Glint & Glare Assessment: Stonyhurst College

For: Green Shield Group Ltd

Site: Stonyhurst College, Stonyhurst, Clitheroe, BB7 9PT

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1. Introduction

1.1 Background

Green Shield Group Ltd (Client) are proposing the installation of roof-mounted solar arrays at Stonyhurst College, Stonyhurst, Clitheroe, BB7 9PT (hereafter referred to as the 'Proposed Development').

It is understood that the Local Planning Authority has raised concerns regarding the potential impact of glint and glare towards elevated residential dwellings, along the driveway to Stonyhurst College and in the south and west gardens at Stonyhurst College.

As such, Green Shield Group Ltd has requested that Arthian Ltd (Arthian) undertake a glint and glare assessment to assess the impact of the potential glare from the Proposed Development.

This report presents the findings of the glint and glare assessment undertaken for the Proposed Development.

1.2 Glint & Glare

Reflectivity refers to light that is reflected off surfaces (e.g. glazed surfaces or areas of metal cladding). The potential effects of reflectivity are glint and glare. The Federal Aviation Administration's (FAA) *'Technical Guidance for Evaluating Selected Solar Technologies on Airports'* provides the following glint and glare definitions:

- *Glint – "a momentary flash of bright light"*
- *Glare – "a continuous source of bright light"*

These present an ocular hazard to light sensitive receptors such as road users, train drivers, occupants of nearby dwellings, pilots, and air-traffic control personnel, as they can cause a brief, temporary or permanent eye damage (ocular impact categories and significance further discussed in Section 4.3).

In general, solar photovoltaic (PV) systems are constructed of dark, light-absorbing material designed to maximise light adsorption and minimise reflection. However, the glass surfaces of solar PV systems also reflect sunlight to varying degrees throughout the day and year, based on the incidence angle of the sun relative to ground-based receptors. Lower incidence angles amount to increased reflection.

As such, the amount of light reflected off a solar PV panel surface or an array of solar panels depends on a variety of factors to include:

- The amount of sunlight hitting the surface;
- Its surface reflectivity;
- Its geographic location;
- Time of the year;
- Cloud coverage; and
- Surface orientation.

1.3 Scope of Work

Based on definitions and factors described in Section 1.2 and in combination with available guidance and good practice recommendations, a desk-based evaluation was undertaken to evaluate the potential to experience the effects of glint and glare towards residential receptors. A solar glare analysis tool was utilised to model the solar PV arrays and examine the times of the year and days such effects may occur, as well as the magnitude of their impact. The results of this study were subsequently interpreted, and appropriate recommendations made.

Section 4.0 provides further details on methodology followed to complete this study.

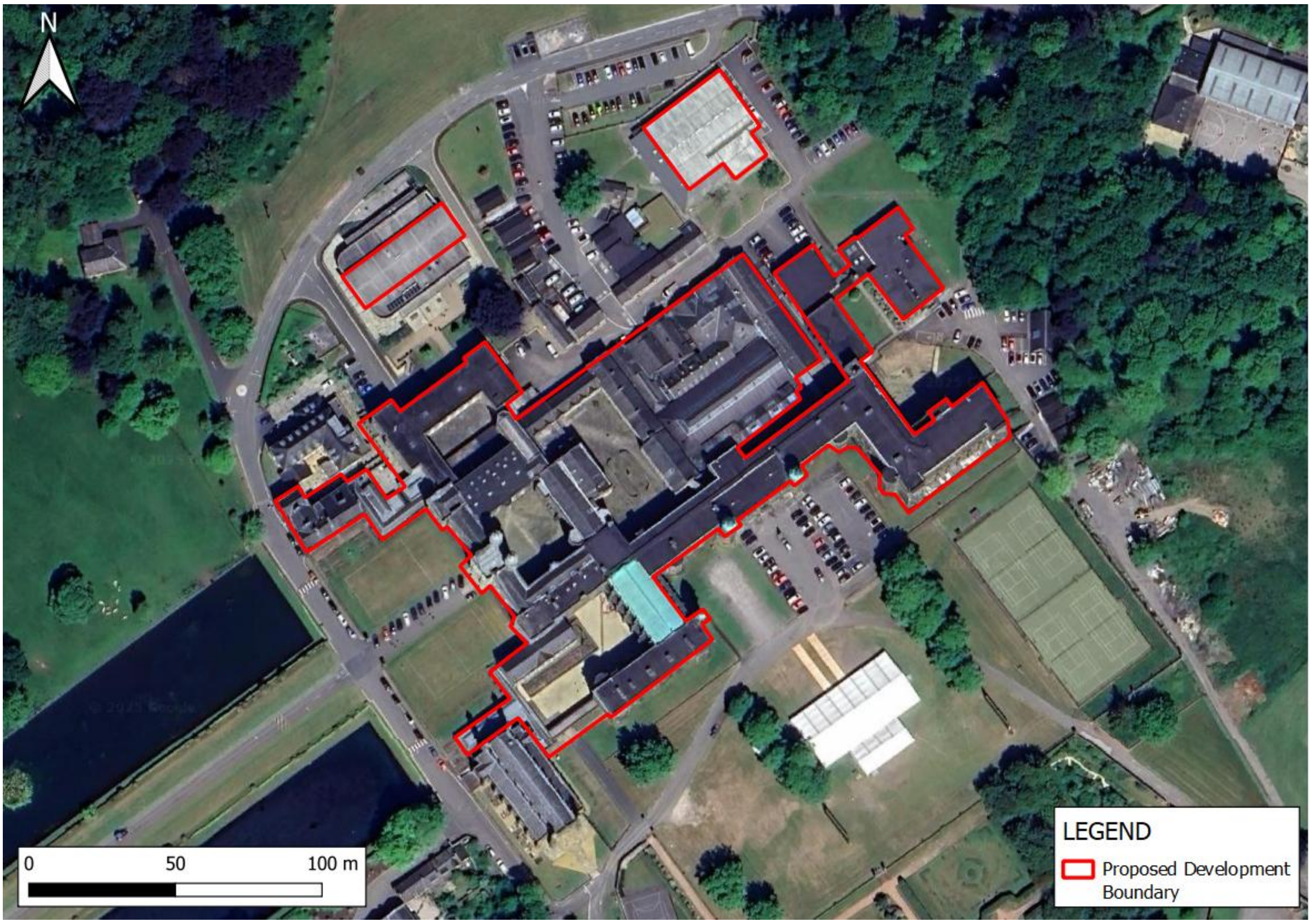
2. Development Characteristics

2.1 Site Description

The site (centred at National Grid Reference, NGR 369073, 439078) is located at Stonyhurst College, Stonyhurst, Clitheroe, BB7 9PT. The site is bounded to the southeast, northwest and northeast by other buildings, green spaces and sports fields/courts on Stonyhurst College campus. It is bordered to the northwest by two bodies of water also on the campus. Beyond these, it is surrounded by green spaces and woodlands, occasional residential dwellings and local roads, with the B6243 located approximately 0.9km south of the site at its closest extent.

The site location is shown in Figure 2.1 below.

Figure 2.1: Site Location



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2.2 Proposed Development

The Proposed Development comprises of roof-mounted arrays at Stonyhurst College. Arrays PV1-PV7 are to be alternating northeast facing and southwest facing. As a worst-case approach, the PV arrays have been modelled in their entirety in both directions.

The modelled PV module orientation and inclination, as well as PV panel height above ground, is summarised in in Table 2.1[1].

Table 2.1: Modelled PV Array Details

PV Array	Orientation (Azimuth)[2]	Panel Tilt	Average Height Above Ground
PV1	53°/232°	10°	15.04m
PV2	53°/232°	10°	16.40m
PV3	53°/232°	10°	18.22m
PV4	53°/232°	10°	16.81m
PV5	53°/232°	10°	17.94m
PV6	53°/232°	10°	18.89m
PV7	53°/232°	10°	21.02m
PV8	143°	5°	6.85m
PV9	143°	10°	5.71m
PV10	323°	10°	5.95m
PV11	19°	5°	7.46m
PV12	199°	5°	7.44m

For the purpose of this assessment the PV panels will be modelled as 'Smooth Glass with Anti-Reflective Coating (ARC)'.

The proposed site plan is shown in Figure 2.2 and Figure 2.3 with the arrays marked up. The simplified PV layout used for modelling is shown in Figure 2.4.

