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Urban & Renewables

Solar Photovoltaic Glint and Glare Study

KeaX Energy

Brookside Solar Farm

August 2022

PLANNING SOLUTIONS FOR:

- Solar
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ADMINISTRATION PAGE

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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from a solar photovoltaic (PV) development located approximately 10km north of Leeston, Canterbury, New Zealand. The assessment pertains to the possible impact upon surrounding road safety, residential amenity, and a high-level overview of aviation concerns for Christchurch Airport.

Pager Power

Pager Power has undertaken over 900 glint and glare assessments in the UK, Europe and internationally. The company's own glint and glare guidance is based on industry experience and extensive consultation with industry stakeholders including airports and aviation regulators.

Conclusions

No significant impacts are predicted upon the surrounding road users, dwellings, or aviation activity associated with Christchurch Airport. No further mitigation is required.

The assessment results are presented on the following page.

Guidance and Studies

There is no known existing planning guidance within New Zealand for the assessment of solar reflections from solar panels towards roads, dwellings, or aviation activity. Guidelines do however exist (in the USA produced by the Federal Aviation Administration) with respect to solar developments and aviation activity. Considering the lack of official guidance, Pager Power has produced its own glint and glare guidance document for solar photovoltaic developments, which was published in early 2017, with the third edition originally published in 2020[1]. This methodology defines a comprehensive process for determining the impact upon 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 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].

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[1] Pager Power Glint and Glare Guidance, Third Edition (3.1), April 2021.

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

Assessment Results – Roads

All roads within the 1km assessment area for consideration of glint and glare effects are local roads. 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.

Overall, no significant impacts upon road users are predicted and no mitigation is required.

Assessment Results – Dwellings

The results of the modelling indicate that solar reflections are geometrically possible towards 39 out of the 40 assessed dwelling receptors[3].

The review of the available imagery and site photography has shown that for all the assessed dwellings where a solar reflection is predicted, screening in the form of existing and/or proposed vegetation will significantly obstruct the views of the reflecting panels. This means that observers located at all the potentially impacted dwellings will not experience solar reflections in practice. No impact is predicted, and no mitigation is required.

Assessment Results – High-Level Aviation

For the approach to runway thresholds 02, 02G, 11, and 29, the orientation is such that any predicted solar reflections will be outside of the pilot's main field of view (50 degrees either side of the approach bearing) and would therefore not be considered significant in accordance with the associated guidance (Appendix D).

For the approach to runway thresholds 20 and 20G, the proposed development will be within a pilot's main field of view. It can be safely presumed that any predicted solar reflections would have a 'low potential for temporary after image' in the worst case, which is acceptable under the associated guidance (Appendix D). This is based on the size of the proposed development, its distance from the airfield, and previous project experience.

For the ATC Tower, it is expected that any solar reflections would not visible due to vegetation screening.

Overall, no significant impact on aviation activity associated with Christchurch Airport is predicted and no further detailed assessment is recommended.

[3] Dwelling receptors 12 to 14, 16 to 19, 48, and 49 have not been taken forward for detailed geometric modelling because they are involved properties.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 53 countries within Europe, Africa, America, Asia and Australasia.

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 possible effects of glint and glare from a solar photovoltaic (PV) development located approximately 10km north of Leeston, Canterbury, New Zealand. The assessment pertains to the possible impact upon surrounding road safety, residential amenity, and a high-level overview of aviation concerns for Christchurch Airport.

This report contains the following:

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

1.2 Pager Power's Experience

Pager Power has undertaken over 900 glint and glare assessments in the UK, Europe and internationally. The company's own glint and glare guidance is based on industry experience and extensive consultation with industry stakeholders including airports and aviation regulators.

1.3 Glint and Glare Definition

The definition of glint and glare is as follows[4]:

- 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.

[4] These definitions are aligned with those of the Federal Aviation Administration (FAA) in the United States of America.

2 PROPOSED DEVELOPMENT LOCATION AND DETAILS

2.1 Proposed Development Site Layout

Figures 1 to 3[5] below and on the following page show the proposed development site layout. The blue rectangular areas denote the solar panel locations.

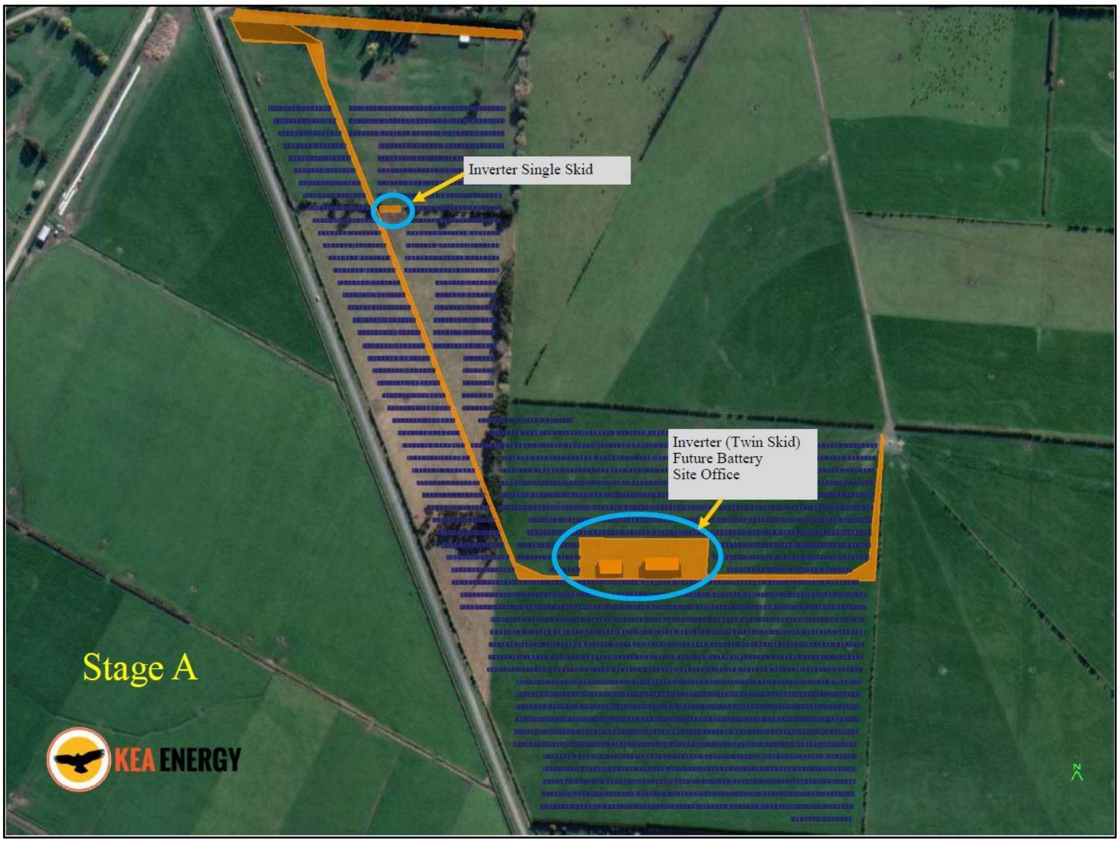

Figure 1 *Proposed development site layout – Stage A*

[5] Source: Appendix 4_site_layout_detail.pdf (cropped)

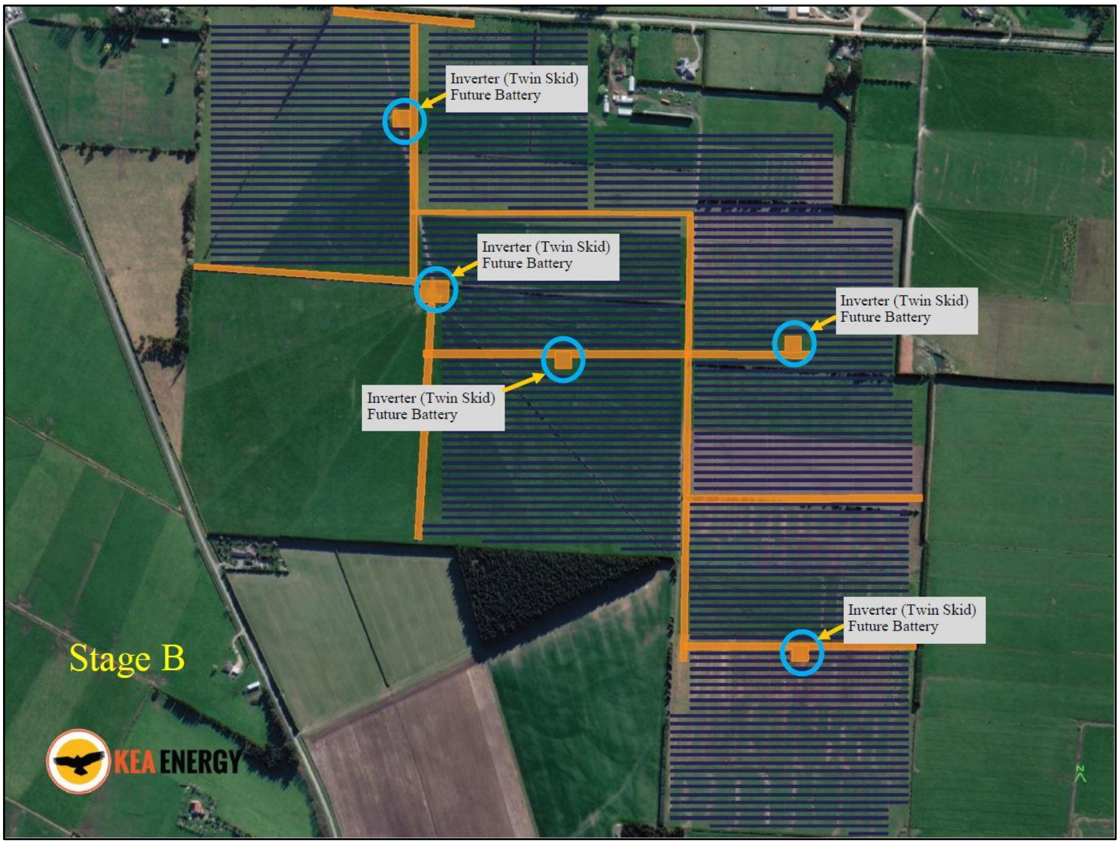

Figure 2 *Proposed development site layout – Stage B*

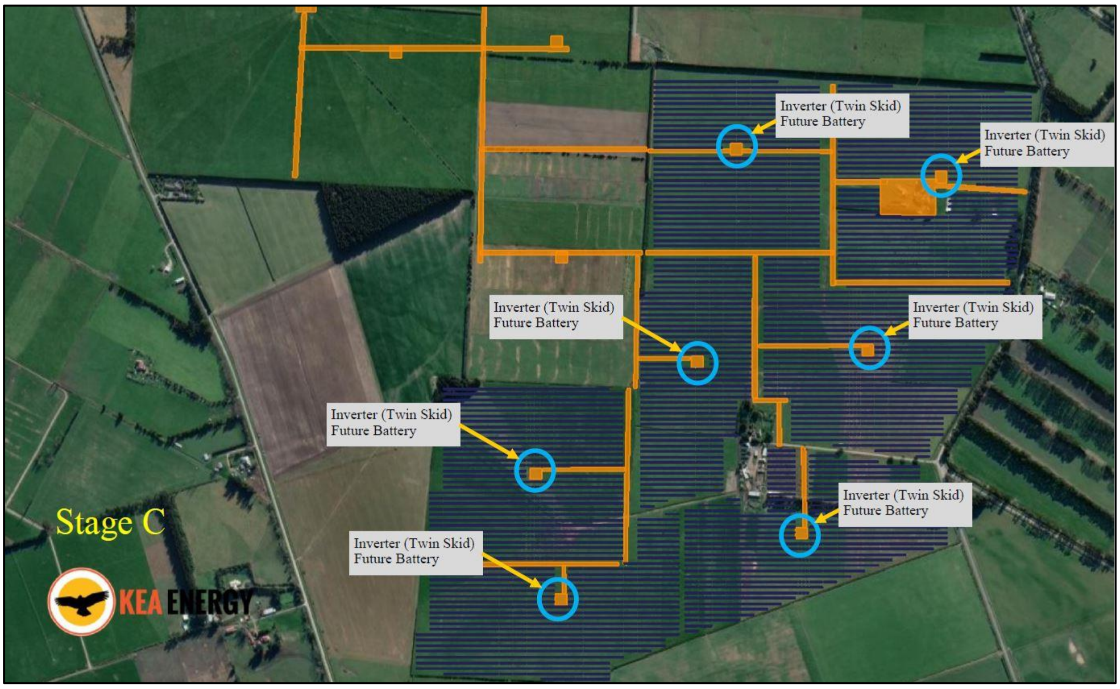

Figure 3 *Proposed development site layout – Stage C*

2.2 Solar Panel Information

The solar panel characteristics are presented in Table 1 below.

Panel Information	
Azimuth angle	0° (north-facing)
Elevation angle	30°
Assessed centre height	1.86m agl (above ground level)[6]

Table 1 *Panel information*

2.3 Landscape Strategy Plan

The landscape strategy plan (with legend highlighted within the figure) for the site is detailed in Figure 4[7] on the following page.

The landscape strategy indicates the location of proposed vegetation screening. The developer has confirmed that the proposed planting surrounding the site will be maintained at 4m[8]. Figure 5 on page 15 indicates the location of the landscape plan on aerial imagery, in particular:

- Proposed planting, new or gap filling, as shown by the green outlined areas.
- Existing planting to be retained, as indicated.

[6] Average heights are used for the glint and glare assessment. This average is taken from a minimum 0.7m up to a maximum 3.02m.
[7] Source: BM210727_009_A3L_SitePlanV2.pdf (cropped and edited).
[8] Source: Information received by the developer via email 27/07/2022.

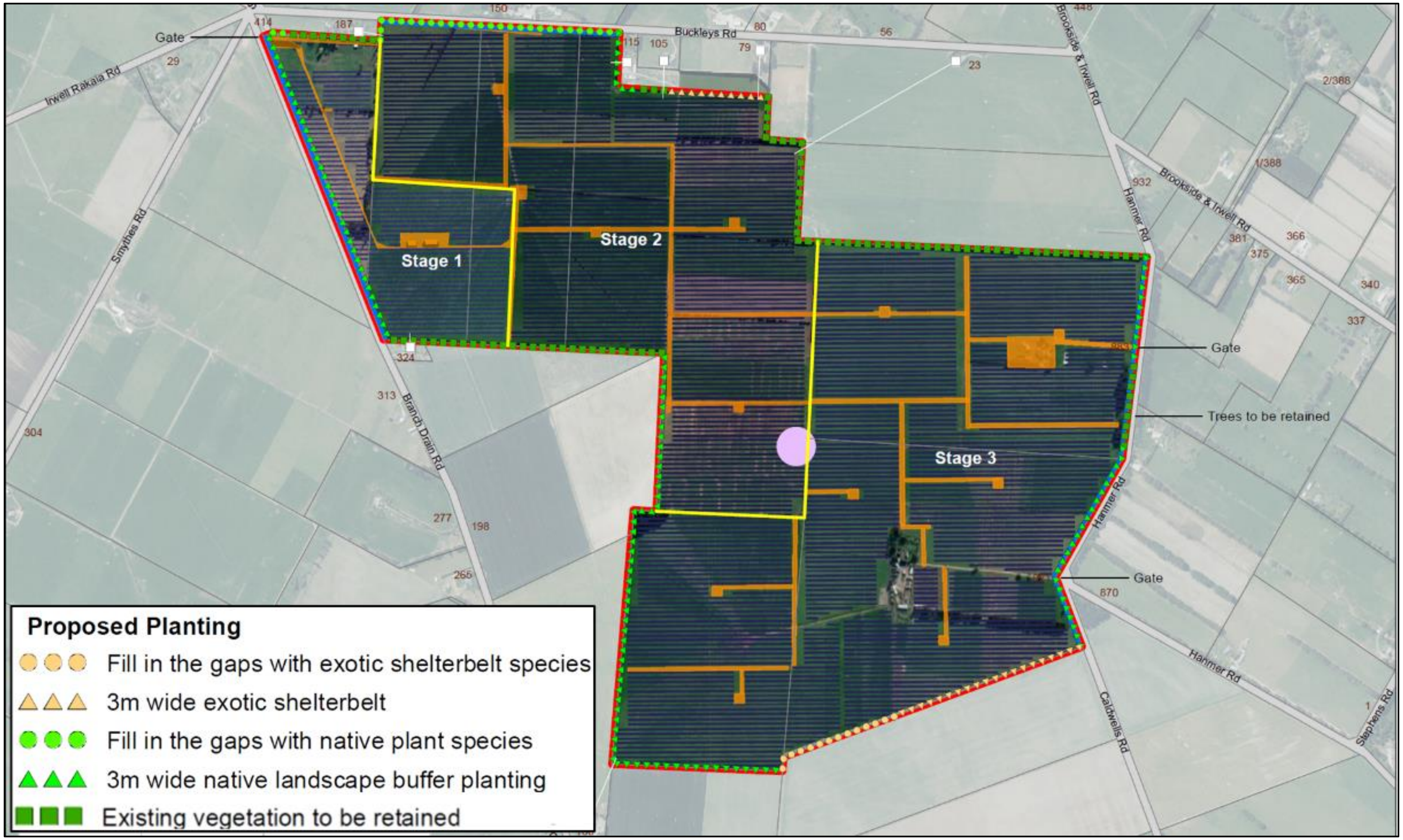

Figure 4 *Landscape Strategy Plan*

Figure 5 *Landscape Strategy Plan – aerial image*

3 HIGH-LEVEL AVIATION CONSIDERATIONS

3.1 Overview

There is no formal buffer distance within which aviation effects must be modelled. However, in practice, concerns are most often raised for developments within 10km of a licensed aerodrome. Requests for modelling at ranges of 10-20km are far less common. Assessment of aviation effects for developments over 20km from a licensed aerodrome is a very unusual requirement.

A high-level aviation assessment has been undertaken considering the nearest aerodrome to the proposed development.

3.2 Christchurch Airport Details

Christchurch Airport is a licensed aerodrome located approximately 30.8km northeast of the proposed development and has three operational runways. It is understood that the airfield has an ATC Tower at 45m above ground level. The runway details are presented below:

- 02/20 – 3288 x 45 metres (asphalt).
- 11/29 – 1741 x 45 metres (asphalt).
- 02G/20G – 515 x 70 metres (grass).

3.3 High-Level Assessment

The location of Christchurch Airport relative to the proposed development is shown in Figure 6 on the following page.

For the approach to runway thresholds 02, 02G, 11, and 29, the orientation is such that any predicted solar reflections will be outside of the pilot’s main field of view (50 degrees either side of the approach bearing) and would therefore not be considered significant in accordance with the associated guidance (Appendix D).

For the approach to runway thresholds 20 and 20G, the proposed development will be within a pilot’s main field of view. It can be safely presumed that any predicted solar reflections would have a ‘low potential for temporary after image’ in the worst case, which is acceptable under the associated guidance (Appendix D). This is based on the size of the proposed development, its distance from the airfield, and previous project experience.

