Metric Survey Specifications for Cultural Heritage

3D Laser scan survey of Stonehenge, Wiltshire

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Preface

The survey brief
The preparation of a brief for the supply of survey services based on the options in this specification should ensure the necessary communication between the information user (the client) and the information supplier (the surveyor) required for the successful application of metric survey.

Performance of metric survey in heritage documentation
In order to obtain metric survey fit for the purposes of heritage management it will be necessary to consider not only the metric performance of measured data but also the required quality of work needed to act as both a record and an archive of the cultural heritage. The conventions of selection and presentation of measured drawing in architecture constitute a visual language that requires careful consideration. This file contains descriptions of the required standard – illustrations will be found in the published document.

Use of the specification
This document is a description of the services and standards required for the supply of various types of metric survey. Sections 1, 2 and 3 describe the general terms, performance and presentation requirements common to all services. Sections 4, 5 and 6 contain standards specific to image based survey, measured building survey and topographic survey, respectively. The use of any part of this specification without reference to the appropriate clauses of sections 1, 2 and 3 plus the appropriate service description from sections 4, 5 and 6 will be a misuse of the document and is very likely to result in an unsatisfactory product. Whilst it is hoped that this specification will be distributed widely and is open to anyone to use, its use is not a guarantee of the required results and it is recommended that, if in doubt, professional advice is sought.

Structure of the document
This document follows the RICS convention for specifications. The contents of this file constitute the clauses of the specification while guidance pertinent to those clauses can be found on the left hand pages of the published document. For many clauses it is necessary to make a choice from a list by deleting the options that are not required. For others, there is a list of possible options to tick or the insertion of text may be needed. If a clause is not edited then the first option should be taken as the default. In most cases this will be the recommended option.

Acknowledgements
The preparation of these specifications would not have been possible without the work of those, past and present, charged with the survey of the historic estate in the care of English Heritage. This edition has particularly benefited from the input of all the members of the English Heritage Metric Survey Team.
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1.1 Project Brief

1.1.1 Name of project
3D Laser scan survey of Stonehenge, Wiltshire

1.1.2 Purpose of project
To carry out a detailed survey of the stones, both standing and fallen, and immediate surrounding landscape within ‘the Triangle’ using a combination of modern laser scanning and digital imaging approaches.

Rather than concentrating on just the stones and carvings, this will cover the surrounding topography and complement the analytical landscape investigation and recording being undertaken by English Heritage’s Archaeological Survey & Investigation and IGS teams.

As well as supplying the ‘point cloud’ data, ‘meshed’ 3D surface models ideally in a textured form are to be supplied. These will be initially supplied to the exhibition designers, who will be overseeing the production of a CGI (computer generated-image) audio-visual display and who are currently advising the Properties Presentation team of English Heritage.

1.1.3 Location
Site Address Stonehenge, Amesbury, Wiltshire, SP4 7DE
Administration address - Administration Office, English Heritage, Wyndham House, 65 The Close, Salisbury, SP1 2EN
Directions Located 2 miles west of Amesbury on the junction of the A303 and A344/A360.
National Grid Reference SU122422

1.1.4 Access arrangements
Access, for both the purposes of estimating and undertaking the work, must be arranged in advance by contacting the Stonehenge Administration Office on 01722 343830, contact Peter Carson (Head of Stonehenge). Applications for access will need to be submitted and agreed prior to arriving on site. Contractors are also to note restrictions are in place for accessing the stones during normal visiting hours. These are noted in Appendix D Terms and Conditions of Stone Circle Access.

1.1.5 Health and Safety statement

1.1.6 Copyright
English Heritage will retain all copyright on the data generated within this survey, as per Clause 14, of Schedule 4. Conditions of a Framework Agreement for the Provision of Metric Survey Services.

1.1.7 Contract
The conditions of contract are ‘Conditions of a Framework Agreement for the Provision of Metric Survey Services’.

1.1.8 Site clearance
Other than some temporary wire fences, used to control visitor traffic around the stones, there are no major obstructions on site and therefore no prior clearance is anticipated. The grassland immediately around the standing stones is kept at a low level through a combination of grounds maintenance and visitor traffic however the grassland in the wider
area can reach a significant height during the summer months. Therefore it is suggested this survey is progressed at a time of year when vegetation growth is at a minimum.

1.1.9 Completeness of survey
The survey is to be as complete as possible using current survey/scanning approaches and technologies. This includes the upper surfaces of the standing stones (trilithons) so a suitable ‘high-level’ access platform will need to be arranged to allow for detailed scanning.

1.1.10 Area and scale of survey
- Topographic landscape within ‘the Triangle’ – using terrestrial laser scanners and appropriate data processing techniques to accurately capture a ground surface model at a point-spacing (resolution) of at least 10cm.
- The stone circle and landscape immediately surrounding it – using terrestrial laser scanners and appropriate data processing techniques to accurately capture a surface model at a point-spacing of at least 2cm for the landscape and up to 1mm for the surfaces of the stones themselves.
- The standing and fallen stones, including Station, Heel and Slaughter stones - using close-range and/or high-resolution terrestrial scanners, combined with appropriate data processing techniques, to accurately capture all visible faces of the stones at a point-spacing of at least 0.5mm.

See ‘Proposed areas of coverage’ summary sheet at the end of this document.

1.1.11 Type of survey required
3D laser scanning in conjunction with digital imaging.

1.1.12 Delivery schedule
The survey is to be carried out and delivered before the end of March 2011.

1.2 Introduction
The general conditions cover aspects of undertaking survey that are common to most metric survey activities carried out on historic sites. The project information will consist of the administrative and logistical aspects of a particular project.

1.2.1 Pertinent legislation
Contractors are to be aware of all current statutory requirements relevant to the contract for survey work. The contractor’s attention is brought to:
- Ancient Monuments and Archaeological Areas Act 1979
- Planning (Listed Buildings and Conservation Areas) Act 1990
- The Construction (Design and Management) Regulations of 1994, introduced under the Health and Safety at Work Act; 1974

Copies of the above legislation can be obtained from The Stationery Office

www.tsoshop.co.uk

Tel. 0870 242 2345

Where the survey work occurs in countries other than England the law of that country will apply.
1.2.2 Client's guidance on matters concerning survey
Contractors are required to comply with the client’s guidance on matters of safety and standards of work regarding the historic fabric.