[1] Based on data provided by Custom Solar Ltd
[2] North referenced at 0°

Figure 2.2: Proposed Site Plan of Site Buildings

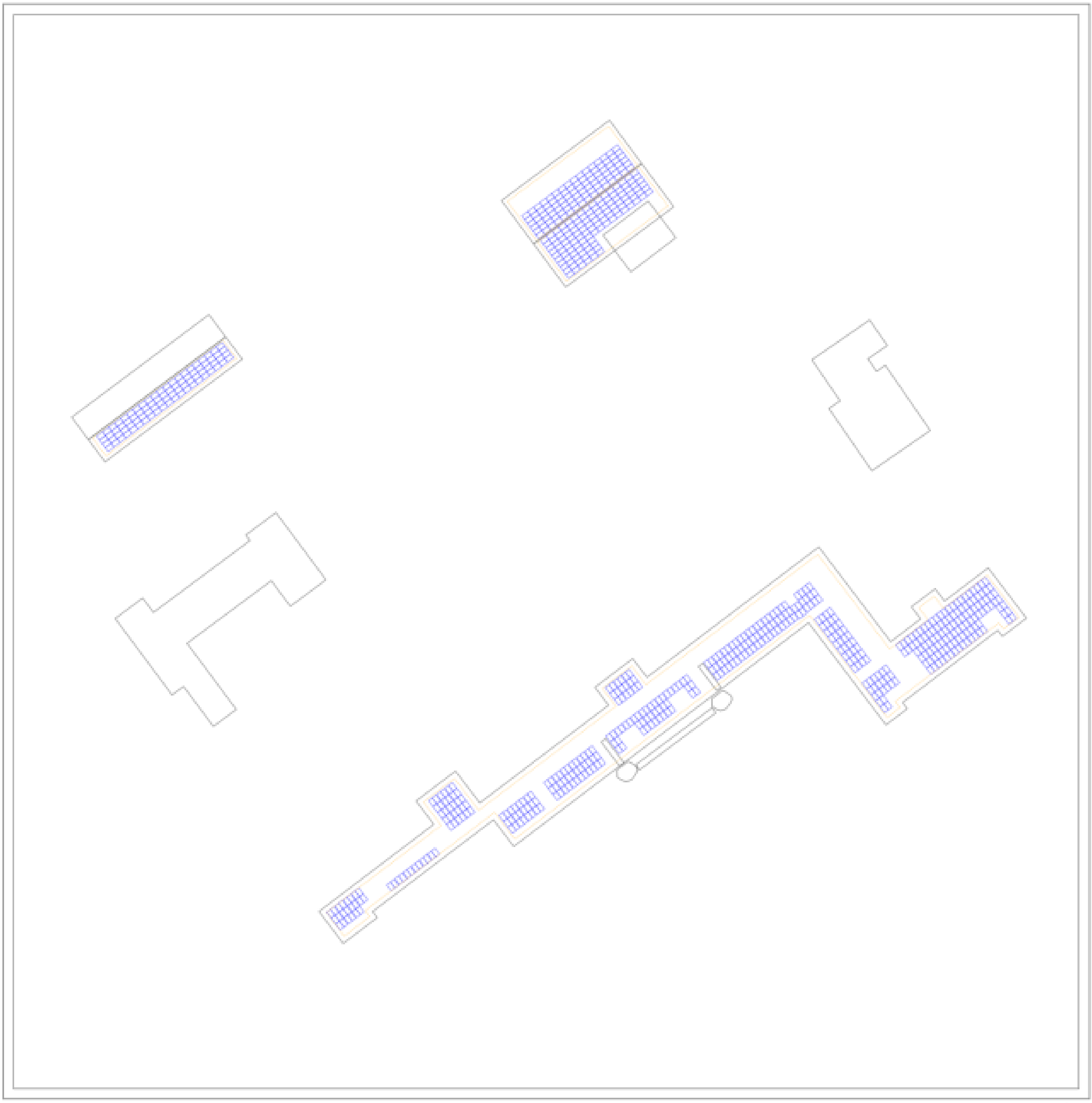
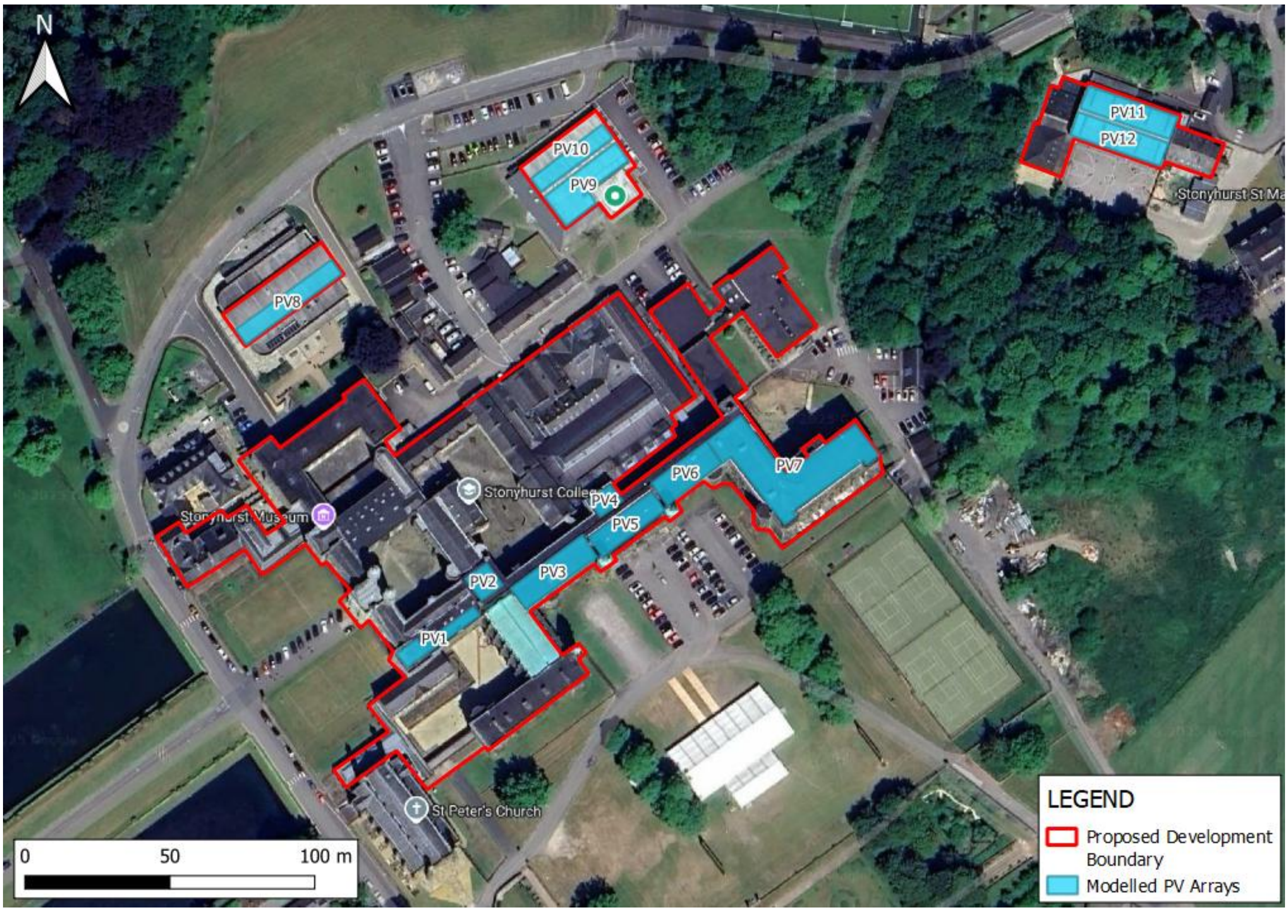


Figure: Overview plan

Figure 2.3: Proposed Site Plan of St Mary's Hall

Figure: Overview Image, 3D Design

Figure 2.4: Modelled PV Arrays



3. Legislation & Guidance

3.1 Planning Legislation & Guidance

3.1.1 The Town and County Planning, (General Permitted Development) (England) Order

The Town and County Planning, (General Permitted Development) (England) Order 2015[3] states that a written application from the developer to the local planning authority must be made before development has commented.

With regard to potential glare from solar panels, it states:

> *"… development is permitted subject to the condition that before beginning the development the developer must apply to the local planning authority for a determination as to whether the prior approval of the authority will be required as to the design or external appearance of the development, in particular the impact of glare on occupiers on neighbouring land …"*

The term 'neighbouring land' is not defined within the legislation and there is not a standard definition. The request for glare assessment may be determined by local authority following consultation with relevant stakeholders. Relevant stakeholders for glare assessment commonly include aviation safeguarding teams, Network Rail, highways and local residents of neighbouring dwellings.

3.1.2 National Planning Practice Guidance

In the absence of specific guidance on solar development, the National Planning Practice Guidance for 'Renewable and Low Carbon Energy'[4] dictates the following with respect to large-scale solar PV developments and glint and glare:

> *"The deployment of large-scale solar farms can have a negative impact on the rural environment, particularly in undulating landscapes. However, the visual impact of a well-planned and well-screened solar farm can be properly addressed within the landscape if planned sensitively.*
>
> *Particular factors a local planning authority will need to consider include:*

- *…the proposal's visual impact, the effect on landscape of glint and glare (see guidance on landscape assessment) and on neighbouring uses and aircraft safety;*
- *the extent to which there may be additional impacts if solar arrays follow the daily movement of the sun;…*
- *great care should be taken to ensure heritage assets are conserved in a manner appropriate to their significance, including the impact of proposals on views important to their setting. As the significance of a heritage asset derives not only from its physical presence, but also from its setting, careful consideration should be given to the impact of large-scale solar farms on such assets. Depending on*

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[3] https://www.legislation.gov.uk/uksi/2015/596/pdfs/uksi_20150596_en.pdf
[4] https://www.gov.uk/guidance/renewable-and-low-carbon-energy

their scale, design and prominence, a large-scale solar farm within the setting of a heritage asset may cause substantial harm to the significance of the asset;

- *the potential to mitigate landscape and visual impacts through, for example, screening with native hedges;...*

The approach to assessing cumulative landscape and visual impact of large scale solar farms is likely to be the same as assessing the impact of wind turbines. However, in the case of ground mounted solar panels it should be noted that with effective screening and appropriate land topography the area of a zone of visual influence could be zero."

3.1.3 National Policy Statement for Renewable Energy Infrastructure

The National Policy Statement for Renewable Energy Infrastructure (EN-3)[5] sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure.

The above policy is applicable to significant renewable energy infrastructure (i.e. solar photovoltaic >50 MW in England, where MW is measured as alternating current). However, the principles should be extended to infrastructure <50MW.

Sections 2.10.27 and 2.10.102-2.10.106 outlines the potential impact of glint and glare that the applicants may consider:

"2.10.27 Utility-scale solar farms are large sites that may have a significant zone of visual influence. The two main impact issues that determine distances to sensitive receptors are therefore likely to be visual amenity and glint and glare. These are considered in Landscape, Visual and Residential Amenity (paragraphs 3.10.84-3.10.92) and Glint and Glare (paragraphs 3.10.93 – 3.10.97) impact sections below."

...

2.10.102 Solar panels are specifically designed to absorb, not reflect, irradiation[6]. However, solar panels may reflect the sun's rays at certain angles, causing glint and glare. Glint is defined as a momentary flash of light that may be produced as a direct reflection of the sun in the solar panel. Glare is a continuous source of excessive brightness experienced by a stationary observer located in the path of reflected sunlight from the face of the panel. The effect occurs when the solar panel is stationed between or at an angle of the sun and the receptor.

2.10.103 Applicants should map receptors to qualitatively identify potential glint and glare issues and determine if a glint and glare assessment is necessary as part of the application.

2.10.104 When a quantitative glint and glare assessment is necessary, applicants are expected to consider the geometric possibility of glint and glare affecting nearby receptors and provide an assessment of potential impact and impairment based on the angle and duration of incidence and the intensity of the reflection.

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[5] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1147382/NPS_EN-3.pdf

[6] Most commercially available solar panels are designed with anti-reflective glass or are produced with anti-reflective coating and have a reflective capacity that is generally equal to or less hazardous than other objects typically found in the outdoor environment, such as bodies of water or glass buildings.

> *2.10.105 The extent of reflectivity analysis required to assess potential impacts will depend on the specific project site and design. This may need to account for 'tracking' panels if they are proposed as these may cause differential diurnal and/or seasonal impacts.*
>
> *2.10.106 When a glint and glare assessment is undertaken, the potential for solar PV panels, frames and supports to have a combined reflective quality may need to be assessed, although the glint and glare of the frames and supports is likely to be significantly less than the panels."*

Sections 2.10.134-2.10.136 outlines the potential mitigations for glint and glare impacts that the applicants may consider:

> *"2.10.134 Applicants should consider using, and in some cases the Secretary of State may require, solar panels to comprise of (or be covered with) anti-glare/anti-reflective coating with a specified angle of maximum reflection attenuation for the lifetime of the permission.*
>
> *2.10.135 Applicants may consider using screening between potentially affected receptors and the reflecting panels to mitigate the effects.*
>
> *2.10.136 Applicants may consider adjusting the azimuth alignment of or changing the elevation tilt angle of a solar panel, within the economically viable range, to alter the angle of incidence. In practice this is unlikely to remove the potential impact altogether but in marginal cases may contribute to a mitigation strategy."*

Sections 2.10.158-2.10.159 outlines further detail on the potential glint and glare impacts that the Secretary of State may consider as part of their decision making:

> *"2.10.158 Solar PV panels are designed to absorb, not reflect, irradiation. However, the Secretary of State should assess the potential impact of glint and glare on nearby homes, motorists, public rights of way, and aviation infrastructure (including aircraft departure and arrival flight paths).*
>
> *2.10.159 Whilst there is some evidence that glint and glare from solar farms can be experienced by pilots and air traffic controllers in certain conditions, there is no evidence that glint and glare from solar farms results in significant impairment on aircraft safety. Therefore, unless a significant impairment can be demonstrated, the Secretary of State is unlikely to give any more than limited weight to claims of aviation interference because of glint and glare from solar farms."*

3.1.4 Ribble Valley Borough Council Core Strategy 2008 - 2028

The Ribble Valley Borough Council Core Strategy was adopted in 2014 as part of the Development plan for Ribble Valley, with its primary aim being to set out the objectives and key principles to guide development in the borough.

Policy DMG1 states:

"POLICY DMG1: GENERAL CONSIDERATIONS

10.4 In determining planning applications, all development must:

- *Be of a high standard of building design which considers the 8 Building in Context Principles (from the CABE/English Heritage Building on Context Toolkit).*
- *Be sympathetic to existing and proposed land uses in terms of its size, intensity and nature as well as scale, massing, style, features and building materials.*
- *Consider the potential traffic and car parking implications.*
- *Ensure safe access can be provided which is suitable to accommodate the scale and type of traffic likely to be generated.*
- *Consider adequate day lighting and privacy distances.*
- *Consider the environmental implications such as SSSIs, County Heritage sites, Local Nature Reserves, Biodiversity Action Plan (BAP) habitats and species, Special Areas of Conservation and Special Protected Areas, protected species, green corridors and other sites of nature conservation.*
- *Consider the protection and enhancement of public rights of way and access.*
- *All development must protect and enhance heritage assets and their settings.*
- *With regards to possible effects upon the natural environment, the Council propose the the principles of the mitigation hierarchy be followed. This gives sequential preference to the following: 1) Enhance the environment 2) Avoid the impact 3) Minimise the impact 4) Restore the damage 5) Compensate for the damage 6) Offset the damage.*
- *All new development proposals will be required to take into account the risks arising from former coal mining and, where necessary, incorporate suitable mitigation measures to address them.*
- *Achieve efficient land use and the reuse and remediation of previously developed sites where possible.*
- *Have regard to public safety and secured by design principles.*
- *Consider the density, layout and relationship between buildings, which is of major importance. Particular emphasis will be placed on visual appearance and the relationship to surroundings, including impact on landscape character, as well as the effects of development on existing amenities.*
- *Not adversely affect the amenities of the surrounding area.*
- *Not prejudice future development which would provide significant environmental and amenity improvements.*
- *Not result in the net loss of important open space, including public and private playing fields without a robust assessment that the sites are surplus to need.*
- *Use sustainable construction techniques where possible and provide evidence that energy efficiency has been incorporated into schemes where possible.*
- *Consider air quality and mitigate adverse impacts where possible.*
- *The Code for Sustainable Homes and Lifetime Homes should be incorporated into schemes.*
- *Have regard to the availability to key infrastructure with capacity. Where key infrastructure with capacity is not available it may be necessary to phase development to allow future infrastructure enhancements to take place.*
- *Consider the potential impact on social infrastructure provision.*

In assessing this, regard must be had to the level of provision and standard of public open space in the area, the importance of playing fields and the need to protect school playing fields to meet future needs. Regard will also be had to the landscape or townscape of an area and the importance the open space has on this.

