Recent geophysical and geoarchaeological investigations within the Stonehenge landscape: implications for the A303 scheme proposals

Paul Garwood
Senior lecturer in Archaeology
University of Birmingham, UK
[redacted]

1. Executive summary

1.1. This submission concerns the significance, and implications, of recent extensive research-led geophysical and geoarchaeological investigations within the Stonehenge landscape for future research, cultural heritage management, and academic, curatorial and public understanding.

1.2. This is based on my involvement in Stonehenge landscape fieldwork nearly every year since 2007, as a project director/co-principal investigator of four research projects (*Palisade Field Survey*; *Stonehenge Riverside*; *Stonehenge Hidden Landscapes*; *Stonehenge Landscapes EMI*).

1.3. Two major geophysical survey projects have been mounted within the WHS since 2010: the *Stonehenge Hidden Landscapes Project* (*SHLP*), and the *Stonehenge Landscapes EMI* (*SLE*) project (see Section 3). These have produced new datasets of unprecedented scale and detail, revealing thousands of new features, including new monuments, with major implications for how we understand the properties and potential of subsurface cultural heritage assets (see Sections 3-5).

1.4. The *SLE* project also combines a new geophysical survey method, motorized Electro-Magnetic Induction (EMI), with invasive geoarchaeological investigations to establish the subsurface soil and geological properties that condition the geophysical data. This has major implications for how these data are modelled and interpreted, and thus their use for archaeological and heritage purposes.

1.5. The SLE project excavations have also revealed the presence of feature types not recognised or investigated before within the WHS (Section 5), both anthropogenic and natural, some of exceptional importance for interpretations of the prehistoric landscapes in the environs of Stonehenge.

1.6. The A303 evaluation process does not appear to have taken account of the methodological and research implications of these geophysical and geoarchaeological projects, despite their significance for the scheme (Sections 4-6).

1.7. Existing research frameworks for the WHS do not fully reflect current knowledge of the richness and complexity of subsurface evidence, while future technological advances will inevitably generate new kinds of evidence. In this light, the A303 evaluation process does not seem to be comprehensive using even current techniques, or compliant with present WHS research and management strategies.

1.8. It is recommended that the A303 scheme minimises damage to the WHS by moving the western tunnel portal to a point outside the WHS, that evaluations of scheme proposals should involve wider and more in-depth consultation with archaeological researchers, and that the full range of geophysical and archaeological methods currently available are used for evaluation purposes.

2. Geophysical survey, research and management agendas, and the OUV of the WHS

The original version of the Stonehenge World Heritage Site Research Framework (Darvill (ed.) 2005) drew particular attention to the need to compile a geophysical map of the area (Objective 14: *ibid*, 131): as a key resource in its own right, and as a means to achieve a range of other high-priority research objectives, including:

Objective 3: Modelling environment and landscape change (*ibid*, 127).

Objective 4: Understanding occupation (*ibid*.).

Objective 15: Filling data gaps (*ibid*., 131).

Objective 17: Validating and dating features (*ibid*., 131-32).

Updates and revisions to the Research Framework have noted the outcomes of geophysical surveys undertaken since 2005 and their value for informing our knowledge of the WHS (Darvill 2012, Leivers & Powell 2016). The most recent Framework also identifies the need to collate digital archives for research and heritage management purposes (*ibid*, 32-4), but surprisingly overlooks the significance of recent geophysical survey results, methods and their future potential for understanding the Stonehenge landscape.

The ways in which research also contributes to the management of the WHS have been addressed in the most recent Management Plan (Simmonds & Thomas 2015), which emphasises the need for sustainable research to *"improve understanding of the archaeological, historic and environmental value of the WHS"* (*ibid*., Aim 7). This recognizes the new insights that fieldwork can provide to enhance understanding of the WHS and its OUV (*ibid*, Issue 52), although the intrinsic sustainability of non-invasive geophysical and other remote sensing methods is not sufficiently highlighted.

