Technical Appendix 5.2

Assessment of Night-time Lighting: Assessment Criteria and Methodology

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1.1 Introduction

1.1.1 In accordance with Civil Aviation Authority (CAA) CAP 764, turbines taller than 150 m require visible aviation lighting and an adjusted visible aviation lighting scheme has been devised for the Proposed Development. In total eight turbines (T1, T4, T6, T9, T11, T13, T16 and T18) are proposed to be fitted with visible red 2000/200 cd steady state lights on the nacelle of each turbine.

1.1.2 This **Technical Appendix** sets out the methodology and approach to the assessment of landscape and visual effects arising from the visible lighting of the Proposed Development set out within the Landscape and Visual Impact Assessment (LVIA) chapter. It has been guided by NatureScot's "Guidance on Aviation Lighting Impact Assessment" (Ref 1) . The written assessment is supported by Zone of Theoretical Visibility (ZTV) plans showing where the lit turbines are visible from in theory (see **Figure 5.8**) and showing the theoretical intensity of the lighting at **Figure 5.9**. Visualisations illustrating the proposed turbine lighting from viewpoints 1, 3, 6 and 9 in the surrounding landscape have also been produced and are included at **Volume 3**. The approach to the production of this supporting visual material is addressed in this appendix.

1.1.3 The primary source of best practice for Landscape and Visual Impact Assessment (LVIA) in the UK is 'The Guidelines for Landscape and Visual Impact Assessment', 3rd Edition (GLVIA3) (Landscape Institute and the Institute for Environmental Management and Assessment, 2013). The assessment criteria for the assessment of effects of visible turbine lighting has been developed in accordance with the principles established in this best practice document. It should however be acknowledged that GLVIA3 establishes guidelines not a specific methodology. The preface to GLVIA3 states:

> *"This edition concentrates on principles and processes. It does not provide a detailed or formulaic 'recipe' that can be followed in every situation – it remains the responsibility of the professional to ensure that the approach and methodology adopted are appropriate to the task in hand."*

1.1.4 The assessment criteria set out below have therefore been developed specifically for this appraisal to ensure that the methodology is fit for purpose.

1.1.5 The purpose of an LVIA when undertaken in the context of an Environmental Impact Assessment (EIA) is to identify any likely significant landscape and visual effects arising as a result of the proposals. An LVIA should consider both:

- effects on the landscape as a resource in its own right (the landscape effects); and
- effects on specific views and visual amenity more generally (the visual effects).

1.1.6 For an assessment during daylight hours, one assesses the worst-case situation (i.e. clear full visibility as if a perfect day). A daytime assessment can therefore describe the full extent of that clear visibility, or lack of it, as a moment in time.

1.1.7 For an assessment of visible aviation lighting an understanding of light conditions after sunset and before sunrise is required.

1.1.8 *"Sunrise and sunset are taken to be the times at which the apparent upper limb of the Sun is on the (astronomical) horizon." "Twilight is the interval preceding sunrise and following sunset when the sky is partially illuminated."* (Ref 2)

1.1.9 The visible aviation lights will be switched on between Evening Civil Twilight and Morning Civil Twilight in accordance with the UK Almanac.

1.1.10 Therefore, the visual assessment of the effects of visible aviation lighting has taken place after the commencement of Evening Civil Twilight, within the period commonly referred to as "dusk", when some degree of the landscape's features can be discerned which is considered to be a reasonable worst-case.

1.1.11 However, it should be recognised that as the sun continues to dip below the horizon through the periods of civil, nautical and astronomical twilight, light levels continue to fall and the amount of discernible landscape features rapidly decreases. Therefore, the assessment has focussed solely on the effects of the visible aviation lighting on visual amenity. Without being able to fully appreciate landscape features and components that contribute to landscape character it is not possible to carry out a meaningful landscape character assessment. This precedent was established in the Scottish Ministers' decision for Crystal Rig IV (WIN-140-8). (Ref 3) (Ref 4)

1.2 Description of the Proposed Turbine Lighting, Mitigation Measures and Assumptions made in the Assessment Visualisations

1.2.1 In accordance with Civil Aviation Authority (CAA) CAP 764 turbines taller than 150 m require visible aviation lighting. An adjusted visible aviation lighting scheme has been devised for the Proposed Development. In total eight turbines (T1, T4,T6, T9, T11, T13, T16 and T18) are proposed to be fitted with visible red 2000/200 cd lights on the nacelle of each turbine. These will operate in the reduced 200 cd intensity where meteorological visibility is greater than 5 km and where visibility is less than 5 km the lights will operate at 2000 cd. The lights are required to be at maximum intensity at 3 degrees above and 1 degree below horizontal. Light intensity reduces beyond those parameters.

1.2.2 It has also been assumed that there will be no requirement for intermediate lighting to be installed halfway between the nacelle and the ground-level.

1.2.3 Should the relevant regulatory actions concerning the mandatory carriage of a compatible Electronic Conspicuity system on aircraft be completed and signed into law the project could consider the installation an Electronic Conspicuity (i.e. transponder) based Aircraft Detection Lighting System, the Applicant is committed to exploring mitigation options and could implement this in discussion and with the agreement of relevant stakeholders in due course should this technology become viable. The installation of such a suitable Aircraft Detection Lighting System would significantly reduce the occasions when the lighting would be visible.

1.2.4 For the purpose of the figures and visualisations prepared to help inform the assessment of visible aviation lighting set out in the LVIA, the following assumptions have therefore been made in light of the proposed mitigation:

- Lighting is only shown on the eight turbines proposed to be fitted with steady state visible aviation lighting;
- No intermediate lighting is illustrated halfway between the nacelle and the ground-level in line with the proposed lighting scheme;
- As the photography was taken in clear weather conditions when visibility was greater than 5 km, the visualisations illustrate the reduced 200 cd intensity to reflect the lighting that would arise in those conditions as a result of the mitigation proposed. It is understood that these images nonetheless represent the worst-case as should visibility be less than 5 km such that the 2000 cd lighting was active, then these poor conditions would of themselves be such as to restrict the visibility of the lighting to no more than that of the 200 cd lighting seen in clear conditions. This approach is consistent with NatureScot guidance on Aviation Lighting Impact Assessment;
- The reduction in the intensity of lights above and below the horizon has been illustrated on **Figure 5.9** – Turbine Lighting Intensity to 20 km with Viewpoints. This ZTV shows the theoretical reduction in the candela intensity of the lights at vertical angles above and below the horizon

to illustrate the reduction in the intensity of the lights at elevations below the level of the turbine lights;