This policy helps deliver the vision for the area and gives an overarching series of considerations that the Council will have regard to in achieving quality development."

3.2 Aviation Guidance

3.2.1 US Federal Aviation Administration Guidance

In general, aviation stakeholders in the UK, as well as internationally, make use of the US FAA relevant guidance on solar energy systems as it provides the most detailed methodology for assessing glint and glare internationally.

3.2.1.1 Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports

The most comprehensive guidelines available for the assessment of solar PV developments near aerodromes were initially produced in November 2010 (entitled 'Technical Guidance for Evaluating Selected Solar Technologies on Airports') by the FAA and updated in 2013 (entitled 'Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports').

3.2.1.2 Technical Guidance for Evaluating Selected Solar Technologies on Airports

The 2013 edition was updated in 2018 as version 1.1 and is entitled 'Technical Guidance for Evaluating Selected Solar Technologies on Airports'. The key changes are as follows:

Version 1.1 (April 2018):

- *Updated Section 3.1.2, Reflectivity, to incorporate the latest information about evaluating solar glint and glare.*
- *Updated corresponding references to glare throughout the document.*
- *Clarified the relationship between solar energy and the FAA's Voluntary Airport Low Emissions (VALE) program in Section 5.3.2.*
- *Added information about the FAA's Airport Energy Efficiency Program to Section 5.3.3.*
- *Updated FAA Contact information on Appendix B (where appropriate).*

Overall, the 2018 update offers three assessment options:

- Assessing Baseline Reflectivity Conditions
- Tests in the Field
- Geometric Analysis

3.2.1.3 Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports

A final policy entitled 'Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports' was released in 2021, which superseded the all previous guidance. The 2021 final policy has taken a step back and allowed aerodromes to safeguard as they see fit, with no longer a recommendation for any given glare model. However, where a proposed solar development is located where a risk to aviation safety is possible, geometric analysis, as per the 2013 guidance, will likely be the only option available to alleviate concerns. Aerodromes in the UK and internationally safeguard against glint and glare based on the 2018 FAA guidance.

Key points from the 2013 guidance are replicated below:

"…the FAA has determined that glint and glare from solar energy systems could result in an ocular impact to pilots and/or air traffic control (ATC) facilities and compromise the safety of the air transportation system. While the FAA supports solar energy systems on airports, the FAA seeks to ensure safety by eliminating the potential for ocular impact to pilots and/or air traffic control facilities due to glare from such projects."

- ***Standard for Measuring Ocular Impact***

"FAA adopts the Solar Glare Hazard Analysis Plot[7] as the standard for measuring the ocular impact of any proposed solar energy system on a federally-obligated airport. To obtain FAA approval to revise an airport layout plan to depict a solar installation and/or a "no objection" to a Notice of Proposed Construction Form 7460-1, the airport sponsor will be required to demonstrate that the proposed solar energy system meets the following standards:

1. No potential for glint or glare in the existing or planned Airport Traffic Control Tower (ATCT) cab, and

2. No potential for glare or "low potential for after-image" (shown in green in hazard plot) along the final approach path for any existing landing threshold or future landing thresholds (including any planned interim phases of the landing thresholds) as shown on the current FAA-approved Airport Layout Plan (ALP). The final approach path is defined as two (2) miles from fifty (50) feet above the landing threshold using a standard three (3) degree glidepath.

Ocular impact must be analysed over the entire calendar year in one (1) minute intervals from when the sun rises above the horizon until the sun sets below the horizon."

- ***Tool to Assess Ocular Impact***

"In cooperation with the Department of Energy (DOE), the FAA is making available free-of-charge the Solar Glare Hazard Analysis Tool (SGHAT). The SGHAT was designed to determine whether a proposed solar energy project would result in the potential for ocular impact as depicted on the Solar Glare Hazard Analysis Plot shown above."

- ***Required Use of SGHAT***

"As of the date of publication of this interim policy, the FAA requires the use of the SGHAT to demonstrate compliance with the standards for measuring ocular impact stated above for any proposed solar energy system located on a federally-obligated airport. The SGHAT is a validated tool specifically designed to measure glare according to the Solar Glare Hazard Analysis Plot. All sponsors of federally obligated airports who propose to install or to permit others to install solar energy systems on the airport must attach the SGHAT report, outlining solar panel glare and ocular impact, for each point of measurement to the Notice of Proposed Construction Form 7460-1. The FAA will consider the use of alternative tools or methods on a case-by-case basis. However, the FAA must approve the use of an alternative tool or method prior to an airport sponsor seeking approval for any proposed on-airport solar energy system. The alternative tool or method must evaluate ocular impact in accordance with the Solar Glare Hazard Analysis Plot."

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[7] Plot provided in Section 4.3.1.

The Glint and Glare evaluation will be undertaken using ForgeSolar software. ForgeSolar succeeds the Solar Glare Hazard Analysis Tool (SGHAT), whose use was required by the FAA to demonstrate compliance with the standards for measuring ocular impact for any proposed solar energy systems at airports. ForgeSolar is the leading software specialist for modelling glare impacts and the software is used extensively across the UK for assessing impacts toward airports, transportation and residential dwellings. Further details are provided in Section 4.1 of this report.

4. Methodology

A desk-based assessment is undertaken to assess glint and glare that may be experienced by light-sensitive receptors within the vicinity of the proposed solar PV development.

4.1 Solar Reflection Model

A computational modelling tool was used, where appropriate/required, to model and assess solar reflectivity of the Proposed Development in relation to specified receptors, in line with FAA guidance.

The tool employs an interactive Google map where the site location, proposed solar energy system and receptor paths/locations can be specified. Latitude, longitude, and elevation are automatically recorded through the Google interface, providing necessary information for sun position and vector calculations.

PV systems are represented by contiguous planar polygon footprints and a set of customisable parameters. Each footprint comprises three or more vertices, defined by a latitude, longitude, elevation, and height. Each distinct PV installation or array is modelled with its own PV array footprint. The PV panel tilt, orientation, and height are considered to be the same across the entire array. This is considered acceptable due to the distance of the sun from the Proposed Development and the relatively small differences in location of the sun over the Proposed Development.

The solar reflectance of the PV modules is specified based on the module surface material. The modelling tool has five general module material reflectance profiles which were developed by analysing different PV module samples. The following options are available:

- Smooth glass without ARC
- Smooth glass with ARC
- Light textured glass without ARC
- Light textured glass with ARC
- Deeply textured glass

During analysis, sunlight is reflected over each PV array on a minute-by-minute basis according to the specified module tilt and orientation or axis tracking parameters, if the system is not fixed-mount. The system then checks whether the resulting solar reflections intersect (impact) the specified receptors, thus predicting glint and glare occurrence.

4.2 Receptor Identification

In general, light-sensitive receptors with view of a solar PV development have potential to experience solar reflection. While no technical distance limits/thresholds are reported within which solar reflections are possible for such receptors, the potential or significance of a reflection decreases with distance due to an observer's decreasing field of vision capability with increasing distance, as well as possible obstructions such as shielding caused by terrain and vegetation. For the purpose of this assessment, the following good practice considerations will be applied, incorporating relevant guidance as laid out in Section 3.0.

Table 4.1: Receptor Identification Criterium

Dwellings	There is not a defined screening distance for consideration of the potential glare impact of rooftop solar panels on residential dwellings. For residential dwellings very close to a proposed rooftop solar development, there will be instances where the resident does not have geometric line of sight of the proposed roof. In addition, there may be obstructions to the line of sight such as other buildings or vegetation screening. Line of sight for this assessment is reviewed using Google Satellite Images and Google Street View. Professional judgement is used to determine a representative number of dwelling points to be modelled. Industry guidance recommends glare modelling for ground floor residential receptors because it is typically the most occupied part of the dwelling during daylight hours. A height of 1.8 m above ground level will be considered to account for observer's eye level on ground floor (main habitable rooms are generally on the ground floor), unless otherwise stated.
Viewpoints	A total of five discrete viewpoints across the site's driveway and gardens will be considered for the technical modelling in order to evaluate the visual impact of the development on said viewpoints. A height of 1.8 m above ground level will be considered to account for observer's eye level on ground level. Line of sight for this assessment is reviewed using Google Satellite Images and Google Street View. Professional judgement is used to determine representative **locations** of dwelling points to be modelled. Impact will be assessed via five individual static receptor locations, three of which will be placed in the site gardens and two across the driveway. The results of the glare modelling will be evaluated using the same criteria as for amenity of residential dwellings, as described above.

4.3 Magnitude of Impact

4.3.1 Ocular Impact

Ocular impact significance depends on the line of sight between the reflector (solar PV panels) and the receptor, the location of the receptor relative to the reflector and thus the solar reflection, the time of the day, they path between the Sun and the reflective surface, and the reflection exposure period (e.g. momentary exposure is less significant that prolonged exposure).

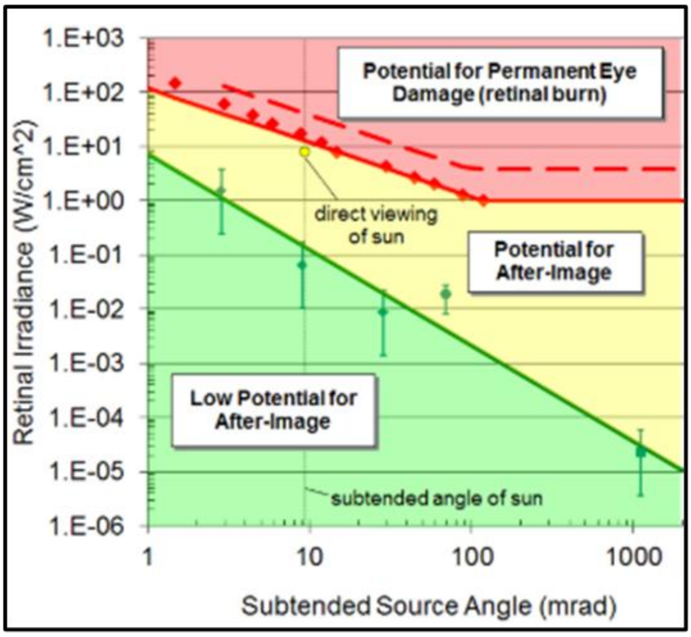
As such, ocular impact can be classified into three levels based on the retinal irradiance and subtended source angle: low potential for after-image (green), potential for after-image (yellow), and potential for permanent eye damage (red). These categories are illustrated in the Ocular Hazard plot[8] shown in Figure 4.1 (NOTE: this is a

[8] Sliney, D.H. and B.C. Freasier, 1973, Evaluation of Optical Radiation Hazards, Applied Optics, 12(1), p. 1-24.

universal Ocular Hazard plot and does not represent potential glare conditions that may be experienced at the Proposed Development).

The subtended source angle represents the size of glare observed by receptor, while the retinal irradiance is the quantity of energy impacting the retina of the observer. As it can be seen from Figure 4.1, wide subtended source angles can cause retinal irritation/damage even at low retinal irradiance.

