PAGERPOWER

Solar Photovoltaic Glint and Glare Study

Prepared for:

Hitatchi Europe Limited

Smart Energy Islands – Scilly Isles

November, 2017

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Issue	Date	Detail of Changes
1	14 November, 2017	Initial issue
2	17 November, 2017	Second issue – glare intensity modelled
3	30 November, 2017	Third issue – additional areas considered

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EXECUTIVE SUMMARY

Report Purpose

This report has assessed the potential glint and glare impacts of multiple proposed rooftop solar panels, and a single ground-mounted solar garden, on aviation activity at St Mary's Airport on the Scilly Isles. Potential reflections have been modelled and evaluated in the context of aviation safety.

Guidance

There is limited formal guidance for the assessment of glint and glare in Europe. Pager Power has published a recommended methodology based on international guidance, independent studies and consultation with industry stakeholders including aviation authorities. This guidance has been referenced throughout the document and is available via the company website or on request.

Receptors

This report has modelled reflections throughout the year towards:

- Pilots on final approach to all available runways out to two miles from the threshold. In the case of St Mary's Airport this has included the east-west runway (09/27) and the northwest-southeast runway (14/32).
- Personnel in the Visual Control Room (Air Traffic Control tower).

Conclusions – Rooftop Panels

<u>Reflections from the rooftop panels are likely to be insignificant with regard to aviation safety</u>. Specifically, the assessment has found:

- Effects would not be noticeable from within the Air Traffic Control tower because the panels areas that could reflect sunlight towards it are unlikely to be visible. This is due to screening and separation distance.
- Impacts would be minimal in practice for pilots on approach to the airport. Reflections are possible towards approaching pilots on all approaches at various times throughout the year. This is because of the scattered locations of the rooftops and their varying orientations. The predicted intensity of the glare in some cases, including the panels nearest the airport itself, is categorised as having 'potential to cause a temporary after-image'. These effects are likely to be tolerable in practice because:
    - Effects are restricted in duration for each individual panel, due to their small size.
    - Effects would be transient for a moving receptor such as an aircraft as it passes through the reflection zone.
    - Many of the panels will be located outside a pilot's primary field of view as the aircraft approaches the runway threshold to land.
- The resulting impact of the rooftop developments may be a 'twinkling' of numerous small illuminations for an observer looking towards the panels. Such effects can be experienced from windows and other reflective surfaces in an urban environment, commonly encountered by pilots.
- The surrounding area contains reflective sources including glass conservatories and bodies of water. Still water has reflective properties and intensities similar to solar panels.

Conclusions – Solar Garden

Reflections from the ground-mounted system proposed at the airport may be operationally tolerable. The predicted intensity of reflection could cause a temporary after-image for approaching pilots. Potential effects are restricted due to the size of the development, and the transient nature of the reflections.

Next Steps

- The results of this assessment should be made available to the planning authority and St Mary's Airport for discussion.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 43 countries within Europe, Africa, America, Asia and Australia.

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 Introduction

Pager Power has been retained to assess the possible effects of glint and glare from a multiple proposed rooftop solar arrays on residential properties located on the Scilly Isles. Specifically, the residences are primarily located in Old Town, Hugh Town and Sally Port. Additional areas have also been modelled, including a ground-mounted system at St. Mary's Airport.

This assessment pertains to the possible effects upon aviation activity – with specific regard to St Mary's 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.
- Mitigation discussion.

1.2 Pager Power's Experience

Pager Power has conducted a comprehensive industry consultation exercise with developers and stakeholders. This has been carried out for specific developments and, in a wider context, in order to produce comprehensive guidelines for the assessment of solar glint and glare.

Pager Power has undertaken over 250 Glint and Glare assessments in the United Kingdom, Ireland, and internationally. The studies have included assessment of civil and military aerodromes, railway infrastructure, radar installations and other ground based receptors including roads and dwellings.

1.3 Glint and Glare Definition

The definition of glint and glare can vary however, the definition used by Pager Power is as follows:

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

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

2 PROPOSED SOLAR DEVELOPMENT LOCATION AND DETAILS

2.1 Rooftop Solar

The proposed development comprises the installation of multiple rooftop panels on residences in Hugh Town, Old Town and Sally Port. The total number of dwellings is approximately ninety. For modelling purposes, adjacent panels with the same characteristics have been combined– resulting in a total of fifty-seven areas that have been modelled.

Additional rooftop locations have been modelled for buildings at St. Mary's Airport, the Desalination Plant, Porthellick Pumping Station, St. Mary's Fire Station and the Porthmellon Waste facility. Finally, a ground-mounted system at the airport has also been modelled.

The azimuth angle – which is the direction the panels are facing – will be determined the location of each rooftop. This means a variety of azimuth angles are utilised over the project as a whole. The relevant angles have been extrapolated from maps and aerial imagery.

The vertical tilt and the height above ground of the panels may vary to an extent, however the assessment has considered a height of six metres above ground level and a vertical tilt angle of 40 degrees above the horizontal. These parameters are typical of a two-storey house. Minor variations in these parameters are unlikely to affect the conclusions of the assessment results significantly.

In the case of the ground-mounted system, the modelling has assumed an azimuth of 180 degrees and modelled vertical tilt angles of 15 and 25 degrees. This covers the range of angles most commonly used for such systems at this latitude.

2.2 Proposed Solar Development Panel Areas

Figures 1 – 10 on the following pages show the proposed panel locations as assessed within this report (provided to Pager Power by Hitachi and Currie and Brown, cropped for clarity). The panel areas are shown by the blue markings. The figure has been annotated with black ellipses to show the combinations that have defined the individually modelled areas within this report.