For the ATC Tower, it is expected that any solar reflections would not visible due to vegetation screening.

Overall, no significant impact on aviation activity associated with Christchurch Airport is predicted and no further detailed assessment is recommended.

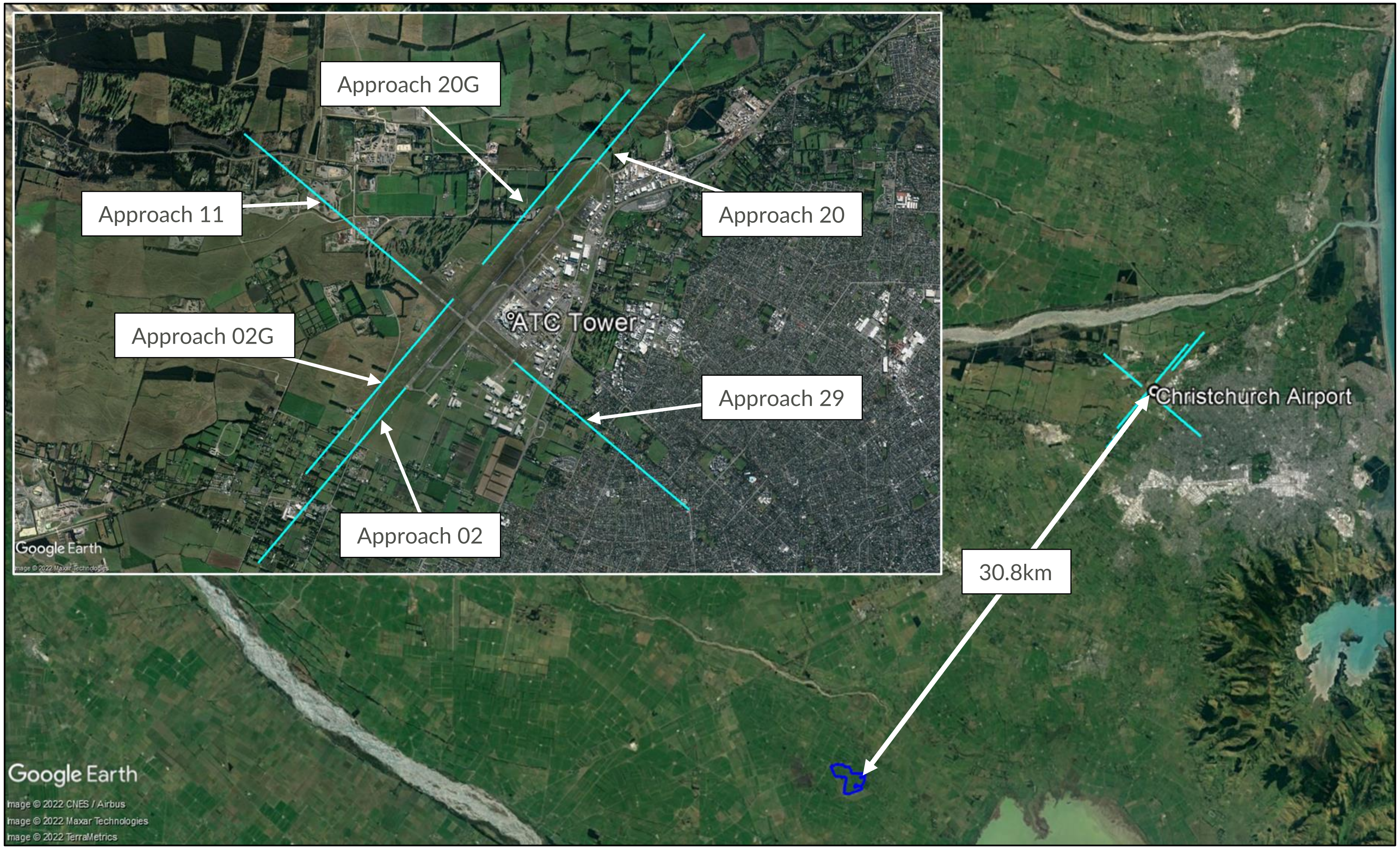

Figure 6 *Christchurch Airport relative to the proposed development*

4 GLINT AND GLARE ASSESSMENT METHODOLOGY

4.1 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.

4.2 Background

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

4.3 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 assessments 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.
- Determine whether a significant detrimental impact is expected in line with the process presented in Appendix D.

4.4 Assessment Methodology and Limitations

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

5 GROUND-BASED RECEPTORS

5.1 Ground-Based Receptors – Overview

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. Reflections towards ground-based receptors located further south than any proposed panel are highly unlikely[9]. Therefore, receptors south of the most southern panel areas have not been modelled. The assessment area (orange outlined area in the proceeding figure) has been designed accordingly as 1km from the proposed development (blue outlined areas), disregarding the area to the south of the southern-most solar panels.

Potential receptors within the associated assessment areas are identified based on mapping and aerial photography of the region. The initial judgement is made based on high-level consideration of aerial photography and mapping i.e. receptors are excluded if it is clear from the outset that no visibility would be possible. A more detailed assessment is made if the modelling reveals a reflection would be geometrically possible.

Terrain elevation heights have been interpolated based on SRTM terrain data. Receptor details can be found in Appendix G.

5.2 Road Receptors

Road types can generally be categorised as[10]:

- Major National – Typically a road with a minimum of two carriageways with a maximum speed limit of up to 70mph/110kph. These roads typically have fast moving vehicles with busy traffic.
- National – Typically a road with a one or more carriageways with a maximum speed limit of up to 60mph/100kph or 70mph/110kph. These roads typically have fast moving vehicles with moderate to busy traffic density.

[9] For fixed, north-facing panels at this latitude.

[10] The roads classifications are applicable internationally. Whilst there may be some variation between road classifications in different countries, the general premise under which glint and glare effects are assessed remains the same i.e. on faster, busier roads, effects are consider more significant compared to quieter, slower roads.

- Regional – Typically a single carriageway with a maximum speed limit of up to 60mph/100kph. 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 surrounding roads have been reviewed based on the available imagery as shown in Figure 7 on the following page. Considering the results of this review, no road receptors have been taken forward for geometric and detailed modelling because, all roads within the 1km assessment area are local roads and therefore would be considered low impact in the worst case.

Overall, no significant impacts upon road users are predicted and no mitigation is required.

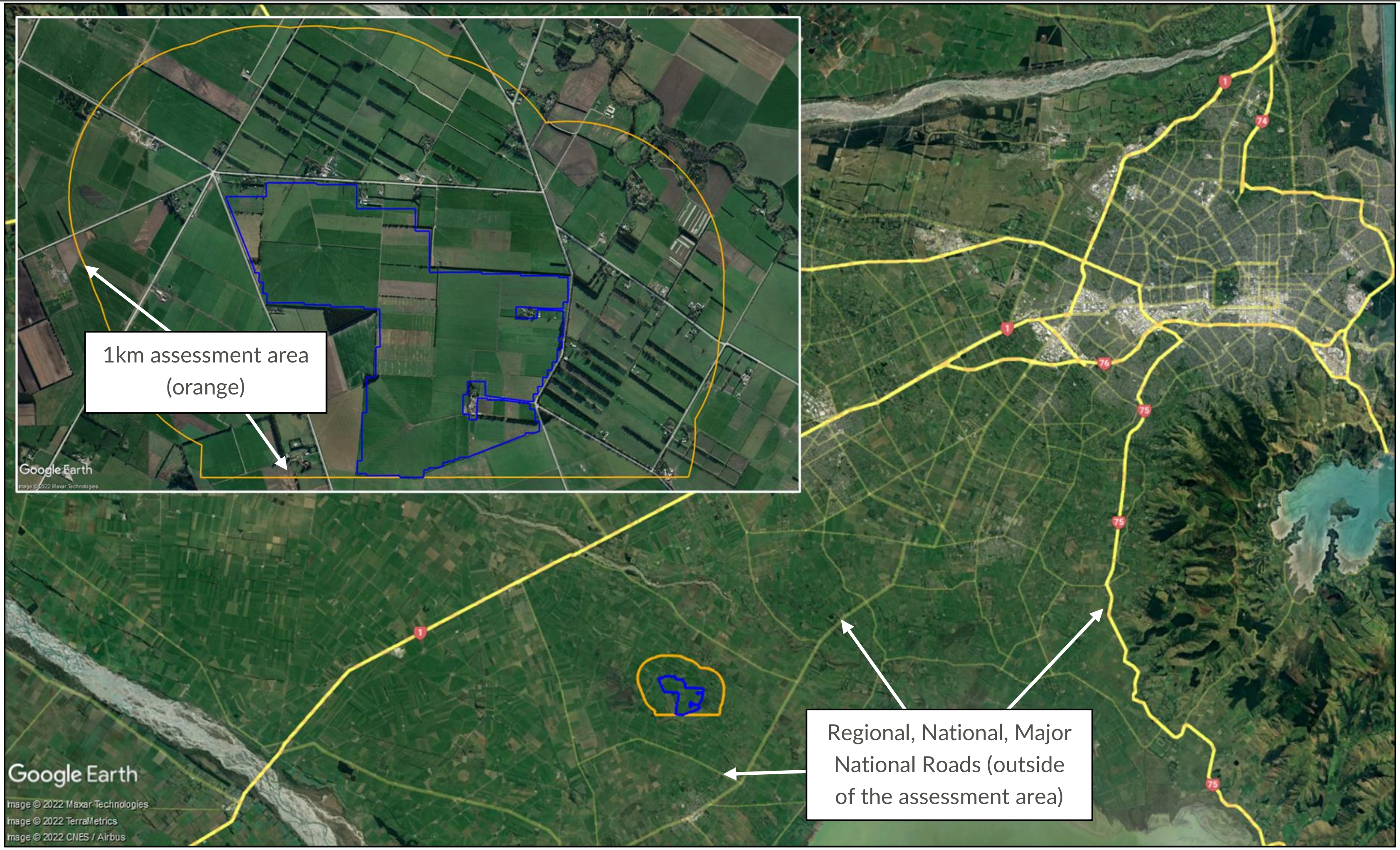

Figure 7 *1km assessment area and roads surrounding the proposed development – aerial image*

5.3 Dwelling Receptors

The analysis has considered dwellings that:

- Are within the 1km assessment area.
- Have a potential view of the panels.

The individual assessed dwelling receptors and an overview of all dwelling receptors are shown in Figures 8 to 22 below and on the following pages. In total, 49 dwelling receptor locations[11,12] have been identified. A height of 1.8 metres above ground level has been taken as typical eye level for an observer on the ground floor of the dwellings[13].

Dwelling receptors 12 to 14, 16 to 19, 48, and 49 have not been taken forward for detailed geometric modelling because they are involved properties.

Figure 8 *Assessed dwelling receptors – 1 to 4*

[11] In some cases, one physical structure is split into multiple separate addresses. In such cases, the results for the assessed location will be applicable to all associated addresses. The sampling resolution is sufficiently high to capture the level of effect for all potentially affected dwellings.

[12] 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.

[13] This fixed height for the dwelling receptors is for modelling purposes. Changes to the modelling height by a few metres is not expected to significantly change the modelling results. Views above ground floor are considered in the results discussion where necessary.

Figure 9 *Assessed dwelling receptors – 5 to 7*

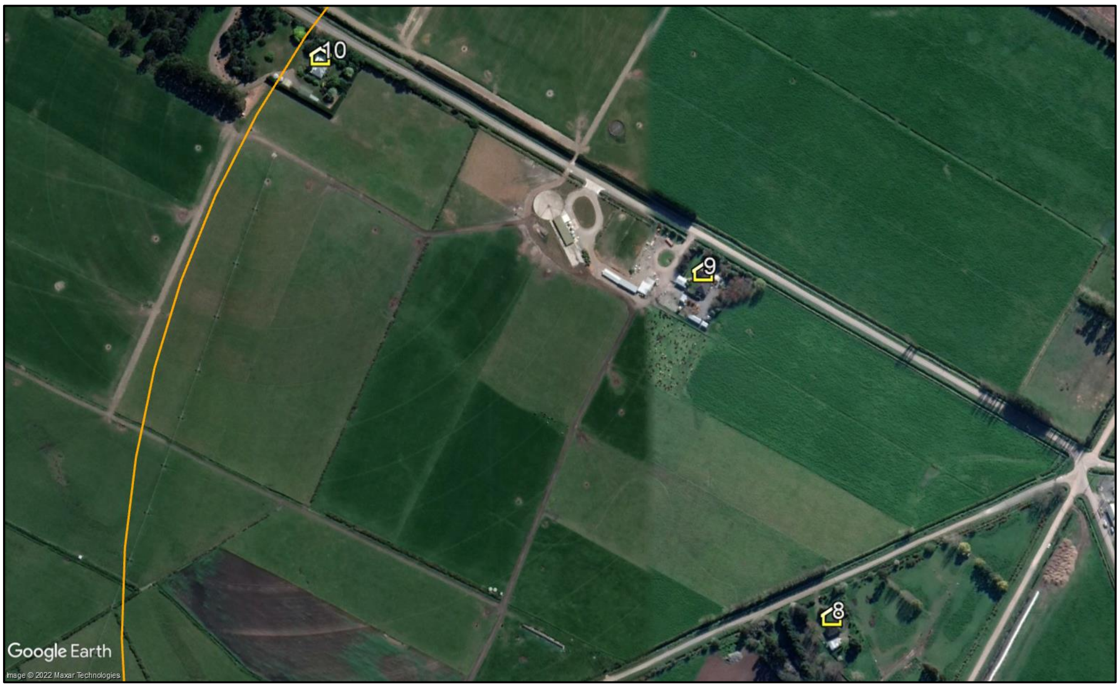

Figure 10 *Assessed dwelling receptors – 8 to 10*

Figure 11 *Assessed dwelling receptors – 11 to 14*

Figure 12 *Assessed dwelling receptors – 16 and 17*

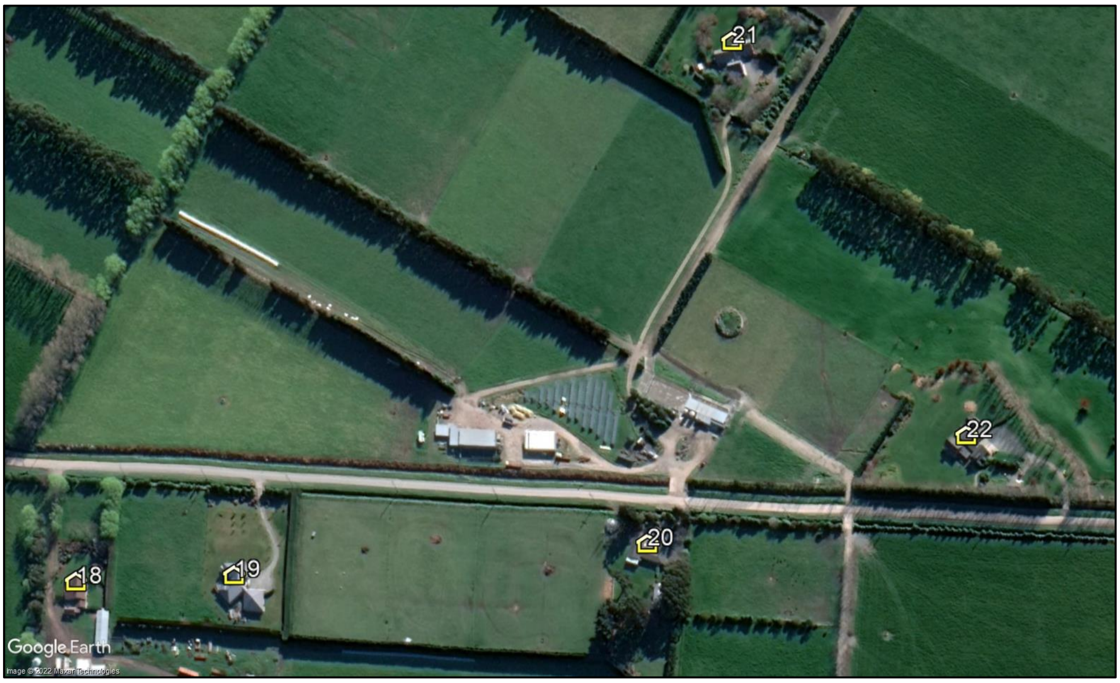

Figure 13 *Assessed dwelling receptors – 18 to 22*

Figure 14 *Assessed dwelling receptor – 23*

Figure 15 *Assessed dwelling receptors – 24 to 27*

Figure 16 *Assessed dwelling receptors – 28 to 33*

Figure 17 *Assessed dwelling receptors – 34 to 40*

Figure 18 *Assessed dwelling receptors – 41 and 42*

Figure 19 *Assessed dwelling receptors – 43 to 47*

Figure 20 *Assessed dwelling receptor – 48*

Figure 21 *Assessed dwelling receptor – 49*

Figure 22 *Dwelling receptors overview*

6 ASSESSED REFLECTOR AREA

6.1 Reflector Area

A resolution of 20m has been chosen for this assessment. This means that a geometric calculation is undertaken for each identified receptor from a point every 20m from within the defined area. This resolution is sufficiently high to maximise the accuracy of the results, increasing the resolution further would not significantly change the modelling output. The number of modelled reflector points are determined by the size of the reflector area and the assessment resolution. The bounding co-ordinates for the proposed solar development have been extrapolated from the site plans. The data can be found in Appendix G.

The assessed reflector area is shown in Figure 23 below.

Figure 23 *Assessed reflector area*

7 GLINT AND GLARE ASSESSMENT – TECHNICAL RESULTS

7.1 Overview

The tables in the following sub-sections summarise the results of the assessment. The tables are based solely on bare-earth terrain i.e., without consideration of screening from buildings and vegetation. Whether a reflection will be experienced in practice, and the significance of any impacts are discussed in the subsequent report sections.

The modelling output for receptors where solar reflections are predicted to be experienced considering screening are shown in Appendix H. The output presents the precise predicted times and the reflecting panel areas.

7.2 Geometric Calculation Results – Dwelling Receptors

The results of the geometric calculations for the dwelling receptors are presented in Table 2 below.

Receptor	Reflection possible towards receptor? (GMT)		Modelling results (bare earth terrain i.e. **no screening considered**)
	am	pm	
1 – 2.	Yes.	No.	Solar reflections predicted for **less** than 60 minutes per day and for **less** than 3 months of the year.
3 – 11.	Yes.	No.	Solar reflections predicted for **less** than 60 minutes per day and for **more** than 3 months of the year.
12 – 14.	N/A.	N/A.	Dwellings 12 to 14 are involved properties and therefore were not taken forward for geometric modelling.
15.	No.	No.	No solar reflections geometrically possible.
16 – 19.	N/A.	N/A.	Dwellings 16 to 19 are involved properties and therefore were not taken forward for geometric modelling.
20 – 24.	No.	Yes.	Solar reflections predicted for **less** than 60 minutes per day and for **more** than 3 months of the year.
25 – 27.	No.	Yes.	Solar reflections predicted for **less** than 60 minutes per day and for **less** than 3 months of the year.

