Frodsham Solar

Environmental Statement: Volume 2

Appendix 4-3: Glint and Glare Assessment

May 2025

Cubico
SUSTAINABLE INVESTMENTS

PINS Ref: EN010153
Document Ref: EN010153/DR/6.2
Planning Act 2008; and Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations Regulation 5(2)(a)

Revision P01

PAGERPOWER
Urban & Renewables

Solar Photovoltaic Glint and Glare Study and Thermal Plume Note

Frodsham Solar Ltd

Frodsham Solar Project

May 2025

PLANNING SOLUTIONS FOR:

- Solar
- Telecoms
- Railways
- Defence
- Buildings
- Wind
- Airports
- Radar
- Mitigation

www.pagerpower.com

ADMINISTRATION PAGE

Job Reference:	11428F3
Author:	Michael Sutton
Email:	[redacted]@pagerpower.com

Reviewed By:	Phillip Charhill; Abdul Wadud
Email:	[redacted]@pagerpower.com; [redacted]@pagerpower.com

Issue	Date	Detail of Changes
1	March 2025	Initial issue
2	May 2025	Assessment of Liverpool John Lennon Airport extended approach receptors
3	May 2025	Inclusion of solar panel constraint

Confidential: The contents of this document may not be disclosed to others without permission.

Copyright © 2025 Pager Power Limited

Stour Valley Business Centre, Brundon Lane, Sudbury, CO10 7GB

T:+44 (0)1787 319001 E:info@pagerpower.com W: www.pagerpower.com

All aerial imagery (unless otherwise stated) is taken from Google Earth. Copyright © 2025 Google

EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the potential effects of glint and glare from a ground-mounted solar photovoltaic development, located northwest of Frodsham, Cheshire.

This assessment pertains to the potential impact upon aviation activity associated with Liverpool John Lennon Airport, road safety, residential amenity, observers at the Frodsham Memorial and boaters using the Weaver Navigation.

Solar Panel Tilt Constraint

To ensure that solar reflections from two areas are experienced by pilots at different times at any location, the Development Consent Order will include a provision that means the tilt between the two areas will be at least five degrees.

The actual tilt of the panels within these areas can be installed at any angle within the assessed envelope, as long as they maintain the required five degrees difference.

Overall Conclusions

A low impact is predicted upon aviation activity associated with Liverpool John Lennon Airport, residential amenity, road safety, and boaters using the Weaver Navigation. No further mitigation measures are recommended.

No impacts upon observers at the Frodsham Memorial are predicted.

Further assessment conclusions are presented on the following pages.

Guidance and Studies

Guidelines exist in the UK (produced by the Civil Aviation Authority) and in the USA (produced by the Federal Aviation Administration) with respect to solar developments and aviation activity. The UK CAA guidance is relatively high-level and does not prescribe a formal methodology.

A national policy for determining the impact of glint and glare on road safety and residential amenity has not been produced to date. Therefore, in the absence of this, Pager Power reviewed more general existing planning guidelines and the available studies in the process of defining its own glint and glare assessment guidance and methodology[1]. This methodology defines the process for determining the impact upon road safety, residential amenity, and aviation activity.

Pager Power's approach is to undertake geometric reflection calculations and, where a solar reflection is predicted, consider the screening (existing and/or proposed) between the receptor and the reflecting solar panels. The scenario in which a solar reflection can occur for all receptors

[1] Pager Power Glint and Glare Guidance, Fourth Edition, September 2022.

is then identified and discussed, and a comparison is made against the available solar panel reflection studies to determine the overall impact.

The available studies have measured the intensity of reflections from solar panels with respect to other naturally occurring and manmade surfaces. The results show that the reflections produced are of intensity similar to or less than those produced from still water and significantly less than reflections from glass and steel[2]. Reflections from solar panels are less intense than those from glass or steel because solar panels are designed in order to absorb light, rather than reflect it, as panels are more efficient when they reflect less light.

Assessment Conclusions – Liverpool John Lennon Airport

Air Traffic Control (ATC) Tower

Solar reflections with a maximum of 'low potential for temporary after-image' are predicted towards the ATC Tower.

Most of the reflecting panels will be obstructed by the solar panels in the closer fields and intervening terrain. It is possible that there will be no visibility of the reflecting panels; however, marginal views of solar panels in two fields cannot be reliably ruled out. The glare scenario considerations to determine the overall impact from the potentially visible areas are as follows:

Based on the glare scenario considerations presented in Section 6.2.3.1, a low impact upon the ATC Tower is predicted, and no mitigation is recommended. Liverpool John Lennon Airport has confirmed the predicted impacts towards the ATC Tower are acceptable.

Two-Mile Runway Approaches

Solar reflections with a maximum of 'low potential for temporary after-image' are geometrically possible towards the Runway 09 and 27 two-mile approaches. This level of glare intensity is considered acceptable in accordance with the associated guidance (Appendix D) and industry best practice.

A low impact upon the two-mile approaches is predicted and mitigation is not required.

Extended Runway Approaches

Solar reflections with a maximum of 'low potential for temporary after-image' are geometrically possible towards the commercial visual, commercial instrument, and VFR extended approaches.

A low impact upon the two-mile approaches is predicted and mitigation is not required.

Visual Circuits

Solar reflections with a maximum of 'low potential for temporary after-image' are geometrically possible towards the entire Runway 09 right-hand (RH) / Runway 27 left-hand (LH) visual circuit, and sections of the Runway 27 RH / Runway 09 LH visual circuit. Considering the associated guidance pertaining to approach paths, which states that this level of glare is acceptable, it can be concluded that this level of glare is also acceptable for the visual circuits.

---

[2] SunPower, 2009, SunPower Solar Module Glare and Reflectance (appendix to Solargen Energy, 2010).

Solar reflections with a maximum of 'low potential for temporary after-image' are geometrically possible towards sections of the Runway 27 RH / Runway 09 LH visual circuit.

A low impact upon the visual circuits is predicted and no mitigation is required.

Visual Reference Points (VRPs)

Solar reflections are not geometrically possible towards aircraft circling the Helsby Hill VRP.

Solar reflections with a maximum of 'low potential for temporary after-image' are predicted towards aircraft circling the Frodsham Hill and Hale Head Lighthouse VRPs. Considering the associated guidance pertaining to approach paths, which states that this level of glare is acceptable, it can be concluded that this level of glare is also acceptable for the VRPs.

A low impact upon the VRPs is predicted and no mitigation is required.

Assessment Conclusions – Roads

The modelling has shown that solar reflections are geometrically possible towards 64 of the 129 assessed road receptors, totalling approximately 6.4km of road.

For sections of roads totalling approximately 5.9km, the reflecting panels are predicted to be significantly obstructed by existing vegetation, buildings, dwellings, and/or the general environment in Frodsham. No impacts upon road users along these sections of road are predicted and no further mitigation is required.

For an approximately 200m section of the M56, views of the reflecting panels outside a road user's primary field-of-view (FOV) (50 degrees either side of the direction of travel) are predicted despite partial screening from existing vegetation. A low impact upon road users along this section of road is predicted and no further mitigation is required.

For two sections of the M56 totalling approximately 500m, temporary views of the reflecting panels outside a road user's primary FOV are predicted despite partials screening in the form of proposed hedgerows (including mature planting or a mesh fence) and existing vegetation. Views of the remaining reflecting panels will be obstructed once additional proposed planting has matured. A low impact upon road users along these sections of road is predicted, reducing to no impact once all proposed planting has matured. No further mitigation is required.

Overall, a maximum of low impact upon surrounding road users is predicted, as such no further mitigation is necessary. This conclusion has been confirmed through consultation with National Highways.

Assessment Conclusions – Dwellings

The modelling has shown that solar reflections are geometrically possible towards 102 of the 143 assessed dwelling receptors.

For 71 of these dwellings, views of the reflecting panels are predicted to be significantly obstructed by existing vegetation, buildings, and/or other dwellings. No impacts upon these dwellings are predicted and no further mitigation is required.

For 16 dwellings, views of the reflecting panels will be limited by existing vegetation and/or other dwellings such that effects are predicted to be experienced for less than three months per year and less than 60 minutes on any given day. A low impact upon these dwellings is predicted and no further mitigation is recommended.

For the remaining 15 dwellings, effects are predicted to be experienced for less than 60 minutes on any given day but for more than three months per year, despite partial screening. There are sufficient mitigating factors in each case that reduce the level of impact to low, including a combination of:

- Effects being restricted to above the ground floor, which is not considered to be the main living space of a dwelling.
- Effects mostly coinciding with direct sunlight, with the sun being a far more significant source of light.
- Most of the reflecting panels being further than 1km, which is the maximum distance out to which glint and glare effects for ground-based receptors are assessed.

Overall, a maximum of low impact upon surrounding dwellings is predicted, and no further mitigation is recommended.

Assessment Conclusions – Frodsham Memorial Results

The modelling has shown that no solar reflections are geometrically possible towards the assessed Frodsham Memorial receptor.

No impacts upon observers at the Frodsham Memorial are predicted and no mitigation is required.

High-Level Conclusions – Weaver Navigation Users

A maximum of low impact is predicted upon boaters using the Weaver Navigation. No mitigation is required.

High-Level Conclusions – Thermal Plume

Thermal plumes from the Proposed Development are expected to be similar to those produced by other industrial and commercial infrastructure. There are also several other surrounding areas that are predicted to radiate more heat, which pilots flying in the area would already be routinely navigating.

In addition, aircraft flying over the Proposed Development are predicted to be at a significantly above where thermal plumes could be experienced.

LIST OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 62 countries within Europe, Africa, America, Asia and Oceania.

The company comprises a team of experts to provide technical expertise and guidance on a range of planning issues for large and small developments.

Pager Power was established in 1997. Initially the company focus was on modelling the impact of wind turbines on radar systems. Over the years, the company has expanded into numerous fields including:

- Renewable energy projects;
- Building developments;
- Aviation and telecommunication systems.

Pager Power prides itself on providing comprehensive, understandable and accurate assessments of complex issues in line with national and international standards. This is underpinned by its custom software, longstanding relationships with stakeholders and active role in conferences and research efforts around the world.

Pager Power's assessments withstand legal scrutiny and the company can provide support for a project at any stage.

1 INTRODUCTION

1.1 Overview

Pager Power has been retained to assess the potential effects of glint and glare from a ground-mounted solar photovoltaic development, located northwest of Frodsham, Cheshire. This assessment pertains to the potential impact upon road safety, residential amenity, and aviation activity associated with Liverpool John Lennon Airport.

This report contains the following:

- Solar development details;
- Explanation of glint and glare;
- Overview of relevant guidance and relevant studies;
- Overview of Sun movement;
- Assessment methodology;
- Identification of receptors;
- Glint and glare assessment for identified receptors;
- Results discussion;
- Mitigation overview;
- Conclusions and recommendations.

1.2 Pager Power's Experience

Pager Power has undertaken over 1,600 Glint and Glare assessments in the UK and internationally. The studies have included assessment of civil and military aerodromes, railway infrastructure and other ground-based receptors including roads and dwellings.

1.3 Glint and Glare Definition

The definition[3] of glint and glare is as follows:

- Glint – a momentary flash of bright light typically received by moving receptors or from moving reflectors;
- Glare – a continuous source of bright light typically received by static receptors or from large reflective surfaces.

The term 'solar reflection' is used in this report to refer to both reflection types i.e. glint and glare.

---

[3] These definitions are aligned with those of the National Policy Statement for Renewable Energy Infrastructure (EN-3) – published by the Department for Energy Security & Net Zero in January 2024, and the Federal Aviation Administration (FAA) in the United States of America.

2 SOLAR DEVELOPMENT LOCATION AND DETAILS

2.1 Solar Panel Layout Background

Based on the results of the initial geometric modelling undertaken at the PEIR stage, mitigation was recommended for nine road receptors and three dwelling receptors i.e. where moderate impacts were predicted. A further two road receptors were deemed to be a low impact; however, mitigation was still proposed due to effects being predicted from within a road user's primary field-of-view (FOV).

Some of these receptors are on higher terrain than the Proposed Development, making the implementation of screening difficult to obstruct all reflecting solar panels from view. Changes to the solar panel configuration have therefore been implemented to change the geometric relationship between the sun, solar panels, and observer such that the solar reflections will no longer be possible or will be significantly reduced.

Additional changes were implemented following the geometric modelling results for some aircraft receptors associated with Liverpool John Lennon Airport showing glare with 'potential for temporary after-image'.

The solar panel details set out in this section are the outcome of these changesand form the basis of the assessment in this report.

2.2 Proposed Development Site Layout

The proposed solar panel areas are shown as the coloured polygons in Figure 1 below. The colour of the area represents the panel configuration – shown in the following sub-section.

Figure 1 *Proposed solar panel areas*

2.3 Solar Panel Technical Information

Table 1 below summarises the technical information used in the assessment.

<table>
<tr><th>Colour</th><th>Tilt (°)[4]</th><th>Azimuth (°)[5]</th><th>Max. Panel Height (m agl)</th></tr>
<tr><td>White</td><td rowspan="7">15-30</td><td rowspan="3">180</td><td rowspan="2">3.5</td></tr>
<tr><td>Forest green</td></tr>
<tr><td>Blue</td><td rowspan="5">4</td></tr>
<tr><td>Navy</td><td>205</td></tr>
<tr><td>Light green</td><td rowspan="2">200</td></tr>
<tr><td>Pink</td></tr>
<tr><td>Purple</td><td>210</td></tr>
</table>

Table 1 *Solar panel technical information*

The panel tilt that is installed for the 'will be within an envelope of 15- to 30-degrees above the horizontal. This assessment has therefore assessed the minimum and maximum tilts to determine any differences in the modelling results and panels capable of producing reflections at each receptor.

The assessment presents the results and reflecting panels for both tilts in combination meaning that the conclusions remain valid regardless of the panel tilt that is installed.

2.3.1 Solar Panel Tilt Constraint

To ensure that solar reflections from the 'white' and 'forest green' areas are experienced by pilots at different times at any location, the Development Consent Order will include a provision that means the tilt between the two areas will be at least five degrees.

The actual tilt of the panels within these areas can be installed at any angle within the assessed envelope, as long as they maintain the required five degrees difference.

---

[4] Above the horizontal
[5] Relative to True North (0°)

3 GLINT AND GLARE ASSESSMENT METHODOLOGY

3.1 Guidance and Studies

Appendices A and B present a review of relevant guidance and independent studies with regard to glint and glare issues from solar panels. The overall conclusions from the available studies are as follows:

- Specular reflections of the Sun from solar panels are possible;
- The measured intensity of a reflection from solar panels can vary from 2% to 30% depending on the angle of incidence;
- Published guidance shows that the intensity of solar reflections from solar panels are equal to or less than those from water. It also shows that reflections from solar panels are significantly less intense than many other reflective surfaces, which are common in an outdoor environment.

3.2 Background

Details of the Sun's movements and solar reflections are presented in Appendix C.

3.3 Methodology

3.3.1 Pager Power's Methodology

The glint and glare assessment methodology has been derived from the information provided to Pager Power through consultation with stakeholders and by reviewing the available guidance and studies. The methodology for this glint and glare assessment is as follows:

- Identify receptors in the area surrounding the solar development;
- Consider direct solar reflections from the solar development towards the identified receptors by undertaking geometric calculations;
- Consider the visibility of the panels from the receptor's location. If the panels are not visible from the receptor then no reflection can occur;
- Based on the results of the geometric calculations, determine whether a reflection can occur, and if so, at what time it will occur;
- Consider both the solar reflection from the solar development and the location of the direct sunlight with respect to the receptor's position;
- Consider the solar reflection with respect to the published studies and guidance - including intensity calculations where appropriate;
- Determine whether a significant detrimental impact is expected in line with the process presented in Appendix D.

3.3.2 Sandia National Laboratories' Methodology

Sandia National Laboratories developed the Solar Glare Hazard Analysis Tool (SGHAT) which is no longer freely available however it is now developed by Forge Solar. Pager Power uses this model where required for aviation receptors. Whilst strictly applicable in the USA and to solar photovoltaic developments only, the methodology is widely used by aviation stakeholders internationally.

3.4 Assessment Methodology and Limitations

Further technical details regarding the methodology of the geometric calculations and limitations are presented in Appendix E and F.

4 IDENTIFICATION OF RECEPTORS

4.1 Aviation Receptors

Liverpool John Lennon Airport is a licenced airport, situated approximately 6km northwest of the Proposed Development. It has one Air Traffic Control (ATC) Tower and one operational runway, the details[6] of which are presented below:

- 09/27 measuring 2,286m by 46m (asphalt).

4.1.1 ATC Tower

It is standard practice to determine whether a solar reflection can be experienced by personnel within an ATC Tower. The ATC Tower is located approximately 420m south of the runway centreline with an observer height of 38.6m agl.

Figure 2 below shows a 3D representation of the ATC Tower and its location to the south of the runway.

Figure 2 *ATC Tower 3D representation*

[6] NATS AIP

4.1.2 Two-Mile Approaches

It is Pager Power's methodology to assess whether a solar reflection can be experienced on approach paths as this is considered to be the most critical stage of the flight. Liverpool John Lennon Airport has one operational runway with two associated approach paths, one for each bearing.

A geometric glint and glare assessment has been undertaken for all aircraft approach paths. The Pager Power approach for determining receptor (aircraft) locations on the approach path is to select locations along the extended runway centre line from 50ft above the runway threshold out to a distance of 2 miles. The height of the aircraft is determined by using a 3-degree descent path relative to the runway threshold height for approach paths 09 and 27.

The assessed two-mile approach paths and ATC Tower relative to the Proposed Development are shown in Figure 3 on the following page.

Figure 3 *Two-mile approach paths and ATC Tower receptors*

4.1.3 Visual Circuits

Liverpool John Lennon Airport requires assessment of General Aviation (GA) aircraft flying the right-hand circuits of the 09/27 runway.

When light aircraft arrive or depart from an aerodrome, they may fly in a standard pattern. A typical circuit is shown in Figure 4 below.

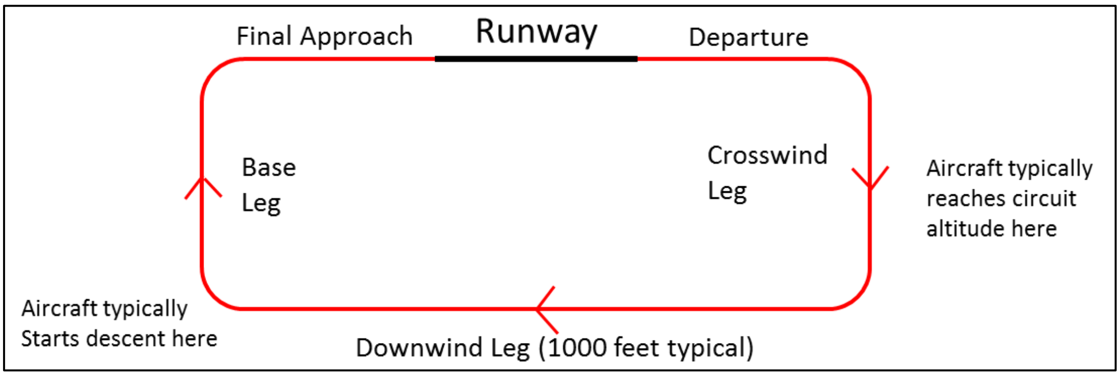


Figure 4 *Typical circuit diagram*

The way circuits are flown varies from airport to airport, pilot to pilot and aircraft to aircraft. An example of this is shown in Figure 5 below, provided to Pager Power by Liverpool John Lennon Airport, showing the tracks of GA aircraft flying the 09RH/27LH circuit.

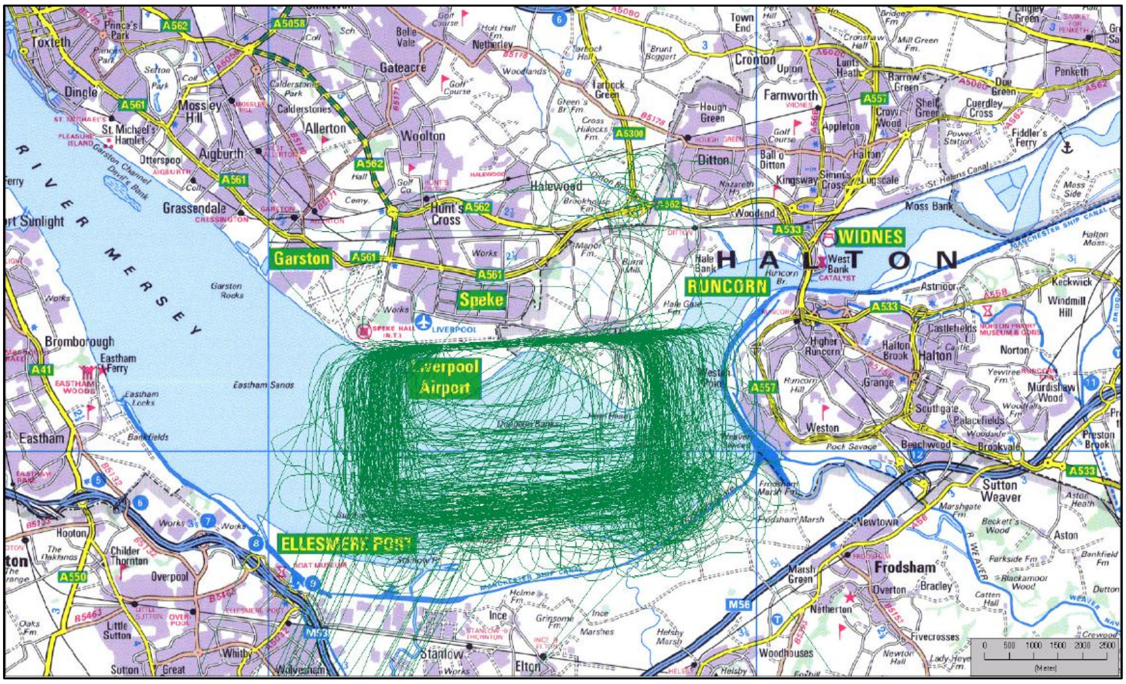


Figure 5 *Aircraft tracks at Liverpool John Lennon Airport*

The safeguarding team at Liverpool John Lennon Airport have provided coordinates and altitude information for the 09LH/27RH circuits. Pager Power has selected 85 points based on this information to model this circuit. These are shown in Figure 6 on the following page.

Figure 6 *Circuit path for runways 09LH/27RH*

The safeguarding team at Liverpool John Lennon Airport have provided coordinates and altitude information for the 09RH/27LH circuit. Pager Power has selected 100 points based on this information to model this circuit. These are shown in Figure 7 below.

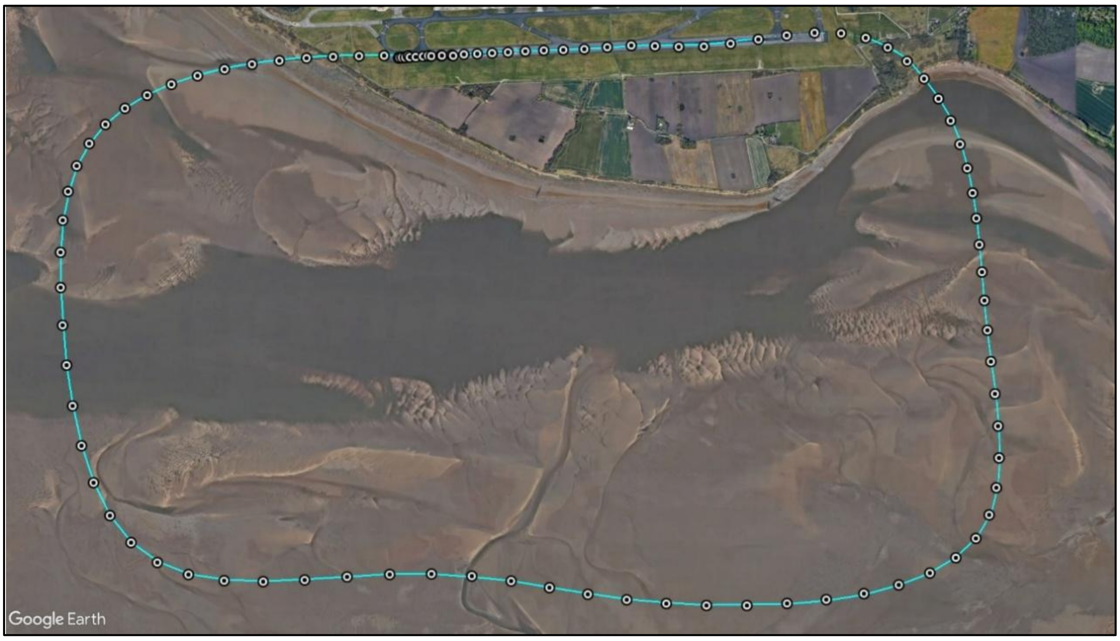


Figure 7 *Circuit path for runways 09RH/27LH*

4.1.4 Commercial Visual Approach

The safeguarding team at Liverpool John Lennon Airport has provided the track information for the commercial visual approach over the Proposed Development for aircraft landing at runway 27. The points selected along this approach are shown in Figure 8 below.

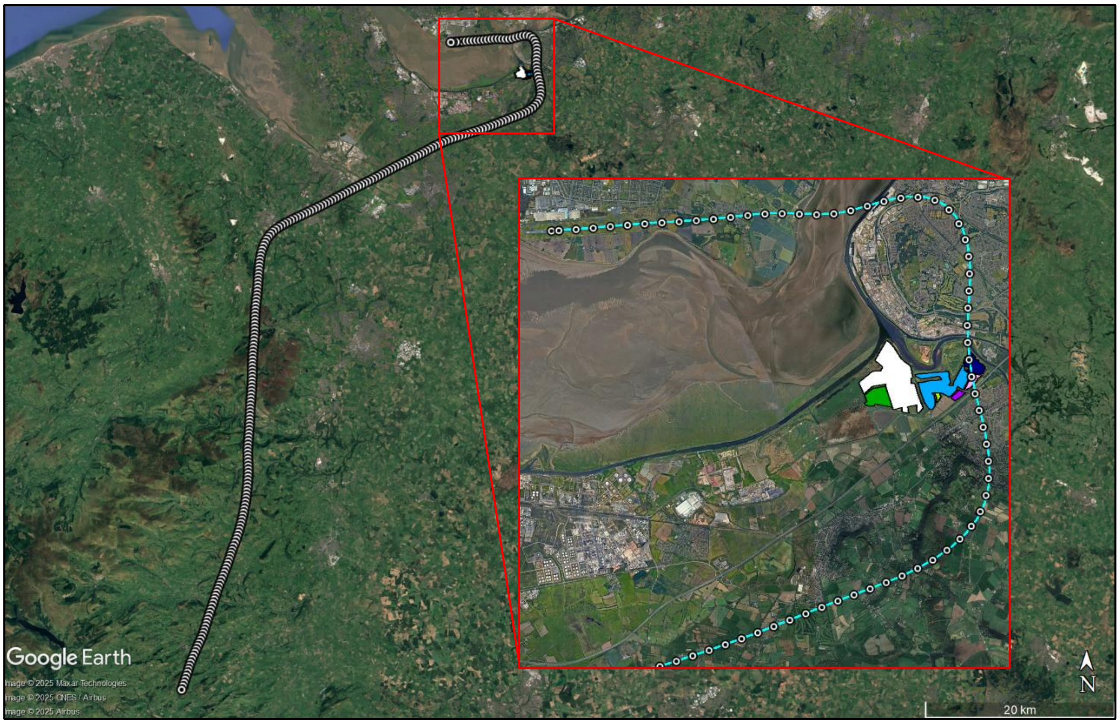


Figure 8 *Commercial visual approach receptors*

4.1.5 Commercial Instrument Approach

The safeguarding team at Liverpool John Lennon Airport has provided the track information for the commercial instrument approach over the Proposed Development for aircraft landing at runway 27. The points selected along this approach are shown in Figure *9* below.

Figure 9 *Commercial instrument approach receptors*

4.1.6 VFR Approach

The safeguarding team at Liverpool John Lennon Airport has provided the track information for the VFR approach close to the Proposed Development for aircraft landing at runway 27. The points selected along this approach are shown in Figure 10 below.

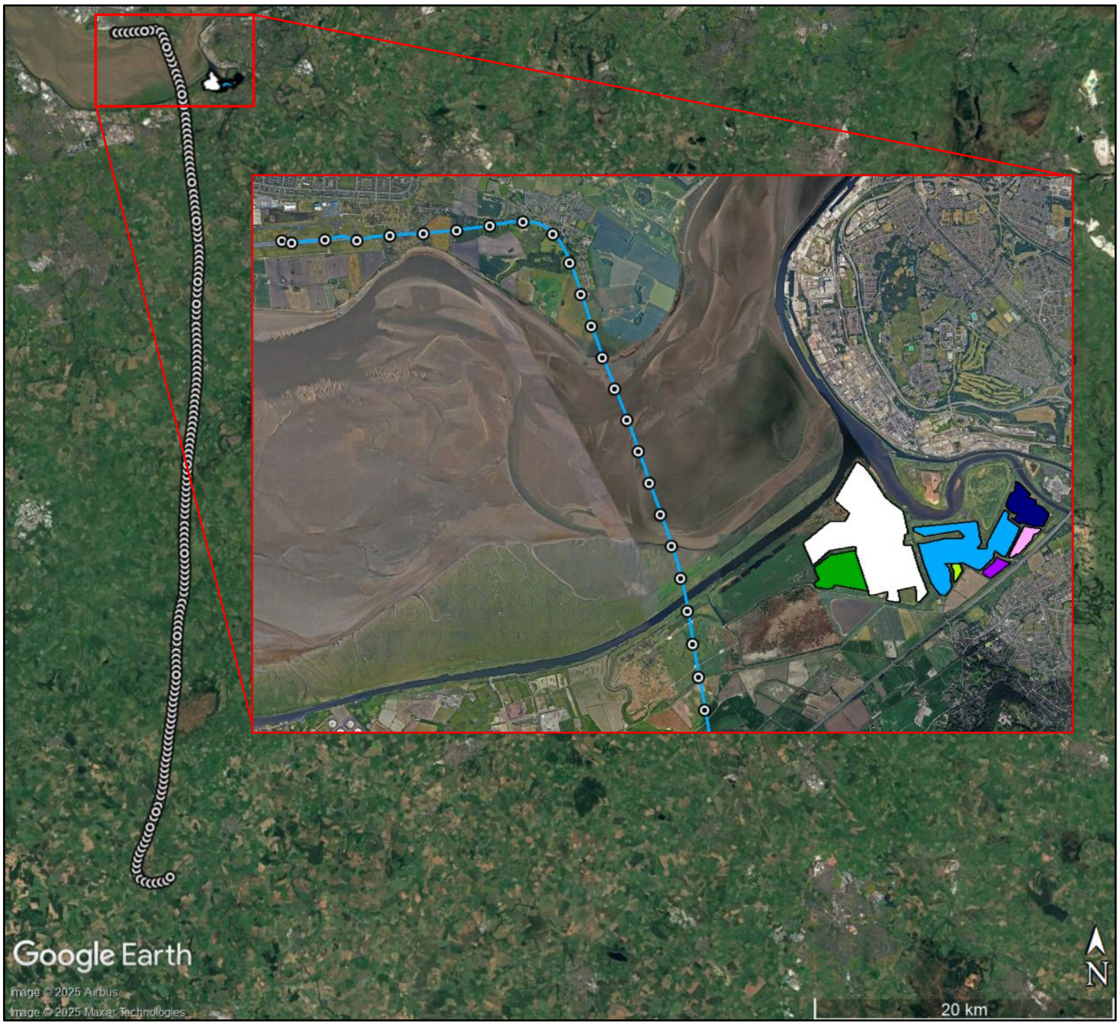


Figure 10 *VFR approach receptors*

4.1.7 Visual Reference Points

Aircraft flying visually typically fly with reference to easily identifiable locations on the ground – referred to as Visual Reference Points (VRPs). This assessment has therefore considered aircraft circling over the three closest VRPs to the site, Hale Head Lighthouse, Frodsham Hill, and Helsby Hill, at the request of Liverpool John Lennon Airport.

The location of the three VRPs and the aircraft receptor locations are shown in Figure 11 below. An altitude of 1,200ft above sea level has been used for the circling altitude as provided by Liverpool John Lennon Airport.

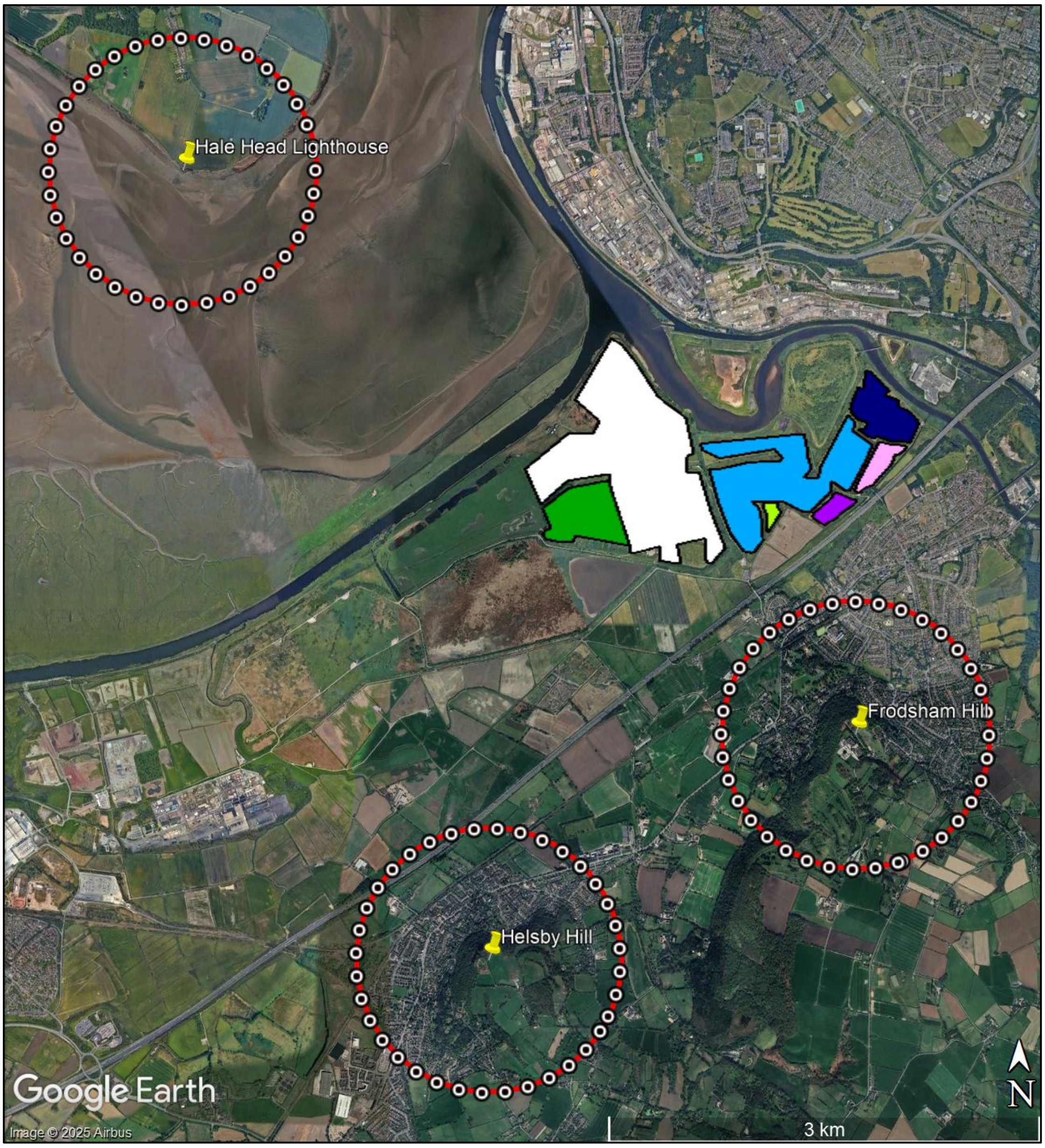


Figure 11 *Assessed VRP receptor locations*

4.2 Ground-Based Receptors

There is no formal guidance with regard to the maximum distance at which glint and glare should be assessed. From a technical perspective, there is no maximum distance for potential reflections. The significance of a reflection however decreases with distance because the proportion of an observer's field of vision that is taken up by the reflecting area diminishes as the separation distance increases. Terrain and shielding by vegetation are also more likely to obstruct an observer's view at longer distances.

The above parameters and industry experience over a significant number of glint and glare assessments undertaken, shows that a 1km assessment area from the Proposed Development is considered appropriate for glint and glare effects on road users and dwellings – shown as the orange areas in Figure 12 and Figure 13 in the following sub-sections.

Potential receptors within the associated assessment area are identified based on mapping and aerial photography of the region. A more detailed assessment is made if the modelling reveals a solar reflection would be geometrically possible.

Terrain data has been interpolated based on OS Terrain 50 DTM data. The assessed receptor details are presented in Appendix A.

4.2.1 Road Receptors

4.2.1.1 Road Receptors Overview

Road types can generally be categorised as:

- Major National – Typically a road with a minimum of two carriageways with a maximum speed limit of up to 70mph. These roads typically have fast moving vehicles with busy traffic;
- National – Typically a road with one or more carriageways with a maximum speed limit 60mph or 70mph. These roads typically have fast moving vehicles with moderate to busy traffic density;
- Regional – Typically a single carriageway with a maximum speed limit of up to 60mph. The speed of vehicles will vary with a typical traffic density of low to moderate;
- Local – Typically roads and lanes with the lowest traffic densities. Speed limits vary.