3. Recent large-scale geophysical surveys within the Stonehenge WHS area

In the last 15 years a large number of small-scale site- and area-specific geophysical surveys have been conducted within the WHS (e.g. as parts of the *Stonehenge Riverside Project (SRP)*, and Historic England's *Stonehenge World Heritage Site Landscape Survey*; summarised in Darvill 2012). A more extensive magnetometry survey covering 2 km^2 to the north of the old A344, between Fargo Plantation and King Barrow Ridge was undertaken in 2011 as part of the *First Monuments Project* (Darvill *et al.* 2013). Most recently, small-scale geophysical surveys have been undertaken as part of the A303 scheme programme of archaeological evaluation (Highways England 2018a; Wessex Archaeology 2016, 2017a, 2017b, 2018). The combined extents of *all* these surveys are dwarfed, however, by the *Stonehenge Hidden Landscapes Project* (*SHLP*) and the *Stonehenge Landscapes EMI* (*SLE*) project, both international collaborations led in the UK by the University of Birmingham.

The *SHLP* (Gaffney *et al.* 2012), led by Prof. Vince Gaffney (University of Bradford, formerly University of Birmingham) and Prof. Wolfgang Neubauer (Ludwig Boltzmann Institute for Geophysical Prospection and Virtual Archaeology, Vienna), with Co-Principal Investigators at the universities of Birmingham (Prof. Henry Chapman, Paul Garwood), and Bradford (Chris Gaffney), is the largest single archaeological geophysics survey ever undertaken. Total *SHLP* geophysical survey coverage (2010-2016) amounts to over 15 km^2, comprising multiple sensor surveys over c.10 km^2 of contiguous mapped area (Gaffney *et al.* 2018; see Fig. 1). The full range of survey methods applied, encompassing several kinds of magnetometry, resistivity, Ground-Penetrating Radar (GPR), Electro-Magnetic Induction, and other methods is shown in Figure 2. In 2016, the *SHLP* and *SRP* teams also came together to investigate the *SHLP* discovery of a huge new monument identified in GPR data beneath the Durrington Walls 'superhenge' bank (Parker Pearson *et al.* 2017).

The *SLE* project (2016–present), a University of Ghent/University of Birmingham collaboration, led by Philippe De Smedt (Ghent), and Henry Chapman and Paul Garwood (Birmingham), is based on the results of extensive motorized Electro-Magnetic Induction (EMI) surveys that cover an area of c.3 km^2 to the north of the A303 (contributing to the *SHLP*; De Smedt *et al.* 2014) (see Figs. 3, 4). Analyses of the EMI results, which comprise magnetic and electrical resistance data recorded simultaneously, were used to identify locales for invasive geoarchaeological investigations through coring (70 boreholes, 2016-18) and excavation (20 trenches, 2017-18). This research programme was designed to: (i) establish the subsurface pedological and geological properties that condition the geophysical data; (ii) determine the character, morphology and date of subsurface anthropogenic features and natural features landforms in the Stonehenge landscape, and; (iii) develop a robust and sustainable methodology for integrated geophysical/geoarchaeological investigations in chalkland landscapes.

4. *Results and implications of the Stonehenge Hidden Landscapes Project*

Some of the results of the *SHLP* have been summarised in brief interim reports (especially Gaffney *et al.* 2012, 2018), and the first project monograph is currently in preparation (for publication in 2020). The sheer scale, resolution and complexity of the data produced by the *SHLP* are unprecedented in terrestrial prospecting, with outcomes ranging from discoveries of new prehistoric monuments to finely detailed mapping of extensive multi-period field systems and modern complexes such as RAF Stonehenge. These results have already transformed our understanding of the Stonehenge landscape, and highlight the extraordinarily complex and diverse character of subsurface features, the full significance of which in research and heritage management terms we are only beginning to understand. For present purposes, three key points require emphasis:

