confident assessment of the impact of construction of the proposed scheme on archaeological remains;
- enable the identification and design of any measures that may be necessary to mitigate the impact of the proposed scheme on newly identified archaeological remains;
- enhance available information about known archaeological remains, where existing information is insufficient to enable a full assessment of impact or the design of mitigation measures.

Site Discussion

Archaeological Background

Results from the ES, which identified a total of 356 sites (within a study area ranging from 500m from the development corridor to 6km from the proposed main crossing), in conjunction with an archaeological desk-based assessment of a wider study area undertaken for the proposed scheme, identified a total of 1200 sites of cultural heritage significance along or close to the development corridor. The results from these studies show that the proposed development corridor and the wider study area collectively constitute a landscape containing archaeological evidence dating from the Mesolithic period, through the prehistoric and medieval periods, up to post-medieval and modern times.

The following provides an overview of this extensive baseline environment and is based on the results provided in the FRC Environmental Statement Chapter 14 (Cultural Heritage).

Evidence for a Mesolithic temporary settlement was identified at Cramond, just east of the Forth Rail Bridge. Activity in this camp was dated to approximately 8500 BC. Evidence of potential Neolithic activity from within the study area was provided by the recovery of two stone axes from Inverkeithing and Dalmeny, and stone axe heads found within the vicinity of Ferry Barns, each of which may date to the Neolithic. A large stone cairn at Cromwell's Mount, Craigdhu, now destroyed, may also have its origins in this period.

Known Bronze Age activity within the wider study area consists of two cists which were identified and excavated prior to excavation of the Forth Road Bridge. Additionally, Bronze Age finds were found in association with the aforementioned cairn at Cromwell's Mount, Craigdhu. Further to this, two cairns and likely dating to the Neolithic period or Bronze Age, were identified to the south-west and to the north-east of Inchgarvie House. The presence of these burial types in an area is important as it has been postulated that they were associated with territorial ownership and ambitions, which in turn arose as a direct result of the introduction of farming and consequently, land ownership. The presence of these monuments within the study area is a testament to the settlement of the region by early farming communities and indeed provides expressions of prehistoric social organisation and ritual undertakings in the area.

Later prehistoric activity is represented by a Late Bronze Age isolated axe found near Kirkliston and Middlebank Souterrain (a Scheduled Monument), potentially dating to the Iron Age and located within the north of the study area. Additionally, several silver medals of Marcus Antoninus (138-161AD) date have been recovered from within the study area, within the vicinity of Inchgarvie House, and long cists, which likely date to the Iron Age period, were identified during ground improvement and leveling works in the grounds of the house during the 19th century.

With regard to evidence relating to the Roman period, the presence of the Antonine Wall, the fort at Carriden and to the east, the fort at Cramond, support the supposition that there was a significant Roman presence in the area during the 2nd century AD.

There are a limited number of known early medieval sites within the study area; nonetheless, the ES Cultural Heritage chapter noted that the presence of early medieval sites in the wider area (particularly towards the upper reaches of the Firth of Forth) indicates that there is good potential for the presence of previously unknown sites dating to this period to be located within the study area.

Medieval activity within the study area is represented by the Royal Burghs of North and South Queensferry and Inverkeithing whose origins date to this period. Furthermore, a number of great houses, dating to the medieval period, have been identified within the study area. The establishment of large country estates continued into the later medieval period, providing a testament to the appeal of this general area to earlier settlers. All of these estates retain several Category A and B Listed Buildings and/or Scheduled Monuments within their grounds.

The industrial period left a clear imprint on the landscape comprising the wider study area of the development corridor. Evidence of surface extraction (e.g. of limestone and sandstone) and subsurface extraction (e.g. of coal and oil shale) is present throughout the study area. These processes were substantially influential in changing the fabric of the landscape through the creation of quarries and mines, the establishment of mills and breweries, and most significantly, spear-heading the industrial revolution throughout the region. The Firth of Forth became the focus for increasing industrial activity from the 18th century onwards with the advent of coal mining and associated salt panning, thus beginning a long history of industrial activity along the shores of the Firth of Forth, particularly around Inverkeithing upon construction of the railway bridge.

As can be seen, the baseline environment comprises a significant archaeological landscape which contains known and documented evidence from the Mesolithic period, right through to post-medieval times. The high density of these sites, and the fact that every period in pre-history and history is represented, collectively serve to heighten the archaeological potential of the study area and thus increase the likelihood for hitherto unknown archaeological stratigraphy to be present within the development corridor.

Site Topography and Land Use

The survey area was split between two land parcels, parcels 4 and 5, respectively. Parcel 5 was located in the south-west of the survey area, with Parcel 4 occupying the remainder.

Parcel 5 is under the ownership of Dundas Estates and had been roughly ploughed at the time of the survey. It seems that these lands were recently under wheat/barley cultivation.

The south-west of Parcel 4 was also under arable cultivation, similar to that described above, but the bulk of Parcel 4 was primarily used as an amenity area, typified by short, neat grass traversed by a series of pathways. Parcel 4 was under the ownership of the Scottish Ministers.

The survey was divided into discreet areas informed by the location of topographical features such as field boundaries and fences: 'West-Field' (Parcel 5, ploughed), 'Centre-West field' (Parcel 4, ploughed) and 'Centre Field' and 'Northern Field' (Parcel 4, grassland).

Site Geology

The results from the geotechnical investigations that were carried out demonstrate that the subsurface stratigraphy underlying the development corridor generally constitute glacial till deposits of varying thickness; these are predominantly comprised of firm to very stiff boulder clay deposits with occasional granular till deposits.

These deposits were noted to increase in thickness within the north of the corridor, and were locally absent at the southern extremity of the site. Recent estuarine and marine deposits comprising very soft to soft silts and clays were also identified within and adjacent to the area of St Margaret's Marsh (Transport Scotland 2010, 30).

The solid geology of the site is typified by Igneous, Alkali Dolerite (BGS Livingstone 32W). The alkali nature of the bedrock geology has the effect of breaking up the structure of clays within the soil matrix which negatively affects its water holding capacity, similar to the effect agricultural lime has on arable soils.

This will generally have the effect of increasing the contact resistance of the soil, resulting in a general loss of quality in the results across the board, as well as increasing the incidences of data 'spikes' caused by poor electrical contact. Efforts to reduce this effect were used to mitigate for this effect and they were, to some extent, successful.

Results

The results are classified according to four categories. The categories serve as a visual guide and an aid to the discussion of the results. They are subjective and site dependant.

High Archaeological Potential – Identifiable, known archaeological feature types that are of high archaeological significance. Often (but not always), additional evidence exists, to support any identification of *High Archaeological Potential* anomalies.

Medium Archaeological Potential – Possible archaeological feature types that may be of high archaeological significance.

Low Archaeological Potential – Known or possible archaeological feature types that are or are likely to be of low archaeological significance.

Parcel 5 (figures 2-4)

A narrow, low resistance, linear anomaly that is east – west orientated is located in the north of the site, which is often typical of 'solid', i.e. masonry, stone etc. features. However, in time of low moisture, the light, organic rich fills of ditches can preferentially evaporate water, creating a drier feature with a consequently higher resistance. It may potentially be a palaeo-channel, or a drainage feature of some kind. It is unclear whether it is solid filled, or rubble filled for the reasons outlined above.

The results from the west field indicate that there are several anomalies of low archaeological potential, one in the west and a cluster of three in the east. No discernable pattern can be determined.

Parcel 5 Centre-West Field (figures 5-7)

The Centre-West field has several anomalies of low archaeological potential. In the west, these are large, but isolated. This may indicate a non-archaeological origin. In the east, there are several small anomalies clustered together which are possibly archaeological features.

Parcel 4 Centre Field (figures 8-10)

There are numerous anomalies in the Centre-Field ranging from Low to High Archaeological Potential. The most significant of these are concentrated in the east. There is a considerable amount of noise of uncertain derivation, although this may be the result of intense anthropogenic activity in itself. There are, however, several areas within the noise where the results are 'clear'.

The most significant anomaly is a linear feature (and associated anomalies in close proximity), featuring a 90 degree angle. It is clearly suggestive of some kind of structural remains, perhaps a wall or a building foundation; however, this cannot be accurately asserted purely on the basis of the geophysical evidence, as any possible return is masked by the adjacent 'noise'.

In addition to this, there are three linear features. One feature immediately north-west of the 'structure' and has been assigned Low Archaeological Potential by virtue of its diffuse appearance. Subsequent trial trenching could result in this anomaly being upgraded to High Archaeological potential. The other features, of Low and Medium Archaeological Potential, are due west of the 'structure'. These are well defined, linear features and are likely to be ditches. Their proximity to the 'structure' increases their potential significance.