Figure 4.1: Ocular Hazard Plot



4.3.2 Glint & Glare Impact Significance

4.3.2.1 Dwellings

While there is no specific government guidance on glint and glare impact significance evaluation, the following industry guidance classifications[9] may be used. The guidance classifications have been based on over 1,000 assessments of glare in the UK, as well as drawing upon a review of existing guidance with respect to other light-based environmental impacts. Additionally, through the review of Nationally Significant Infrastructure Projects, the assessment approach has been accepted by the Planning Inspectorate for the assessment of solar panel impacts at sites across the UK.

Table 4.2: Dwelling Impact Significance Guidance

No Impact	Solar reflection is not geometrically possible or will not be visible from the assessed receptor.
Low	Predicted glare of any intensity (green or yellow) occurs for less than 60 minutes per day and for less than three months per year.

[9] https://www.pagerpower.com/wp-content/uploads/2022/09/Solar-Photovoltaic-Glint-and-Glare-Guidance-Fourth-Edition.pdf

	Predicted glare of any intensity (green or yellow) occurs for longer than 60 minutes and for more than 3 months per year. However, there are additional mitigating factors that when considered renders the residual potential glare to be not significant. Additional mitigation is not required.
Moderate	Predicted glare of any intensity (green or yellow) occurs for longer than 60 minutes or for more than 3 months per year. There are additional mitigating factors but the residual potential glare remains significant. Predicted glare of any intensity (green or yellow) occurs for longer than 60 minutes and for more than 3 months per year. There are additional mitigating factors but the residual potential glare remains significant. Additional mitigation may be required at planner's discretion.
High	Predicted glare of any intensity (green or yellow) occurs for longer than 60 minutes per day and for more than 3 months of the year. There are no mitigating factors to consider. Additional mitigation will be required if the proposed development is to proceed.

4.3.2.2 Viewpoints

In accordance with UK industry leaders on glare assessment, it is not considered possible to have significant impacts upon users of viewpoints from glint and glare.

It is considered that the sensitivity of viewpoint receptors (in terms of amenity and safety) are of low significance because:

- The typical density of users on a viewpoint is generally low in a rural environment;
- Reflections typically coincide with direct sunlight. Impacts that coincide with direct sunlight appear less prominent than those that do not as the sun is a far more significant source of light than reflecting panels;
- Any resultant effect is much less serious and has far lesser consequences than, for example, solar reflections experienced towards a road network whereby the resultant impacts of a solar reflection can be much more serious to safety;
- Glint and glare effects towards receptors at a viewpoint are transient, and time and location sensitive whereby a pedestrian could move beyond the solar reflection zone with ease with little impact upon safety or amenity.

Furthermore, any effect is likely to have a low magnitude because the reflection intensity is similar for solar panels and still water which is a common feature of the outdoor environment. Therefore, the reflections are likely to be comparable to those from common outdoor sources whilst navigating the natural and built environment on a regular basis.

Whilst significant impacts are not considered possible, modelling has been undertaken for this assessment at the request of the applicant. For the purposes of this assessment, glare has been evaluated using the same amenity-based significance criteria with which dwellings are evaluated, as described in Table 4.2 above.

Significance of glare impact for both dwellings and viewpoints may be mitigated by several factors:

- The distance of a viewpoint receptor from the glare source, as impacts decrease with distance;
- The time of day at which glare is experienced;
- The likely density of users at a given viewpoint, in relation to both location and time;
- The extent to which glare impacts coincide with other sources of glare originating from similar points in space, as impacts that coincide with direct sunlight are found to be much less significant in comparison to a more significant source of light like the Sun;
- The intensity of solar panel glare in relation to other common sources of glare in natural or built environments, as the reflection intensity of solar panel glare is found to be similar to other common sources such as car windows or still water;
- Any screening by topography, existing infrastructure or vegetation.

4.4 Time Zone / Datum

The UK uses British Summer Time (BST, UTC +01:00) in the summer and Greenwich Mean Time (GMT, UTC +0) in the winter. For the purpose of this report all time references are in GMT. All locations are given in Eastings and Northings using the UK National Grid Reference system, unless otherwise specified.

4.5 Assumptions, Limitations & Fixed Model Variables

Provided in Appendix A is a list of assumptions, limitations and fixed variables of the model and assessment methodology.

4.6 Elevation Data

Elevation data for the modelled arrays and residential receptors were obtained using Defra Survey[10] LiDAR data database. Digital Terrain Model data was downloaded from the most recent survey. ForgeSolar employs an interactive Google map such that latitude, longitude, and ground elevation of PV geometry and receptors are automatically queried from Google, providing necessary information for sun position and vector calculations.

[10] https://environment.data.gov.uk/survey

5. Receptor Screening & Model Considerations

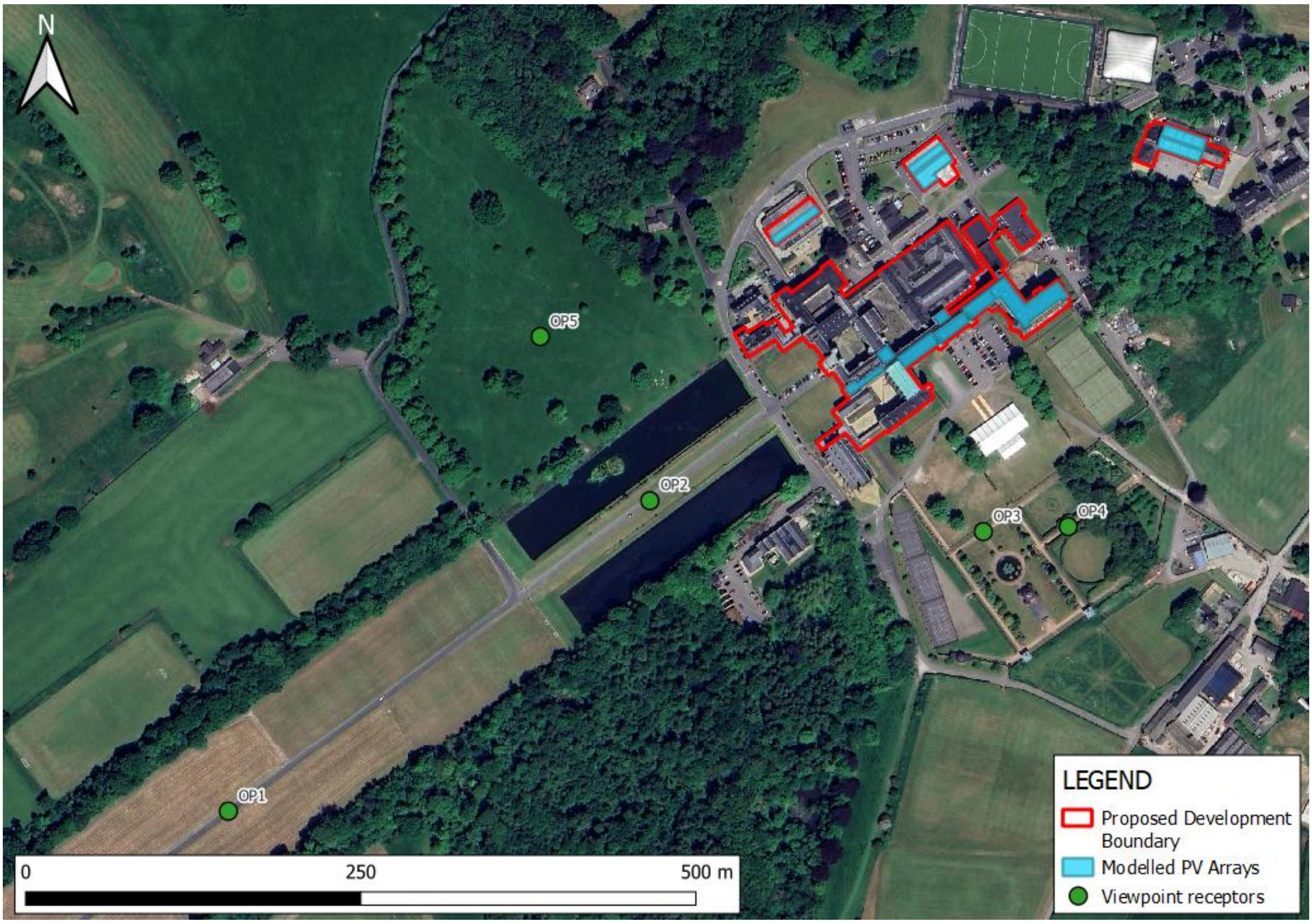
5.1 Viewpoint Receptors

Five viewpoints across the College's driveway and gardens with a potential line of sight towards the Proposed Development were considered.

Observation points OP1 to OP5 represent viewpoints. A height of 1.8m above ground level is considered representative of eye level for ground floor receptors. A height of 1.8m above ground level is considered representative of eye level for ground floor receptors.

The five viewpoints that were included in the model are shown in Figure 5.1.

Figure 5.1: Modelled Viewpoint Receptors



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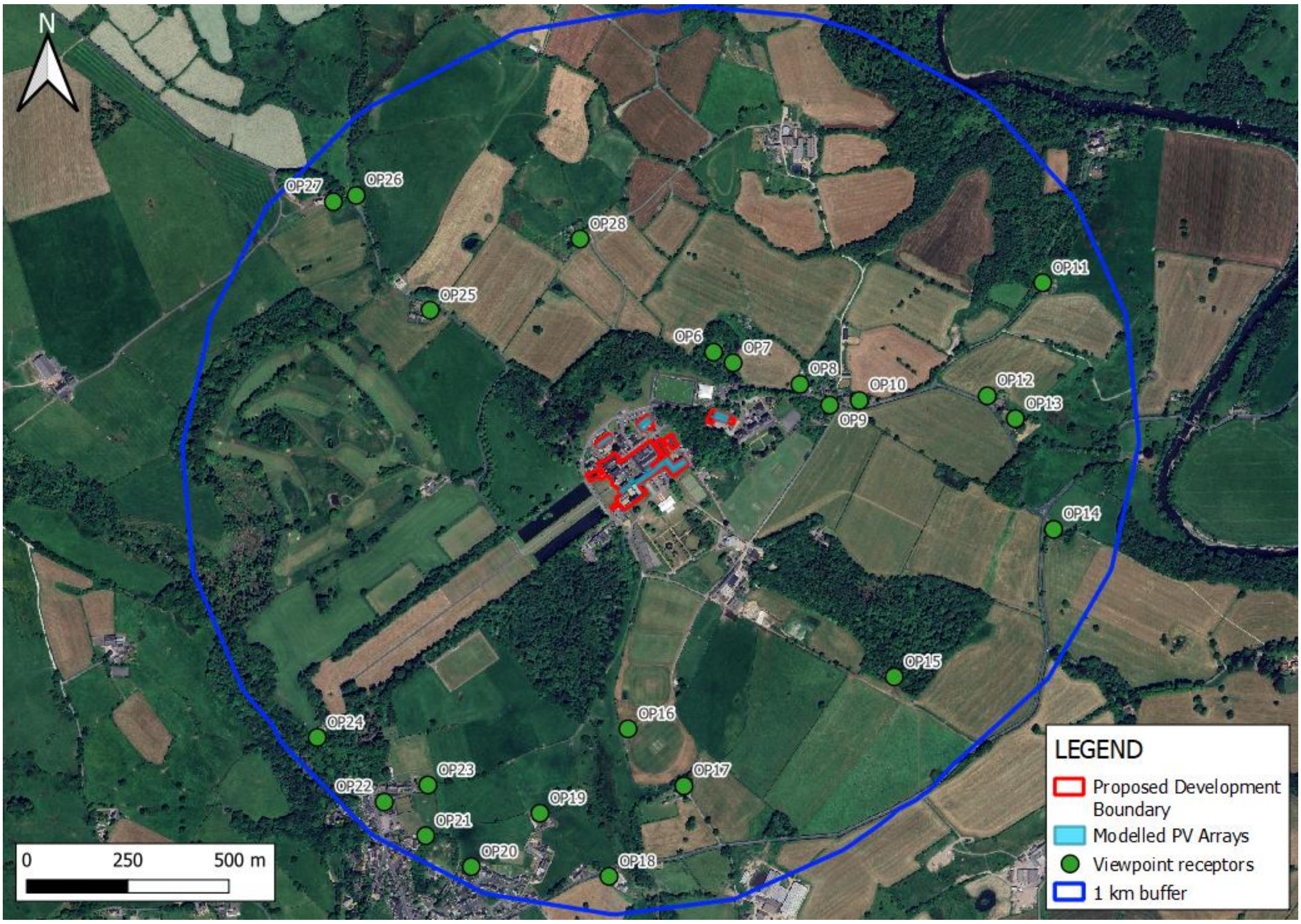
5.2 Residential Dwellings

Only the neighbouring receptor points closest to the Proposed Development with a potential line of sight towards the PV panels were considered, as other dwellings are expected to be screened by these receptors, as well as vegetation and/or other buildings found in between them.