(i). The recent revolution in geophysical survey methods (in little more than a decade), bringing together higher-resolution techniques, new methods (especially 3-dimensional volumetric survey systems such as GPR), motorization, and precise integral GPS-mapping of survey data), has not fed through fully to research or commercial project design. Even more significantly, whilst data capture has expanded exponentially, enhanced systems of data processing, analysis and interpretation capable of managing and making sense of vastly greater datasets are only in development. Consequently, understanding the significance of new geophysical data and their implications for understanding landscapes such as the Stonehenge WHS is an on-going process, and present knowledge and interpretative assumptions will inevitably change. Approaches to both geophysical evaluation of the A303 route, and consideration of the evidence sets provided by SHLP, for example, do not appear to reflect these current conditions of enquiry.

(ii). Integration of multiple survey methods, which recover entirely different kinds of data (i.e. what is 'visible' in one is very often not evident in another), should be a condition of all present and future geophysical survey projects, and fundamentally so where there is any possibility of ground disturbance. It does not appear that assessment of the subsurface evidence along the A303 route has involved (let alone integrated) all currently available geophysical survey methods, such as magnetometry, earth resistance, GPR, and EMI.

(iii). As the SHLP demonstrates, the development and application of new geophysical survey techniques, and the enhancement of existing systems, is a continuous process with unknown future potential. The outcomes of technical innovation in this area cannot be anticipated and may produce new technologies (e.g. graviometry experiments during the *SHLP*) that allow for data capture in unprecedented ways. Destruction of parts of the WHS in this context will deny future researchers access to potentially significant data that are currently unrecognised/unrecoverable.

5. *Results and implications of the Stonehenge Landscapes EMI Project*

The *SLE* project is unlike other geophysics-based archaeological projects in that the primary aim is not to produce 'maps' of subsurface features and investigate what appears to be 'significant', but rather to determine the pedological, sedimentary, geological and morphological properties of features and deposits that *produce* the magnetic and electrical data. This is critical for understanding

EMI data generally and in chalkland landscapes in particular, and for robust interpretation and predictive modelling of the subsurface evidence within the Stonehenge WHS. Targeted coring and excavation of features and landforms have also produced significant new evidence for understanding the formation of the Stonehenge landscape and human activity within it. Important results so far (De Smedt *et al.* 2017, 2018) include the following:

(i) Evaluation of EMI datasets

- Extensive electrical conductivity survey (not previously undertaken within the WHS) provides entirely different insights into subsurface features and deposits that can be compared with magnetic and other datasets. *Combined* electrical and magnetic survey, in particular, greatly facilitates the classification and interpretation of features and deposits.
- The morphological characteristics of subsurface features in magnetic EMI datasets can be predictively indicative of an anthropogenic or natural origin.
- Magnetic responses of feature fills do not, however, simply reflect depth, and chemical and mechanical demagnetization can render large features (partly or wholly) invisible in magnetic datasets. This has major implications for the use of magnetic data for subsurface survey, which most archaeological geophysical surveys, including A303 evaluations, are over-reliant on.
- 'Negative' magnetic features are present throughout EMI data (and other magnetic survey results), but remain little understood; these require further investigation.

(ii) Selected period-specific archaeological results

- Periglacial and fluvial features such as channels, sinkholes, cryoturbated sediments, and solution hollows (dating to the last c.150,000 years), some containing redeposited wind-blown silts (loess), are widely present in the WHS area. Investigation of these is providing new major insights into how the prehistoric landscape was formed.
- Investigation of these landforms and other 'natural' features such as ancient tree throws are also proving important for clarifying the character of the earlier Holocene landscape, and as locales for prehistoric activity (in one case stratified Mesolithic and Middle Neolithic material).
- The unprecedented discovery of the largest Early Mesolithic pit in northwest Europe (possibly a hunting trap), dating to the early 8th millennium BC, emphasizes the potential presence of hitherto unknown feature types within the WHS, and significant human activity in the early Holocene that is presently very little understood. Demagnetization and plough-truncation may have rendered other such features invisible in existing *magnetic* datasets.
- A large 'monumental' pit with external bank close to Stonehenge, dating to the early 4th millennium BC, highlights the significant presence of Early Neolithic activity in the Stonehenge landscape of kinds that are rarely investigated and remain little understood.
- Another 'monumental' pit of late 4thmillennium BC date also emphasises the wider structuring of the Middle Neolithic sacred landscape when the first Stonehenge enclosure was in use.
- The potential of modern techniques for investigating truncated prehistoric field systems revealed in EMI datasets has been demonstrated (e.g. identifying arable fields and paddocks).