Parcel 4 North Field (figures 11-13)

The results from the Northern field are marred by general geological trends that were difficult to remove with processing. The most significant is the patch of diffuse noise that extends in to the centre of the area and exits the survey area to the south. This is the result of dolerite bedrock intrusions within this area visible on the British Geological Survey 1:50000 map of the area (Livingstone 32W).

In the east of the survey area there are two clusters of anomalies. One of these clusters is the group of irregular, diffuse anomalies visible in the centre east of the site. The three anomalies clustered together are potentially the most significant; however, they do not immediately conform to any known type of archaeological feature. The second is the group of linear features in the north-east of the site, within a relatively 'quiet' part of the survey area. It is likely that although broken in appearance, they are representative of a linear feature, possibly a field drain, but potentially something more significant, because there are a few very diffuse linear anomalies that *may* be ditches and therefore interpreting this feature as a field drain becomes less likely.

In the west of the site there are several large potential features, or clusters of potential features. An archaeological interpretation is tenuously offered, as these may be geologically derived.

Conclusions and Recommendations

At the end of the survey, it became clear that the predominant geologies (alluvial marine deposits/Glacial till), were not at first glance, amenable to the production of detailed plans of sub-surface plans of archaeological features, as people have come to expect from geophysical surveys.
Most of the survey results depict a range of ethereal anomalies with no definable shape. In some areas, there is a suggestion that there may be individual clusters, but generally these are isolated anomalies.

However, in some areas, notably in the east of the Centre Field, there were several anomalies that suggested a more obvious archaeological derivation.

There is sufficient evidence to provide a detailed trial trenching plan that targets many of the anomalies, and it is anticipated that more features of archaeological derivation should be identified, than if uninformed testing were used.

There are numerous isolated anomalies throughout the survey area but they occasionally occur in clusters. Care was taken to remove the influence of geology from the data plots; however, it is possible that some of these anomalies may be geological in origin. Preliminary results from some of the areas that have been test trenched indicate that at least some of these anomalies are related to features that can be identified on the ground, such as field drains and palaeo-channels. These do not

appear as linear anomalies as we have generally come to expect from geophysical surveys, but rather a linear progression of broken, irregular anomalies.

It must be remembered, that where the anomalies are found to be non-archaeological, or undetectable through test trenching, this does not indicate that the geophysics served no purpose. It is highly likely that some of the anomalies are the results of chemical changes in the soil, caused by anthropogenic actions that are undetectable by any other means. Where there are clusters of these anomalies, these provide valid locations to target with test trenches. Targeting these clusters, may identify areas of archaeological activity that may otherwise have not been identified.

It must be noted that the *existence* of an anomaly is not in question, but rather whether a definitive archaeological interpretation can be assigned to it.

It is recommended that no further work be undertaken based on the results of the geophysics, other than the trial trenching that has already been scheduled. This recommendation is based purely on the geophysical results and is subject to change when the results of the trial trenching report are known.

TECHNICAL INFORMATION

Legislative Framework and Guidelines

Headland Archaeology (UK) Ltd. conduct geophysical surveys to the highest professional standards as detailed in *Geophysical Survey in Archaeological Field Evaluation*, English Heritage Research and Professional Services Guideline No. 1, 2nd ed (English Heritage 2008) and *The Use of Geophysical Techniques in Archaeological Evaluations*, Institute of Field Archaeologists Paper, No. 6 (IfA 2002).

All data provided by Headland Archaeology (UK) Ltd., will be treated in accordance with the guidelines laid out in *Geophysical Data in Archaeology: A Guide to Good Practice* (AHDS Guides to Good Practice; Schmidt 2001).

A site specific Health and Safety Risk Assessment and Method Statement was produced and circulated to all relevant parties for approval. All survey personnel were required to familiarize themselves with this document before the commencement of any works.

Headland Archaeology (Ireland) Ltd. acknowledged at all times, the instructions of the Engineering Consultants (Jacob Arup).

Copies of the report and the data archive created during the course of the survey will be made available to the Curator, the Royal Commission on the Ancient and Historic Monuments of Scotland (RCAHMS) and OASIS, as required under the terms of the tender.

Survey Strategy

Two identically-configured RM-15D Advanced earth resistance meters, with additional MPX15 Multiplexers were used throughout the survey. These were placed on to rigid frames, on to which the probes were attached.

Both units were used in a double dipole array configuration, known as a 'parallel-twin'. This allows the collection of two lines of data at the same time.

Each pair of probes was separated by 0.5m and samples were taken at the proscribed rate of 1 m x 1.

A system of 30m² grids was drafted throughout Parcels 4 and 5 in AutoCAD. This grid system was uploaded to a dGPS, capable of full RTK precision (<0.02 m) and set-out on site to allow the results to be accurately tied to their British National Grid Coordinates.

A series of ropes, with appropriate markings along their length, were laid out across the grids to guide the surveyors.

Data Processing

Once the earth resistance data has been processed in ArcheoSurveyor to highlight and clarify any anomalies that may be of archaeological derivation, the data can be exported as ASCII grid files. This file type performs the dual function of fulfilling all archive requirements, as it can be opened and edited in any text editor, while at the same time being inherently spatially aware, and therefore able to be opened directly in CAD/GIS software.

CAD and GIS software will be used to create the illustrations at an appropriate scale (max 1:1000 scale). The interpretations will be produced *in situ* and exported as both GIS shapefiles and CAD DXFs, so that the interpretations can be combined with any other spatially aware data that may be produced during the scheme.

The data was processed in ArcheoSurveyor data processing software. The details of applied processes are detailed below:

Despike – Earth resistance data often has many isolated 'spikes' caused by poor surface contact. These spikes are generally not considered archaeological. Despike will analyze the data using a pre-defined window size (usually 3 x 3 readings, or 0.75 m x 0.75 m). If the centre reading is x number of standard deviations (usually 1.5 SD) above or below the mean data value for the window size, it is consider anomalous and its value is reduced to the mean data value for the window.

Low Pass Filter – Low pass filtering has two possible uses. Firstly, if used with a very small window size (3 x 3 readings), it will very gently 'smooth' the data. This has the effect of removing any minor data artefacts introduced while correcting the raw data, as well as giving additional clarity to the anomalies. The effects of this are very subtle. Secondly, as the window size increases, the smoothing

effect becomes more pronounced. This decreases the variability, while at the same time enhancing large scale trends throughout the data.

High Pass Filter – High pass filtering is generally used with a very large window size (21 x 21 readings) and removes general, often geological, trends across the site and highlights more subtle anomalies. This has the effect of giving additional clarity to the anomalies.

Clip – Clipping the data values will increase the contrast of the important (archaeological) data values clustered around the centre point.

Archival Process

A full data archive is generally not provided with draft reports, the final report will conform to the reporting requirements as detailed in the Contract document with the data archive conforming to the standards and guidance for project archiving of the Royal Commission on the Ancient and Historical Monuments of Scotland. Included with the data archive will be the following as a minimum:

- data sheet stating the contents of the archive
- details of the recipients of the archive
- full report text and accompanying illustrations (pdf)
- raw Trace Data Plots (pdf)
- grid (re)location data (CAD/GIS compatible)
- raw grid files (CAD/GIS compatible)
- processed composite files (CAD/GIS compatible)
- geophysical anomaly interpretations (CAD/GIS compatible)

References

British Geological Survey 1:50000 Bedrock and Superficial Geologies Maps (Livingston 32W)

English Heritage 2008 *Geophysical Survey in Archaeological Field Evaluation*. English Heritage Research and Professional Services Guideline No. 1 (2nd ed). English Heritage, London.

Institute for Archaeologists 2002 *The Use of Geophysical Techniques in Archaeological Evaluations*, Institute of Field Archaeologists Paper, No. 6.

Transport Scotland 2010 *Forth Replacement Crossing.* 'Competition for the Land Based Invasive and Non-Invasive Archaeological Survey and Evaluation Contract Volume 2: Tender Document'

Schmidt, A. 2001 *Geophysical Data in Archaeology: A Guide to Good Practice.* AHDS Guides to Good Practice. Oxbow Books, Oxford.