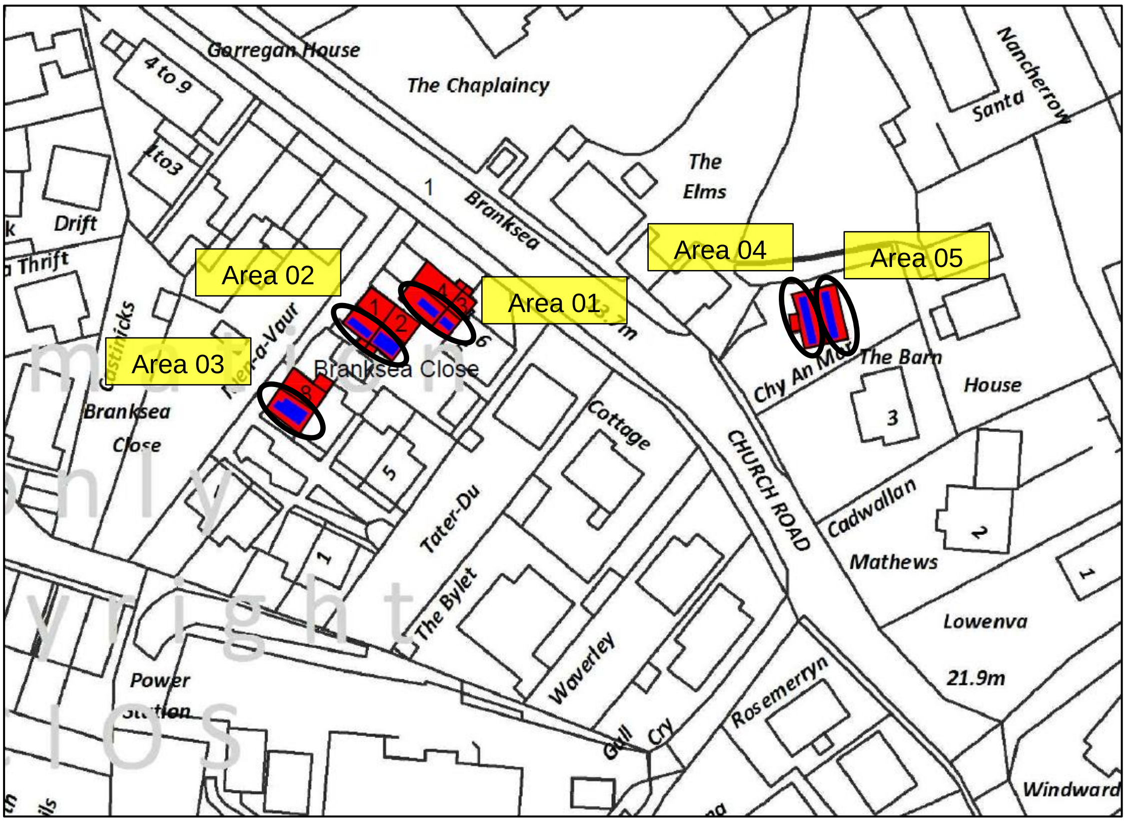

Figure 1 *Panel area Hugh Town (1 of 2)*

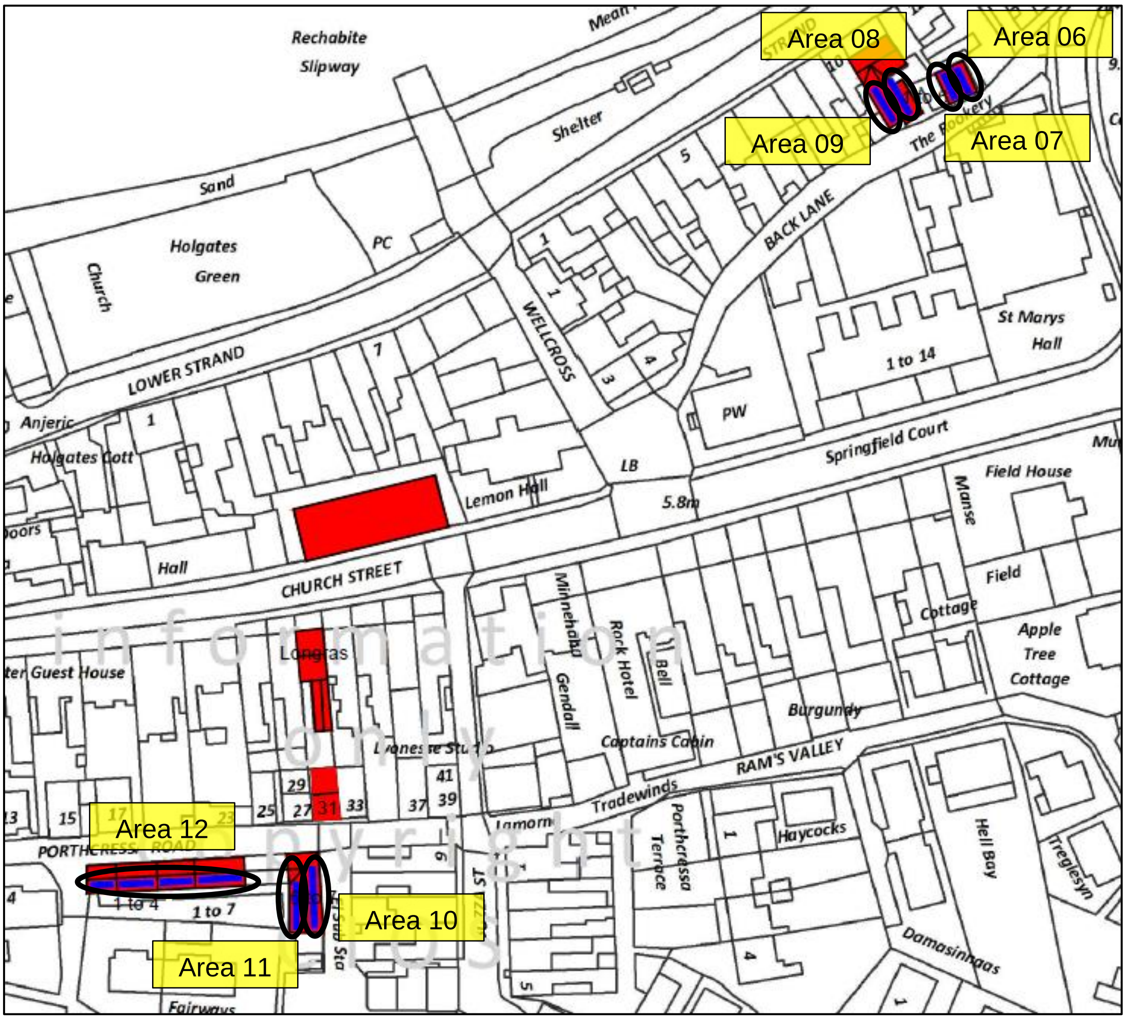

Figure 2 *Panel area Hugh Town (2 of 2)*

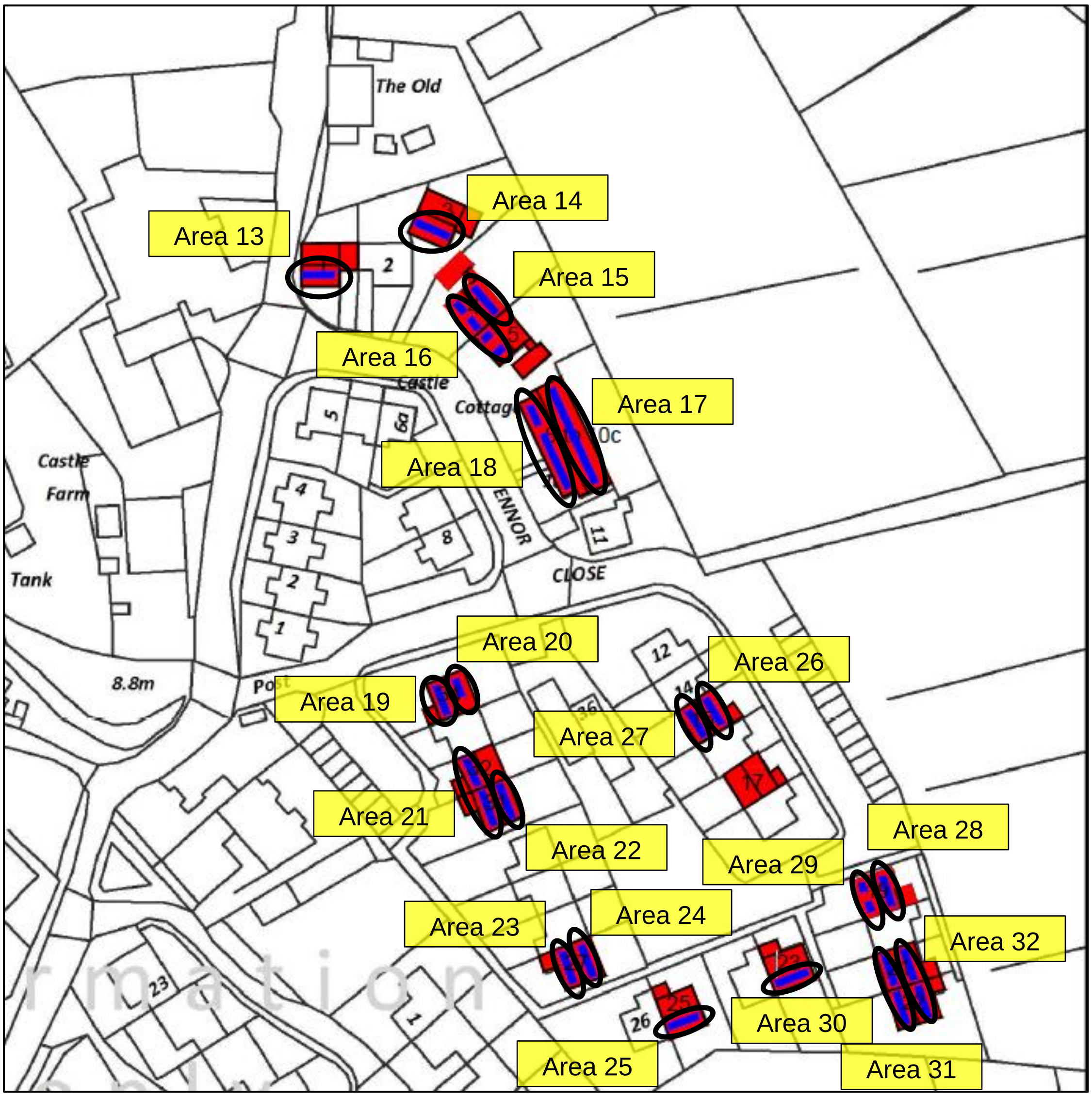

Figure 3 *Panel area Old Town*

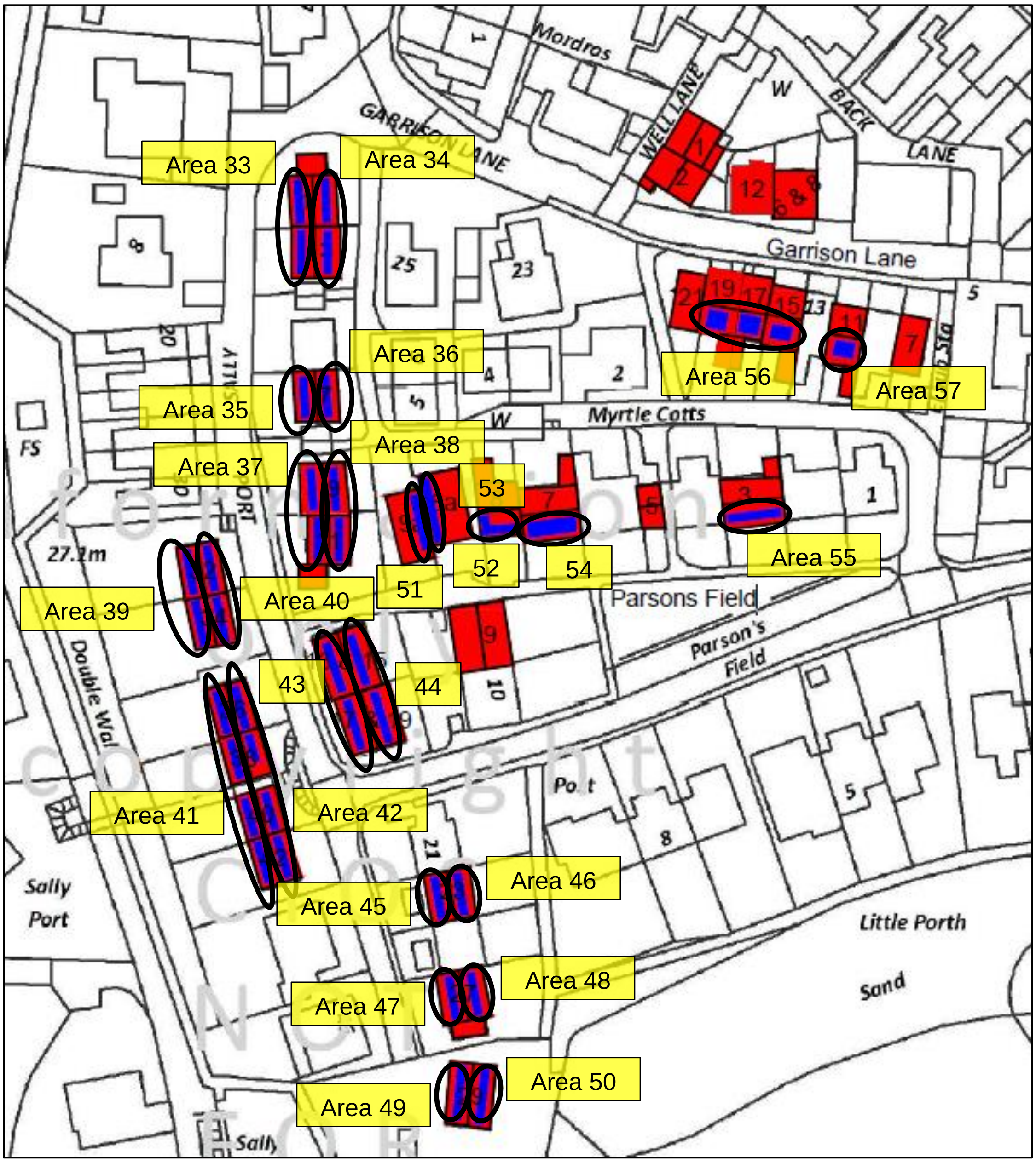

Figure 4 *Panel area Sally Port*

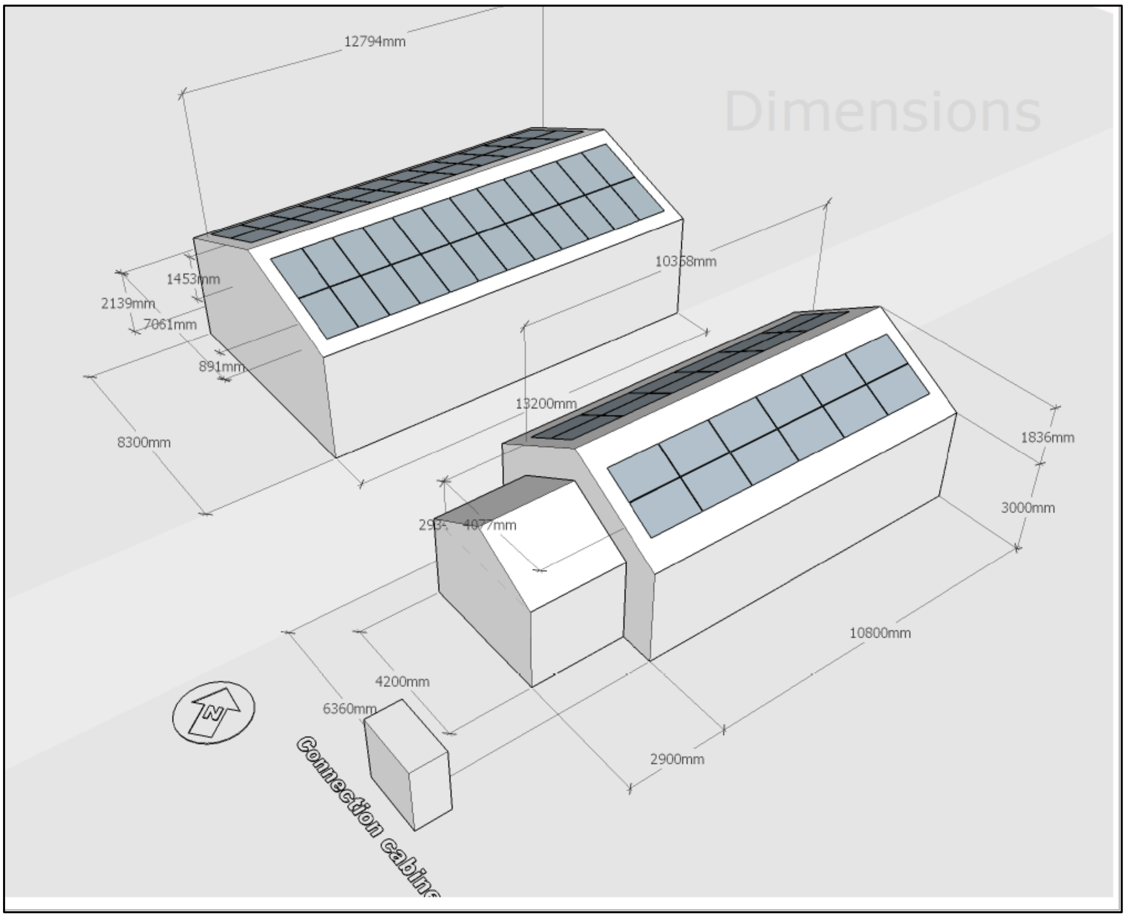

Figure 5 *Panel areas at Desalination Plant (modelled as areas 58-61)*

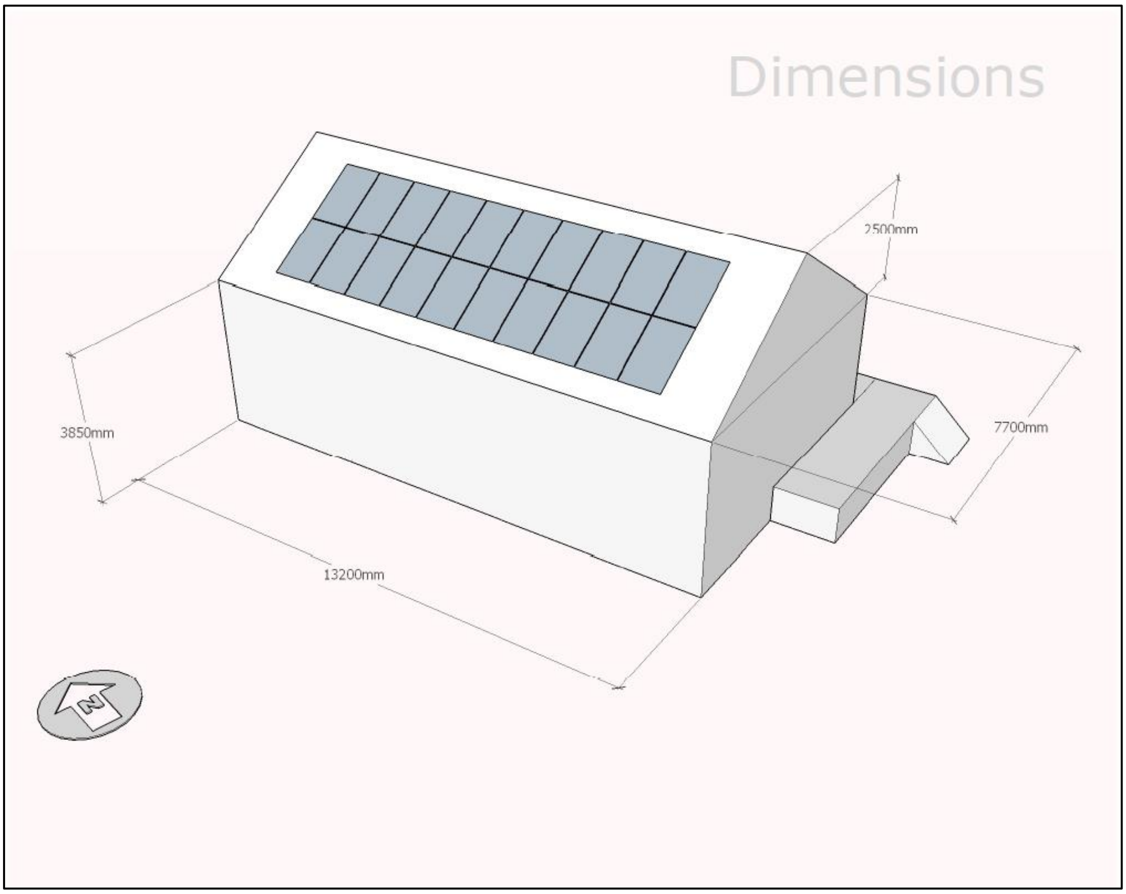

Figure 6 *Panel areas at Pothellick (modelled as areas 62-63)*

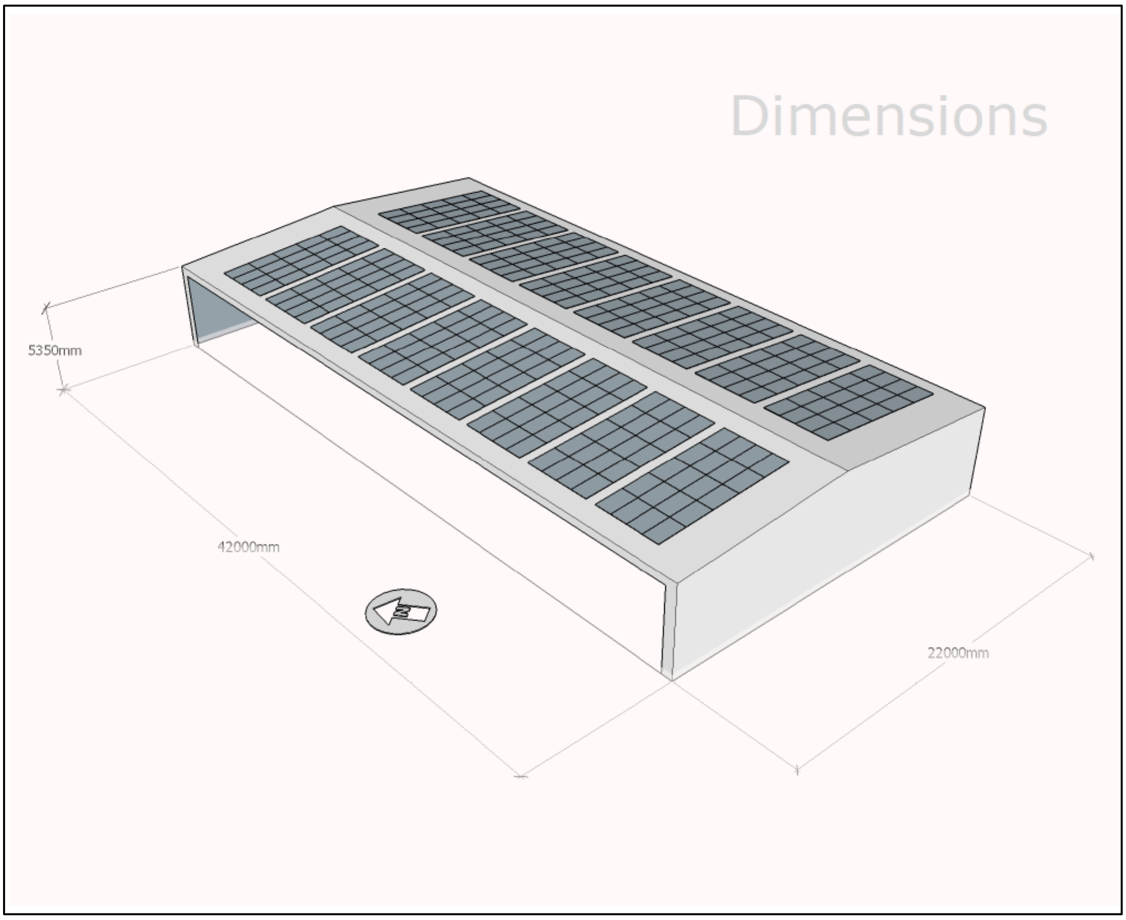

Figure 7 *Panel areas at Porthmellon (modelled as areas 64-65)*

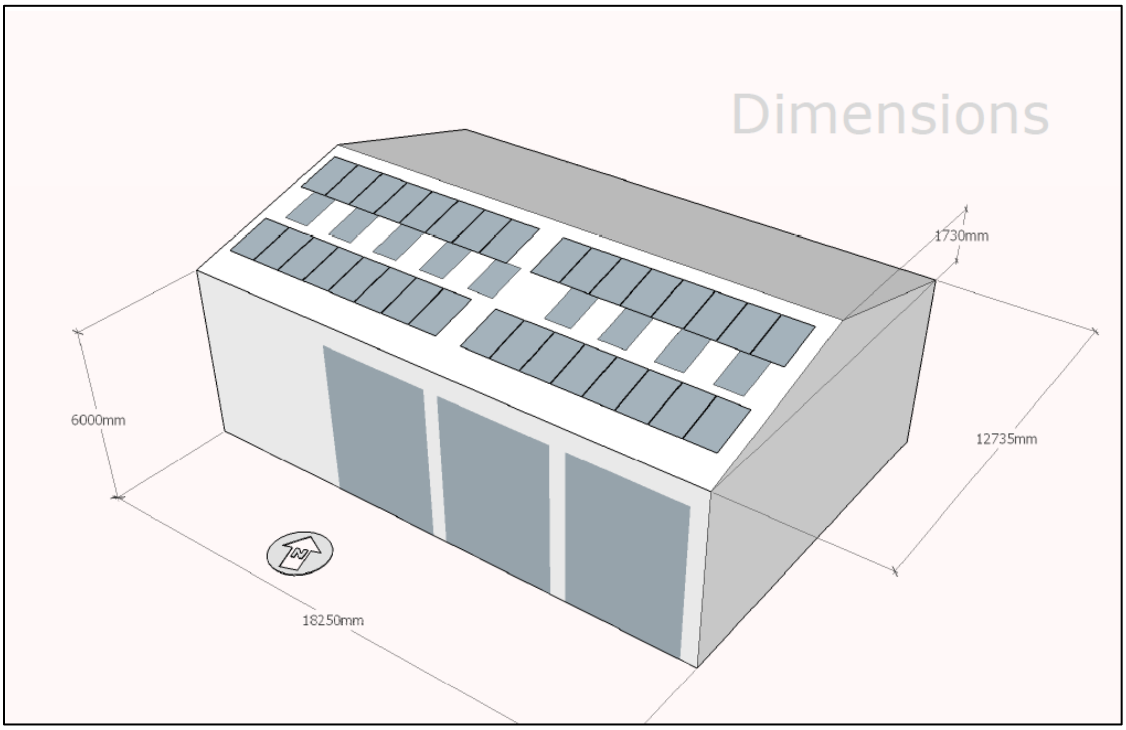

Figure 8 *Panel area at St. Mary's Fire Station (modelled as area 66)*

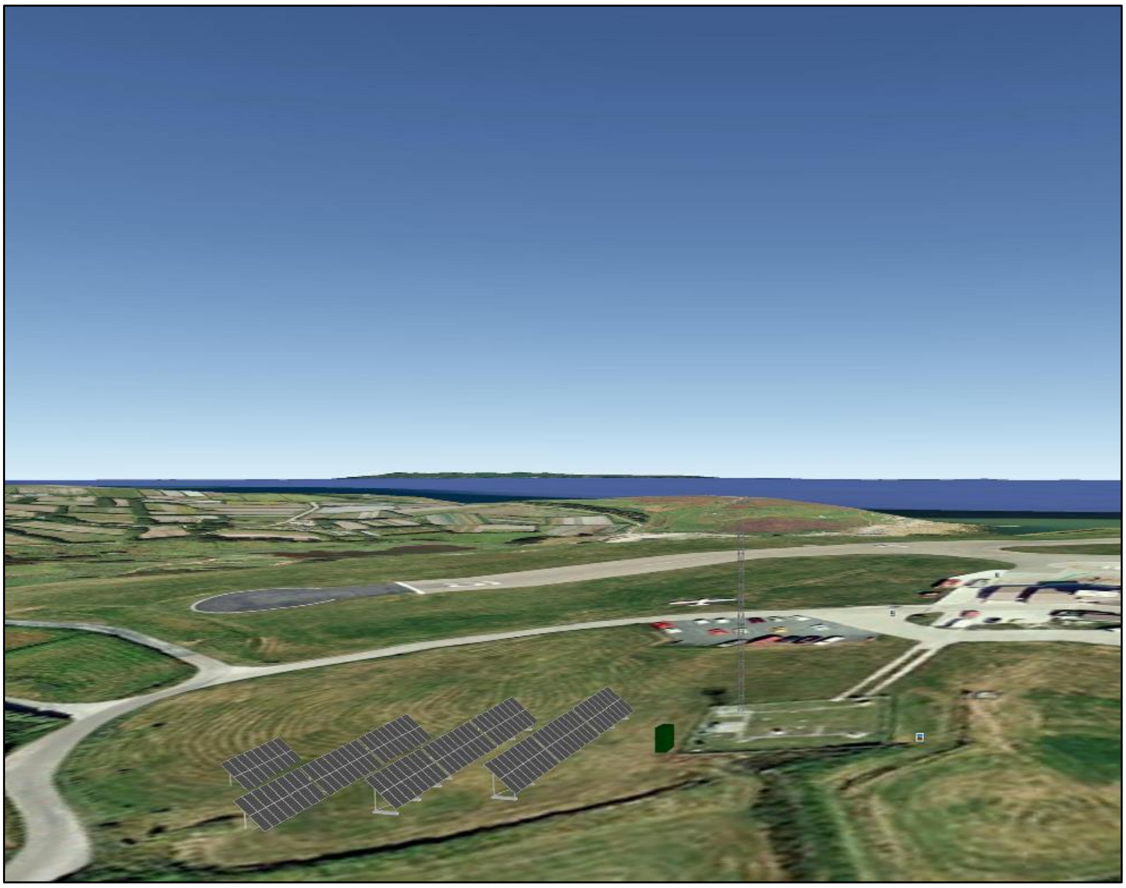

Figure 9 *Ground-mounted system at St. Mary's Airport (modelled as area 67)*

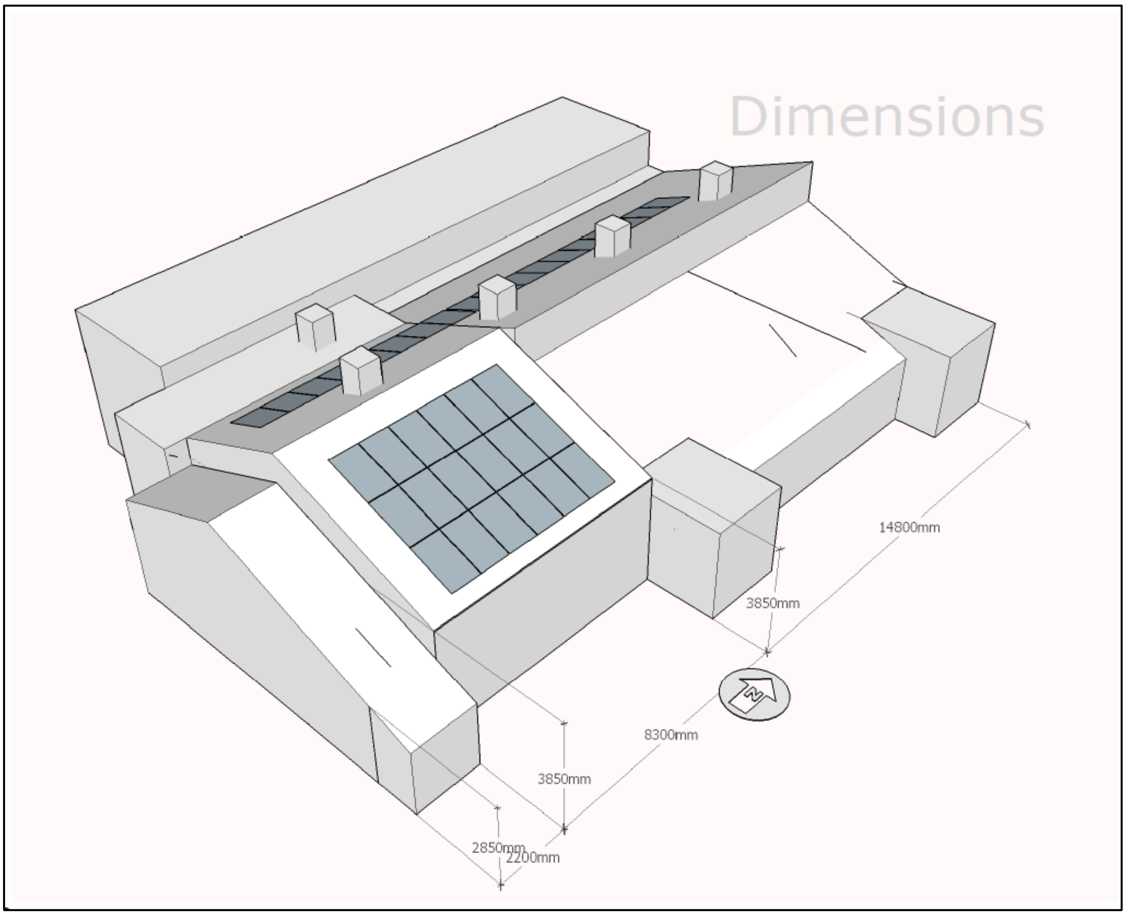

Figure 10 *Rooftop panel areas at St. Mary's Airport (modelled as areas 68-69)*