1.3.1 Contract
The contract will be supplied by the Historic Environment Commissions team, based in Room 1/20, National Monuments Record Centre, Kemble Drive, Swindon SN2 2GZ. It will consist of this specification including any edits made specifically for the project plus any attached documents or diagrams.

1.3.2 Method statement
A method and resource statement is to be provided by the contractor and must include:
- the proposed method/s for providing the required survey data
- the survey equipment, scanners, cameras etc to be used and their respective performance specifications
- any access equipment to be used on site
- any lighting and electrical equipment to be used
- any alternative survey methods and their respective performance
- the anticipated level of survey completion
- your proposed data retention and archiving policies
- the number of and positions of staff to be employed on the project
- delivery schedule.

1.3.3 Risk assessment
A risk assessment must also be supplied with the tender. Anticipated hazards include but are not limited to:
- driving to site
- use of access equipment
- slips and trips
- exposure
- interaction with public
- laser safety.

1.3.4 Site visits
The contractor may wish to visit the site to verify the requirements of the project and facilitate the production of the tender, method statement and risk assessment.

Where access to land not in the client’s care is necessary, assistance will be provided to secure the appropriate way-leaves.

1.4 Contractual Details

1.4.1 Completion of survey
The client will seek agreement with the contractor on the extent of cover, within the acceptable limits of tolerance and method (i.e. are there areas which require an alternative survey technique or which cannot be covered). Where obstructions to survey exist, the client will seek agreement about the possible extent of completion.

1.4.2 Right of rejection
The client reserves the right to reject the application of any proposed survey technique or submitted survey product.
1.5 Health and Safety Requirements

1.5.1 Contractor’s responsibilities for safety
The following requirements are included here as a guide and contractors must ensure that all relevant safety requirements, associated with provision of survey on behalf of the client are met during the contract period. The contractor’s attention is brought to the need for best practice in matters of safety.

1.5.2 Health and Safety Manual
English Heritage has prepared guidance on safety matters specific to work on historic structures and fabric. Full details are included in the ‘Metric Survey Specifications for Cultural Heritage' document, within Appendices 1.1, 1.2 & 1.3. A pdf version of the specification document can be provided upon request.

1.5.3 Health and Safety at Work Act, 1974
Under this Act employers have responsibilities to their employees and those affected by their work (e.g. members of the public and staff on the site). Further information on this can be obtained from:

Health and Safety Executive
www.hse.gov.uk
Infoline tel. 0845 345 0055

To order a publication
www.hsebooks.com
Tel. 01787 881 165

1.5.4 Construction (Design and Management) Regulations, 2007
The Construction (Design and Management) Regulations 2007, introduced under the Health and Safety at Work Act 1974, relate to contractor’s responsibilities for safe working practice on construction projects. These regulations exclude site survey work prior to a contractor starting on site but it is good practise to apply the principles of the regulations, so that the client, surveyor and designer plan for the safety of everyone involved in the project.

The points below do not constitute an exhaustive list but are considered relevant to contractors undertaking survey work on historic sites.

Risk assessment
The client will require a risk assessment from the contractor prior to the site survey work commencing. This will identify hazards during the fieldwork stage and set out the contractor’s method of eliminating or managing the risks.

Access equipment
Access equipment supplied or used by contractors or their agents must conform to the current safety standards. Contractor’s attention is drawn to:

  www.opsi.gov.uk/si/si2005/20050735.htm

Full details, certification and nominated safety contacts on proposed access equipment, where relevant, are to be included in the method statement. The contractor will comply with English Heritage Safety Instruction No 7.4, Safe Use and Maintenance of Ladders (see 1.5.2).

**Electrical equipment**

On inspection, all mains powered equipment, including extension leads, shall have a Portable Appliance Test certificate that is no older than three months. The contractor will comply with English Heritage Safety Instruction No 7.2, Portable Electrical Equipment (see 1.5.2).

**Survey equipment**
Survey instruments or associated laser scanning/pointing devices, which may be a health hazard to people working in or visiting the site during the project, must be included in the risk assessment. Any certificates or statements from the manufacturers concerning the safety of the equipment must be included in the assessment along with any requirement for notification of ‘lasers in operation’ on site. English Heritage requires all such equipment to comply with:

BS EN 60825 *Safety of Laser Products: Equipment classification, requirements and users’ guide.*

### 1.6 Damage to Site and Fabric
Contractors are reminded that there are a range of penalties and powers of prosecution under the provisions of the Ancient Monuments and Archaeological Areas Act 1979 and the Planning (Listed Buildings and Conservation Areas) Act 1990 should unauthorised work be carried out or damage be caused to the building or monument.

#### 1.6.1 Use of marks
The use of nails, temporary control and permanent station markers etc is subject to prior approval of the mark and its location. The insertion of any mark may require scheduled monument consent (SMC) and must not be done without the prior permission of the client.

#### 1.6.2 Use of surface attachment for targets
Where possible temporary targets, as used for scanning and photographic control, should not be fixed directly on the surface of the stones. However where this is unavoidable the details of both the target and proposed adhesive must be discussed with the client prior to their location to ensure no damage will be caused to the stone surface. On completion of the survey all targets must be removed.

#### 1.6.3 Lichens on stones
It should be noted that the lichens that exist on the stones at Stonehenge are of international importance and hence all precautions must be undertaken during survey to ensure no damage at all occurs to them. Also lichens have no annual cycles, like plants, instead responding to weather conditions - when wet from rain or dew, they grow actively.
Therefore the timetable for close-range scanning will need to be adjusted to maximise survey coverage during any dry periods.

1.7 Survey Material Supplied

1.7.1 Copyright
It is the policy of English Heritage to retain all Intellectual Property Rights over all goods and services produced during the performance of an English Heritage contract.