British Geological Survey 1:50000 Bedrock and Superficial Geologies Maps (Livingston 32W)

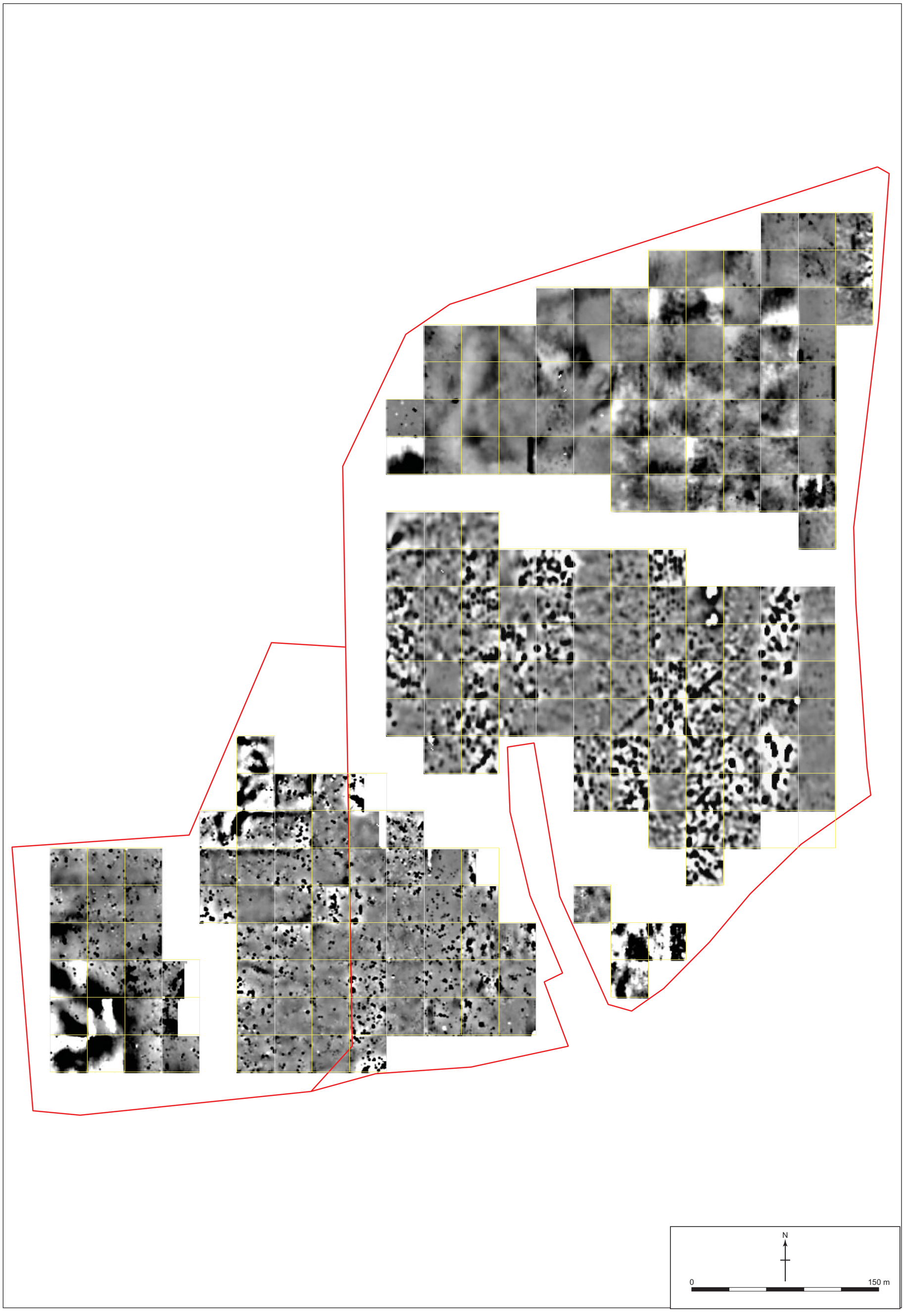

Figure 1 - Forth Road Crossing, Edinburgh:
Overall view (1:3000 Scale)

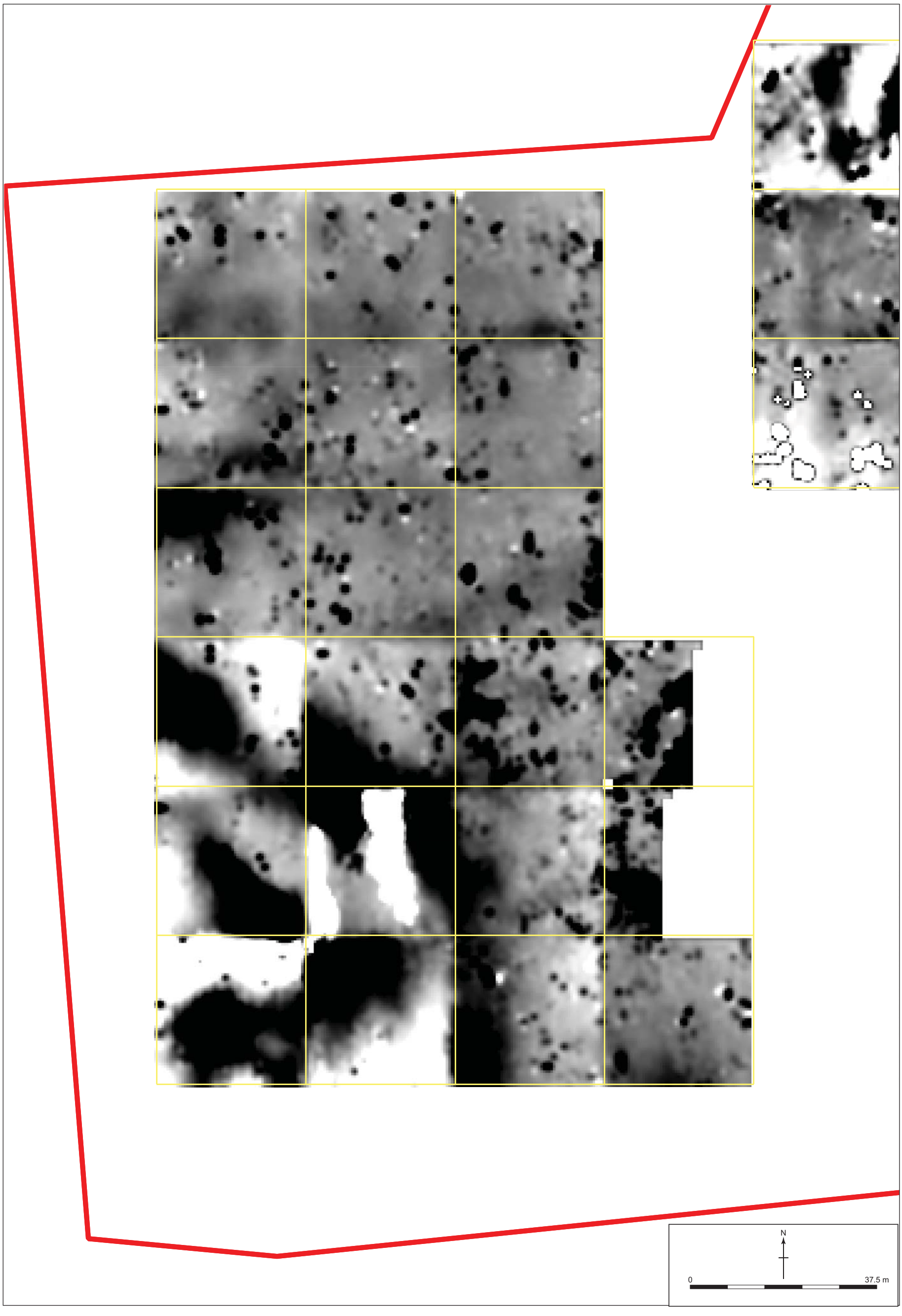

Figure 2 - Forth Road Crossing, Edinburgh:
Western Field (Parcel 5), Processed data (1:750 Scale)