Receptor	Reflection possible towards receptor? (GMT)		Modelling results (bare earth terrain i.e. **no screening considered**)
	am	pm	
28 – 42.	No.	Yes.	Solar reflections predicted for **less** than 60 minutes per day and for **more** than 3 months of the year.
43 – 47.	No.	Yes.	Solar reflections predicted for **less** than 60 minutes per day and for **less** than 3 months of the year.
48 – 49.	N/A.	N/A.	Dwellings 48 and 49 are involved properties and therefore were not taken forward for geometric modelling.

Table 2 *Geometric calculation results – dwelling receptors*

8 GEOMETRIC ASSESSMENT RESULTS AND DISCUSSION

8.1 Overview

The following sub-section presents the significance of any predicted impact in the context of existing 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, landscape strategy plan, and site photography is undertaken, whereby it is assumed views of the panels are possible if it cannot be reliably determined that existing screening will remove effects.

8.2 Dwelling Receptors

The results of the modelling indicate that solar reflections are geometrically possible towards 39 out of the 40 assessed dwelling receptors (1 to 11 and 20 to 47). The assessed dwellings where solar reflections are geometrically possible are shown in Figure 24 on the following page[14].

[14] Dwelling receptors 12 to 14, 16 to 19, 48, and 49 have not been taken forward for detailed geometric modelling because they are involved properties.

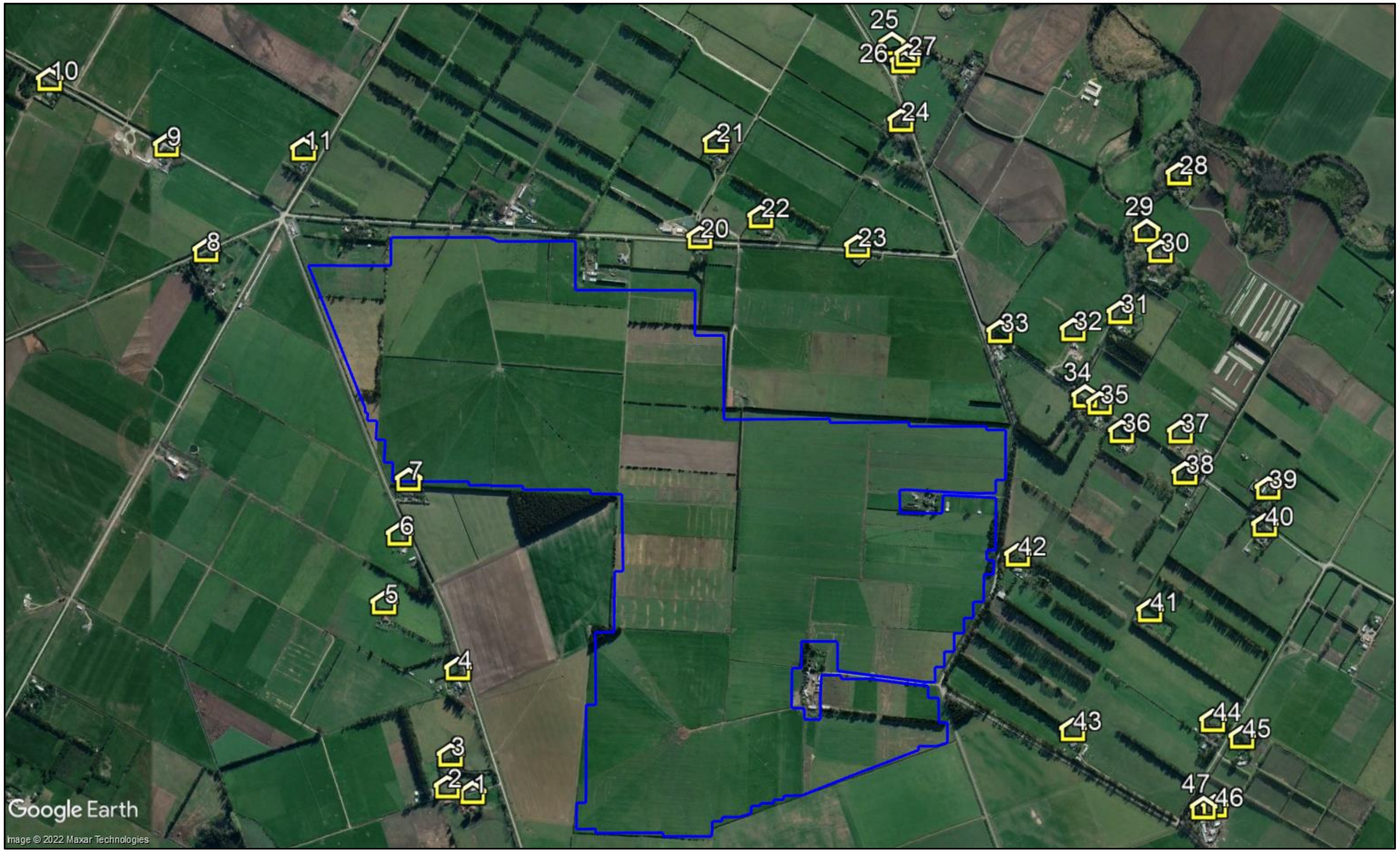

Figure 24 *Dwellings where reflections are geometrically possible*

The process for quantifying impact significance is defined in the report appendices. For dwelling receptors, the key considerations are:

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

Where effects are predicted to be experienced for less than 3 months per year and less than 60 minutes per day, or where the separation distance to the nearest visible reflecting panel is over 1km, the impact significance is low, and mitigation is not required.

Where effects are predicted to be experienced for more than 3 months per year or for more than 60 minutes per day, the impact significance is moderate and expert assessment of the following mitigating factors is required to determine the mitigation requirement:

- The separation distance to the panel area. Larger separation distances reduce the proportion of an observer's field of view 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.

Where effects are predicted to be experienced for more than 3 months per year and more than 60 minutes per day, the impact significance is high, and mitigation is required.

The desk-based review is shown in Figures 25 to 34 on the following pages. Representative visual points ('VP' blue icons) indicating the location and direction of relevant site photography and/or street view imagery are marked on aerial imagery, where appropriate. The yellow radial icons shown within the figures represent the location of the cumulative reflecting areas associated with the receptors. The green outlined areas within the figures represent the location of proposed vegetation screening (new planting and/or gap filling) adjacent to the proposed development (see Section 2.3 for further details). Specifically, each figure shows representative viewpoints.

The review of the available imagery and site photography has shown that for all the assessed dwellings where a solar reflection is predicted, screening in the form of existing and/or proposed vegetation will significantly obstruct the views of the reflecting panels. This means that observers located at all the potentially impacted dwellings will not experience solar reflections in practice. No impact is predicted, and no mitigation is required.

Figure 25 *Viewpoint and reflecting areas - dwelling receptors 1 to 3*

Figure 26 *Viewpoint and reflecting areas - dwelling receptors 4 to 7*

Figure 27 *Viewpoints and reflecting areas - dwelling receptors 8 to 11*

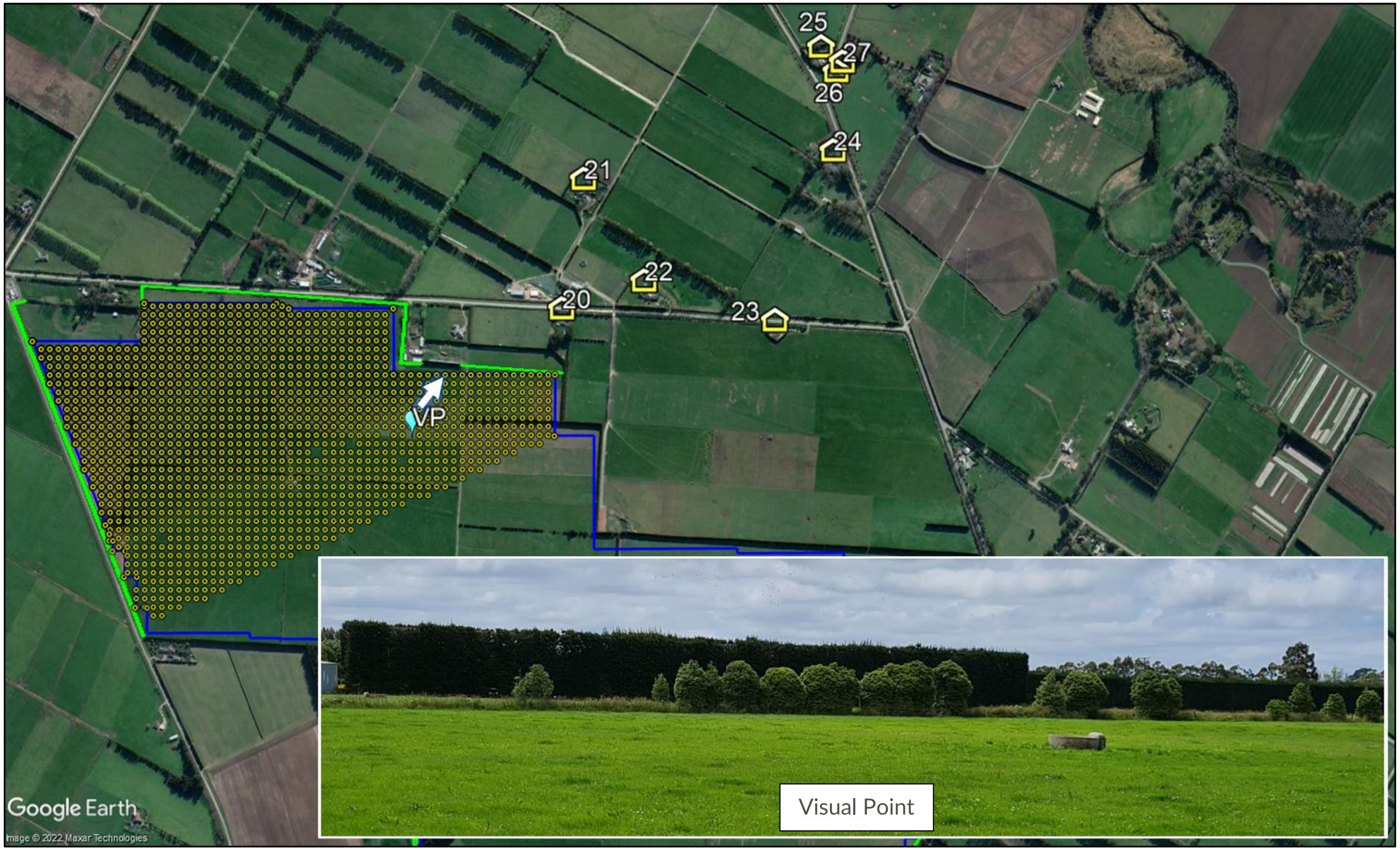

Figure 28 *Viewpoint and reflecting areas - dwelling receptors 20 to 27*

Figure 29 *Viewpoint and reflecting areas - dwelling receptors 28 to 33*

Figure 30 *Viewpoint and reflecting areas - dwelling receptors 34 to 40*

Figure 31 *Viewpoints and reflecting areas - dwelling receptor 41*

Figure 32 *Viewpoint and reflecting areas - dwelling receptor 42*

Figure 33 *Viewpoint and reflecting areas - dwelling receptors 43 to 45*

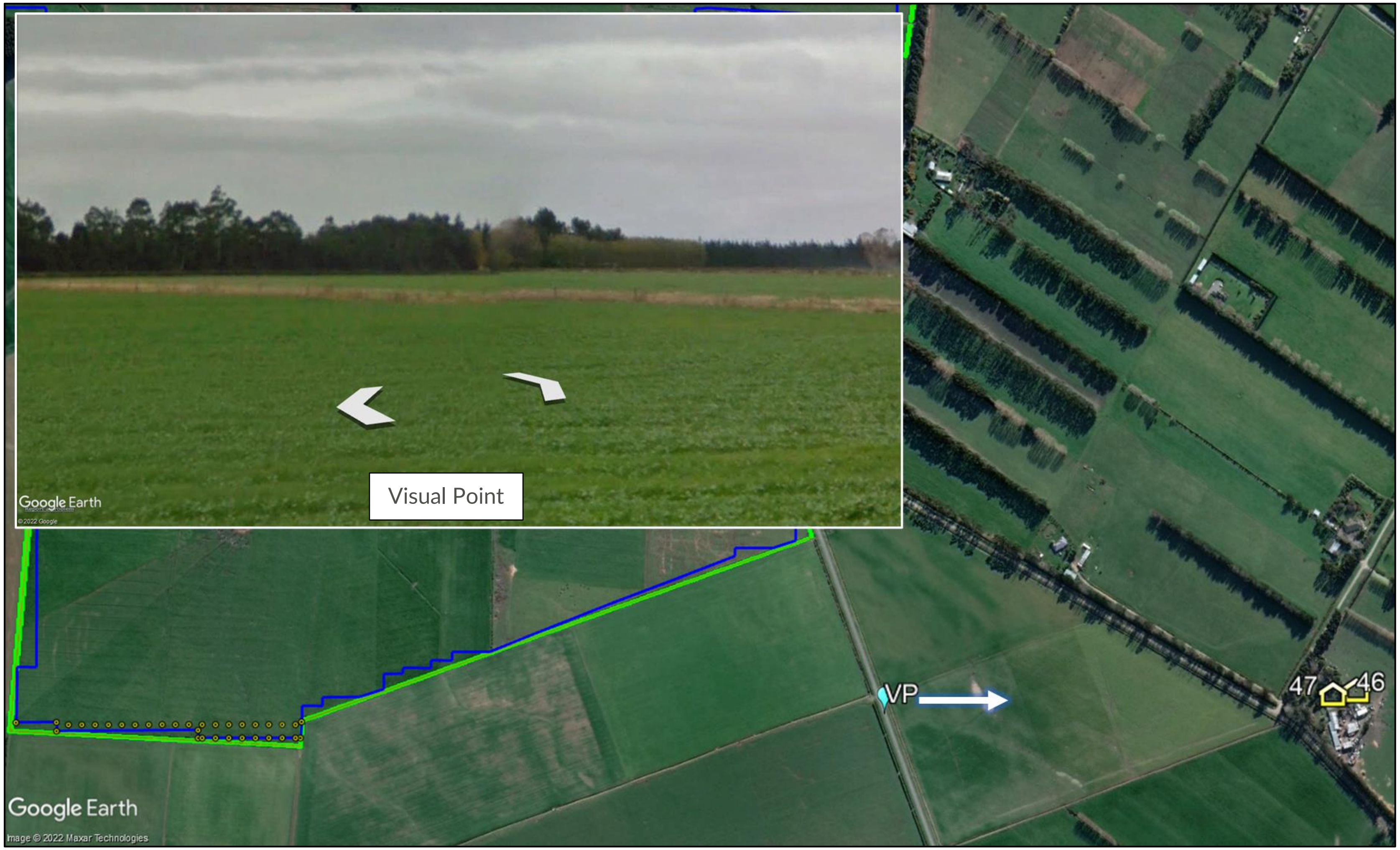

Figure 34 *Viewpoint and reflecting areas - dwelling receptors 46 and 47*

9 OVERALL CONCLUSIONS

9.1 Roads

All roads within the 1km assessment area for consideration of glint and glare effects are local roads. 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.

Overall, no significant impacts upon road users are predicted and no mitigation is required.

9.2 Dwellings

The results of the modelling indicate that solar reflections are geometrically possible towards 39 out of the 40 assessed dwelling receptors[15].

The review of the available imagery and site photography has shown that for all the assessed dwellings where a solar reflection is predicted, screening in the form of existing and/or proposed vegetation will significantly obstruct the views of the reflecting panels. This means that observers located at all the potentially impacted dwellings will not experience solar reflections in practice. No impact is predicted, and no mitigation is required.

9.3 High-Level Aviation

For the approach to runway thresholds 02, 02G, 11, and 29, the orientation is such that any predicted solar reflections will be outside of the pilot's main field of view (50 degrees either side of the approach bearing) and would therefore not be considered significant in accordance with the associated guidance (Appendix D).

For the approach to runway threshold 20 and 20G, the proposed development will be within a pilot's main field of view. It can be safely presumed that any predicted solar reflections would have a 'low potential for temporary after image' in the worst case, which is acceptable under the associated guidance (Appendix D). This is based on the size of the proposed development, its distance from the airfield, and previous project experience.

For the ATC Tower, it is expected that any solar reflections would not visible due to vegetation screening.

Overall, no significant impact on aviation activity associated with Christchurch Airport is predicted and no further detailed assessment is recommended.

9.4 Overall Conclusions

No significant impacts are predicted upon the surrounding road users, dwellings, or aviation activity associated with Christchurch Airport. No further mitigation is required.

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[15] Dwelling receptors 12 to 14, 16 to 19, 48, and 49 have not been taken forward for detailed geometric modelling because they are involved properties.

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'. The guidance is taken from the UK and is for reference purposes only.

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.

UK Planning Policy

The National Planning Policy Framework under the planning practice guidance for Renewable and Low Carbon Energy[16] (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.'

Assessment Process – Ground-Based Receptors

No process for determining and contextualising the effects of glint and glare are, however, 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

[16] Renewable and low carbon energy, Ministry of Housing, Communities & Local Government, date: 18 June 2015, accessed on: 17/06/2020

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[17] which was produced due to the absence of existing guidance and a specific standardised assessment methodology.

[17] Pager Power Glint and Glare Guidance, Third Edition (3.1), April 2021.