3 GLINT AND GLARE ASSESSMENT METHODOLOGY

3.1 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. Independent studies regarding the relative reflectivity of solar panels and other materials have been undertaken (see Appendices A and B).

Pager Power's assessment methodology is based on compiled guidance from these sources, industry experience and consultation with the relevant bodies.

Key points from the literature are:

- 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.
- The intensity of reflections from solar panels are equal to or less than those from water. 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 Pager Power 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. The methodology for the aviation glint and glare assessment is shown below.

- Identify receptors in the area surrounding the proposed solar development.
- Consider direct solar reflections from the proposed 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 proposed 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 accordance with the methodology presented in Appendix D.

Within the Pager Power model, the solar development area is defined, as well as the relevant receptor locations. The result is a chart that shows whether a reflection can occur, the duration and the panels that can produce the solar reflection towards the receptor. See Appendix E for technical information regarding the methodology.

3.4 Assessment Limitations

The list of assumptions and limitations are presented in Appendix F.

4 ST MARY'S AIRPORT DETAILS

4.1 Airport Information

St Mary's Airport is a licensed aerodrome with two runways. An ATC tower is present on the airport.

Runway information and the bearing of incoming aircraft have been taken from the NATS AIP accessed November 2017.

4.2 Solar Development and Airport Location

The relative location of the airport to the proposed solar farm is shown[1] in Figure 11 below.