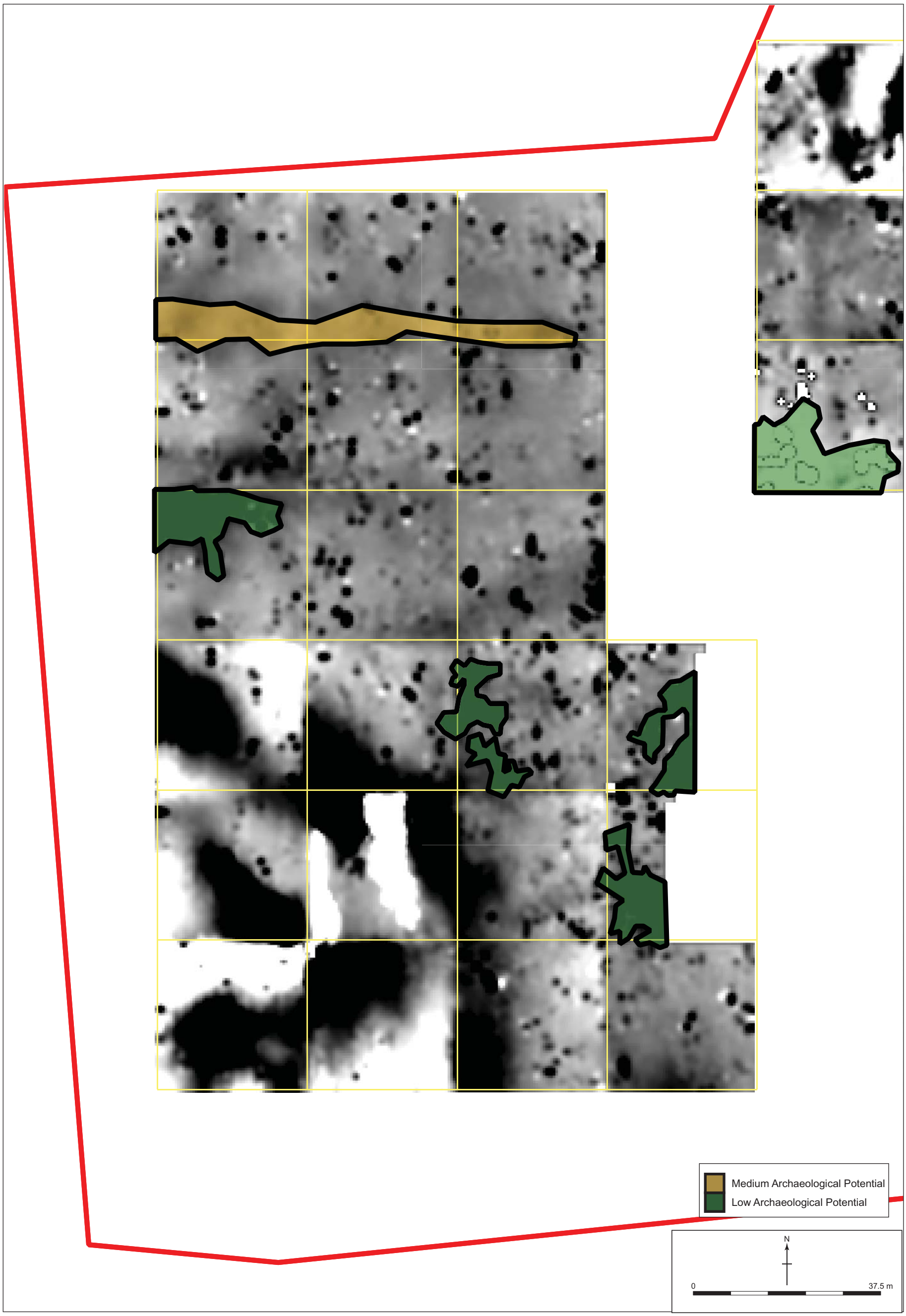

Figure 3 - Forth Road Crossing, Edinburgh:
Western Field (Parcel 5), Interpreted data (1:750 Scale)

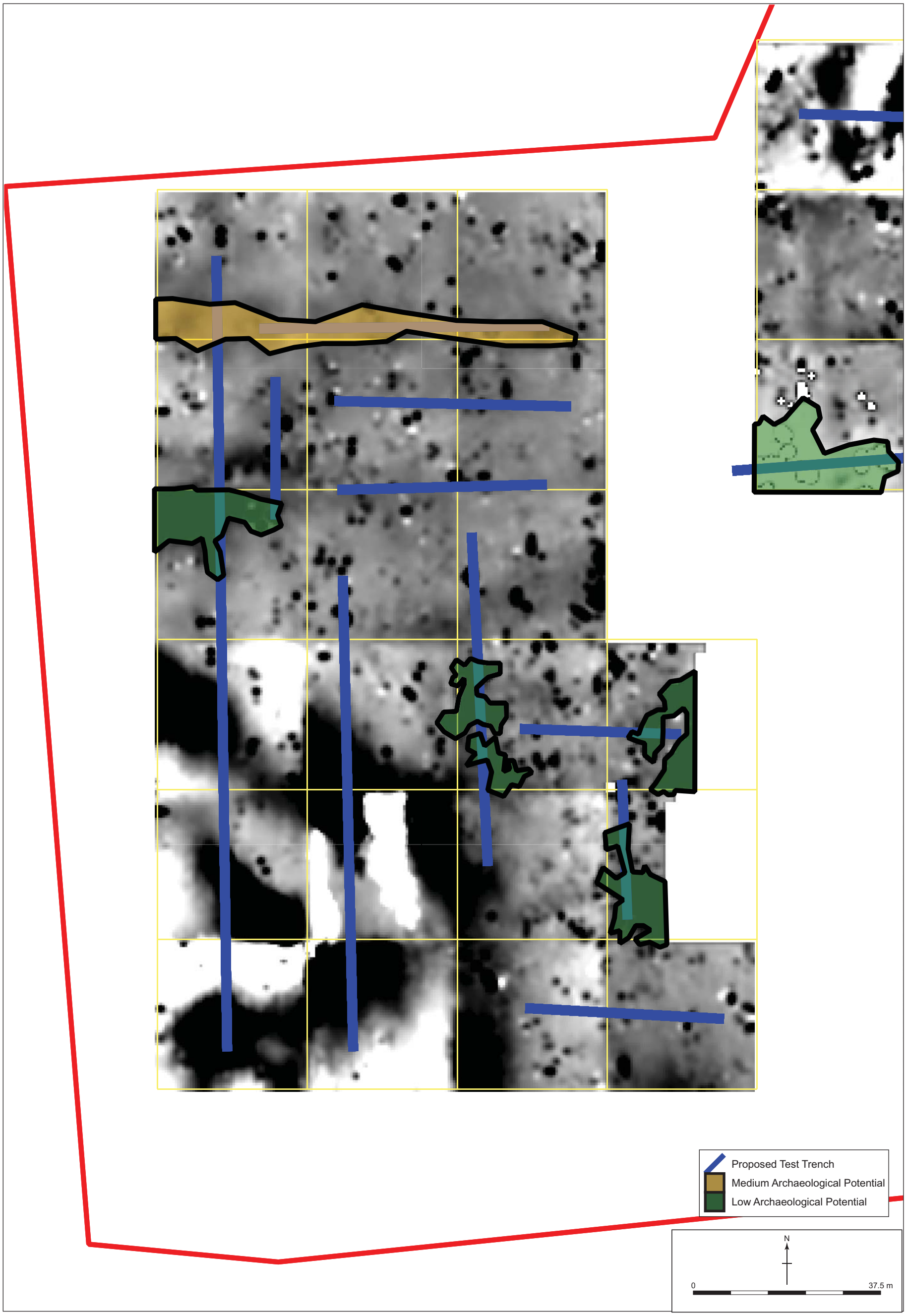

Figure 4 - Forth Road Crossing, Edinburgh:
Western Field (Parcel 5), Proposed test trench layout (1:750 Scale)