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

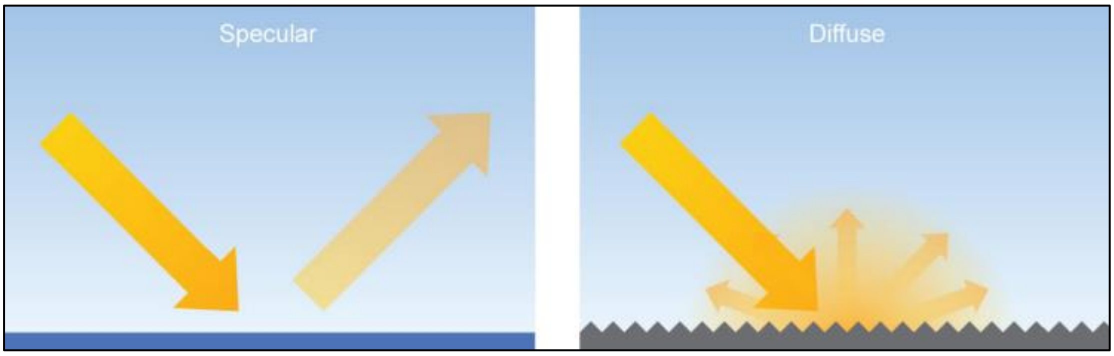
Overview

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[18], 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

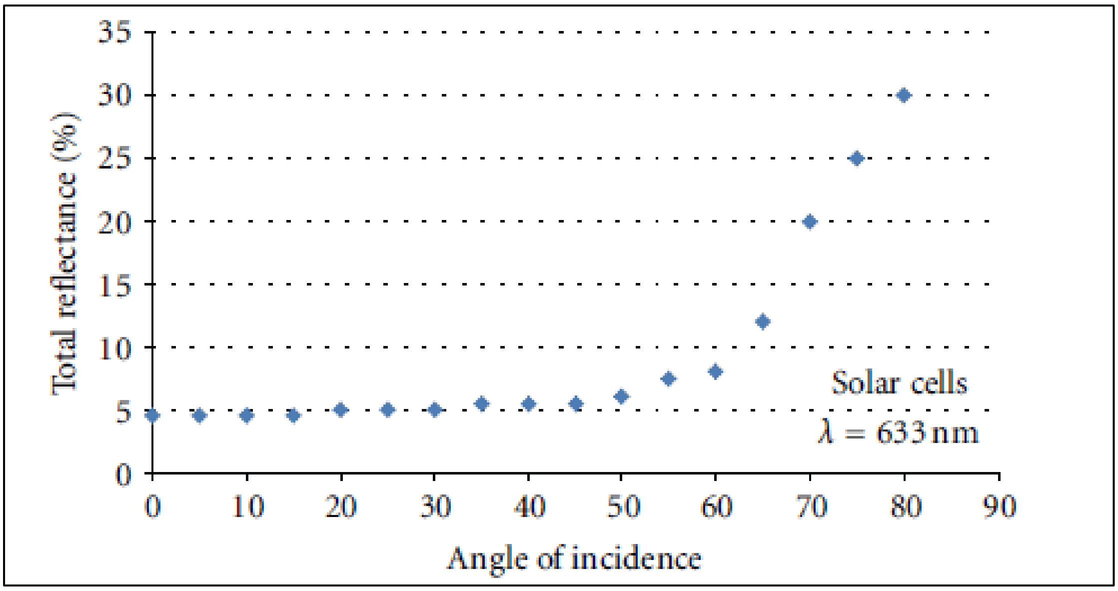
[18] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.

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*[19]". 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.

[19] 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"[20]

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[21]
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).

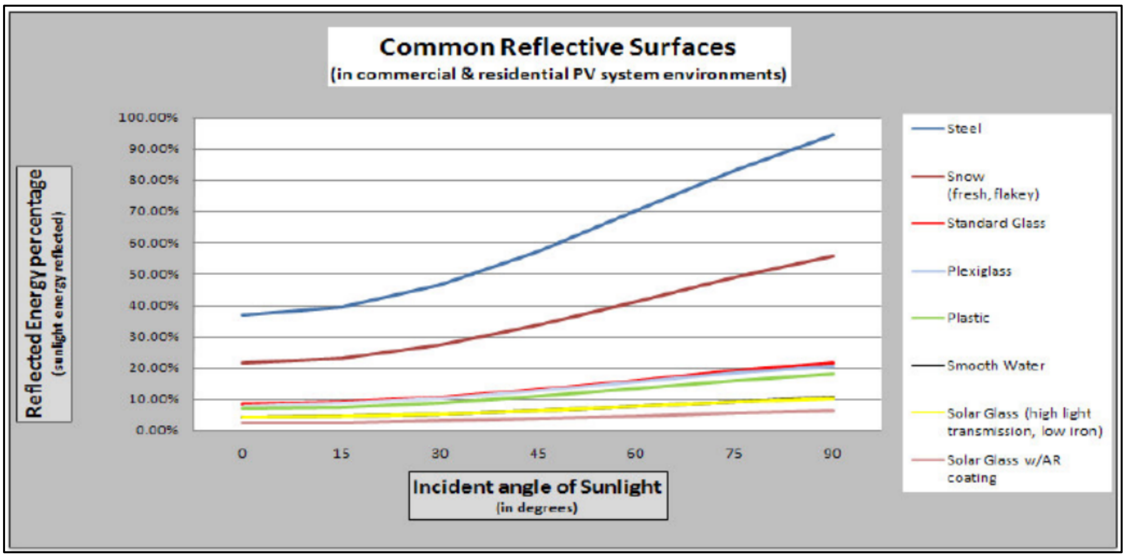
An important comparison in this table is the reflectivity compared to water which will produce a reflection of very similar intensity when compared to that from a solar panel. The study by Riley and Olsen study (2011) also concludes that still water has a very similar reflectivity to solar panels.

[20] Technical Guidance for Evaluating Selected Solar Technologies on Airports, Federal Aviation Administration (FAA), date: 04/2018, accessed on: 20/03/2019.
[21] Extrapolated data, baseline of 1,000 W/m^2 for incoming sunlight.

SunPower Technical Notification (2009)

SunPower published a technical notification[22] to '*increase awareness concerning the possible glare and reflectance impact of PV Systems on their surrounding environment'*.

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.

[22] Source: Technical Support, 2009. SunPower Technical Notification – Solar Module Glare and Reflectance.

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 north at this time.
- The Sun rises highest on 22 December (longest day).
- On 22 June, 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.

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

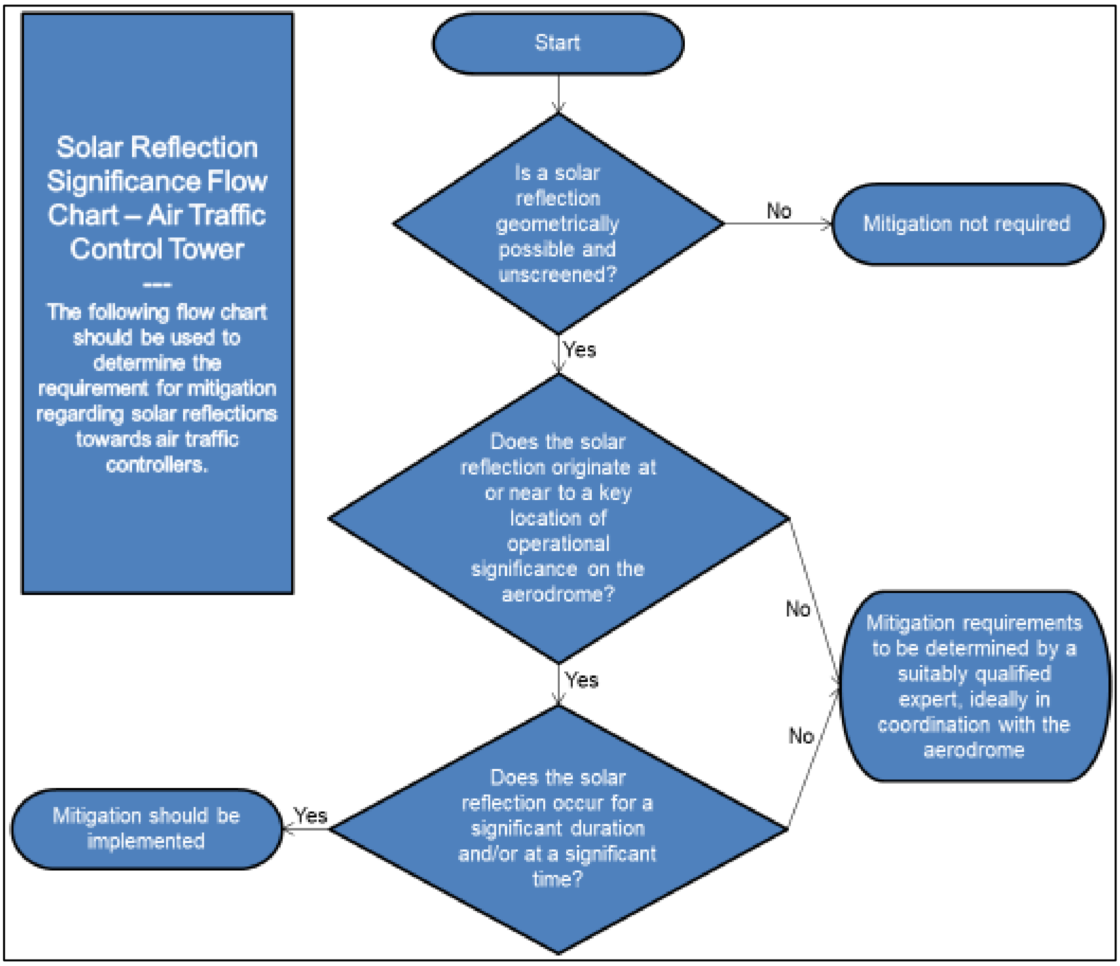
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

Impact Significance	Definition	Mitigation Requirement
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.	No mitigation required.
Moderate	A solar reflection is geometrically possible and visible however it occurs under conditions that do not represent a worst-case.	Whilst the impact may be acceptable, consultation and/or further analysis should be undertaken to determine the requirement for mitigation.
Major	A solar reflection is geometrically possible and visible under conditions that will produce a significant impact. Mitigation and consultation is recommended.	Mitigation will be required if the proposed solar development is to proceed.

Impact significance definition

Assessment Process – ATC Tower

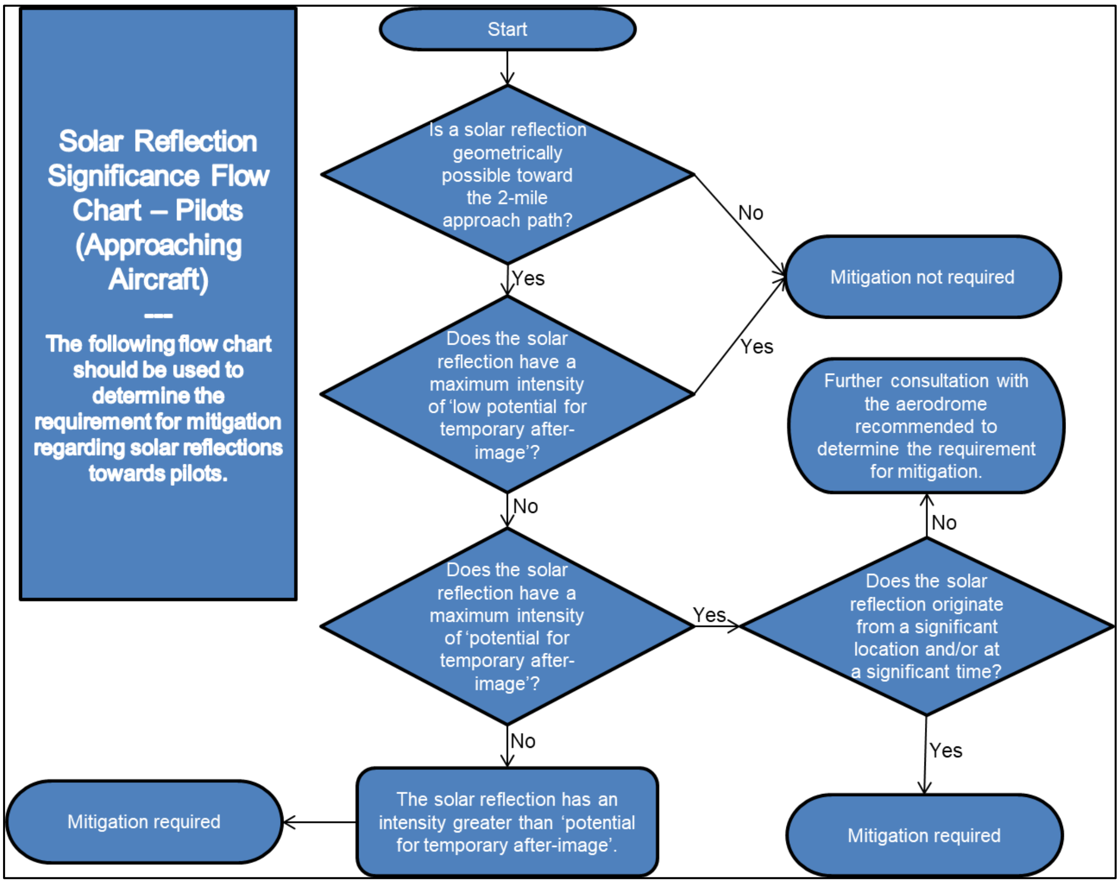
The charts relate to the determining the potential impact upon the ATC Tower.



ATC tower impact significance flow chart

Assessment Process – Approaching Aircraft

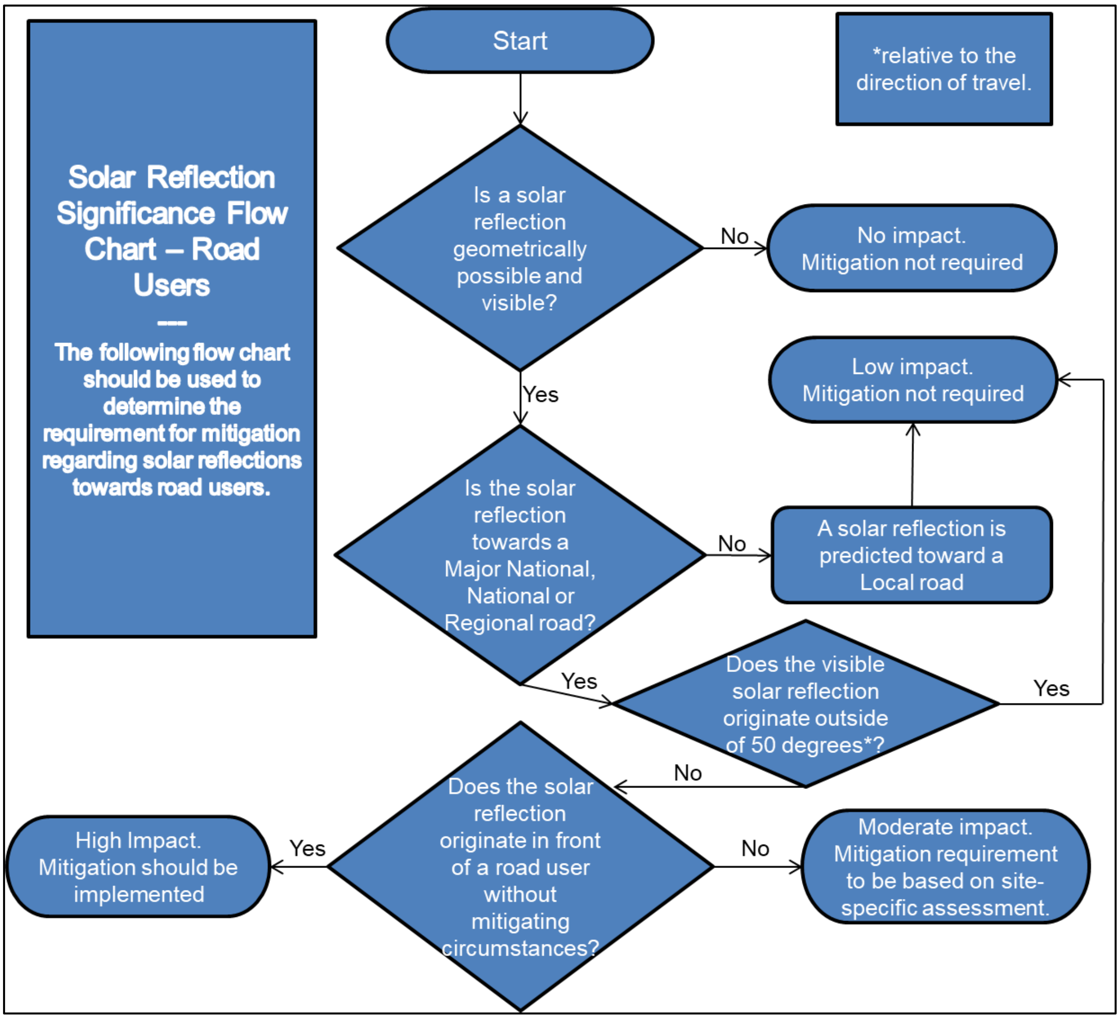
The charts relate to the determining the potential impact upon approaching aircraft.



Pilots (approaching aircraft) impact significance flow chart

Assessment Process for Road Receptors

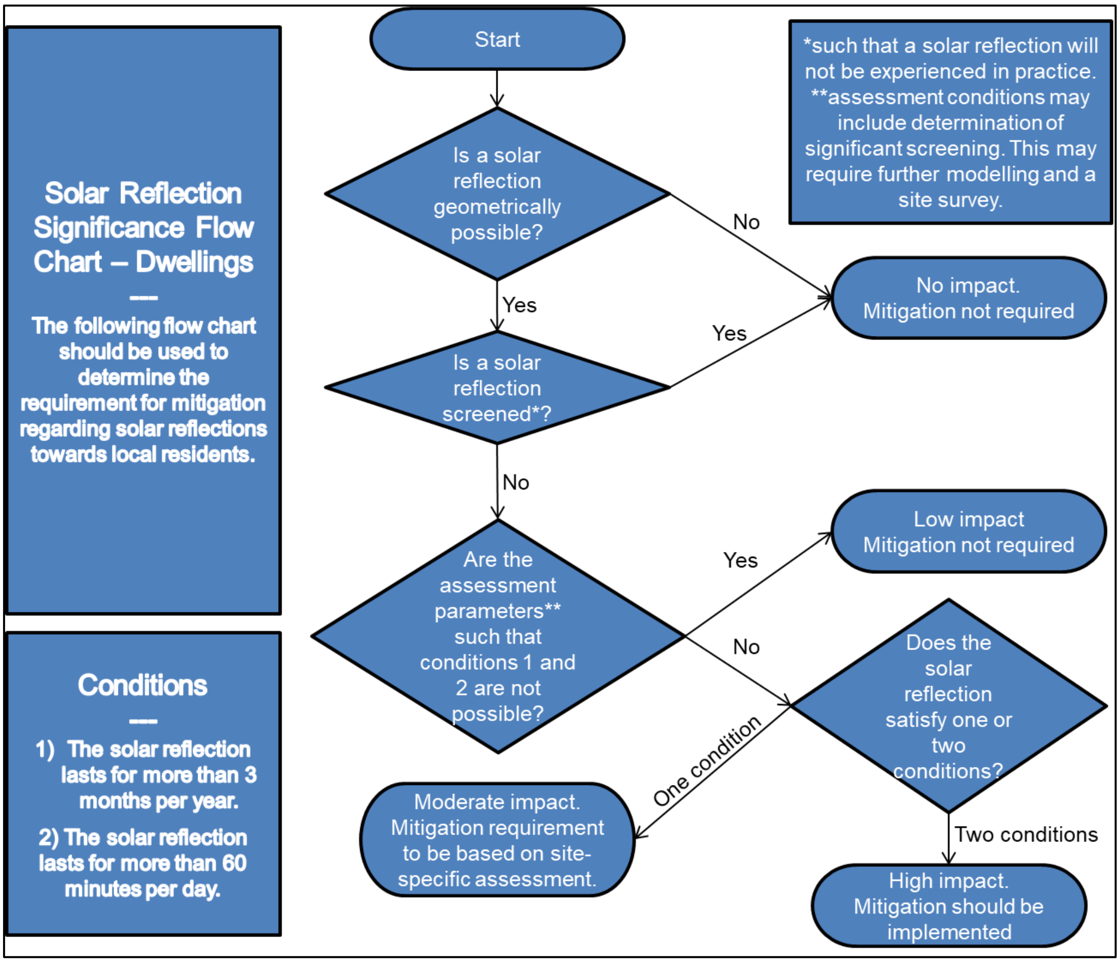
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



Road user impact significance flow chart

Assessment Process for Dwelling Receptors

The flow chart presented below has been followed when determining the mitigation requirement for dwelling receptors.