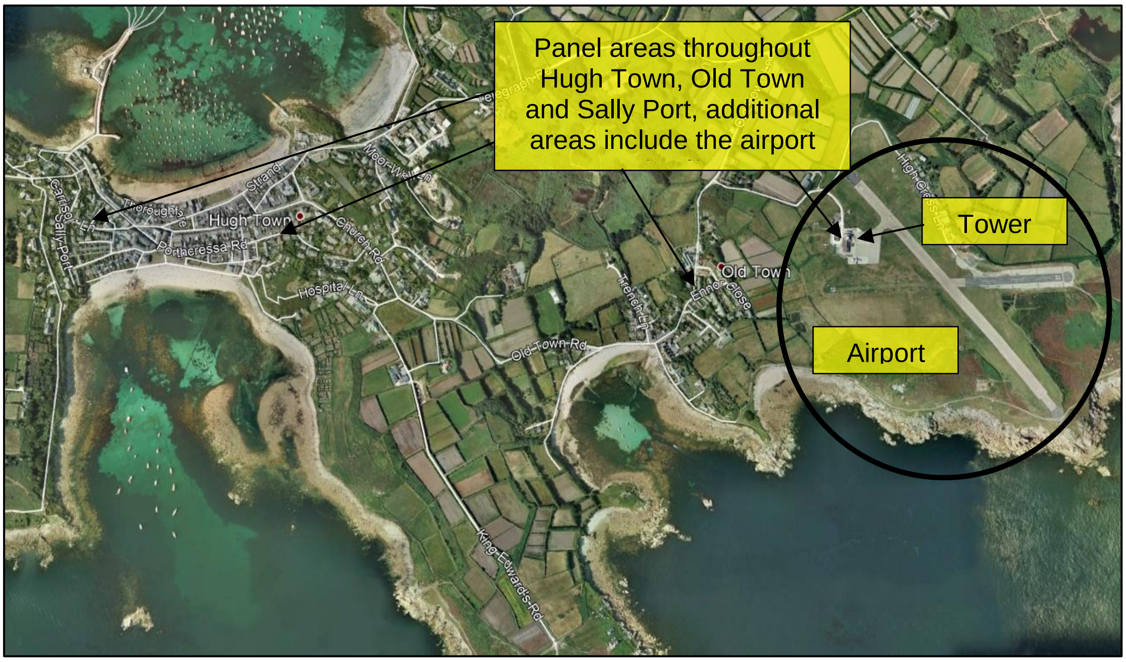

Figure 11 *St Mary's Airport*

[1] Copyright 2017 Getmapping plc, Google

5 IDENTIFICATION OF RECEPTORS

5.1 Air Traffic Control Tower

It is important to determine whether a solar reflection can be experienced by personnel within the ATC tower.

The tower co-ordinates have been extrapolated from aerial imagery. The ground elevation is taken from Pager Power's digital terrain database and ATC height has been estimated as 8 metres above ground level based on available imagery.

Figure 12[2] below shows an aerial photograph of the ATC tower. Panels are proposed on the rooftop immediately south of the tower itself.

Figure 12 *ATC tower location*

[2] Copyright 2017 Getmapping plc, Google

5.2 Airborne Receptors – Approaching Aircraft

It is Pager Power's methodology to assess whether a solar reflection can be experienced on the approach paths for the associated runways because this is considered to be the most critical stage of the flight.

A geometric glint and glare assessment has therefore been undertaken for aircraft approaching runway 09/27 and 14/32. 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.

Figure 13 below shows[3] the receptor points for approaching aircraft (blue icons) and the ATC tower (pink icon).

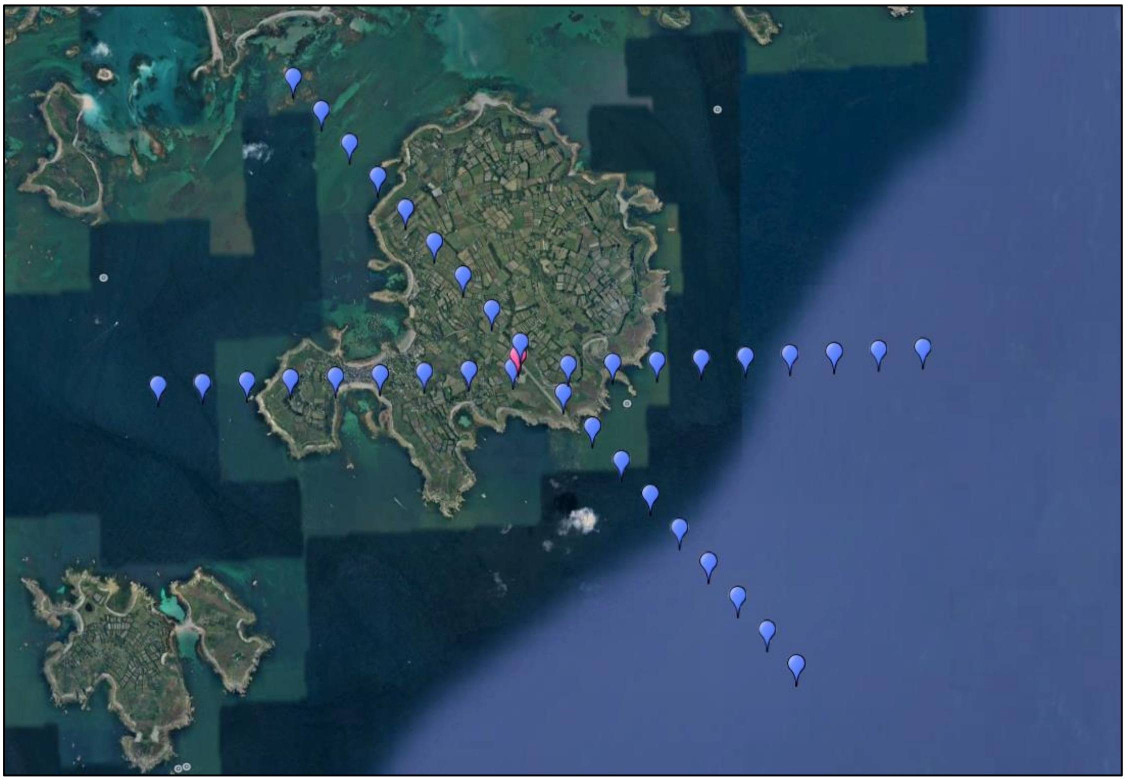

Figure 13 *Approach and ATC receptor locations*

[3] Copyright 2017 Getmapping plc, Google

6 MODELLING THE SOLAR DEVELOPMENT

6.1 Resolution

A number of representative panel locations are selected within each of the modelled areas set out in Section 2. The number of locations is determined by the size of the area and the assessment resolution. All ground heights have been taken from Pager Power's database. Boundary coordinate data is shown in Appendix G.

A resolution of 1 metre has been chosen for this assessment. This means a geometric calculation is undertaken for each identified receptor every 1 metre from within each defined solar panel area. 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 development.

7 GLINT AND GLARE ASSESSMENT

7.1 Findings

Table 1 below summarises the results of the modelling. A full breakdown of dates and times is not presented for each individual panel area, due to the amount of raw data – if required each individual glint and glare chart can be provided upon request.

Appendix H presents the modelling results for a number of the assessed areas – these charts have been examined for all areas and all receptor points in order to build the summary presented below.

Area	Reflections Towards:				
	ATC Tower	Approach 14	Approach 32	Approach 09	Approach 27
01	No	No	Yes	No	Yes
02	No	No	Yes	No	Yes
03	No	No	Yes	No	Yes
04	No	No	No	No	No
05	No	Yes	No	No	No
06	No	Yes	No	No	No
07	No	No	No	No	No
08	No	Yes	No	No	No
09	No	No	No	No	No
10	No	Yes	No	No	No
11	No	No	No	No	No
12	Yes	Yes	Yes	Yes	Yes
13	No	No	Yes	Yes	Yes
14	No	No	Yes	No	Yes
15	No	Yes	No	No	No
16	No	No	No	No	Yes
17	No	Yes	No	No	No
18	No	No	No	No	No
19	No	No	No	No	No
20	No	Yes	No	No	No
21	No	No	No	No	No
22	No	Yes	No	No	No
23	No	No	No	No	Yes

Area	Reflections Towards:				
	ATC Tower	Approach 14	Approach 32	Approach 09	Approach 27
24	No	Yes	No	No	No
25	No	No	Yes	Yes	Yes
26	No	Yes	No	No	No
27	No	No	No	No	No
28	No	Yes	No	No	No
29	No	No	No	No	No
30	No	No	Yes	Yes	Yes
31	No	No	No	No	Yes
32	No	Yes	No	No	No
33	No	No	No	No	No
34	No	Yes	No	No	No
35	No	No	No	No	No
36	No	Yes	No	No	No
37	No	No	No	No	No
38	No	Yes	No	No	No
39	No	No	No	No	No
40	No	Yes	No	No	No
41	No	No	No	No	No
42	No	Yes	No	No	No
43	No	No	No	No	No
44	No	Yes	No	No	No
45	No	Yes	No	No	No
46	No	Yes	No	No	No
47	No	No	No	No	No
48	No	Yes	No	No	No
49	No	No	No	No	No
50	No	Yes	No	No	No
51	No	No	No	No	No
52	No	Yes	No	No	No
53	Yes	Yes	Yes	Yes	Yes

Area	Reflections Towards:				
	ATC Tower	Approach 14	Approach 32	Approach 09	Approach 27
54	Yes	Yes	Yes	Yes	Yes
55	Yes	Yes	Yes	Yes	Yes
56	Yes	No	Yes	Yes	Yes
57	No	No	Yes	No	Yes
58	No	No	No	No	No
59	No	No	No	No	No
60	No	No	Yes	No	No
61	No	No	No	No	No
62	No	No	No	No	No
63	No	Yes	No	No	No
64	No	Yes	No	No	No
65	No	Yes	No	No	No
66	No	Yes	No	Yes	No
67	No	No	No	Yes	Yes
68	No	No	No	Yes	Yes
69	No	Yes	No	No	No

Table 1 *Analysis results summary*

The summary shows that:

- There are 23 areas that do not produce reflections towards any of the aviation receptors.
- There are four areas that produce reflections towards the tower and some portion of each approach.
- The remaining areas produce effects to particular receptor points.

The table above does not consider screening that may limit the visibility of the panel areas from a receptor. Furthermore, a **reflection does not automatically imply a significant impact**. This is discussed further in the following section.