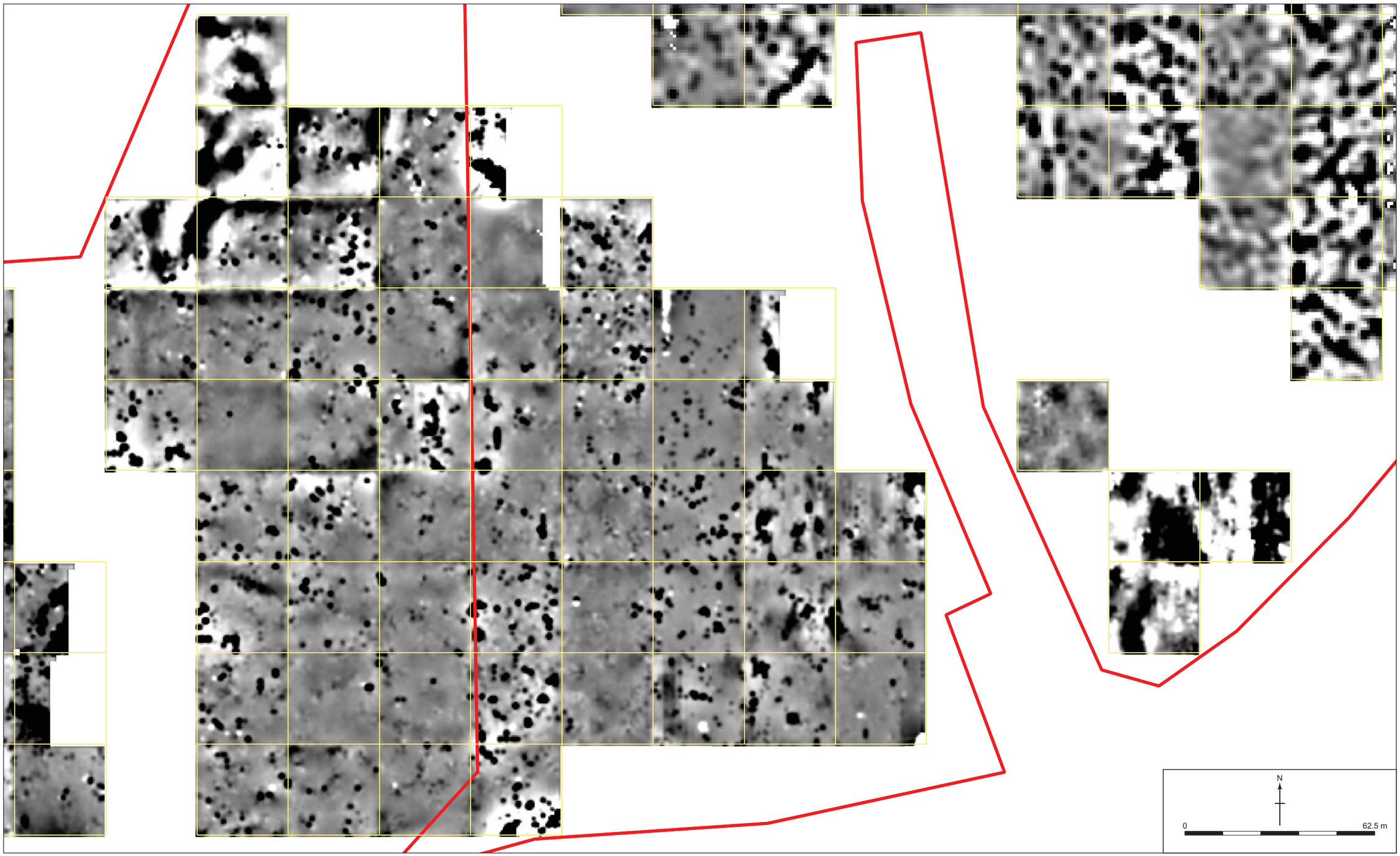

Figure 5 - Forth Road Crossing, Edinburgh:
Western Field (Parcels 4 and 5), Processed data (1:1250 Scale)

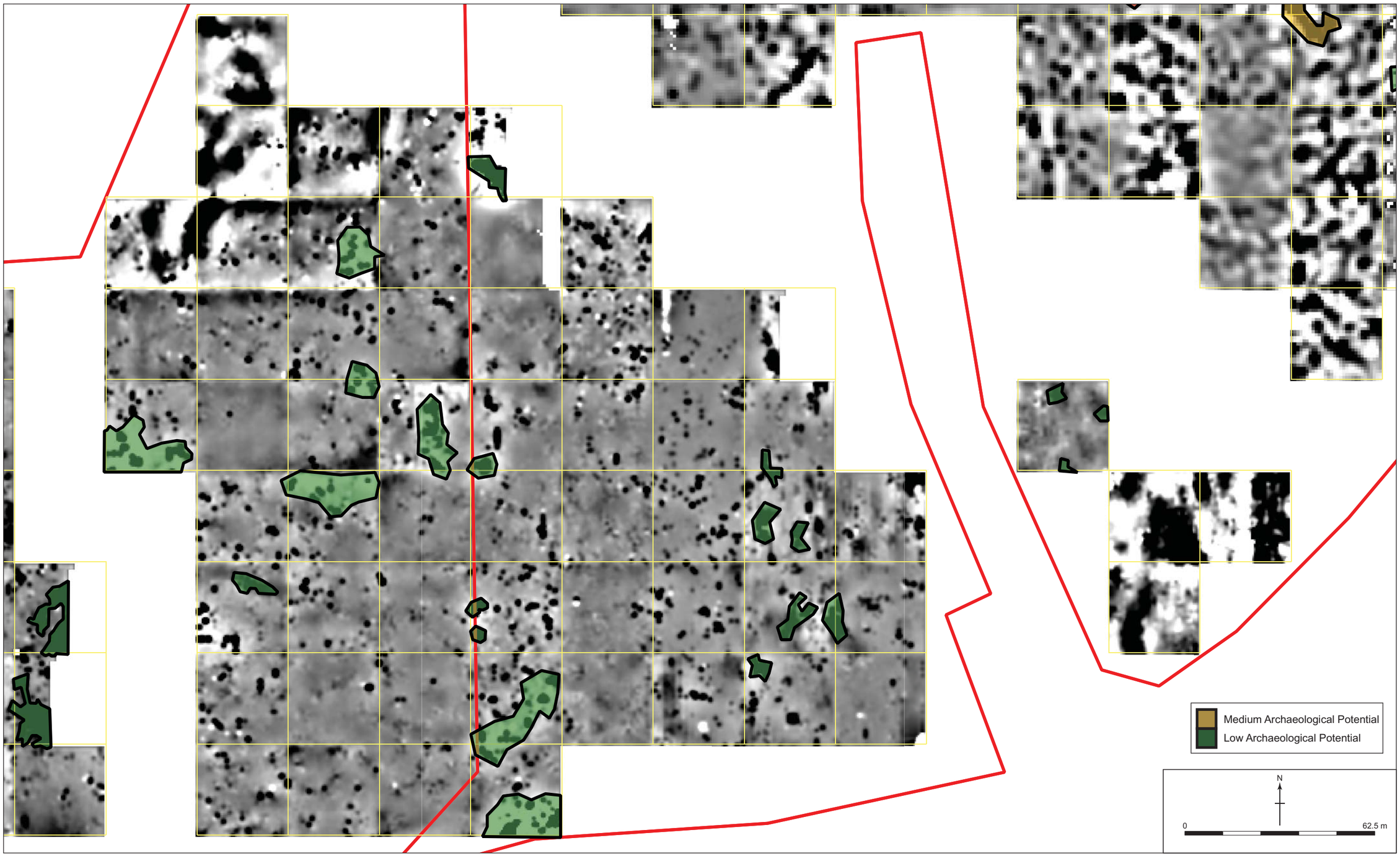

Figure 6 - Forth Road Crossing, Edinburgh:
Western Field (Parcels 4 and 5), Interpreted data (1:1250 Scale)