Observation points OP6 to OP28 represent houses. A height of 1.8m above ground level is considered representative of eye level for ground floor receptors. For additional floors (e.g. flats), an additional height of 3m would be added to the modelled height above ground level to represent the observer's eye level.

Residential dwellings with a potential line of sight to the Proposed Development that were included in the model are shown in Figure 5.2.

Figure 5.2: Modelled Residential Receptors



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6. Modelling Results & Interpretation

6.1 Modelling Results

6.1.1 Viewpoint Receptors

Table 6.1: Modelled Results - Viewpoint Receptors

Receptor	Results	Impact
OP1	Glare predicted from PV9 and PV12. Glare is predicted from PV9 from early June to early July between 03:30-04:30 for a maximum of 5 minutes per day. Glare is predicted from PV12 from early June to early July between 04:00-05:00 for a maximum of 25 minutes per day. Based on industry guidance, glare predicted for less than 60 minutes per day and for less than 3 months of the year may be classified as ‘low impact’, and no further mitigation is recommended.	**Low Impact**
OP2	Glare predicted from PV12. Glare is predicted from PV12 from mid-May to mid-July between 04:00-05:00 for a maximum of 30 minutes per day. Based on industry guidance, glare predicted for less than 60 minutes per day and for less than 3 months of the year may be classified as ‘low impact’, and no further mitigation is recommended.	**Low Impact**
OP3	***No glare predicted towards OP3.***	**No Impact**
OP4	***No glare predicted towards OP4.***	**No Impact**
OP5	Glare predicted from PV1 (west facing), PV2 (west facing), PV3 (west facing), PV4 (west facing), PV5 (west facing), PV7, PV10, and PV12. Glare is predicted from PV1 (west facing) from mid-March to mid-April and late August to late September between 06:30-08:00 for a maximum of 25 minutes per day. Glare is predicted from PV2 (west facing) from late March to mid-April and mid-August to mid-September between 06:30-07:30 for a maximum of 30 minutes per day. Glare is predicted from PV3 (west facing) from late March to late April and mid-August to mid-September between 06:00-07:30 for a maximum of 35 minutes per day.	Further Review (See Section 0) **(<60 minutes daily but >3 months of the year**)

Receptor	Results	Impact
	Glare is predicted from PV4 (west facing) from mid-April to early May and early to late August between 06:00-07:00 for a maximum of 30 minutes per day. Glare is predicted from PV5 (west facing) from early April to early May and early August to early September between 06:00-07:30 for a maximum of 35 minutes per day. Glare is predicted from PV6 (west facing) from mid-April to early May and early to late August between 06:00-07:00 for a maximum of 35 minutes per day. Glare is predicted from PV7 (west facing) from early April to mid-May and late July to late August between 06:00-07:00 for a maximum of 40 minutes per day. Glare is predicted from PV10 from early to mid-May and late July to early August between 04:30-05:30 for a maximum of 30 minutes. Glare is predicted from PV12 from mid-April to mid-May and late July to late August between 05:00-06:00 for a maximum of 25 minutes per day. As such, glare is predicted for less than 60 minutes per day but for more than three months of the year. A review of mitigation considerations has been undertaken in Section 6.2.	

Detailed results can be provided upon request.

As detailed above, modelling predicts no glare at 2 of the 5 viewpoint receptors (OP3 and OP4). **As such, a 'no impact' significance is assigned to receptors OP3 and OP4.** Further review of these OPs is not undertaken.

With reference to the guidance in Section 4.3.2.1, a 'low impact' significance can be classified where glare of any intensity occurs for less than 60 minutes per day and for less than three months per year. **Low impacts are predicted to occur at receptors OP1 and OP2.** Further review of the impacts at these OPs is not undertaken.

With reference to the guidance in Section 4.3.2.1, a 'moderate impact' significance may be classified where unmitigated glare of any intensity occurs for longer than 60 minutes or for more than 3 months per year. **Receptor OP5** is predicted to receive glare for less than 60 minutes daily duration. However, the incidence of glare is predicted to exceed the 3 months criteria.

Mitigating factors that have not already been considered in the modelling are considered in Section 0 for receptor OP5 to determine residual glare significance.

6.1.2 Residential Dwellings

Table 6.2: Modelled Results – Residential Dwellings

Receptor	Results	Impact
OP6	Glare predicted from PV1 (east facing), PV2 (east facing), PV3 (east facing), PV4 (east facing), PV5 (east facing), PV6 (east facing) and PV10. Glare is predicted from PV1 (east facing) from late January to late February and mid-October to early November between 13:30 and 15:00 for a maximum of 35 minutes per day. Glare is predicted from PV2 (east facing) from late January to mid-February and mid-October to mid-November between 13:30 and 15:00 for a maximum of 35 minutes per day. Glare is predicted from PV3 (east facing) from mid-January to mid-February and late October to mid-November between 13:00 and 15:00 for a maximum of 40 minutes per day. Glare is predicted from PV4 (east facing) from late January to mid-February and late October to mid-November between 13:00 and 15:00 for a maximum of 35 minutes per day. Glare is predicted from PV5 (east facing) from mid-January to mid-February and late October to late November between 13:00 and 15:00 for a maximum of 40 minutes per day. Glare is predicted from PV6 (east facing) from early January to early February and late October to early December between 13:00 and 14:30 for a maximum of 40 minutes per day. Glare is predicted from PV7 (east facing) from early November to early February between 12:30 and 14:30 for a maximum of 70 minutes per day. Glare is predicted from PV10 from early December to early January between 15:00-16:00 for a maximum of 15 minutes per day. As such, glare is predicted for more than 60 minutes per day but for more than three months of the year. A review of mitigation considerations has been undertaken in Section 6.2.	Further Review (See Section 0) **(>60 minutes daily and >3 months of the year**)
OP7	Glare predicted from PV1 (east facing), PV2 (east facing), PV3 (east facing), PV4 (east facing), PV5 (east facing), PV6 (east facing) and PV7 (east facing). Glare is predicted from PV1 (east facing) from early February to early March and early to late October between 14:00-15:30 for a maximum of 35 minutes per day.	Further Review (See Section 0) **(<60 minutes daily but >3 months of the year**)

Receptor	Results	Impact
	Glare is predicted from PV2 (east facing) from early February to early March and early to late October between 14:00-15:30 for a maximum of 35 minutes per day. Glare is predicted from PV3 (east facing) from early to late February and mid-October to early November between 13:30-15:30 for a maximum of 35 minutes per day. Glare is predicted from PV4 (east facing) from early to late February and mid-October to early November between 13:30-15:30 for a maximum of 35 minutes per day. Glare is predicted from PV5 (east facing) from late January to late February and mid-October to early November between 13:30-15:00 for a maximum of 35 minutes per day. Glare is predicted from PV6 (east facing) from late January to late February and mid-October to mid-November between 13:30-15:00 for a maximum of 40 minutes per day. Glare is predicted from PV7 (east facing) from early January to mid-February and late October to early December between 13:00-15:00 for a maximum of 60 minutes per day. As such, glare is predicted for less than 60 minutes per day but for more than three months of the year. A review of mitigation considerations has been undertaken in Section 6.2.	
OP8	Glare predicted from PV1 (east facing), PV2 (east facing), PV3 (east facing), PV4 (east facing), PV5 (east facing), PV6 (east facing), PV7 (east facing) and PV9. Glare is predicted from PV1 (east facing) from early to late March and mid-September to early October between 15:00-16:30 for a maximum of 30 minutes per day. Glare is predicted from PV2 (east facing) from early to late March and mid-September to early October between 15:30-16:30 for a maximum of 30 minutes per day. Glare is predicted from PV3 (east facing) from early to mid-March and late September to early October between 15:00-16:30 for a maximum of 30 minutes per day. Glare is predicted from PV4 (east facing) from early to mid-March and mid-September to early October between 15:30-16:30 for a maximum of 30 minutes per day.	**Low Impact**

Receptor	Results	Impact
	Glare is predicted from PV5 (east facing) from early to mid-March and late September to early October between 15:30-16:30 for a maximum of 35 minutes per day. Glare is predicted from PV6 (east facing) from early to mid-March and late September to early October between 15:30-16:30 for a maximum of 30 minutes per day. Glare is predicted from PV7 (east facing) from late February to mid-March and late September to mid-October between 15:00-16:30 for a maximum of 45 minutes per day. Glare is predicted from PV9 from late February to mid-March and late September to mid-October between 16:30-18:00 for a maximum of 15 minutes per day. Based on industry guidance, glare predicted for less than 60 minutes per day and for less than 3 months of the year may be classified as 'low impact', and no further mitigation is recommended.	
OP9	Glare predicted from PV1 (east facing), PV2 (east facing), PV3 (east facing), PV4 (east facing), PV5 (east facing), PV6 (east facing), PV7 (east facing), PV8 and PV9. Glare is predicted from PV1 (east facing) from mid-March to early April and early to late September between 15:30-17:00 for a maximum of 30 minutes per day. Glare is predicted from PV2 (east facing) from mid-March to early April and early to late September between 15:30-17:00 for a maximum of 30 minutes per day. Glare is predicted from PV3 (east facing) from mid-March to early April and mid to late September between 15:30-17:00 for a maximum of 35 minutes per day. Glare is predicted from PV4 (east facing) from mid-March to early April and early to late September between 16:00-17:00 for a maximum of 30 minutes per day. Glare is predicted from PV5 (east facing) from mid-March to early April and early to late September between 15:30-17:00 for a maximum of 35 minutes per day. Glare is predicted from PV6 (east facing) from mid-March to early April and mid to late September between 16:00-17:30 for a maximum of 30 minutes per day.	**Low Impact**

Receptor	Results	Impact
	Glare is predicted from PV7 (east facing) from mid-March to early April and mid-September to early October between 15:30-17:30 for a maximum of 40 minutes per day. Glare is predicted from PV8 from early to late March and mid-September to early October between 17:00-18:00 for a maximum of 20 minutes per day. Glare is predicted from PV9 from mid-March to early April and early to late September between 16:30-18:00 for a maximum of 20 minutes per day. Based on industry guidance, glare predicted for less than 60 minutes per day and for less than 3 months of the year may be classified as 'low impact', and no further mitigation is recommended.	
OP10	Glare predicted from PV1 (east facing), PV2 (east facing), PV3 (east facing), PV4 (east facing), PV5 (east facing), PV6 (east facing), PV7 (east facing), PV8 and PV9. Glare is predicted from PV1 (east facing) from mid-March to early April and early to late September between 16:00-17:00 for a maximum of 30 minutes per day. Glare is predicted from PV2 (east facing) from mid-March to early April and early to late September between 16:00-17:00 for a maximum of 30 minutes per day. Glare is predicted from PV3 (east facing) from mid-March to early April and early to late September between 16:00-17:00 for a maximum of 30 minutes per day. Glare is predicted from PV4 (east facing) from mid-March to early April and early to late September between 16:00-17:00 for a maximum of 30 minutes per day. Glare is predicted from PV5 (east facing) from mid-March to early April and early to late September between 16:00-17:00 for a maximum of 35 minutes per day. Glare is predicted from PV6 (east facing) from mid-March to early April and early to late September between 16:00-17:30 for a maximum of 30 minutes per day. Glare is predicted from PV7 (east facing) from mid-March to early April and early to late September between 16:00-17:30 for a maximum of 40 minutes per day.	**Low Impact**