7.2 Glare Intensity Modelling

Where the Pager Power model has predicted a solar reflection, glare intensity calculations are required to determine the acceptability of the impact. Pager Power's methodology is to utilise the approach published by Sandia Laboratories in the USA. This model is recommended by the Federal Aviation Administration in the USA and has been referenced by aerodrome operators in other countries including the UK.

Historically, a model called the 'Solar Glare Hazard Analysis Tool (SGHAT) was available to perform such calculations. At the time of writing, this tool is only available to military or government users. The methodology behind the calculations is available and has been replicated by Pager Power, in order to assess developments against the recommended standard. Table 2 below sets out the glare intensity categories utilised within the assessment.

Coding Used	Intensity Key
Low potential	Low potential for temporary after-image
Potential	Potential for temporary after-image
Potential for permanent eye damage	Potential for permanent eye damage

Table 2 *Glare intensity designation*

This coding has been used in the table where a reflection has been calculated for four scenarios, covering:

- Panels in the three main development areas (Hugh Town, Old Town and Sally Port).
- Panels that are the closest to the airport – including those on the airport building and the ground-mounted system.
- Panels that produce glare to the highest number of receptors.

In each case, the predicted reflections were considered in order to identify the date and time at which worst-case effects could reasonably be expected, based on professional judgement.

The Sandia Laboratories model allows for assessment of a variety of solar panel surface materials. In the first instance, a solar panel surface material of 'smooth glass without an anti-reflective coating' is assessed. This is the most reflective solar panel surface and allows for a 'worst case' assessment. Other surfaces that could be modelled include:

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

Table 3 below sets out the scenarios that have been modelled, and the results of the intensity calculations.

Area	Receptor	Notes	Result	Conclusion
12	Runway 32 (2 miles) 01 August 15:40 GMT	This area was selected because it produces glare towards all approaches. The receptor was selected because it is predicted to have the longest duration of glare (based on inspection of the modelling results).	Low potential for temporary after-image.	This level of glare is acceptable for an approaching aircraft.
17	Runway 14 (0.5 miles) 15 December 10:10 GMT	This area was selected for its proximity to the airport. The receptor was selected because of its proximity to the reflecting panel.	Potential for temporary after-image.	This level of glare requires further consideration to determine its acceptability.

Area	Receptor	Notes	Result	Conclusion
32	Runway 14 (threshold) 01 August 11:55 GMT	This area was selected for its proximity to the airport. The receptor was selected because it is a runway threshold and because of its proximity to the reflecting panel.	Potential for temporary after-image.	This level of glare requires further consideration to determine its acceptability.
42	Runway 14 (0.75 miles) 29 November 10:45 GMT	This area was selected because it is located in the Sally Port region. The receptor was selected because it's the closest affected location to the panels.	Low potential for temporary after-image.	This level of glare is acceptable for an approaching aircraft.
67 (15°)	Runway 27 (Threshold) 01 May 18:40 GMT	This area was selected because of the panels' location on the airport itself. The receptor was selected because it is a runway threshold in close proximity to the panels.	Potential for temporary after-image.	This level of glare requires further consideration to determine its acceptability.
67 (25°)	Runway 27 (Threshold) 01 May 18:15 GMT	This area was selected because of the panels' location on the airport itself. The receptor was selected because it is a runway threshold in close proximity to the panels.	Potential for temporary after-image.	This level of glare requires further consideration to determine its acceptability.
68	Runway 14 (0.25 miles) 05 October 12:20 GMT	This area was selected because of the panels' location on the airport itself.	Potential for temporary after-image.	This level of glare requires further consideration to determine its acceptability.

Table 3 *Glare intensity calculations*

8 RESULTS DISCUSSION

8.1 ATC Tower

There are five areas that could produce a reflection towards the ATC Tower at some point throughout the year. These are areas 12 and 53-56. Figure 14 below shows[4] these locations.

Figure 14 *Panel areas that reflect towards the ATC tower*

These panel areas are more than a kilometre from the ATC tower. Furthermore, due to the low terrain in Hugh Town, and the presence of other buildings around the rooftops containing panels, it is unlikely that an observer in the ATC tower would have a view of the reflecting panels.

<u>No impact on the ATC tower is predicted in practice.</u>

[4] Copyright 2017 Getmapping plc, Google

8.2 Pilots on Approach to Runways

The runway approaches could all experience reflections at some points throughout the year due to the panel locations.

Panel areas that cause reflections would do so for a very limited duration and a small proportion of the year. Figure 15 below shows the potential reflections towards an aircraft at the Runway 14 threshold from Area 12 for reference purposes. The blue lines show the time of day/year that reflections could occur. Whilst the times, dates and durations vary for the different panel areas, this level of reflection is typical for the majority of cases.

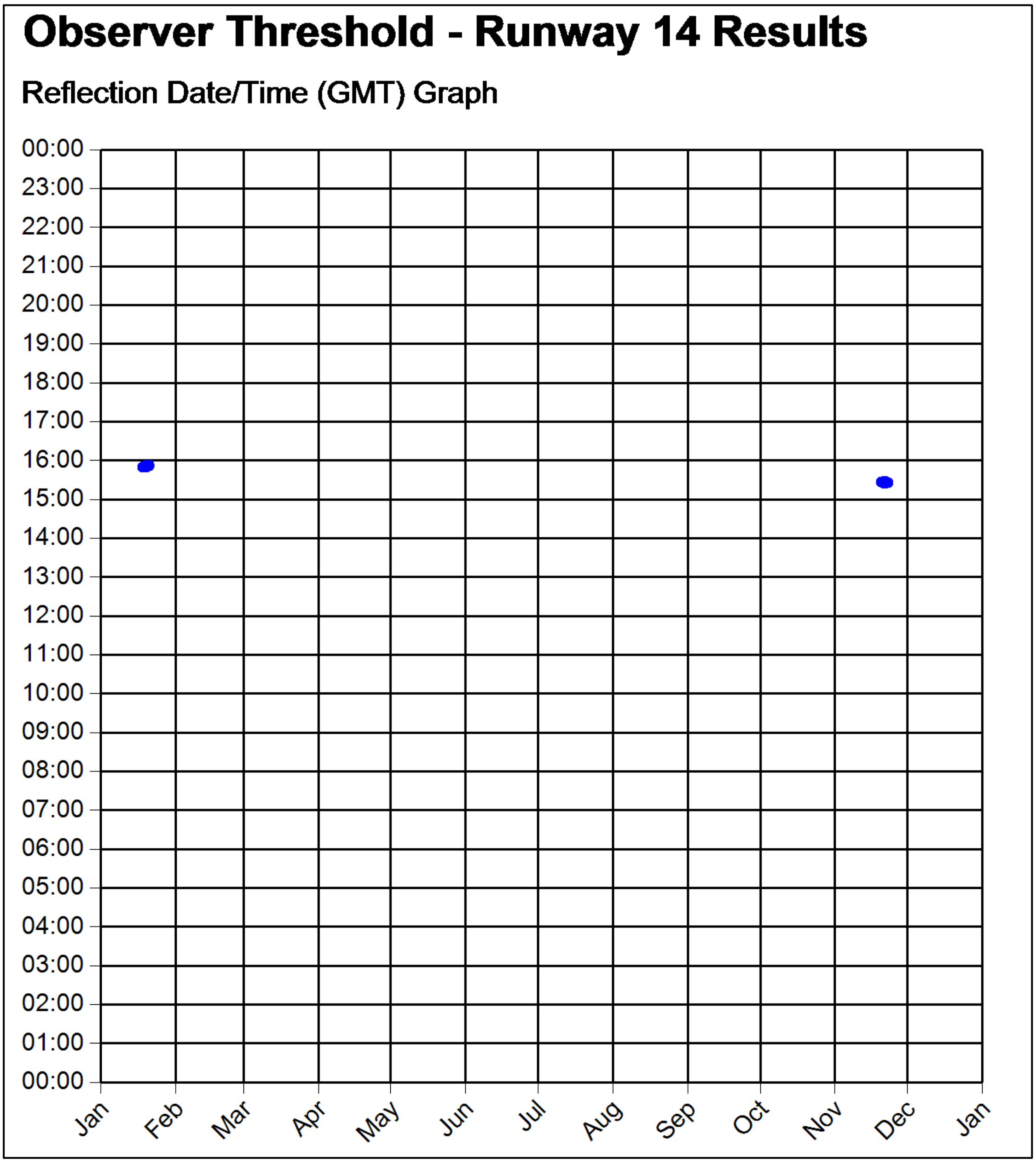

Figure 15 *Glare chart for Runway 14 Threshold*

Further charts are provided in the Appendices – including the scenarios that were modelled as set out in in Table 3.

Yellow glare has been predicted for some of the proposed panels. This includes the panels on the rooftop of the building at the airport and the ground-mounted solar system. Pager Power's assessment methodology for yellow glare on approach to a runway, as set out in Appendix D, is to consider whether the reflection originates from a significant location and for a significant amount of time.

Key points to consider when evaluating the impact in this context are:

- Effects are restricted in duration for each individual panel, due to their small size (particularly for the rooftop developments).
- Effects would be transient for a moving receptor such as an aircraft as it passes through the reflection zone.
- Many of the panels will be located outside a pilot's primary field of view as the aircraft approaches the runway threshold to land.
- The existing environment contains existing reflectors, including bodies of water that are significantly larger than the individual panel areas.

In practice, any noticeable reflections would likely cause a 'twinkling' effect, where a series of illuminations appear instantaneously for an observer looking towards the panels. Such effects are commonly experienced due to windows and other reflective sources in an urban environment.

The proposed solar garden (the ground-mounted system) should be discussed in more detail with the airport, since this is likely to be the largest element of the scheme. It is also located on the airport itself and has the potential to produce a temporary after-image for approaching pilots.

The resulting impact, in accordance with Appendix D is moderate, however the rooftop effects are likely to be operationally tolerable in practice.

<u>The modelling results should be made available to St Mary's Airport for discussion</u>.

9 MITIGATION

9.1 Overview

No mitigation requirement pertaining to the rooftop developments has been identified because no significant impacts are predicted. Discussions with the airport are recommended to fully understand their position regarding the proposed development.

Discussion with the airport is recommended for the whole scheme, in particular the elements that are proposed on the airport itself.

10 OVERALL CONCLUSIONS

10.1 Analysis Results

Table 4 below summarises the results of this assessment.