(iii) General archaeological results

- Understanding of the EMI 'signatures' of features and their morphologies, sediments, fill sequences and chronologies, requires a multiplicity of comparative excavation datasets from both anthropogenic and natural features.
- Even small-scale excavations in areas that have attracted little attention within the WHS can provide significant new insights into the nature and distribution of prehistoric activity.
- 'Pits' encompass a wide range of feature types including structures that are best understood as part of the spectrum of 'monumental' architectural forms in the Stonehenge landscape.

- Intensive wet sieve sampling to recover artefacts (especially lithic microdebitage and ceramic fragments), charred plant remains and bone fragments, from both anthropogenic and natural feature fills (100% in some cases) and deposits (including topsoil/ploughzone contexts), should be standard practice in all field investigations in the WHS. Dry sieve sampling alone is not sufficient to gain a reliable appreciation of human activity in the Stonehenge landscape.
- The finite character of the archaeological resource within the WHS, its research and heritage management sensitivity, and the need for sustainability (Simmonds & Thomas 2015, Aim 7, 240-43; Leivers & Powell 2016, *Research Principle 2*), demands the highest possible recovery and recording of data from any field investigation. In the case of the SLE project, for example, in addition to wet sieve sampling, this has included molluscan, pollen, C14, Optical Spin Luminescence, magnetic susceptibility, soil micromorphology, and geological sampling, together with high-resolution 3D photogrammetric recording of all trenches and features.

6. *Recommendations*

The results of recent geophysical and geoarchaeological projects within the WHS are of exceptional importance for our knowledge and understanding of the Stonehenge landscape, and the significance of potential subsurface evidence for current and future research and heritage management. Except for basic survey results provided by the *SHLP* (noted in Highways England 2018a, 23), the A303 evaluation process does not appear to have taken account of the methodological and research implications of these projects, despite their significance for the scheme.

This applies especially (but not only) to the western part of the WHS, and immediately to the west of the WHS, where proposed ground works would permanently reconfigure the landscape and destroy all subsurface evidence in the areas affected: c.10 ha of the WHS from the western tunnel portal to the edge of the WHS, and at least 20 ha in the area of the proposed Longbarrow Junction and A360 road realignments. It is not clear at present what full archaeological 'mitigation' might amount to, but determining a DAMS based only on conventional programmes of (mainly) magnetometer survey, topsoil sampling (with dry sieving), and evaluation trenching conducted (cf. Highways England 2018b) seems inadequate in the light of the geophysical and geoarchaeological research outlined above.

Moreover, a key lesson from recent developments in archaeological field methods is that current knowledge does not reflect the richness, complexity and value of subsurface evidence, and that investigative techniques will be augmented in the future by new methods that will continue to generate greater and unprecedented new data. Wilful destruction of sources of evidence within the Stonehenge WHS area is clearly out of keeping with both UNESCO's OUV statement and current WHS management and research strategies.

In the light of these observations, and the implications of recent field research outlined in Sections 4 and 5, the author recommends the following:

1. Should the Scheme be approved in any form, the western tunnel portal should be moved at least 1.5 kms further west (as strongly advocated by the WHC/ICOMOS Advisory Mission; 2018, section 3.5), to ensure that there is no damage to intact subsurface deposits and features within the WHS.

2. Archaeological and heritage evaluations of the A303 scheme should involve far wider and more in-depth consultation with archaeological researchers active in the WHS, and with those involved in the development and innovation of relevant field investigation techniques and methodologies.