Technical modelling is not recommended for local roads, where traffic densities are likely to be relatively low. Any solar reflections from the Proposed Development that are experienced by a road user along a local road would be considered low impact in the worst case in accordance with the guidance presented in Appendix D. The analysis has therefore considered major national, national, and regional roads that:

- Are within the one-kilometre assessment area;
- Have a potential view of the panels.

4.2.1.2 Identified Road Receptors

The assessed receptors along the A56 (1 – 25), the B5152 (26 – 31), the B5394 (32 – 36), the M56 (37 – 74), the Weston Point Expressway (75 – 113), and Rocksavage Way (114 – 129) are shown in Figure 12 below.

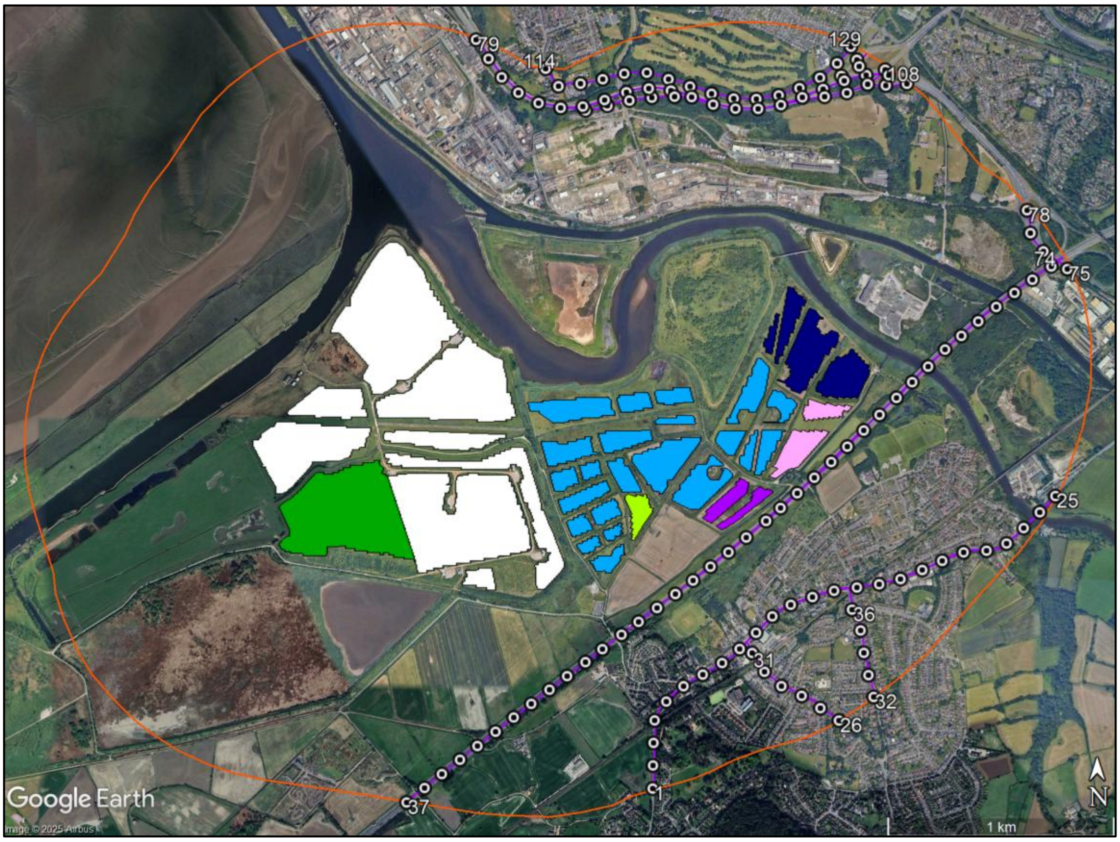


Figure 12 *Assessed road receptors*

4.2.2 Dwelling Receptors

4.2.2.1 Dwelling Receptors Overview

The analysis has considered dwellings that:

- Are within the one-kilometre assessment area; and
- Have a potential view of the panels.

In residential areas with multiple layers of dwellings, only the outer dwellings have been considered for assessment. This is because they will mostly obscure views of the solar panels to the dwellings behind them, which will therefore not be impacted by the Proposed Development because line of sight will be removed, or they will experience comparable effects to the closest assessed dwelling. Further analysis pertaining to visibility from residential dwellings in Frodsham is presented in Appendix H.

Additionally, in some cases, a single receptor point may be used to represent a small number of separate addresses. In such cases, the results for the receptor will be representative of the adjacent observer locations, such that the overall level of effect in each area is captured reliably.

4.2.2.2 Identified Dwelling Receptors

The assessed dwelling receptors are shown in Figure 13 below. In total, 143 dwellings have been assessed. An additional 1.8m height above ground is used in the modelling to simulate the typical viewing height of an observer on the ground floor[7].

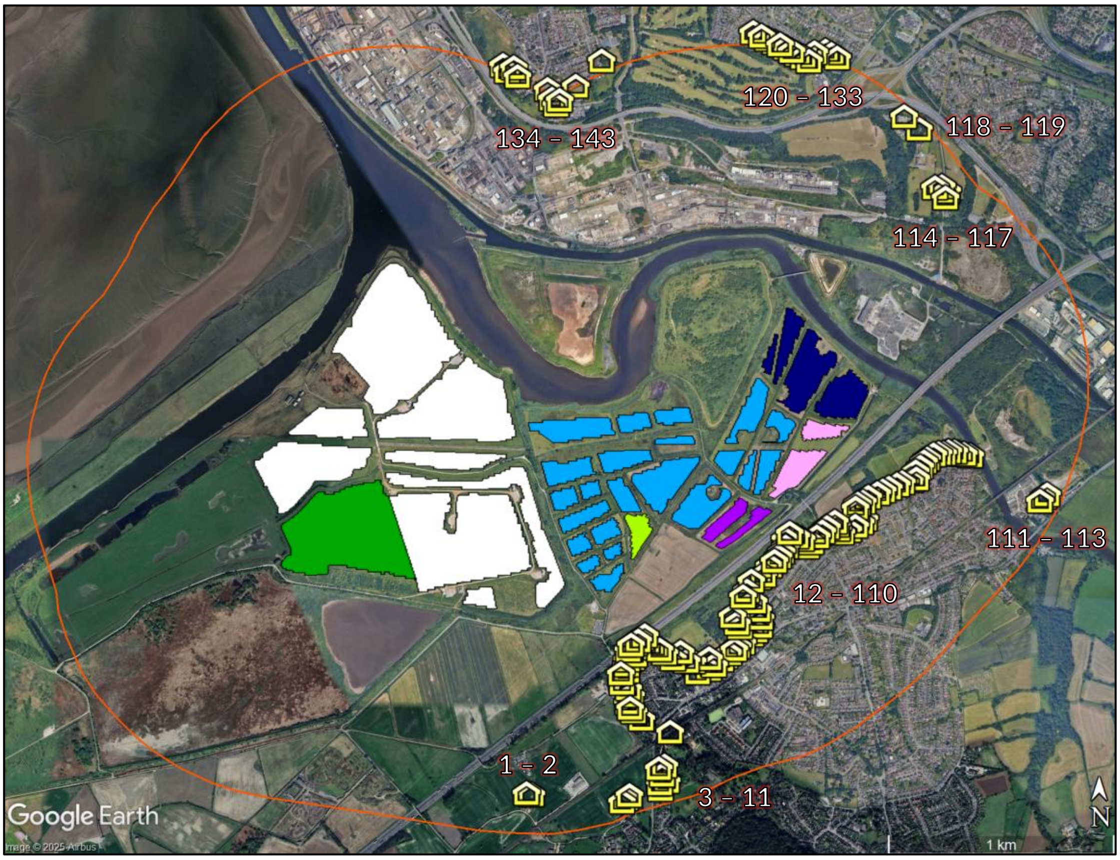


Figure 13 *Assessed dwelling receptors*

4.3 Viewpoint Receptor

4.3.1 Viewpoint Receptor Overview

The impact upon surrounding viewpoints is considered to be, at most, 'low' when considering the possible impacts on safety and amenity. The worst-case impact is also considered to be less than those possible towards a road user or upon the amenity of surrounding residents within the assessed dwellings.

Based on its local importance, the viewpoint from Frodsham Memorial on Frodsham Hill has been included within this assessment.

[7] Small changes to this height are not significant, and views above the ground floor considered are considered where appropriate.

4.3.2 Identified Viewpoint Receptor

The assessed viewpoint receptor is shown in Figure 14 below. An additional 1.7m height above ground is used in the modelling to simulate the typical standing height of an observer.

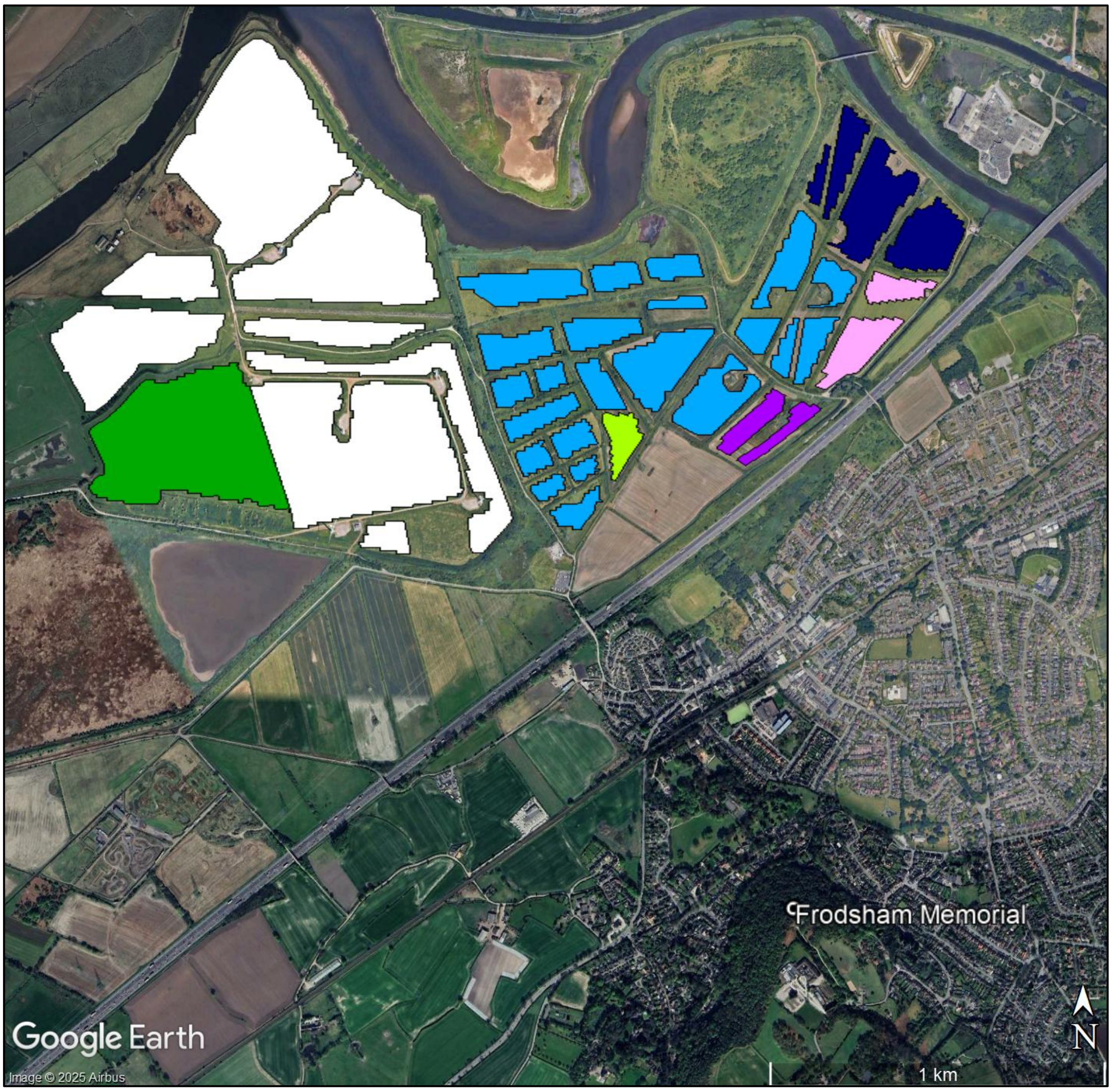


Figure 14 *Assessed viewpoint receptor*

5 ASSESSED REFLECTOR AREAS

5.1 Reflector Areas

The bounding coordinates for the Proposed Development reflector areas have been extrapolated from the solar panel areas presented in Section 2.1 - the data can be found in Appendix G.

The Pager Power model has used a resolution of 40m for this assessment. This means that a geometric calculation is undertaken for each identified receptor every 40m from within the defined areas. This resolution is sufficiently high to maximise the accuracy of the results – increasing the resolution further would not significantly change the modelling output. If a reflection is experienced from an assessed panel location, then it is likely that a reflection will be viewable from similarly located panels within the proposed solar development.

5.2 Aviation Reflector Areas

For the purposes of assessing aviation receptors, panel areas sharing the same configuration (outlined in Section 2.3) are grouped together to consider potential cumulative impacts. The reflector areas used for the aviation assessment are shown in Figure 15 below.

Figure 15 *Assessed aviation reflector areas*

6 GEOMETRIC ASSESSMENT RESULTS AND DISCUSSION

6.1 Overview

The following sub-section presents the results of the assessment and the significance of any predicted impact in the context of screening and the relevant criteria set out in each sub-section. The criteria are determined by the assessment process for each receptor, which are set out in Appendix D.

When determining the visibility of the reflecting panels for an observer, a conservative review of the available imagery and landscaping plans has been undertaken, whereby it is assumed views of the panels are possible if it cannot be reliably determined that existing screening will remove effects.

The tables in the following subsections summarise the results of the assessment. The predicted effects are first based on bare-earth terrain i.e. without consideration of screening from buildings and vegetation. The final column summarises the predicted impact considering the level of predicted screening based on a desk-based review of the available imagery.

The modelling output showing the precise predicted times are shown in Appendix I. Where relevant, desk-based review of imagery is presented in Appendix J.

6.2 Aviation Results

6.2.1 Glare Intensity Categorisation

The Pager Power and Forge models will be used to determine whether reflections are possible. Intensity calculations in line with the Sandia National Laboratories methodology have been undertaken for aviation receptors. These calculations are routinely required for solar photovoltaic developments on or near aerodromes. The intensity model calculates the expected intensity of a reflection with respect to the potential for an after-image (or worse) occurring. The designation used by the model is presented in Table 2 below along with the associated colour coding.

Coding Used	Intensity Key
Glare outside 50°	'Glare outside of a pilot's primary FOV (50 degrees horizontally either side of the direction of travel)'
'Green' glare	'Low potential for temporary after-image'
'Yellow' glare	'Potential for temporary after-image'
'Red' glare	'Potential for permanent eye damage'

Table 2 *Glare intensity designation*

This coding will be used in the results tables where a reflection has been calculated and is in accordance with Sandia National Laboratories' methodology. In addition, the intensity model allows for the assessment of a variety of solar panel surface materials. This assessment will considered solar panels with a surface material of 'smooth glass with an anti-reflective coating'. It is understood that this is the most commonly used solar panel surface material. Other surfaces that could be modelled include:

- Smooth glass without an anti-reflective coating;
- Light textured glass without an anti-reflective coating;
- Light textured glass with an anti-reflective coating; or
- Deeply textured glass.

If significant glare is predicted, modelling of less reflective surfaces could be undertaken.

6.2.2 Impact Significance Determination

6.2.2.1 ATC Tower

The key considerations for quantifying the impact significant upon an ATC Tower are:

- Whether a reflection is predicted to be experienced in practice;
- Whether a reflection is predicted to be operationally significant in practice or not.

Where no solar reflections are geometrically possible or where solar reflections are predicted to be significantly screened, no impact is predicted, and mitigation is not required.

Glare of any kind towards an ATC tower was formerly not permissible under the interim guidance provided by the Federal Aviation Administration in the USA[8] for on-airfield solar. Pager Power recommends a pragmatic approach to consider glare towards the ATC Tower in an operational context. Where solar reflections have 'low potential for temporary after-image' (green glare) expert assessment of the following factors is required to determine the impact significance[9]:

- The likely traffic volumes and level of safeguarding at the aerodrome. Licensed aerodromes typically have higher traffic volumes and are formally safeguarded;
- The time of day at which glare is predicted and whether the ATC Tower be operational at these times;
- The duration of any predicted glare; as glare that is experienced for low durations throughout the year is less significant than longer durations;
- Glare location relative to key operational areas;
- The relative size of the reflecting panel area and whether the reflecting area takes up a large percentage of an ATC controller's FOV[10];

---

[8] This FAA guidance from 2013 has since been superseded by the FAA guidance in 2021 whereby airports are tasked with determining safety requirements themselves.

[9] This approach taken is reflective of the changes made in the 2021 FAA guidance; however, it should be noted that this guidance states that it is up to the airport to determine the safety requirements themselves. Therefore, an airport may not accept any glare towards an ATC Tower.

[10] 210 degrees azimuth FOV.

- The location of the source of glare relative to the position of the Sun at the times and dates in which solar reflections are geometrically possible – effects that coincide with direct sunlight appear less prominent than those that do not;
- The level of predicted effect relative to existing sources of glare – a solar reflection is less noticeable by ATC controllers when there are existing reflective surfaces in the surrounding environment.

Following consideration of these mitigating factors, where the solar reflection is not deemed significant, a low impact is predicted, and mitigation is not recommended. Where the solar reflection is deemed significant or where glare with 'potential for temporary after-image' (yellow glare) is predicted, the impact significance is moderate, and mitigation is recommended.

Where solar reflections have 'potential for permanent eye damage', the impact significance is high, and mitigation is required.

6.2.2.2 Airborne Receptors

The key considerations for quantifying the impact significance upon airborne receptors are:

- Whether a reflection is predicted to be experienced in practice.
- The location of glare relative to a pilot's primary FOV (50 degrees either side of the approach bearing).
- The intensity of glare for the solar reflections:
  - Glare with 'low potential for temporary after-image' (green glare);
  - Glare with 'potential for temporary after-image' (yellow glare);
  - Glare with 'potential for permanent eye damage' (red glare).
- Whether a reflection is predicted to be operationally significant in practice or not.

Where no solar reflections are geometrically possible or where solar reflections are predicted to be significantly screened, no impact is predicted, and mitigation is not required.

Where solar reflections have 'low potential for temporary after-image' (green glare) or occur outside of a pilot's primary field of view (50 degrees either side of the approach bearing), the impact significance is low, and mitigation is not recommended.

Solar reflections that have 'potential for a temporary after-image' (yellow glare) was formerly not permissible under the interim guidance provided by the Federal Aviation Administration in the USA[11] for on-airfield solar. Whilst this guidance was never formally applicable outside of the USA, it has been a common point of reference internationally. Pager Power recommends a pragmatic approach whereby instances of 'yellow' glare are evaluated in a technical and operational context. As per Pager Power's glint and glare guidance document[12], where solar

[11] This FAA guidance from 2013 has since been superseded by the FAA guidance in 2021 whereby airports are tasked with determining safety requirements themselves.
[12] Pager Power Glint and Glare Guidance, Fourth Edition, September 2022.

reflections have ‘potential for temporary after-image’ expert assessment of the following relevant factors is required to determine the impact significance[13]:

- The likely traffic volumes and level of safeguarding at the aerodrome – licensed aerodromes typically have higher traffic volumes and are formally safeguarded;
- The time of day at which glare is predicted and whether the aerodrome will be operational such that pilots can be on the approach at these times;
- The duration of any predicted glare – glare that occurs for low durations throughout the year is less likely to be experienced than glare that occurs for longer durations throughout the year;
- The location and size of the reflecting panel area relative to a pilot’s primary FOV;
- The location of the source of glare relative to the position of the Sun at the times and dates in which solar reflections are geometrically possible – effects that coincide with direct Sunlight appear less prominent than those that do not;
- The level of predicted effect relative to existing sources of glare – a solar reflection is less noticeable by pilots when there are existing reflective surfaces in the surrounding environment.

Following consideration of these mitigating factors, where the solar reflection is not considered significant, a low impact is predicted, and mitigation is not recommended; however, consultation with the aerodrome is recommended to understand their position along with any feedback or comments regarding the Proposed Development. Where the solar reflection is considered significant, the impact significance is moderate, and mitigation is recommended.

Where solar reflections have ‘potential for permanent eye damage’, the impact significance is high, and mitigation is required.

[13] This approach taken is reflective of the changes made in the 2021 FAA guidance; however, it should be noted that this guidance states that it is up to the airport to determine the safety requirements themselves. Therefore, an airport may not accept any yellow glare towards approach paths.

6.2.3 Geometric Modelling Results – ATC Tower and Two-Mile Approaches

The results of the geometric modelling for the ATC Tower and two-mile approaches are presented in Table 3 below.

Receptor/Runway	Geometric Modelling Result	Worst-Case Glare Category	Identified Screening (Desk-Based Review)	Relevant Factors	Impact Classification
ATC Tower	Solar reflections with a maximum of 'low potential for temporary after-image' are predicted	'Green'	Marginal views of the reflecting panels cannot be ruled out despite screening from the solar panels in the closer fields themselves	See Section 6.2.3.1	Low
Runway 09	Solar reflections with a maximum of 'low potential for temporary after-image' are geometrically possible towards the entire two-mile approach		N/A	N/A	Low
Runway 27	Solar reflections outside of a pilot's primary FOV[14] are geometrically possible between the threshold and 1.1-miles from the threshold	'Outside 50°'	N/A	N/A	Low
Solar reflections towards two-mile approaches shown in Figure 16 on the following page					

Table 3 *Geometric modelling results – ATC Tower and approaches*

[14] 50° either side of the approach path

Figure 16 *Solar reflections towards two-mile approaches*

6.2.3.1 ATC Tower Results Further Discussion

The glare charts for the ATC Tower are shown in Figure 17 below.

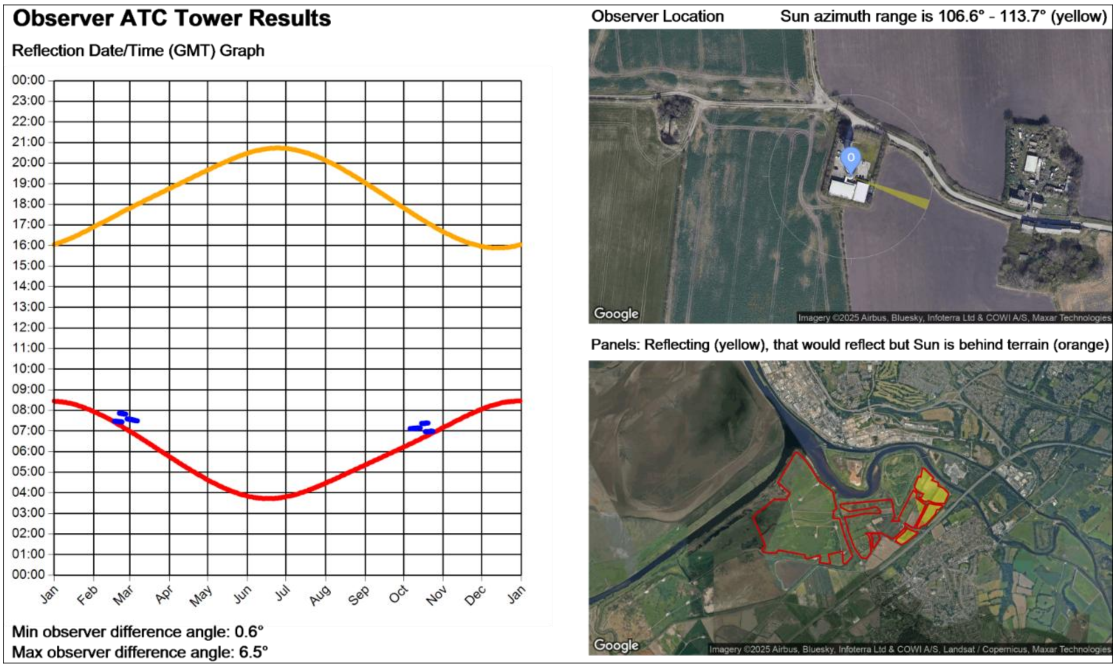


Figure 17 *ATC Tower glare charts*

Most of the reflecting panels will be obstructed by the solar panels in the closer fields and intervening terrain. It is possible that no visibility of the reflecting panels; however, marginal views of the 'navy' and 'pink' areas cannot be reliably ruled out.

Guidance pertaining to solar developments stated that glare of any kind towards an ATC tower was formerly not permissible under the 2013 FAA Policy for on-airfield solar however this was amended in the 2021 Policy. It now states that an ocular assessment is required and gives the airport more authority to decide whether the impact is significant or not. Whilst this guidance was never formally applicable outside of the USA, it has been a common point of reference internationally.

Relevant considerations to determine the impact upon an ATC Tower include:

- The time of day at which glare is predicted.
- The duration of any predicted glare.
- The location of the source of glare relative to the runway thresholds.
- The intensity of the predicted glare.
- The level of predicted effect relative to existing sources of glare.

The considerations in relation to the ATC Tower and the Proposed Development from the potentially visible panels are as follows:

- All solar reflections are predicted within approximately one hour after sunrise meaning that they will coincide with direct sunlight, which is a far more significant source of light – see Figure 18 on the following page.
- Solar reflections are predicted to be experienced for a maximum of approximately 560 minutes (9.33 hours) per year. This equates to 0.21% of total daylight hours across the year[15]. The weather would also have to be clear and sunny at the specific times when glare is possible.
- The Proposed Development is in the opposite direction to the runway 09 threshold and 40 degrees laterally from the runway 27 threshold. An air traffic controller will therefore not be looking directly towards the reflecting panels when observing the key operational areas, including taxiways.
- Glare intensities are of a maximum of 'green' category and do not border onto the next significant category 'yellow', i.e. solar reflections do not border on having 'potential for temporary after-image'.

Based on the above considerations, a low impact upon the ATC Tower is predicted, and no mitigation is recommended. Liverpool John Lennon Airport has confirmed the predicted impacts towards the ATC Tower are acceptable.

---

[15] Based on an average of 12 hours of sunlight per day.

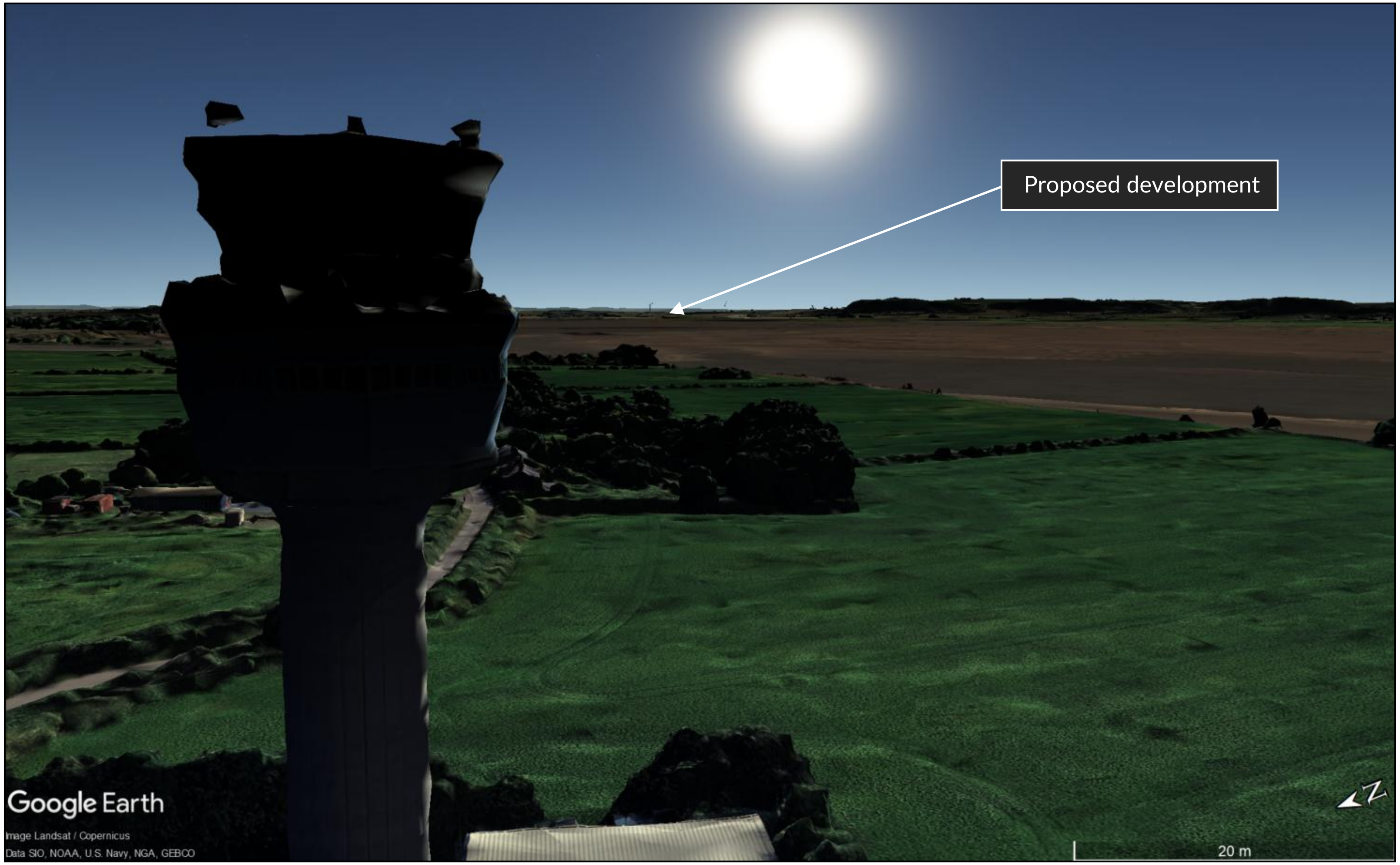


Figure 18 *Viewpoint from ATC Tower and sun location at 07:50 AM on 10/10*

6.2.4 Geometric Modelling Results – Extended Approaches

The results of the geometric modelling for the extended approaches are presented in Table 4 below.

Approach	Geometric Modelling Result	Worst-Case Glare Category	Relevant Factors	Impact Classification
Commercial visual	Solar reflections outside of a pilot's primary FOV are geometrically possible towards two sections of the commercial visual approach	'Outside 50°'	N/A	Low
Commercial instrument	Solar reflections outside of a pilot's primary FOV are geometrically possible towards three sections of the commercial instrument approach	'Green'	N/A	Low
VFR	Solar reflections outside of a pilot's primary FOV are geometrically possible towards a section of the VFR approach	'Outside 50°'	N/A	Low
Solar reflections towards the extended approaches are shown in Figure 19 to Figure 21 on the following pages				

Table 4 *Geometric modelling results – extended approaches*

Figure 19 *Solar reflections towards commercial visual approach*

Figure 20 *Solar reflections towards commercial instrument approach*

Figure 21 *Solar reflections towards VFR approach*

6.2.5 Geometric Modelling Results – Visual Circuits

The results of the geometric modelling for the visual circuits are presented in Table 5 below.

<table>
<tr><th>Visual Circuit</th><th>Geometric Modelling Result</th><th>Worst-Case Glare Category</th><th>Relevant Factors</th><th>Impact Classification</th></tr>
<tr><td>09RH / 27LH</td><td>Solar reflections are geometrically possible towards the entire visual circuit with a maximum of ‘low potential for temporary after-image’</td><td rowspan="2">‘Green’</td><td rowspan="2">N/A</td><td rowspan="2">Low</td></tr>
<tr><td>27RH / 09LH</td><td>Solar reflections are geometrically possible towards a section of the visual circuit with a maximum of ‘low potential for temporary after-image’</td></tr>
<tr><td colspan="5"><u>Solar reflections towards visual circuits are shown in Figure 22 and Figure 23 on the following pages</u></td></tr>
</table>

Table 5 *Geometric modelling results – visual circuits*

Figure 22 *Solar reflections towards 09RH/27LH visual circuit*

Figure 23 *Solar reflections towards 09LH/ 27RH visual circuit*

6.2.6 Geometric Modelling Results – VRPs

The results of the geometric modelling for the VRP receptors are presented in Table 6 below.

<table>
<tr><th>VRP</th><th>Geometric Modelling Result</th><th>Worst-Case Glare Category</th><th>Relevant Factors</th><th>Impact Classification</th></tr>
<tr><td>Hale Head Lighthouse</td><td rowspan="2">Solar reflections with a maximum of ‘low potential for temporary after-image’ towards most of the circling pattern are predicted</td><td rowspan="2">‘Green’</td><td rowspan="2">N/A</td><td rowspan="2">Low</td></tr>
<tr><td>Frodsham Hill</td></tr>
<tr><td>Helsby Hill</td><td>No solar reflections are geometrically possible</td><td>N/A</td><td>N/A</td><td>No impact</td></tr>
<tr><td colspan="5"><u>Worst-case solar reflections towards aircraft circling over VRPs shown in Figure 24 on the following page</u></td></tr>
</table>

Table 6 *Geometric modelling results – VRPs*

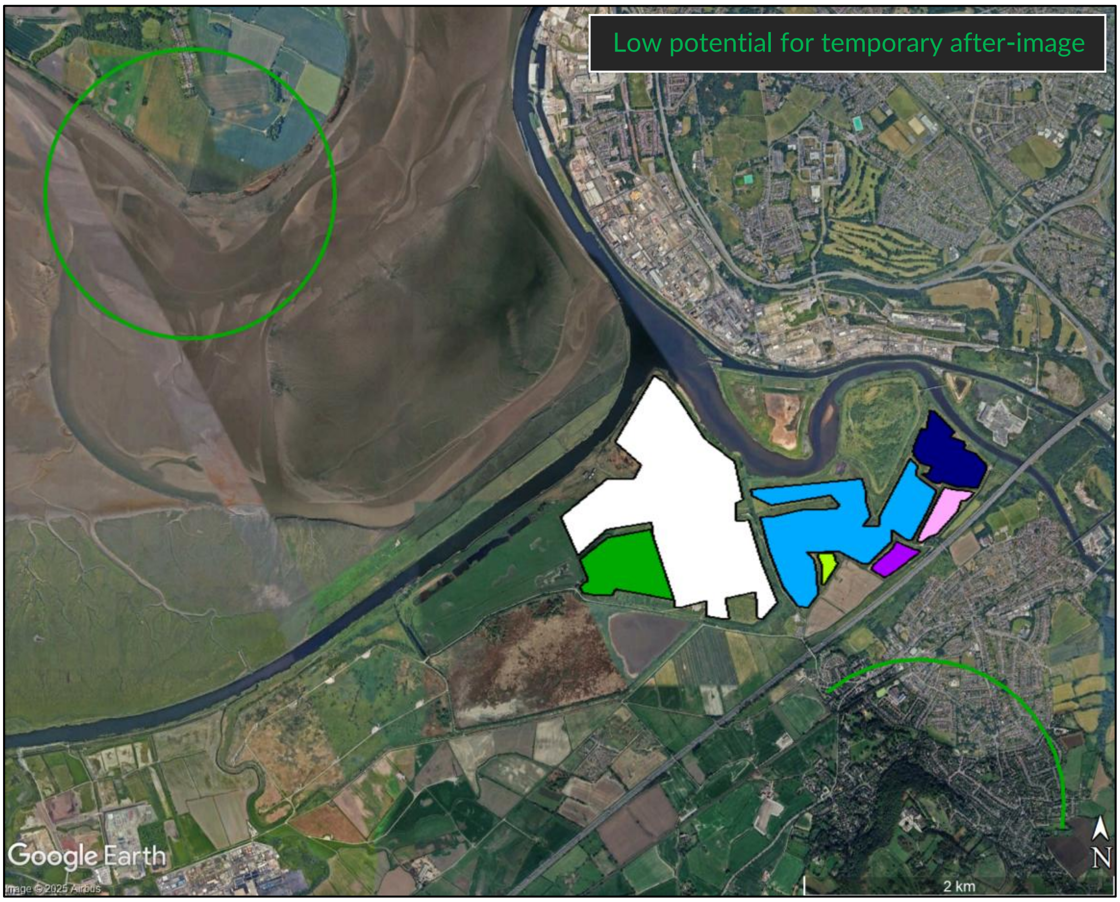


Figure 24 *Solar reflections towards aircraft circling over VRPs*

6.3 Road Results

6.3.1 Impact Significance Determination

The key considerations for quantifying the impact significance upon road users along major national, national, and regional roads are:

- Whether a reflection is predicted to be experienced in practice; and
- The location of the reflecting panel relative to a road user's direction of travel.

Where reflections are geometrically possible but expected to be screened, no impact is predicted, and mitigation is not required.

Where reflections originate from outside of a road user's primary FOV (50 degrees either side of the direction of travel), or the closest reflecting panel is over 1km from the road user, the impact significance is low, and mitigation is not recommended.

Where reflections are predicted to be experienced from inside of a road user's primary FOV, expert assessment of the following relevant factors is required to determine the impact significance and mitigation requirement:

- Whether visibility is likely for elevated drivers (relevant to dual carriageways and motorways[16]);
- Whether the solar reflection originates from directly in front of a road user. Solar reflections that are directly in front of a road user are more hazardous;
- The separation distance to the reflecting panel area. Larger separation distances reduce the proportion of an observer's FOV that is affected by glare;
- The position of the Sun. Effects that coincide with direct sunlight appear less prominent than those that do not. The Sun is a far more significant source of light.

Following consideration of these relevant factors, where the solar reflection is not deemed significant, a low impact is predicted, and mitigation is not recommended. Where the solar reflection is deemed significant, the impact significance is moderate, and mitigation is recommended.

Where reflections originate from directly in front of a road user and there are no further mitigating factors, the impact significance is high, and mitigation is required.

---

[16] There is typically a higher density of elevated drivers (such as HGVs) along dual carriageways and motorways compared to other types of roads.