Receptor	Technical Effects	Likely Impact	Conclusion
ATC tower.	Reflections towards the ATC tower are possible for five of the sixty-nine modelled panel areas.	None – visibility of the reflecting panel locations is not predicted from the ATC tower.	No impact is predicted.
Pilots on final approach (rooftop panels).	Reflections are predicted towards the approaches for all runways from various panel locations.	Some of the areas, including those nearest the airport itself, have the potential to produce a temporary after image in the direction of approaching aircraft. The individual reflecting areas are small and effects will be transient in nature. Any noticeable reflections would most likely produce a twinkling effect caused by a series of low-intensity illuminations from disparate panel areas.	The predicted effects are likely to be tolerable in practice.
Pilots on final approach (solar garden).	Reflections are possible towards pilots approaching runways 09 and 27.	The reflections have the potential to produce a temporary after-image. The effects would be transient in nature and would be restricted due to their limited duration throughout the year.	It is possible that these effects could be operationally tolerated by the airport. Further engagement is recommended.

Table 4 *Analysis results summary*

10.2 Mitigation Requirement

No mitigation requirement has been identified.

10.3 Recommendation

The results of this assessment should be made available to St Mary's Airport and the planning authority.

APPENDIX A – OVERVIEW OF GLINT AND GLARE GUIDANCE

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.

UK Planning Policy

UK National Planning Practice Guidance dictates that in some instances a glint and glare assessment is required however, there is no specific guidance with respect to the methodology for assessing the impact of glint and glare.

The planning policy from the Department for Communities and Local Government (paragraph 27[5]) states:

'Particular factors a local planning authority will need to consider include… the effect on landscape of glint and glare and on ***neighbouring uses and aircraft safety****.'*

The National Planning Policy Framework for Renewable and Low Carbon Energy[6] (specifically regarding the consideration of solar farms) 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

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

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[5] http://planningguidance.planningportal.gov.uk/blog/guidance/renewable-and-low-carbon-energy/

[6]Reference ID: 5-013-20140306, paragraph 13-13,http://planningguidance.planningportal.gov.uk/blog/guidance/renewable-and-low-carbon-energy/particular-planning-considerations-for-hydropower-active-solar-technology-solar-farms-and-wind-turbines/

APPENDIX B – OVERVIEW OF GLINT AND GLARE STUDIES

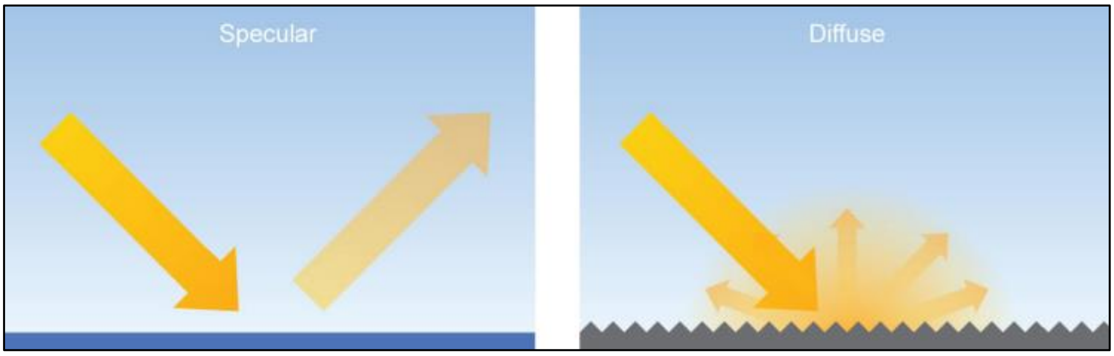
Overview

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

There are no specific studies for determining the effect of reflections from solar panels with respect to roads and dwellings. 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[7], taken from the FAA guidance, 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

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*[8]". 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 on the following page.

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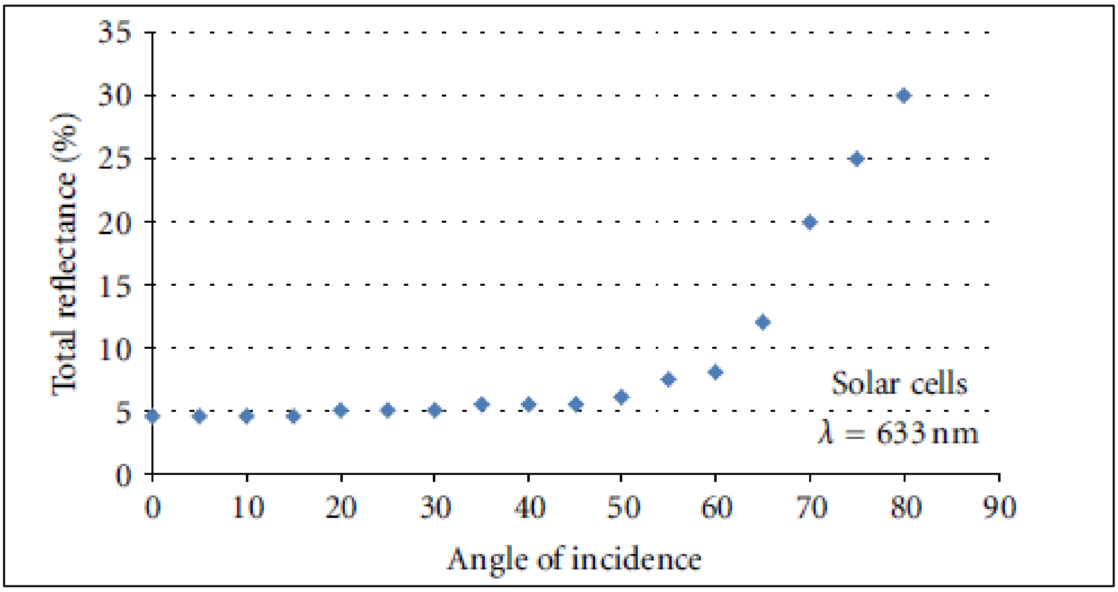
[7] http://www.faa.gov/airports/environmental/policy_guidance/media/airport_solar_guide_print.pdf

[8] 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



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.

FAA Guidance- "Technical Guidance for Evaluating Selected Solar Technologies on Airports"[9]

The 2010 FAA Guidance (discussed in section 4) 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[10] within the FAA guidance, is presented on the following page.

[9] FAA, November (2010): *Technical Guidance for Evaluating Selected Solar Technologies on Airports.*
[10] http://www.faa.gov/airports/environmental/policy_guidance/media/airport_solar_guide_print.pdf

Surface	Approximate Percentage of Light Reflected[11]
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[12] to '*increase awareness concerning the possible glare and reflectance impact of PV Systems on their surrounding environment'.* The study revealed that the reflectivity of a solar panel is considerably lower than that 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.

Figures within the document show the relative reflectivity of solar panels compared to other natural and manmade materials including smooth water, standard glass and steel. 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 produced from these surfaces.

[11] Extrapolated data, baseline of 1,000 W/m^2 for incoming sunlight.
[12] 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 combination of the Sun's azimuth angle and vertical elevation will affect the direction and angle of the reflection from a solar panel.

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.

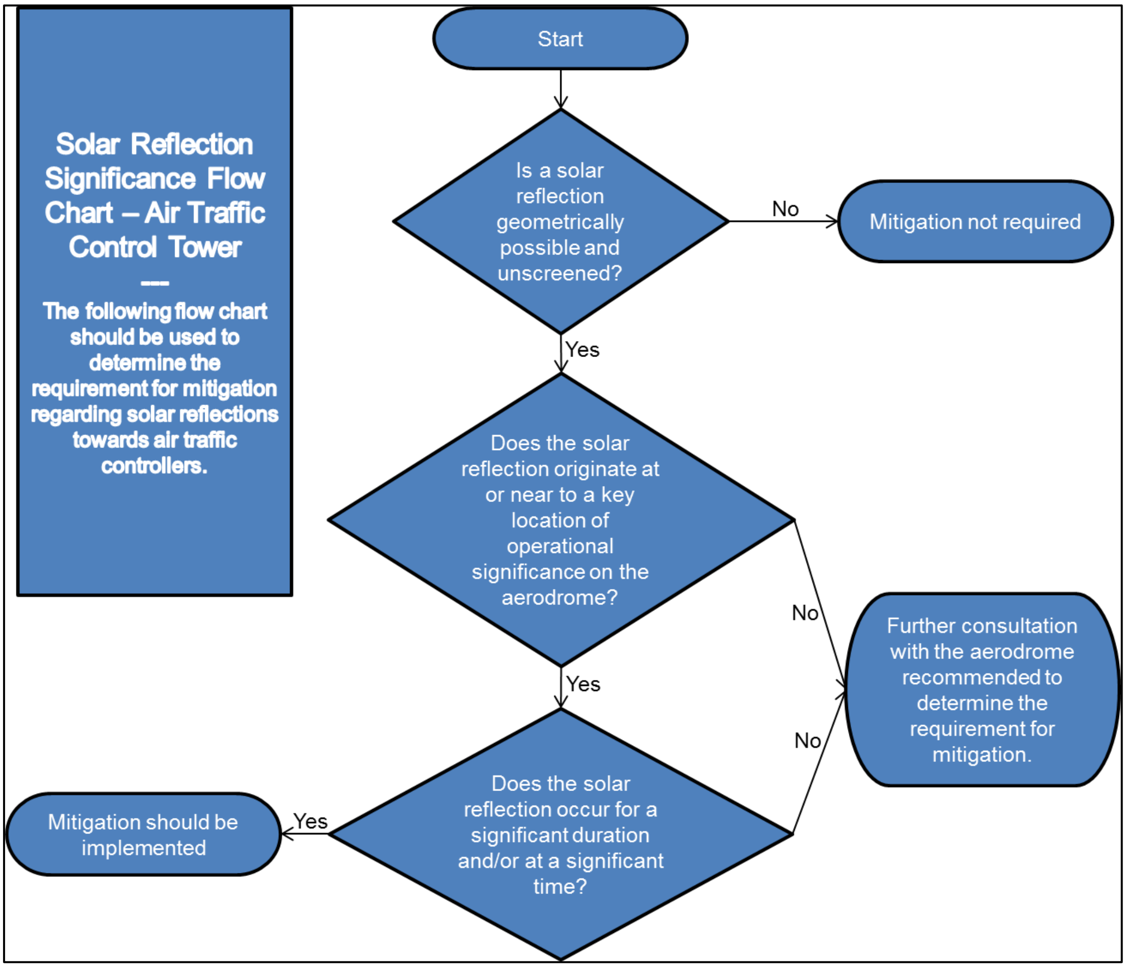
Impact Significance	Definition	Mitigation Requirement
No Impact	A solar reflection is not geometrically possible or will not be visible from the assessed receptor.	No mitigation required.
Low	A solar reflection is geometrically possible however any impact is considered to be small such that mitigation 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