3. The *full* range of geophysical and archaeological methods that are currently available (of the kinds identified in Sections 3-5) should be used for evaluation purposes within the Stonehenge WHS (and indeed in all landscape settings where nationally significant archaeological evidence may be affected by development plans).

References

Darvill, T. (ed.) 2005. *Stonehenge World Heritage Site: an archaeological research framework*. London and Bournemouth: English Heritage and Bournemouth University

Darvill, T. 2012. *Research Framework for the Stonehenge, Avebury and Associated Sites World Heritage Site: research activity in the Stonehenge Landscape 2005–2012*.

Darvill, T., Lüth, F., Rassmann, K., Fischer, A. and Winkelmann, K. 2013. Stonehenge, Wiltshire, UK: high resolution geophysical surveys in the surrounding landscape, 2011, *European Journal of Archaeology* 16 (1), 63–93.

De Smedt, P., Van Meirvenne, M., Saey, T., Baldwin, E., Gaffney, C., and Gaffney, V., 2014. Unveiling the prehistoric landscape at Stonehenge through multi-receiver EMI, *Journal of Archaeological Science* 50, 16-23

De Smedt, P., Garwood, P. and Chapman, H. 2017. *Geoarchaeological investigations at Stonehenge. Interim report of the invasive calibration and validation of EMI survey data. Phase 1 - borehole sampling*. Unpublished report; University of Birmingham/Ghent University.

De Smedt, P., Garwood, P. and Chapman, H. 2018. *Stonehenge EMI Landscape Project. Geoarchaeological Investigations at Stonehenge, July 2017: Interim Report*. Unpublished report; University of Birmingham/Ghent University.

Gaffney, C, Gaffney, V, Neubauer, W, Baldwin, E, Chapman, H, Garwood, P, Moulden, H, Sparrow, T, Bates, R, Locker, K., Hinterleitner, A., Trinks, I, Nau, E., Zitz, T, Floery, S, Verhoeven, G. and Doneus, M. 2012. The Stonehenge Hidden Landscapes Project, *Archaeological Prospection* 19, 147–55

Gaffney, V., Neubauer, W., Garwood, P., Gaffney, C., Löcker, K., Bates, R., De Smedt, P., Baldwin, E., Chapman, H., Hinterleitner, A., Wallner, M., Filsweiser, R., Nau, E., Kainz, J., Schneidhofer, P., Zotti, G., and Lugmayer, A. 2018. Durrington Walls and the Stonehenge Hidden Landscape Project 2010-2016, *Archaeological Prospection* 25, 255-69

Highways England 2018a. *A303 Amesbury to Berwick Down TR010025: Application Document 6.1: Environmental Statement; Chapter 6, Cultural Heritage*.

Highways England 2018b. *A303 Amesbury to Berwick Down TR010025: Application Document 6.3: Environmental Statement Appendices; Appendix 6.2, Archaeology Baseline Report.*

Leivers, M. & Powell, A.B. 2016. *A Research Framework for the Stonehenge, Avebury and Associated Sites World Heritage Site. Research agenda and strategy*. Wessex Archaeology Monograph 39.

Parker Pearson, M., Chan, B., Chapman, H., Gaffney, V., Garwood, P., Marshall, P., Aldrian, L., and Neubauer, W. 2017. Durrington Walls: was this the start of Britain's Copper Age, *PAST* 86, 3-5.

Simmonds, S. and Thomas, B. 2015. *Stonehenge, Avebury and Associated Sites World Heritage Site Management Plan 2015*. Stonehenge and Avebury WHS Steering Committees.

Wessex Archaeology 2016. *A303 Amesbury to Berwick Down TR010025: Geophysical Survey Report, Phase 1*. Wessex Archaeology on behalf of Highways England, Ref. 113220-09. Salisbury.

Wessex Archaeology 2017a. *A303 Amesbury to Berwick Down TR010025: Geophysical Survey Report, Phase 2*. Wessex Archaeology on behalf of Highways England, Ref.113223-07. Salisbury.