1.7.2 Retention of survey documentation
On request the contractor shall make available to the client all materials used for the compilation of the required survey. This information must be retained on file by the contractors for a minimum of six years and will include field notes and/or diagrams generated whilst on site; the raw and processed data used for the final computation of control values and a working digital copy of the metric survey data that forms each survey (including formatted 2-D and ‘raw’ 3-D data files). The precise digital format and file type of this archive will be specified in Section 3.1. If during this period the contractor wishes to change the format of this data archive, they are to seek the client’s prior permission.

1.7.3 Use of English Heritage corporate device (or logo)
English Heritage’s corporate device (or logo), as supplied by English Heritage, must be used on all printed/plotted survey material supplied as part of this project. The logo is only to be used on material supplied to English Heritage; use of the logo on other material is not permitted without prior written consent or instruction from English Heritage. Copies of the logo are available upon request from the Photogrammetry team of English Heritage (tel 01904 601959).
SECTION 2

General Performance and Control of Metric Survey

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   2.1.4 Completeness of survey
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   2.2.2 Control observation
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   2.2.6 Establishment of permanent survey marks
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2.1 General Performance Requirements
Metric survey techniques are required to deliver data that can be verifiably repeated. There are three aspects to the required performance of metric survey data. These are

- measurement performance
- feature selection performance
- presentation performance.

2.1.1 Measurement performance
Measurement performance may be considered in terms of both accuracy and precision. There will also be different requirements and constraints on 3-D data as compared with 2-D data.

Definition of accuracy
Accuracy describes the closeness between measurements and their true values. The closer a measurement is to its true value the more accurate it is.

Definition of precision
In surveying precision is taken to describe the consistency with which a measurement or set of measurements can be repeated.

3-D data performance
There may be a variation in the performance of height or depth measurements compared with those in plan. Any variation must, however, remain within the tolerances stated in Section 2.1.2. Where a separate technique is used to derive height values (e.g. levelling for heights on a building plan) variation in the acceptable performance will allow for this.

2-D data performance
The performance of 2-D data is dependent on the data source and the projection used to present it. This is to be an orthogonal projection unless described otherwise in the relevant section according to survey type. The performance of the data is to be equal in both axes used.

2.1.2 Scale tolerance and point density
The precision of a survey is to be commensurate with the intended scale of presentation within the tolerances tabulated below. It is expected that surveyed data will allow repetition of a given measurement as presented on a plotted drawing within the following maximum tolerances when checked from the nearest control point.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Acceptable precision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:10</td>
<td>+/- 5 mm</td>
</tr>
<tr>
<td>1:20</td>
<td>+/- 6 mm</td>
</tr>
<tr>
<td>1:50</td>
<td>+/- 15 mm</td>
</tr>
<tr>
<td>1:100</td>
<td>+/- 30 mm</td>
</tr>
<tr>
<td>1:200</td>
<td>+/- 60 mm</td>
</tr>
<tr>
<td>1:500</td>
<td>+/- 150 mm</td>
</tr>
</tbody>
</table>

No less than 67% of a sample is to be within the stated tolerances and no less than 90% is to be within 1.65 times the stated tolerances.
Point density / Rate of capture

<table>
<thead>
<tr>
<th>Scale</th>
<th>Point cloud</th>
<th>Vectorisation by indirect methods*</th>
<th>Vectorisation by direct methods†</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:10</td>
<td>1 mm</td>
<td>1 - 15 mm</td>
<td>2 - 30 mm (max 0.5 m)</td>
</tr>
<tr>
<td>1:20</td>
<td>3 mm</td>
<td>3 - 30 mm</td>
<td>5 - 60 mm (max 1 m)</td>
</tr>
<tr>
<td>1:50</td>
<td>5 mm</td>
<td>5 - 50 mm</td>
<td>10 - 100 mm (max 2 m)</td>
</tr>
<tr>
<td>1:100</td>
<td>15 mm</td>
<td>15 - 100 mm</td>
<td>20 - 200 mm (max 3 m)</td>
</tr>
<tr>
<td>1:200</td>
<td>30 mm</td>
<td>30 - 300 mm</td>
<td>50 - 600 mm (max 5 m)</td>
</tr>
<tr>
<td>1:500</td>
<td>75 mm</td>
<td>75 - 750 mm</td>
<td>0.1 – 1.5 m (max 10 m)</td>
</tr>
</tbody>
</table>

* Stream digitising from photogrammetric stereo model or point cloud. The higher value in each range represents the maximum permissible point interval.
†E.g. by EDM or GPS. Where lines appear straight or detail is sparse the interval may be increased up to the maximum shown in brackets.

Repeatability of capture method
Data capture must be by a method that can be repeated, by the use of similar equipment and personnel to that described in the method statement, to the appropriate order of precision. For this reason the provision of data by a unique or undisclosed method is unacceptable.

Consistency of precision
The precision achieved must be commensurate with the required scale across the entirety of the survey.

Appropriate orders of control
The provision of control points by a method without full rigorous observation (e.g. the extension of a ground traverse to high level floor plans) is

(a) accepted by agreement depending on the requirements of the project and the constraints of the site

2.1.3 Performance of feature selection and presentation
The performance requirements for feature selection and presentation are described in detail in the subsequent sections for each type of survey. General principles for each type of presentation are shown below.

Vector presentation
The products of measurement systems are variable and dependant on both measurement performance and feature selection performance. The indicator of performance is, in all cases, a comparison between the subject of the survey and the final product. Feature selection is dependent on both the effective density of measured points and the differentiation required to meet the presentation standard at the requested scale.

Image based representation
The performance of images (rectified photography and orthophotography) as survey products is determined by the image resolution and the quality of the captured image (e.g. coverage, attitude, exposure, sharpness, extent of shadow and incident illumination) as well as the reproduction standard used.

2.1.4 Completeness of survey
It is not acceptable for survey coverage to be determined by the performance or limitations of a given method unless by agreement between the surveyor and the client.
Survey coverage, with regard to both the extent of the survey and the completion required within that extent, is to be determined by the needs of the project. Elevations and sectional elevations shall be complete to full height unless otherwise specified in Section 1.1.10 of the project brief. Any requirement for the field completion of obscured areas in a photogrammetric survey is addressed at Section 4.1.5.