Dwelling impact significance flow chart

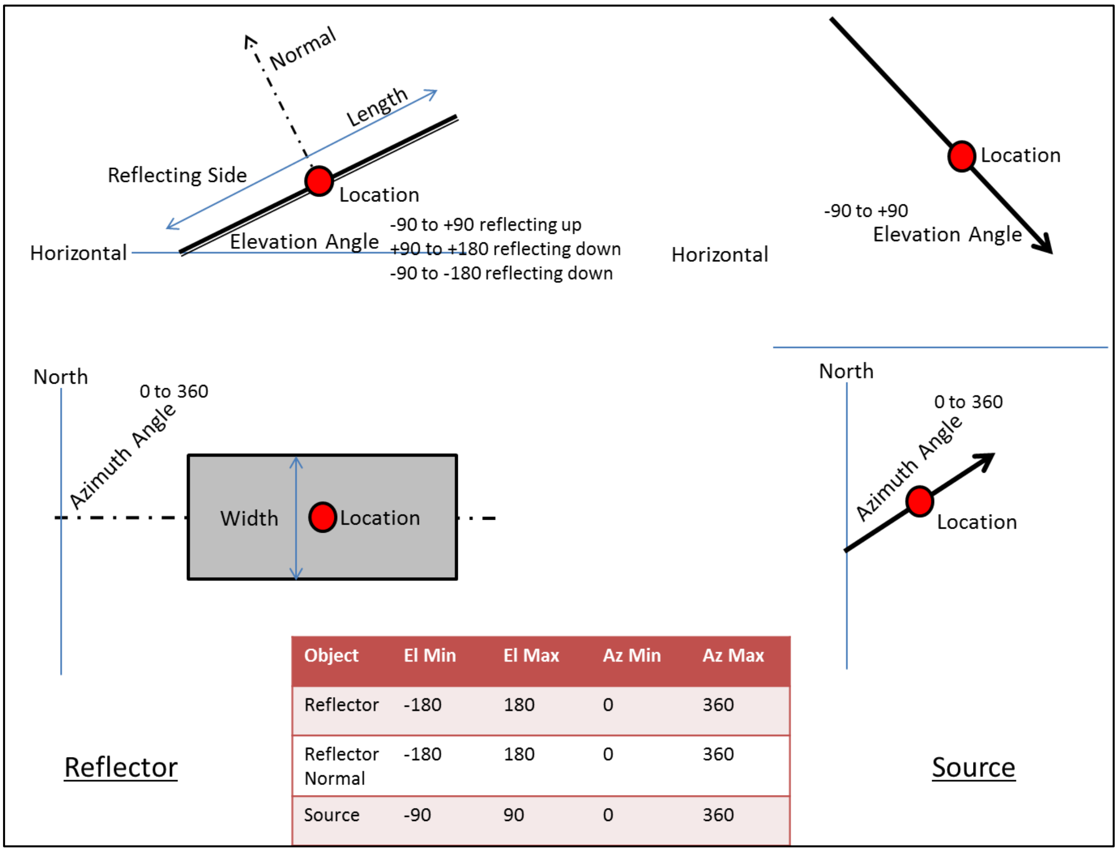
APPENDIX E – REFLECTION CALCULATIONS METHODOLOGY

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

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.

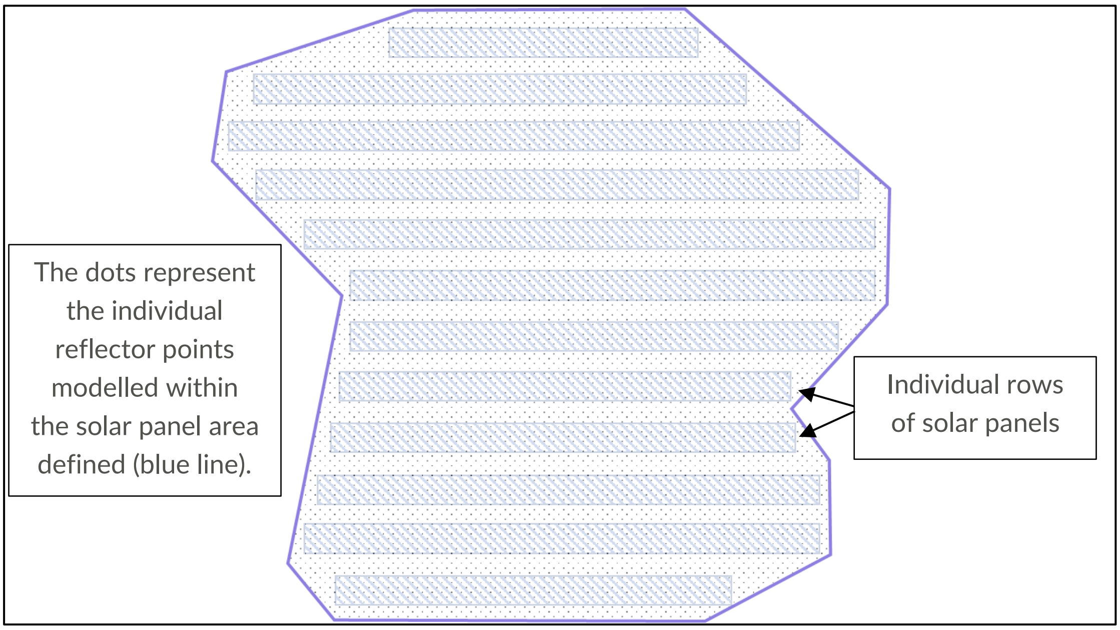
It is assumed that the panel elevation angle assessed represents the elevation angle for all of the panels within each solar panel area defined.

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 of the 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.



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.

APPENDIX G – RECEPTOR AND REFLECTOR AREA DETAILS

Dwelling Receptor Data

An additional height of 1.8m has been added to the ground height, this has been taken as typical eye level for an observer on the ground floor.

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
1	172.28404	-43.71744	26	172.30086	-43.69680
2	172.28307	-43.71727	27	172.30104	-43.69660
3	172.28319	-43.71638	28	172.31163	-43.69996
4	172.28347	-43.71394	29	172.31036	-43.70156
5	172.28060	-43.71207	30	172.31090	-43.70215
6	172.28120	-43.71014	31	172.30934	-43.70387
7	172.28155	-43.70859	32	172.30750	-43.70436
8	172.27368	-43.70213	33	172.30464	-43.70441
9	172.27214	-43.69917	34	172.30796	-43.70624
10	172.26760	-43.69731	35	172.30854	-43.70643
11	172.27748	-43.69927	36	172.30940	-43.70724
12	172.27796	-43.70040	37	172.31170	-43.70725
13	172.27917	-43.70115	38	172.31188	-43.70842
14	172.28002	-43.70118	39	172.31513	-43.70884
15	172.27938	-43.69497	40	172.31499	-43.70988
16	172.28416	-43.70087	41	172.31051	-43.71230
17	172.28477	-43.70072	42	172.30534	-43.71073
18	172.28867	-43.70196	43	172.30750	-43.71567
19	172.28985	-43.70192	44	172.31298	-43.71541
20	172.29293	-43.70175	45	172.31412	-43.71588
21	172.29356	-43.69905	46	172.31306	-43.71783

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
22	172.29530	-43.70117	47	172.31262	-43.71789
23	172.29908	-43.70200	48	172.30198	-43.70884
24	172.30077	-43.69845	49	172.29742	-43.71341
25	172.30041	-43.69629			

Dwelling Receptor Data

Modelled Reflector Data

An additional height of 1.86m has been added to the ground height at each point.

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
1	172.27765	-43.70213	64	172.29957	-43.71381
2	172.28087	-43.70214	65	172.30069	-43.71392
3	172.28087	-43.70134	66	172.30183	-43.71401
4	172.28469	-43.70134	67	172.30183	-43.71434
5	172.28504	-43.70145	68	172.30224	-43.71434
6	172.28806	-43.70145	69	172.30225	-43.71504
7	172.28806	-43.70283	70	172.30259	-43.71504
8	172.29273	-43.70283	71	172.30259	-43.71561
9	172.29272	-43.70411	72	172.30217	-43.71571
10	172.29385	-43.70411	73	172.30146	-43.71571
11	172.29385	-43.70648	74	172.30146	-43.71582
12	172.29799	-43.70646	75	172.30030	-43.71614
13	172.29799	-43.70657	76	172.29918	-43.71645
14	172.30108	-43.70655	77	172.29765	-43.71689
15	172.30108	-43.70667	78	172.29689	-43.71710
16	172.30411	-43.70667	79	172.29619	-43.71711
17	172.30411	-43.70677	80	172.29619	-43.71722
18	172.30486	-43.70678	81	172.29580	-43.71722

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
19	172.30485	-43.70819	82	172.29580	-43.71732
20	172.30447	-43.70819	83	172.29528	-43.71732
21	172.30447	-43.70856	84	172.29528	-43.71740
22	172.30331	-43.70856	85	172.29492	-43.71740
23	172.30098	-43.70846	86	172.29492	-43.71761
24	172.30071	-43.70847	87	172.29447	-43.71771
25	172.30074	-43.70911	88	172.29378	-43.71771
26	172.30238	-43.70913	89	172.29378	-43.71783
27	172.30241	-43.70861	90	172.29340	-43.71783
28	172.30317	-43.70864	91	172.29340	-43.71804
29	172.30448	-43.70869	92	172.29338	-43.71826
30	172.30446	-43.71017	93	172.29147	-43.71826
31	172.30412	-43.71017	94	172.29147	-43.71815
32	172.30412	-43.71045	95	172.28885	-43.71816
33	172.30440	-43.71046	96	172.28884	-43.71804
34	172.30438	-43.71085	97	172.28809	-43.71805
35	172.30402	-43.71085	98	172.28811	-43.71730
36	172.30400	-43.71163	99	172.28847	-43.71731
37	172.30359	-43.71163	100	172.28848	-43.71454
38	172.30360	-43.71209	101	172.28885	-43.71454
39	172.30323	-43.71209	102	172.28883	-43.71249
40	172.30323	-43.71252	103	172.28956	-43.71249
41	172.30285	-43.71252	104	172.28959	-43.71077
42	172.30285	-43.71304	105	172.28992	-43.71076
43	172.30246	-43.71304	106	172.28987	-43.70859
44	172.30246	-43.71347	107	172.28865	-43.70857

Location	Longitude (°)	Latitude (°)	Location	Longitude (°)	Latitude (°)
45	172.30210	-43.71347	108	172.28865	-43.70846
46	172.30211	-43.71390	109	172.28601	-43.70846
47	172.30169	-43.71390	110	172.28601	-43.70836
48	172.30054	-43.71379	111	172.28482	-43.70835
49	172.29938	-43.71368	112	172.28465	-43.70833
50	172.29829	-43.71358	113	172.28390	-43.70833
51	172.29829	-43.71275	114	172.28390	-43.70823
52	172.29688	-43.71275	115	172.28092	-43.70823
53	172.29688	-43.71350	116	172.28094	-43.70769
54	172.29652	-43.71350	117	172.28060	-43.70769
55	172.29649	-43.71463	118	172.28065	-43.70705
56	172.29700	-43.71464	119	172.28028	-43.70705
57	172.29699	-43.71495	120	172.28032	-43.70651
58	172.29762	-43.71496	121	172.27995	-43.70651
59	172.29762	-43.71441	122	172.27996	-43.70629
60	172.29764	-43.71403	123	172.27986	-43.70629
61	172.29766	-43.71370	124	172.27986	-43.70615
62	172.29843	-43.71370	125	172.27975	-43.70596
63	172.29844	-43.71381			

Modelled Reflector Data

APPENDIX H – DETAILLED MODELLING RESULTS

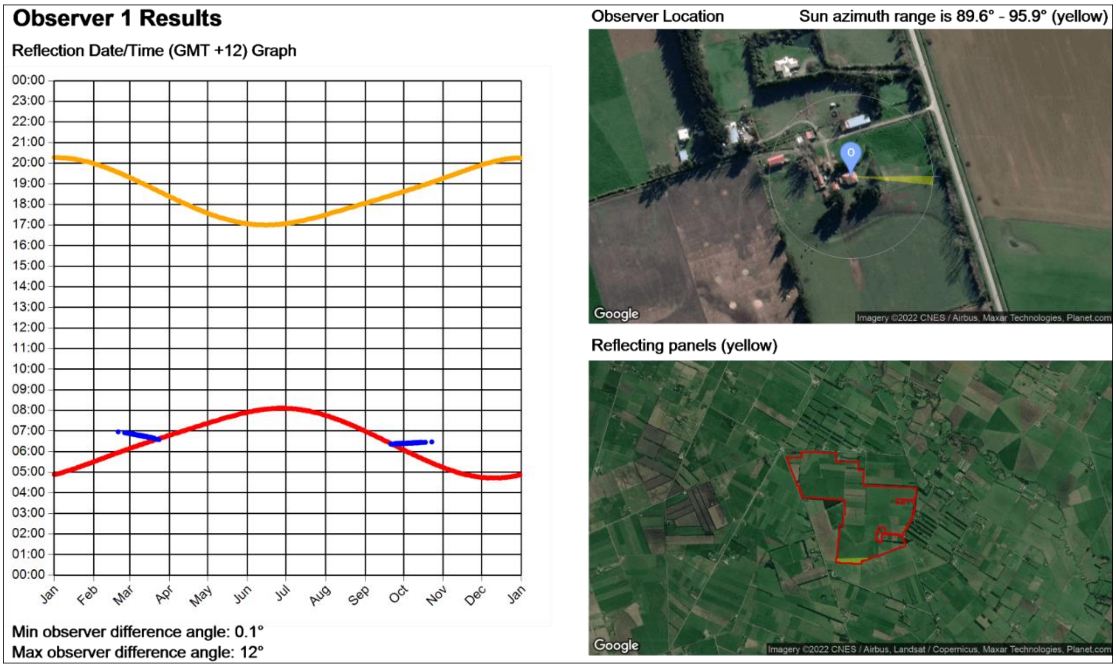
Overview

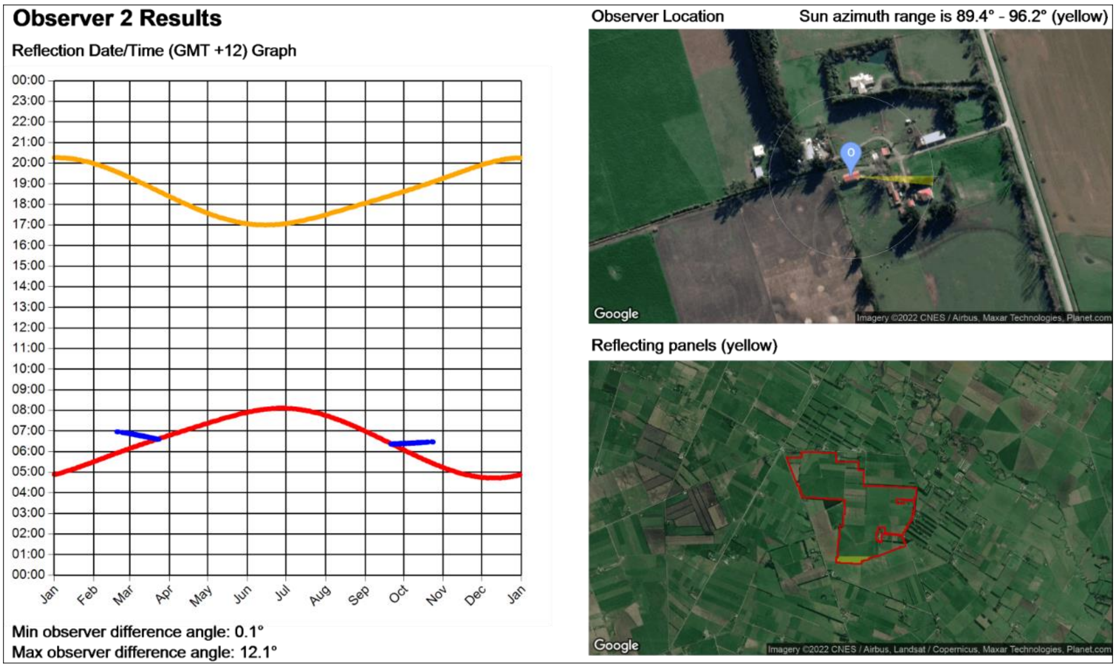
The Pager Power charts for the receptors are shown below and on the following pages for completeness. Each chart shows:

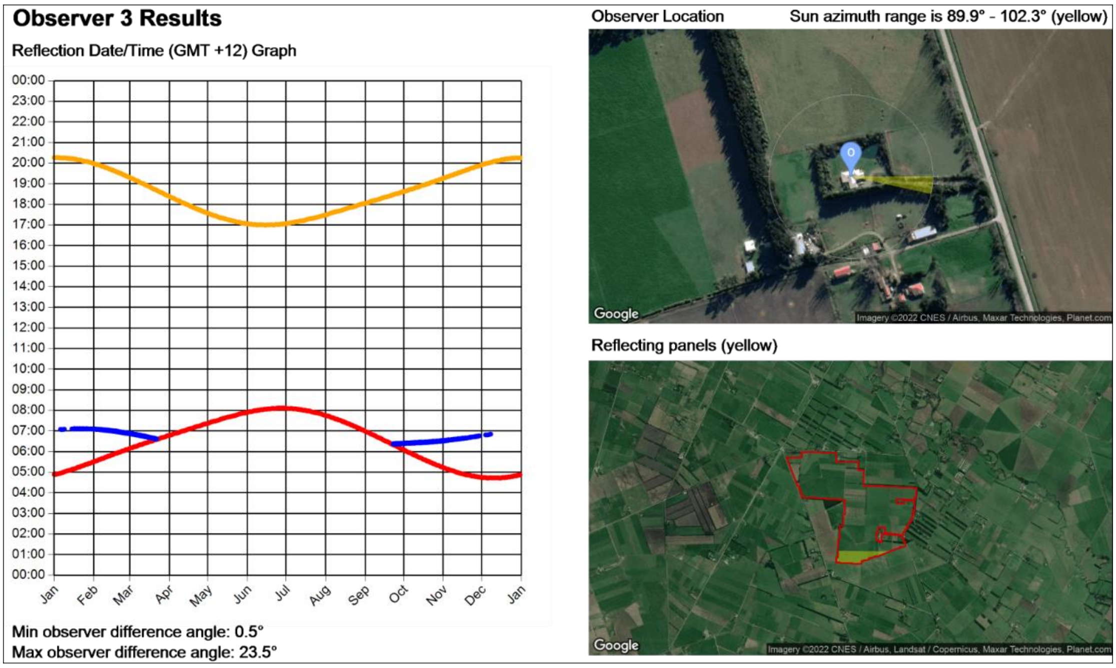
- The receptor (observer) location – top right image. This also shows the azimuth range of the Sun itself at times when reflections are possible. If sunlight is experienced from the same direction as the reflecting panels, the overall impact of the reflection is reduced as discussed within the body of the report;
- The reflecting panels – bottom right image. The reflecting area is shown in yellow. If the yellow panels are not visible from the observer location, no issues will occur in practice. Additional obstructions which may obscure the panels from view are considered separately within the analysis;
- The reflection date/time graph – left hand side of the page. 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).