- Whilst the lighting would reduce in intensity above and below the horizontal this reduction has not been illustrated in the night-time visualisations. As such the visualisations are a worst-case. This matter has however been considered within the assessment judgements, with reference to **Figure 5.9**;
- The visualisations illustrate the period after the commencement of Evening Civil Twilight, when sufficient ambient light remains for the landform of the landscape on which the wind farm is proposed, to remain partially visible. The assessment also focuses on this period, which represents a 'worst-case';
- Whilst the implementation of a suitable Aircraft Detection Lighting System would significantly reduce the occasions when the lighting would be visible, this has not been factored into the judgements of lighting effects which focus on the 'worst-case' scenario of the period when the lighting would be visible;
- It is noted that the matter of darkness adaption is also a relevant consideration, with some receptors, in particular car drivers, not perceiving the lighting in the same manner as if they were in a fully dark environment, due to their vision being influenced by lighting sources in their proximity (i.e. car headlights). The same would apply to residents of residential properties who were viewing the aviation lighting from a location with existing lighting present (i.e. it is unlikely that residents would themselves be fully in a dark environment and their eyes therefore adapted to take in the full extent of the light from the turbines). This serves to further reduce the effects compared to how they are set out in the assessment, which again can be considered to represent a 'worst-case' position compared to what would be experienced by many of the receptors in practice; and
- The frequency in which a viewpoint is likely to be visited during the hours of darkness is not a factor which is considered within the assessment of magnitude or sensitivity. However, it should be noted that viewpoints at hills summits and on long distance footpaths would be unlikely to be visited after daylight hours. Any assessment of these receptors should therefore be considered a 'worst-case' scenario as in many cases the actual numbers of individuals who would be likely to experience the view would be very limited, although it is recognised that there will be a few individuals such as landscape photographers who may visit hilltops to take photographs at sunset or sunrise or people star gazing.

1.3 Analysis of Aviation Lighting

1.3.1 In order to help inform the judgements made, site visits have been undertaken to the Middleton Wind Farm, East Renfrewshire, an operational commercial scale wind farm with aviation lights operating simultaneously at both 2000 candela (cd) and 200 cd. This has enabled consideration of aviation lighting in comparable low light levels, during the hours of darkness, for use as context and an aid to the work undertaken. A Photographic Record of images of the Middleton Wind Farm during low light conditions is set out at **Annex 1** to this **Technical Appendix**, along with a further supporting record of images of the Emley Moor Transmitter mast in **Annex 2**, which has also been used as a guide (Emley Moor is a 300 m concrete tower and mast lit with 2,000 candela lights close to the Pegasus Office in Leeds, which has also been used as a convenient control and test location to 'ground truth' judgements).

1.3.2 Whilst these two sites act as an aide, it should be acknowledged that the aviation lighting proposed for the Proposed Development is different and will use the latest technology to mitigate the effect on the surrounding area.

1.3.3 Part of this additional site work also sought to consider if there would be any potential for surface illumination of the turbine blades, tower or nacelle as a result of the aviation lighting to be visible in the wider landscape surrounding a wind farm. There was no clear visibility of such phenomena in the wider landscape during the site work undertaken, however, it is understood that such events may be possible in proximity to lit turbines in locations with very low natural light. It is therefore acknowledged as part of the judgements made within the assessment that such occurrences may be possible as a worse-case scenario but that they would not be typical of the general experience of the lighting when seen from the landscape.

1.3.4 A separate phenomenon which was experienced during the site visit to Middleton, was the manner in which the turbine blades passing in front of the turbine lighting serve to cause a temporary dimming and brightening of the lights. This is something which only occurs when the turbines are viewed with the blades in front of the nacelle and therefore is dependent on the prevailing wind direction on any given day. The dimming and brightening effect serve to increase the noticeability of the turbines within the view and therefore increases their visual effect. It is therefore acknowledged as part of the judgements made within the assessment that such occurrences would periodically occur in relation to the proposed turbines (albeit the occurrence being most likely for locations to the south-west of the turbines where there are likely to be fewer visual receptors during the low light level period).

1.4 Approach to Sensitivity

Nature (Sensitivity) of Visual Receptors

1.4.1 The nature or sensitivity of a visual receptor group reflects their susceptibility to change and the value associated with the specific view in question. It varies depending on a number of factors such as the occupation of the viewer, their viewing expectations, duration of view and the angle or direction in which they would see the site. Whilst most views are valued by someone, certain viewpoints are particularly highly valued for either their cultural or historical associations and this can increase the sensitivity of the view. The following criteria are provided for guidance only and are not exhaustive:

- **Very Low Sensitivity** – People engaged in industrial and commercial activities, or military activities, who would be unlikely to have any particular expectation of their wider night-time view.
- **Low Sensitivity** - People at their place of work (e.g. offices); shoppers; users of trunk/major roads and passengers on commercial railway lines (except where these form part of a recognised and promoted scenic route). The primary interest of such receptors would not generally be on the dusk/night-time view.
- **Medium Sensitivity** - Users of public rights of way and minor roads which do not appear to be used primarily for recreational activities or the specific enjoyment of the landscape; recreational activities not specifically focused on the landscape (e.g. football). Such receptors may have some interest in their dusk/night-time view of the wider landscape, but generally their primary concern would be their immediate landscape context.
- **High Sensitivity** – Residents at home; users of caravan parks, campsites and 'destination' hotels; tourist attractions open after daylight hours with opportunities for views of the landscape (but not specifically focused on a particular vista); users of public rights of way or minor roads which appear to be used for recreational purposes or the specific enjoyment of the landscape during dusk/night-time (often likely to be in close proximity to residential areas).
- **Very High Sensitivity** - People at recognised vantage points (often with interpretation boards) which are designed to take in a night-time view, people at tourist attractions with a focus on a specific view which is available at dusk/ night-time, visitors to historic features/estates where the setting is important to an appreciation and understanding of cultural value and can be visited and appreciated during dusk/night-time.

1.4.2 It is important to appreciate that it is the visual receptor (i.e. the person) that has a sensitivity and not a property, public right of way or road. Therefore, a large number of people may use a motorway during dusk/ night-time, for example, but this does not increase the sensitivity of the receptors using it. Conversely, a residential property may only have one person living in it but this does not reduce the sensitivity of that one receptor.

1.4.3 Where judgements are made about the sensitivity of assessment viewpoints, the sensitivity rating provided shall be an evaluation of the sensitivity of the receptor represented by the viewpoint and not a reflection of the number of people who may experience the view.

1.4.4 It is also important not to confuse the concept of visual sensitivity with the perception of turbines. It is acknowledged that some people consider turbines to be unattractive, but many people also enjoy the sight of them. This matter is therefore not a factor when determining sensitivity.

1.5 Approach to Nature (Magnitude) of Effects

Nature (Magnitude) of effects on Views and Visual Amenity

1.5.1 Visual effects are caused by the introduction of new elements into the views of a landscape, or the removal of elements from the existing view. In this case the effects would be brought about by the addition of visible lighting.

1.5.2 Professional judgement shall be used to determine the magnitude of impacts using the following criteria as guidance only:

- **Very Low Magnitude of Change** - No change or negligible change in views;
- **Low Magnitude of Change** - Some change in the view that is not prominent but visible to some visual receptors;
- **Medium Magnitude of Change** - Some change in the view that is clearly notable in the view and forms an easily identifiable component in the view;
- **High Magnitude of Change** - A major change in the view that is highly prominent and has a strong influence on the overall view; and
- **Very High Magnitude of Change** – A change in the view that has a dominating or overbearing influence on the overall view.

1.5.3 Using this set of criteria, determining levels of magnitude is primarily dependant on how prominent the lighting associated with the development would be in the landscape, and what may be judged to flow from that prominence or otherwise.