Wessex Archaeology 2017b. *A303 Amesbury to Berwick Down TR010025: Geophysical Survey Report, Phase 3*. Wessex Archaeology on behalf of Highways England, Ref.113224.11. Salisbury.

Wessex Archaeology 2018. *A303 Amesbury to Berwick Down TR010025: Geophysical Survey Report, Phase 4.* Wessex Archaeology on behalf of Highways England. Salisbury.

World Heritage Committee 2013. *Annex of Document WHC-13/37.COM/8E.* 37th session of the World Heritage Committee June 2013, Committee Decisions 37 COM 8E: Adoption of retrospective Statements of Outstanding Universal Value (http://whc.unesco.org/en/list/373).

Figure 1: *Stonehenge Hidden Landscapes Project*: coverage, 2010-16.

Option	Feature	Landsacpe	2010 Area (ha)	2011 Area (ha)	2012 Area (ha)	2013 Area (ha)	2014 Area (ha)	2015 Area (ha)	2016 Area (ha)	Total Area (ha)
Earth Resistance										
Twin	x	–	–	0.04	–	–	–	–	–	0.04
Square	x	–	0.32	–	–	–	–	–	–	0.32
Electrical imaging										
Campus Tigre RM	x	–	0.00	–	–	–	0.10	0.15	–	0.26
FlashRES64	x	–	–	0.34	–	–	–	–	–	0.34
Magnetometer										
CV Cart	x	–	–	3.83	–	–	–	–	–	3.83
FF Cart	x	x	15.10	–	5.00	15.00	–	–	–	35.10
FF Motorized	x	x	28.16	221.10	482.00	219.00	21.00	–	–	971.26
Bartington HH	x	–	4.40	–	–	1.20	–	–	–	5.60
GPR										
Mala Motorized	x	x	16.80	31.90	–	22.00	40.00	–	–	110.70
S&S Motorized	x	x	13.40	–	–	35.00	–	–	–	48.40
Single	x	–	2.40	1.00	1.00	1.50	0.82	1.35	0.99	9.06
EM										
EM31	x	x	0.54	–	–	–	–	–	–	0.54
EM38	x	x	–	–	–	–	–	0.16	–	0.16
Dualem motorized		x	–	–	21.00	22.00	153.00	100.00	–	296.00
CMD Mini Explorer	x	–	–	1.60	–	–	25.00	0.16	–	26.76
Laserscan										
Leica	x	–	2.30	3.30	0.50	1.00	1.75	2.36	2.61	13.82
Riegl	–	x	–	287.00	217.00	446.20	–	–	–	950.20
			83.4	550.1	726.5	762.9	241.7	104.2	3.6	2472.4
Geophysics			81.1	259.8	509.0	315.7	239.9	101.8	1.0	1508.4

Figure 2: *Stonehenge Hidden Landscapes Project* methods applied and coverage, 2010-16 (Gaffney *et al.* 2018, Tbl.1).