6.3.2 Geometric Modelling Results

The modelling has shown that solar reflections are geometrically possible towards 64 of the 129 assessed road receptors, totalling approximately 6.4km of road. Table 7 below and on the following pages summarises the predicted impact at these receptors.

Road Receptor	Geometric Modelling Results (screening not considered)	Identified Screening and Predicted Visibility (desk-based review)	Whether reflections are experienced inside a road user's primary FOV (screening considered)	Mitigating Factors	Predicted Impact Classification
1 – 3	Solar reflections are **not geometrically possible**	N/A	N/A	N/A	No impact
4 – 9	Solar reflections are geometrically possible from **outside** a road user's primary FOV	Views of the reflecting panels will be significantly obstructed by buildings, dwellings, and the general environment in Frodsham	N/A	N/A	No impact
	See Figure J27 to Figure J29 on pages 137 to 139				
10 – 25	Solar reflections are geometrically possible from **inside** a road user's primary FOV	Views of the reflecting panels will be significantly obstructed by buildings, dwellings, and the general environment in Frodsham	N/A	N/A	No impact
	See Figure J30 to Figure J34 on pages 140 to 144				

Road Receptor	Geometric Modelling Results (screening not considered)	Identified Screening and Predicted Visibility (desk-based review)	Whether reflections are experienced inside a road user's primary FOV (screening considered)	Mitigating Factors	Predicted Impact Classification
26 – 31	Solar reflections are geometrically possible from **inside** a road user's primary FOV	Views of the reflecting panels will be significantly obstructed by buildings, dwellings, and the general environment in Frodsham	N/A	N/A	No impact
	See Figure J35 and Figure J36 on pages 145 and 146				
32 – 36	Solar reflections are geometrically possible from **outside** a road user's primary FOV	Views of the reflecting panels will be significantly obstructed by buildings, dwellings, and the general environment in Frodsham	N/A	N/A	No impact
	See Figure J37 to Figure J39 on pages 147 to 149				
37 – 45	Solar reflections are **not geometrically possible**	N/A	N/A	N/A	No impact
46 – 49	Solar reflections are geometrically possible from **outside** a road user's primary FOV	Views of the reflecting panels will be significantly obstructed by existing vegetation on the site boundary Solar reflections occur between mid-April and mid-August, when vegetation is predicted to be in-leaf	N/A	N/A	No impact

<table>
<tr><th>Road Receptor</th><th>Geometric Modelling Results (screening not considered)</th><th>Identified Screening and Predicted Visibility (desk-based review)</th><th>Whether reflections are experienced inside a road user’s primary FOV (screening considered)</th><th>Mitigating Factors</th><th>Predicted Impact Classification</th></tr>
<tr><td></td><td colspan="5"><u>See Figure J40 to Figure J42 on pages 150 to 152</u></td></tr>
<tr><td rowspan="2">50 – 53</td><td>Solar reflections are geometrically possible from <u>inside</u> a road user’s primary FOV</td><td>Views of the reflecting panels will be significantly obstructed by existing vegetation
Solar reflections occur between mid-March and late September, when vegetation is predicted to be in-leaf</td><td>N/A</td><td>N/A</td><td>No impact</td></tr>
<tr><td colspan="5"><u>See Figure J43 to Figure J45 on pages 153 to 155</u></td></tr>
</table>

Road Receptor	Geometric Modelling Results (screening not considered)	Identified Screening and Predicted Visibility (desk-based review)	Whether reflections are experienced inside a road user's primary FOV (screening considered)	Mitigating Factors	Predicted Impact Classification
54 – 55	Solar reflections are geometrically possible from **inside** a road user's primary FOV	Existing vegetation will screen most of the reflecting panels Solar reflections occur between mid-March and late September, when vegetation is predicted to be in-leaf Hedgerow screening will be implemented to significantly obstruct views of the reflecting solar panels within a road user's FOV Mature planting or mesh fencing of 3.5m above ground will be used to provide immediate screening and to avoid any temporary significant effects Additional hedgerow planting will significantly obstruct views of the reflecting panels once matured	Solar reflections predicted to be experienced from **outside** a road user's primary FOV temporarily	N/A	Low reducing to no impact
	See Figure J46 to Figure J48 on page 156 to 158				

Road Receptor	Geometric Modelling Results (screening not considered)	Identified Screening and Predicted Visibility (desk-based review)	Whether reflections are experienced inside a road user's primary FOV (screening considered)	Mitigating Factors	Predicted Impact Classification
56 – 58	Solar reflections are geometrically possible from **inside** a road user's primary FOV	Existing vegetation will significantly obstruct views of the reflecting panels within a road user's primary FOV Solar reflections occur between mid-March and late September, when vegetation is predicted to be in-leaf Views of reflecting panels outside the primary FOV remain under baseline conditions Hedgerow and tree planting will significantly obstruct views of the remaining visible panels once matured	Solar reflections predicted to be experienced from **outside** a road user's primary FOV temporarily	N/A	Low reducing to no impact
	See Figure J49 to Figure J52 on pages 159 to 162				

Road Receptor	Geometric Modelling Results (screening not considered)	Identified Screening and Predicted Visibility (desk-based review)	Whether reflections are experienced inside a road user's primary FOV (screening considered)	Mitigating Factors	Predicted Impact Classification
59 – 60	Solar reflections are geometrically possible from **<u>inside</u>** a road user's primary FOV	Views of the reflecting panels will be significantly obstructed by existing roadside vegetation Solar reflections occur between mid-March and late September, when vegetation is predicted to be in-leaf	N/A	N/A	No impact
	<u>See Figure J53 to Figure J54 on pages 163 to 164</u>				

Road Receptor	Geometric Modelling Results (screening not considered)	Identified Screening and Predicted Visibility (desk-based review)	Whether reflections are experienced inside a road user's primary FOV (screening considered)	Mitigating Factors	Predicted Impact Classification
61 – 63	Solar reflections are geometrically possible from **inside** a road user's primary FOV	Existing vegetation will significantly obstruct views of the reflecting panels within a road user's primary FOV Solar reflections occur between mid-March and late September, when vegetation is predicted to be in-leaf Views of reflecting panels outside the primary FOV remain under baseline conditions Hedgerow and tree planting will significantly obstruct views of the remaining visible panels once matured	Solar reflections predicted to be experienced from **outside** a road user's primary FOV temporarily	N/A	Low reducing to no impact
	See Figure J55 to Figure J57 on pages 165 to 167				

<table>
<tr><th>Road Receptor</th><th>Geometric Modelling Results (screening not considered)</th><th>Identified Screening and Predicted Visibility (desk-based review)</th><th>Whether reflections are experienced inside a road user’s primary FOV (screening considered)</th><th>Mitigating Factors</th><th>Predicted Impact Classification</th></tr>
<tr><td rowspan="2">64</td><td>Solar reflections are geometrically possible from <u>inside</u> a road user’s primary FOV</td><td>Views of the reflecting panels will be significantly obstructed by existing roadside vegetation
Solar reflections occur between mid-March and late September, when vegetation is predicted to be in-leaf</td><td>N/A</td><td>N/A</td><td>No impact</td></tr>
<tr><td colspan="5"><u>See Figure J58 and Figure J59 on pages 168 and 169</u></td></tr>
<tr><td rowspan="2">65 – 67</td><td>Solar reflections are geometrically possible from <u>inside</u> a road user’s primary FOV</td><td>Existing vegetation will significantly obstruct views of the reflecting panels within a road user’s primary FOV
Solar reflections occur between mid-March and late September, when vegetation is predicted to be in-leaf
Views of reflecting panels outside FOV are predicted</td><td>Predicted to be experienced from <u>outside</u> a road user’s primary FOV</td><td>N/A</td><td>Low</td></tr>
<tr><td colspan="5"><u>See Figure J60 to Figure J62 on pages 170 to 172</u></td></tr>
</table>

Road Receptor	Geometric Modelling Results (screening not considered)	Identified Screening and Predicted Visibility (desk-based review)	Whether reflections are experienced inside a road user's primary FOV (screening considered)	Mitigating Factors	Predicted Impact Classification
68	Solar reflections are geometrically possible from **outside** a road user's primary FOV	Existing vegetation and Frodsham Sub Station will significantly obstruct views of the reflecting panels Solar reflections occur between mid-March and late September, when vegetation is predicted to be in-leaf	N/A	N/A	No impact
	See Figure J63 and Figure J64 on pages 173 and 174				
69 – 74	Solar reflections are geometrically possible from **inside** a road user's primary FOV	Views of the reflecting panels will be significantly obstructed by the bridge on which the vehicles will be travelling, the power station, and existing vegetation	N/A	N/A	No impact
	See Figure J65 to Figure J68 on pages 175 to 178				

Road Receptor	Geometric Modelling Results (screening not considered)	Identified Screening and Predicted Visibility (desk-based review)	Whether reflections are experienced inside a road user's primary FOV (screening considered)	Mitigating Factors	Predicted Impact Classification
75 – 76	Solar reflections are geometrically possible from **inside** a road user's primary FOV	Views of the reflecting panels will be significantly obstructed by existing vegetation Solar reflections occur between mid-March and late September, when vegetation is predicted to be in-leaf	N/A	N/A	No impact
	See Figure J69 and Figure J70 on pages 179 and 180				
77 – 129	Solar reflections are **not** geometrically possible	N/A	N/A	N/A	No impact

Table 7 *Geometric modelling results – road receptors*

6.4 Dwelling Results

6.4.1 Impact Significance Determination

The key considerations for quantifying the impact upon residential dwellings are:

- Whether a reflection is predicted to be experienced in practice;
- The duration of the predicted effects, relative to thresholds of:
  - three months per year;
  - 60 minutes on any given day.

Where reflections are geometrically possible but expected to be screened, no impact is predicted, and mitigation is not required.

Where effects occur for less than three months per year and less than 60 minutes on any given day, or the closest reflecting panel is over 1km from the dwelling, the impact significance is low, and mitigation is not recommended.

Where reflections are predicted to be experienced for more than three months per year **and/or** for more than 60 minutes on any given day, expert assessment of the following relevant factors is required to determine the impact significance and mitigation requirement:

- The separation distance to the reflecting panel area[17]. Larger separation distances reduce the proportion of an observer's FOV that is affected by glare;
- The position of the Sun. Effects that coincide with direct sunlight appear less prominent than those that do not. The Sun is a far more significant source of light;
- Whether solar reflections will be experienced from all storeys. The ground floor is typically considered the main living space and therefore has a greater significance with respect to residential amenity;
- Whether the dwelling appears to have windows facing the reflecting areas. An observer may need to look at an acute angle to observe the reflecting areas.

Following consideration of these relevant factors, where the solar reflection is not deemed significant, a low impact is predicted, and mitigation is not recommended. Where the solar reflection is deemed significant, the impact significance is moderate, and mitigation is recommended.

If there are no mitigating factors and the effects last for more than three months per year **and** for more than 60 minutes on any given day, the impact significance is high, and mitigation is required.

---

[17] Which is often greater than the nearest panel boundary, because not all areas of the site cause specular reflections towards particular receptor locations.

6.4.2 Geometric Modelling Results

The modelling has shown that solar reflections are geometrically possible towards 102 of the 143 assessed dwelling receptors. Table 8 below and on the following pages summarises the predicted impact at these receptors.

Dwelling Receptor	Geometric Modelling Results (without consideration of screening)	Identified Screening and Predicted Visibility (desk-based review)	Duration of effects (with consideration of screening)	Mitigating Factors	Impact Classification
1 – 11	Solar reflections are **not geometrically possible**	N/A	N/A	N/A	No impact
12 – 20	Solar reflections geometrically possible for: **Less** than 60 minutes on any given day **Less** than three months per year	Views of the reflecting panels will be significantly obstructed by existing vegetation Solar reflections occur between early May and early August, when vegetation is predicted to be in-leaf	None	N/A	No impact
	See Figure J71 on page 182				

Dwelling Receptor	Geometric Modelling Results (without consideration of screening)	Identified Screening and Predicted Visibility (desk-based review)	Duration of effects (with consideration of screening)	Mitigating Factors	Impact Classification
21 – 61	Solar reflections geometrically possible for: **Less** than 60 minutes on any given day **More** than three months per year	Views of the reflecting panels will be significantly obstructed by existing vegetation and/or other dwellings Solar reflections occur between mid-March and late September, when vegetation is predicted to be in-leaf	None	N/A	No impact
	See Figure J72 to Figure J74 on pages 183 to 185				
62 – 71	Solar reflections geometrically possible for: **Less** than 60 minutes on any given day **More** than three months per year	Marginal views through small gaps in vegetation cannot be ruled out from some first storey windows Solar reflections occur between mid-March and late September, when vegetation is predicted to be in-leaf	Solar reflections predicted to be experienced for: **Less** than 60 minutes on any given day **More** than three months per year	Effects will only be experienced from above the ground floor Effects will mostly coincide with direct sunlight	Low
	See Figure J75 and Figure J76 on pages 186 and 187				

Dwelling Receptor	Geometric Modelling Results (without consideration of screening)	Identified Screening and Predicted Visibility (desk-based review)	Duration of effects (with consideration of screening)	Mitigating Factors	Impact Classification
72 – 75	Solar reflections geometrically possible for: **Less** than 60 minutes on any given day **More** than three months per year	Marginal views through small gaps between the surrounding dwellings and existing vegetation cannot be ruled out Solar reflections occur between mid-March and late September, when vegetation is predicted to be in-leaf	Solar reflections predicted to be experienced for: **Less** than 60 minutes on any given day **Less** than three months per year	N/A	Low
	See Figure J77 on page 188				

Dwelling Receptor	Geometric Modelling Results (without consideration of screening)	Identified Screening and Predicted Visibility (desk-based review)	Duration of effects (with consideration of screening)	Mitigating Factors	Impact Classification
76 – 78	Solar reflections geometrically possible for: Less than 60 minutes on any given day More than three months per year	Partial views through gaps in vegetation cannot be ruled out from some first storey windows Solar reflections occur between mid-March and late September, when vegetation is predicted to be in-leaf Hedgerow planting will provide additional layers of vegetation between the dwellings and closest reflecting panels	Solar reflections predicted to be experienced for: Less than 60 minutes on any given day More than three months per year	Effects are expected to be limited to above the ground floor only Effects will mostly coincide with direct sunlight The distance to the closest visible reflecting panel is significant	Low
	See Figure J78 on page 189				

Dwelling Receptor	Geometric Modelling Results (without consideration of screening)	Identified Screening and Predicted Visibility (desk-based review)	Duration of effects (with consideration of screening)	Mitigating Factors	Impact Classification
79 – 90	Solar reflections geometrically possible for: Less than 60 minutes on any given day More than three months per year	Marginal views cannot be ruled out despite partial screening from existing vegetation Solar reflections occur between mid-March and late September, when vegetation is predicted to be in-leaf	Solar reflections predicted to be experienced for: Less than 60 minutes on any given day Less than three months per year	N/A	Low
	See Figure J79 and Figure J80 on pages 190 and 191				
91 – 92	Solar reflections geometrically possible for: Less than 60 minutes on any given day More than three months per year	Partial views through gaps in vegetation cannot be ruled out from some first storey windows Solar reflections occur between mid-March and late September, when vegetation is predicted to be in-leaf	Solar reflections predicted to be experienced for: Less than 60 minutes on any given day More than three months per year	Effects will only be experienced from above the ground floor Effects will mostly coincide with direct sunlight The windows typically do not face the reflecting panel area	Low
	See Figure J81 on page 192				

Dwelling Receptor	Geometric Modelling Results (without consideration of screening)	Identified Screening and Predicted Visibility (desk-based review)	Duration of effects (with consideration of screening)	Mitigating Factors	Impact Classification
93 – 110	Solar reflections geometrically possible for: **Less** than 60 minutes on any given day **More** than three months per year	Views of the reflecting panels will be significantly obstructed by existing vegetation Solar reflections occur between mid-March and late September, when vegetation is predicted to be in-leaf	None	N/A	No impact
	See Figure J82 on page 193				
111 – 113	Solar reflections geometrically possible for: **Less** than 60 minutes on any given day **More** than three months per year	Views of the reflecting panels will be significantly obstructed by commercial buildings and existing vegetation Solar reflections occur between mid-March and late September, when vegetation is predicted to be in-leaf	None	N/A	No impact
	See Figure J84 on page 195				
114 – 143	Solar reflections are **not geometrically possible**	N/A	N/A	N/A	No impact

Table 8 *Geometric modelling results – dwellings*

6.5 Frodsham Memorial Results

6.5.1 Geometric Modelling Results

The modelling has shown that no solar reflections are geometrically possible towards the assessed Frodsham Memorial receptor.

No impacts upon observers at the Frodsham Memorial are predicted and no mitigation is required.

7 HIGH-LEVEL ASSESSMENT OF WEAVER NAVIGATION USERS

7.1 Overview

The Weaver Navigation run to the north and west of the Proposed Development and is approximately 260m from the closest solar panel. Reflections towards users of these rivers could therefore be experienced if visibility of the panel face is possible and under certain conditions (typically coinciding with sunrise/sunset i.e. when the Sun is low in the sky and beyond the panels).

7.2 Assessment

It is predicted that visibility of the solar panel faces from the river will be significantly limited, if not completely obstructed. This is due to most of the Weaver Navigation being mostly to the north of the Proposed Development and the river being lower than the banks and environment.

In the unlikely scenario that visibility of the solar panel faces are possible, and solar reflections are experienced, no significant impacts to boaters on the surrounding rivers are predicted. The reasoning is due to the sensitivity of the receptors (in terms of amenity and safety) being concluded to be of low significance because:

- Effects would typically coincide with direct sunlight. The Sun is a far more significant source of light;
- The reflection intensity is similar for solar panels and still water (and significantly less than reflections from glass and steel[18]) which is frequently a feature of the outdoor environment surrounding rivers, including the river water itself. Therefore, the reflections are likely to be comparable to those from common outdoor sources whilst navigating the river on a regular basis;
- 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 on a river are transient, and time and location sensitive whereby a boat could move beyond the solar reflection zone with ease with little impact upon safety or amenity.

7.3 Conclusions

A maximum of low impact is predicted upon boaters along the Weaver Navigation. No mitigation is required.

[18] SunPower, 2009, SunPower Solar Module Glare and Reflectance (appendix to Solargen Energy, 2010).

8 THERMAL PLUME TECHNICAL NOTE

8.1 Background

Liverpool John Lennon Airport has raised as a potential concern, the effects from thermal plume (heat radiation) from the solar panels. This technical note considers (at a high-level) the potential for an updraft caused by heat radiation from the Proposed Development.

8.2 Thermal Plumes from Solar Panels

Solar panels are designed to absorb light from the sun and typically operate most efficiently at a temperature of approximately 25°C. The panels are therefore designed to remain cool in direct sunlight, and it is not anticipated that panels would reach temperatures significantly greater than other common surfaces in an industrial and commercial environment.

There are also currently many ground surfaces surrounding Liverpool John Lennon Airport and the Proposed Development which would be expected to have greater thermal conductivity and diffusivity than solar panels and bare-earth such as asphalt on the runway and taxiways, the asphalt on the M56, and dwellings in and around Frodsham. These surfaces all have the potential to create more significant thermal plumes which pilots flying in the area would already be routinely navigating.

Many UK aerodromes have solar panels sited underneath their approach paths or in the area which could potentially cause thermal plumes - this is therefore a common occurrence which pilots should be expected to be aware of and navigate.

8.3 Height of Aircraft

Based on the altitude data provided by Liverpool John Lennon Airport for aircraft circling the Visual Reference Points (VRPs) in the area, aircraft are expected to be more than 1,100ft (335m) above the solar panels.

Though it is possible that some thermal plumes would be caused by the Proposed Development, it is predicted that this would be limited to a relatively low level and the heat would have dissipated at the height of the aircraft.

8.4 Conclusions

Thermal plumes can be produced from solar panels; however, they are expected to be similar to those produced by other industrial and commercial infrastructure. There are also several other surrounding areas that are predicted to radiate more heat, which pilots flying in the area would already be routinely navigating.

In addition, aircraft flying over the Proposed Development are predicted to be at a significantly above where thermal plumes could be experienced.

Overall, negligible impacts upon aircraft flying over the Proposed Development from thermal plumes are predicted.

9 OVERALL CONCLUSIONS

9.1 Assessment Conclusions – Liverpool John Lennon Airport

9.1.1 ATC Tower

Solar reflections with a maximum of 'low potential for temporary after-image' are predicted towards the ATC Tower.

Most of the reflecting panels will be obstructed by the solar panels in the closer fields and intervening terrain. It is possible that there will be no visibility of the reflecting panels; however, marginal views of solar panels in two fields cannot be reliably ruled out. The glare scenario considerations to determine the overall impact from the potentially visible areas are as follows:

Based on the glare scenario considerations presented in Section 6.2.3.1, a low impact upon the ATC Tower is predicted, and no mitigation is recommended. Liverpool John Lennon Airport has confirmed the predicted impacts towards the ATC Tower are acceptable.

9.1.2 Two-Mile Runway Approaches

Solar reflections with a maximum of 'low potential for temporary after-image' are geometrically possible towards the Runway 09 and 27 two-mile approaches.

A low impact upon the two-mile approaches is predicted and mitigation is not required.

9.1.3 Extended Runway Approaches

Solar reflections with a maximum of 'low potential for temporary after-image' are geometrically possible towards the commercial visual, commercial instrument, and VFR extended approaches.

A low impact upon the two-mile approaches is predicted and mitigation is not required.

9.1.4 Visual Circuits

Solar reflections with a maximum of 'low potential for temporary after-image' are geometrically possible towards the entire Runway 09 RH / Runway 27 LH visual circuit.

Solar reflections with a maximum of 'low potential for temporary after-image' are geometrically possible towards sections of the Runway 27 RH / Runway 09 LH visual circuit.

A low impact upon the visual circuits is predicted and no mitigation is required.

9.1.5 VRPs

Solar reflections are not geometrically possible towards aircraft circling the Helsby Hill VRP.

Solar reflections with a maximum of 'low potential for temporary after-image' are predicted towards aircraft circling the Frodsham Hill and Hale Head Lighthouse VRPs. Considering the associated guidance pertaining to approach paths, which states that this level of glare is acceptable, it can be concluded that this level of glare is also acceptable for the VRPs.

A low impact upon the VRPs is predicted and no mitigation is required.

9.2 Assessment Conclusions – Roads

The modelling has shown that solar reflections are geometrically possible towards 64 of the 129 assessed road receptors, totalling approximately 6.4km of road.

For most of these sections of roads, the reflecting panels are predicted to be significantly obstructed by existing vegetation, buildings, dwellings, and/or the general environment in Frodsham. No impacts upon road users along these sections of road are predicted and no further mitigation is required.

For an approximately 200m section of the M56, views of the reflecting panels outside a road user's primary FOV are predicted despite partial screening from existing vegetation. A low impact upon road users along this section of road is predicted and no further mitigation is required.

For two sections of the M56 totalling approximately 500m, temporary views of the reflecting panels outside a road user's primary FOV are predicted despite partials screening in the form of proposed hedgerows (including mature planting or a mesh fence) and existing vegetation. Views of the remaining reflecting panels will be obstructed once additional proposed planting has matured. A low impact upon road users along these sections of road is predicted, reducing to no impact once all proposed planting has matured. No further mitigation is required.

Overall, a maximum of low impact upon surrounding road users is predicted, as such no further mitigation is necessary. This conclusion has been confirmed through consultation with National Highways.

9.3 Assessment Conclusions – Dwellings

The modelling has shown that solar reflections are geometrically possible towards 102 of the 143 assessed dwelling receptors.

For 71 of these dwellings, views of the reflecting panels are predicted to be significantly obstructed by existing vegetation, buildings, and/or other dwellings. No impacts upon these dwellings are predicted and no further mitigation is required.

For 16 dwellings, views of the reflecting panels will be limited by existing vegetation and/or other dwellings such that effects are predicted to be experienced for less than 3 months per year and less than 60 minutes on any given day. A low impact upon these dwellings is predicted and no further mitigation is recommended.

For the final 15 dwellings, effects are predicted to be experienced for less than 60 minutes on any given day but for more than 3 months per year, despite partial screening. There are sufficient mitigating factors in each case that reduce the level of impact to low, including a combination of:

- Effects being experienced from above the ground floor, which is not considered to be the main living space of a dwelling.
- Effects mostly coinciding with direct sunlight, with the sun being a far more significant source of light.
- Most of the reflecting panels being further than 1km, which is the maximum distance out to which glint and glare effects for ground-based receptors are assessed.

Overall, a maximum of low impact upon surrounding dwellings is predicted, and no further mitigation is recommended.

9.4 Assessment Conclusions – Frodsham Memorial Results

The modelling has shown that no solar reflections are geometrically possible towards the assessed Frodsham Memorial receptor.

No impacts upon observers at the Frodsham Memorial are predicted and no mitigation is required.

9.5 High-Level Conclusions – Weaver Navigation Users

A maximum of low impact is predicted upon boaters using the Weaver Navigation. No mitigation is required.

9.6 High-Level Conclusions – Thermal Plume

Thermal plumes from the Proposed Development are expected to be similar to those produced by other industrial and commercial infrastructure. There are also several other surrounding areas that are predicted to radiate more heat, which pilots flying in the area would already be routinely navigating.

In addition, aircraft flying over the Proposed Development are predicted to be at a significantly above where thermal plumes could be experienced.

APPENDIX A – OVERVIEW OF GLINT AND GLARE GUIDANCE

Overview

This section presents details regarding the relevant guidance and studies with respect to the considerations and effects of solar reflections from solar panels, known as 'Glint and Glare'.

This is not a comprehensive review of the data sources, rather it is intended to give an overview of the important parameters and considerations that have informed this assessment, and is shown for reference.

UK Planning Policy

Renewable and Low Carbon Energy

The National Planning Policy Framework under the planning practice guidance for Renewable and Low Carbon Energy[19] (specifically regarding the consideration of solar farms, paragraph 013) states:

'What are the particular planning considerations that relate to large scale ground-mounted solar photovoltaic Farms?

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;

…

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.'

---

[19] Renewable and low carbon energy, Ministry of Housing, Communities & Local Government, date: 18 June 2015, accessed on: 01/11/2021

National Policy Statement for Renewable Energy Infrastructure

The National Policy Statement for Renewable Energy Infrastructure (EN-3)[20] sets out the primary policy for decisions by the Secretary of State for nationally significant renewable energy infrastructure. Sections 2.10.102-106 state:

'2.10.102 Solar panels are specifically designed to absorb, not reflect, irradiation.[21] 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.

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.'

The EN-3 does not state which receptors should be considered as part of a quantitative glint and glare assessment. Based on Pager Power's extensive project experience, typical receptors include residential dwellings, road users, aviation infrastructure, and railway infrastructure.

Sections 2.10.134-136 state:

'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.

---

[20] National Policy Statement for Renewable Energy Infrastructure (EN-3), Department for Energy Security & Net Zero, date: January 2024, accessed on: 17/01/2024.

[21] *'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.'*

In practice this is unlikely to remove the potential impact altogether but in marginal cases may contribute to a mitigation strategy.'

The mitigation strategies listed within the EN-3 are relevant strategies that are frequently utilised to eliminate or reduce glint and glare effects towards surrounding observers. The most common form of mitigation is the implementation of screening along the site boundary.

Sections 2.10.158-159 state:

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.

The EN-3 goes some way in acknowledging that the issue is more complex than presented in the early draft issues; though, this is still unlikely to be welcomed by aviation stakeholders, who will still request a glint and glare assessment on the basis that glare may lead to a potentially significant impact upon aviation safety.

Finally, the EN-3 relates solely to nationally significant renewable energy infrastructure and therefore does not apply to all planning applications for solar farms.

Assessment Process – Ground-Based Receptors

No process for determining and contextualising the effects of glint and glare is provided for assessing the impact of solar reflections upon surrounding roads and dwellings. Therefore, the Pager Power approach is to determine whether a reflection from the proposed solar development is geometrically possible and then to compare the results against the relevant guidance/studies to determine whether the reflection is significant.

The Pager Power approach has been informed by the policy presented above, current studies (presented in Appendix B) and stakeholder consultation. Further information can be found in Pager Power's Glint and Glare Guidance document[22] which was produced due to the absence of existing guidance and a specific standardised assessment methodology.

[22] Pager Power Glint and Glare Guidance, Fourth Edition (4.0), August 2022.

Aviation Assessment Guidance

The UK Civil Aviation Authority (CAA) issued interim guidance relating to Solar Photovoltaic Systems (SPV) on 17 December 2010 and was subject to a CAA information alert 2010/53. The formal policy was cancelled on September 7th, 2012[23] however the advice is still applicable[24] until a formal policy is developed. The relevant aviation guidance from the CAA is presented in the section below.

CAA Interim Guidance

This interim guidance makes the following recommendations (p.2-3):

'8. It is recommended that, as part of a planning application, the SPV developer provide safety assurance documentation (including risk assessment) regarding the full potential impact of the SPV installation on aviation interests.

9. Guidance on safeguarding procedures at CAA licensed aerodromes is published within CAP 738 Safeguarding of Aerodromes and advice for unlicensed aerodromes is contained within CAP 793 Safe Operating Practices at Unlicensed Aerodromes.

10. Where proposed developments in the vicinity of aerodromes require an application for planning permission the relevant LPA normally consults aerodrome operators or NATS when aeronautical interests might be affected. This consultation procedure is a statutory obligation in the case of certain major airports, and may include military establishments and certain air traffic surveillance technical sites. These arrangements are explained in Department for Transport Circular 1/2003 and for Scotland, Scottish Government Circular 2/2003.

11. In the event of SPV developments proposed under the Electricity Act, the relevant government department should routinely consult with the CAA. There is therefore no requirement for the CAA to be separately consulted for such proposed SPV installations or developments.

12. If an installation of SPV systems is planned on-aerodrome (i.e. within its licensed boundary) then it is recommended that data on the reflectivity of the solar panel material should be included in any assessment before installation approval can be granted. Although approval for installation is the responsibility of the ALH[25], as part of a condition of a CAA Aerodrome Licence, the ALH is required to obtain prior consent from CAA Aerodrome Standards Department before any work is begun or approval to the developer or LPA is granted, in accordance with the procedures set out in CAP 791 Procedures for Changes to Aerodrome Infrastructure.

13. During the installation and associated construction of SPV systems there may also be a need to liaise with nearby aerodromes if cranes are to be used; CAA notification and permission is not required.

14. The CAA aims to replace this informal guidance with formal policy in due course and reserves the right to cancel, amend or alter the guidance provided in this document at its discretion upon receipt of new information.

---

[23] Archived at Pager Power

[24] Reference email from the CAA dated 19/05/2014.

[25] Aerodrome Licence Holder.

15. Further guidance may be obtained from CAA's Aerodrome Standards Department via aerodromes@caa.co.uk.'

FAA Guidance

The most comprehensive guidelines available for the assessment of solar developments near aerodromes has been produced by the United States Federal Aviation Administration (FAA). The first guidelines were produced initially in November 2010 and updated in 2013. A final policy was released in 2021, which superseded the interim guidance.

The 2010 document is entitled 'Technical Guidance for Evaluating Selected Solar Technologies on Airports'[26], the 2013 update is entitled 'Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports'[27], and the 2021 final policy is entitled 'Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports'[28].

Key excerpts from the final policy are presented below:

Initially, FAA believed that solar energy systems could introduce a novel glint and glare effect to pilots on final approach. FAA has subsequently concluded that in most cases, the glint and glare from solar energy systems to pilots on final approach is similar to glint and glare pilots routinely experience from water bodies, glass-façade buildings, parking lots, and similar features. However, FAA has continued to receive reports of potential glint and glare from on-airport solar energy systems on personnel working in ATCT cabs. Therefore, FAA has determined the scope of agency policy should be focused on the impact of on-airport solar energy systems to federally-obligated towered airports, specifically the airport's ATCT cab.

The policy in this document updates and replaces the previous policy by encouraging airport sponsors to conduct an ocular analysis of potential impacts to ATCT cabs prior to submittal of a Notice of Proposed Construction or Alteration Form 7460-1 (hereinafter Form 7460-1). Airport sponsors are no longer required to submit the results of an ocular analysis to FAA. Instead, to demonstrate compliance with 14 CFR 77.5(c), FAA will rely on the submittal of Form 7460-1 in which the sponsor confirms that it has analyzed the potential for glint and glare and determined there is no potential for ocular impact to the airport's ATCT cab. This process will enable FAA to evaluate the solar energy system project, with assurance that the system will not impact the ATCT cab.

FAA encourages airport sponsors of federally-obligated towered airports to conduct a sufficient analysis to support their assertion that a proposed solar energy system will not result in ocular impacts. There are several tools available on the open market to airport sponsors that can analyze potential glint and glare to an ATCT cab. For proposed systems that will clearly not impact ATCT cabs (e.g., on-airport solar energy systems that are blocked from the ATCT cab's view by another structure), the use

---

[26] Archived at Pager Power

[27] Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports, Department of Transportation, Federal Aviation Administration (FAA), date: 10/2013, accessed on: 08/12/2021.

[28] Federal Aviation Administration Policy: Review of Solar Energy System Projects on Federally-Obligated Airports, Federal Aviation Administration, date: May 2021, accessed on: 08/12/2021.

of such tools may not be necessary to support the assertion that a proposed solar energy system will not result in ocular impacts.

The excerpt above states where a solar PV development is to be located on a federally obligated aerodrome with an ATC Tower, it will require a glint and glare assessment to accompany its application. It states that pilots on approach are no longer a specific assessment requirement due to effects from solar energy systems being similar to glint and glare pilots routinely experience from water bodies, glass-façade buildings, parking lots, and similar features. Ultimately it comes down to the specific aerodrome to ensure it is adequately safeguarded, and it is on this basis that glint and glare assessments are routinely still requested.

The policy also states that several different tools and methodologies can be used to assess the impacts of glint and glare, which was previously required to be undertaken by the Solar Glare Hazard Analysis Tool (SGHAT) using the Sandia National Laboratories methodology.

In 2018, the FAA released the latest version (Version 1.1) of the 'Technical Guidance for Evaluating Selected Solar Technologies on Airports'[29]. Whilst the 2021 final policy also supersedes this guidance, many of the points are still relevant because aerodromes are still safeguarding against glint and glare irrespective of the FAA guidance. The key points are presented below for reference:

- Reflectivity refers to light that is reflected off surfaces. The potential effects of reflectivity are glint (a momentary flash of bright light) and glare (a continuous source of bright light). These two effects are referred to hereinafter as "glare," which can cause a brief loss of vision, also known as flash blindness[30].
- The amount of light reflected off a solar panel surface depends on the amount of sunlight hitting the surface, its surface reflectivity, geographic location, time of year, cloud cover, and solar panel orientation.
- As illustrated on Figure 16[31], flat, smooth surfaces reflect a more concentrated amount of sunlight back to the receiver, which is referred to as specular reflection. The more a surface is polished, the more it shines. Rough or uneven surfaces reflect light in a diffused or scattered manner and, therefore, the light will not be received as bright.
- Because the FAA has no specific standards for airport solar facilities and potential glare, the type of glare analysis may vary. Depending on site specifics (e.g., existing land uses, location and size of the project) an acceptable evaluation could involve one or more of the following levels of assessment:
    - A qualitative analysis of potential impact in consultation with the Control Tower, pilots and airport officials;

[29] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 21/03/2025.

[30] Flash Blindness, as described in the FAA guidelines, can be described as a temporary visual interference effect that persists after the source of illumination has ceased. This occurs from many reflective materials in the ambient environment.

[31] First figure in Appendix B.

- A demonstration field test with solar panels at the proposed site in coordination with FAA Tower personnel;
- A geometric analysis to determine days and times when an impact is predicted.

- The extent of reflectivity analysis required to assess potential impacts will depend on the specific project site and system design.
- **1. Assessing Baseline Reflectivity Conditions** – Reflection in the form of glare is present in current aviation operations. The existing sources of glare come from glass windows, auto surface parking, rooftops, and water bodies. At airports, existing reflecting surfaces may include hangar roofs, surface parking, and glassy office buildings. To minimize unexpected glare, windows of air traffic control towers and airplane cockpits are coated with anti-reflective glazing. Operators also wear polarized eye wear. Potential glare from solar panels should be viewed in this context. Any airport considering a solar PV project should first review existing sources of glare at the airport and the effectiveness of measures used to mitigate that glare.
- **2. Tests in the Field** – Potential glare from solar panels can easily be viewed at the airport through a field test. A few airports have coordinated these tests with FAA Air Traffic Controllers to assess the significance of glare impacts. To conduct such a test, a sponsor can take a solar panel out to proposed location of the solar project, and tilt the panel in different directions to evaluate the potential for glare onto the air traffic control tower. For the two known cases where a field test was conducted, tower personnel determined the glare was not significant. If there is a significant glare impact, the project can be modified by ensuring panels are not directed in that direction.
- **3. Geometric Analysis** – Geometric studies are the most technical approach for reflectivity issues. They are conducted when glare is difficult to assess through other methods. Studies of glare can employ geometry and the known path of the sun to predict when sunlight will reflect off of a fixed surface (like a solar panel) and contact a fixed receptor (e.g., control tower). At any given site, the sun moves across the sky every day and its path in the sky changes throughout year. This in turn alters the destination of the resultant reflections since the angle of reflection for the solar panels will be the same as the angle at which the sun hits the panels. The larger the reflective surface, the greater the likelihood of glare impacts.
- Facilities placed in remote locations, like the desert, will be far from receptors and therefore potential impacts are limited to passing aircraft. Because the intensity of the light reflected from the solar panel decreases with increasing distance, an appropriate question is how far you need to be from a solar reflected surface to avoid flash blindness. It is known that this distance is directly proportional to the size of the array in question[32] but still requires further research to definitively answer.
- **Experiences of Existing Airport Solar Projects** – Solar installations are presently operating at a number of airports, including megawatt-sized solar facilities covering

[32] Ho, Clifford, Cheryl Ghanbari, and Richard Diver. 2009. Hazard Analysis of Glint and Glare From Concentrating Solar Power Plants. SolarPACES 2009, Berlin Germany. Sandia National Laboratories.

multiple acres. Air traffic control towers have expressed concern about glint and glare from a small number of solar installations. These were often instances when solar installations were sited between the tower and airfield, or for installations with inadequate or no reflectivity analysis. Adequate reflectivity analysis and alternative siting addressed initial issues at those installations.