1.5.4 For clarification, the use of the term ‘prominent’ relates to how noticeable the lighting associated with the Proposed Development would be. This is affected by how close the viewpoint is to the Proposed Development but not entirely dependent on this factor. Other modifying factors include: the focus of the view, visual screening and the nature and scale of other landscape features and visible lighting within the view. Rather than specifying crude bands of distance at which the turbines will be prominent or incidental to the view etc, the prominence of the turbines in each view is described in detail for each viewpoint or receptor group taking all the relevant variables into consideration.

1.6 Consideration of the Duration and Reversibility of effect

1.6.1 Prior to the publication of GLVIA3, LVIA practice had evolved over time in tandem with most other environmental disciplines to consider significance principally as a function of two factors, namely: the sensitivity of the receptor and the magnitude of the effect (the term ‘magnitude’ being a word most commonly used in LVIA and most other environmental disciplines to describe the size or scale of an effect).

1.6.2 The flow diagram on page 39 of GLVIA3 now suggests that the magnitude of effect is a function of three factors (the size/scale of the effect, the duration of the effect and the reversibility of the effect). This, however, is somewhat problematic in the context of assessing wind energy development. This is because wind energy developments are generally consented for a time limited period and are largely reversible at the end of their operational period. Whilst this is a material consideration in the planning balance it does not however, reduce the scale of the effect during the period in which the scheme is operational (i.e. the 'magnitude' of the effect in the traditional and commonly understood sense of the word). In this regard, it would be incorrect to report a lesser magnitude of change to the view during the operational phase as a result of the time limited period of the effect, or the relative reversibility of the effect.

1.6.3 The approach proposed to be taken in this assessment is therefore, to consider magnitude of effect solely as the scale or size of the effect in the traditional sense of the term 'magnitude'.

1.7 Approach to the Level Effects

1.7.1 The purpose of an LVIA when produced in the context of an EIA is to identify any significant effects on landscape and visual amenity arising from the proposed development.

1.7.2 The Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017 (Ref 5) do not define a threshold at which an effect may be determined to be significant. In certain other environmental disciplines, there are regulatory thresholds or quantitative standards which help to determine the threshold of what constitutes a significant effect. However, in LVIA, any judgement about what constitutes a significant effect is the judgement of a competent and appropriately qualified professional assessor.

1.7.3 The level (relative significance) of the landscape and visual effects is determined by combining judgements regarding sensitivity of the landscape or the viewer, the magnitude of change, duration of effect and the reversibility of the effect. In determining the level of residual effects, all mitigation measures are taken into account.

1.7.4 The level (relative significance) of effect shall be described as **Major, Moderate major, Moderate, Minor moderate, Minor, Negligible**. No Effect may also be recorded as appropriate where the effect is so negligible it is not even noteworthy.

1.7.5 In the assessment, those effects described as **Major, Moderate major** and in some cases **Moderate** may be regarded as significant effects as required by the EIA Regulations. These are the effects which the authors of the LVIA consider to be most material in the decision-making process.

1.8 Production of the Zone of Theoretical Visibility (ZTV) Plans

1.8.1 A Zone of Theoretical Visibility (ZTV) illustrates the extents from which a feature (in this case the visible lighting from a number of wind turbines) would theoretically be visible within a defined study area. Two types of ZTV plans have been prepared. **Figure 5.8** shows the theoretical visibility of the turbines proposed to be lit and illustrates the number of lit turbines theoretically visible from any point in the surrounding study area. In contrast, **Figure 5.9** illustrates the theoretical intensity of the turbine lights, taking into account the difference in elevation between the lights and any point in the surrounding study area and the resulting reduced candela. It does not, however, allow for the reduction in intensity due to distance from the turbine light.

1.8.2 ZTVs are generated assuming a 'bare ground' terrain model. This means that the ZTVs presented are generated from topographical data only and they do not take any account of vegetation or the built environment, which may screen views of the development. They are, as such, a 'worst case' zone of visual influence and considerably over-emphasises the actual visibility of the scheme. In reality trees, hedges and buildings may restrict views of the Proposed Development from many of the areas indicated on the ZTV as experiencing theoretical visibility.

1.8.3 The ZTVs have been generated using GIS software and are based on OS Terrain 5 height data. In the case of **Figure 5.8**, the programme then calculates whether any of the turbine lights would be visible from each 5m x 5m grid square for a specified distance in all directions. In the case of **Figure 5.9** the

programme calculates the theoretical visibility in each elevation band in degrees above and below the horizon.

1.8.4 It should be noted that when light travels from its source it diminishes in intensity, limiting the area that its source can illuminate, a process known as 'atmospheric attenuation' and is the result of absorption and scattering processes. Therefore, whilst the ZTV presented at **Figure 5.9** does not illustrate any reduction in intensity due to distance from the proposed lit turbines, it should be recognised that the aviation lighting would diminish in intensity with increased distance from the Proposed Development.

1.8.5 It should be noted that there are several limitations to the use of ZTVs. For a discussion of these limitations please refer to Visual Representation of Wind farms – Version 2.2 (SNH February 2017). In particular, it should be noted that the ZTV plan shall simply illustrate theoretical visibility and will not imply or assign any level of significance to those areas identified as being within the ZTV. A ZTV is a tool to assist the Landscape Architect to identify where the turbine lighting would potentially be visible from, however, the assessment of landscape and visual effects shall not rely solely on the ZTV and in all cases professional judgement shall be used to evaluate the significance of effects.

1.9 Production of Dusk Period Visualisations

Introduction

1.9.1 SNH (now NatureScot) Guidance, Visual Representation of Wind Farms, Version 2.2, February 2017, considers the matter of visible turbine lighting at paragraphs 174 to 177. This highlights that:

> *"Where an illustration of lighting is required, a basic visualisation showing the existing view alongside an approximation of how the wind farm might look at night with aviation lighting may be useful."*

1.9.2 The Guidance goes on to note that:

> *"This is only likely to be required in particular situations where the wind farm is likely to be regularly viewed at night (e.g. from a settlement, transport route) or where there is a particular sensitivity to lighting (e.g. in or near a Dark Sky Park or Wild Land Area). Not all viewpoints will need to be illustrated in this way".*

1.9.3 The following section provides background information in relation to the Dusk Period Visualisations which have been prepared to illustrate the visible lighting proposed as part of the Proposed Development. The text explains how the photography was taken and how the visualisations were prepared and presented. It includes instructions for how the visualisations should be viewed and explains the limitations of the visualisation material.

Viewpoints Illustrated with Dusk Period Visualisations

1.9.4 The starting point for consideration for which locations should be illustrated with dusk period visualisations was the locations proposed as assessment viewpoints for the main daytime period visual assessment. Of these viewpoints a review was then undertaken in order to establish which were likely to be representative of visual receptors during low light conditions. In this regard, viewpoints at distances of beyond 10 km from the site were discounted, along with viewpoints at hills summits and on long distance footpaths which would be unlikely to be visited after daylight hours.

Dusk Period Photography

1.9.5 SNH advises that:

> *"The visualisation should use photographs taken in low light conditions, preferably when other artificial lighting (such as street lights and lights on buildings) are on, to show how the wind farm lighting will look compared to the existing baseline at night. It is only necessary to illustrate visible lighting, not infrared or other alternative lighting requirements.".*

1.9.6 It goes on to note that:

> *"We have found that approximately 30 minutes after sunset provides a reasonable balance between visibility of the landform and the apparent brightness of artificial lights, as both should be visible in the image. It is important that the photographs represent the levels of darkness as seen by the naked eye at the time and the camera exposure does not make the image appear artificially brighter than it is in reality. It can also be helpful to note the intensity of other lights in the area to enable comparison (e.g. television transmitters) as this can aid the assessment process."*

1.9.7 In this context, the following text explains how the baseline photography was taken for each viewpoint illustrated with a visualisation.