Dwelling Receptors

The modelling results for the assessed dwelling receptors have been included in this document below for completeness even though no visible solar reflection is predicted.

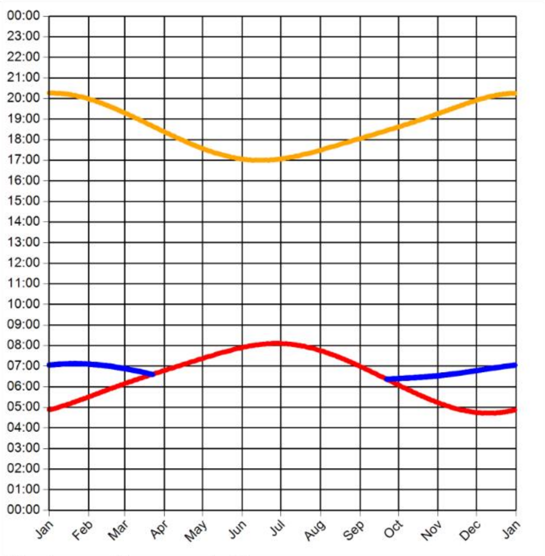



Observer 2 Results
Reflection Date/Time (GMT +12) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 0.1°
Max observer difference angle: 12.1°
Observer Location
Sun azimuth range is 89.4° - 96.2° (yellow)
Google
Imagery ©2022 CNES / Airbus, Maxar Technologies, Planet.com
Reflecting panels (yellow)
Google
Imagery ©2022 CNES / Airbus, Landsat / Copernicus, Maxar Technologies, Planet.com


Observer 3 Results
Reflection Date/Time (GMT +12) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Min observer difference angle: 0.5°
Max observer difference angle: 23.5°
Observer Location
Sun azimuth range is 89.9° - 102.3° (yellow)
Google
Imagery ©2022 CNES / Airbus, Maxar Technologies, Planet.com
Reflecting panels (yellow)
Google
Imagery ©2022 CNES / Airbus, Landsat / Copernicus, Maxar Technologies, Planet.com

Observer 4 Results

Reflection Date/Time (GMT +12) Graph



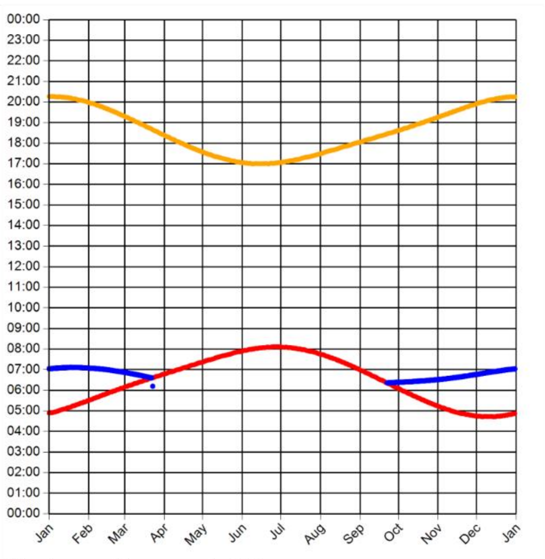
Min observer difference angle: 0°
Max observer difference angle: 24.8°

Observer Location — Sun azimuth range is 89.6° - 102.8° (yellow)

Reflecting panels (yellow)

Observer 5 Results

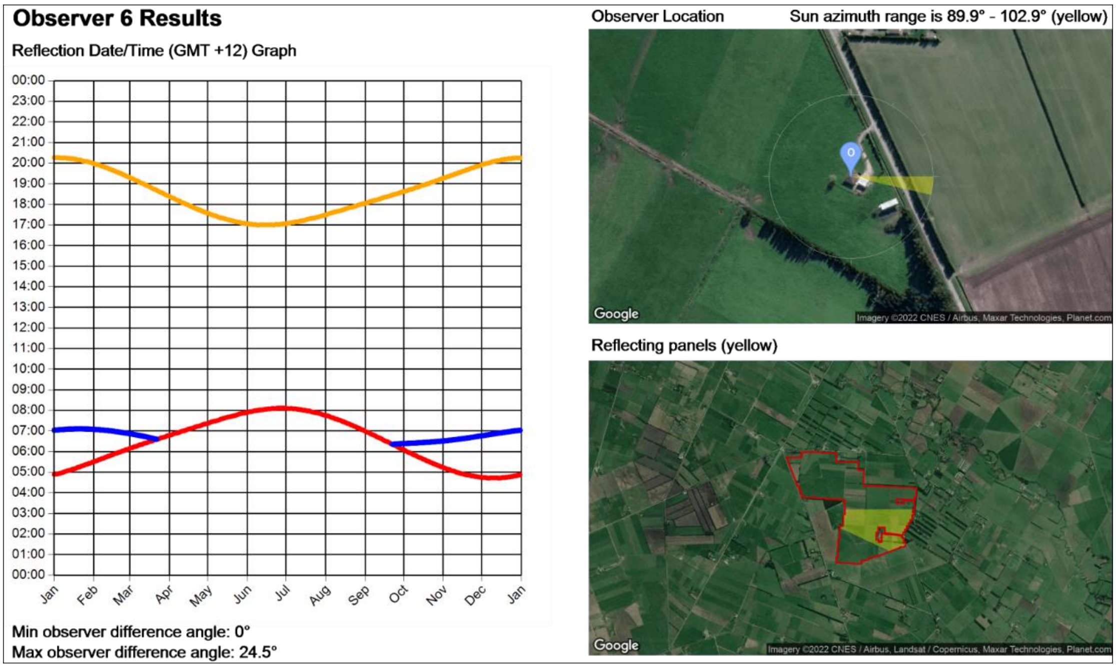
Reflection Date/Time (GMT +12) Graph

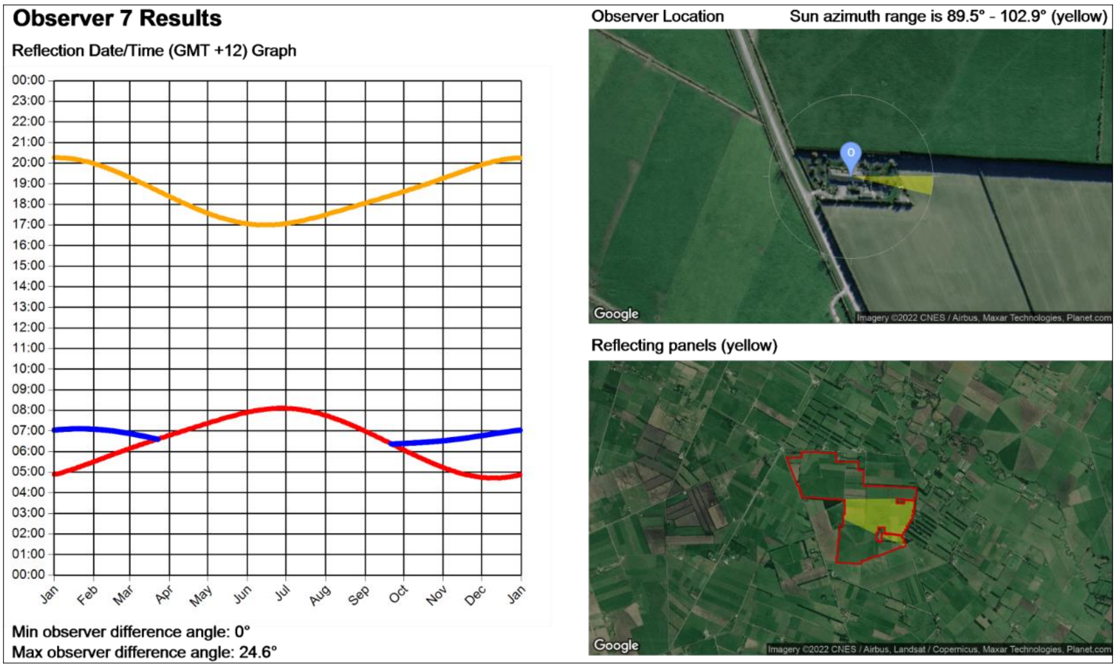


Min observer difference angle: 0.1°
Max observer difference angle: 24.7°

Observer Location — Sun azimuth range is 89.9° - 102.9° (yellow)

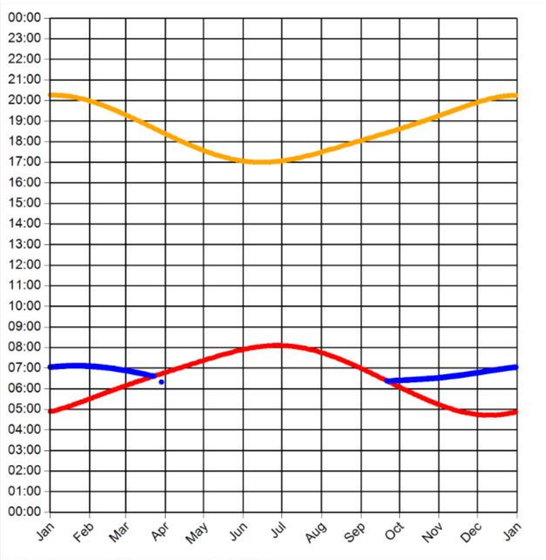
Reflecting panels (yellow)


Observer 6 Results
Reflection Date/Time (GMT +12) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 0°
Max observer difference angle: 24.5°
Observer Location
Sun azimuth range is 89.9° - 102.9° (yellow)
Google
Imagery ©2022 CNES / Airbus, Maxar Technologies, Planet.com
Reflecting panels (yellow)
Google
Imagery ©2022 CNES / Airbus, Landsat / Copernicus, Maxar Technologies, Planet.com


Observer 7 Results
Reflection Date/Time (GMT +12) Graph
00:00
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
12:00
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
Min observer difference angle: 0°
Max observer difference angle: 24.6°
Observer Location
Sun azimuth range is 89.5° - 102.9° (yellow)
Google
Imagery ©2022 CNES / Airbus, Maxar Technologies, Planet.com
Reflecting panels (yellow)
Google
Imagery ©2022 CNES / Airbus, Landsat / Copernicus, Maxar Technologies, Planet.com

Observer 8 Results

Reflection Date/Time (GMT +12) Graph



Min observer difference angle: 0.2°

Max observer difference angle: 25.1°

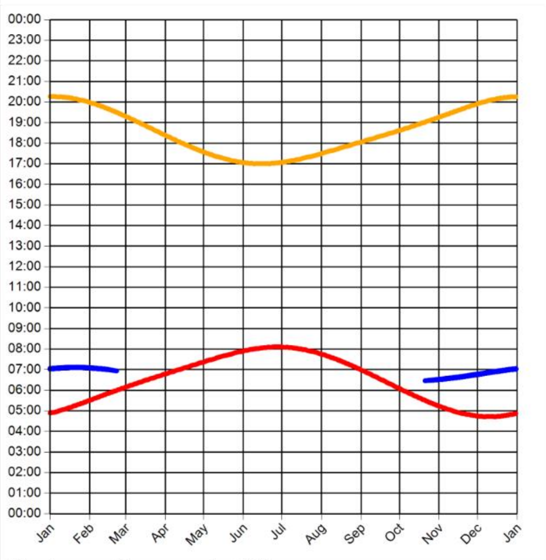
Observer Location

Sun azimuth range is 89.4° - 102.9° (yellow)

Reflecting panels (yellow)

Observer 9 Results

Reflection Date/Time (GMT +12) Graph



Min observer difference angle: 11.2°

Max observer difference angle: 24.6°

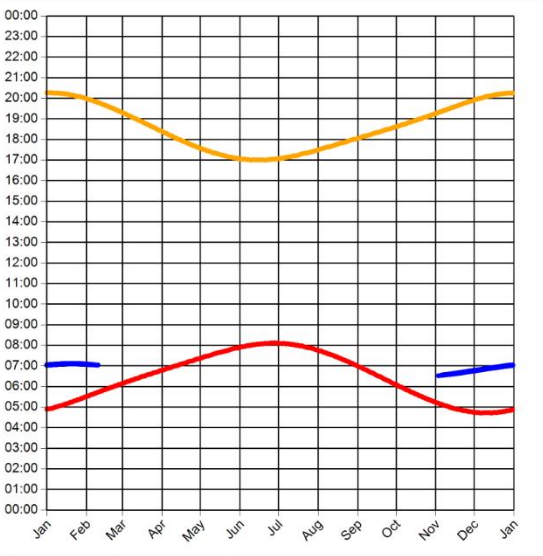
Observer Location

Sun azimuth range is 95.5° - 102.9° (yellow)

Reflecting panels (yellow)

Observer 10 Results

Reflection Date/Time (GMT +12) Graph



Min observer difference angle: 15.4°
Max observer difference angle: 24.5°

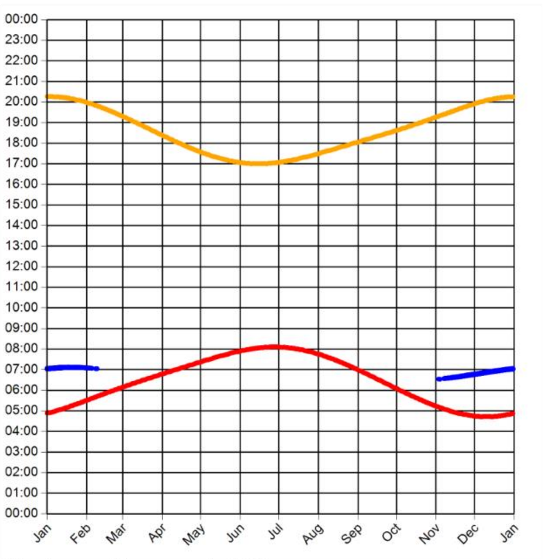
Observer Location

Sun azimuth range is 97.7° - 102.9° (yellow)

Reflecting panels (yellow)

Observer 11 Results

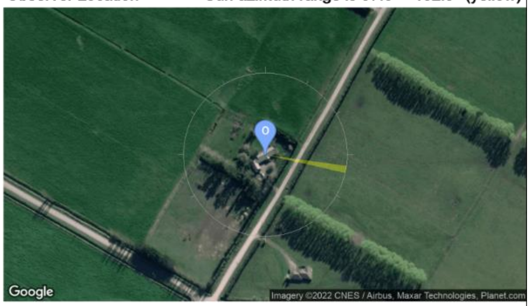
Reflection Date/Time (GMT +12) Graph



Min observer difference angle: 15.9°
Max observer difference angle: 24.9°

Observer Location

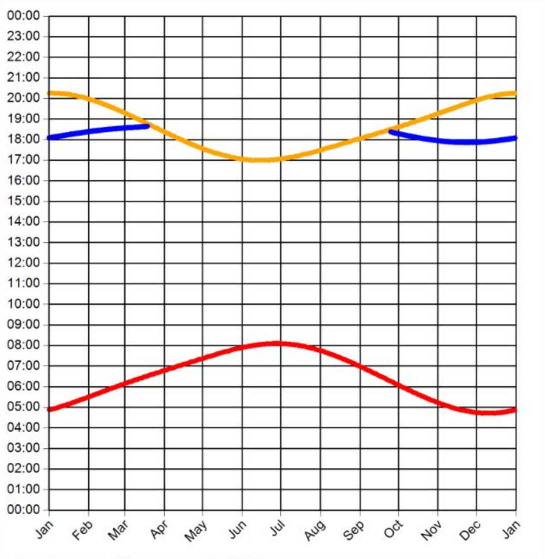
Sun azimuth range is 97.8° - 102.9° (yellow)



Reflecting panels (yellow)

Observer 20 Results

Reflection Date/Time (GMT +12) Graph



Min observer difference angle: 0.8°
Max observer difference angle: 24.1°

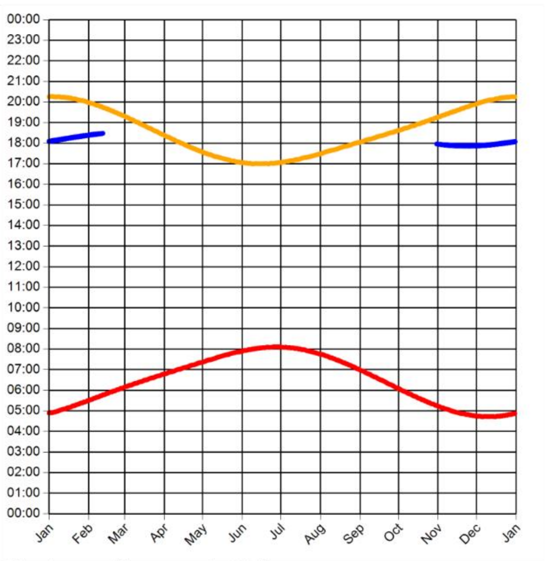
Observer Location

Sun azimuth range is 257° - 269.4° (yellow)

Reflecting panels (yellow)

Observer 21 Results

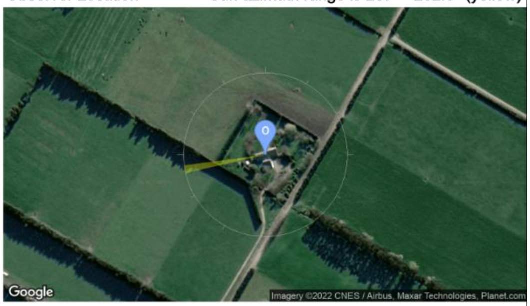
Reflection Date/Time (GMT +12) Graph



Min observer difference angle: 14.1°
Max observer difference angle: 24.1°

Observer Location

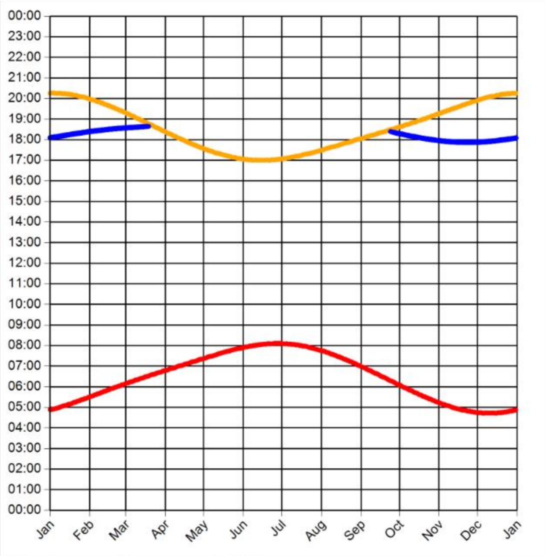
Sun azimuth range is 257° - 262.6° (yellow)