Air Navigation Order (ANO) 2016

In some instances, an aviation stakeholder can refer to the ANO 2016[33] with regard to safeguarding. Key points from the document are presented below.

Lights liable to endanger

224. (1) A person must not exhibit in the United Kingdom any light which—

(a) by reason of its glare is liable to endanger aircraft taking off from or landing at an aerodrome; or

(b) by reason of its liability to be mistaken for an aeronautical ground light is liable to endanger aircraft.

(2) If any light which appears to the CAA to be a light described in paragraph (1) is exhibited, the CAA may direct the person who is the occupier of the place where the light is exhibited or who has charge of the light, to take such steps within a reasonable time as are specified in the direction—

(a) to extinguish or screen the light; and

(b) to prevent in the future the exhibition of any other light which may similarly endanger aircraft.

(3) The direction may be served either personally or by post, or by affixing it in some conspicuous place near to the light to which it relates.

(4) In the case of a light which is or may be visible from any waters within the area of a general lighthouse authority, the power of the CAA under this article must not be exercised except with the consent of that authority.

Lights which dazzle or distract

225. A person must not in the United Kingdom direct or shine any light at any aircraft in flight so as to dazzle or distract the pilot of the aircraft.'

The Order states that no 'light', 'dazzle' or 'glare' should be produced which will create a detrimental impact upon aircraft safety.

---

[33] The Air Navigation Order 2016. [online] Available at: <https://www.legislation.gov.uk/uksi/2016/765/contents/made> [Accessed 4 February 2022].

Endangering safety of an aircraft

240. A person must not recklessly or negligently act in a manner likely to endanger an aircraft, or any person in an aircraft.

Endangering safety of any person or property

241. A person must not recklessly or negligently cause or permit an aircraft to endanger any person or property

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

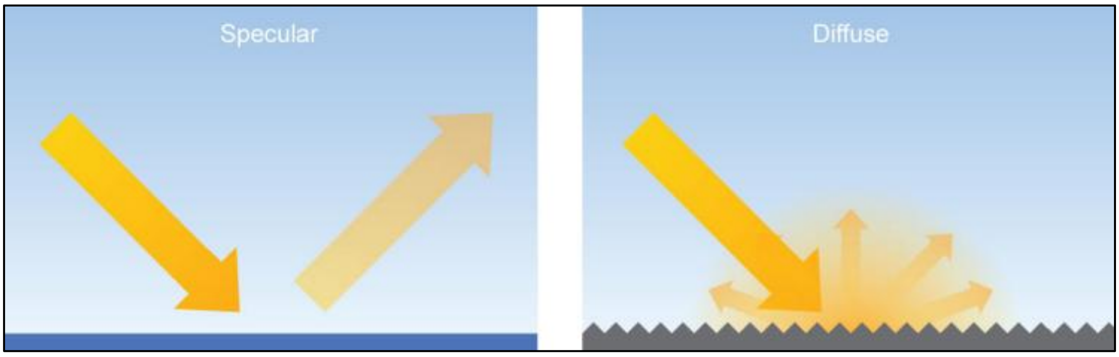
Overview

Studies have been undertaken assessing the type and intensity of solar reflections from various surfaces including solar panels and glass. An overview of these studies is presented below.

The guidelines presented are related to aviation safety. The results are applicable for the purpose of this analysis.

Reflection Type from Solar Panels

Based on the surface conditions reflections from light can be specular and diffuse. A specular reflection has a reflection characteristic similar to that of a mirror; a diffuse will reflect the incoming light and scatter it in many directions. The figure below, taken from the FAA guidance[34], illustrates the difference between the two types of reflections. Because solar panels are flat and have a smooth surface most of the light reflected is specular, which means that incident light from a specific direction is reradiated in a specific direction.



Specular and diffuse reflections

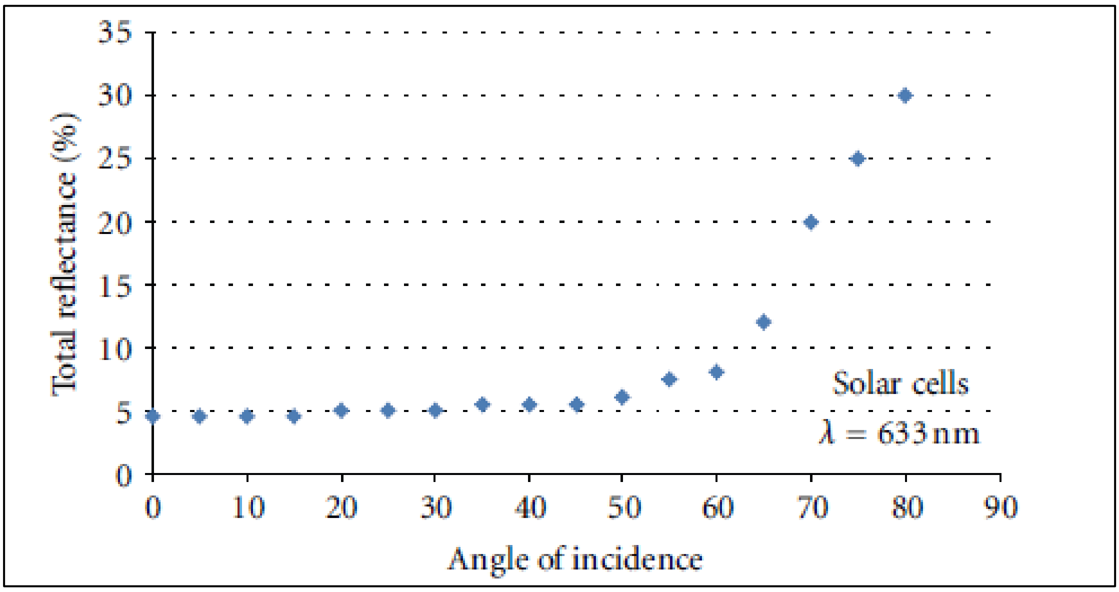
[34] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 21/03/2025.

Solar Reflection Studies

An overview of content from identified solar panel reflectivity studies is presented in the subsections below.

Evan Riley and Scott Olson, "A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems"

Evan Riley and Scott Olson published in 2011 their study titled: A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems[35]". They researched the potential glare that a pilot could experience from a 25 degree fixed tilt PV system located outside of Las Vegas, Nevada. The theoretical glare was estimated using published ocular safety metrics which quantify the potential for a postflash glare after-image. This was then compared to the postflash glare after-image caused by smooth water. The study demonstrated that the reflectance of the solar cell varied with angle of incidence, with maximum values occurring at angles close to 90 degrees. The reflectance values varied from approximately 5% to 30%. This is shown on the figure below.



Total reflectance % when compared to angle of incidence

The conclusions of the research study were:

- The potential for hazardous glare from flat-plate PV systems is similar to that of smooth water;
- Portland white cement concrete (which is a common concrete for runways), snow, and structural glass all have a reflectivity greater than water and flat plate PV modules.

[35] Evan Riley and Scott Olson, "A Study of the Hazardous Glare Potential to Aviators from Utility-Scale Flat-Plate Photovoltaic Systems," ISRN Renewable Energy, vol. 2011, Article ID 651857, 6 pages, 2011. doi:10.5402/2011/651857

FAA Guidance – "Technical Guidance for Evaluating Selected Solar Technologies on Airports"[36]

The 2010 FAA Guidance included a diagram which illustrates the relative reflectance of solar panels compared to other surfaces. The figure shows the relative reflectance of solar panels compared to other surfaces. Surfaces in this figure produce reflections which are specular and diffuse. A specular reflection (those made by most solar panels) has a reflection characteristic similar to that of a mirror. A diffuse reflection will reflect the incoming light and scatter it in many directions. A table of reflectivity values, sourced from the figure within the FAA guidance, is presented below.

Surface	Approximate Percentage of Light Reflected[37]
Snow	80
White Concrete	77
Bare Aluminium	74
Vegetation	50
Bare Soil	30
Wood Shingle	17
Water	5
Solar Panels	5
Black Asphalt	2

Relative reflectivity of various surfaces

Note that the data above does not appear to consider the reflection type (specular or diffuse).

An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

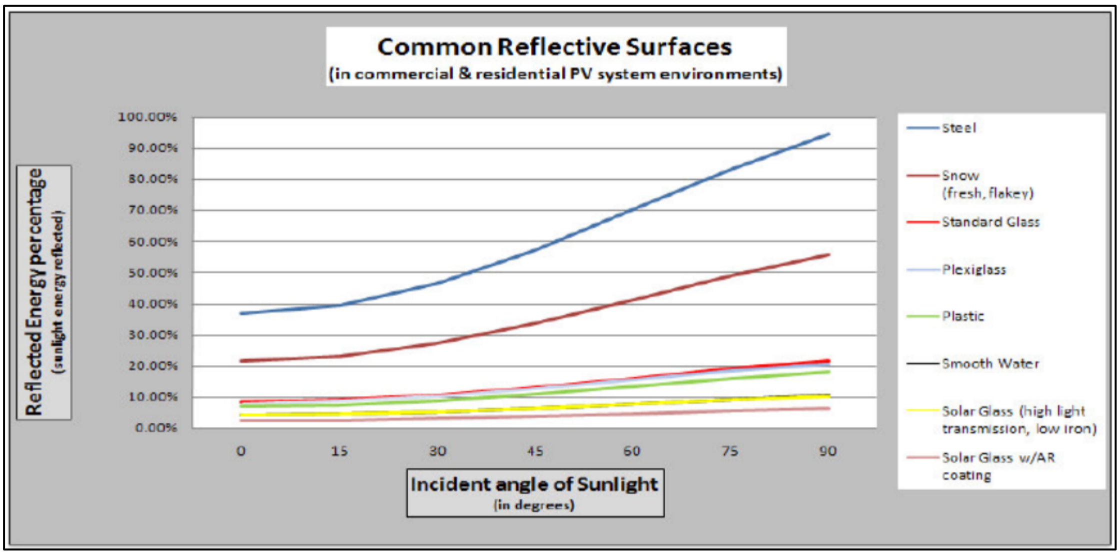
SunPower Technical Notification (2009)

SunPower published a technical notification[38] to 'increase awareness concerning the possible glare and reflectance impact of PV Systems on their surrounding environment'.

---

[36] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 21/03/2025.
[37] Extrapolated data, baseline of 1,000 W/m^2 for incoming sunlight.
[38] Source: Technical Support, 2009. SunPower Technical Notification – Solar Module Glare and Reflectance.

The figure presented below shows the relative reflectivity of solar panels compared to other natural and manmade materials including smooth water, standard glass and steel.



Common reflective surfaces

The results, similarly to those from Riley and Olsen study (2011) and the FAA (2010), show that solar panels produce a reflection that is less intense than those of 'standard glass and other common reflective surfaces'.

With respect to aviation and solar reflections observed from the air, SunPower has developed several large installations near airports or on Air Force bases. It is stated that these developments have all passed FAA or Air Force standards with all developments considered "No Hazard to Air Navigation". The note suggests that developers discuss any possible concerns with stakeholders near proposed solar farms.

APPENDIX C – OVERVIEW OF SUN MOVEMENTS AND RELATIVE REFLECTIONS

The Sun's position in the sky can be accurately described by its azimuth and elevation. Azimuth is a direction relative to true north (horizontal angle i.e. from left to right) and elevation describes the Sun's angle relative to the horizon (vertical angle i.e. up and down).

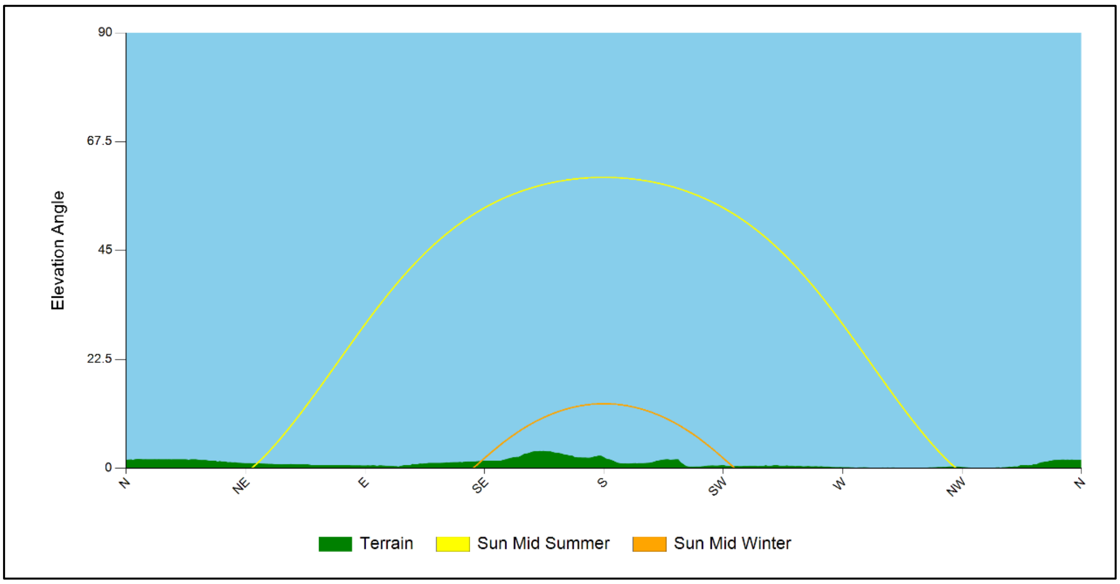
The Sun's position can be accurately calculated for a specific location. The following data being used for the calculation:

- Time;
- Date;
- Latitude;
- Longitude.

The following is true at the location of the solar development:

- The Sun is at its highest around midday and is to the south at this time;
- The Sun rises highest on 21 June (longest day);
- On 21 December, the maximum elevation reached by the Sun is at its lowest (shortest day).

The combination of the Sun's azimuth angle and vertical elevation will affect the direction and angle of the reflection from a reflector. The figure below shows terrain at the horizon from the proposed development location as well as the sunrise and sunset curves throughout the year.



Sunrise and sunset curves

APPENDIX D – GLINT AND GLARE IMPACT SIGNIFICANCE

Overview

The significance of glint and glare will vary for different receptors. The following section presents a general overview of the significance criteria with respect to experiencing a solar reflection.

Impact Significance Definition

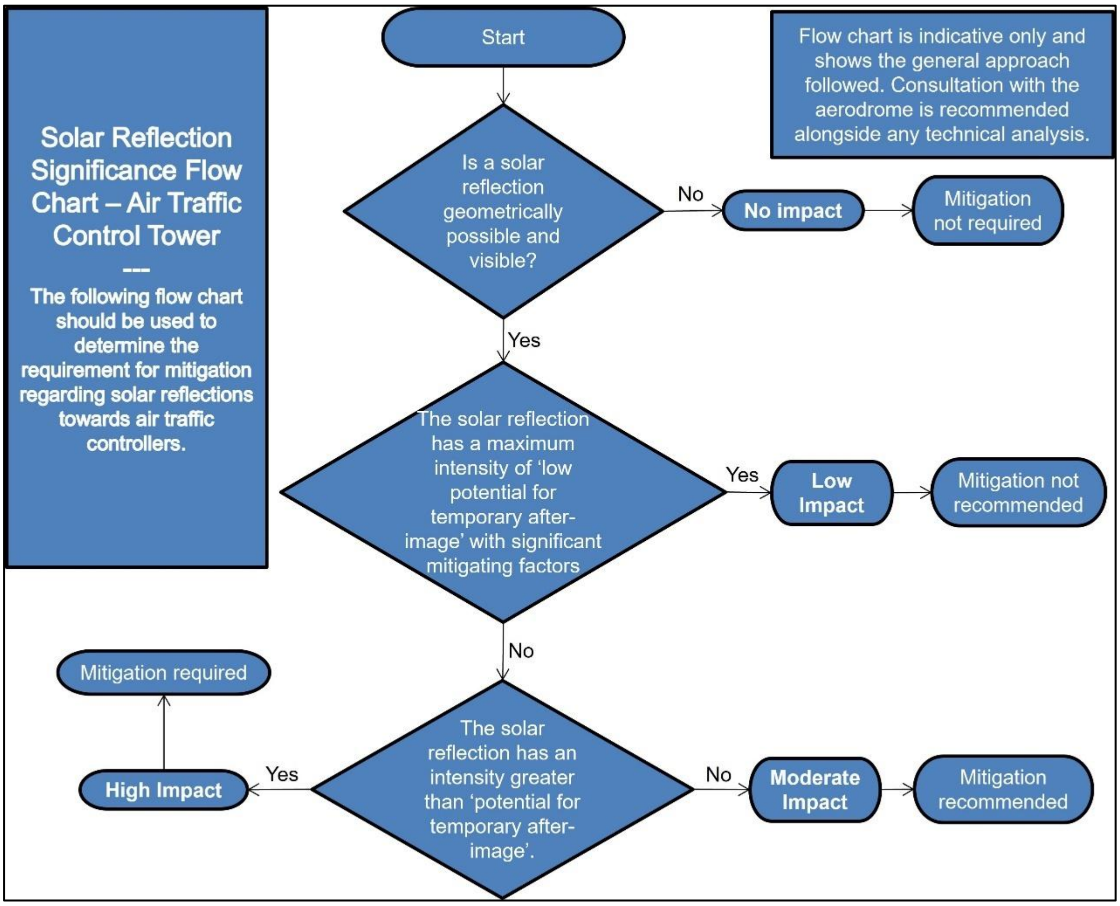
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

Impact Significance	Definition	Mitigation
No Impact	A solar reflection is not geometrically possible or will not be visible from the assessed receptor.	No mitigation required.
Low	A solar reflection is geometrically possible however any impact is considered to be small such that mitigation is not required e.g. intervening screening will limit the view of the reflecting solar panels significantly.	No mitigation recommended.
Moderate	A solar reflection is geometrically possible and visible however it occurs under conditions that do not represent a worst-case given individual receptor criteria.	Mitigation recommended.
High	A solar reflection is geometrically possible and visible under worst-case conditions that will produce a significant impact given individual receptor criteria	Mitigation will be required if the proposed development is to proceed.

Impact significance definition

Impact Significance Determination for ATC Towers

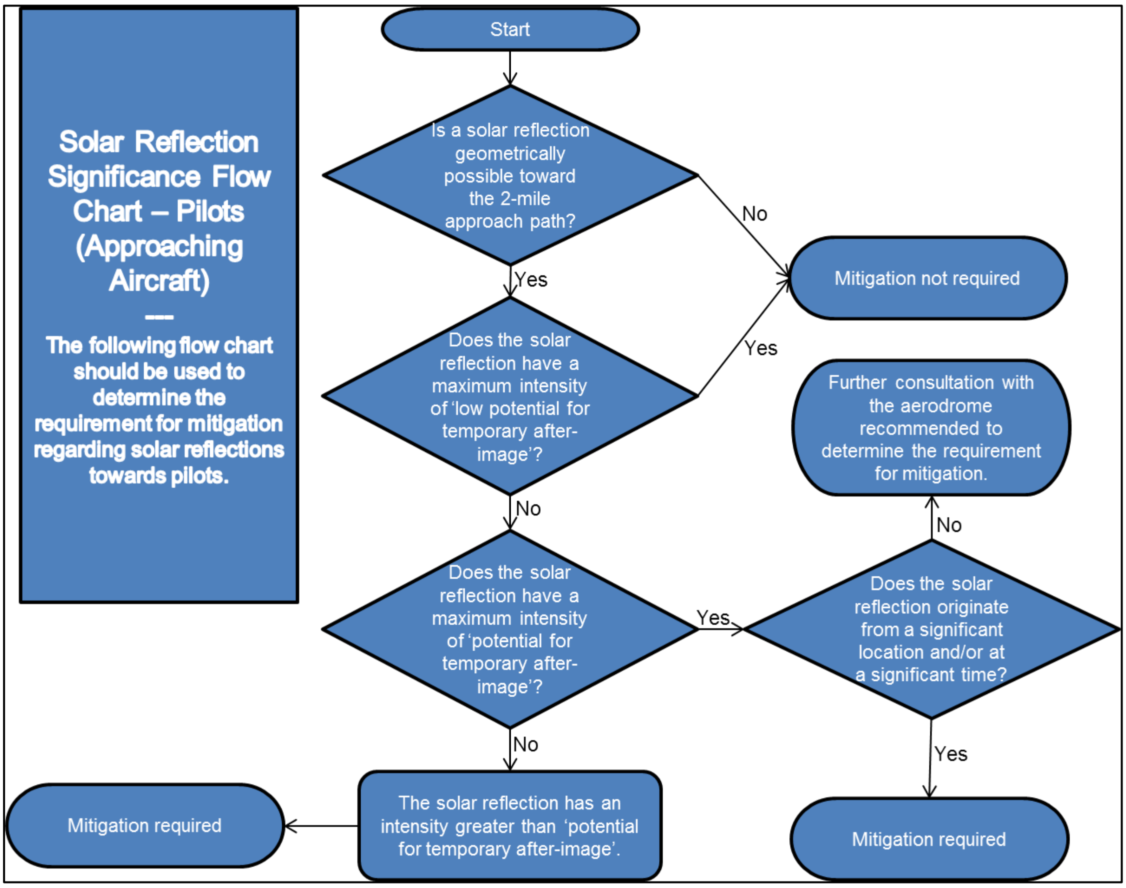
The flow chart presented below has been followed when determining the impact significance for ATC Towers.



ATC Tower receptor impact significance flow chart

Impact Significance Determination for Airborne Receptors

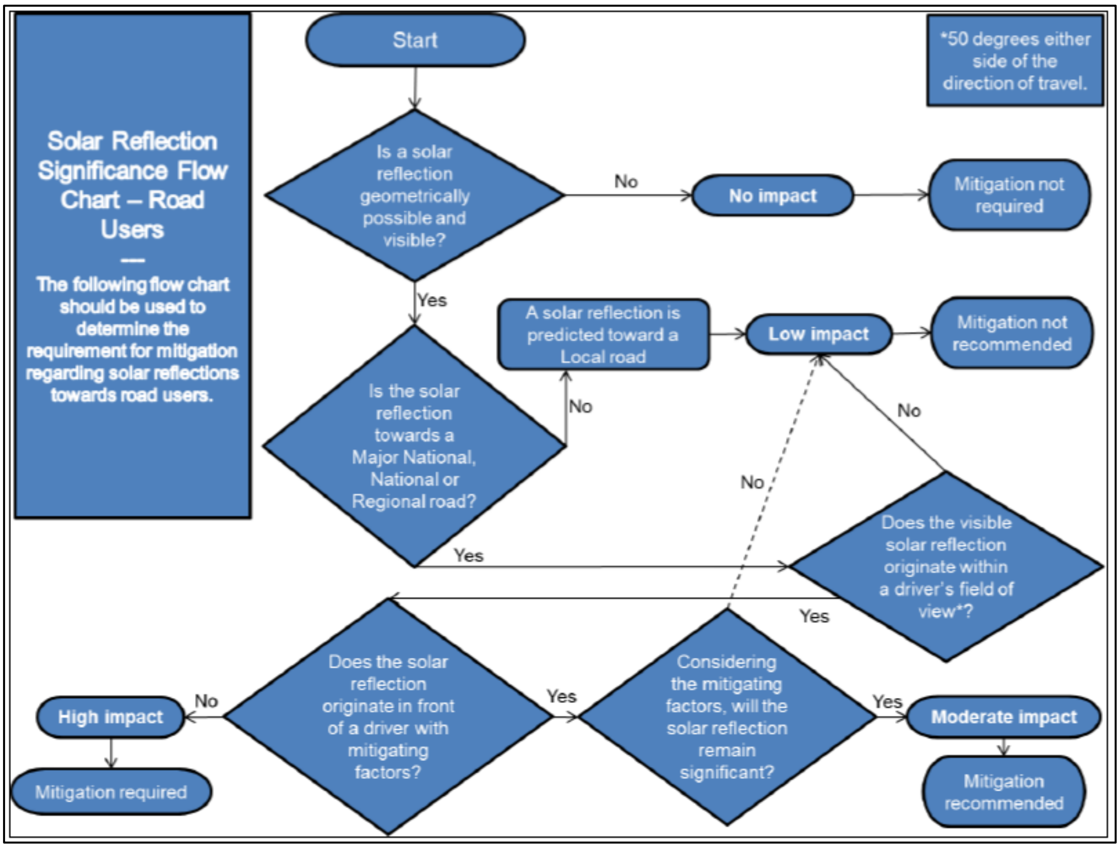
The flow chart presented below has been followed when determining the impact significance for airborne receptors.



Airborne receptor impact significance flow chart

Impact Significance Determination for Road Receptors

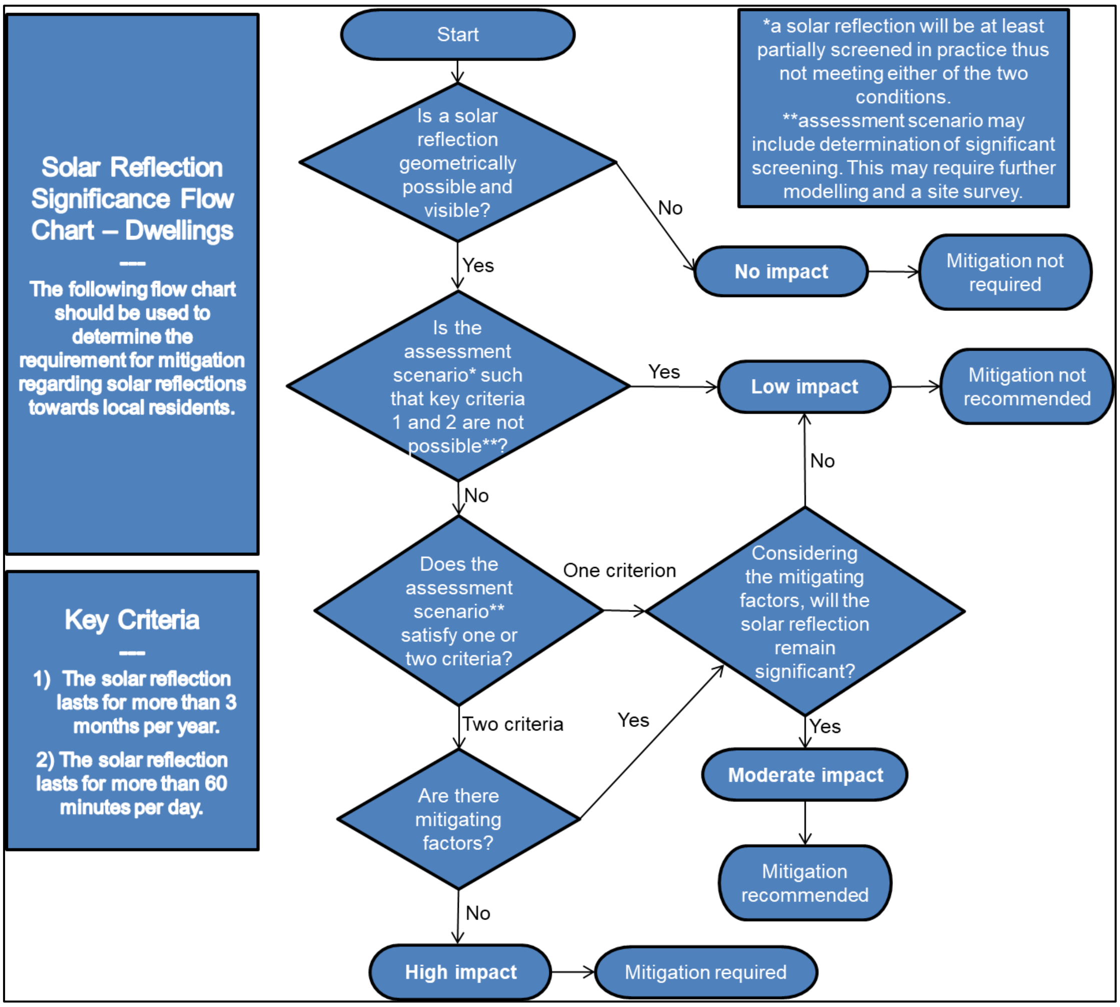
The flow chart presented below has been followed when determining the impact significance for road receptors.



Road receptor impact significance flow chart

Impact Significance Determination for Dwelling Receptors

The flow chart presented below has been followed when determining the impact significance for dwelling receptors.



Dwelling receptor impact significance flow chart

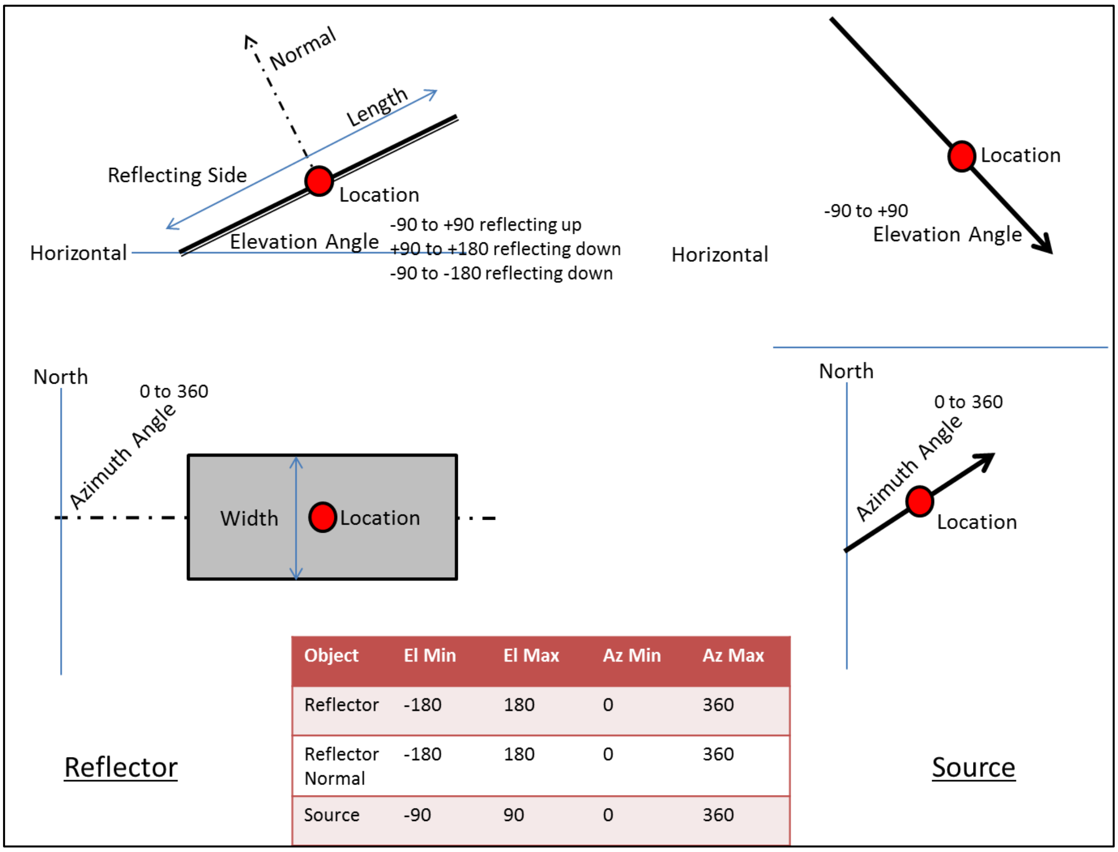
APPENDIX E – REFLECTION CALCULATIONS METHODOLOGY

Pager Power Methodology

The calculations are three dimensional and complex, accounting for:

- The Earth's orbit around the Sun;
- The Earth's rotation;
- The Earth's orientation;
- The reflector's location;
- The reflector's 3D Orientation.

Reflections from a flat reflector are calculated by considering the normal which is an imaginary line that is perpendicular to the reflective surface and originates from it. The diagram below may be used to aid understanding of the reflection calculation process.



Object	El Min	El Max	Az Min	Az Max
Reflector	-180	180	0	360
Reflector Normal	-180	180	0	360
Source	-90	90	0	360

Reflection calculation process

The following process is used to determine the 3D Azimuth and Elevation of a reflection:

- Use the Latitude and Longitude of reflector as the reference for calculation purposes;
- Calculate the Azimuth and Elevation of the normal to the reflector;
- Calculate the 3D angle between the source and the normal;
- If this angle is less than 90 degrees a reflection will occur. If it is greater than 90 degrees no reflection will occur because the source is behind the reflector;
- Calculate the Azimuth and Elevation of the reflection in accordance with the following:
    - The angle between source and normal is equal to angle between normal and reflection;
    - Source, Normal and Reflection are in the same plane.

APPENDIX F – ASSESSMENT LIMITATIONS AND ASSUMPTIONS

Pager Power's Model

The model considers 100% sunlight during daylight hours which is highly conservative.

The model does not account for terrain between the reflecting solar panels and the assessed receptor where a solar reflection is geometrically possible.

The model considers terrain between the reflecting solar panels and the visible horizon (where the sun may be obstructed from view of the panels)[39].

It is assumed that the panel elevation angle assessed represents the elevation angle for all of the panels within each solar panel area defined.

It is assumed that the panel azimuth angle assessed represents the azimuth angle for all of the panels within each solar panel area defined.

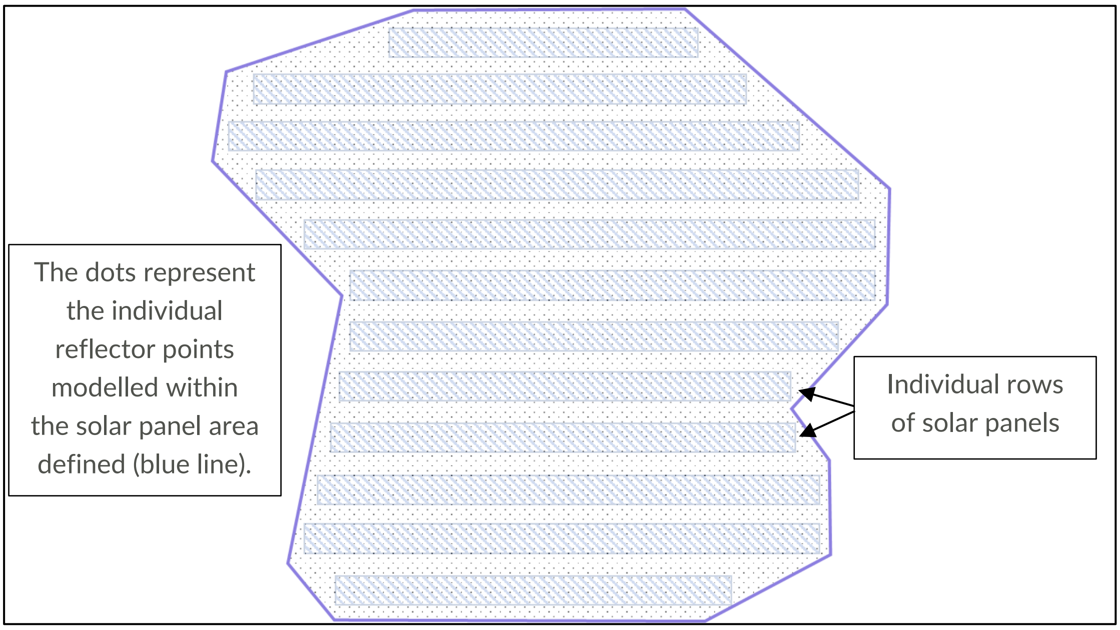
Only a reflection from the face of the panel has been considered. The frame or the reverse or frame of the solar panel has not been considered.

The model assumes that a receptor can view the face of every panel (point, defined in the following paragraph) within the development area whilst in reality this, in the majority of cases, will not occur. Therefore any predicted solar reflection from the face of a solar panel that is not visible to a receptor will not occur in practice.

A finite number of points within each solar panel area defined is chosen based on an assessment resolution so that a comprehensive understanding of the entire development can be formed. This determines whether a solar reflection could ever occur at a chosen receptor. The model does not consider the specific panel rows or the entire face of the solar panel within the development outline, rather a single point is defined every 'x' metres (based on the assessment resolution) with the geometric characteristics of the panel. A panel area is however defined to encapsulate all possible panel locations. See the figure below which illustrates this process.

---

[39] UK only.



Solar panel area modelling overview

A single reflection point is chosen for the geometric calculations. This suitably determines whether a solar reflection can be experienced at a receptor location and the time of year and duration of the solar reflection. Increased accuracy could be achieved by increasing the number of heights assessed however this would only marginally change the results and is not considered significant.

The available street view imagery, satellite mapping, terrain and any site imagery provided by the developer has been used to assess line of sight from the assessed receptors to the modelled solar panel area, unless stated otherwise. In some cases, this imagery may not be up to date and may not give the full perspective of the installation from the location of the assessed receptor.

Any screening in the form of trees, buildings etc. that may obstruct the Sun from view of the solar panels is not within the modelling unless stated otherwise. The terrain profile at the horizon is considered if stated.

Forge's Sandia National Laboratories' (SGHAT) Model

The following text is taken from Forge[40] and is presented for reference.