1.9.8 Each viewpoint illustrated with a dusk period visualisation was visited during the 'dusk period' and photographs taken at regular intervals as the light levels decreased across the dusk period. In particular, it was sought to gather photographs during the period where street lighting and other light sources of visible light in the baseline are illuminated, but the landform remains partially visible. The ambient light conditions were recorded during each round of photography with a light meter to seek to ensure consistency across the visualisations prepared.

1.9.9 Baseline photographs of the existing view were taken using a full frame camera in accordance with NatureScot guidance.

1.9.10 As far as possible, photographs were taken in good weather and clear visibility conditions.

1.9.11 Photographs are captured in high resolution JPEG format and as RAW metadata files.

1.9.12 At each dusk period viewpoint the camera is mounted on a levelled tripod at a height of approximately 1.5 m above ground level (providing an approximation of average adult eye level).

1.9.13 The camera is set up on a panoramic rotating head and photographs taken at 20 degree increments of rotation from left to right.

1.9.14 In each case the camera focus is locked on the distant horizon (infinity). In doing so the photographs are in each case focussed on the development site whilst very close objects in the foreground may in some cases be out of focus. This approach is in line with best practice photography techniques. The exposure is set correctly for the centre of the Proposed Development site and then locked off so that it remained constant as the camera is rotated through the panorama.

Stitching of Panoramas and Post-Photographic Processing

1.9.15 Each of the panoramic images used for the Visualisations is comprised of five single frame photographs stitched together and then cropped down to a particular horizontal and vertical field of view.

1.9.16 The panoramic baseline photographs which illustrate a 90 degree horizontal angle of view are stitched in cylindrical projection as per the NatureScot guidance.

1.9.17 The photomontages which show a 53.5 degree horizontal field of view are based on the same single frame panoramic photographs but stitched in planar projection in accordance with the NatureScot guidance.

1.9.18 In some cases a degree of post photography processing of the raw image files may be undertaken to enhance the quality of the baseline photographs. As stated in the NatureScot guidance:

> *"Photographic processing involves judgements - there is no process by which a 'pure' photograph can be produced without the application of human decision-making, from exposure timing to the specification of the camera, and whether this is applied manually or automatically....."*
>
> *"In reality there is no way to avoid a photograph being enhanced as this is an integral part of photography and photomontage production."*

1.9.19 The extent of image enhancement undertaken in the production of the photomontages is however limited to that which would conventionally occur in a darkroom to improve the clarity of an image and does not in any case change the essential character of the image. Overall, a minimum of post-photography image enhancement takes place and during the stitching process none of the photographs are distorted in terms of scaling (other than that which is an inherent and unavoidable product of stitching photography in planar projection).

Production of Wirelines and Photomontages

Wirelines

1.9.20 A wireline visualisation (sometimes also referred to as a wireframe visualisation) is a computer-generated 3D outline of a particular structure (in this case a wind farm) placed on top of a 3D ground terrain model, which again is represented by a wireline. No rendering is given to any of the surfaces.

1.9.21 The wireline images of the proposed turbines (as well as any other cumulative turbines modelled) is generated utilising the actual dimensions of the proposed turbines and a model of the structures placed in position over a ground terrain model generated from Ordnance Survey Terrain 50 DTM data.

1.9.22 The coordinates of the viewpoints are recorded using a Global Positioning System (GPS) in the field. Checks on these coordinates are made with reference to Google Earth. These coordinates are then used to set up viewpoints in the model from which to view the turbines. The wirelines are generated using specialist computer software package 'WindFarm' by ReSoft Ltd.

1.9.23 The wireline images are generated on a bare ground model and therefore do not take account of any vegetation or the built environment between the viewpoint and the Proposed Development. As such, they represent a worst-case view.

1.9.24 For each of the viewpoints which are illustrated with a dusk period visualisation, a 90 degree cylindrical cumulative wireline is presented to scale beneath a 90 degree cylindrical baseline photograph to illustrate the view on Sheet E. A 53.5 degree planar wireline showing the Proposed Development only is presented Sheet F. The wireline images illustrate the anticipated scale and position of the turbines in relation to the terrain. Each of the lit turbines is identified on the wireline as set out in best practice guidance.

Dusk Period Photomontages

1.9.25 In simple terms, a photomontage is the superimposition of a rendered, photorealistic, computer-generated model of a development (in this case a wind farm with visible lighting) on to a baseline photograph to illustrate how it will appear in the surrounding landscape context.

1.9.26 The production of the photomontages begins with the generation of a 3D digital ground terrain model and wireline images of the turbines, using ReSoft Ltd WindFarm software (as described above). The model of the structures is then rendered, and the lighting levels set appropriate to the date, time and orientation on which the photograph was taken.

1.9.27 Using world coordinates in the computer modelling programme, the photographic viewpoints for which a photomontage is to be prepared is replicated such that a view is set up looking at the structures from exactly the same location as where the baseline photograph was taken from. The view from the model is then superimposed over the original photograph and edited as necessary in Adobe Photoshop to give a final photomontage. Several known landmarks in the far distance of the baseline photographs are recorded on site using a GPS and used to check that the positioning and scale of the structures is correct.

1.9.28 Whilst every effort is made to ensure the accuracy of the photomontages, it must be appreciated that no photomontage could ever claim to be 100% accurate as there are a number of technical limitations in the model relating to the accuracy of information available from Ordnance Survey and from the GPS. In particular, it should be recognised that baseline photographs on which photomontages are based can, at best, only ever be a 'flattened' 2D representation of what the eye sees in 3D on site. A photograph will never capture as much detail as the eye would see in the field, it therefore follows

that a photomontage can never truly capture the sense of perspective and detail which would be possible in reality.

1.9.29 Additionally, it has been established during the field work undertaken for previous similar studies that dusk period photographs of visible lighting do not always capture the extent to which the eye perceives light sources during the dusk period. Often photography will appear to show the lighting to be more recessive than it is actually perceived in the field. The photomontages therefore do not seek to replicate the manner in which a dusk period photograph would capture the aviation lighting, rather they seek to replicate the manner in which the lighting is perceived when it is viewed in the field.

1.9.30 In some cases, the visibility of the turbines may also be slightly digitally enhanced to ensure that they are visible when printed out.

1.9.31 Each of the photomontages should be viewed from the stated viewing distance to give an accurate representation of what the development will look like. However, the photomontages are simply a tool to assist the Landscape Architect in their assessment of effects. The assessment of visual effects does not rely solely on the photomontages as it is ultimately professional judgement which is used to evaluate the significance of effects.