Receptor	Results	Impact
	Glare is predicted from PV8 from early to mid-March and mid-September to early October between 17:00-18:00 for a maximum of 15 minutes per day. Glare is predicted from PV9 from mid-March to early April and early to late September between 17:00-18:00 for a maximum of 20 minutes per day. Based on industry guidance, glare predicted for less than 60 minutes per day and for less than 3 months of the year may be classified as 'low impact', and no further mitigation is recommended.	
OP11	Glare predicted from PV1 (east facing), PV2 (east facing), PV3 (east facing), PV4 (east facing), PV5 (east facing), PV6 (east facing), PV7 (east facing), PV9 and PV11. Glare is predicted from PV1 (east facing) from mid to late March and mid to late September between 15:30 - 16:30 for a maximum of 30 minutes. Glare is predicted from PV2 (east facing) from mid to late March and mid to late September between 15:30 -16:30 for a maximum of 30 minutes. Glare is predicted from PV3 (east facing) from mid to late March and mid to late September between 15:30 - 16:30 for a maximum of 15 minutes. Glare is predicted from PV4 (east facing) from mid to late March and mid to late September between 15:30-16:30 for a maximum of 30 minutes. Glare is predicted from PV5 (east facing) from mid to late March and mid to late September between 15:30-16:30 for a maximum of 30 minutes. Glare is predicted from PV6 (east facing) from mid to late March and mid to late September between 15:30-16:30 for a maximum of 25 minutes. Glare is predicted from PV7 (east facing) from mid to late March and mid to late September between 15:30-16:30 for a maximum of 30 minutes. Glare is predicted from PV9 from late February to early March and from early to mid-October between 16:30-17:30 for a maximum of 10 minutes per day. Glare is predicted from PV11 from late February to early March and from early to mid-October between 16:00 -17:30 for a maximum of 20 minutes per day. Based on industry guidance, glare predicted for less than 60 minutes per day and for less than 3 months of the year may be classified as 'low impact', and no further mitigation is recommended.	**Low Impact**

Receptor	Results	Impact
OP12	Glare predicted from PV1 (east facing), PV2 (east facing), PV3 (east facing), PV4 (east facing), PV5 (east facing), PV6 (east facing), PV7 (east facing), PV8 and PV9. Glare is predicted from PV1 (east facing) from late March to mid-April and late August to mid-September between 16:30 -17:30 for a maximum of 30 minutes per day. Glare is predicted from PV2 (east facing) from late March to mid-April and late August to mid-September between 16:30-17:30 for a maximum of 30 minutes per day. Glare is predicted from PV3 (east facing) from late March to early April and early to mid-September between 16:30-17:30 for a maximum of 15 minutes per day. Glare is predicted from PV4 (east facing) from late March to mid-April and late August to mid-September between 16:30-17:30 for a maximum of 30 minutes per day. Glare is predicted from PV5 (east facing) from late March to mid-April and late August to mid-September between 16:30-17:30 for a maximum of 30 minutes per day. Glare is predicted from PV6 (east facing) from late March to mid-April and late August to mid-September between 16:30-17:30 for a maximum of 30 minutes per day. Glare is predicted from PV7 (east facing) from late March to mid-April and late August to mid-September between 16:30-17:30 for a maximum of 35 minutes per day. Glare is predicted from PV8 from early to late March and mid-September to early October between 17:00-18:30 for a maximum of 20 minutes per day. Glare is predicted from PV9 from mid-March to early April and from early to late September between 17:00-18:00 for a maximum of 20 minutes per day. Based on industry guidance, glare predicted for less than 60 minutes per day and for less than 3 months of the year may be classified as ‘low impact’, and no further mitigation is recommended.	**Low Impact**
OP13	Glare predicted from PV1 (east facing), PV2 (east facing), PV3 (east facing), PV4 (east facing), PV5 (east facing), PV6 (east facing), PV7 (east facing), PV8 and PV9.	**Low Impact**

Receptor	Results	Impact
	Glare is predicted from PV1 (east facing) from late March to mid-April and late August to mid-September between 16:30-17:30 for a maximum of 30 minutes per day. Glare is predicted from PV2 (east facing) from early to mid-April and late August to mid-September between 16:30-17:30 for a maximum of 30 minutes per day. Glare is predicted from PV4 (east facing) from early to mid-April and late August to early September between 16:30-17:30 for a maximum of 30 minutes per day. Glare is predicted from PV5 (east facing) from early to mid-April and late August to mid-September between 16:30-17:30 for a maximum of 30 minutes per day. Glare is predicted from PV6 (east facing) from early to mid-April and from late August to early September between 16:30-17:30 for a maximum of 30 minutes per day. Glare is predicted from PV7 (east facing) from early to mid-April and from late August to early September between 16:30-17:30 for a maximum of 30 minutes per day. Glare is predicted from PV8 from mid-March to early April and from early to late September between 17:30-18:30 for a maximum of 20 minutes per day. Glare is predicted from PV9 from late March to mid-April and late August to mid-September between 17:00-18:00 for a maximum of 20 minutes per day. Based on industry guidance, glare predicted for less than 60 minutes per day and for less than 3 months of the year may be classified as 'low impact', and no further mitigation is recommended.	
OP14	Glare predicted from PV1 (east facing), PV2 (east facing), PV3 (east facing), PV4 (east facing), PV5 (east facing), PV6 (east facing), PV7 (east facing), PV8 and PV9. Glare is predicted from PV1 (east facing) from mid-April to early May and from early to late August between 17:30-18:30 for a maximum of 30 minutes per day. Glare is predicted from PV2 (east facing) from mid-April to early May and from early to late August between 17:30-18:30 for a maximum of 30 minutes per day.	**Low Impact**

Receptor	Results	Impact
	Glare is predicted from PV3 (east facing) from mid to late April and from mid to late August between 17:30-18:30 for a maximum of 30 minutes per day. Glare is predicted from PV4 (east facing) from mid-April to early May and from early to late August between 17:30-18:30 for a maximum of 30 minutes per day. Glare is predicted from PV5 (east facing) from mid-April to early May and from early to late August between 17:30-19:00 for a maximum of 35 minutes per day. Glare is predicted from PV6 (east facing) from late April to early May and from early to mid-August between 17:30-19:00 for a maximum of 30 minutes per day. Glare is predicted from PV7 (east facing) from late April to mid-May and from early to mid-August between 17:30-19:00 for a maximum of 35 minutes per day. Glare is predicted from PV8 from early to late April and from mid-August to early September between 18:00-19:00 for a maximum of 25 minutes per day. Glare is predicted from PV9 from late April to late May and from mid-July to mid-August between 18:00-19:00 for a maximum of 25 minutes per day. Based on industry guidance, glare predicted for less than 60 minutes per day and for less than 3 months of the year may be classified as ‘low impact’, and no further mitigation is recommended.	
OP15	Glare predicted from PV1 (east facing). Glare is predicted from PV1 (east facing) from late May to mid-July between 19:30-20:30 for a maximum of 20 minutes per day. Based on industry guidance, glare predicted for less than 60 minutes per day and for less than 3 months of the year may be classified as ‘low impact’, and no further mitigation is recommended.	**Low Impact**
OP16	***No glare predicted towards OP16.***	**No Impact**
OP17	***No glare predicted towards OP17.***	**No Impact**
OP18	***No glare predicted towards OP18.***	**No Impact**
OP19	***No glare predicted towards OP19.***	**No Impact**
OP20	***No glare predicted towards OP20.***	**No Impact**
OP21	***No glare predicted towards OP21.***	**No Impact**

Receptor	Results	Impact
OP22	***No glare predicted towards OP22.***	**No Impact**
OP23	***No glare predicted towards OP23.***	**No Impact**
OP24	***No glare predicted towards OP24.***	**No Impact**
OP25	Glare predicted from PV1 (east facing), PV2 (east facing), PV3 (east facing), PV4 (east facing), PV5 (east facing), PV6 (east facing), PV7 (east facing) and PV10. Glare is predicted from PV1 (east facing) from late November to mid-January between 08:00-09:00 for a maximum of 20 minutes per day. Glare is predicted from PV1 (west facing) from late October to early December and from late December to mid-February between 08:00-09:30 for a maximum of 35 minutes per day. Glare is predicted from PV2 (west facing) from mid-January to mid-February and from late October to late November between 08:00-09:30 for a maximum of 30 minutes per day. Glare is predicted from PV3 (west facing) from mid-January to mid-February and from late October to late November between 08:00-09:30 for a maximum of 25 minutes per day. Glare is predicted from PV4 (west facing) from late January to late February and from mid-October to mid-November between 08:00-09:30 for a maximum of 30 minutes per day. Glare is predicted from PV5 (west facing) from late January to late February and from mid-October to mid-November between 07:30-09:30 for a maximum of 35 minutes per day. Glare is predicted from PV6 (west facing) from early to late February and from mid-October to early November between 07:30-09:30 for a maximum of 30 minutes per day. Glare is predicted from PV7 (west facing) from early February to early March and from early October to early November between 07:30-09:00 for a maximum of 35 minutes per day. Glare is predicted from PV10 from late March to early April and from early to mid-September between 07:30-09:00 for a maximum of 35 minutes per day. As such, glare is predicted for less than 60 minutes per day but for more than three months of the year. A review of mitigation considerations has been undertaken in Section 6.2.	Further Review (See Section 0) **(<60 minutes daily but >3 months of the year**)

Receptor	Results	Impact
OP26	Glare predicted from PV1 (east facing), PV1 (west facing), PV2 (east facing), PV2 (west facing), PV3 (west facing), PV4 (west facing), PV5 (west facing), PV6 (west facing), PV7 (west facing), PV10, PV11 and PV12. Glare is predicted from PV1 (east facing) from early December to early January between 08:30-09:30 for a maximum of 20 minutes per day. Glare is predicted from PV1 (west facing) from mid-November to late January between 08:30-09:30 for a maximum of 35 minutes per day. Glare is predicted from PV2 (east facing) from early December to early January between 08:30-09:30 for a maximum of 5 minutes per day. Glare is predicted from PV2 (west facing) from mid-November to late January between 08:30-09:30 for a maximum of 30 minutes per day. Glare is predicted from PV3 (west facing) from early November to early February between 08:00-09:30 for a maximum of 25 minutes per day. Glare is predicted from PV4 (west facing) from early November to early February between 08:00-09:30 for a maximum of 30 minutes per day. Glare is predicted from PV5 (west facing) from early November to early February between 08:00-09:30 for a maximum of 35 minutes per day. Glare is predicted from PV6 (west facing) from early January to early February and from early November to early December between 08:00-09:30 for a maximum of 30 minutes per day. Glare is predicted from PV7 (west facing) from early January to mid-February and from late October to late November between 08:00-09:30 for a maximum of 35 minutes per day. Glare is predicted from PV10 from mid to late March and from mid-September to early October between 08:00-09:30 for a maximum of 35 minutes per day. Glare is predicted from PV11 from early to mid-February and from late October to early November between 07:30-08:30 for a maximum of 25 minutes per day. Glare is predicted from PV12 from late January to early February and from late October to mid-November between 07:30-08:30 for a maximum of 10 minutes per day. As such, glare is predicted for less than 60 minutes per day but for more than three months of the year. A review of mitigation considerations has been undertaken in Section 6.2.	Further Review (See Section 0) **(<60 minutes daily but >3 months of the year)**

Receptor	Results	Impact
OP27	Glare predicted from PV1 (east facing), PV1 (west facing), PV2 (east facing), PV2 (west facing), PV3 (west facing), PV4 (west facing), PV5 (west facing), PV6 (west facing), PV7 (west facing), PV10 and PV12. Glare is predicted from PV1 (east facing) from late November to early January between 08:00-09:30 for a maximum of 25 minutes per day. Glare is predicted from PV1 (west facing) from early November to early February between 08:00-09:30 for a maximum of 35 minutes per day. Glare is predicted from PV2 (east facing) from late November to early January between 08:00-09:00 for a maximum of 10 minutes per day. Glare is predicted from PV2 (west facing) from early January to early February and from early November to early December between 08:00-09:30 for a maximum of 30 minutes per day. Glare is predicted from PV3 (west facing) from early January to early February and from early November to early December between 08:00-09:30 for a maximum of 25 minutes per day. Glare is predicted from PV4 (west facing) from mid-January to mid-February and from late October to late November between 08:00-09:30 for a maximum of 30 minutes per day. Glare is predicted from PV5 (west facing) from mid-January to mid-February and from late October to late November between 08:00-09:30 for a maximum of 35 minutes per day. Glare is predicted from PV6 (west facing) from mid-January to mid-February and from late October to mid-November between 08:00-09:30 for a maximum of 30 minutes per day. Glare is predicted from PV7 (west facing) from late January to mid-February and from mid-October to mid-November between 07:30-09:30 for a maximum of 35 minutes per day. Glare is predicted from PV10 from mid to late March and from mid to late September between 08:00-09:30 for a maximum of 35 minutes per day. Glare is predicted from PV12 from late January to early February and from late October to mid-November between 07:00-08:30 for a maximum of 5 minutes per day. As such, glare is predicted for less than 60 minutes per day but for more than three months of the year. A review of mitigation considerations has been undertaken in Section 6.2.	Further Review (See Section 0) **(<60 minutes daily but >3 months of the year**)

Receptor	Results	Impact
OP28	Glare predicted from PV1 (east facing), PV2 (east facing), PV10 and PV11. Glare is predicted from PV1 (east facing) from early December to early January between 10:30-12:00 for a maximum of 30 minutes per day. Glare is predicted from PV2 (east facing) from early to late December between 10:30-11:30 for a maximum of 15 minutes per day. Glare is predicted from PV10 from early to late February and mid-October to early November between 10:00-12:00 for a maximum of 40 minutes per day. Glare is predicted from PV11 from mid-November to late January between 08:30-10:00 for a maximum of 30 minutes per day. As such, glare is predicted for less than 60 minutes per day but for more than three months of the year. A review of mitigation considerations has been undertaken in Section 6.2.	Further Review (See Section 0) **(<60 minutes daily but >3 months of the year**)

Detailed results can be provided upon request.