Summary of assumptions and abstractions required by the SGHAT/ForgeSolar analysis methodology

1. Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.
2. Result data files and plots are now retained for two years after analysis completion. Files should be downloaded and saved if additional persistence is required.
3. 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, we have validated our models 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.
4. Several calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results for large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare. This primarily affects analyses of path receptors.
5. Random number computations are utilized by various steps of the annual hazard analysis algorithm. Predicted minutes of glare can vary between runs as a result. This limitation primarily affects analyses of Observation Point receptors, including ATCTs. Note that the SGHAT/ForgeSolar methodology has always relied on an analytical, qualitative approach to accurately determine the overall hazard (i.e. green vs. yellow) of expected glare on an annual basis.
6. The subtended source angle (glare spot size) is constrained by the PV array footprint size. Partitioning large arrays into smaller sections will reduce the maximum potential subtended angle, potentially impacting results if actual glare spots are larger than the sub-array size. Additional analyses of the combined area of adjacent sub-arrays can provide more information on potential glare hazards. (See previous point on related limitations.)
7. The algorithm assumes that the PV array is aligned with a plane defined by the total heights of the coordinates outlined in the Google map. For more accuracy, the user should perform runs using minimum and maximum values for the vertex heights to bound the height of the plane containing the solar array. Doing so will expand the range of observed solar glare when compared to results using a single height value.
8. The algorithm does not consider obstacles (either man-made or natural) between the observation points and the prescribed solar installation that may obstruct observed glare, such as trees, hills, buildings, etc.
9. The variable direct normal irradiance (DNI) feature (if selected) scales the user-prescribed peak DNI using a typical clear-day irradiance profile. This profile has a lower DNI in the mornings and evenings and a maximum at solar noon. The scaling uses a clear-day irradiance profile based on a normalized time relative to sunrise, solar noon, and sunset, which are prescribed by a sun-position algorithm and the latitude and longitude obtained from Google maps. The actual DNI on any given day can be affected by cloud cover, atmospheric attenuation, and other environmental factors.
10. The ocular hazard predicted by the tool depends on a number of environmental, optical, and human factors, which can be uncertain. We provide input fields and typical ranges of values for these factors so that the user can vary these parameters to see if they have an impact on the results. The speed of SGHAT allows expedited sensitivity and parametric analyses.
11. The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.
12. 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.
13. Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
14. Glare vector plots are simplified representations of analysis data. Actual glare emanations and results may differ.
15. PV array tracking assumes the modules move instantly when tracking the sun, and when reverting to the rest position.

[40] Source: https://www.forgesolar.com/help/#assumptions

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

Liverpool John Lennon Airport Details

The table below presents the data for Liverpool John Lennon Airport. The receptor locations are based on the methodology set out in Section 4.1.

Threshold	Bearing	Runway Dimensions (m)	Longitude (°)	Latitude (°)	Threshold Elevation (ft amsl)
09	85.60°	2,286 x 46	-2.86600	53.33289	59.6
27	265.62°		-2.83271	53.33442	77.8

Liverpool John Lennon Airport details

Road Receptor Details

The road receptor coordinates are presented in the table below. An additional 1.5m height has been added to the terrain elevation to account for the eye-level of a road user.

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-2.73193	53.29025	66	-2.71475	53.30632
2	-2.73191	53.29116	67	-2.71370	53.30693
3	-2.73187	53.29205	68	-2.71259	53.30756
4	-2.73180	53.29294	69	-2.71150	53.30814
5	-2.73103	53.29369	70	-2.71038	53.30872
6	-2.72989	53.29429	71	-2.70919	53.30929
7	-2.72862	53.29475	72	-2.70798	53.30985
8	-2.72734	53.29521	73	-2.70679	53.31036
9	-2.72617	53.29577	74	-2.70554	53.31089
10	-2.72509	53.29641	75	-2.70449	53.31079
11	-2.72401	53.29706	76	-2.70606	53.31149
12	-2.72279	53.29751	77	-2.70677	53.31225
13	-2.72136	53.29782	78	-2.70715	53.31311
14	-2.71993	53.29807	79	-2.74362	53.31986

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
15	-2.71842	53.29820	80	-2.74279	53.31910
16	-2.71694	53.29832	81	-2.74192	53.31837
17	-2.71553	53.29853	82	-2.74082	53.31776
18	-2.71409	53.29889	83	-2.73948	53.31735
19	-2.71277	53.29925	84	-2.73802	53.31716
20	-2.71135	53.29958	85	-2.73655	53.31722
21	-2.70984	53.29965	86	-2.73511	53.31747
22	-2.70851	53.29993	87	-2.73366	53.31778
23	-2.70738	53.30054	88	-2.73219	53.31793
24	-2.70631	53.30117	89	-2.73072	53.31785
25	-2.70528	53.30181	90	-2.72935	53.31759
26	-2.71961	53.29294	91	-2.72793	53.31729
27	-2.72083	53.29343	92	-2.72645	53.31713
28	-2.72207	53.29391	93	-2.72495	53.31712
29	-2.72341	53.29430	94	-2.72343	53.31727
30	-2.72453	53.29487	95	-2.72202	53.31758
31	-2.72535	53.29561	96	-2.72065	53.31790
32	-2.71731	53.29387	97	-2.71925	53.31823
33	-2.71766	53.29473	98	-2.71780	53.31846
34	-2.71796	53.29561	99	-2.71630	53.31845
35	-2.71817	53.29650	100	-2.73638	53.31706
36	-2.71874	53.29732	101	-2.73493	53.31725
37	-2.74821	53.28970	102	-2.73347	53.31745
38	-2.74702	53.29027	103	-2.73198	53.31756
39	-2.74588	53.29082	104	-2.73048	53.31760
40	-2.74468	53.29139	105	-2.72055	53.31760

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
41	-2.74352	53.29193	106	-2.71907	53.31775
42	-2.74232	53.29249	107	-2.71769	53.31810
43	-2.74112	53.29306	108	-2.71654	53.31867
44	-2.73996	53.29360	109	-2.71944	53.31842
45	-2.73875	53.29416	110	-2.71841	53.31906
46	-2.73759	53.29469	111	-2.71510	53.31811
47	-2.73638	53.29525	112	-2.71650	53.31805
48	-2.73525	53.29576	113	-2.71825	53.31880
49	-2.73399	53.29633	114	-2.73901	53.31871
50	-2.73286	53.29684	115	-2.73816	53.31802
51	-2.73164	53.29739	116	-2.73670	53.31812
52	-2.73042	53.29794	117	-2.73523	53.31829
53	-2.72926	53.29847	118	-2.73381	53.31852
54	-2.72811	53.29902	119	-2.73231	53.31855
55	-2.72692	53.29959	120	-2.73088	53.31830
56	-2.72574	53.30017	121	-2.72945	53.31801
57	-2.72458	53.30077	122	-2.72803	53.31772
58	-2.72346	53.30134	123	-2.72656	53.31753
59	-2.72236	53.30192	124	-2.72507	53.31751
60	-2.72123	53.30254	125	-2.72359	53.31765
61	-2.72011	53.30316	126	-2.72221	53.31794
62	-2.71905	53.30377	127	-2.72085	53.31835
63	-2.71796	53.30441	128	-2.71972	53.31892
64	-2.71691	53.30502	129	-2.71881	53.31958
65	-2.71579	53.30569			

Road receptor details

Dwelling Receptor Details

The dwelling receptor coordinates are presented in the tables below. An additional 1.8m height has been added to the terrain elevation to account for the eye-level of an observer at these dwellings.

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-2.74035	53.29013	73	-2.72204	53.30025
2	-2.74002	53.29008	74	-2.72169	53.29994
3	-2.73399	53.28979	75	-2.72141	53.30011
4	-2.73376	53.28992	76	-2.72103	53.30034
5	-2.73350	53.29005	77	-2.72066	53.30054
6	-2.73142	53.29029	78	-2.72035	53.30072
7	-2.73148	53.29051	79	-2.71984	53.30093
8	-2.73102	53.29061	80	-2.71971	53.30082
9	-2.73133	53.29085	81	-2.71965	53.30065
10	-2.73155	53.29112	82	-2.71939	53.30050
11	-2.73117	53.29123	83	-2.71891	53.30060
12	-2.73087	53.29261	84	-2.71847	53.30077
13	-2.73271	53.29308	85	-2.71811	53.30090
14	-2.73323	53.29338	86	-2.71786	53.30105
15	-2.73346	53.29353	87	-2.71837	53.30138
16	-2.73361	53.29373	88	-2.71845	53.30149
17	-2.73340	53.29403	89	-2.71830	53.30165
18	-2.73359	53.29430	90	-2.71796	53.30173
19	-2.73400	53.29451	91	-2.71761	53.30192
20	-2.73407	53.29490	92	-2.71700	53.30207
21	-2.73368	53.29500	93	-2.71664	53.30218
22	-2.73367	53.29525	94	-2.71624	53.30228
23	-2.73364	53.29545	95	-2.71570	53.30241

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
24	-2.73332	53.29550	96	-2.71536	53.30250
25	-2.73315	53.29563	97	-2.71475	53.30259
26	-2.73357	53.29583	98	-2.71441	53.30265
27	-2.73339	53.29604	99	-2.71445	53.30293
28	-2.73314	53.29610	100	-2.71415	53.30312
29	-2.73292	53.29620	101	-2.71390	53.30333
30	-2.73269	53.29631	102	-2.71368	53.30345
31	-2.73248	53.29641	103	-2.71327	53.30361
32	-2.73234	53.29599	104	-2.71293	53.30366
33	-2.73201	53.29599	105	-2.71262	53.30366
34	-2.73174	53.29592	106	-2.71227	53.30373
35	-2.73150	53.29585	107	-2.71188	53.30372
36	-2.73117	53.29571	108	-2.71154	53.30365
37	-2.73060	53.29549	109	-2.71125	53.30363
38	-2.73010	53.29575	110	-2.71082	53.30357
39	-2.72970	53.29539	111	-2.70619	53.30176
40	-2.72929	53.29537	112	-2.70591	53.30192
41	-2.72897	53.29493	113	-2.70571	53.30202
42	-2.72822	53.29507	114	-2.71246	53.31383
43	-2.72787	53.29523	115	-2.71234	53.31410
44	-2.72820	53.29550	116	-2.71271	53.31429
45	-2.72740	53.29544	117	-2.71316	53.31424
46	-2.72713	53.29557	118	-2.71423	53.31657
47	-2.72687	53.29570	119	-2.71521	53.31707
48	-2.72652	53.29586	120	-2.71967	53.31941
49	-2.72630	53.29597	121	-2.72005	53.31955

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
50	-2.72599	53.29612	122	-2.72045	53.31969
51	-2.72615	53.29674	123	-2.72119	53.31962
52	-2.72635	53.29690	124	-2.72154	53.31928
53	-2.72664	53.29718	125	-2.72193	53.31943
54	-2.72540	53.29644	126	-2.72231	53.31955
55	-2.72513	53.29660	127	-2.72270	53.31967
56	-2.72481	53.29678	128	-2.72307	53.31980
57	-2.72478	53.29711	129	-2.72347	53.31993
58	-2.72495	53.29742	130	-2.72382	53.32003
59	-2.72523	53.29775	131	-2.72431	53.32015
60	-2.72595	53.29797	132	-2.72471	53.32027
61	-2.72569	53.29820	133	-2.72526	53.32042
62	-2.72539	53.29859	134	-2.73535	53.31929
63	-2.72490	53.29871	135	-2.73708	53.31829
64	-2.72458	53.29881	136	-2.73815	53.31772
65	-2.72418	53.29919	137	-2.73837	53.31753
66	-2.72385	53.29937	138	-2.73865	53.31777
67	-2.72358	53.29955	139	-2.73895	53.31816
68	-2.72337	53.29974	140	-2.74095	53.31867
69	-2.72311	53.29994	141	-2.74120	53.31902
70	-2.72313	53.30025	142	-2.74164	53.31887
71	-2.72284	53.30049	143	-2.74192	53.31911
72	-2.72239	53.30035			

Dwelling receptor details

Frodsham Memorial Receptor Details

The Frodsham Memorial receptor coordinates are presented in the table below. An additional 1.7m height has been added to the terrain elevation to account for the eye-level of an observer.

Longitude (°)	Latitude (°)
-2.72521	53.28864

Frodsham Memorial receptor details

Modelled Reflector Areas

The modelled aviation reflector area footprint coordinates are presented in the tables below. The individual panel areas used for the ground-based receptors can be provided upon request.

White

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-2.74102	53.30492	17	-2.74756	53.29873
2	-2.74182	53.30711	18	-2.74691	53.29873
3	-2.74471	53.30843	19	-2.74450	53.29911
4	-2.74711	53.31066	20	-2.74459	53.29823
5	-2.74846	53.31165	21	-2.74301	53.29807
6	-2.74960	53.31207	22	-2.74234	53.29808
7	-2.75333	53.30824	23	-2.74273	53.29924
8	-2.75083	53.30691	24	-2.73979	53.29961
9	-2.75150	53.30614	25	-2.73971	53.29826
10	-2.75411	53.30612	26	-2.73956	53.29808
11	-2.75856	53.30393	27	-2.73910	53.29808
12	-2.75692	53.30171	28	-2.73771	53.29902
13	-2.75414	53.30320	29	-2.73926	53.30137
14	-2.74984	53.30362	30	-2.74045	53.30373
15	-2.74965	53.30271	31	-2.74171	53.30372
16	-2.74766	53.29916	32	-2.74166	53.30473

White panel area details

Forest Green

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-2.74991	53.30321	7	-2.75674	53.29989
2	-2.75409	53.30274	8	-2.75643	53.29957
3	-2.75673	53.30147	9	-2.75516	53.29941
4	-2.75605	53.30049	10	-2.75359	53.29942
5	-2.75601	53.30018	11	-2.75329	53.29978
6	-2.75625	53.30018	12	-2.74766	53.29916

Forest green panel area details

Blue

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-2.73480	53.29870	20	-2.72797	53.30339
2	-2.73380	53.29949	21	-2.72950	53.30340
3	-2.73401	53.30104	22	-2.72876	53.30397
4	-2.73422	53.30151	23	-2.72920	53.30482
5	-2.73492	53.30191	24	-2.72926	53.30550
6	-2.73178	53.30193	25	-2.72957	53.30612
7	-2.72956	53.30125	26	-2.74029	53.30551
8	-2.72890	53.30126	27	-2.74013	53.30513
9	-2.72672	53.30253	28	-2.73830	53.30460
10	-2.72667	53.30318	29	-2.73261	53.30517
11	-2.72524	53.30260	30	-2.73175	53.30461
12	-2.72476	53.30260	31	-2.73208	53.30439
13	-2.72320	53.30434	32	-2.73512	53.30437
14	-2.72246	53.30534	33	-2.73830	53.30393
15	-2.72244	53.30546	34	-2.73941	53.30393
16	-2.72440	53.30631	35	-2.73846	53.30189
17	-2.72424	53.30686	36	-2.73719	53.29991

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
18	-2.72496	53.30729	37	-2.73579	53.29881
19	-2.72790	53.30396			

Blue panel area details

Navy

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-2.71770	53.30697	15	-2.72469	53.30769
2	-2.71864	53.30756	16	-2.72454	53.30746
3	-2.71977	53.30781	17	-2.72395	53.30703
4	-2.71970	53.30795	18	-2.72286	53.30682
5	-2.71967	53.30812	19	-2.72322	53.30640
6	-2.71975	53.30824	20	-2.72372	53.30641
7	-2.72113	53.30853	21	-2.72376	53.30635
8	-2.72073	53.30875	22	-2.72287	53.30597
9	-2.72069	53.30882	23	-2.72225	53.30584
10	-2.72259	53.30997	24	-2.72187	53.30596
11	-2.72303	53.31006	25	-2.72039	53.30566
12	-2.72340	53.30891	26	-2.71842	53.30562
13	-2.72386	53.30902	27	-2.71758	53.30672
14	-2.72457	53.30802	28	-2.71770	53.30697

Navy panel area details

Pink

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-2.72401	53.30298	9	-2.71946	53.30491
2	-2.72426	53.30256	10	-2.71908	53.30511
3	-2.72384	53.30246	11	-2.71879	53.30531
4	-2.72305	53.30280	12	-2.71925	53.30541
5	-2.72239	53.30291	13	-2.72048	53.30547

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
6	-2.72036	53.30426	14	-2.72164	53.30562
7	-2.72003	53.30484	15	-2.72190	53.30540
8	-2.71968	53.30485	16	-2.72401	53.30298

Pink panel area details

Purple

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-2.72869	53.30090	7	-2.72445	53.30203
2	-2.72739	53.30044	8	-2.72620	53.30250
3	-2.72632	53.30083	9	-2.72646	53.30237
4	-2.72406	53.30190	10	-2.72664	53.30212
5	-2.72401	53.30196	11	-2.72848	53.30119
6	-2.72441	53.30209	12	-2.72869	53.30090

Purple panel area details

Light Green

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	-2.73202	53.30113	9	-2.73381	53.30173
2	-2.73193	53.30128	10	-2.73380	53.30161
3	-2.73220	53.30148	11	-2.73342	53.30112
4	-2.73220	53.30167	12	-2.73349	53.30097
5	-2.73237	53.30182	13	-2.73343	53.30030
6	-2.73257	53.30187	14	-2.73342	53.30007
7	-2.73363	53.30186	15	-2.73321	53.30002
8	-2.73378	53.30178	16	-2.73202	53.30113

Light green panel area details

APPENDIX H - VISIBILITY OF DWELLINGS IN FRODSHAM

Overview

Pager Power's methodology, as set out in Section 4.4.1 is to assess the dwellings closest to the proposed development in large residential areas because these dwellings typically obstruct views of the proposed development to the dwellings behind them.

It is however acknowledged that Frodsham is located on terrain that rises as it gets further from the proposed development. If the slope of the terrain was at a certain level then it is possible that views would be possible over the top of the dwelling in front of it.

This analysis has therefore considered the visibility of dwellings further from the proposed development in Frodsham to determine whether Pager Power's methodology remains appropriate.

Visibility Analysis

Analysis to determine the visibility of dwellings in Frodsham was undertaken by evaluating line-of-sight profiles from the ground floor of random dwellings to the top of the solar panels above ground level. The profiles used were all orientated east/west as this is the orientation in which most effects are expected to be geometrically possible, and 1km in length as this is the maximum distance in which glint and glare effects could be considered significant towards ground-based receptors.

These profiles were plotted onto 3D aerial imagery and inspected to determine whether the profiles were intercepted by obstructions before reaching the proposed development. The 2D representation of the profiles is shown in Figure H25 below and the 3D representation is shown in Figure H26 on the following page.

Figure H25 *2D representation of line-of-sight profiles*

Figure H26 *3D representation of line-of-sight profiles*

Conclusion

Inspection of the line-of-sight profiles showed that visibility of the proposed development would be significantly obstructed for all randomly selected dwellings. It is therefore concluded that the approach followed by Pager Power is appropriate for the dwellings in Frodsham.

This analysis inspected randomly selected dwellings in Frodsham and it is possible that individual dwellings that were not considered will have marginal views of the proposed development. If so, the partial screening from other dwellings in Frodsham and existing vegetation identified throughout this report is likely to sufficiently reduce the duration of effects such that no significant impacts would be predicted.

APPENDIX I – DETAILLED MODELLING RESULTS

Overview

The Pager Power (roads and dwellings) and Forge (aviation) charts for receptors are shown on the following pages. Further modelling charts can be provided upon request.

Each Pager Power chart shows:

- The receptor (observer) location – top right image. This also shows the azimuth range of the Sun itself at times when reflections are possible. If sunlight is experienced from the same direction as the reflecting panels, the overall impact of the reflection is reduced as discussed within the body of the report;
- The reflection date/time graph – left hand side of image. The blue line indicates the dates and times at which geometric reflections are possible. This relates to reflections from the yellow areas;
- The sunrise and sunset curves throughout the year (red and yellow lines).

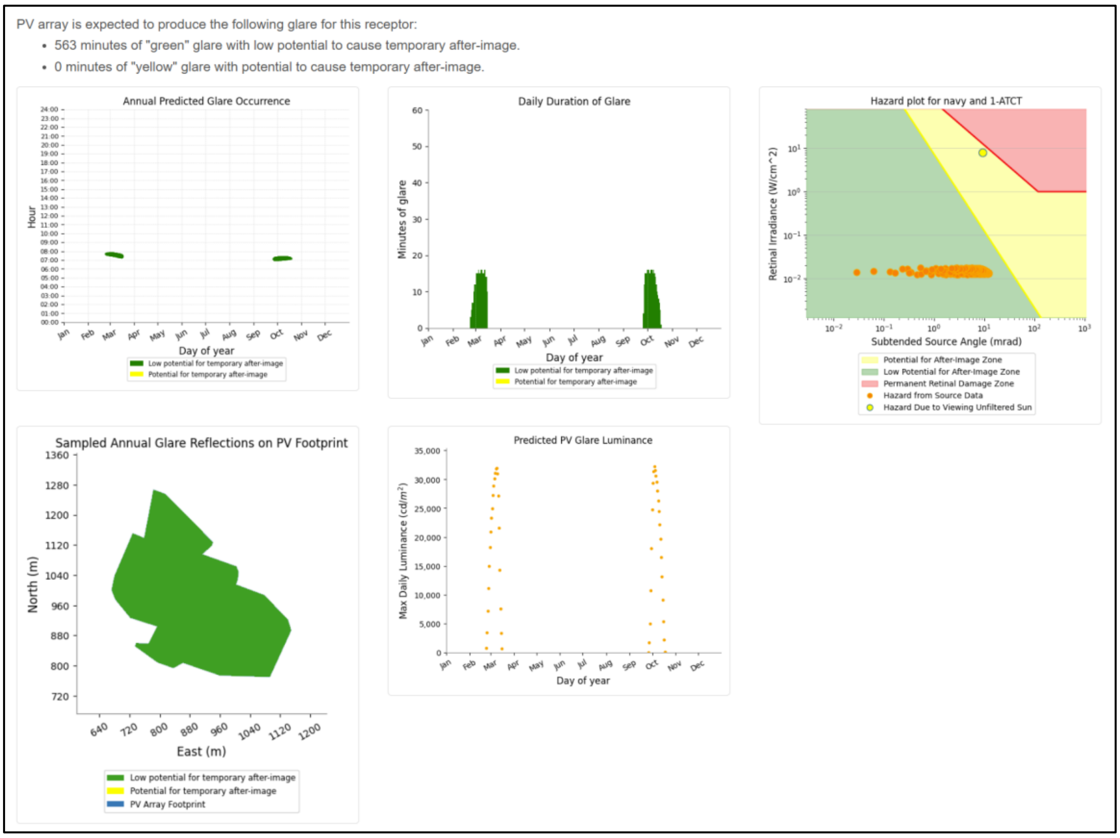
Each Forge chart shows:

- The annual predicted solar reflections.
- The daily duration of the solar reflections.
- The predicted glare luminance (ATC Tower only).
- The location of the proposed development where glare will originate.
- The calculated intensity of the predicted solar reflections.

ATC Tower

Charts where views of the reflecting panels are predicted are presented below.

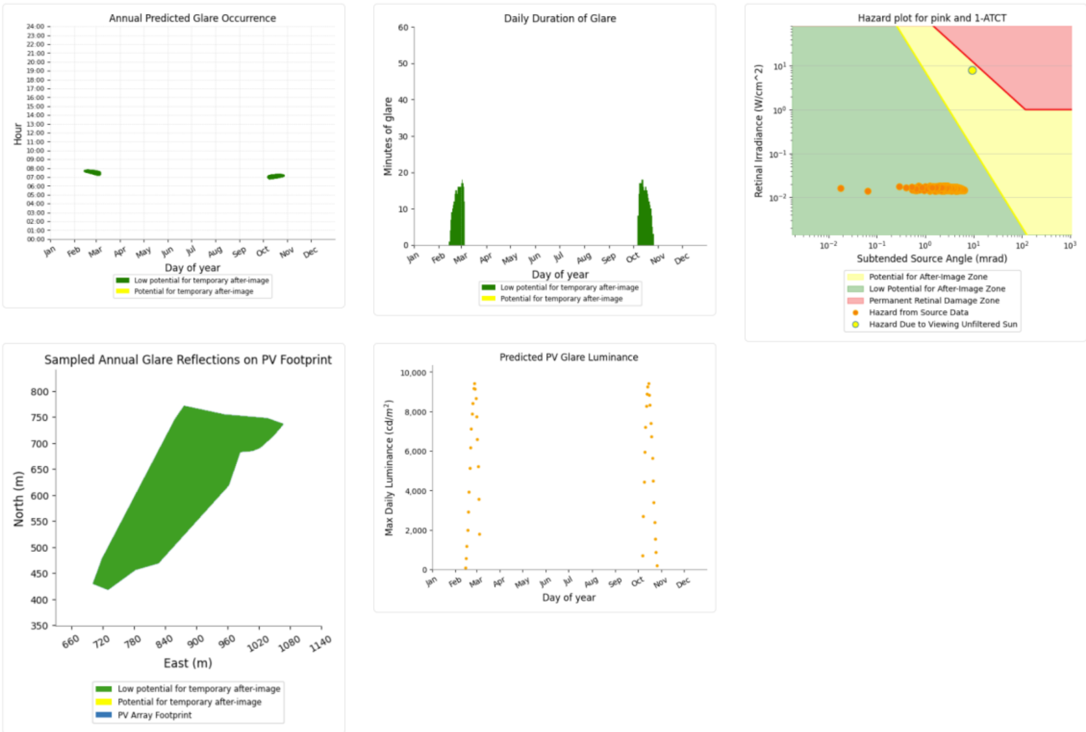
Navy



Pink

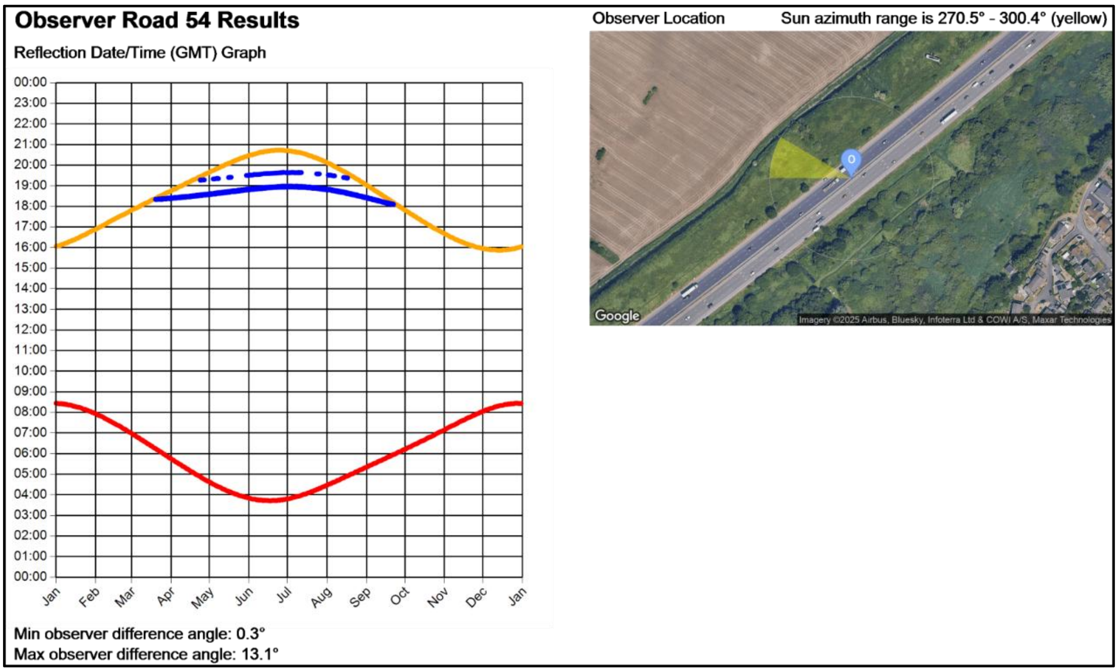
PV array is expected to produce the following glare for this receptor:

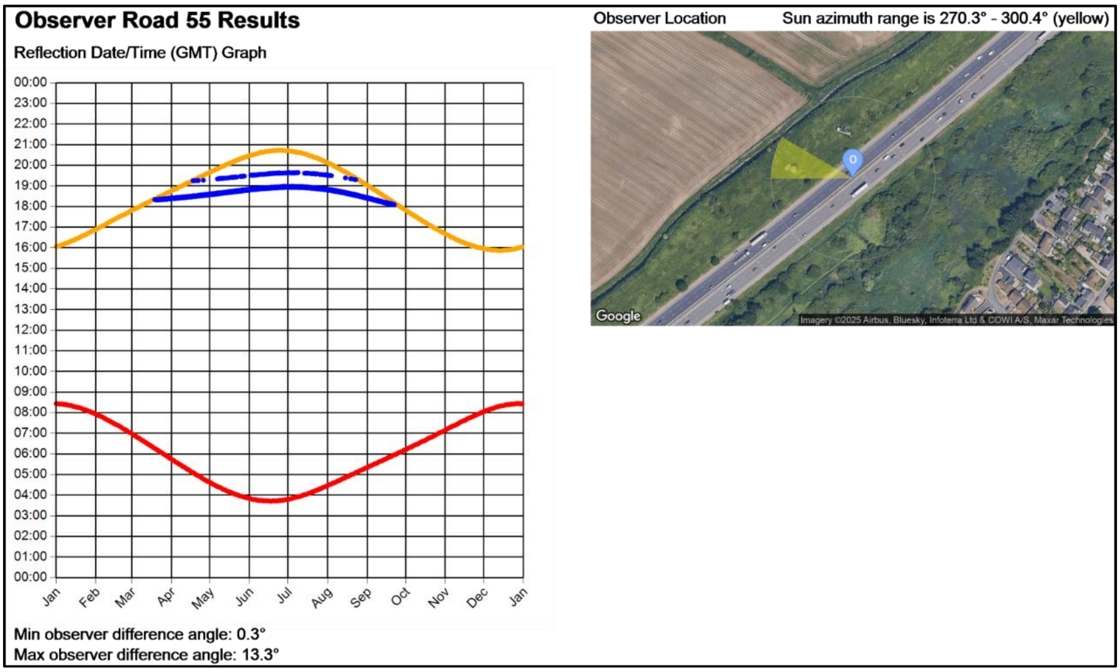
- 519 minutes of "green" glare with low potential to cause temporary after-image.
- 0 minutes of "yellow" glare with potential to cause temporary after-image.



Road Receptors

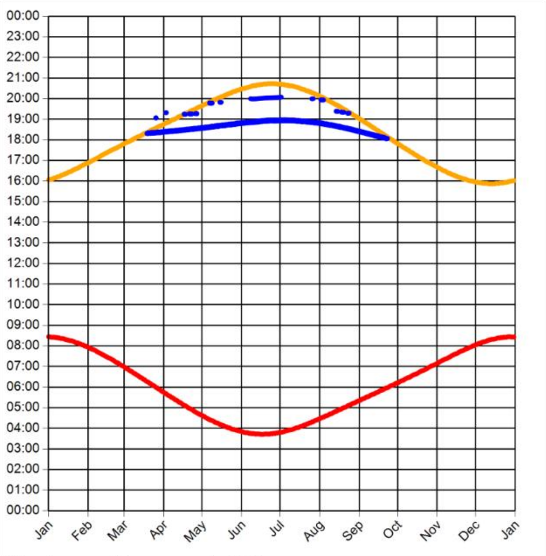
Charts where views of the reflecting panels are predicted are presented below.





Observer Road 56 Results

Reflection Date/Time (GMT) Graph

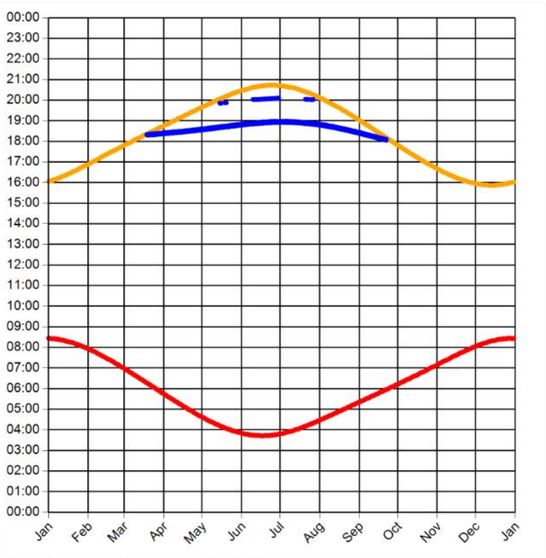


Observer Location | Sun azimuth ranges (yellow)

Min observer difference angle: 0.3°
Max observer difference angle: 13.4°

Observer Road 57 Results

Reflection Date/Time (GMT) Graph

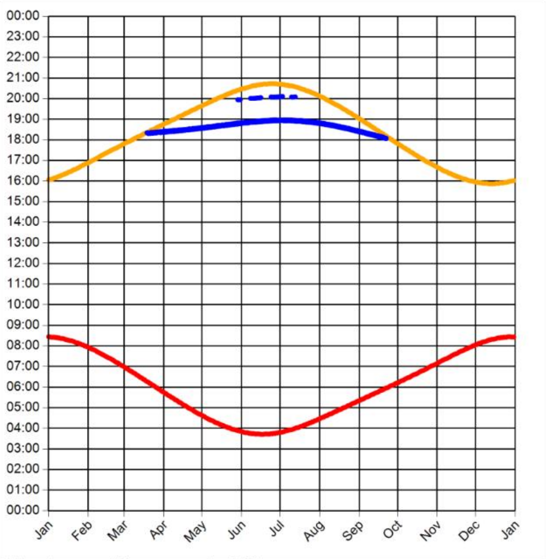


Observer Location | Sun azimuth ranges (yellow)

Min observer difference angle: 0.3°
Max observer difference angle: 13.4°

Observer Road 58 Results

Reflection Date/Time (GMT) Graph



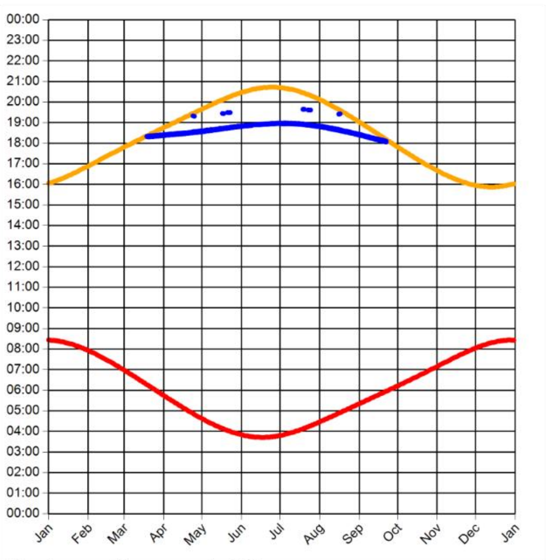
Min observer difference angle: 0.3°
Max observer difference angle: 13.3°

Observer Location

Sun azimuth ranges (yellow)

Observer Road 61 Results

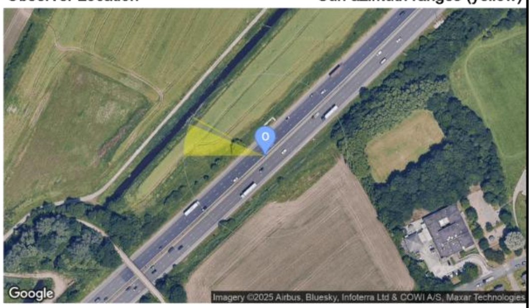
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.2°
Max observer difference angle: 12.8°

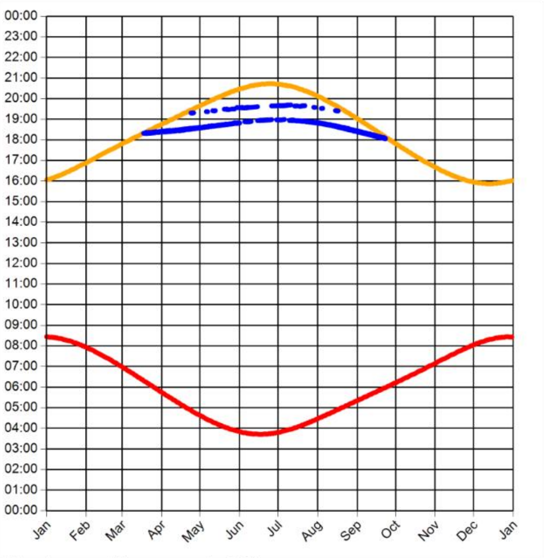
Observer Location

Sun azimuth ranges (yellow)



Observer Road 62 Results

Reflection Date/Time (GMT) Graph



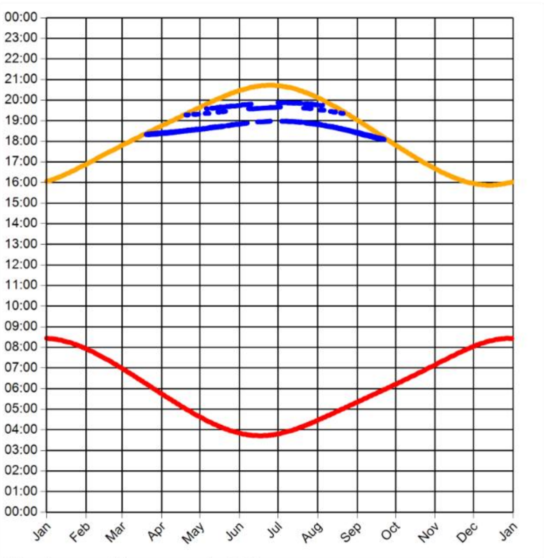
Min observer difference angle: 0.2°
Max observer difference angle: 12.5°

Observer Location

Sun azimuth range is 269.7° - 300.5° (yellow)