Presentation of the Visualisation Sheets

1.9.32 For each Dusk Period Viewpoint Visualisation, the following additional visualisation sheets are presented after the daytime visualisations

Sheet E: Dark Sky Baseline Photograph (For LVIA Viewpoints 1, 3, 6, 9 only)

1.9.33 In addition to a dark sky hours baseline photograph, this sheet includes a wireline image of the Proposed Development alone and highlights which turbines are proposed to be lit. Both images present a 90 degree horizontal field of view and a 14.2 degree vertical field of view. This sheet presents the information required of the 'Baseline Panorama and Wireline' as set out in Annex C of the NatureScot guidance (2017). Both of the images on this sheet are presented in cylindrical projection and the principal viewing distance (the distance at which one should view the image to obtain a geometrically accurate impression) is 500 mm when the image is curved through the same radius.

Sheet F: Wireline of the Proposed Development (For LVIA Viewpoints 1, 3, 6, 9 only)

1.9.34 This sheet provides an enlarged and cropped wireline image of the Proposed Development. The image illustrates a 53.5 degree horizontal field of view and an 18 degree vertical field of view. Whilst it is essentially an enlargement of the wireframe presented in Sheet A, with the exclusion of other cumulative wind farms, this wireframe is presented in planar projection and identifies the turbines proposed lit turbines. As such the image should be viewed on a flat surface. The principal viewing distance (the distance at which one should view the image to obtain a geometrically accurate impression) is 812.5 mm. This sheet presents the information required of the 'Wireline' as set out in Annex C of the NatureScot guidance (2017) (Ref 1).

Sheet G: Dark Sky Hours Photomontage of the Proposed Development (For LVIA Viewpoints 1, 3, 6, 9 only)

1.9.35 This sheet comprises a photomontage of the Proposed Development showing 200 candela visible aviation lighting on the turbines proposed to be lit. This has been modelled in the wind farm software and the lighting levels have been set appropriate to the date, time and orientation on which the photograph was taken.

1.9.36 For the purposes of clarification this photomontage illustrates only the Proposed Development and does not show other consented but as yet unbuilt turbines, or any schemes that are in planning.

Limitations of the Visualisations

1.9.37 Annex A of 'Visual Representation of Wind Farms, Version 2.2 (SNH, February 2017) sets out a summary of the key limitations of visualisations and recommends that these are set out for each windfarm application. The following text is therefore reproduced from Annex A of the aforementioned guidance:

> *"Visualisations of wind farms have a number of limitations which you should be aware of when using them to form a judgement on a wind farm proposal. These include:*

- *A visualisation can never show exactly what the wind farm will look like in reality due to factors such as: different lighting, weather and seasonal conditions which vary through time and the resolution of the image;*
- *The images provided give a reasonable impression of the scale of the turbines and the distance to the turbines, but can never be 100 % accurate;*
- *A static image cannot convey turbine movement, or flicker or reflection from the sun on the turbine blades as they move;*
- *The viewpoints illustrated are representative of views in the area, but cannot represent visibility at all locations;*
- *To form the best impression of the impacts of the wind farm proposal these images are best viewed at the viewpoint location shown;*
- *The images must be printed at the right size to be viewed properly (260 mm by 820 mm);*
- *You should hold the images flat at a comfortable arm's length. If viewing these images on a wall or board at an exhibition, you should stand at arm's length from the image presented to gain the best impression.*
- *It is preferable to view printed images rather than view images on screen. If you do view images on screen, you should do so using a normal PC screen with the image enlarged to the full screen height to give a realistic impression. Do not use a tablet or other device with a smaller screen to view the visualisations described in this guidance."*

1.9.38 It should also be noted that the quality of all printed visualisations is also dependent on the printing methods, paper and ink used.

2 References

1. NatureScot. Guidance on Aviation Lighting Impact Assessment. (November 2024). Available at: https://www.nature.scot/doc/guidance-aviation-lighting-impact-assessment - judging-night-time-sensitivity

2. HM Nautical Almanac Office. Twilights. Available at: https://astro.ukho.gov.uk/nao/miscellanea/twilight/

3. The Scottish Government. Crystal Rig IV Wind Farm (WIND-140-8). Reporter's Decision. 22 January 2021. Available at: https://www.dpea.scotland.gov.uk/Document.aspx?id=732056

4. Crystal Rig Inquiry (WIN-140-8). Core Document ELC09. SNH Photos from aviation lighting visits November 2017. Available at: https://www.dpea.scotland.gov.uk/CaseDetails.aspx?ID=120491

5. Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017. Available at: https://www.legislation.gov.uk/ssi/2017/101/contents

Annex 1

Photographic Record of images of the Middleton Wind Farm during Low Light Conditions

View looking towards existing Middleton Wind Farm

Time period of photograph 16:17

Viewpoint Information

OS Reference: 252223 656272

Viewpoint height: 130m

Direction from site: North east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

Lux: 622

View looking towards existing Middleton Wind Farm

Time period of photograph 16:22

Viewpoint Information

OS Reference: 252223 656272

Viewpoint height: 130m

Direction from site: North east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

Lux: 454

View looking towards existing Middleton Wind Farm

Time period of photograph 16:27

Viewpoint Information

OS Reference: 252223 656272

Viewpoint height: 130m

Direction from site: North east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

Lux: 334

View looking towards existing Middleton Wind Farm

Time period of photograph 16:32

Viewpoint Information

OS Reference: 252223 656272

Viewpoint height: 130m

Direction from site: North east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

Lux: 212

View looking towards existing Middleton Wind Farm

Time period of photograph 16:36

Viewpoint Information

OS Reference: 252223 656272

Viewpoint height: 130m

Direction from site: North east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

Lux: 127

View looking towards existing Middleton Wind Farm

Time period of photograph 16:42

Viewpoint Information

OS Reference: 252223 656272

Viewpoint height: 130m

Direction from site: North east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

Lux: 61

View looking towards existing Middleton Wind Farm

Time period of photograph 16:46

Viewpoint Information

OS Reference: 252223 656272

Viewpoint height: 130m

Direction from site: North east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

Lux: 33

View looking towards existing Middleton Wind Farm

Time period of photograph 16:51

Viewpoint Information

OS Reference: 252223 656272

Viewpoint height: 130m

Direction from site: North east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