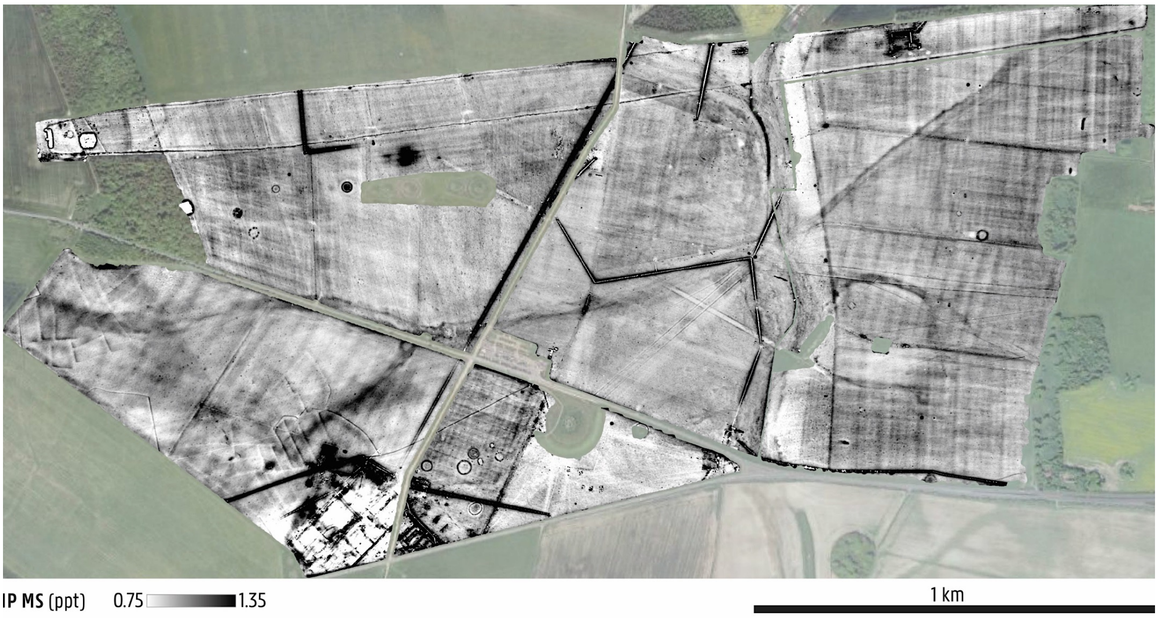

Figure 3: *Stonehenge Landscapes EMI Project*: magnetic data plot.

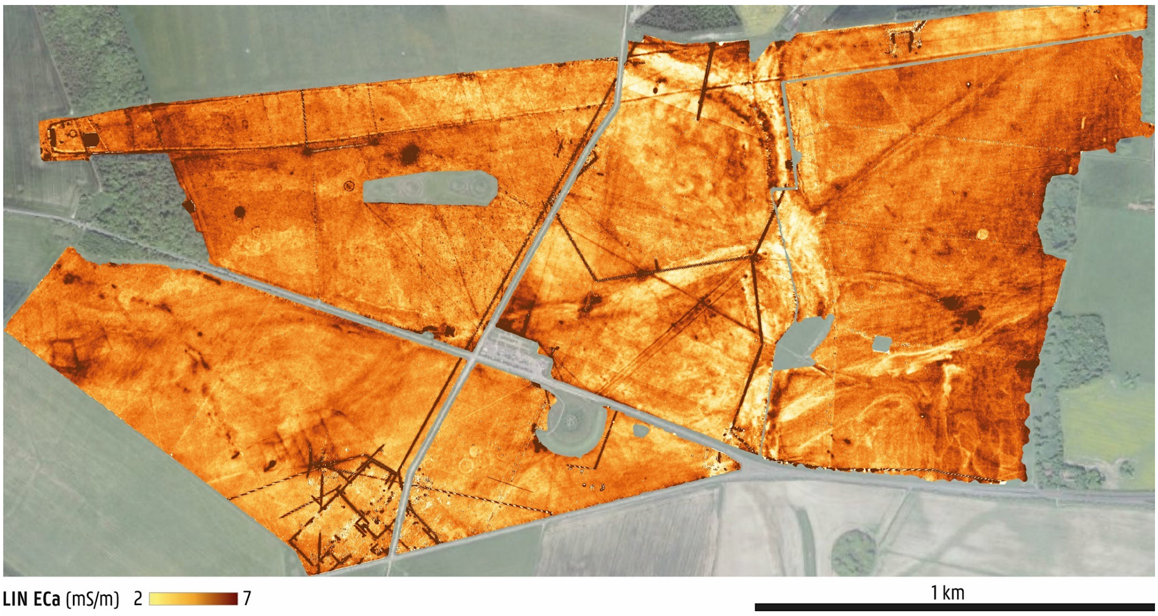

Figure 4: *Stonehenge Landscapes EMI Project*: electrical conductivity data plot.