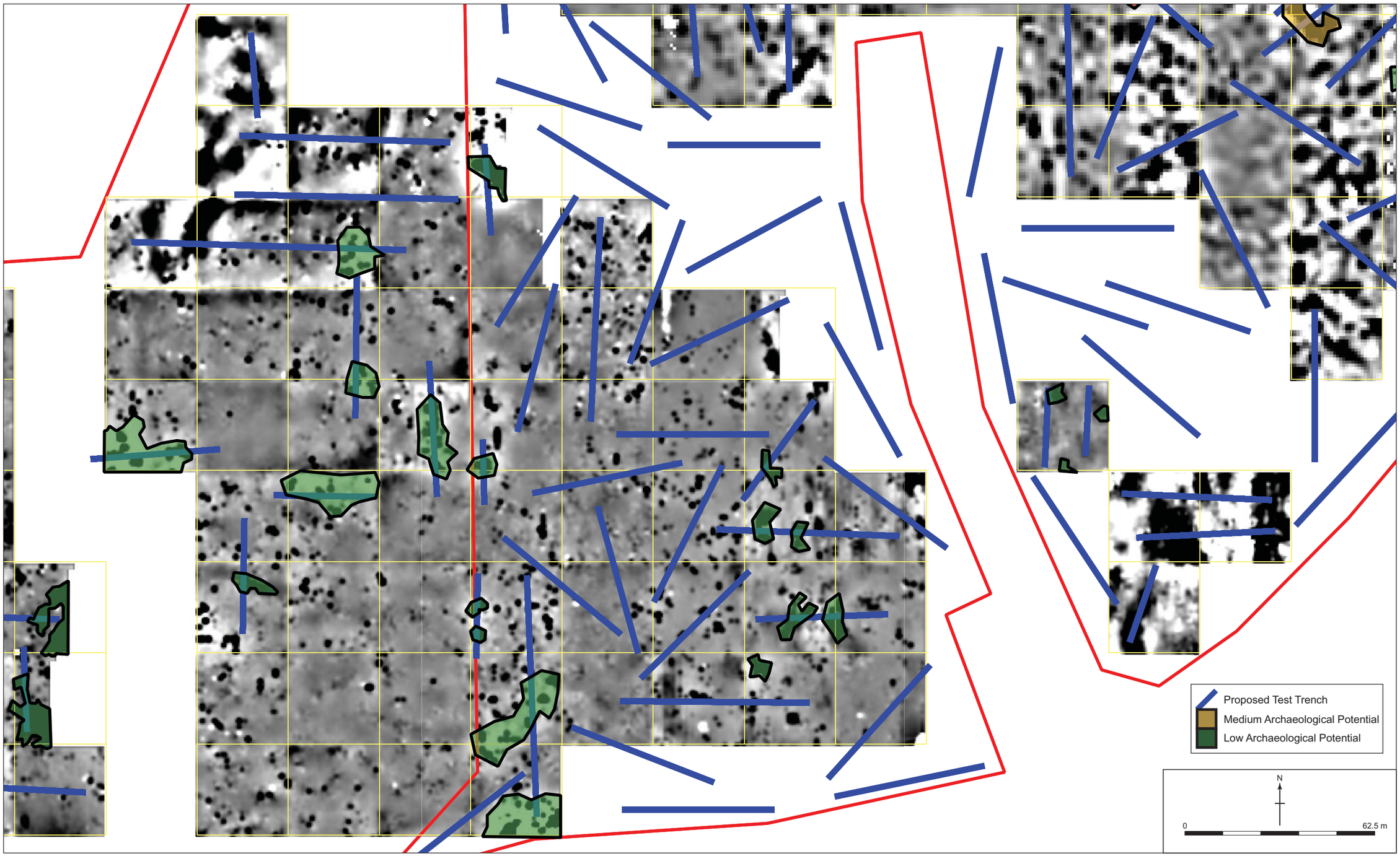

Figure 7 - Forth Road Crossing, Edinburgh:
Western Field (Parcels 4 and 5), Proposed test trench layout (1:1250 Scale)

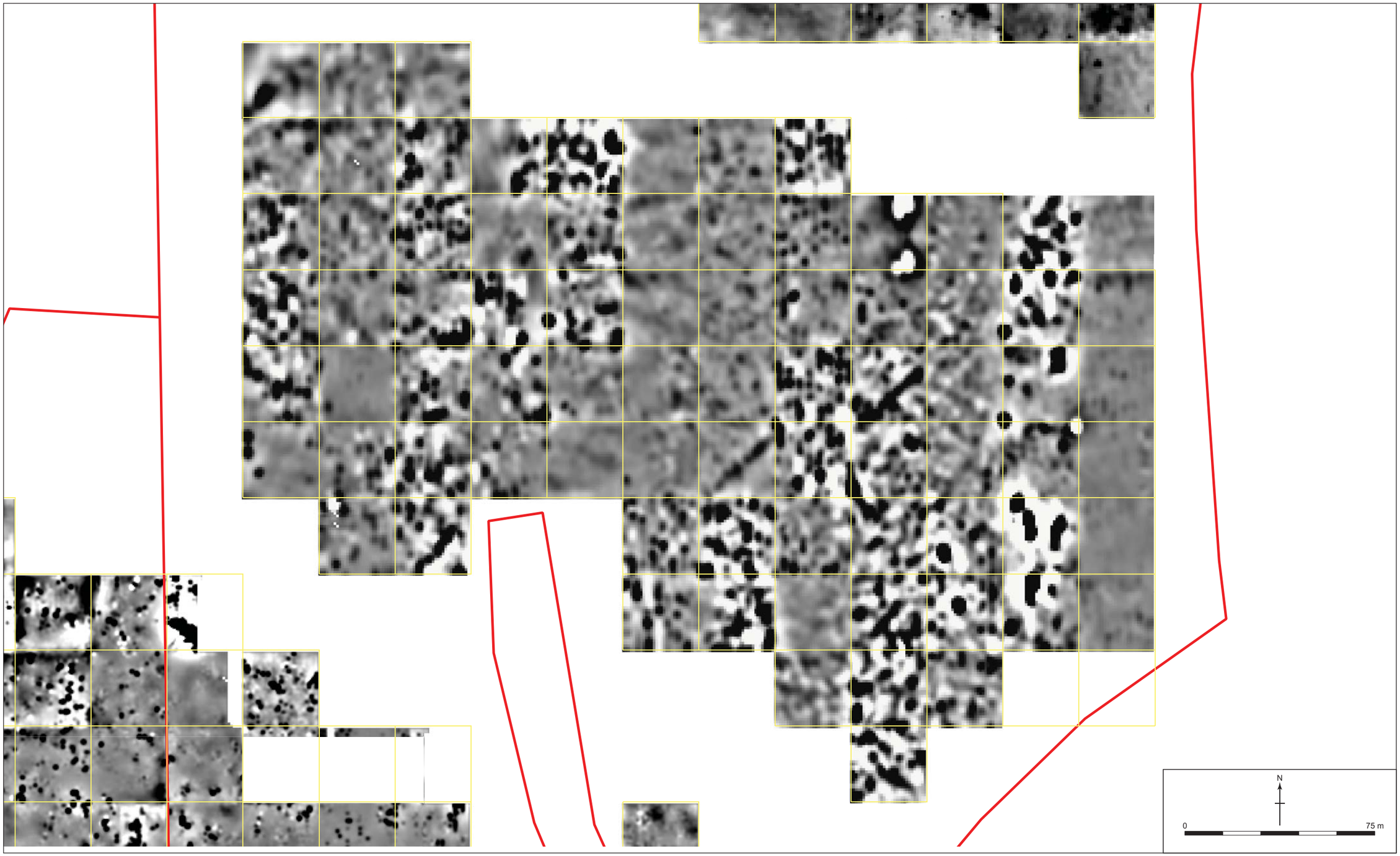

Figure 8 - Forth Road Crossing, Edinburgh:
Centre Field (Parcel 4), Processed data (1:1500 Scale)

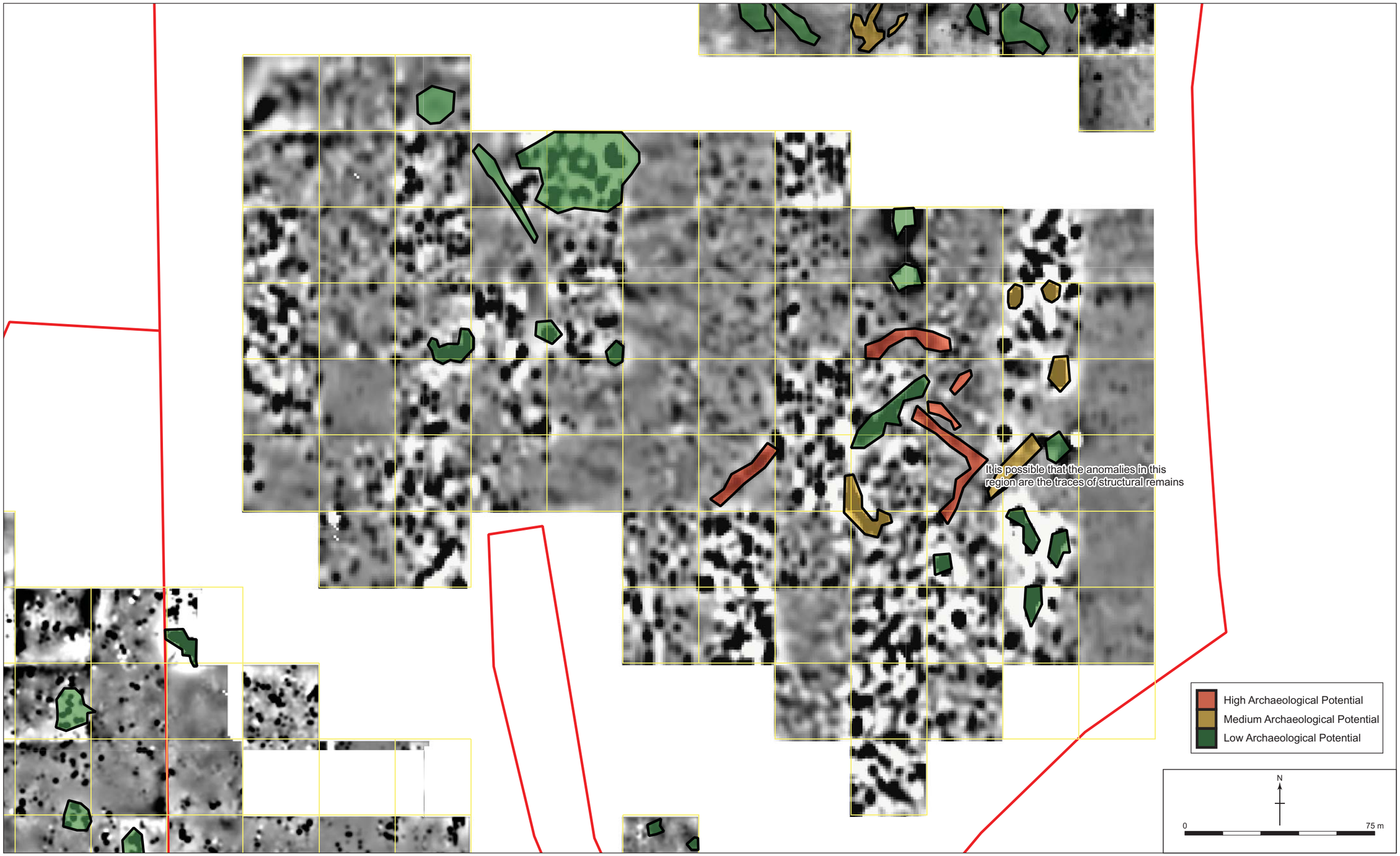

Figure 9 - Forth Road Crossing, Edinburgh:
Centre Field (Parcel 4), Interpreted data (1:1500 Scale)