Lux: 15

View looking towards existing Middleton Wind Farm

Time period of photograph 16:57

Viewpoint Information

OS Reference: 252223 656272

Viewpoint height: 130m

Direction from site: North east

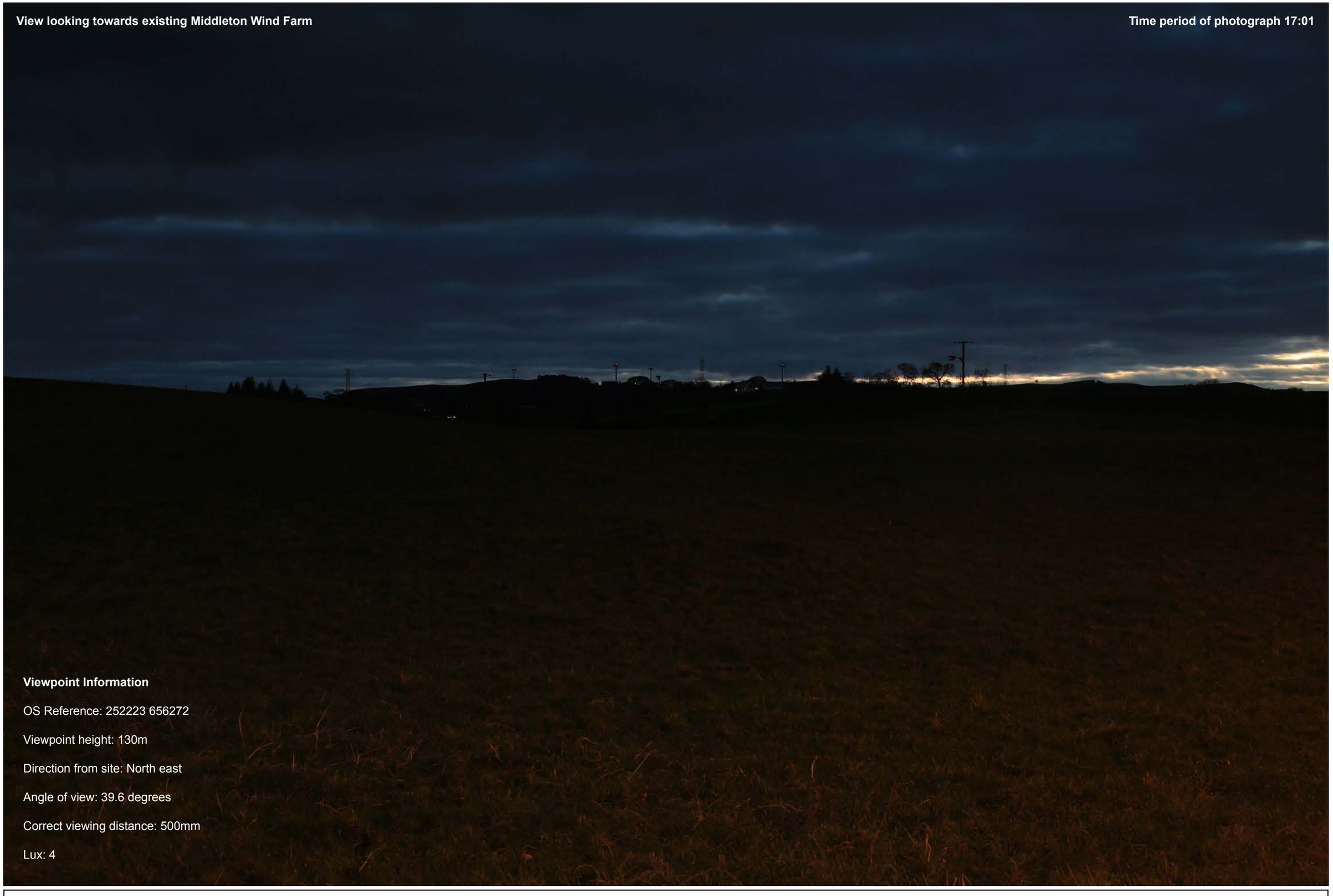
Angle of view: 39.6 degrees

Correct viewing distance: 500mm

Lux: 7

View looking towards existing Middleton Wind Farm

Time period of photograph 17:01



Viewpoint Information

OS Reference: 252223 656272

Viewpoint height: 130m

Direction from site: North east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

Lux: 4

View looking towards existing Middleton Wind Farm

Time period of photograph 17:06

Viewpoint Information

OS Reference: 252223 656272

Viewpoint height: 130m

Direction from site: North east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

Lux: 2-3

View looking towards existing Middleton Wind Farm

Time period of photograph 17:11

Viewpoint Information

OS Reference: 252223 656272

Viewpoint height: 130m

Direction from site: North east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

Lux: 2

View looking towards existing Middleton Wind Farm

Time period of photograph 17:17

Viewpoint Information

OS Reference: 252223 656272

Viewpoint height: 130m

Direction from site: North east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

Lux: 2

View looking towards existing Middleton Wind Farm

Time period of photograph 17:23

Viewpoint Information

OS Reference: 252223 656272

Viewpoint height: 130m

Direction from site: North east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

Lux: 1

View looking towards existing Middleton Wind Farm

Time period of photograph 17:32

Viewpoint Information

OS Reference: 252223 656272

Viewpoint height: 130m

Direction from site: North east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

Lux: 1

View looking towards existing Middleton Wind Farm

Time period of photograph 17:37

Viewpoint Information

OS Reference: 252223 656272

Viewpoint height: 130m

Direction from site: North east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

Lux: 1

View looking towards existing Middleton Wind Farm

Time period of photograph 17:45

Viewpoint Information

OS Reference: 252223 656272

Viewpoint height: 130m

Direction from site: North east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

Lux: 1

View looking towards existing Middleton Wind Farm

Time period of photograph 17:56

Viewpoint Information

OS Reference: 252223 656272

Viewpoint height: 130m

Direction from site: North east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

Lux: 1

Annex 2

Images of the Emley Moor Transmitter Mast

View looking towards Emley Moor Mast

Time period of photograph 16:39

Viewpoint Information

OS Reference: 424306 410397

Viewpoint height: 156m

Direction from site: South east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

View looking towards Emley Moor Mast

Time period of photograph 16:46

Viewpoint Information

OS Reference: 424306 410397

Viewpoint height: 156m

Direction from site: South east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

View looking towards Emley Moor Mast

Time period of photograph 16:52

Viewpoint Information

OS Reference: 424306 410397

Viewpoint height: 156m

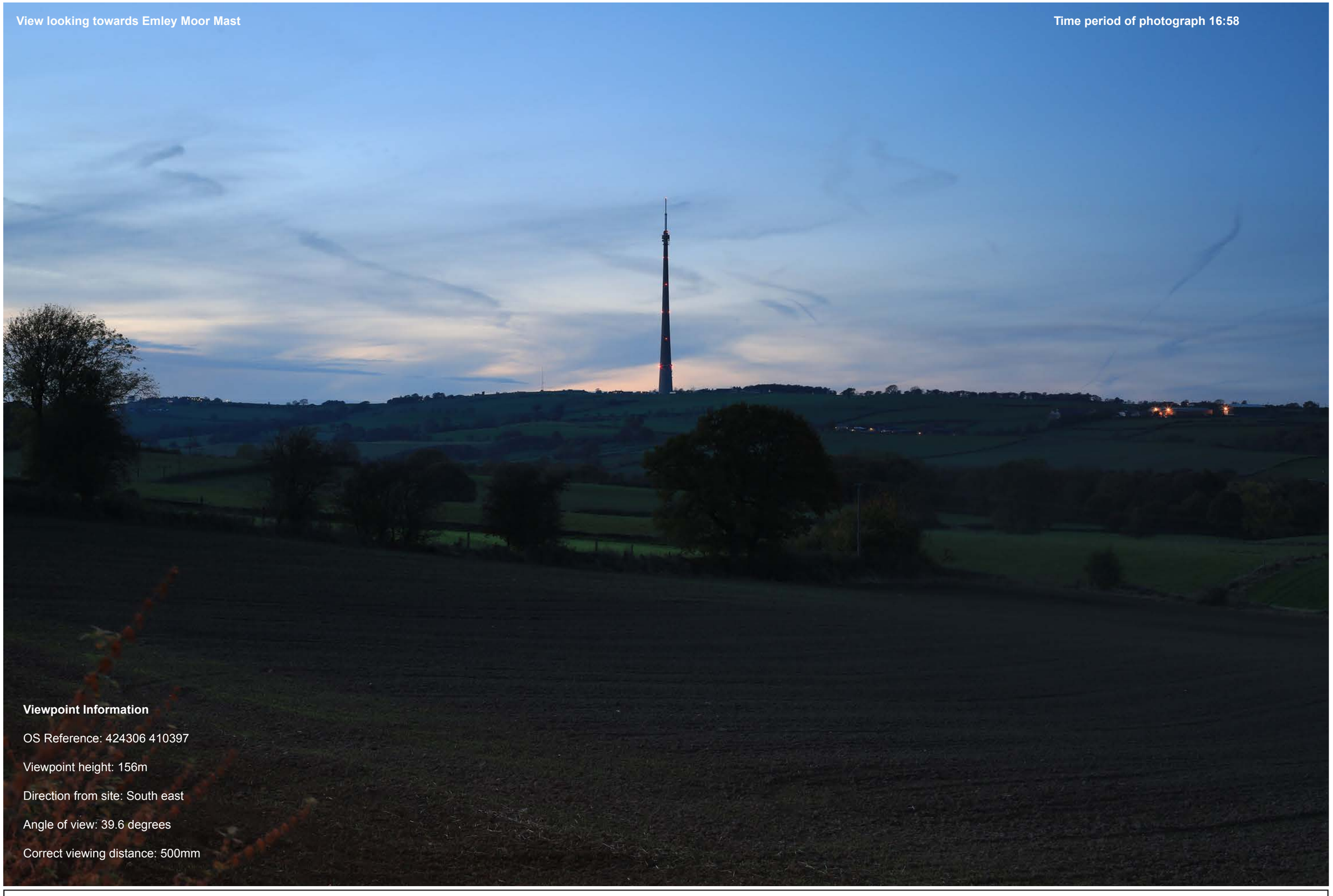
Direction from site: South east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