Reflecting panels (yellow)

Observer 22 Results

Reflection Date/Time (GMT +12) Graph



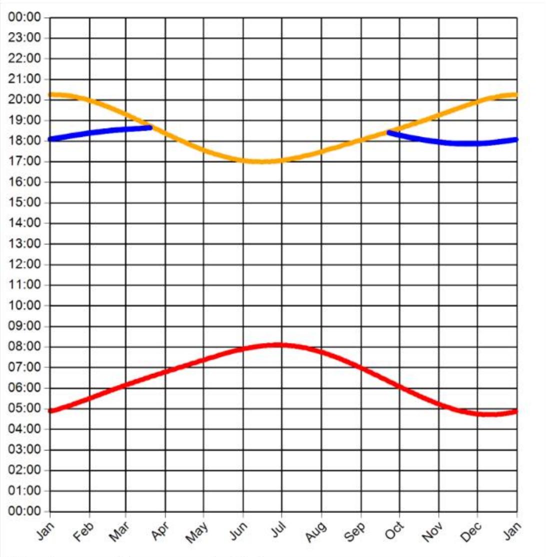
Min observer difference angle: 0.5°
Max observer difference angle: 24°

Observer Location — Sun azimuth range is 257° - 269.6° (yellow)

Reflecting panels (yellow)

Observer 23 Results

Reflection Date/Time (GMT +12) Graph



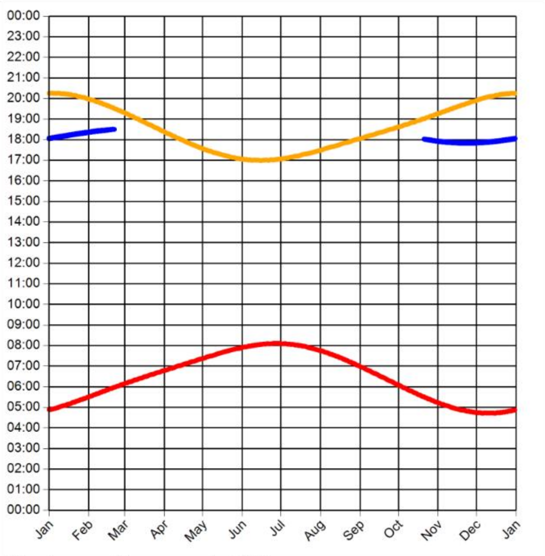
Min observer difference angle: 0.2°
Max observer difference angle: 24°

Observer Location — Sun azimuth range is 257° - 269.8° (yellow)

Reflecting panels (yellow)

Observer 24 Results

Reflection Date/Time (GMT +12) Graph



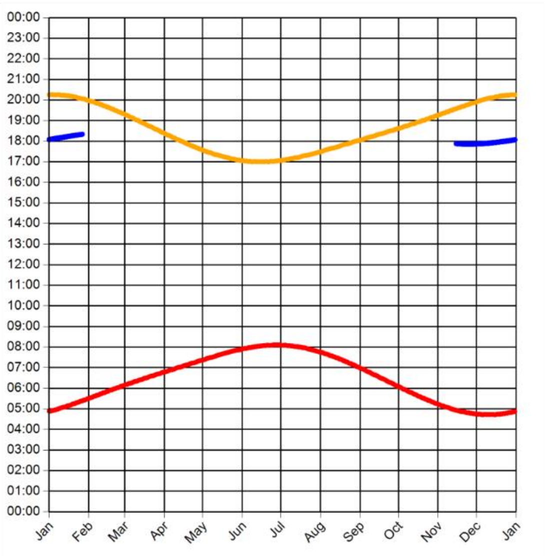
Min observer difference angle: 11.5°
Max observer difference angle: 24.9°

Observer Location — Sun azimuth range is 257.2° - 264.7° (yellow)

Reflecting panels (yellow)

Observer 25 Results

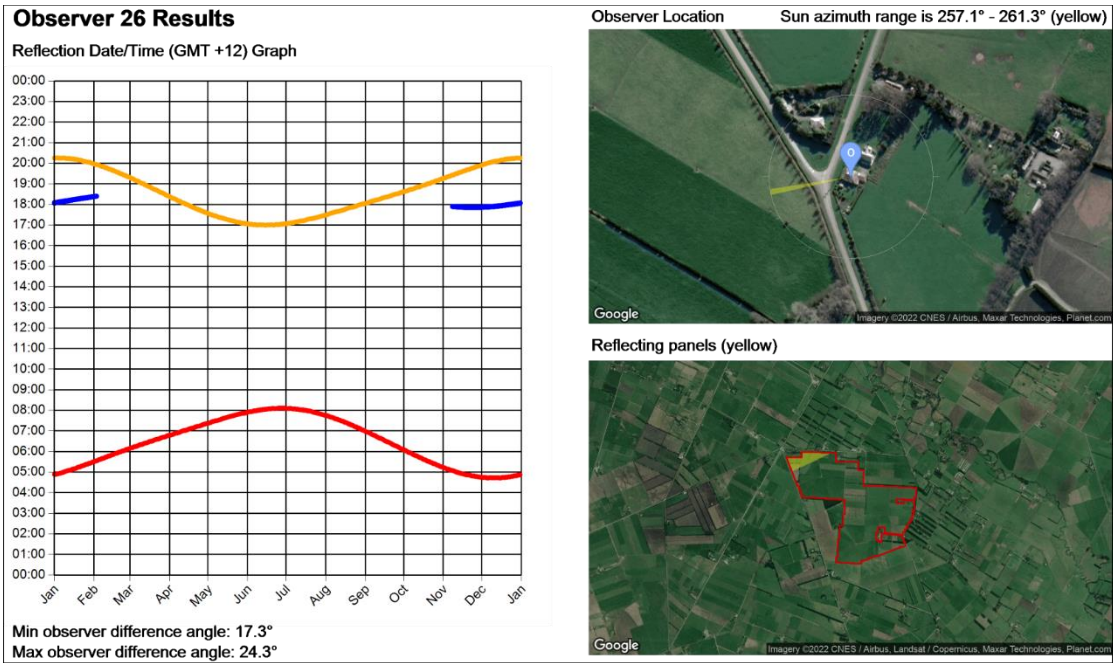
Reflection Date/Time (GMT +12) Graph



Min observer difference angle: 19.1°
Max observer difference angle: 24.3°

Observer Location — Sun azimuth range is 257.1° - 260.2° (yellow)

Reflecting panels (yellow)


Observer 26 Results
Reflection Date/Time (GMT +12) Graph
Min observer difference angle: 17.3°
Max observer difference angle: 24.3°
Observer Location
Sun azimuth range is 257.1° - 261.3° (yellow)
Reflecting panels (yellow)
Google
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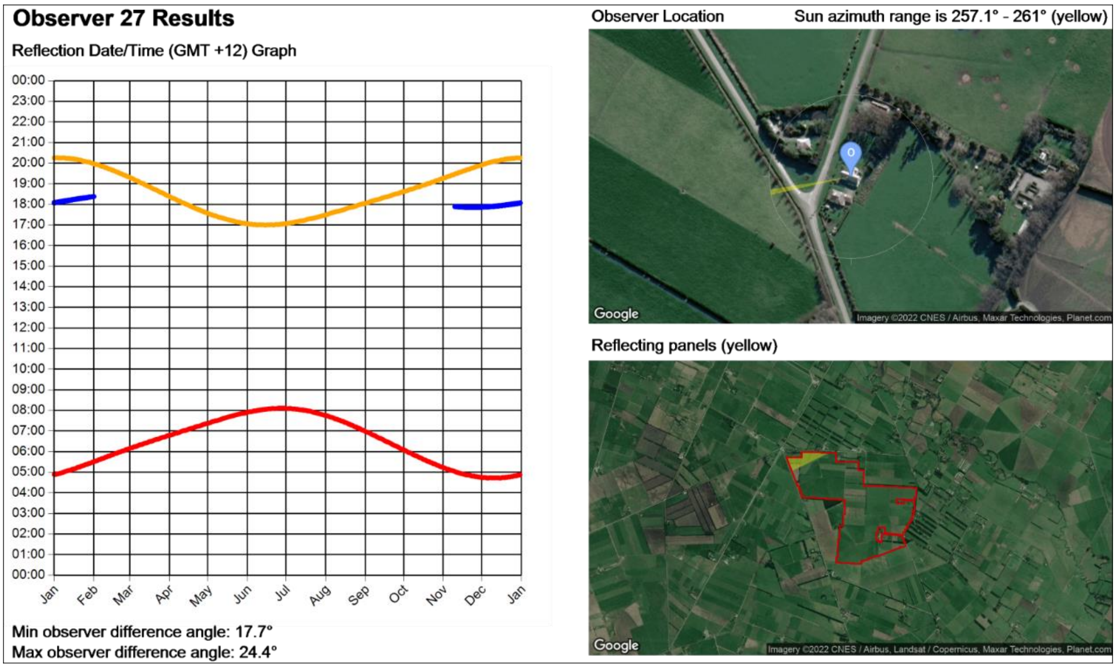
Imagery ©2022 CNES / Airbus, Landsat / Copernicus, Maxar Technologies, Planet.com


Observer 27 Results
Reflection Date/Time (GMT +12) Graph
Min observer difference angle: 17.7°
Max observer difference angle: 24.4°
Observer Location
Sun azimuth range is 257.1° - 261° (yellow)
Reflecting panels (yellow)
Google
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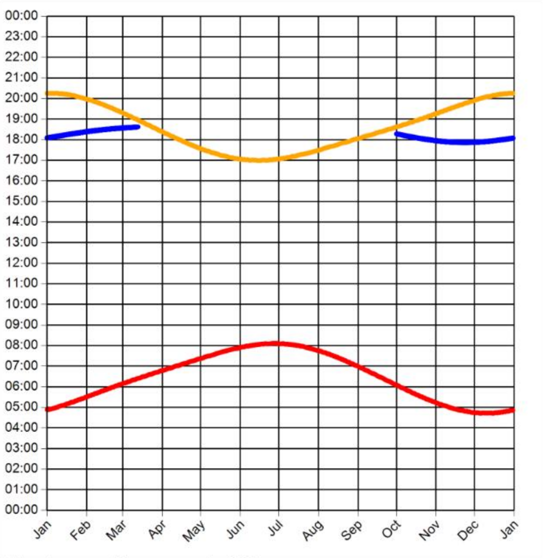
Observer 28 Results

Reflection Date/Time (GMT +12) Graph



Min observer difference angle: 3.2°
Max observer difference angle: 24.1°

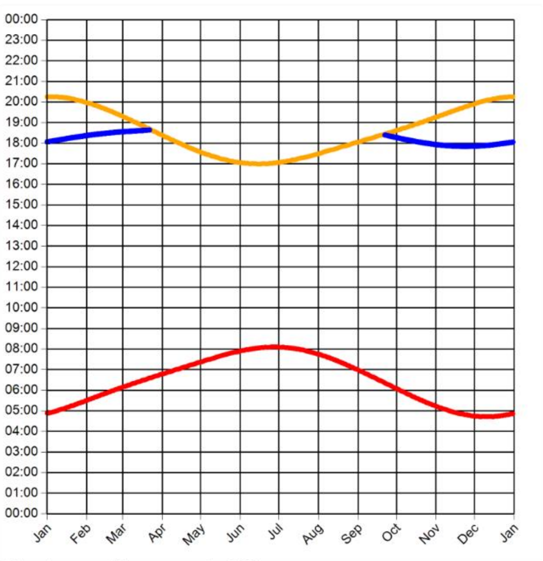
Observer Location

Sun azimuth range is 257° - 268.3° (yellow)

Reflecting panels (yellow)

Observer 29 Results

Reflection Date/Time (GMT +12) Graph



Min observer difference angle: 0.2°
Max observer difference angle: 24.7°

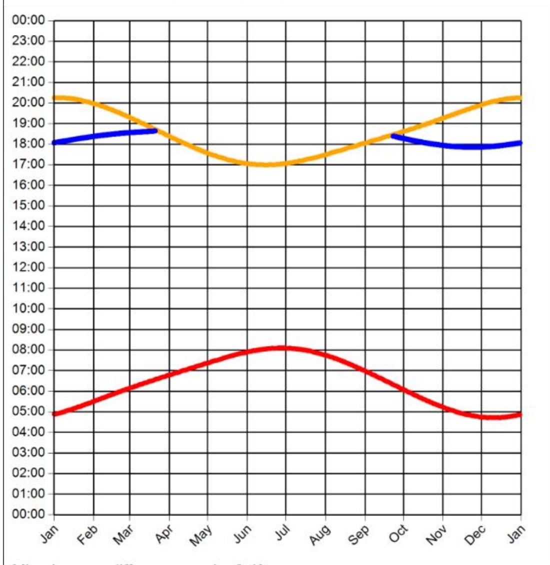
Observer Location

Sun azimuth range is 257.2° - 270.3° (yellow)

Reflecting panels (yellow)

Observer 30 Results

Reflection Date/Time (GMT +12) Graph



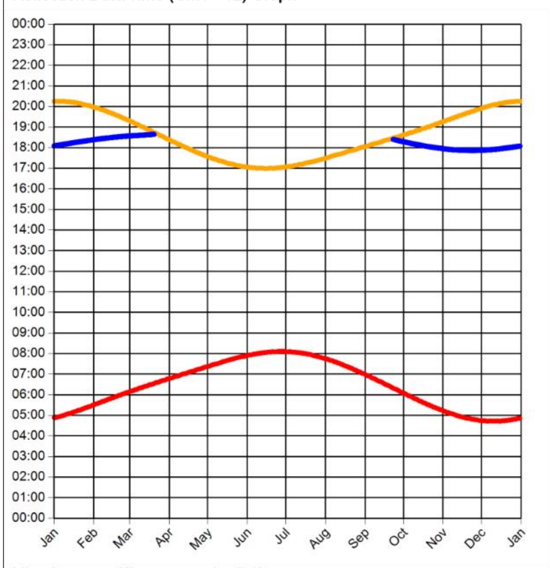
Min observer difference angle: 0.4°
Max observer difference angle: 24.5°

Observer Location — Sun azimuth range is 257.1° - 270° (yellow)

Reflecting panels (yellow)

Observer 31 Results

Reflection Date/Time (GMT +12) Graph



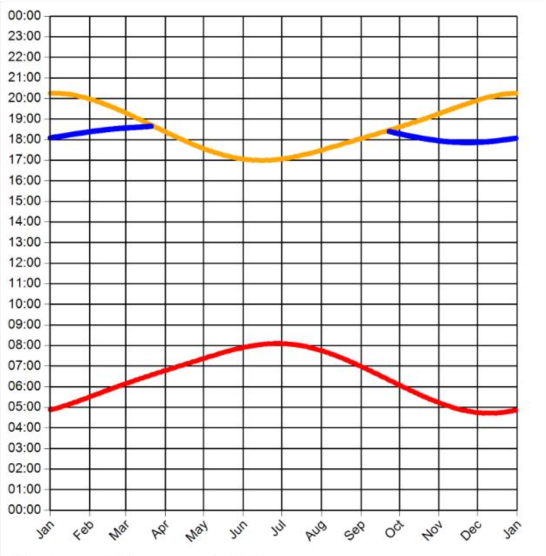
Min observer difference angle: 0.4°
Max observer difference angle: 24°

Observer Location — Sun azimuth range is 257° - 269.8° (yellow)

Reflecting panels (yellow)

Observer 32 Results

Reflection Date/Time (GMT +12) Graph



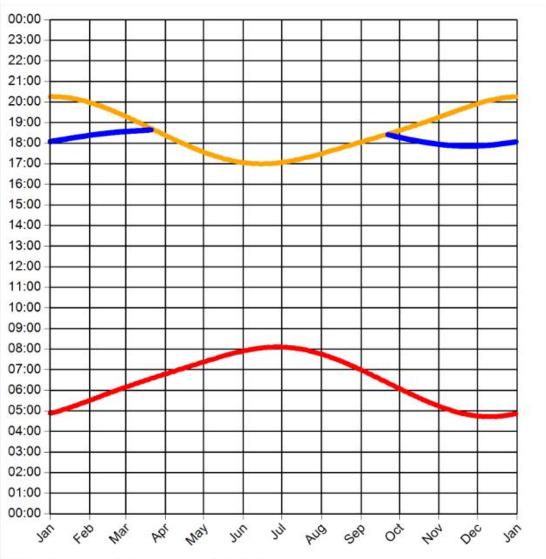
Min observer difference angle: 0.3°
Max observer difference angle: 24.2°

Observer Location — Sun azimuth range is 257.1° - 270° (yellow)

Reflecting panels (yellow)

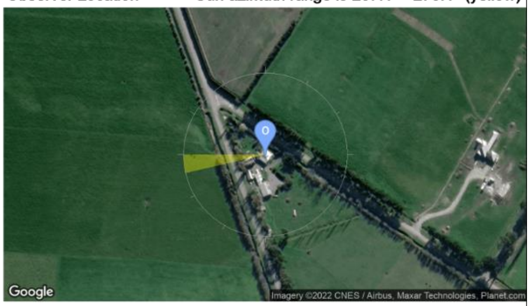
Observer 33 Results

Reflection Date/Time (GMT +12) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 24.4°

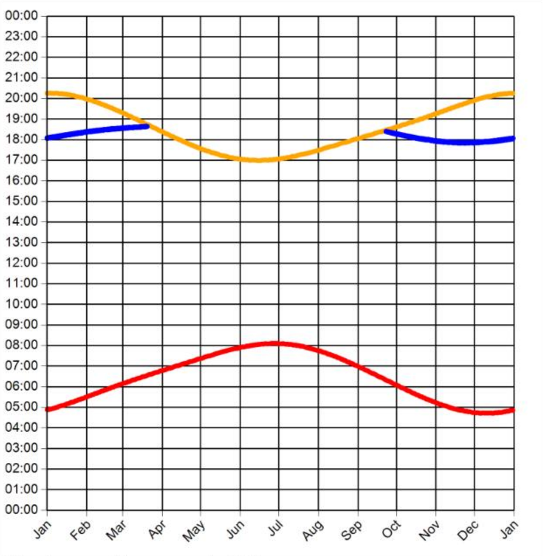
Observer Location — Sun azimuth range is 257.1° - 270.1° (yellow)



Reflecting panels (yellow)