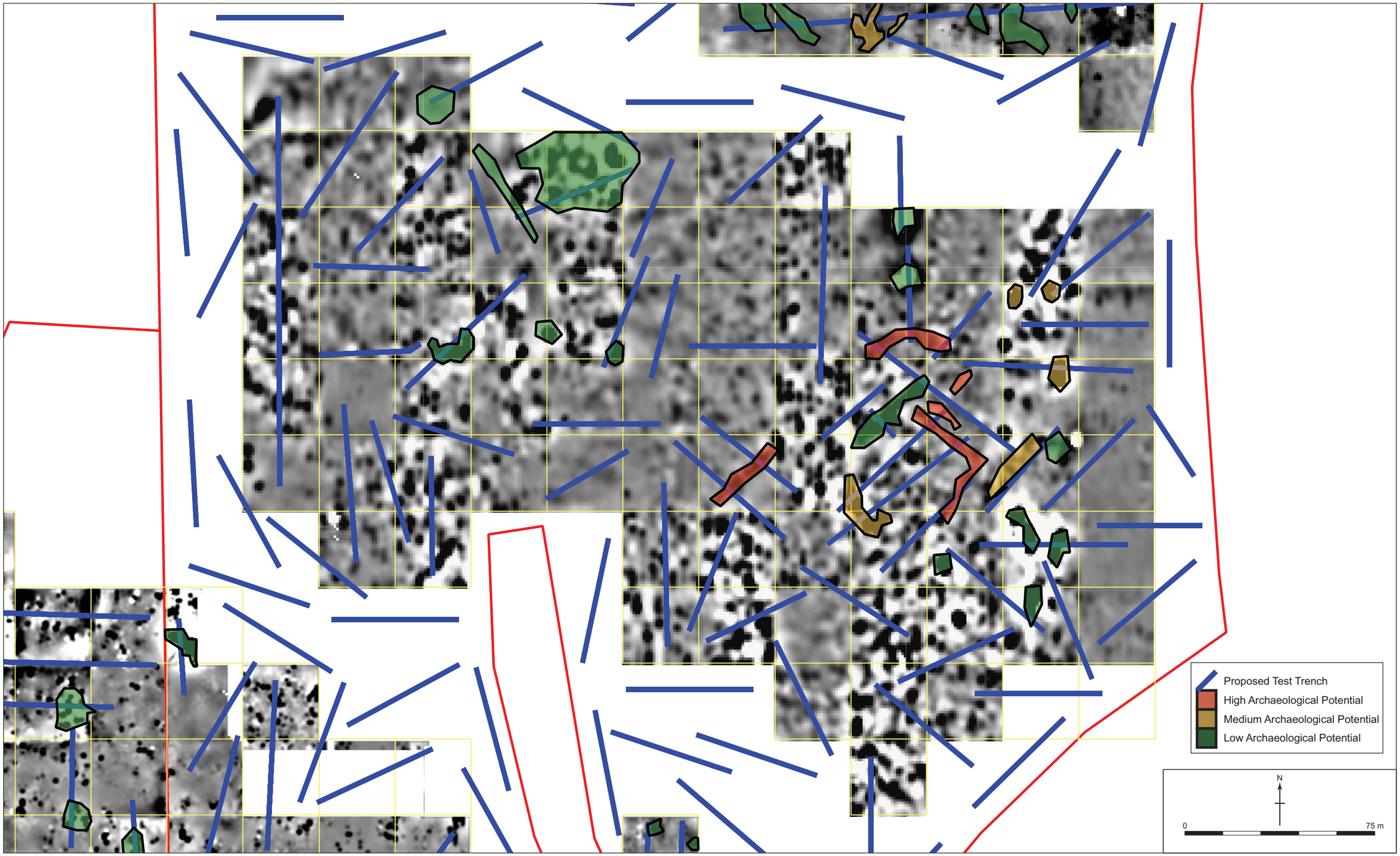

Figure 10 - Forth Road Crossing, Edinburgh:
Centre Field (Parcel 4), Proposed test trench layout (1:1500 Scale)

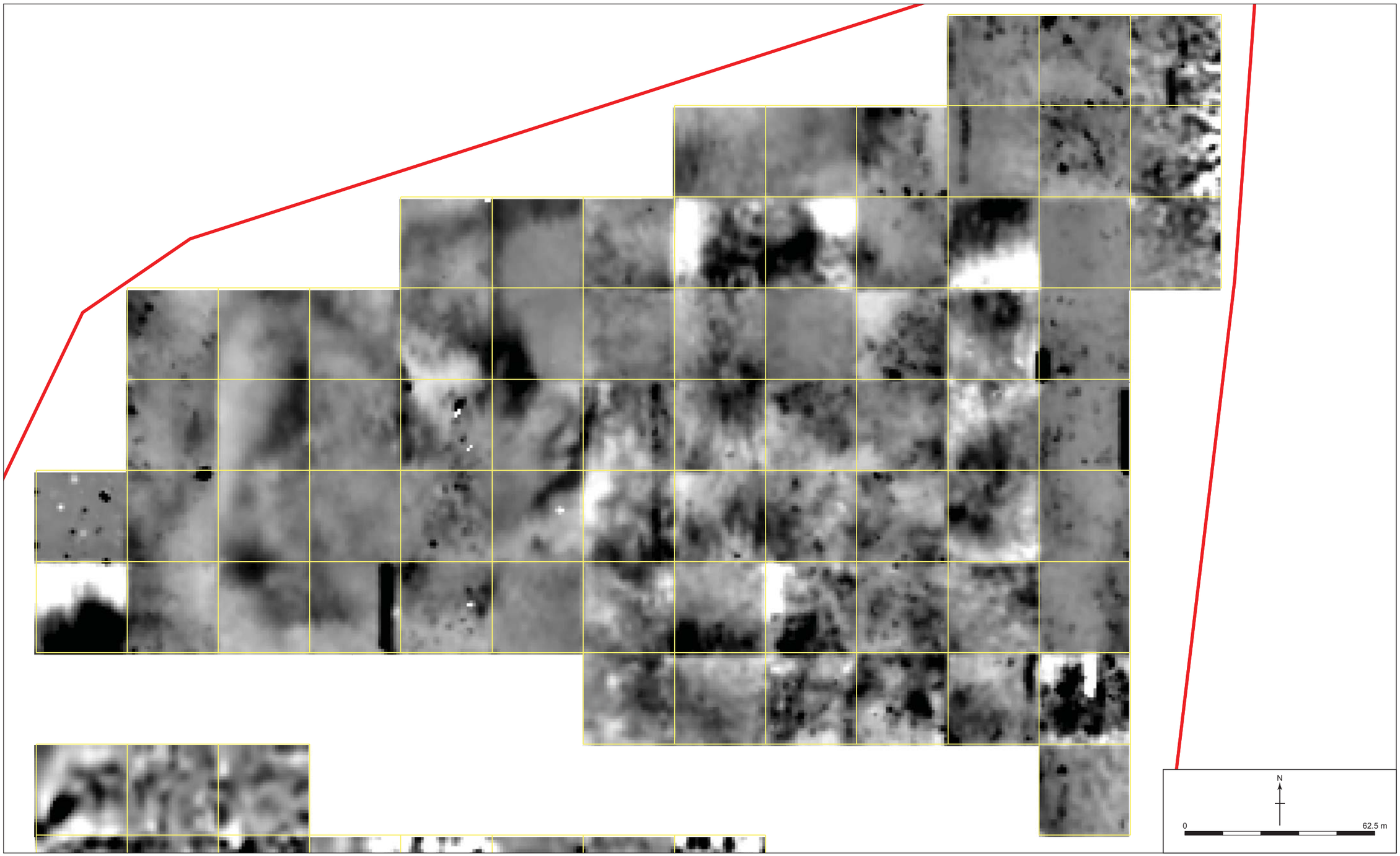

Figure 11 - Forth Road Crossing, Edinburgh:
North Field (Parcel 4), Processed data (1:1250 Scale)