View looking towards Emley Moor Mast

Time period of photograph 16:58



Viewpoint Information

OS Reference: 424306 410397

Viewpoint height: 156m

Direction from site: South east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

View looking towards Emley Moor Mast

Time period of photograph 17:05

Viewpoint Information

OS Reference: 424306 410397

Viewpoint height: 156m

Direction from site: South east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

View looking towards Emley Moor Mast

Time period of photograph 17:11

Viewpoint Information

OS Reference: 424306 410397

Viewpoint height: 156m

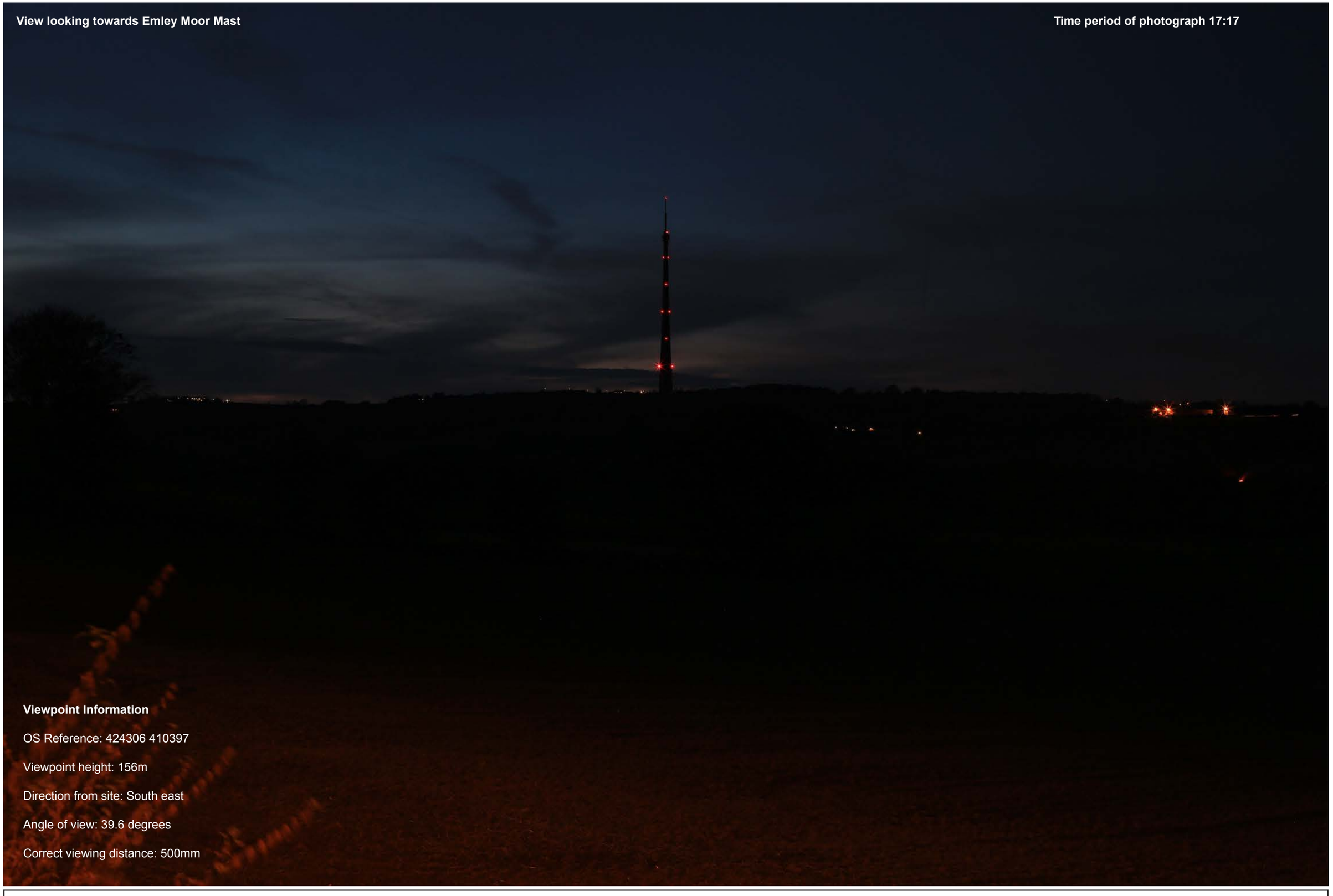
Direction from site: South east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