Observer 34 Results

Reflection Date/Time (GMT +12) Graph



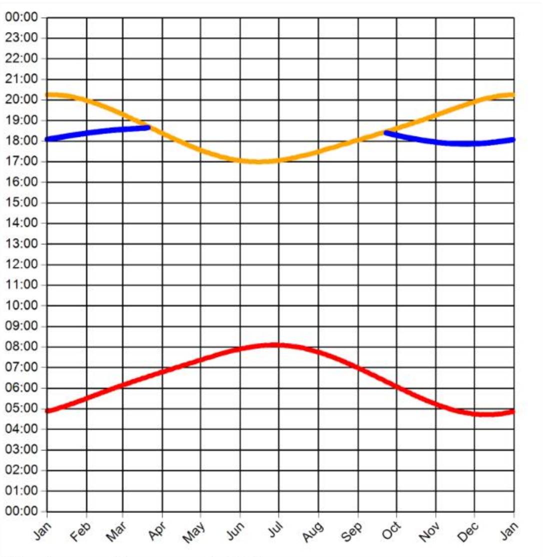
Min observer difference angle: 0.4°
Max observer difference angle: 25.1°

Observer Location Sun azimuth range is 257.1° - 269.9° (yellow)

Reflecting panels (yellow)

Observer 35 Results

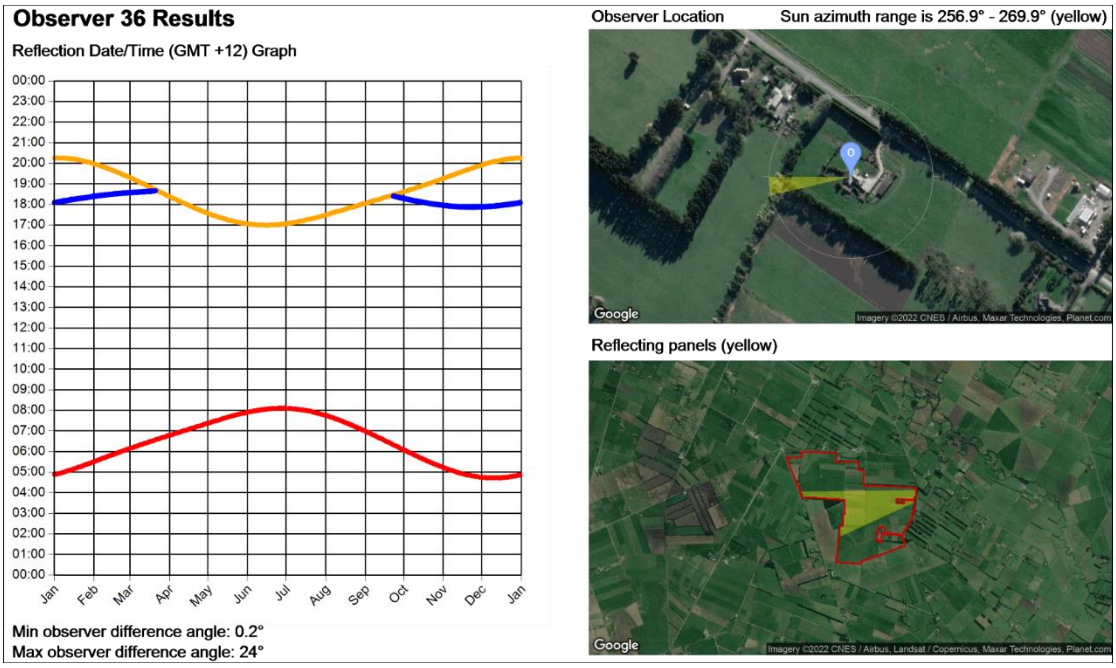
Reflection Date/Time (GMT +12) Graph

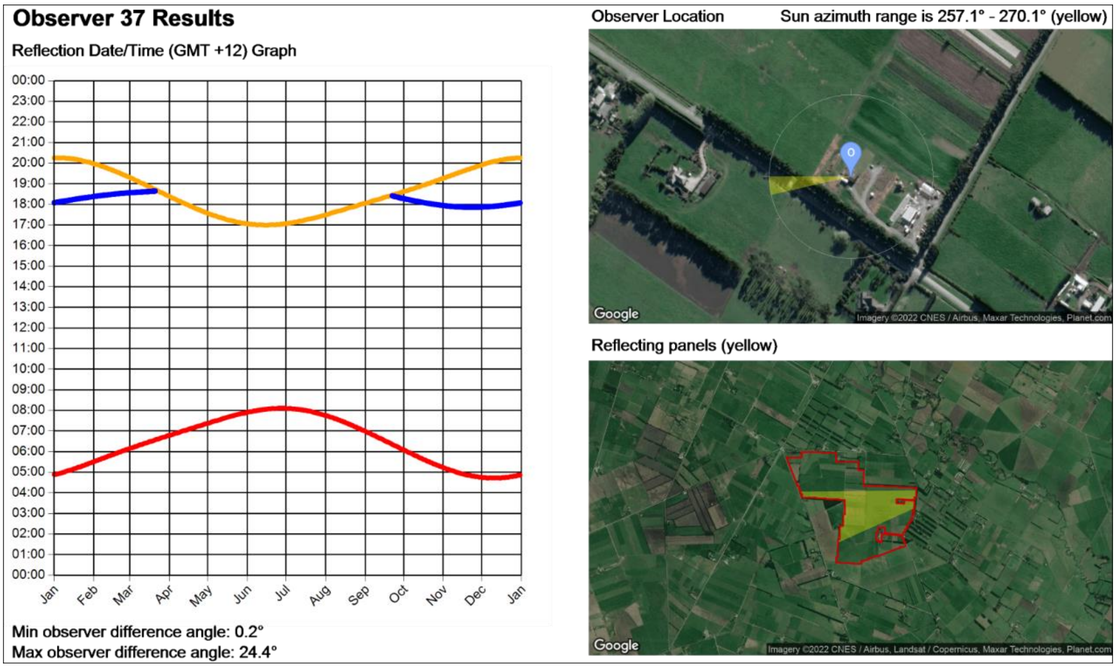


Min observer difference angle: 0.3°
Max observer difference angle: 24.1°

Observer Location Sun azimuth range is 257° - 269.9° (yellow)

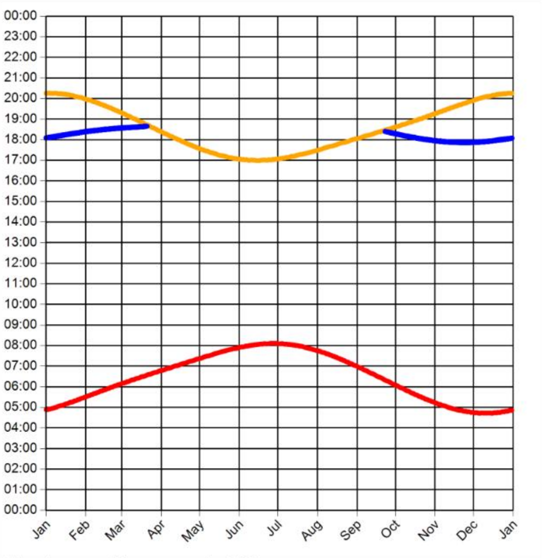
Reflecting panels (yellow)


Observer 36 Results
Reflection Date/Time (GMT +12) Graph
Min observer difference angle: 0.2°
Max observer difference angle: 24°
Observer Location
Sun azimuth range is 256.9° - 269.9° (yellow)
Reflecting panels (yellow)


Observer 37 Results
Reflection Date/Time (GMT +12) Graph
Min observer difference angle: 0.2°
Max observer difference angle: 24.4°
Observer Location
Sun azimuth range is 257.1° - 270.1° (yellow)
Reflecting panels (yellow)

Observer 38 Results

Reflection Date/Time (GMT +12) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 24.2°

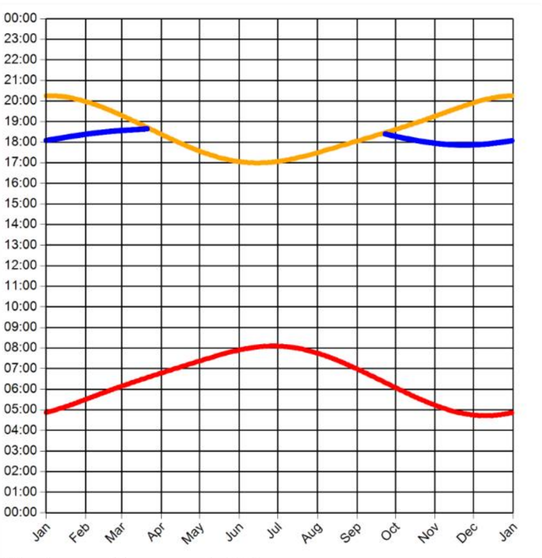
Observer Location

Sun azimuth range is 257° - 269.9° (yellow)

Reflecting panels (yellow)

Observer 39 Results

Reflection Date/Time (GMT +12) Graph



Min observer difference angle: 0.3°
Max observer difference angle: 24.2°

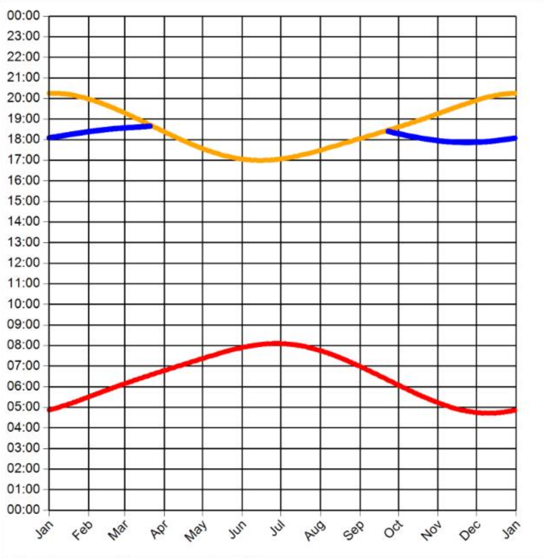
Observer Location

Sun azimuth range is 257.1° - 270° (yellow)

Reflecting panels (yellow)

Observer 40 Results

Reflection Date/Time (GMT +12) Graph



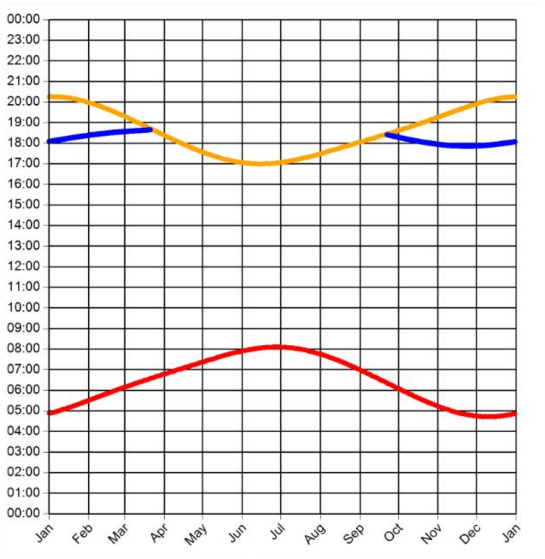
Min observer difference angle: 0.3°
Max observer difference angle: 24°

Observer Location — Sun azimuth range is 257° - 269.9° (yellow)

Reflecting panels (yellow)

Observer 41 Results

Reflection Date/Time (GMT +12) Graph



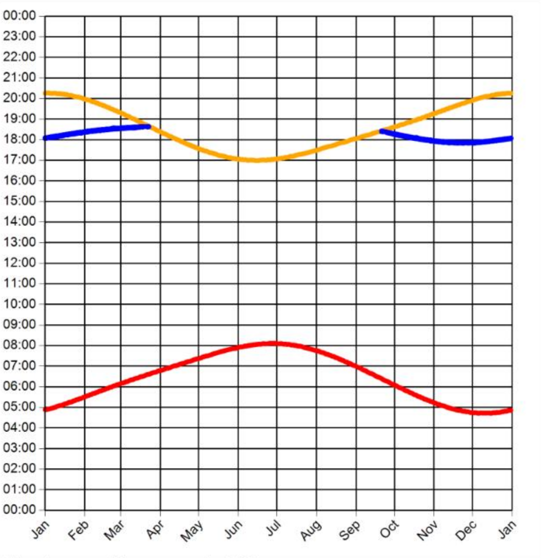
Min observer difference angle: 0.2°
Max observer difference angle: 24.3°

Observer Location — Sun azimuth range is 257° - 270° (yellow)

Reflecting panels (yellow)

Observer 42 Results

Reflection Date/Time (GMT +12) Graph



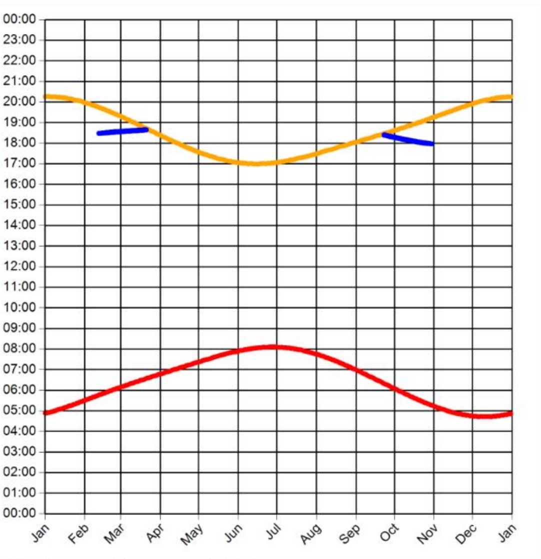
Min observer difference angle: 0.3°
Max observer difference angle: 24.6°

Observer Location — Sun azimuth range is 257.1° - 270.6° (yellow)

Reflecting panels (yellow)

Observer 43 Results

Reflection Date/Time (GMT +12) Graph



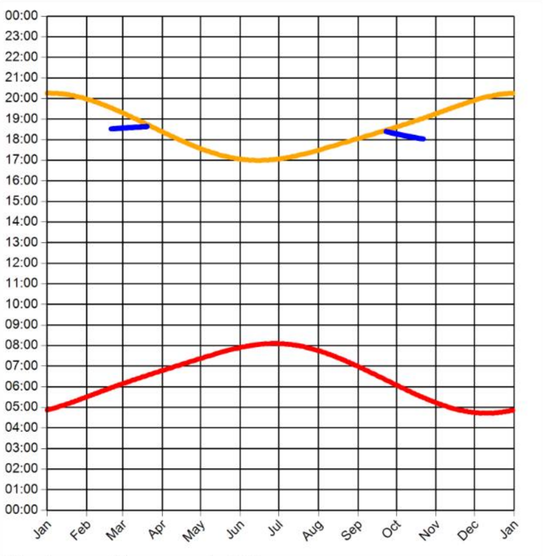
Min observer difference angle: 0.3°
Max observer difference angle: 14°

Observer Location — Sun azimuth range is 262.6° - 270° (yellow)

Reflecting panels (yellow)

Observer 44 Results

Reflection Date/Time (GMT +12) Graph



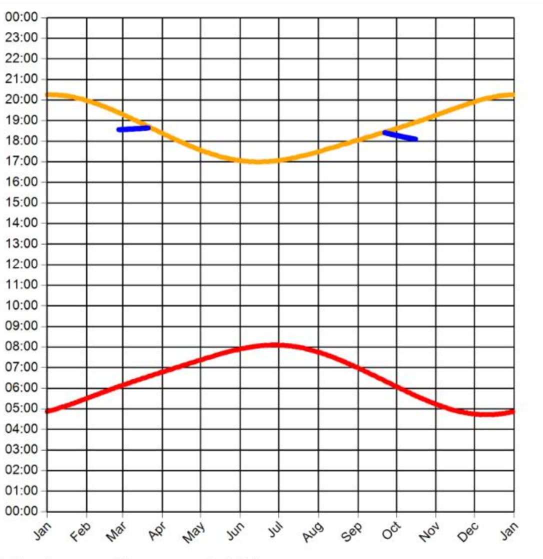
Min observer difference angle: 0.5°
Max observer difference angle: 11.3°

Observer Location   Sun azimuth range is 264.1° - 269.9° (yellow)

Reflecting panels (yellow)

Observer 45 Results

Reflection Date/Time (GMT +12) Graph



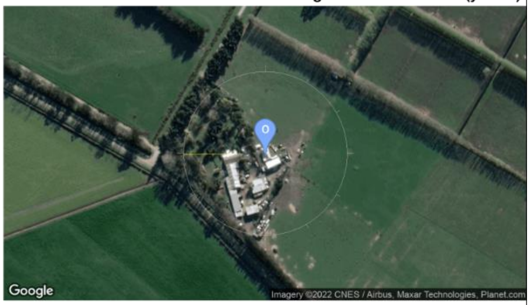
Min observer difference angle: 0.2°
Max observer difference angle: 8.9°

Observer Location   Sun azimuth range is 265.3° - 270.2° (yellow)

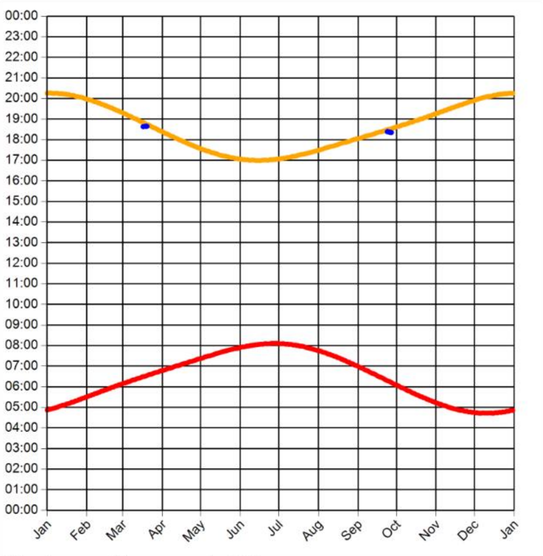
Reflecting panels (yellow)

Observer 46 Results

Observer Location — Sun azimuth range is 268.9° - 269.7° (yellow)



Reflection Date/Time (GMT +12) Graph



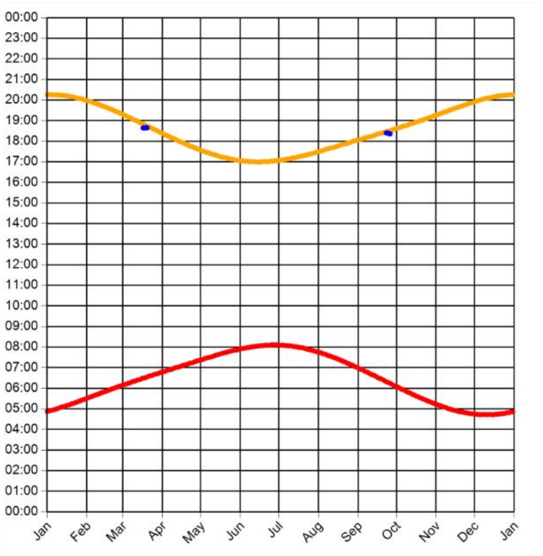
Reflecting panels (yellow)

Min observer difference angle: 0.5°
Max observer difference angle: 1.5°

Observer 47 Results

Observer Location — Sun azimuth range is 269° - 269.8° (yellow)

Reflection Date/Time (GMT +12) Graph



Reflecting panels (yellow)

Min observer difference angle: 0.3°
Max observer difference angle: 1.4°

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