As detailed above, modelling predicts no glare at 9 of the 23 residential receptors (OP16 – OP24). **As such, a 'no impact' significance is assigned to receptors OP16 – OP24.** Further review of these OPs is not undertaken.

With reference to the guidance in Section 4.3.2.1, a 'low impact' significance can be classified where glare of any intensity occurs for less than 60 minutes per day and for less than three months per year. **Low impacts are predicted to occur at receptors OP8 – OP15.** Further review of the impacts at these OPs is not undertaken.

With reference to the guidance in Section 4.3.2.1, a 'moderate impact' significance may be classified where unmitigated glare of any intensity occurs for longer than 60 minutes or for more than 3 months per year. **Receptors OP7 and OP25 – OP28** are predicted to receive glare for less than 60 minutes daily duration. However, the incidence of glare is predicted to exceed the 3 months criteria.

With reference to the guidance in Section 4.3.2.1, a 'high impact' significance may be classified where unmitigated glare of any intensity occurs for longer than 60 minutes and for more than 3 months per year. **Receptor OP6** is predicted to receive glare for both more than 60 minutes daily duration, and for more than three months per year.

Mitigating factors that have not already been considered in the modelling are considered in Section 0 for receptors OP6, OP7 and OP25-OP28 to determine residual glare significance.

6.2 Further Review

Mitigating factors have been considered to determine residual impact significance. These include:

- The extent to which direct sunlight and glare impacts coincide;
- The extent to which cloud cover and glare impacts coincide; and
- Screening by intervening infrastructure/vegetation

6.2.1 Viewpoint Receptors

6.2.1.1 Coincidence of Direct Sunlight and Glare Impacts

Effects that coincide with direct sunlight appear less prominent than those that do not as the Sun is a far more significant source of light than the reflecting panels.

A review of the predicted glare towards OP5 indicates that it will coincide with sunrise, where the sun is lower in the sky. It is therefore considered that glare impact from the east facing panels may be mitigated as the glare from the sun and reflective areas are predicted to originate from the same point in space.

Additional review of the predicted glare towards OP5 indicates that the experienced glare will take place between the hours of 06:00 and 08:00 in early morning, prior to the College's opening hours. It is unlikely that the gardens will be inhabited at these times, and thus, glare is unlikely to have any visual impact upon the College.

6.2.2 Residential Dwellings

6.2.2.1 Coincidence of Direct Sunlight and Glare Impacts

Effects that coincide with direct sunlight appear less prominent than those that do not as the Sun is a far more significant source of light than the reflecting panels.

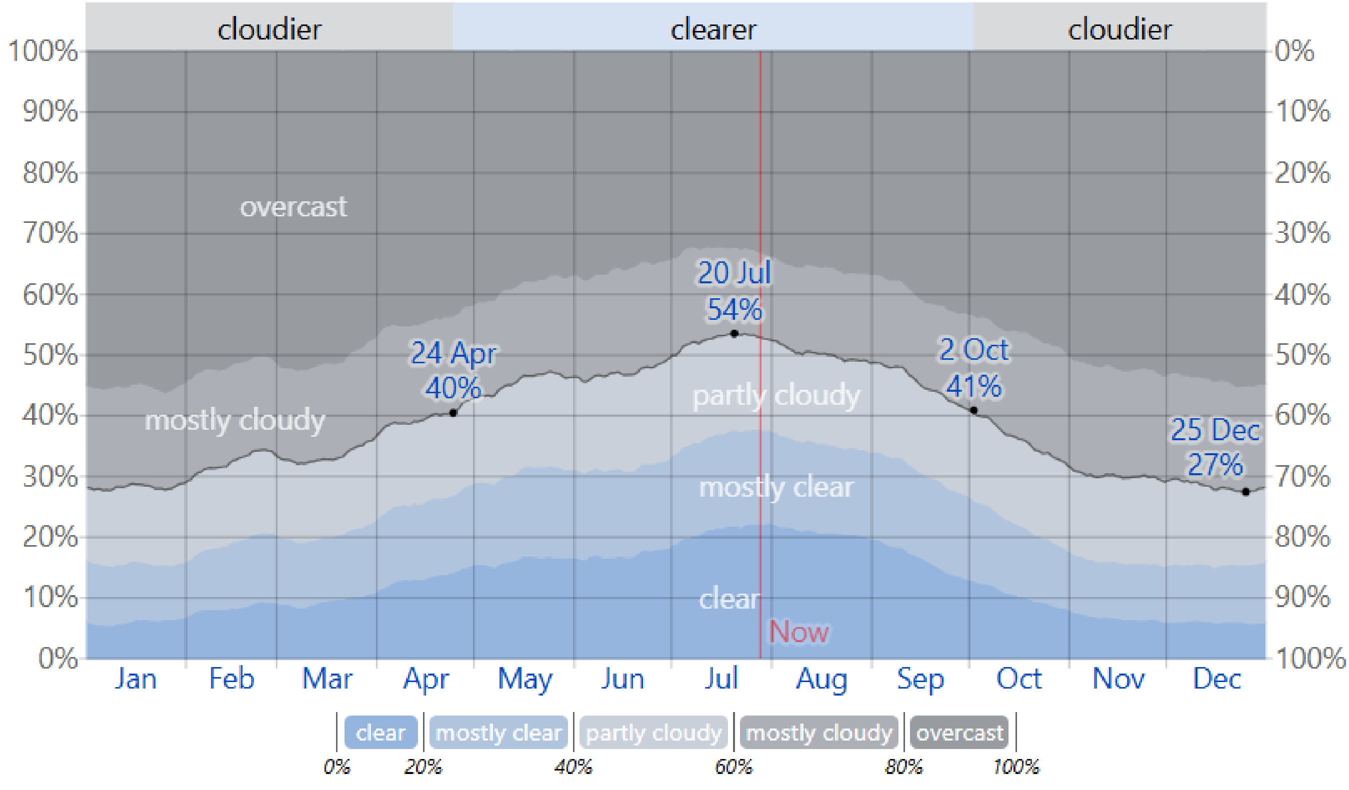
A review of the predicted glare towards OP25, OP26 and OP27 indicates that it will coincide with sunrise, where the sun is lower in the sky. It is therefore considered that glare impact from the east facing panels may be mitigated as the glare from the sun and reflective areas are predicted to originate from the same point in space.

6.2.2.2 Coincidence of Cloud Cover and Glare Impacts

As the worst-case approach, the model assumes clear sky conditions all year round. During the affected months (September – May) cloudier conditions (overcast and mostly cloudy) exist in Billington (nearest weather data available) for 52-73% of the time, as shown in Figure 6.1[11]. This would reduce the glare experienced by all affected receptors.

[11] https://weatherspark.com/y/39767/Average-Weather-in-Billington-United-Kingdom-Year-Round

Figure 6.1: Annual Cloud Cover Percentage in Billington



Considering the cloud cover that is likely to occur in the area during the affected months, the modelled glare from the Proposed Development is likely to occur at least 52% less often than predicted as a minimum. This would likely reduce the amount of glare experienced at modelled receptors.

6.2.2.3 Screening by Infrastructure and Vegetation

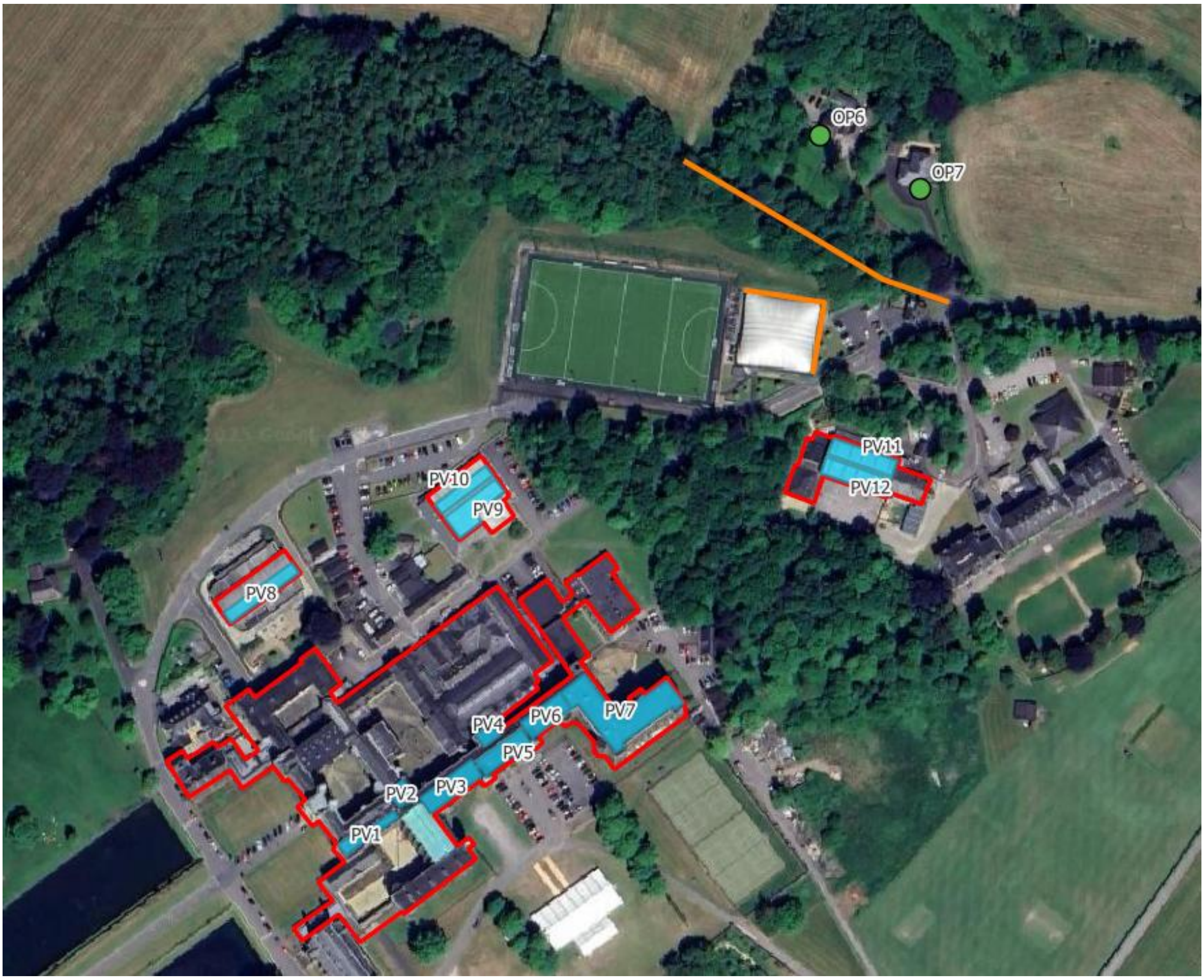
OP6-OP8

Glare is predicted towards OP6 from mid-October to late February between 12:30 and 16:00 for a maximum of 70 minutes per day.