View looking towards Emley Moor Mast

Time period of photograph 17:17



Viewpoint Information

OS Reference: 424306 410397

Viewpoint height: 156m

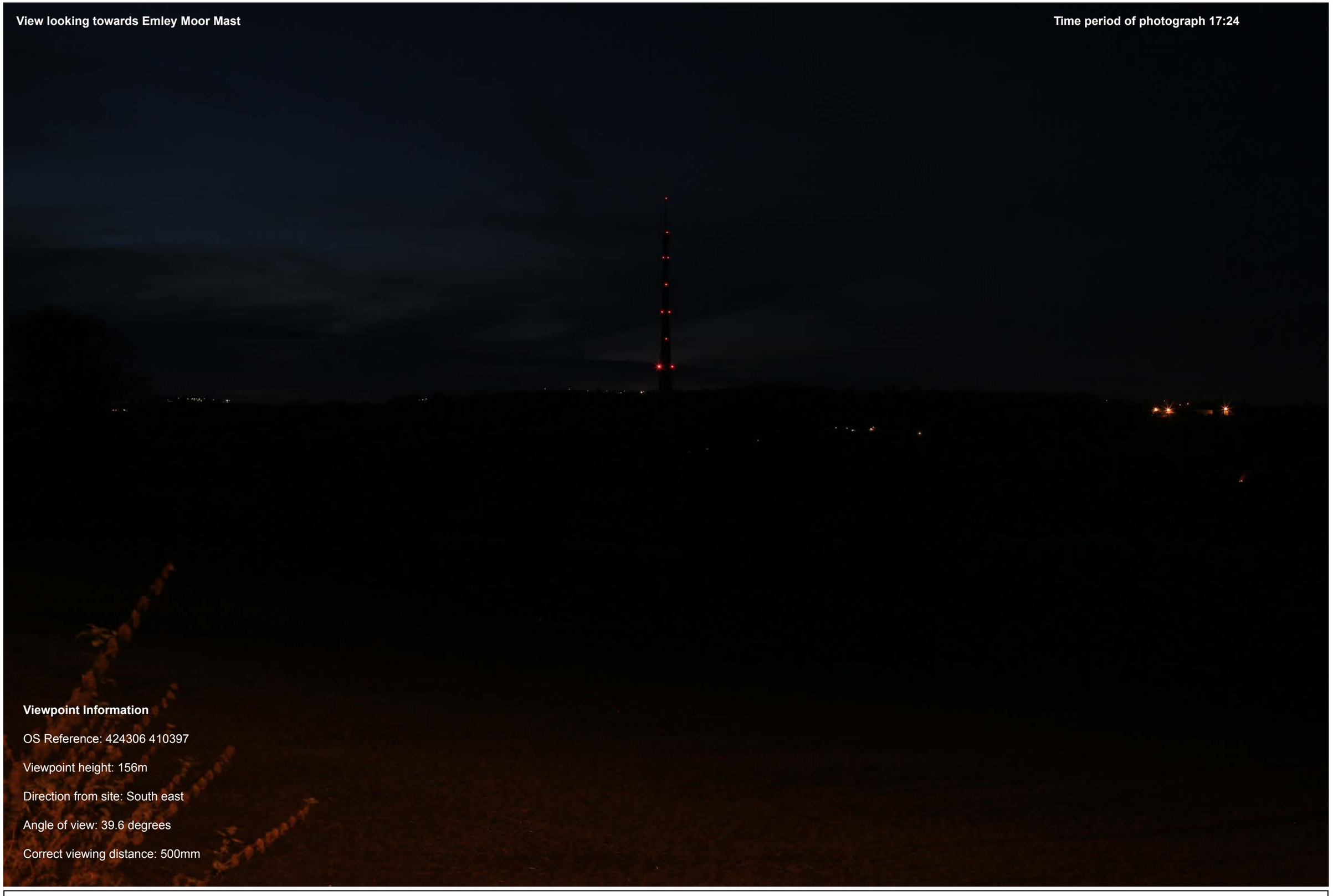
Direction from site: South east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

View looking towards Emley Moor Mast

Time period of photograph 17:24



Viewpoint Information

OS Reference: 424306 410397

Viewpoint height: 156m

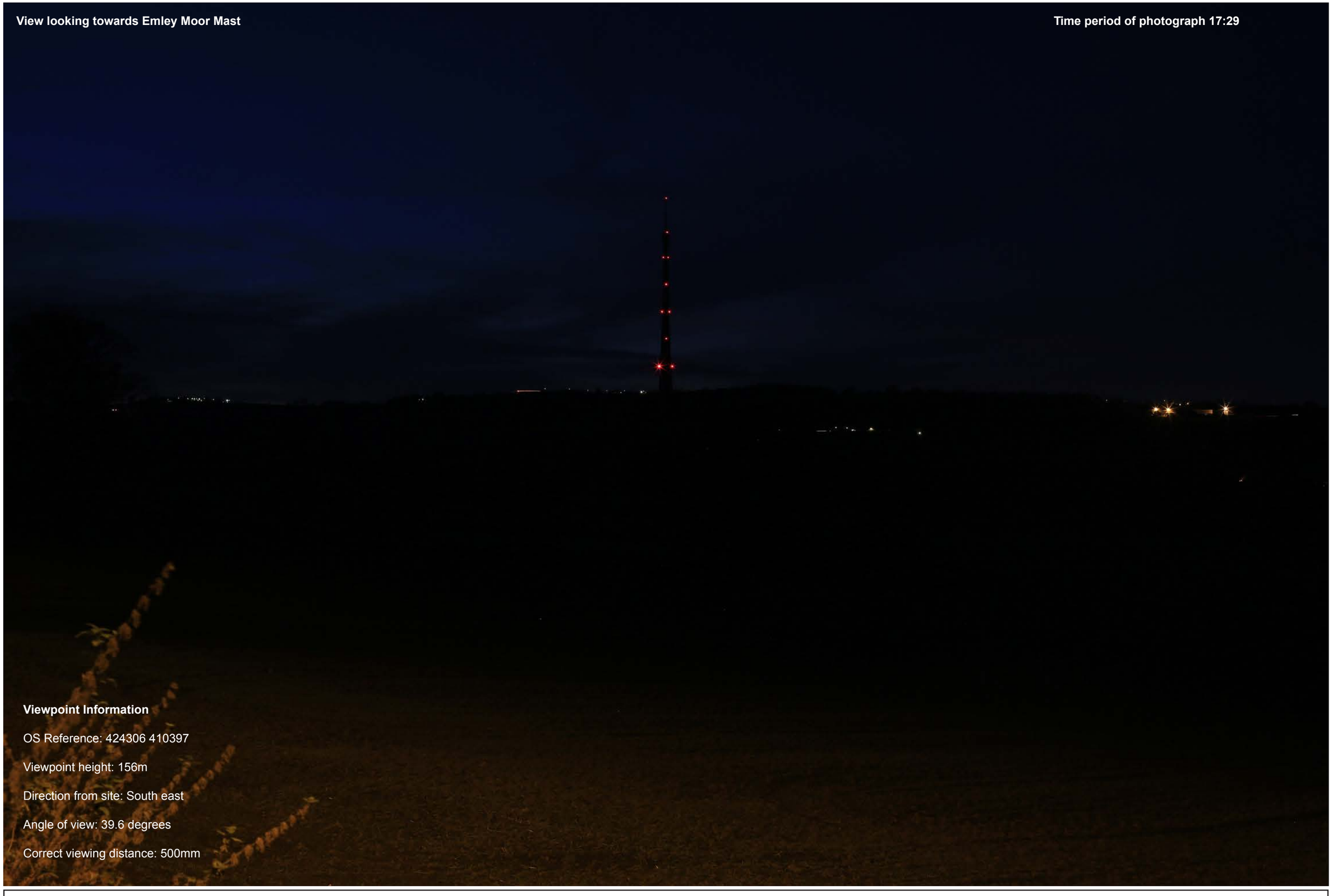
Direction from site: South east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm

View looking towards Emley Moor Mast

Time period of photograph 17:29



Viewpoint Information

OS Reference: 424306 410397

Viewpoint height: 156m

Direction from site: South east

Angle of view: 39.6 degrees

Correct viewing distance: 500mm