Observer Road 63 Results

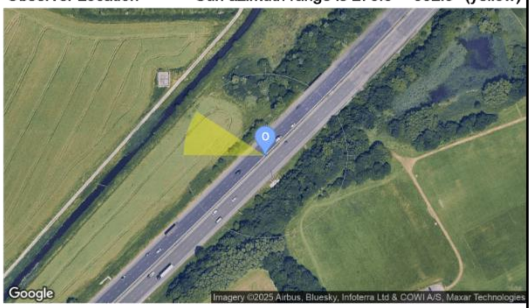
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 12.4°

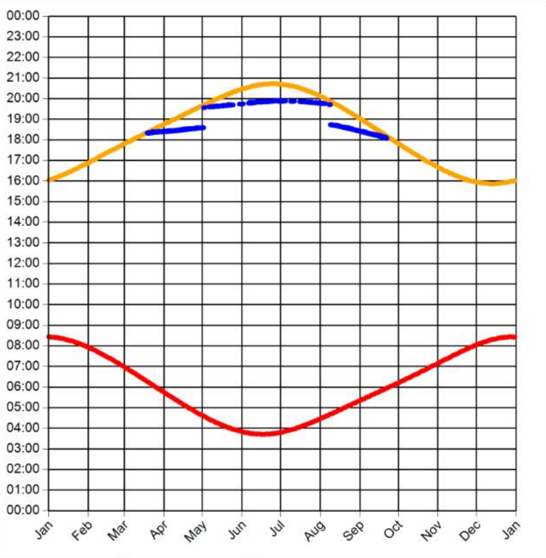
Observer Location

Sun azimuth range is 270.5° - 302.9° (yellow)



Observer Road 65 Results

Reflection Date/Time (GMT) Graph



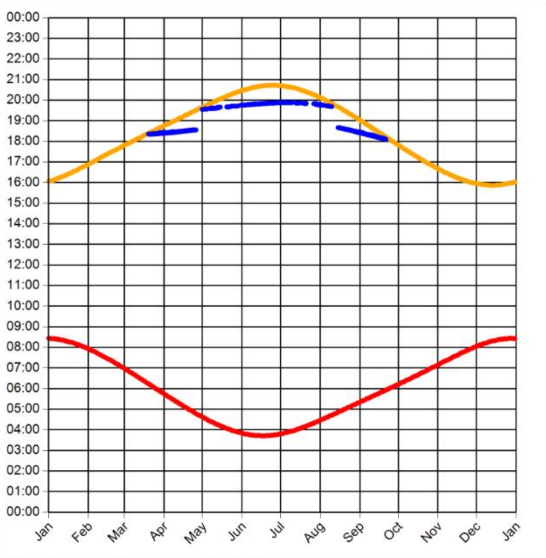
Min observer difference angle: 0.3°

Max observer difference angle: 8.5°

Observer Location | Sun azimuth ranges (yellow)

Observer Road 66 Results

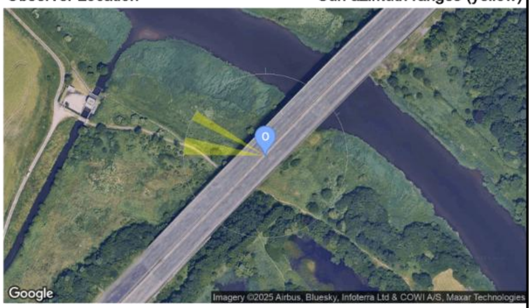
Reflection Date/Time (GMT) Graph

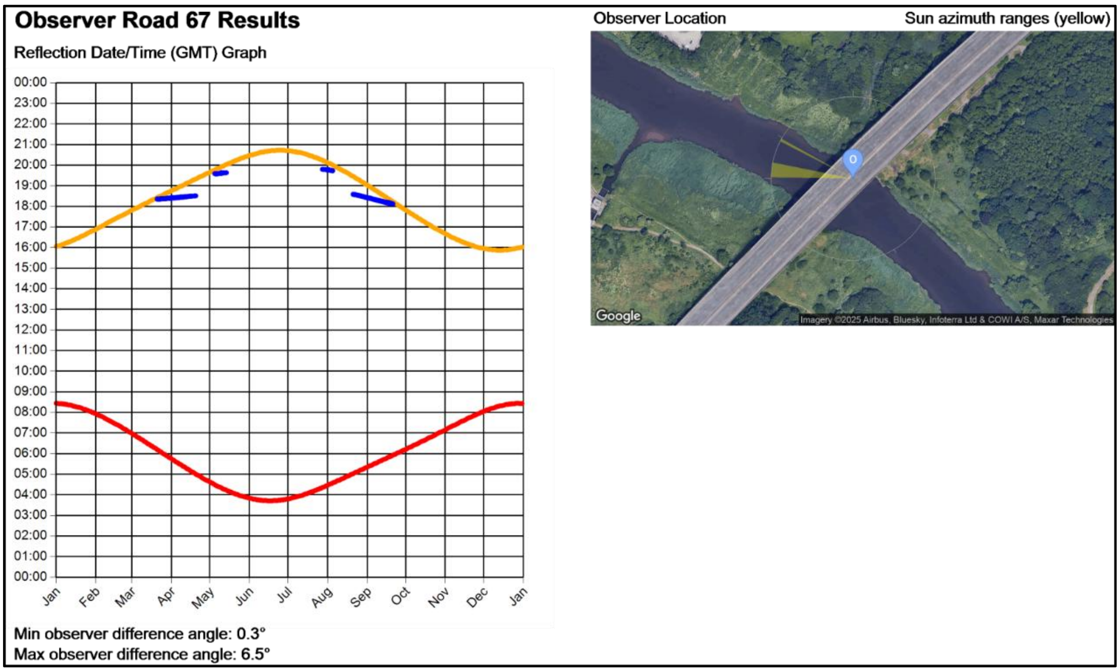


Min observer difference angle: 0.3°

Max observer difference angle: 7.5°

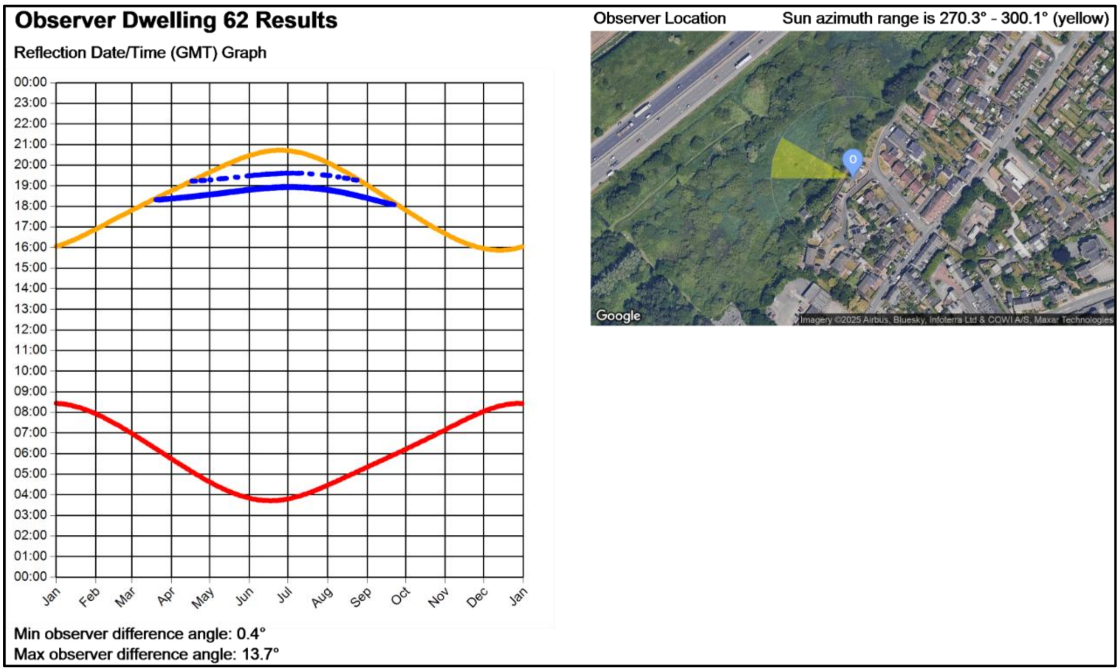
Observer Location | Sun azimuth ranges (yellow)





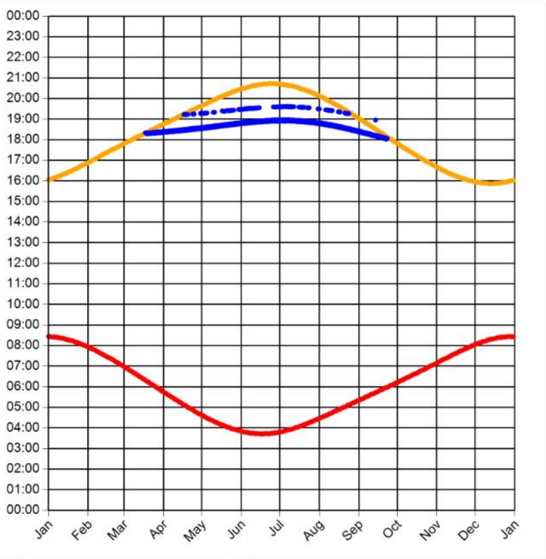
Dwelling Receptors

Charts where views of the reflecting panels are predicted are presented below.



Observer Dwelling 63 Results

Reflection Date/Time (GMT) Graph



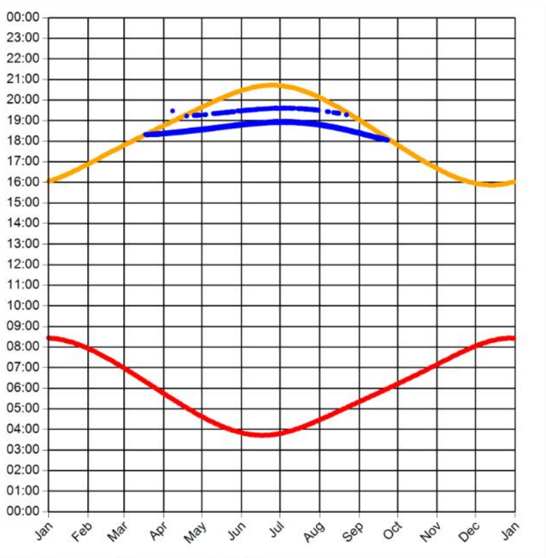
Min observer difference angle: 0.3°
Max observer difference angle: 13.6°

Observer Location

Sun azimuth range is 269.7° - 299.9° (yellow)

Observer Dwelling 64 Results

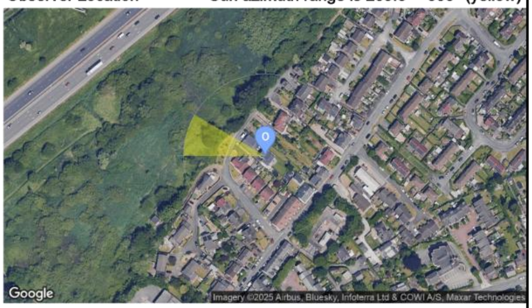
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 13.6°

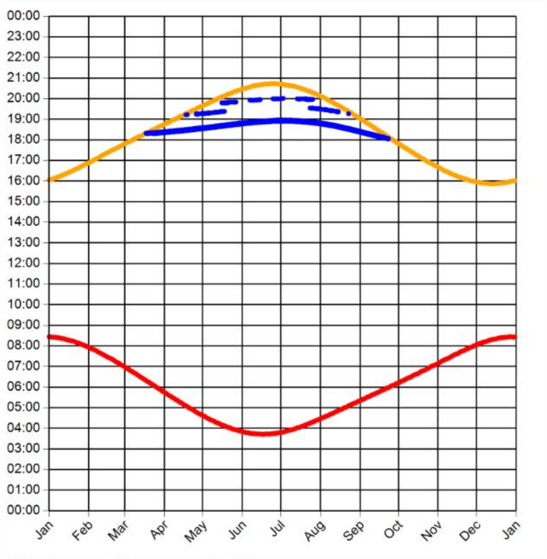
Observer Location

Sun azimuth range is 269.8° - 300° (yellow)



Observer Dwelling 65 Results

Reflection Date/Time (GMT) Graph

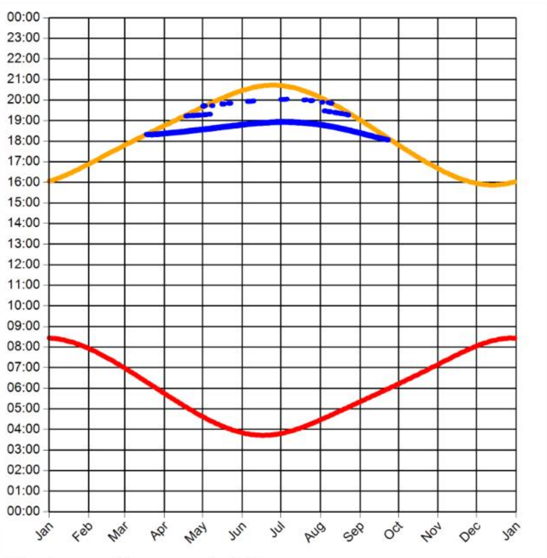


Min observer difference angle: 0.2°
Max observer difference angle: 13.9°

Observer Location | Sun azimuth ranges (yellow)

Observer Dwelling 66 Results

Reflection Date/Time (GMT) Graph

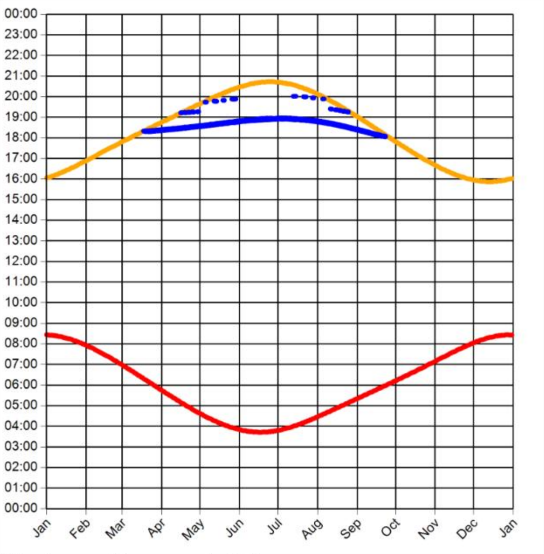


Min observer difference angle: 0.3°
Max observer difference angle: 13.7°

Observer Location | Sun azimuth range is 269.9° - 304.6° (yellow)

Observer Dwelling 67 Results

Reflection Date/Time (GMT) Graph



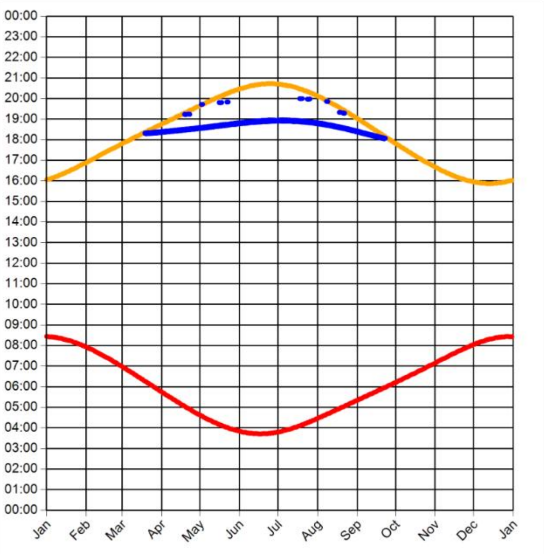
Min observer difference angle: 0.3°
Max observer difference angle: 13.8°

Observer Location

Sun azimuth ranges (yellow)

Observer Dwelling 68 Results

Reflection Date/Time (GMT) Graph



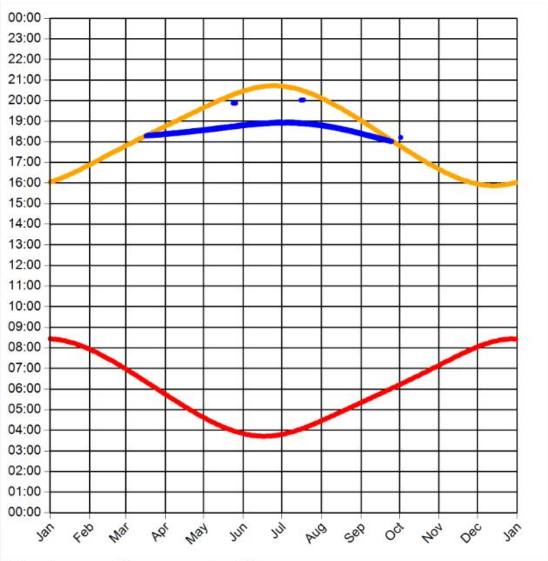
Min observer difference angle: 0.3°
Max observer difference angle: 13.7°

Observer Location

Sun azimuth ranges (yellow)

Observer Dwelling 69 Results

Reflection Date/Time (GMT) Graph



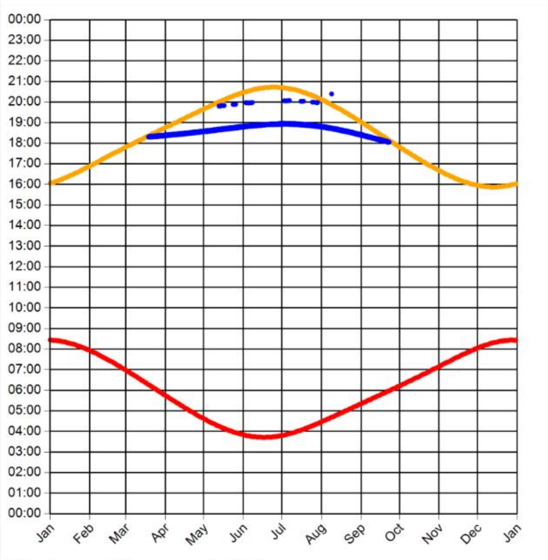
Min observer difference angle: 0.2°
Max observer difference angle: 13.7°

Observer Location

Sun azimuth ranges (yellow)

Observer Dwelling 70 Results

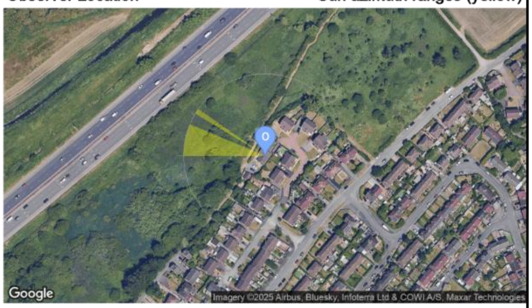
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.4°
Max observer difference angle: 13.5°

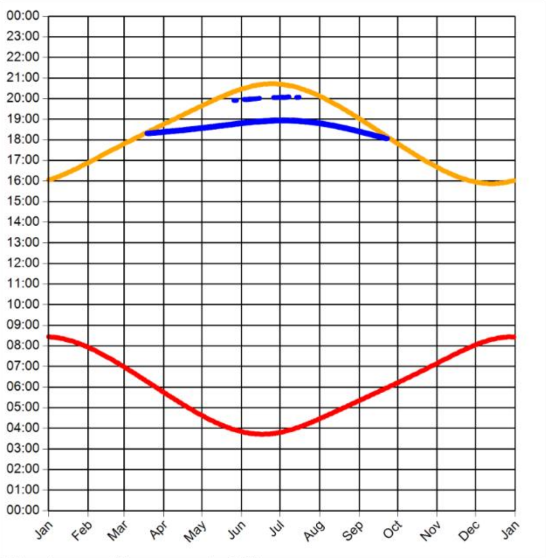
Observer Location

Sun azimuth ranges (yellow)



Observer Dwelling 71 Results

Reflection Date/Time (GMT) Graph



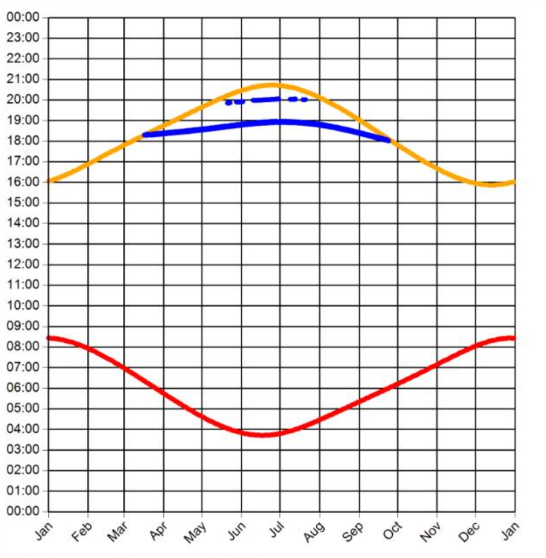
Min observer difference angle: 0.3°
Max observer difference angle: 13.5°

Observer Location

Sun azimuth ranges (yellow)

Observer Dwelling 72 Results

Reflection Date/Time (GMT) Graph



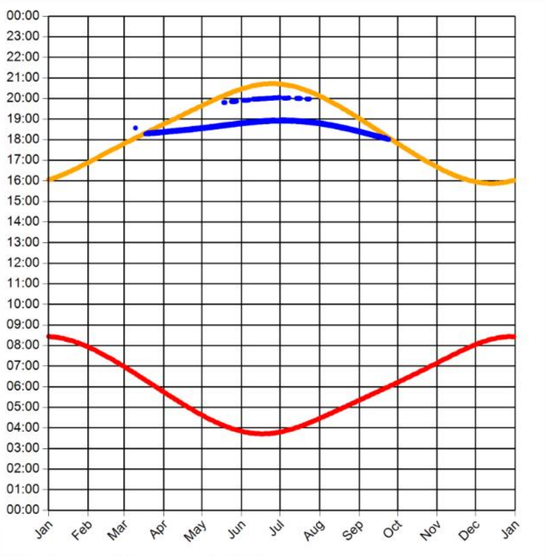
Min observer difference angle: 0.2°
Max observer difference angle: 13.7°

Observer Location

Sun azimuth ranges (yellow)

Observer Dwelling 73 Results

Reflection Date/Time (GMT) Graph

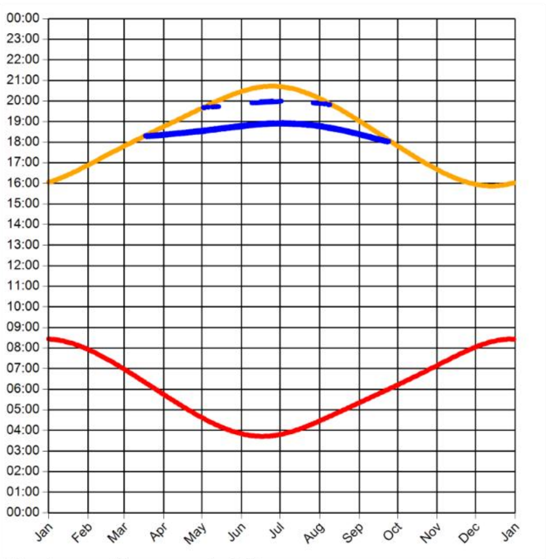


Min observer difference angle: 0.2°
Max observer difference angle: 13.8°

Observer Location | Sun azimuth ranges (yellow)

Observer Dwelling 74 Results

Reflection Date/Time (GMT) Graph

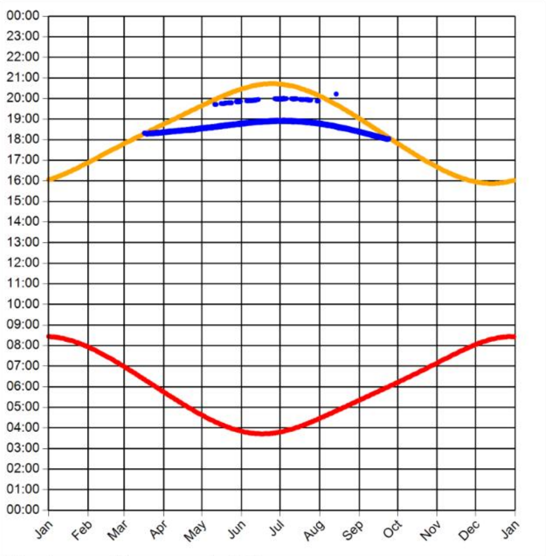


Min observer difference angle: 0.3°
Max observer difference angle: 14.1°

Observer Location | Sun azimuth ranges (yellow)

Observer Dwelling 75 Results

Reflection Date/Time (GMT) Graph

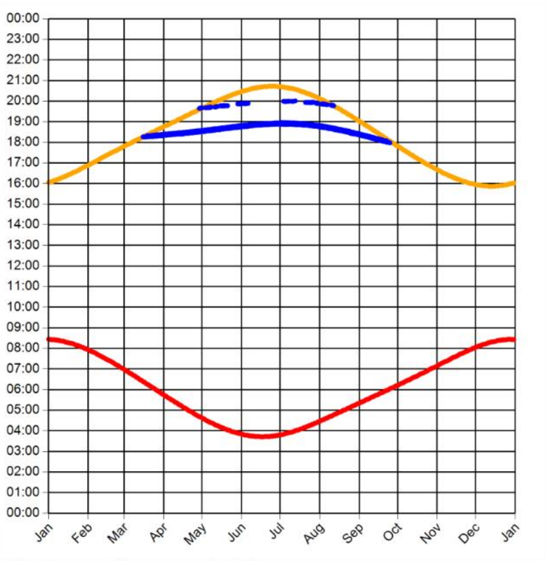


Min observer difference angle: 0.3°
Max observer difference angle: 14.1°

Observer Location | Sun azimuth ranges (yellow)

Observer Dwelling 76 Results

Reflection Date/Time (GMT) Graph

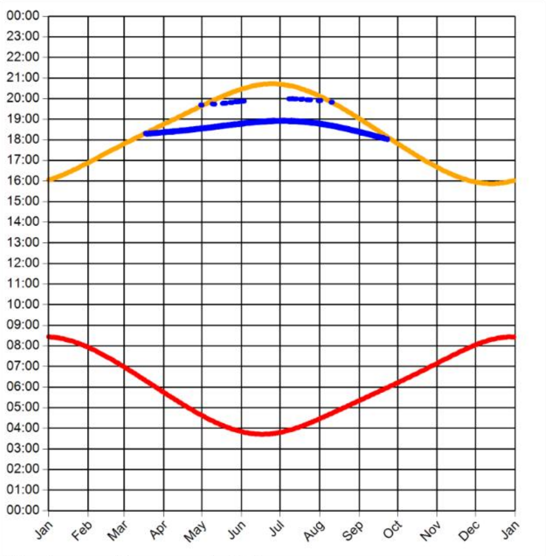


Min observer difference angle: 0.5°
Max observer difference angle: 14.1°

Observer Location | Sun azimuth ranges (yellow)

Observer Dwelling 77 Results

Reflection Date/Time (GMT) Graph



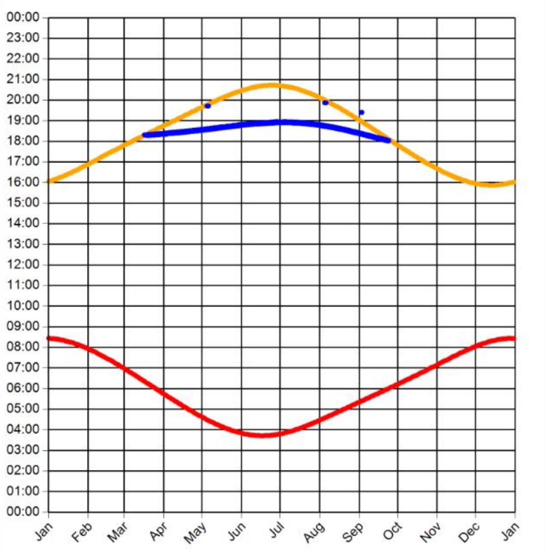
Min observer difference angle: 0.3°
Max observer difference angle: 14°

Observer Location

Sun azimuth ranges (yellow)

Observer Dwelling 78 Results

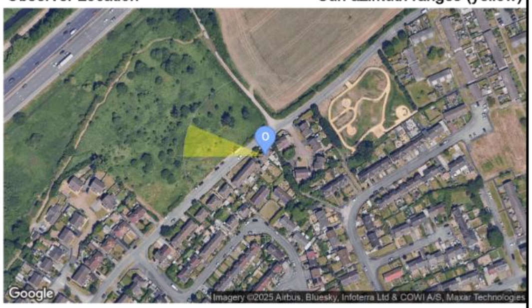
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 14°

Observer Location

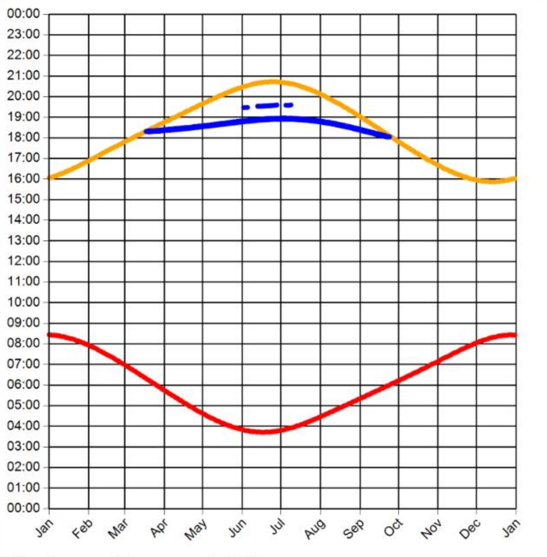
Sun azimuth ranges (yellow)



Observer Dwelling 79 Results

Observer Location | Sun azimuth ranges (yellow)

Reflection Date/Time (GMT) Graph

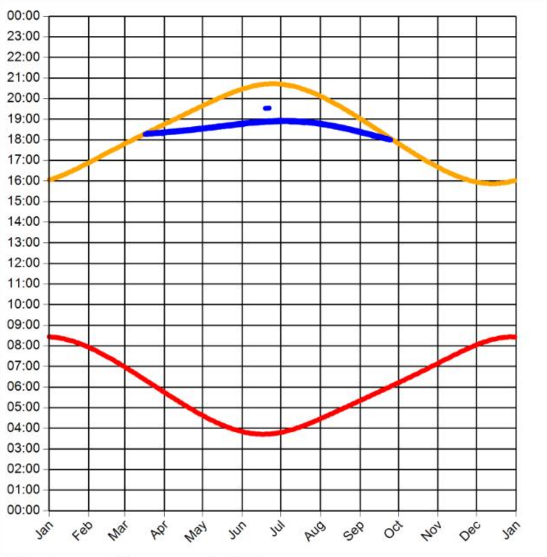


Min observer difference angle: 0.3°
Max observer difference angle: 13.8°

Observer Dwelling 80 Results

Observer Location | Sun azimuth ranges (yellow)

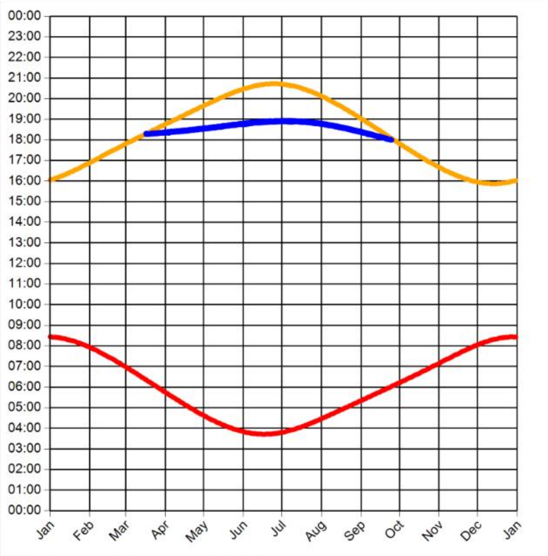
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.4°
Max observer difference angle: 14.2°

Observer Dwelling 81 Results

Reflection Date/Time (GMT) Graph

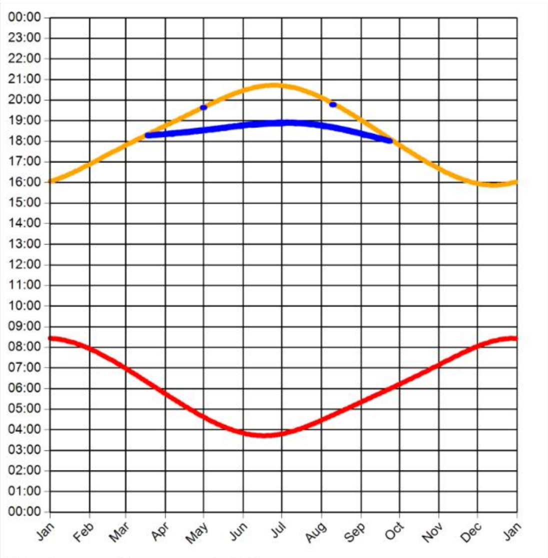


Min observer difference angle: 0.3°
Max observer difference angle: 14.4°

Observer Location — Sun azimuth range is 268.8° - 292.6° (yellow)

Observer Dwelling 82 Results

Reflection Date/Time (GMT) Graph

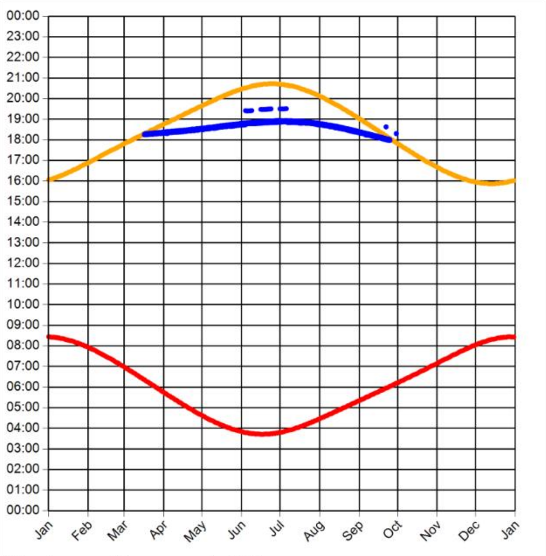


Min observer difference angle: 0.3°
Max observer difference angle: 14.8°

Observer Location — Sun azimuth ranges (yellow)

Observer Dwelling 83 Results

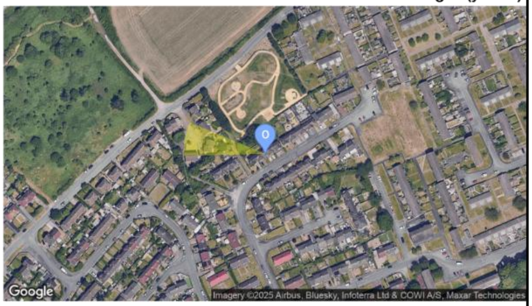
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.4°
Max observer difference angle: 14.9°

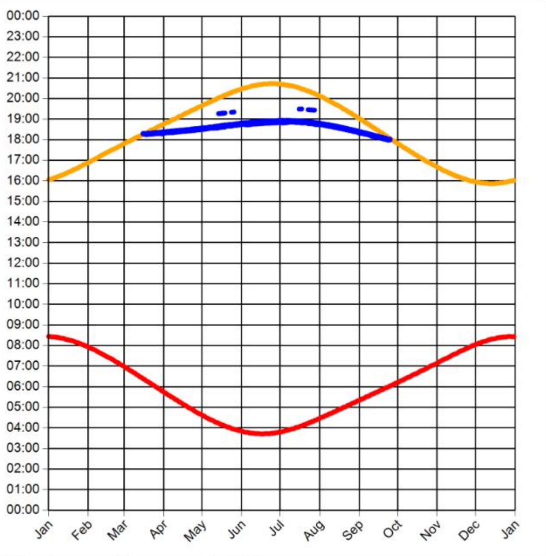
Observer Location

Sun azimuth ranges (yellow)



Observer Dwelling 84 Results

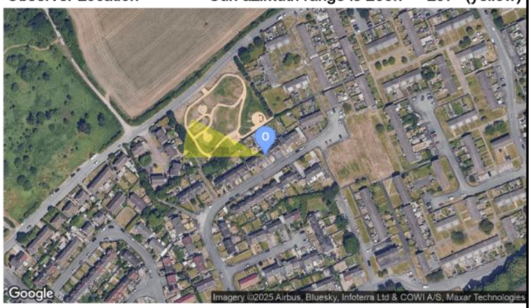
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.2°
Max observer difference angle: 15.5°

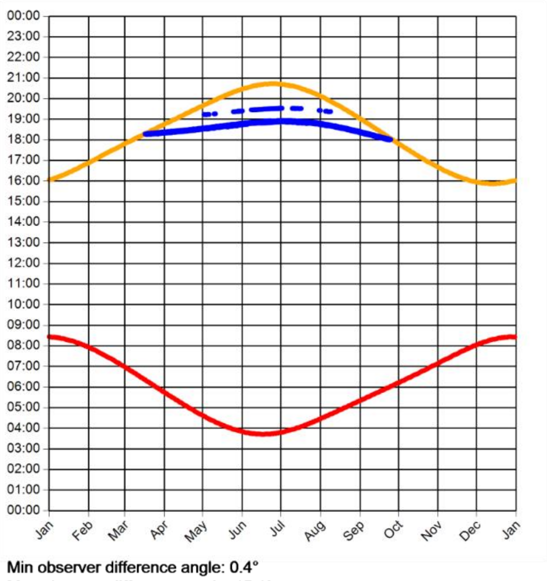
Observer Location

Sun azimuth range is 268.7° - 297° (yellow)