Glare is predicted towards OP7 from late January to early March and early October to early December between 13:00-15:30 for a maximum of 60 minutes per day.

It is expected that OP6 and OP7 are screened from the site by vegetation along Knowles Brow, and that line of sight from OP6 and OP7 will also be obstructed by the nearby sports building, as highlighted in orange below on Figure 6.2:.

Figure 6.2: Screening between OP6 and OP7 and the Proposed Development



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As shown by Figures 6.3 and 6.4 below (Google Street View images taken in times of low vegetation to simulate worst-case scenario), OP6 and OP7 are both set back approximately 40m from Knowles Brow and screened from the site by two rows of vegetation along either side of the road such that any glare is likely to be significantly mitigated.

Figure 6.3: OP6 line of sight towards Proposed Development (OP6 in rear left side of photo, Proposed Development located in northwest/northeast directions)

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Figure 6.4: OP7 line of sight towards Proposed Development (OP7 to rear left side out of photo, St. Mary's Hall circled)

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<u>OP25</u>

Glare is predicted towards OP25 from early October to late February between 07:30 and 09:30 for a maximum of 35 minutes per day.

Line of sight between OP25 and the Proposed Development is also restricted by vegetation, as shown below in Figure 6.5.

Figure 6.5 : OP25 line of sight towards Proposed Development (Stonyhurst College ahead, OP25 to right of photo)

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<u>OP26 and OP27</u>

Glare is predicted toward OP26 from mid-September to late February and mid-to-late March between 08:00 and 10:30 for a maximum of 35 minutes per day.

Glare is predicted toward OP27 from mid-October to early December and from early January to late February between 07:30 and 09:30 for a maximum of 35 minutes per day.

It is expected that OP26 and OP27 are both screened from the Proposed Development due to a mix of both vegetation and natural topographical features, as shown by Figure 6.6 below.

Figure 6.6: OP26 and OP27 line of sight towards Proposed Development (OP26 to left of screenshot, OP27 to upper right)

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<u>OP28</u>

Glare is predicted towards OP28 from mid-October to early November, from mid-November to late January and from early to late February between 08:30 and 12:00 for a maximum of 40 minutes per day.

As shown by Figure 6.7 below, OP28 is likely to be screened from site by vegetation, with Figure 6.8: and LiDAR data indicating that the vegetation is located at a height of approximately 15m above the ground. As such, it is expected that potential glare toward the dwelling will be mitigated.

Figure 6.7: Screening between OP28 and the Proposed Development

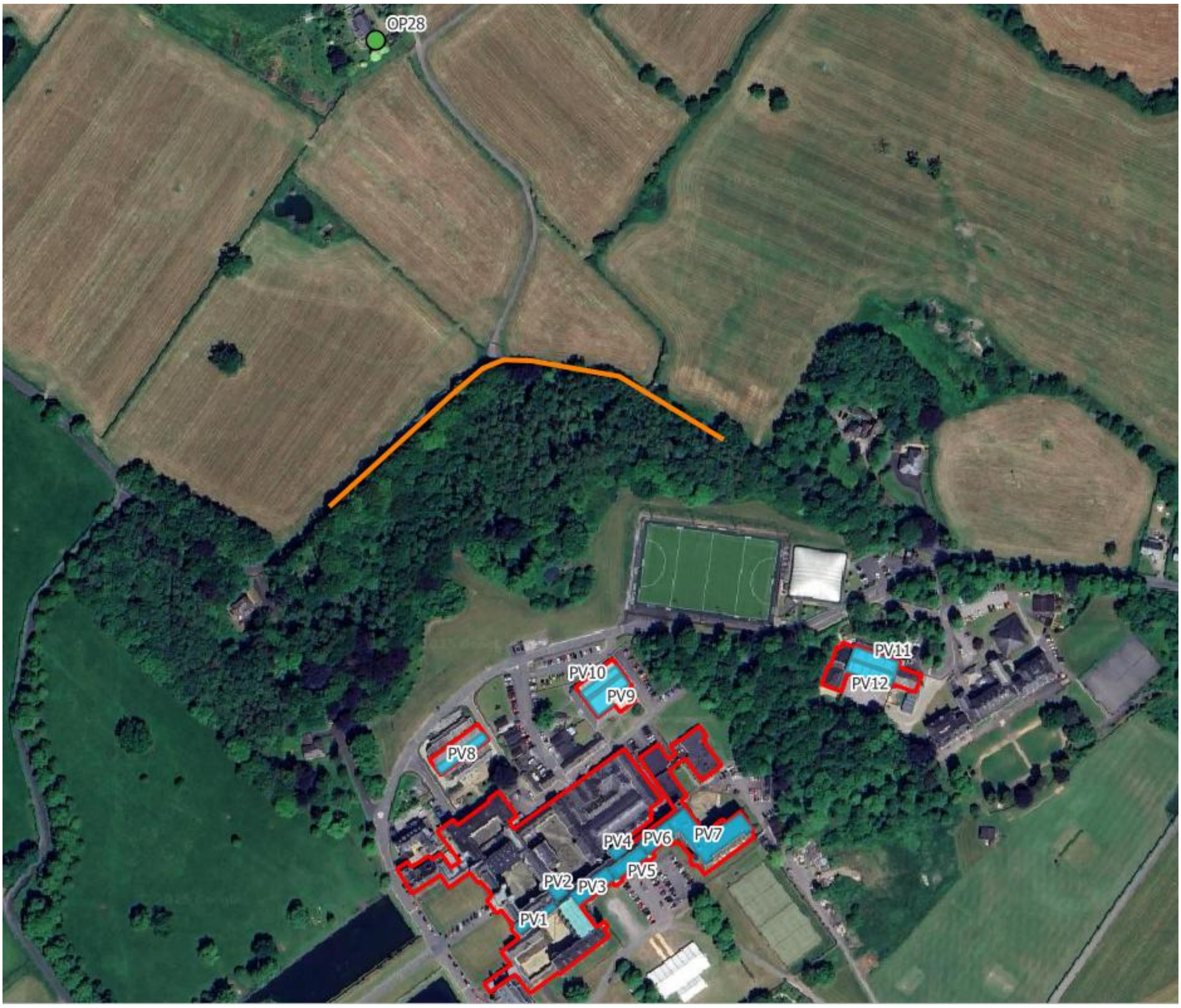

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Figure 6.8: Vegetation between OP28 and Proposed Development (OP28 approximately 250m behind photo)

6.3 Residual Significance of Impact

Table 6.3: Residual Impact Significance at Viewpoint Receptors

Receptor	Residual Impact
OP1	**Low Impact**
OP2	**Low Impact**
OP3	**No Impact**
OP4	**No Impact**
OP5	**Low Impact** (due to mitigating factors)

Table 6.4: Residual Impact Significance at Residential Dwellings

Receptor	Residual Impact
OP6	**Low Impact** (due to mitigating factors)
OP7	**Low Impact** (due to mitigating factors)
OP8	**Low Impact**
OP9	**Low Impact**
OP10	**Low Impact**
OP11	**Low Impact**
OP12	**Low Impact**
OP13	**Low Impact**
OP14	**Low Impact**
OP15	**Low Impact**

Receptor	Residual Impact
OP16	**No Impact**
OP17	**No Impact**
OP18	**No Impact**
OP19	**No Impact**
OP20	**No Impact**
OP21	**No Impact**
OP22	**No Impact**
OP23	**No Impact**
OP24	**No Impact**
OP25	**Low Impact** (due to mitigating factors)
OP26	**Low Impact** (due to mitigating factors)
OP27	**Low Impact** (due to mitigating factors)
OP28	**Low Impact** (due to mitigating factors)

7. Conclusions

Technical glare modelling was undertaken for the potential impact of the Proposed Development on nearby light-sensitive receptors.

7.1 Viewpoint Receptors

As regards viewpoint receptors, no impact was predicted for 2 out of 5 modelled receptors and low impact glare was predicted at 2 out of 5 modelled receptors.

The model predicted that glare would occur for greater than three months of the year (but for less than 60 minutes per day) at one receptor. Following a review of mitigating factors, due to the origin of the glare compared to direct sunlight, the time of day of predicted glare, predicted cloud cover and likely screening by intervening infrastructure and vegetation, it is predicted that the residual impact for receptor OP5 is likely to be low.

Furthermore, the significance of glare impact is considered to be low for viewpoints as the reflection intensity is similar to still water which is frequently a feature of the outdoor environment surrounding viewpoints. Therefore, the reflections are likely to be comparable to those from common outdoor sources whilst navigating the natural and built environment on a regular basis. As such, no further mitigation is recommended.

7.2 Residential Dwellings

As regards residential dwellings, glare with no impact was predicted for 9 out of 23 modelled receptors and low impact glare was predicted at 8 of the modelled receptors.

The model predicted that glare would occur for greater than three months of the year (but for less than 60 minutes per day) at 5 receptors. Following a review of mitigating factors, due to the origin of the glare compared to direct sunlight, the time of day of predicted glare, predicted cloud cover and likely screening by intervening infrastructure and vegetation, it is predicted that the residual impact for receptors OP7 and OP25 – OP28 is likely to be low.

The model predicted that glare would occur for greater than three months of the year (and for more than 60 minutes per day) at one receptor. Following a review of mitigating factors, due to the origin of the glare compared to direct sunlight, the time of day of predicted glare, predicted cloud cover and possible screening by intervening infrastructure and vegetation, it is predicted that the residual impact for receptor OP6 is likely to be low.

7.3 Summary

As such, the results of this assessment indicate that the Proposed Development will not introduce an unacceptable impact towards the surrounding residential dwellings and visual observation points. On this basis, no further mitigation is recommended.

Appendices

Appendix A: Assumptions, Limitations & Fixed Model Variables

1. The sun position and glare analysis will be determined throughout the year on a 1-minute basis.
2. The maximum amount of solar power striking surface normal to the sun per unit area (Peak direct normal irradiance, DNI) is set at 1,000 W/m^2. This will be scaled for each time step to account for changing sun position.
3. The average subtended angle of the sun as viewed from earth is 9.3 mrad.
4. The ocular transmission coefficient for the radiation that is absorbed in the eye before reaching the retina, is set to 0.5.[12,13]
5. Observer pupil diameter is set at the typical value of 0.002 m for daylight.[12,13]
6. Eye focal length for the distance between the nodal point (where rays intersect in the eye) and the retina is set at the typical value of 0.017 m. [12,13]
7. The algorithm does not rigorously represent the detailed geometry of a system; detailed features such as gaps between modules, variable height of the PV array, and support structures may impact actual glare results. However, models have been validated against several systems, including a PV array causing glare to the air-traffic control tower at Manchester-Boston Regional Airport and several sites in Albuquerque, and the tool accurately predicted the occurrence and intensity of glare at different times and days of the year.[14]
8. The algorithm assumes that the PV array is aligned with a plane defined by the total heights (ground elevation plus PV array height) of the coordinates outlined in the Google map.
9. The actual DNI on any given day can be affected by cloud cover, atmospheric attenuation, and other environmental factors. As such, calculated DNI may vary from actual DNI experienced by observer.
10. The system output calculation is a DNI-based approximation that assumes clear, sunny skies all year-round.
11. Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
12. Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
13. Glare vector plots are simplified representations of analysis data. Actual glare emanations and results may differ.
14. PV array tracking assumes the modules move instantly when tracking the sun, and when reverting to the rest position.

[12] Ho, C. K., Ghanbari, C. M., and Diver, R. B., 2011, Methodology to Assess Potential Glint and Glare Hazards From Concentrating Solar Power Plants: Analytical Models and Experimental Validation, ASME J. Sol. Energy Eng., 133.
[13] Sliney, D.H. and B.C. Freasier, 1973, Evaluation of Optical Radiation Hazards, Applied Optics, 12(1), p. 1-24.
[14] https://www.forgesolar.com/help/#assumptions