2.1.5 Meta-data, materials and data formats
The table below describes the general requirements for meta-data. Any specific requirements will be described in later sections. All information supplied must be clearly referenced to the associated records, component records and the originator(s) thereof.

<table>
<thead>
<tr>
<th>Required field</th>
<th>Encoded as</th>
<th>From</th>
<th>Presented as</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project title</td>
<td></td>
<td>Client</td>
<td></td>
</tr>
<tr>
<td>Site name</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site location</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site component</td>
<td>ASCII/written record</td>
<td>Supplier</td>
<td>ASCII/typewritten record</td>
</tr>
<tr>
<td>Date of record</td>
<td>ASCII/written record</td>
<td>Supplier</td>
<td>ASCII/typewritten record</td>
</tr>
<tr>
<td>Authorship</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project reference number</td>
<td>Client</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Associated records</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control data: to include co-ordinate schedule, witnessing and network diagram</td>
<td>Data file, Digital or paper plan/diagram</td>
<td>ASCII data, Digital file or drawing on drafting film</td>
<td></td>
</tr>
<tr>
<td>Point cloud registration data</td>
<td>Data file</td>
<td></td>
<td>ASCII data</td>
</tr>
<tr>
<td>Photo location</td>
<td>Digital or paper plan/diagram</td>
<td></td>
<td>Digital file or drawing on drafting film</td>
</tr>
<tr>
<td>Colour index</td>
<td>Reference to colour index used and its manufacturing details</td>
<td>Supplier</td>
<td></td>
</tr>
<tr>
<td>Camera calibration</td>
<td>ASCII/written record</td>
<td>Supplier</td>
<td>ASCII/typewritten record</td>
</tr>
<tr>
<td>Process history</td>
<td>ASCII/written record</td>
<td>Supplier</td>
<td>ASCII/typewritten record</td>
</tr>
<tr>
<td>Origin of request</td>
<td>ASCII/written record</td>
<td>Supplier</td>
<td>ASCII/typewritten record</td>
</tr>
</tbody>
</table>

2.2 Control of Survey
The control for all survey projects must be reliable, repeatable and capable of generating the required co-ordinates within the tolerances stated. The method, network and equipment for providing survey control are discretionary, however details of the method and equipment proposed must be included in the method statement.

2.2.1 Accuracy of site control
The maximum error between permanently marked survey stations is to be no greater than
An estimate of the precision achievable is to be included in the method statement.

### 2.2.2 Control observation

All co-ordinate and level values generated must be expressed in metres to three decimal places and presented in the order of easting (X), northing (Y) and height (Z). They are to be derived from a rigorously observed traverse and/or GPS network to ensure that the following tolerances are satisfied before adjustment:

(b) The horizontal closure error of any traverse shall not exceed ± 10mm
   The vertical closure error of any traverse shall not exceed ± 10mm

Adjustments carried out to the observed network, including type and method of adjustment used and the results of transformations, are to be detailed in the final survey report.

### 2.2.3 Existing co-ordinate system

There is

(a) an existing site co-ordinate system (see Appendix C Survey Station Information).

Where a previously defined site co-ordinate system exists, the necessary information will be supplied by the client to allow the re-occupation of permanently marked points. This will include a full listing of 3-D co-ordinates and witness diagrams. During re-occupation and re-observation the precision of any co-ordinate and level information provided must be evaluated to ensure the new survey can be generated within the appropriate tolerances. Where discrepancies are found, the client is to be contacted to agree any necessary variations.

### 2.2.4 New co-ordinate system

N/A

### 2.2.5 Vertical datum (Height control)

The vertical datum for the survey is to be

(a) the Ordnance Survey height datum. This is to be achieved by means of GPS observation as described in Section 2.5.1 and the OSGM02 transformation.

### 2.2.6 Establishment of permanent survey marks

Due to the archaeologically sensitive nature of the site

(b) The establishment of new permanent survey marks is not required unless natural features can be used. Temporary stations should be marked with small nails or short wooden pegs and removed before the commission is completed.

Any re-survey in the future may have to be matched to the current survey through GPS observation therefore it is recommended that extended occupation times are allowed for.

### 2.2.7 Witnessing of stations

Full witness diagrams are to be provided with the survey for any permanently marked stations. Witness diagram sheets must include:

- Co-ordinate values to three decimal places as eastings (X), northing (Y) and height (Z)
• A sketch diagram and dimensions to at least three points of hard detail
• A written description of the mark
• A photograph of the location.

A traverse diagram must also be provided (see Sections 3.3.6 and 3.4.5).

2.2.8 Use of ground marks
Permanent or temporary ground marks are to be as non-invasive as possible and preferably existing detail should be used. The type and location of any permanent mark must be approved by the client before insertion. In some cases scheduled monument consent (SMC) will be required.

2.2.9 Use of targets on historic fabric
Where survey targets are to be applied to historic fabric, a suitable non-marking, non-destructive adhesive must be used. This must allow the removal of the targets without damage to, or marking of, the fabric. Details of the proposed adhesive are to be included in the method statement for the survey. The client reserves the right to refuse application if the proposed substance is deemed to be unsuitable for historic buildings or monuments. All targets must be removed before the commission is completed; any targets still remaining after completion will still have to be removed at the contractor’s expense.