Observer Dwelling 85 Results

Reflection Date/Time (GMT) Graph



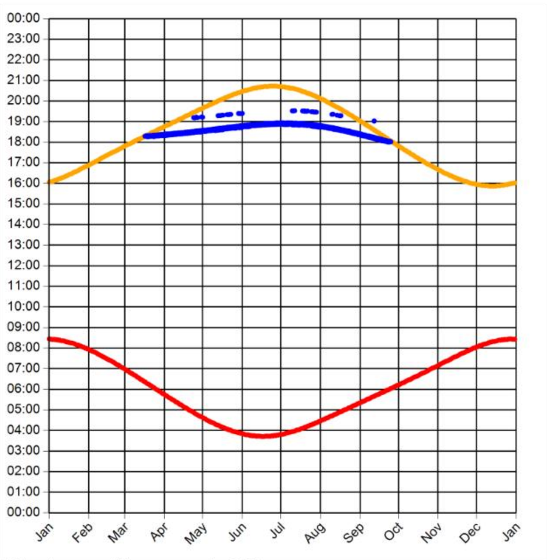
Min observer difference angle: 0.4°
Max observer difference angle: 15.1°

Observer Location

Sun azimuth range is 269° - 299.2° (yellow)

Observer Dwelling 86 Results

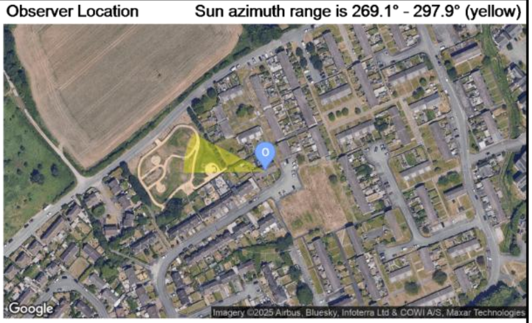
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 14.7°

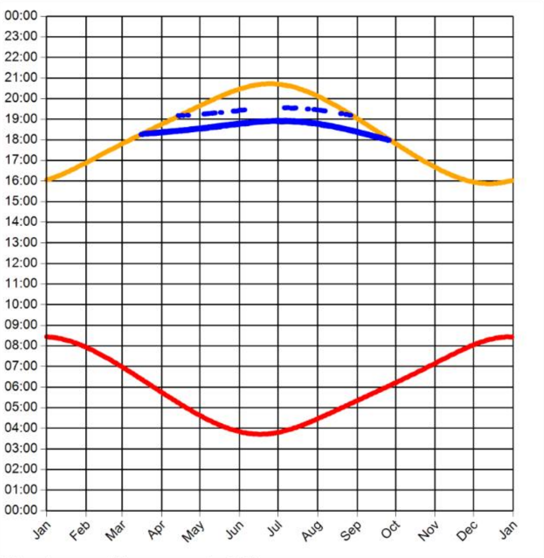
Observer Location

Sun azimuth range is 269.1° - 297.9° (yellow)



Observer Dwelling 87 Results

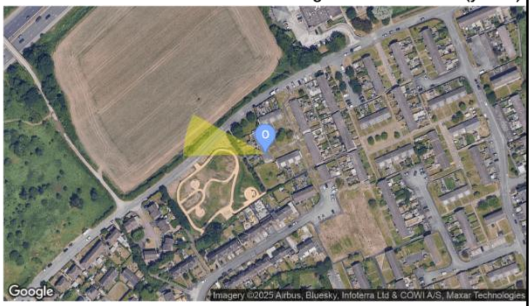
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 14.2°

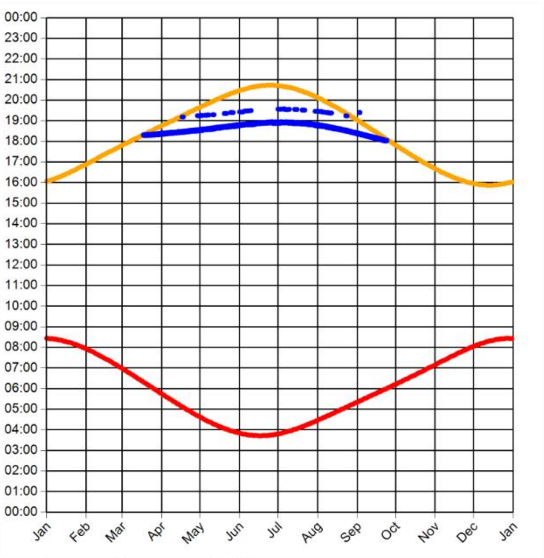
Observer Location

Sun azimuth range is 268.5° - 298.8° (yellow)



Observer Dwelling 88 Results

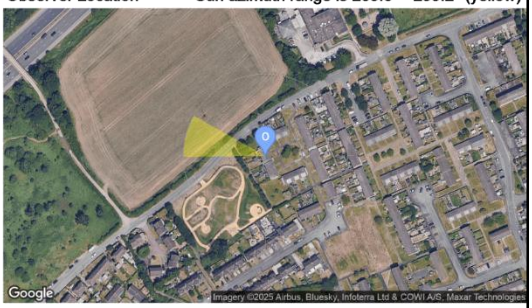
Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.2°
Max observer difference angle: 14.3°

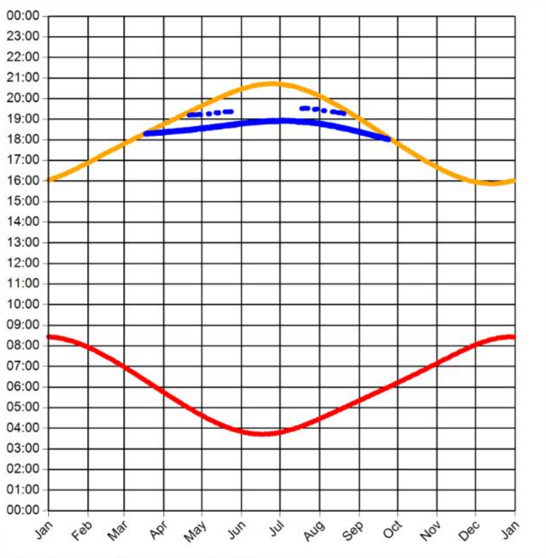
Observer Location

Sun azimuth range is 269.3° - 299.2° (yellow)



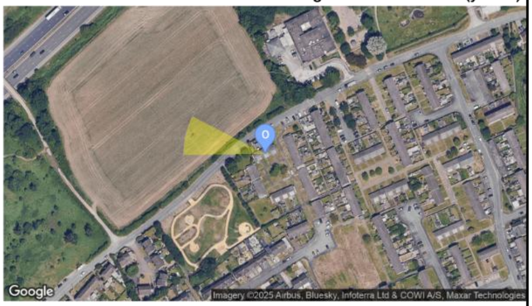
Observer Dwelling 89 Results

Reflection Date/Time (GMT) Graph



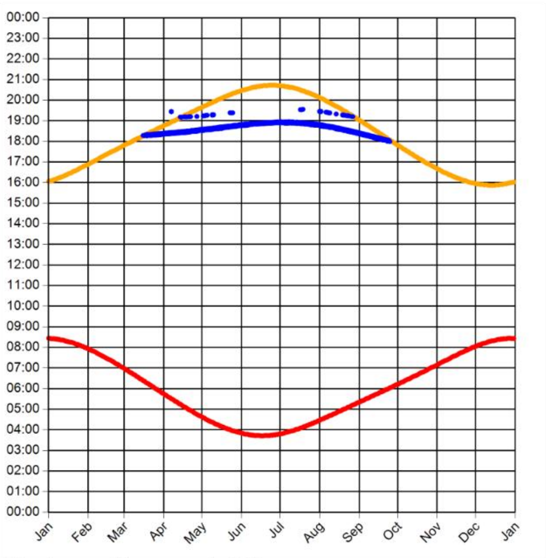
Min observer difference angle: 0.3°
Max observer difference angle: 14°

Observer Location   Sun azimuth range is 269.2° - 297.1° (yellow)



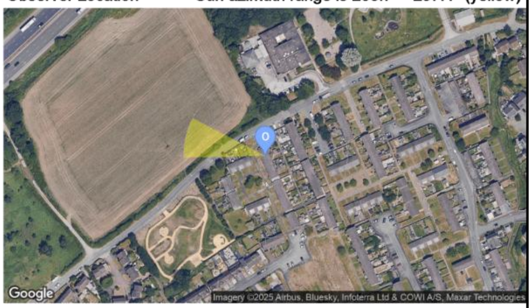
Observer Dwelling 90 Results

Reflection Date/Time (GMT) Graph



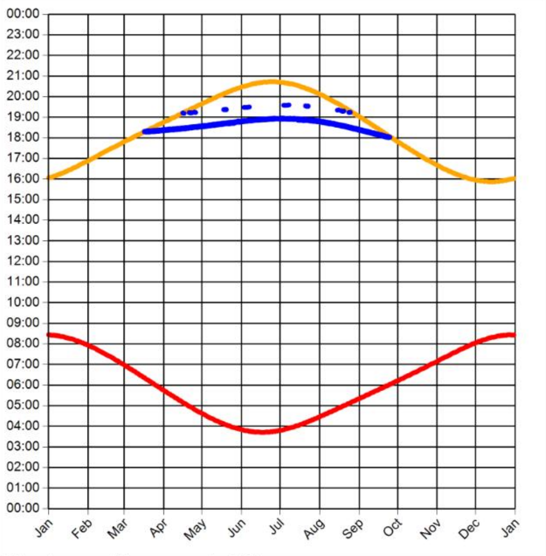
Min observer difference angle: 0.3°
Max observer difference angle: 13.9°

Observer Location   Sun azimuth range is 268.7° - 297.4° (yellow)



Observer Dwelling 91 Results

Reflection Date/Time (GMT) Graph

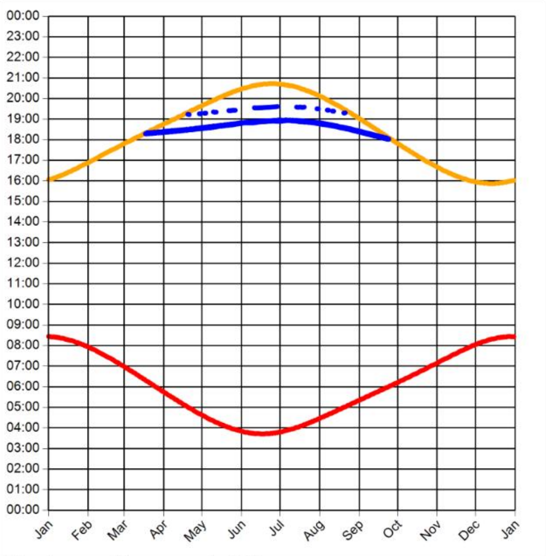


Min observer difference angle: 0.2°
Max observer difference angle: 13.7°

Observer Location   Sun azimuth range is 269.2° - 299.3° (yellow)

Observer Dwelling 92 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 13.7°

Observer Location   Sun azimuth range is 269.4° - 299.9° (yellow)

APPENDIX J – DESK-BASED REVIEW OF IMAGERY

Road Receptors

The desk-based analysis for road receptors is shown in Figure J27 to Figure J70 on the following pages. The figures show:

- The receptor (observer) location(s);
- The reflecting panels (coloured in yellow);
- Identified vegetation screening, where appropriate.

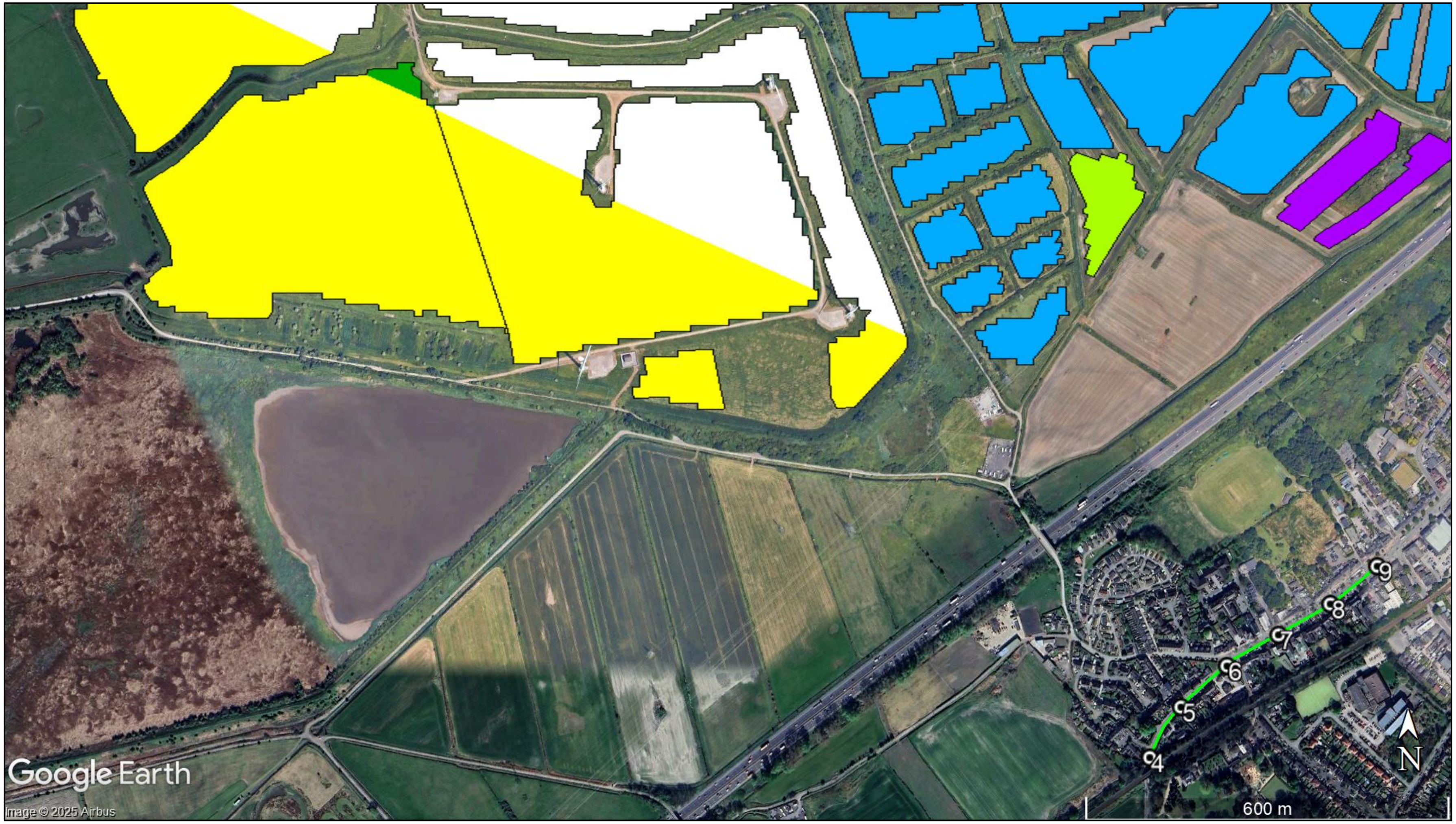


Figure J27 *Reflecting panel areas for road receptors 4 to 9*

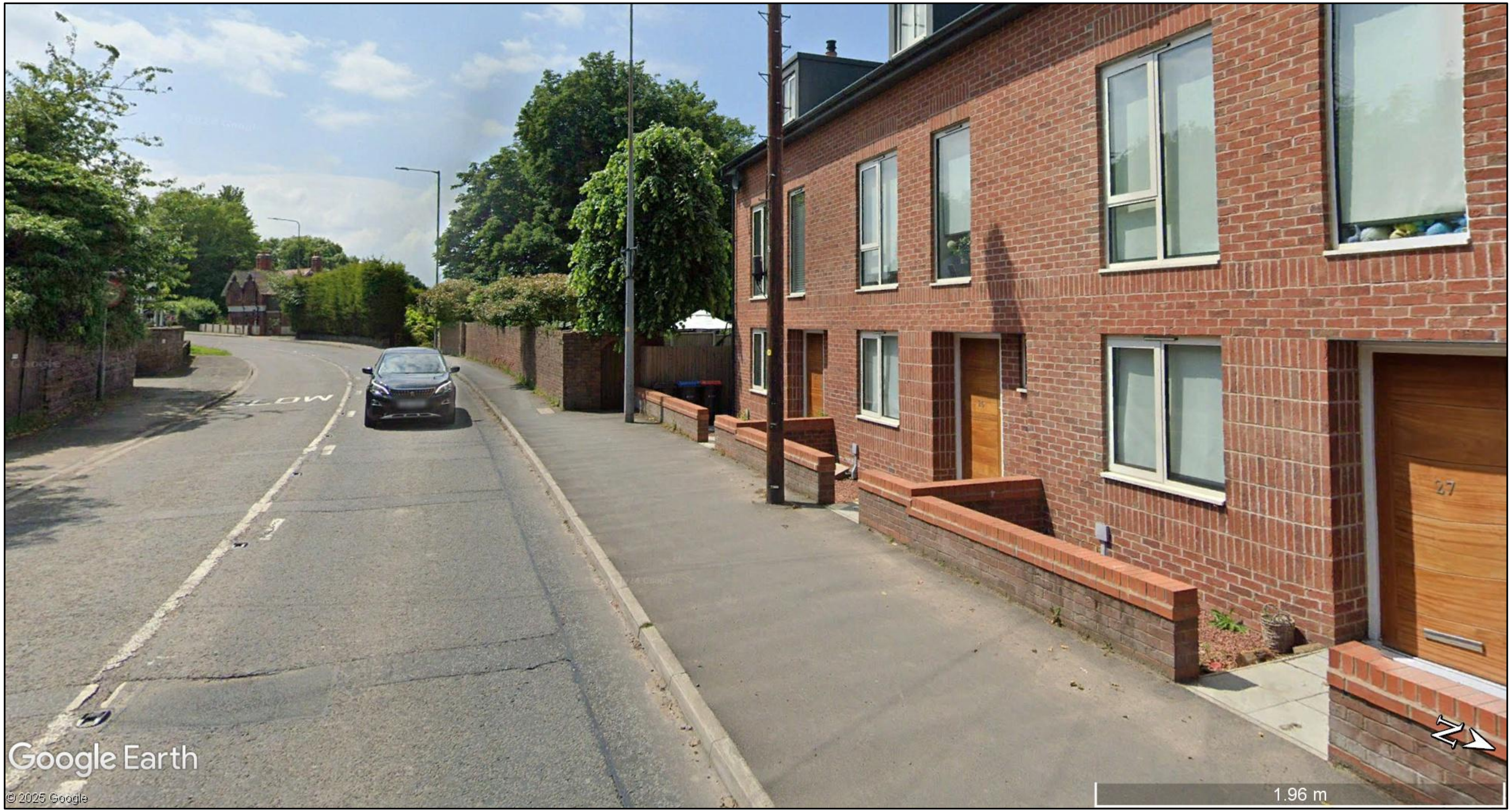


Figure J28 *Representative viewpoint at road receptor 5*

Figure J29 *Representative viewpoint at road receptor 9*

Figure J30 *Reflecting panel areas for road receptors 10 to 25*

Figure J31 *Representative viewpoint at road receptor 10*

Figure J32 *Representative viewpoint at road receptor 15*

Figure J33 *Representative viewpoint at road receptor 20*

Figure J34 *Representative viewpoint at road receptor 25*

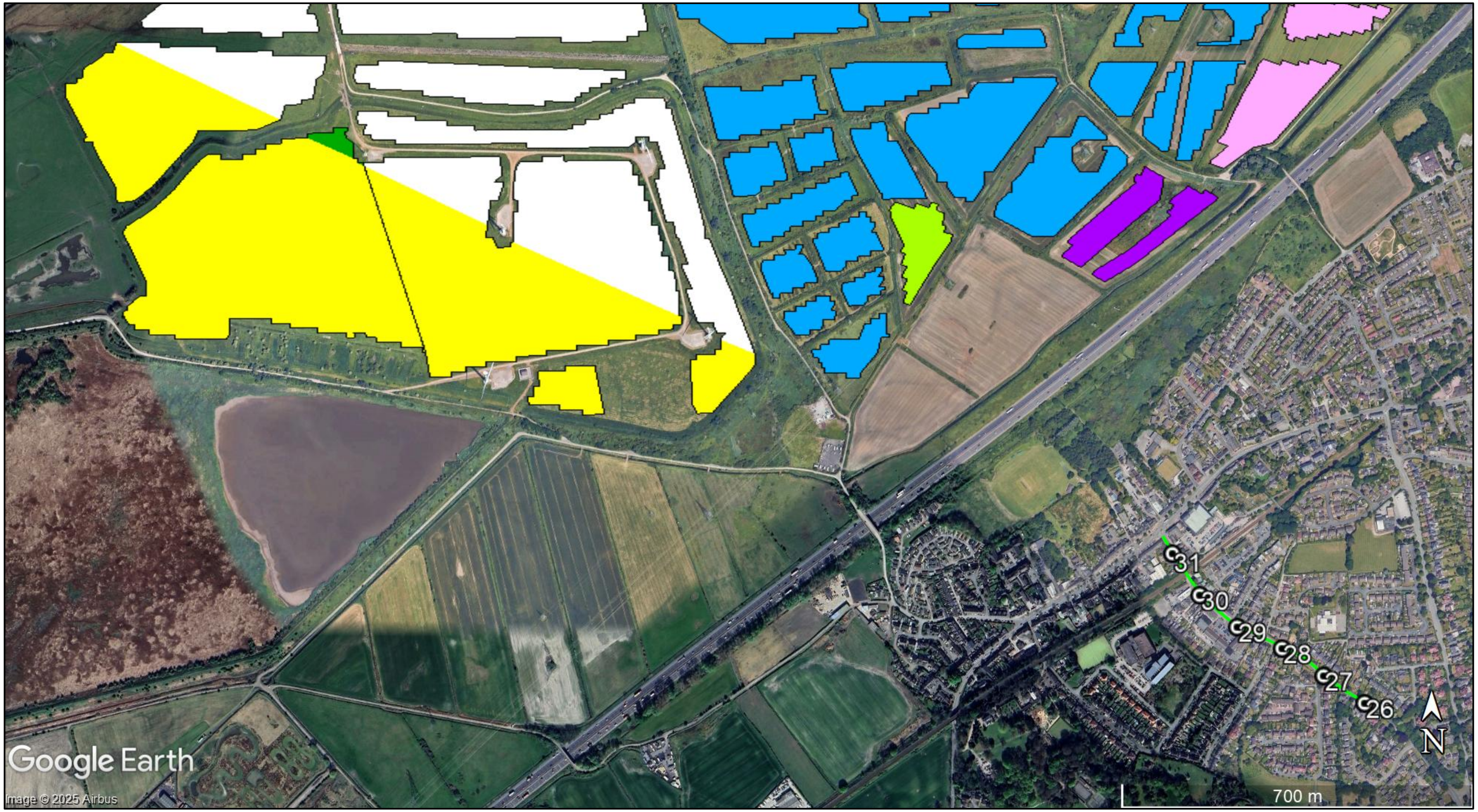


Figure J35 *Reflecting panel areas for road receptors 26 to 31*

Figure J36 *Representative viewpoint at road receptor 31*

Figure J37 *Reflecting panel areas for road receptors 32 to 36*

Figure J38 *Representative viewpoint at road receptor 33*

Figure J39 *Representative viewpoint at road receptor 36*

Figure J40 *Reflecting panel areas for road receptors 46 to 49*

Figure J41 *Representative viewpoint at road receptor 47*

Figure J42 *Representative viewpoint at road receptor 49*

Figure J43 *Reflecting panel areas for road receptors 50 to 53*

Figure J44 *Representative viewpoint at road receptor 50*

Figure J45 *Representative viewpoint at road receptor 52*

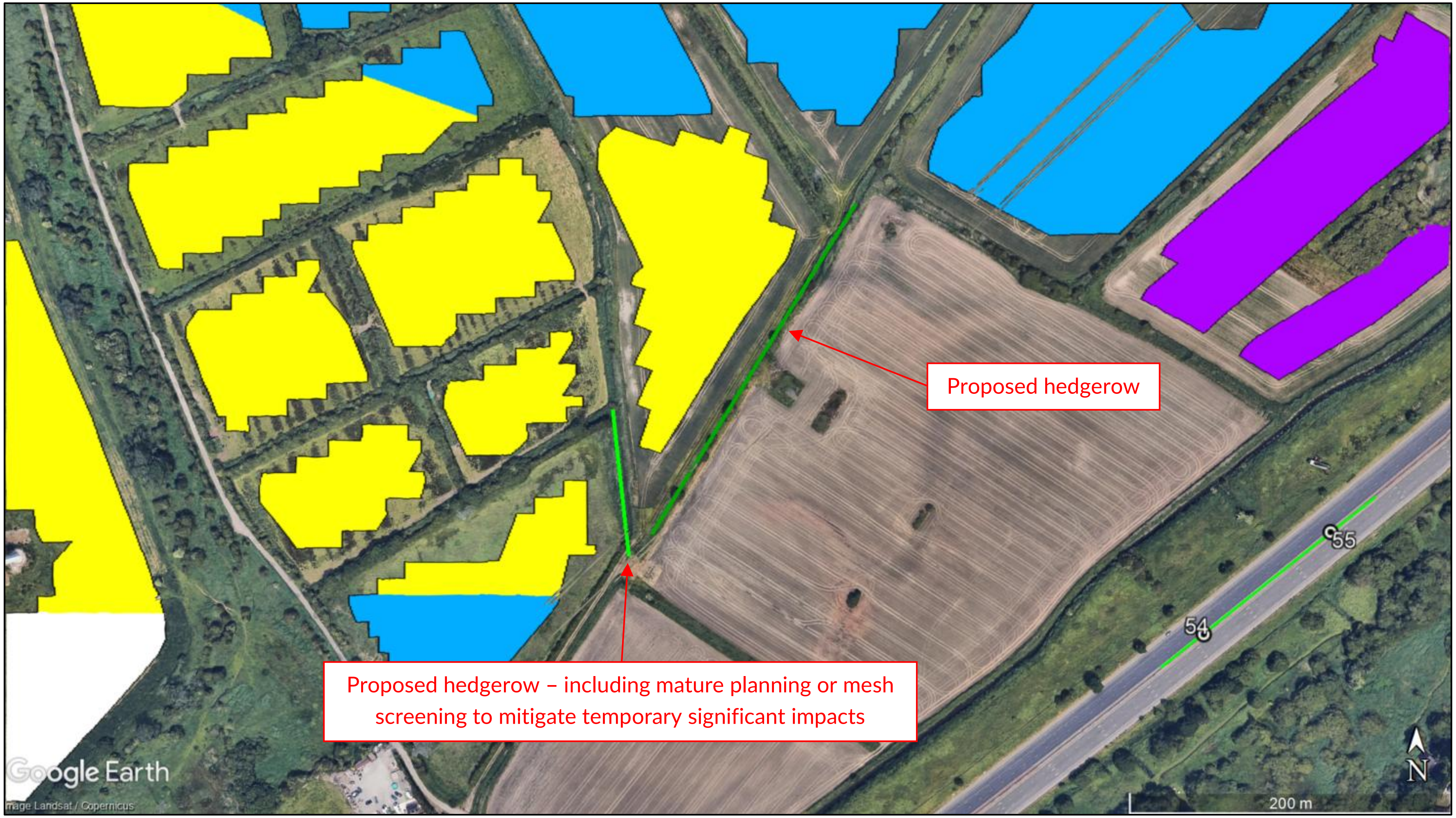


Figure J46 *Reflecting panel areas and relevant proposed hedgerows for road receptors 54 and 55*

Figure I47 *Representative viewpoint at road receptor 54*

Figure J48 *Representative viewpoint at road receptor 55*

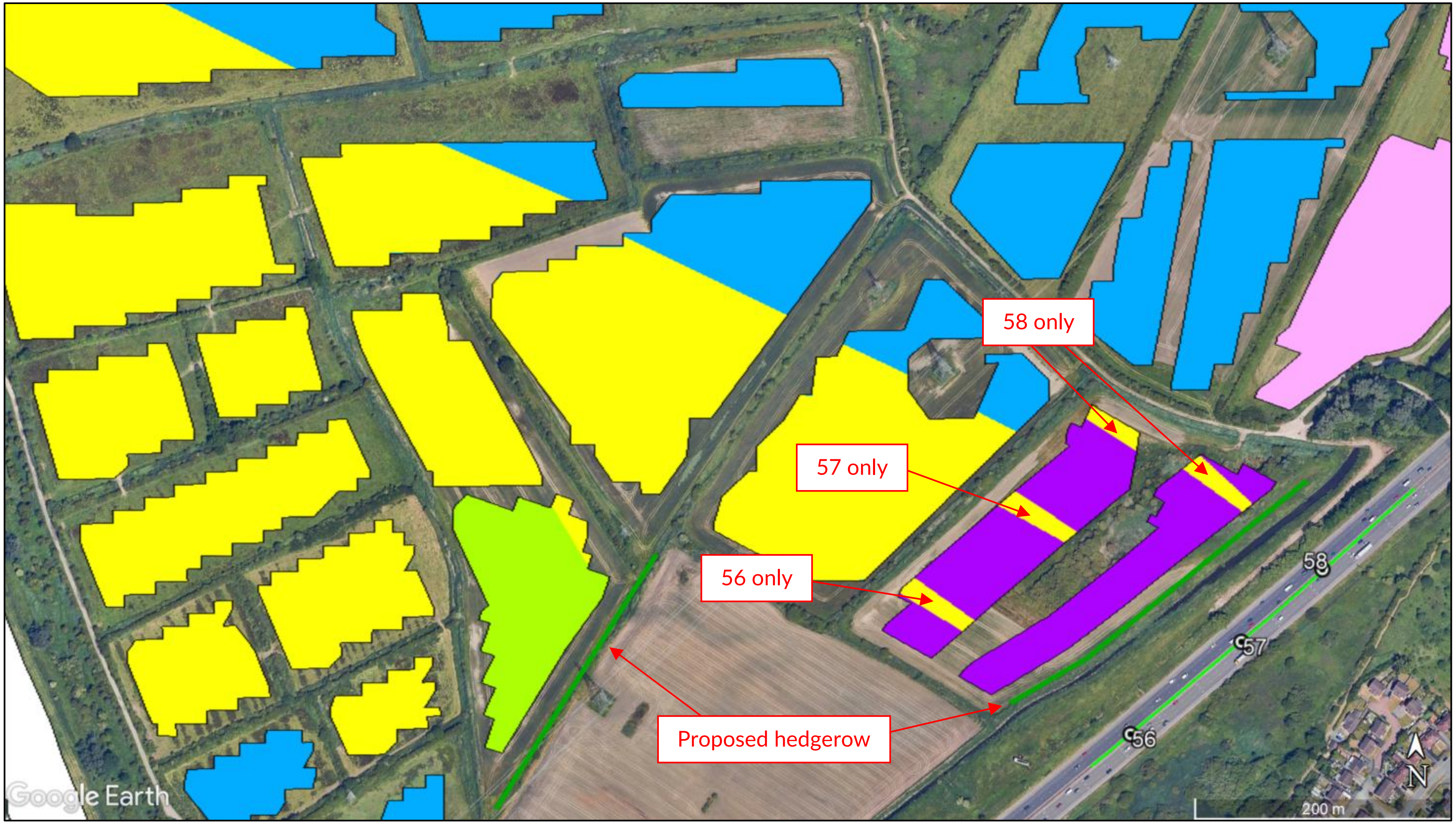


Figure J49 *Reflecting panel areas and relevant proposed hedgerow for road receptors 56 to 58*

Figure J50 *Representative viewpoint at road receptor 56*

Figure J51 *Representative viewpoint at road receptor 57*

Figure J52 *Representative viewpoint at road receptor 58*

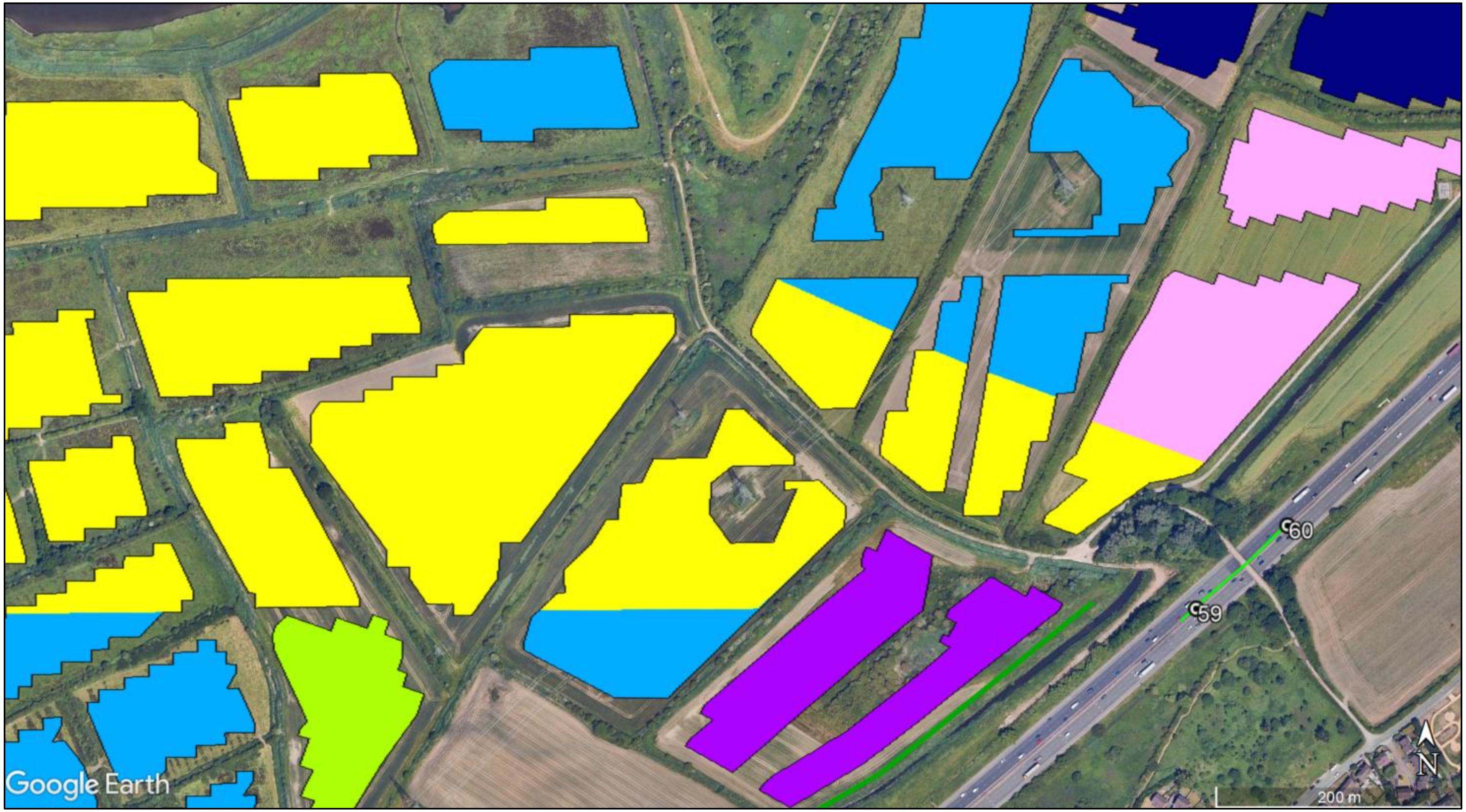


Figure J53 *Reflecting panel areas for road receptors 59 and 60*

Figure J54 *Representative viewpoint at road receptor 60*

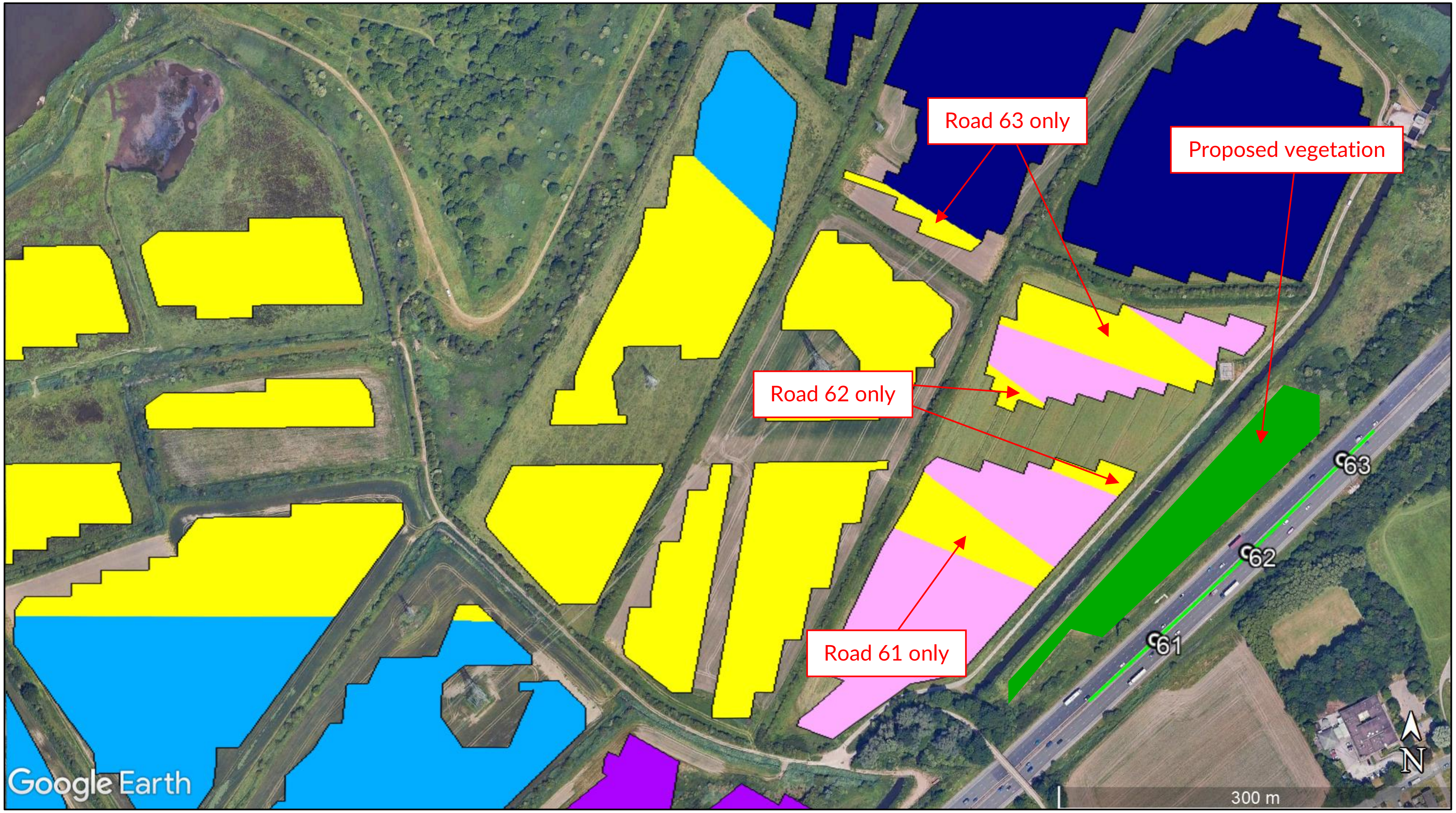


Figure J55 *Reflecting panel areas for road receptors 61 to 63*

Figure J56 *Representative viewpoint at road receptor 61 (prior to implementation of proposed vegetation)*