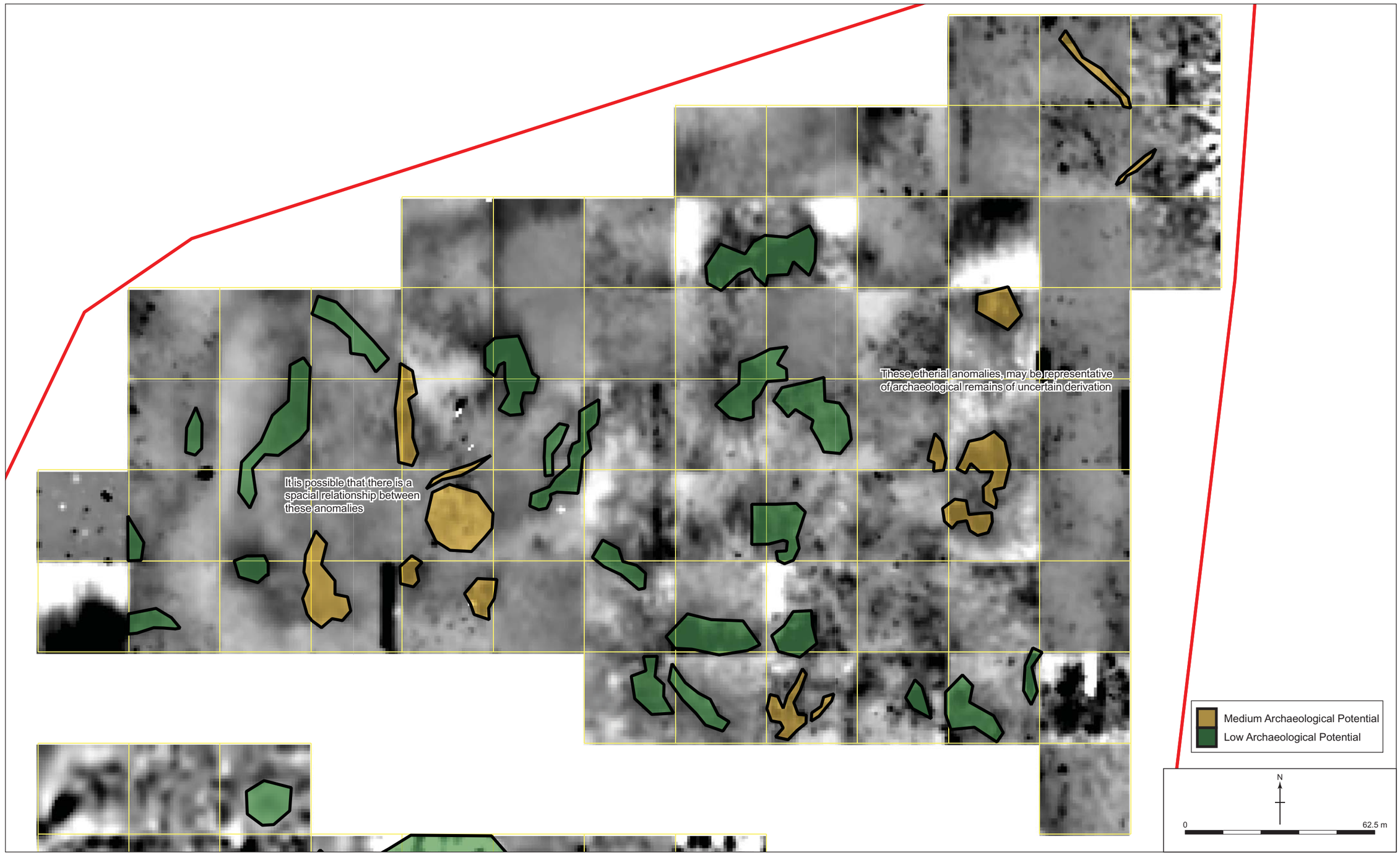

Figure 12 - Forth Road Crossing, Edinburgh:
North Field (Parcel 4), Interpreted data (1:1250 Scale)

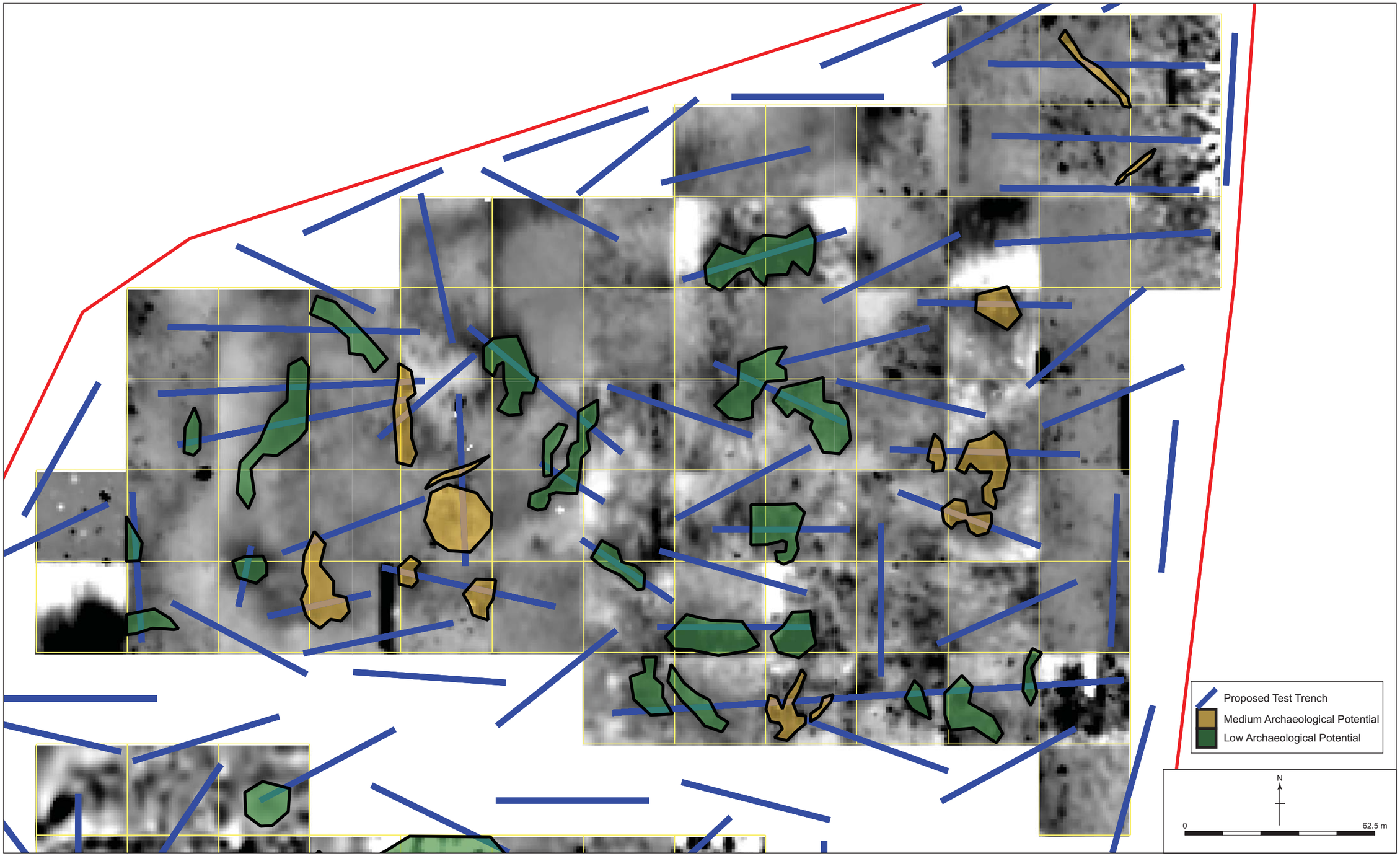

Figure 13 - Forth Road Crossing, Edinburgh:
North Field (Parcel 4), Proposed test trench layout (1:1250 Scale)