2.3 Image-based Surveys
N/A

2.4 Measured Building Surveys
N/A

2.5 Topographic Surveys
N/A
SECTION 3

Format, Presentation and Provision of Survey Data

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   3.1.3 Digital image format
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   3.4.4 Labelling of final material
   3.4.5 Survey material to be supplied

3.5 Provision of Survey Material
   3.5.1 Preliminary plots
   3.5.2 Delivery of material
3.1 Digital Data

3.1.1 CAD and digital images filenames
All CAD, digital image filenames are to be eight characters in length and must follow
(a) the following file referencing system. The standard abbreviation for the site is STN

<table>
<thead>
<tr>
<th>Characters</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – 3</td>
<td>Standard abbreviation of the monument name e.g. STN (Stonehenge)</td>
</tr>
<tr>
<td>4 – 5</td>
<td>Year survey/plotting carried out e.g. 09 (2009)</td>
</tr>
<tr>
<td>6</td>
<td>Type of survey</td>
</tr>
<tr>
<td>P</td>
<td>(photogrammetry – original images and 3-D CAD data)</td>
</tr>
<tr>
<td>Q</td>
<td>(photogrammetry – CAD drawing sheets)</td>
</tr>
<tr>
<td>O</td>
<td>(orthophotography – images and CAD files)</td>
</tr>
<tr>
<td>R</td>
<td>(rectified photography - images and CAD files)</td>
</tr>
<tr>
<td>M</td>
<td>(measured survey)</td>
</tr>
<tr>
<td>T</td>
<td>(topographic survey)</td>
</tr>
<tr>
<td>7 – 8</td>
<td>Sequential file number from 01 to 99</td>
</tr>
</tbody>
</table>

E.g. STN09P01.DWG, STN09R01.TIF

3.1.2 CAD data format
All CAD files including any drawing sheets used to provide any rectified photography, orthophotography and any digital elevation model (DEM) data are to be
(a) AutoCAD 2007 .DWG

3.1.3 Digital image format
Any digital images are to be supplied
(a) as shown below
• Where film negatives have been scanned, original uncompressed TIF files.
• Where digital cameras have been used, one set of the original RAW image files, if applicable, plus TIFF versions.
• Where the product is rectified photography or orthophotography the processed images as TIF files.

3.1.4 Storage medium
All of the required CAD data, image files and associated listings are to be supplied on
(c) portable hard-disk

See Section 1.7.2 Retention of survey documentation.

3.2 CAD Requirements

3.2.1 Use of CAD co-ordinate systems
A user co-ordinate system (UCS) other than the world co-ordinate system (WCS) may be used to facilitate the presentation of the survey (or part thereof) on the desired sheet layout. See Section 3.3.2 Standard views, for further details. Any such UCS must be saved with a name related to its function e.g. ‘SHEETVIEW’ for a UCS set up for a drawing sheet.
Original 3-D photogrammetric data, without the addition of any title or border information, is to be provided set up in the following AutoCAD co-ordinate systems:

- The ‘WCS’ related directly to the site (ground control) co-ordinate system
- A ‘UCS’ called ‘FRONT’ to enable the separate elevations to be viewed and edited directly as an orthogonal view. The origin of the UCS must ensure that all elements within the object area are positive with low co-ordinate values, e.g. the lower left-hand control point given arbitrary values of 10 m for the X and Z axes. The Y axis must be set to the true heights of the ground control.

See Figure 3.1

As well as original 3-D data, the data for each formatted drawing sheet is to be provided in

(a) 2-D form only

3.2.2 Insertion point
The default origin of (0,0,0) in the WCS is to be used for insertions.

3.2.3 CAD drawing unit
The CAD drawing unit is to be

(a) 1 m

3.2.4 Other CAD variables
Where possible, a dashed linetype is to be used for dashed lines as opposed to using a broken line. The linetype scale is to be commensurate with the plot scale so that it actually appears as a dashed line when plotted.

Use of Paper space
(b) Paper space is not to be used. Each printed drawing sheet must be represented by a unique CAD file.

3.3 Presentation

3.3.1 Drawing sheets
No hard-copy output is required.

3.5 Provision of Survey Material

3.5.1 Preliminary plots
N/A

3.5.2 Delivery of material
Two (2) sets of all related digital data, formatted as per section 7, is to be delivered to the following addresses:

Paul Bryan
English Heritage,
37 Tanner Row,
York
YO1 6WP
UK
SECTION 7

Standard Specification for the Collection and Archiving of Terrestrial Laser Scan Data

7.1 Definition of Terms
   7.1.1 Terrestrial laser scanning
   7.1.2 Point cloud
   7.1.3 Point density

7.2 Data Collection
   7.2.1 Pre-survey deliverables
   7.2.2 Certification requirements
   7.2.3 Health and Safety
   7.2.4 Point density and measurement precision
   7.2.5 Overview and detail scans
   7.2.6 Overlapping scans
   7.2.7 Data voids
   7.2.8 High level coverage
   7.2.9 Weather
   7.2.10 Survey control and co-ordinate systems
   7.2.11 Targets and control points

7.3 Provision of Point Cloud Data
   7.3.1 Standard deliverables
   7.3.2 Registration
   7.3.3 Intensity/colour information
   7.3.4 Additional image data

7.4 Storage and Archive of Point Cloud Data
   7.4.1 Data format
   7.4.2 File naming convention
   7.4.3 Scan metadata
   7.4.4 Project metadata
   7.4.5 Registration information
   7.4.6 Control information
   7.4.7 File sizes
   7.4.8 Media
   7.4.9 Retention of survey documentation

Appendix 7.1 Health and Safety Considerations

Appendix A Proposed Areas of Coverage

Appendix B Proposed Outputs

Appendix C Survey Station Information
7.1 Definition of Terms

7.1.1 Terrestrial laser scanning
For the purposes of this document terrestrial laser scanning is defined as the use of a ground based device that employs a laser to measure the three-dimensional co-ordinates of a given region of the surface of an object automatically, in a systematic order and at a high rate in (near) real time.

7.1.2 Point cloud
A collection of XYZ co-ordinates in a common co-ordinate system that portrays to the viewer an understanding of the spatial distribution of a subject or site. It may also include additional information such as an intensity or red, green, blue (RGB) values. Generally a point cloud contains a relatively large number of co-ordinates in comparison with the volume the cloud occupies, rather than a few widely distributed points.

7.1.3 Point density
The average distance between XYZ co-ordinates in a point cloud represented in a spatial or angular manner. Where a spatial value is given this must be supported by the distance from the scanner to the subject. The quoted point density for any scan should always be given as the minimum density of points for data on the subject, not including, peripheral data (i.e. data outside the area of interest).