Figure J57 *Representative viewpoint at road receptor 63 (prior to implementation of proposed vegetation)*

Figure J58 *Reflecting panel areas for road receptor 64*

Figure J59 *Representative viewpoint at road receptor 64*

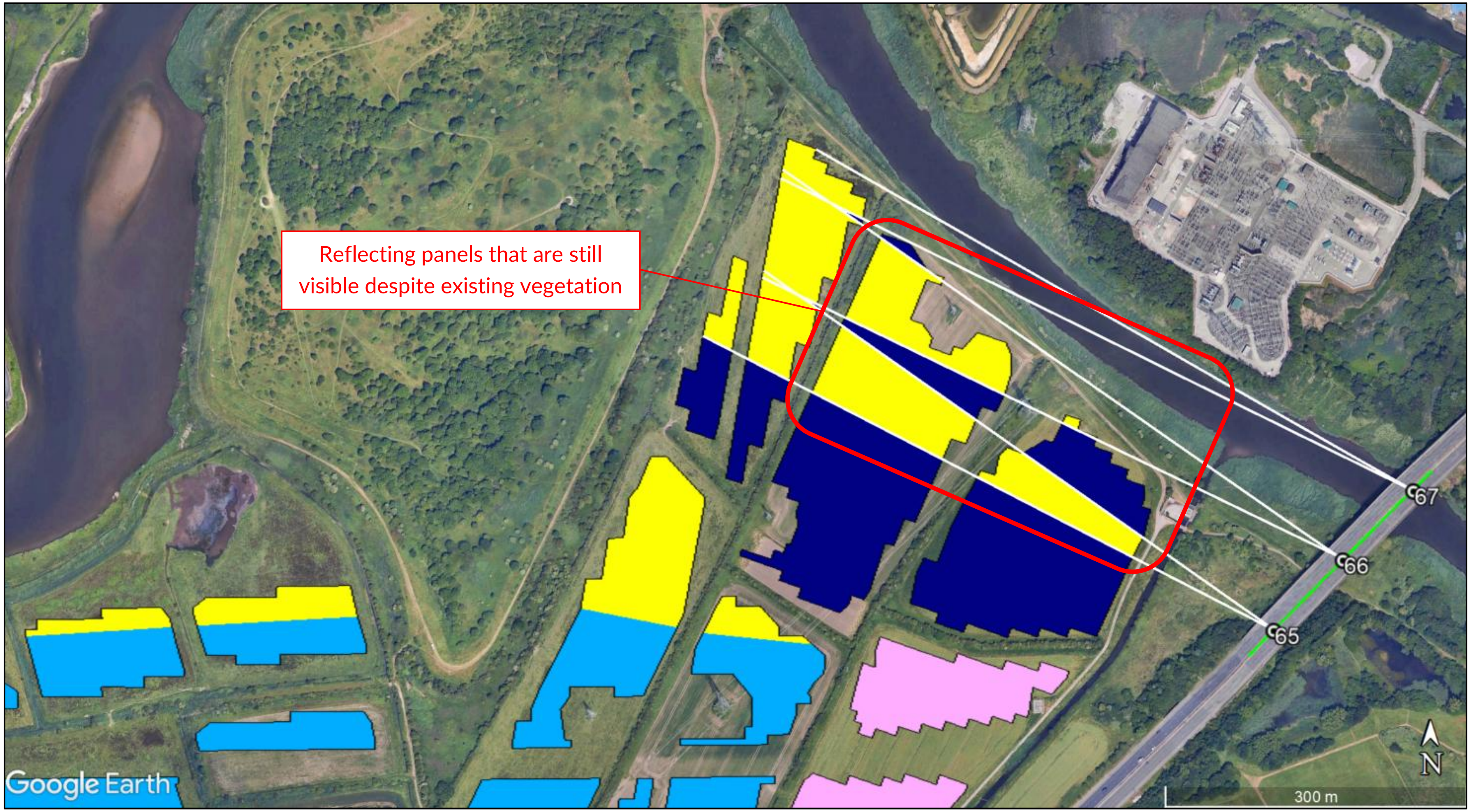


Figure J60 *Reflecting panel areas for road receptors 65 to 67*

Figure J61 *Representative viewpoint at road receptor 65*

Figure J62 *Representative viewpoint at road receptor 67*

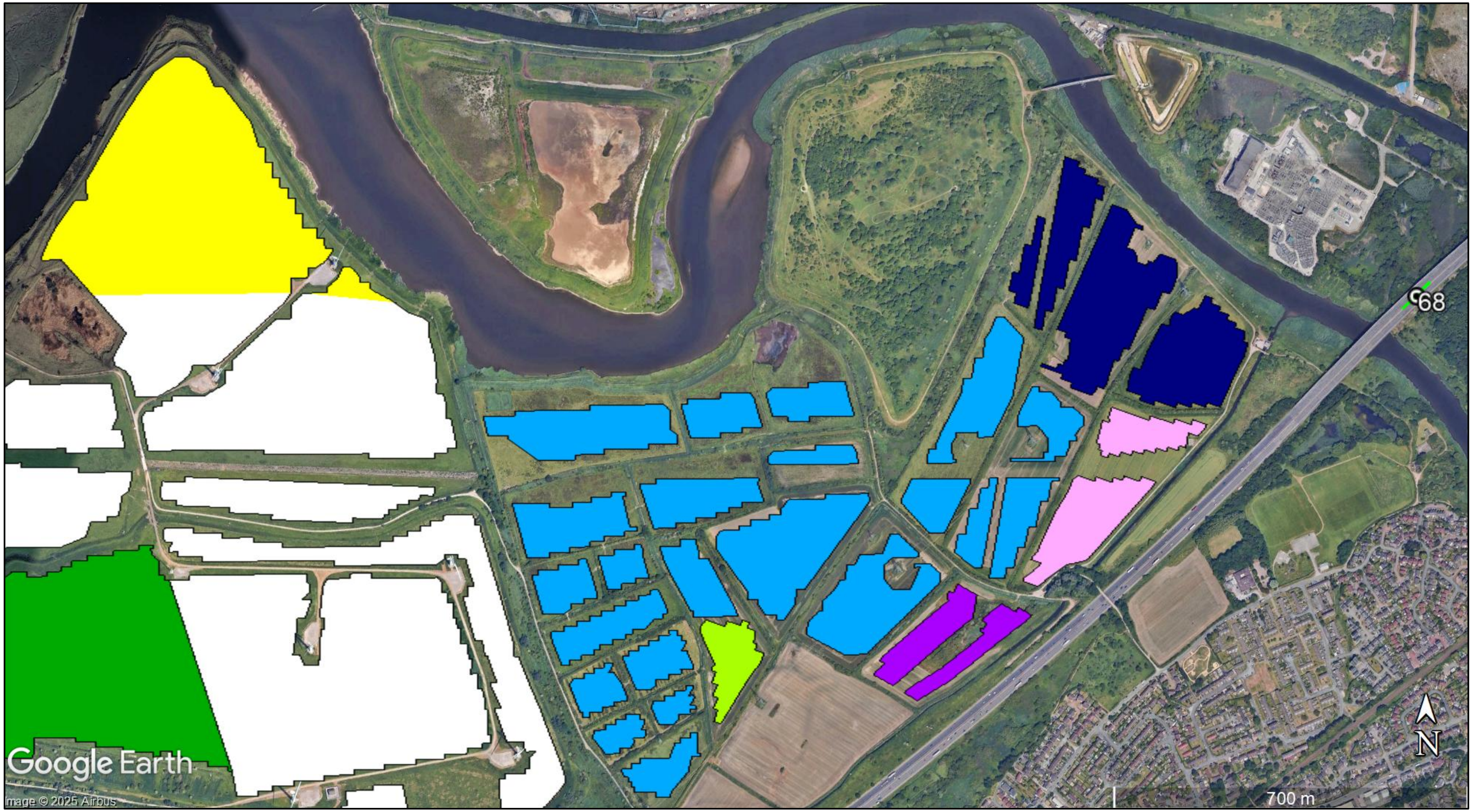


Figure J63 *Reflecting panel areas for road receptor 68*

PAGERPOWER
Urban & Renewables

Figure J64 *Representative viewpoint at road receptor 68*

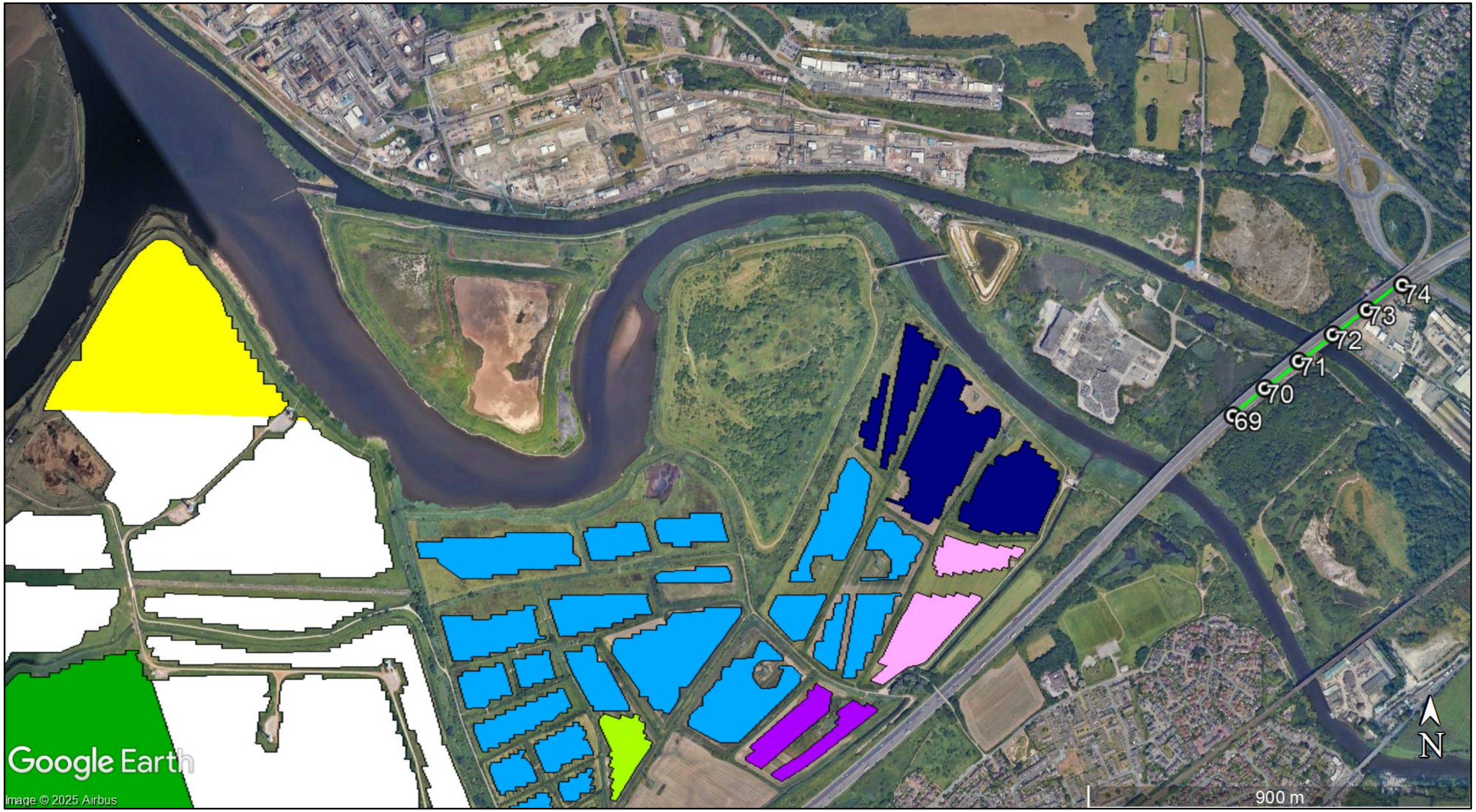


Figure J65 *Reflecting panel areas for road receptors 69 to 74*

Figure J66 *Representative viewpoint at road receptor 69*

Figure J67 *Representative viewpoint at road receptor 72*

Figure J68 *Representative viewpoint at road receptor 74*

Figure J69 *Reflecting panel areas for road receptors 75 and 76*

Figure J70 *Representative viewpoint at road receptor 75*

Dwelling Receptors

The desk-based analysis for the dwelling receptors is shown in Figure J71 to Figure J76 on the following pages. The figures show:

- The receptor (observer) location(s);
- The reflecting panels (coloured in yellow);
- Identified vegetation screening, where appropriate.

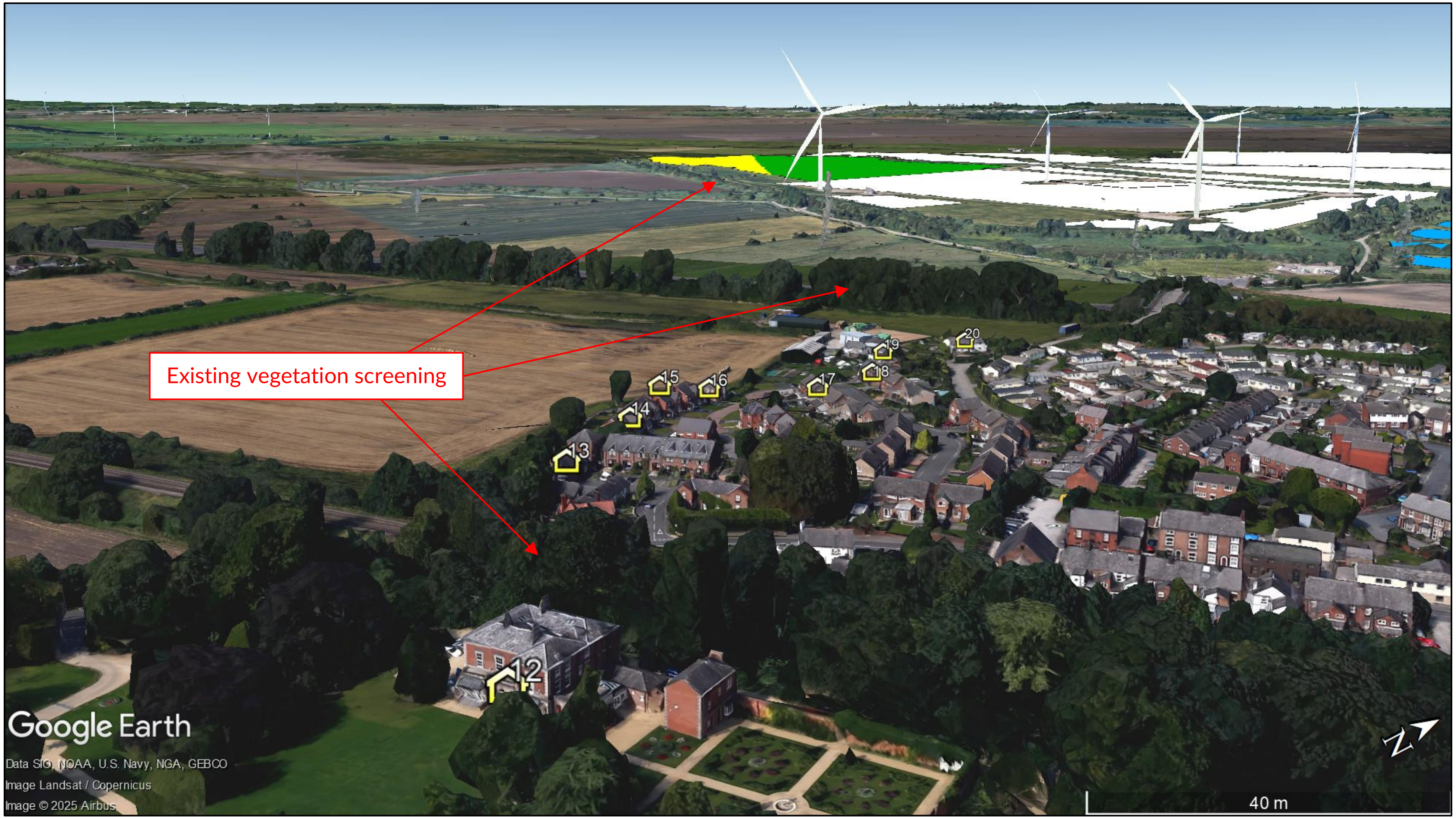


Figure J71 *Reflecting panel area and screening for dwelling receptors 12 to 20*

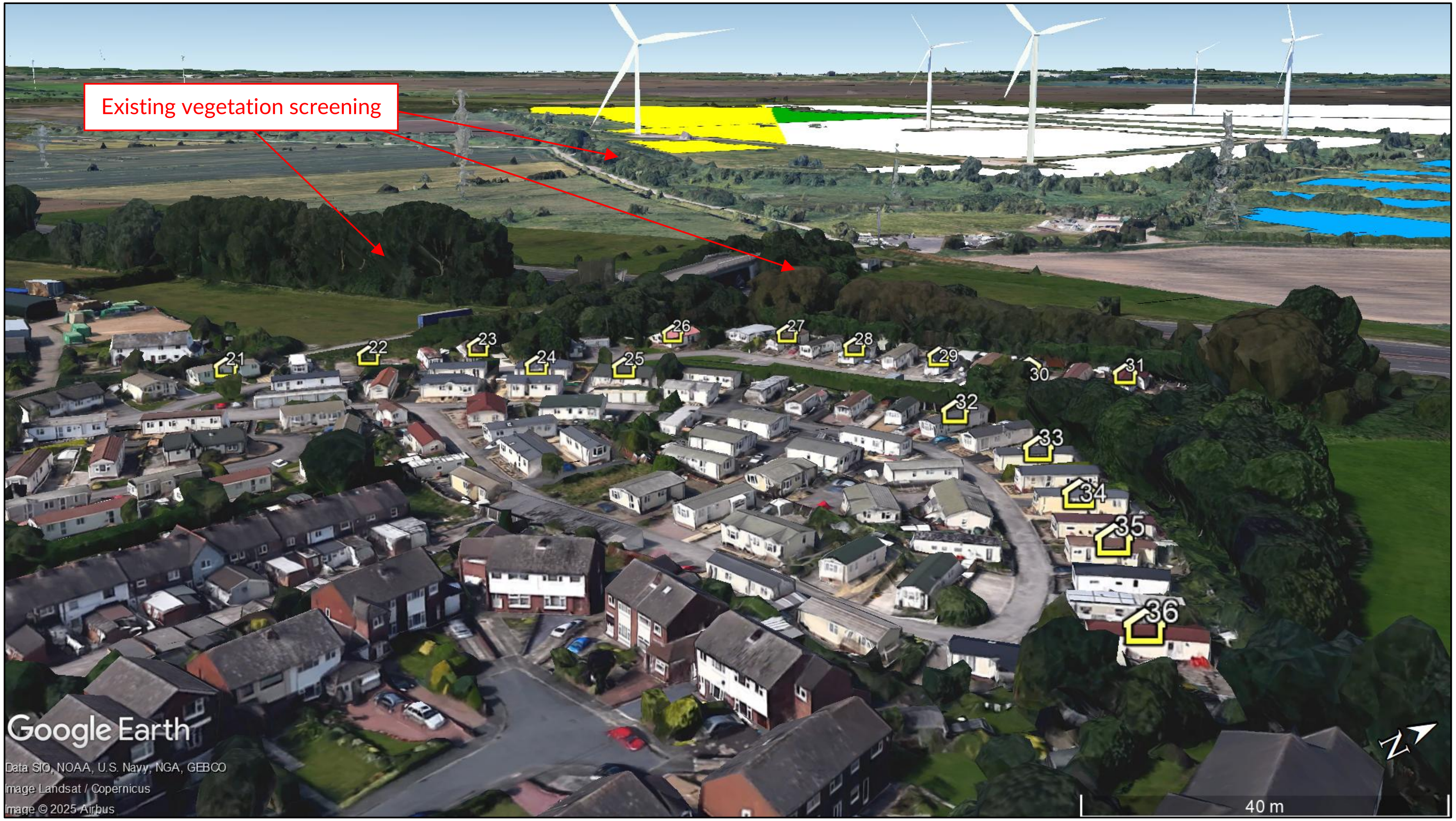


Figure J72 *Reflecting panel areas and screening for dwelling receptors 21 to 36*

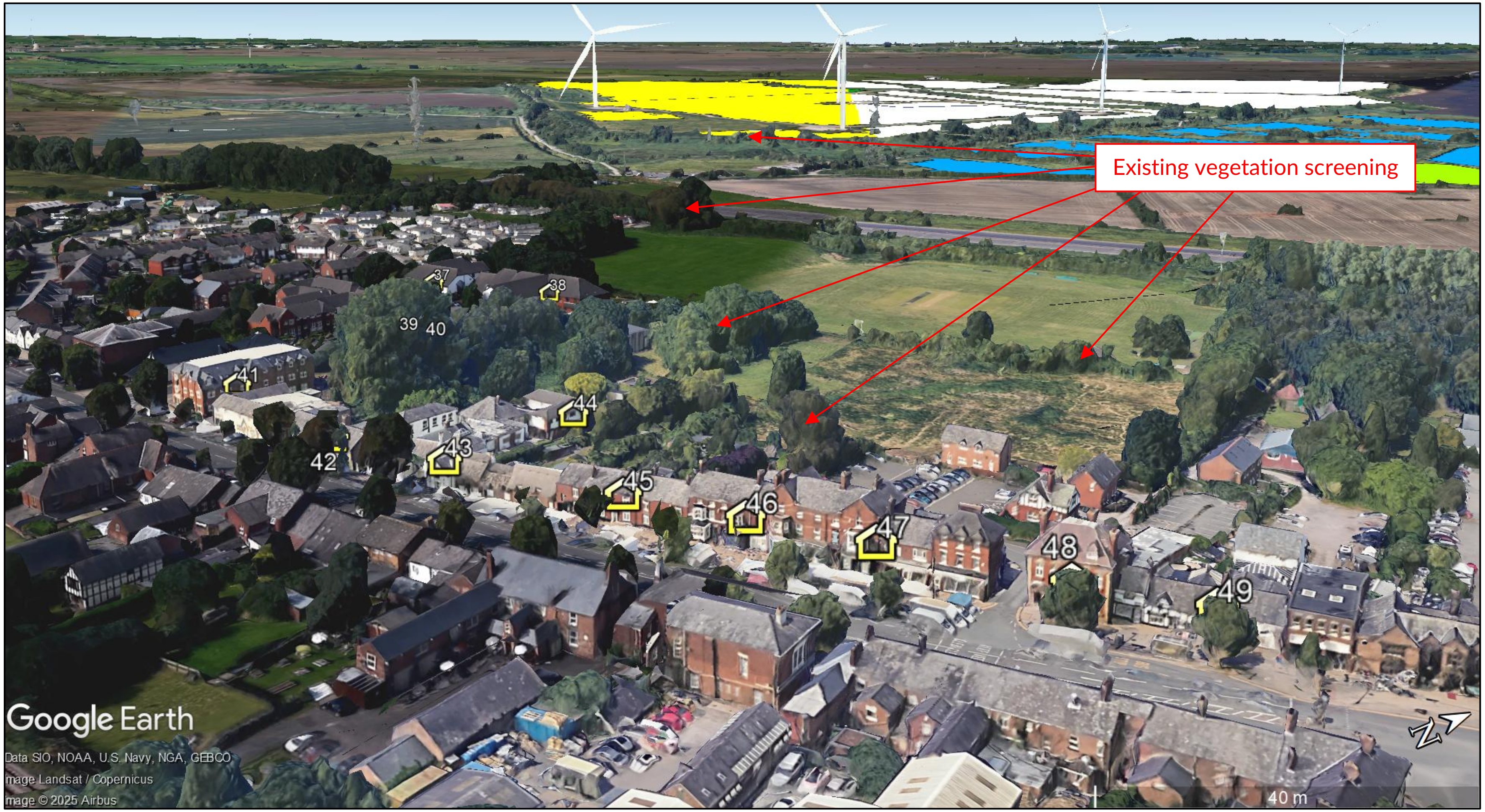


Figure J73 *Reflecting panel areas and partial terrain screening for dwelling receptors 37 to 49*

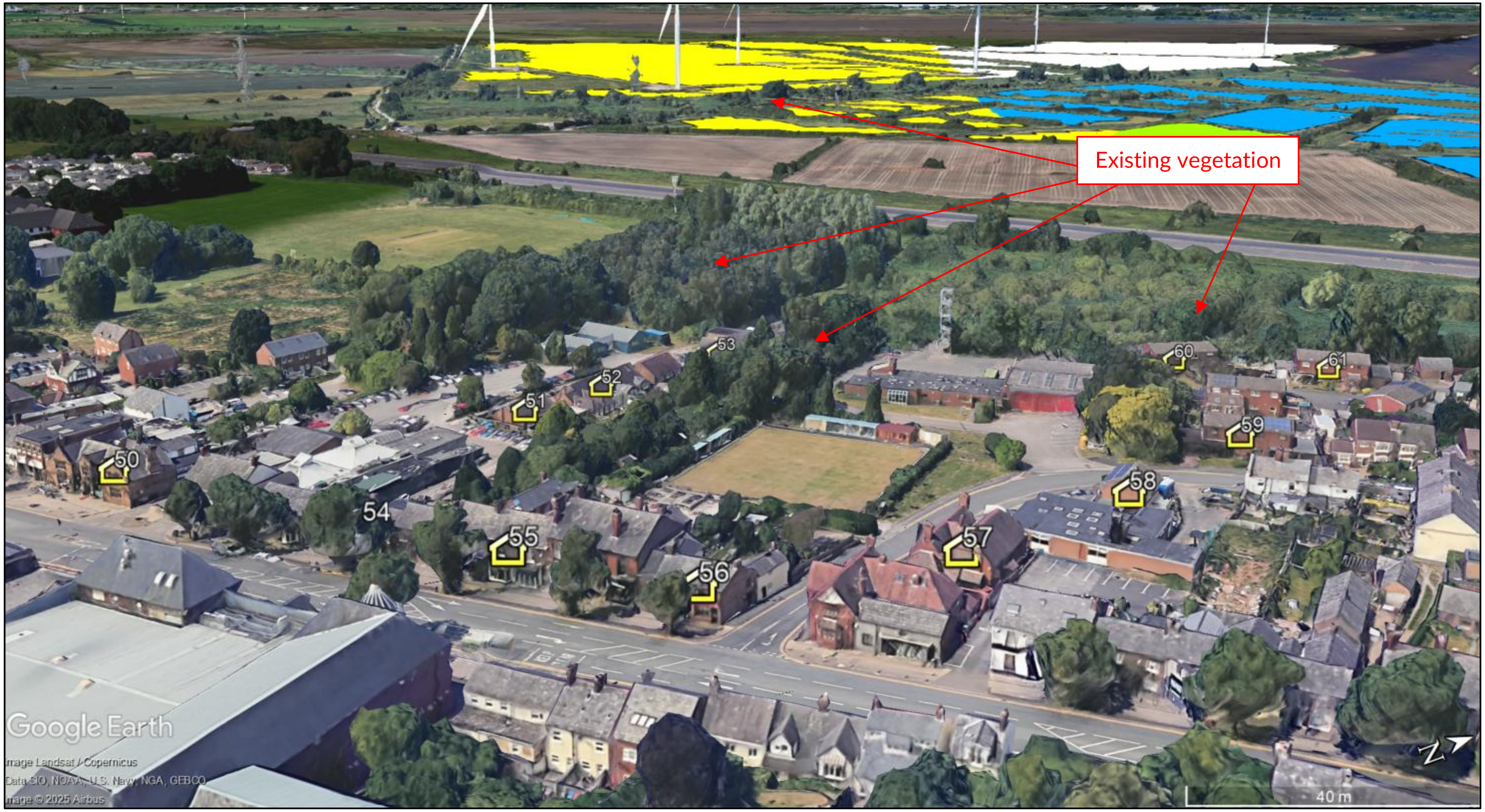


Figure J74 *Reflecting panel area and screening for dwelling receptors 50 to 61*

Figure J75 *Reflecting panel area and partial screening for dwelling receptor 62 to 64*

Figure J76 *Reflecting panel area and partial screening for dwelling receptors 65 to 71*

Figure J77 *Reflecting panel area and partial screening for dwelling receptors 72 to 75*

Figure J78 *Reflecting panels and partial screening for dwelling receptors 76 to 78*

Figure J79 *Reflecting panels and partial screening for dwelling receptors 79 to 83*

Figure J80 *Reflecting panels and partial screening for dwelling receptors 84 to 90*

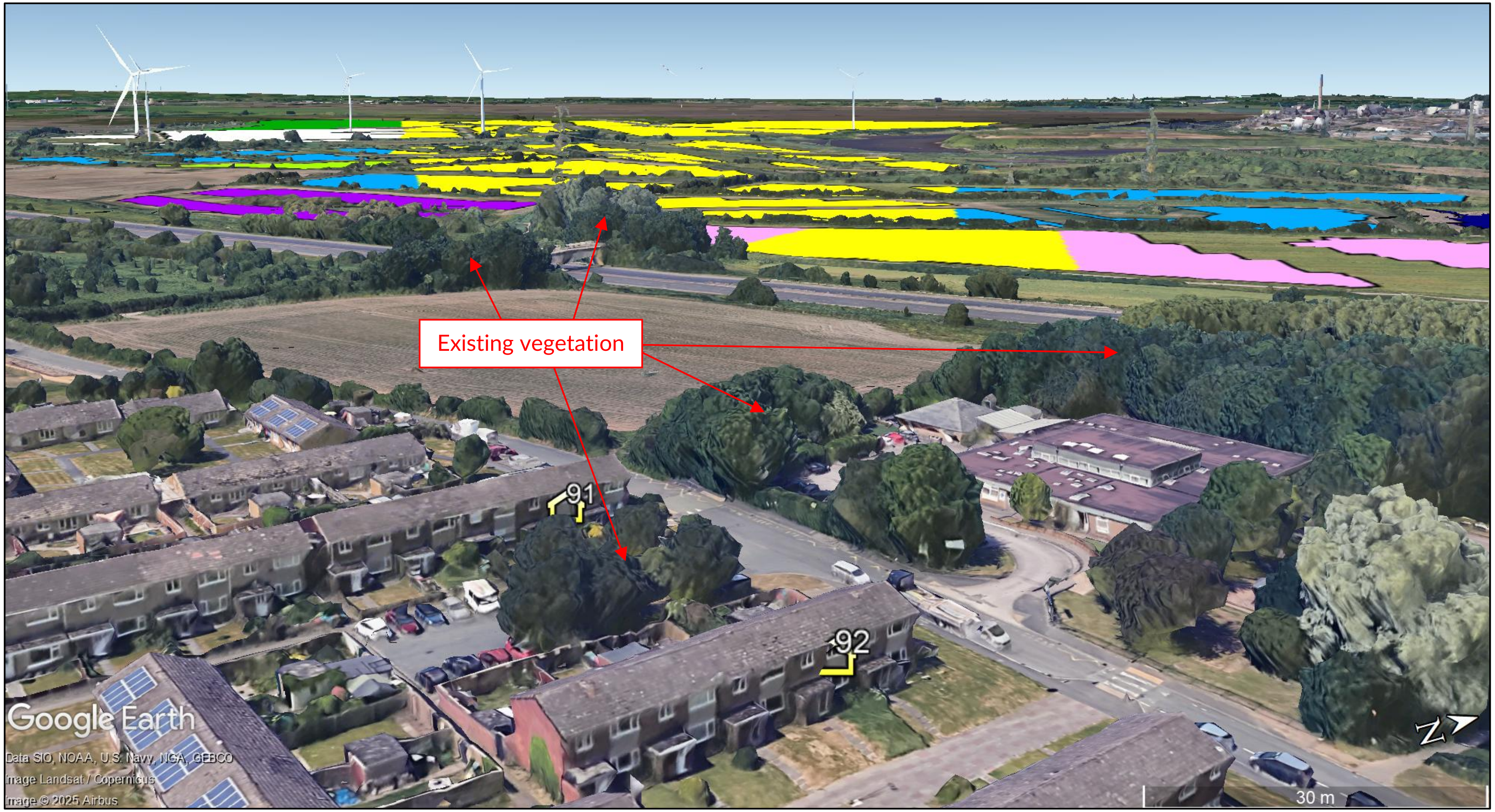


Figure J81 *Reflecting panels and partial screening for dwelling receptors 91 and 92*

Figure J82 *Reflecting panels and screening for dwelling receptors 93 to 100*

Figure J83 *Reflecting panels and screening for dwelling receptors 101 to 110*

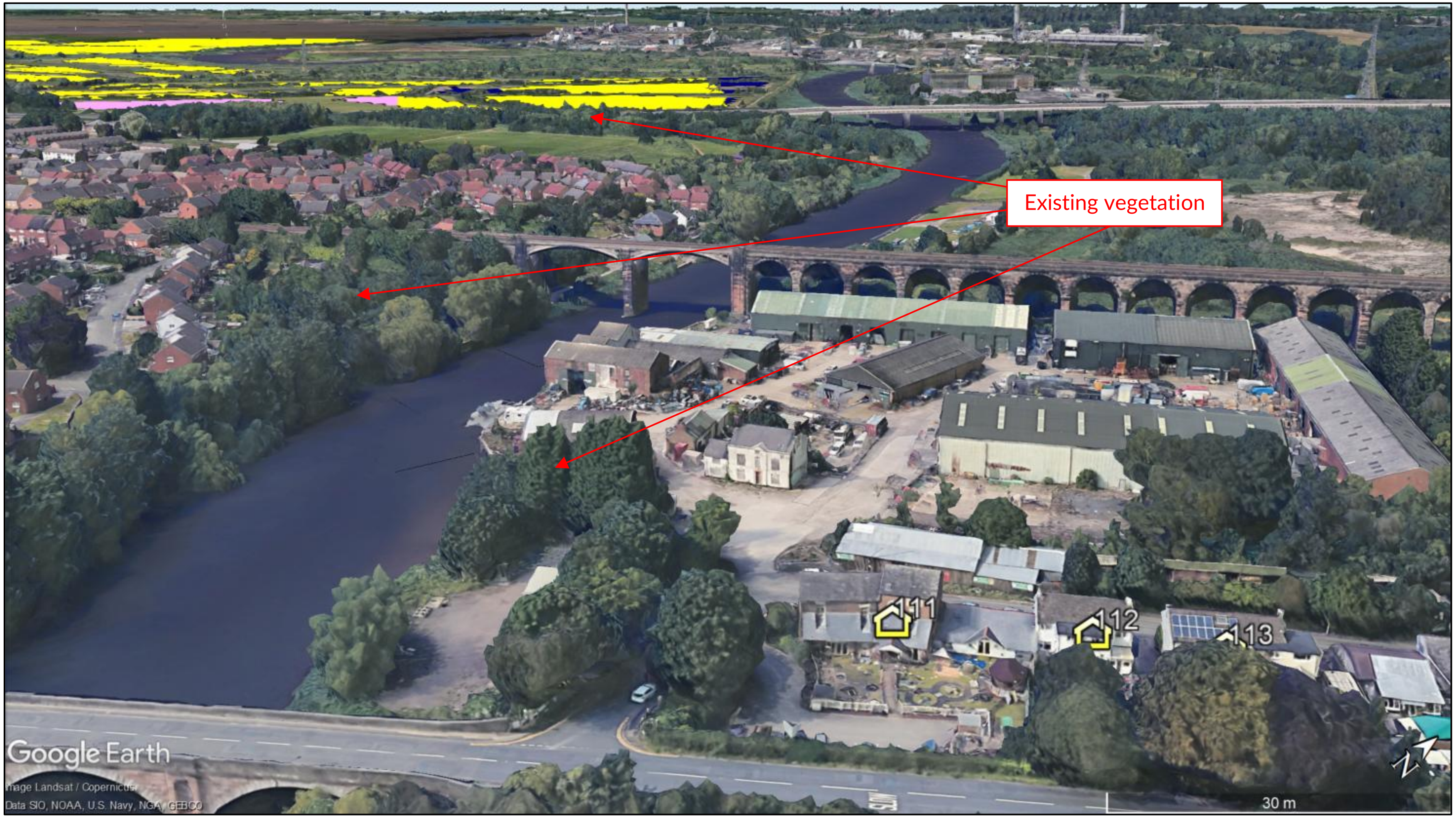


Figure J84 *Reflecting panels and screening for dwelling receptors 111 to 113*

PAGERPOWER
Urban & Renewables

Pager Power Limited
Stour Valley Business Centre
Sudbury
Suffolk
CO10 7GB

Tel: +44 1787 319001 **Email:** info@pagerpower.com **Web:** www.pagerpower.com