7.2 Data Collection

7.2.1 Pre-survey deliverables
Prior to survey a method statement as defined in Section 1.3.2 is required. In the case of terrestrial laser scanning the method statement is also to include
- technical specifications of the scanning system(s) to be used
- the proposed point density
- the location and extent of potential data voids and a proposal for their amelioration.

7.2.2 Certification requirements
The method statement is to be accompanied by

either (a) a calibration certificate for the laser scanning system
or (b) details of tests, performed within the last 12 months, which show that the scanner has achieved the required geometric precision and geometric accuracy.

7.2.3 Health and Safety
Readers are referred to IEC 60825:1 (2001) for the full precautions on the user of lasers. However, explicitly

- only an appropriately trained individual may operate a laser scanner on site. Signs warning visitors that lasers are in use must also be displayed.
systems that use Class 3B or Class 4 lasers are not acceptable for use on English Heritage sites.

7.2.4 Point density and measurement precision
All reference to point density is to be given as the average 3-D distance between points at a defined range.

- Landscape within the 'triangle' – using terrestrial laser scanners to capture a point-spacing (resolution) of at least 10cm
- The stone circle and landscape immediately surrounding it – using terrestrial laser scanners to capture a point-spacing of at least 2cm for the landscape and up to 1mm for the stones themselves
- The standing and fallen stones - using close-range and/or high-resolution terrestrial scanners to capture as many visible faces of the stones at a point-spacing of at least 0.5mm

7.2.5 Overview and detail scans
Overview scans are

(b) not required

Detail scans are

(a) required at the above resolutions

7.2.6 Overlapping scans
It will

(b) be acceptable

to filter areas of overlapping scan data, so as to reduce the point density in the final registered point cloud.

7.2.7 Data voids
Data voids are to be kept to an absolute minimum. Voids caused by temporary obstructions such as cars and pedestrians will not be acceptable, unless it is impossible to restrict access in which case this is to be highlighted in the method statement. Voids caused by occlusion are to be minimised by using multiple scans or access equipment. If significant problems with occlusion are anticipated then this is to be highlighted in the method statement.

7.2.8 High level coverage
High level coverage of the upper surfaces of the stones, including trilithons, is required.

7.2.9 Weather
If working outdoors, the weather conditions during the survey should be recorded. Scanning/image capture must not be performed in adverse weather conditions where the quality of observed data could be affected.

7.2.10 Survey control and co-ordinate systems
The methods and networks used for providing survey control are discretionary. However, details of the method and equipment proposed must be included in the method statement. Where a survey co-ordinate system already exists the necessary information will be
supplied to allow the reoccupation of previously installed points. This will include a full listing of 3-D co-ordinates and witness diagrams.

7.2.11 Targets and control points

Targets must not be so positioned, or be so large, that they obscure important details of the subject. A description of the targets to be used must be given in the method statement and the location and naming of targets is to be clearly given on the site sketches that accompany the survey report.

The use of natural detail points should be avoided, but where necessary the use of distinct features is acceptable providing the point density of the scan is sufficient to maintain the registration requirements in Section 7.3.2 of this document. The use of features at distinct corners or edges is not permitted. Where natural detail points are to be used this must be noted in the method statement. See also Sections 1.6.2 and 2.2.9.

7.3 Provision of Point Cloud Data

7.3.1 Standard deliverables

The following standard deliverables are required. See Section 7.4 for a full description of the appropriate media, formats and required metadata. The standard deliverables in digital form are:

- Project metadata
- Raw scan data (for archive)
- Registered scan data (for archive)
- Scan metadata
- Registration information for all raw scans to the site co-ordinate system
- Control information.
- In addition the data is to be ‘meshed’ to provide 3D surface models, ideally in textured form, for both the surrounding landscape, standing and fallen stones.

A survey report, supplied as a PDF file, is also required containing:

- Diagrams showing the position of scanning stations and control points.
- Details of the traverse/control network used, three-dimensional co-ordinates of all control points and residuals for the computed XYZ control.
- The precision of any parameters derived in the registration process for each scan along with the residuals of the registration.
- A summary outlining the completeness of the point cloud and all known data voids.
- Any site sketches/additional field notes made during field work.

Two copies of all digital and hardcopy data/documentation are required on delivery.
7.3.2 Registration

Individual scans used to achieve the required coverage must be registered together. The residuals of the registration process must be shown to be equal to or better than the geometric precision required by the end deliverable. Registration is to be done:

(a) via a resection calculation from controlled targets – each scan must contain a minimum of four appropriately distributed XYZ control points/targets. The residuals of the registration process and the geometric precision of the estimated parameters should be noted in the survey report.

or

(c) using a known station position/s and orientation/s – the data must include at least three appropriately distributed XYZ control points and the residuals of the registration process and the precisions of the estimated parameters should be noted in the survey report.

Irregular features in the scan data caused by cracks or features on the subject that could be misinterpreted as errors in the registration must be augmented with illustrative photography and noted in the final survey report.

7.3.3 Intensity/colour information

Intensity/colour information can be recorded on a per point basis at each scan position where the instrumentation allows. Intensity/colour information

(a) is required

7.3.4 Additional image data

Additional image data is to be collected to both show the location of the scanner and the subject being scanned. As well as being used for narrative purposes this will also form textural information for the resultant 3D model/s. This imagery is to be of a high resolution and must clearly portray the subject in question. It is to be delivered as specified in Section 3.

7.4 Storage and Archive of Point Cloud Data

7.4.1 Data format

The scan ‘point cloud’ data is to be delivered in the following format

(c) both ASCII and proprietary scanner format

Contactors must ensure that all of the standard file header information is included.

In addition scans are to be provided in the Leica ‘Truview’ format to enable desktop viewing.

The 3D model data is to be supplied in OBJ format. However the contractor is to advise on the following:

- what arrangement of 3D data points will be used – gridded or irregular
- degree of decimation proposed for both the landscape, standing and fallen stones.
7.4.2 File naming convention

(a) following the convention described in section 3.1.1.

The contractor must provide a 'readme' file to document the contents, structure and naming of the delivered data.

7.4.3 Scan metadata

Metadata (information relating to the captured information) is required with all raw scan data and scanning projects. Metadata is to be provided in both hardcopy and digital form. It must include:

- File name of the raw data
- Date of capture
- Scanning system used - with manufacturer’s serial number
- Company name
- Monument name
- Monument number (if known)
- Survey number (if known)
- Scan number (unique scan number for this survey)
- Total number of points
- Point density on the object (with reference range)
- A record of the weather conditions during scanning (external scanning only)

7.4.4 Project metadata

A single project metadata file is required with the project. This must include the following:

- Filename(s) of the raw data used in the registration
- Data of capture (month and year)
- Scanning system(s) used - with manufacturer’s serial number(s)
- Company name
- Monument name
- Monument number (if known)
- Survey number (if known)
- Number of individual scans
- Scan numbers of all scans
- Total number of points
- Filename of the control data
- Description of registration method (e.g. “All scans registered to local site grid using targeted points.”)
- An index plan showing the data collected with individual scan points named
- Weather during survey (external scans only)
- Any scanner specific information.

7.4.5 Registration information

The following is to be supplied as registration information:

- Translations in the X, Y and Z axes necessary to transform the scan origin to the scan position.
- Rotations around the X, Y and Z axes. This should be carried out in the order X, Y and Z.

7.4.6 Control information

The following information should be supplied as control information:

- Point ID, X, Y, Z, comment (optional)

7.4.7 File sizes

Individual file sizes are to be limited to the capacity of a standard single DVD-ROM (4.7 GB).

7.4.8 Media

All data is to be provided on portable hard disk.

7.4.9 Retention of survey documentation

See Section 1.7.2 for general requirements.
Appendix 7.1 Health and Safety Considerations

The European Standard ‘Safety of Laser Products – Part 1: Equipment classification, requirements and users guide’ (IEC 60825-1: 2001) provides information on lasers and describes precautions on the use of laser products. Users should refer directly to this document when preparing health and safety assessments. However, a brief summary is provided below.

Dangers

Lasers used in survey applications may have risks associated with eye damage. The European Standard (IEC 60825-1: 2001) provides seven classes of lasers.

- **Class 1** lasers are safe under reasonably foreseeable conditions of operation, including the use of optical instruments for intrabeam viewing.
- **Class 1M** lasers are safe under reasonably foreseeable conditions of operation, but may be hazardous if optics are employed within the beam.
- **Class 2** lasers normally evoke a blink reflex that protects the eye; this reaction is expected to provide adequate protection under reasonably foreseeable conditions, including the use of optical instruments for intrabeam viewing.
- **Class 2M** lasers normally evoke a blink reflex that protects the eye, this reaction is expected to provide adequate protection under reasonably foreseeable conditions. However, viewing of the output may be more hazardous if the user employs optics within the beam.
- **Class 3R** lasers are potentially hazardous where direct intrabeam viewing is involved, although the risk is lower than that for Class 3B lasers.
- **Class 3B** lasers are normally hazardous when direct intrabeam exposure occurs, although viewing diffuse reflections is normally safe. This class of laser is generally not suited for survey applications.
- **Class 4** lasers will cause eye or skin damage if viewed directly. Lasers of this class are also capable of producing hazardous reflections. This class of laser is not suited for survey applications.

Users of laser scanning systems should always be aware of the class of their instrument. In particular the user should ensure the correct classification system is being used (e.g. IEC 60825-1: 2001 and not BS EN 60825-1: 1994 or other standard which differ slightly in classification).

Precautions

The European Standard IEC EN 60825-1: 2001 provides a number of safety precautions that should be observed during use of laser scanning surveys. For lasers up to Class 3R (those normally used in survey applications) and where applicable to laser scanning for metric survey these precautions are briefly outlined below.

For a full description the user is referred directly to the European Standard, however, generally:
• Care should be taken to prevent the unintentional specular reflection of radiation.

• Open laser beam paths should be located above or below eye level where practical.

• Only persons who have received training to an appropriate level should be placed in control of laser systems. The training, which may be given by the manufacturer or supplier of the system, the laser safety officer or an approved external organisation should include, but is not limited to: familiarization of operating procedures; the proper use of hazard control procedures, warning signs etc; the need for personal protection; accident reporting procedures and bioeffects of the laser upon the eye and skin.

• Particular care should be taken through the use of magnifiers or telescopes around laser devices that may pose a risk when intrabeam viewing is used.

• The instrument should only be used in accordance with the manufacturer’s instructions.

For lasers that emit energy outside the wavelength range of 400 nm to 700 nm special considerations are often required. For example

• Where using a Class 3R laser a laser safety officer should be appointed.

• Beam paths should be as short as possible and avoid crossing walkways and access routes.

Particular precautions and procedures are outlined in the IEC standard for Class 1M, Class 2M and Class 3R laser products used in surveying, alignment and levelling. Those with relevance to laser scanning are:

• Only qualified and trained persons should be assigned to install, adjust and operate the laser equipment.

• Areas where these lasers are used should be posted with an appropriate laser warning sign.

• Precautions should be taken to ensure that persons do not look into the beam (prolonged intrabeam viewing can be hazardous). Direct viewing of the beam through optical instruments (theodolites, etc.) may also be hazardous.

• Precautions should be taken to ensure that the laser beam is not unintentionally directed at mirror-like (specular) surfaces.

• When not in use the laser should be stored in a location where unauthorized personnel cannot gain access.

Other considerations

In addition to the risks associated with lasers, users should be aware that due to the size and weight of some systems there is a risk of injury to visitors, especially children, if systems are left unaccompanied.

The effect of laser scanning on features such as lichens and delicate fabrics is not well understood. Consideration should be given to the use of lasers in the vicinity of such features.
Appendix A Proposed Areas of Coverage

**Proposed application of laser scanning within AS&I project**

- This will hopefully cover the following:
  - Landscape within the ‘triangle’ – using terrestrial laser scanners to capture a point-spacing (resolution) of at least 10cm
  - The stone circle and landscape immediately surrounding it – using terrestrial laser scanners to capture a point-spacing of at least 2cm for the landscape and up to 1mm for the standing stones themselves
  - The stones, both standing and fallen - using close-range and/or high-resolution terrestrial scanners to capture as many visible faces of the stones at a point-spacing of at least 0.5mm
## Appendix B Proposed Outputs

<table>
<thead>
<tr>
<th>Proposed outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Individual raw scan data files supplied in both ASCII and proprietary formats</td>
</tr>
<tr>
<td>• Registered scan data files supplied in both ASCII and proprietary formats</td>
</tr>
<tr>
<td>• Scan data supplied in Leica’s Truview format</td>
</tr>
<tr>
<td>• 3D surface model/s supplied in OBJ format</td>
</tr>
</tbody>
</table>
### Survey Station Information

**Site Name**: Stonehenge  

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Stonehenge</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Station Number</th>
<th>Z1</th>
<th>Status</th>
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<tr>
<td>Type of Mark</td>
<td>Rivet in concrete at depth of 0.1-0.15m</td>
<td>NMR number</td>
<td></td>
</tr>
<tr>
<td>Date of Survey</td>
<td>18-Mar-09</td>
<td>SAM number</td>
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<td>Office of Origin</td>
<td>Swindon</td>
<td>Surveyors</td>
<td>DF; TP</td>
</tr>
<tr>
<td>Methodology</td>
<td>Point surveyed to OS National Grid using Trimble R8 GNSS receiver over 180 epochs with differential correction delivered via Trimble VRS from OS Active Station network</td>
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<td></td>
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<table>
<thead>
<tr>
<th>Coordinate Scheme</th>
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<th>Northings</th>
<th>Height</th>
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</thead>
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<td>Local Grid</td>
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### SURVEY STATION INFORMATION

<table>
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<th>SITE NAME</th>
<th>Stonehenge</th>
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<tr>
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<td>Z2</td>
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<td>Status</td>
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<tr>
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</tr>
<tr>
<td>Status</td>
<td>NMR number</td>
</tr>
<tr>
<td>Date of Survey</td>
<td>18-Mar-09</td>
</tr>
<tr>
<td>SAM number</td>
<td></td>
</tr>
<tr>
<td>Office of Origin</td>
<td>Swindon</td>
</tr>
<tr>
<td>Surveyors</td>
<td>DF, TP</td>
</tr>
<tr>
<td>Methodology</td>
<td>Point surveyed to OS National Grid using Trimble R8 GNSS receiver over 180 epochs with differential correction delivered via Trimble VRS from OS Active Station network</td>
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</table>

### CO-ORDINATE SCHEME

<table>
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<th>Northing</th>
<th>Height</th>
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</thead>
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<tr>
<td>Local Grid</td>
<td></td>
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**SURVEY STATION INFORMATION**

<table>
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<tr>
<th><strong>SITE NAME</strong></th>
<th>Stonehenge</th>
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</thead>
<tbody>
<tr>
<td><strong>Station Number</strong></td>
<td>Z4</td>
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<tr>
<td><strong>Status</strong></td>
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<tr>
<td><strong>Type of mark</strong></td>
<td>Rivet in concrete block at depth of 0.1-0.15m NMR number</td>
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<tr>
<td><strong>Date of Survey</strong></td>
<td>18-Mar-09 SAM number</td>
</tr>
<tr>
<td><strong>Office of Origin</strong></td>
<td>Swindon Surveyors DF; TP</td>
</tr>
<tr>
<td><strong>Methodology</strong></td>
<td>Point surveyed to OS National Grid using Trimble R8 GNSS receiver over 180 epochs with differential correction delivered via Trimble VRS from OS Active Station network</td>
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<table>
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<th><strong>CO-ORDINATE SCHEME</strong></th>
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<th><strong>Northing</strong></th>
<th><strong>Height</strong></th>
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<td>99.8</td>
</tr>
<tr>
<td>Local Grid</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Note: Access into the Stone Circle is only permitted outside normal visitor opening times.

Stonehenge Visitor Opening Times:
- 16 March – 31 May: 09.30 – 18.00
- 1 June – 31 August: 09.00 – 19.00
- 1 September – 15 October: 09.30 – 18.00
- 16 October - 15 March: 09.30 – 16.00

1. English Heritage requires the submission of a method statement and risk assessments for every activity which is planned. These are to be submitted to the project assurance officer at least six weeks before commencement of activities. English Heritage reserves the right to prohibit or modify planned activities.

2. English Heritage requires that contractors working at Stonehenge carry a minimum of £5m public liability insurance.

3. English Heritage accepts no liability for any injury to persons or damage to property, arising in any way whatsoever whilst at Stonehenge.

4. If it is a requirement to have access to the monument at night when it is dark then it is necessary for the contractor to supply adequate and appropriate lighting. Note: there is no artificial lighting available at Stonehenge, nor are there any power sources close to hand.

5. No person may touch, lean against, stand on, or climb on the stones, or disturb the ground in any way. No equipment can be attached to, leant on or supported by the stones.

6. Suitable matting/boards must be provided for all equipment that is approved, to prevent damage to the underlying ground.

7. All equipment must be stowed responsibly when not in use.

8. If it is necessary to use temporary targets, either in the ground or on the stones English Heritage must be supplied with specifications. If there is an agreed need to fix targets to the surface of any stones English Heritage must be supplied with the data sheets in order to ensure that there is no damage to the stones or the lichens growing on them.

9. If cabling is a necessity, then it should be kept to a minimum, with any loose cabling being matted to prevent a tripping hazard.

10. There must be no damage as a result of access. This includes ground penetration and wear and tear of the ground. If any chemicals are to be brought onto site a full data sheet must accompany the relevant risk assessment. English Heritage reserves the right to refuse the use of certain chemicals.

11. No dogs are allowed beyond the main entrance point [except guide dogs].

12. The contractor and their representatives must adhere to any instruction(s) given by English Heritage staff or their representatives regarding the use of the monument prior to and during access. The applicant will be required to pay the reasonable costs of any damage caused.

13. Eating, drinking or smoking is not permitted at any time inside the stone circle or anywhere in the Monument Field.

14. Any breach of these Terms and Conditions, especially climbing on the stones, will result in any individual or group being asked to leave the site.