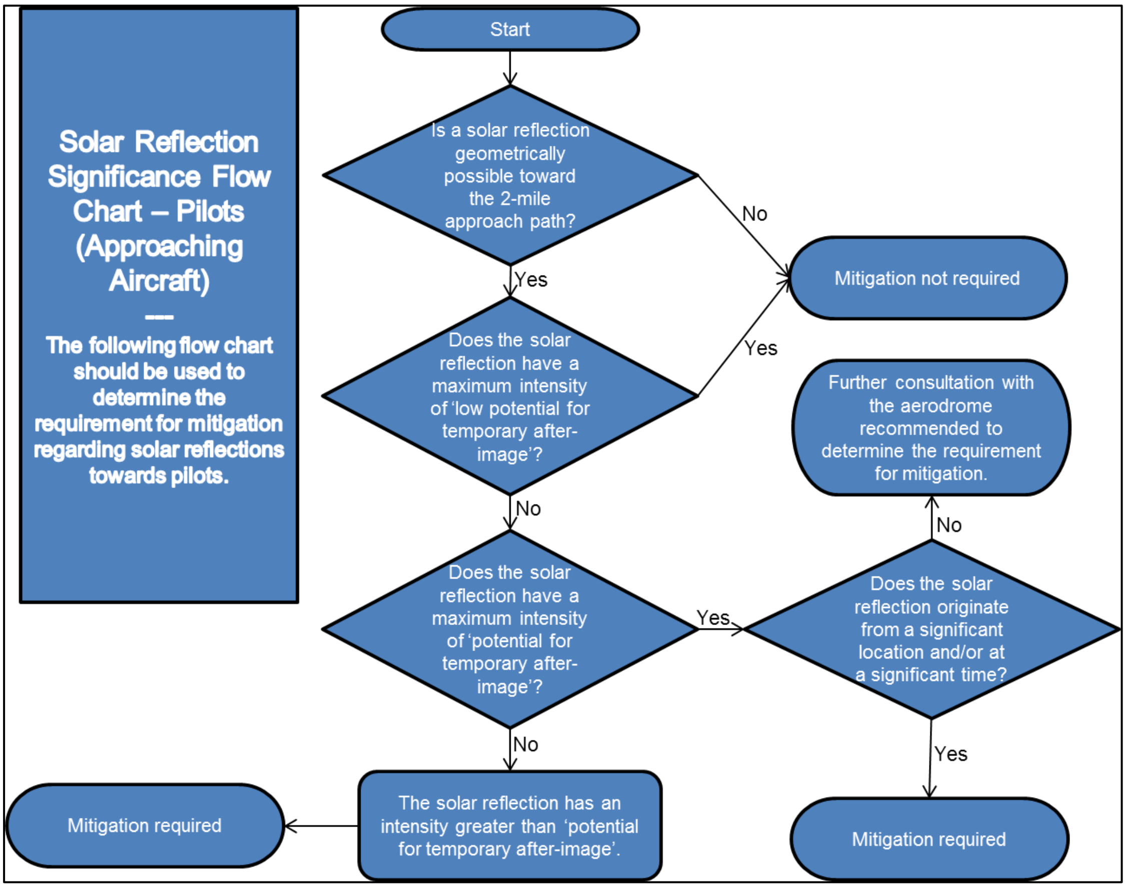
Assessment process for aviation receptors

The flow charts presented below and on the following page have been followed when determining the mitigation requirement for aviation receptors.

The charts relate to the ATC tower and approaching aircraft respectively.



ATC tower mitigation requirement flow chart



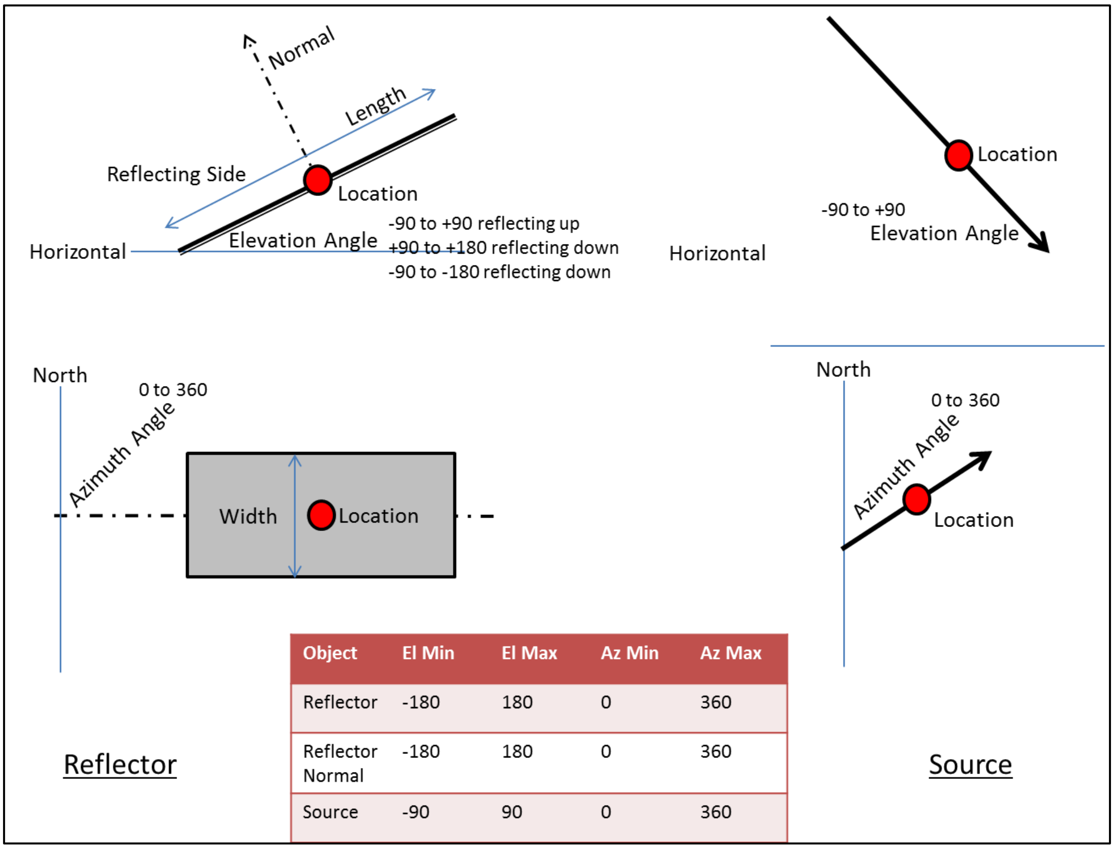
Aircraft receptor mitigation requirement flow chart

APPENDIX E – PAGER POWER'S REFLECTION CALCULATIONS 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

It is assumed that the panel elevation angle provided by the developer represents the elevation angle for all of the panels within the solar development.

It is assumed that the panel azimuth angle provided by the developer represents the azimuth angle for all of the panels within the solar development.

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

The model assumes that a receptor can view the face of every panel within the proposed solar development area whilst in reality this, in the majority of cases, will not occur.

Therefore any predicted reflection from the face of a solar panel that is not visible to a receptor will not occur.

A finite number of points within the proposed solar development are chosen based on an assessment resolution so we can build a comprehensive understanding of the entire development. This will determine whether a reflection could ever occur at a chosen receptor. The calculations do not incorporate all of the possible panel locations within the development outline.

A single reflection point on the panel has been chosen for the geometric calculations. This will suitably determine whether a reflection can be experienced at a location and the general time of year and duration of this 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.

Whilst line of sight to the development from receptors has been considered, only available street view imagery and satellite mapping has been used. 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 considered unless stated.

APPENDIX G – COORDINATE DATA

Panel Areas

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
1.1	-6.309957	49.914483	29.4	-6.297730	49.912972
1.2	-6.310036	49.914519	30.1	-6.297889	49.912869
1.3	-6.310048	49.914504	30.2	-6.297939	49.912854
1.4	-6.309969	49.914469	30.3	-6.297929	49.912842
2.1	-6.310057	49.914462	30.4	-6.297879	49.912856
2.2	-6.310112	49.914489	31.1	-6.297682	49.912893
2.3	-6.310128	49.914474	31.2	-6.297699	49.912887
2.4	-6.310071	49.914448	31.3	-6.297643	49.912795
3.1	-6.310203	49.914349	31.4	-6.297626	49.912800
3.2	-6.310253	49.914371	32.1	-6.297634	49.912903
3.3	-6.310268	49.914355	32.2	-6.297653	49.912899
3.4	-6.310218	49.914335	32.3	-6.297595	49.912809
4.1	-6.309124	49.914577	32.4	-6.297577	49.912815
4.2	-6.309145	49.914574	33.1	-6.318174	49.914594
4.3	-6.309123	49.914513	33.2	-6.318195	49.914592
4.4	-6.309103	49.914516	33.3	-6.318177	49.914472
5.1	-6.309075	49.914583	33.4	-6.318157	49.914474
5.2	-6.309094	49.914581	34.1	-6.318119	49.914597
5.3	-6.309074	49.914522	34.2	-6.318141	49.914594
5.4	-6.309055	49.914523	34.3	-6.318124	49.914476
6.1	-6.311672	49.915595	34.4	-6.318102	49.914477
6.2	-6.311692	49.915587	35.1	-6.318146	49.914328
6.3	-6.311657	49.915554	35.2	-6.318165	49.914328
6.4	-6.311638	49.915562	35.3	-6.318159	49.914271
7.1	-6.311713	49.915581	35.4	-6.318141	49.914271
7.2	-6.311730	49.915574	36.1	-6.318095	49.914331
7.3	-6.311696	49.915539	36.2	-6.318114	49.914330
7.4	-6.311679	49.915546	36.3	-6.318108	49.914274
8.1	-6.311850	49.915567	36.4	-6.318089	49.914275
8.2	-6.311866	49.915561	37.1	-6.318111	49.914202
8.3	-6.311804	49.915500	37.2	-6.318132	49.914200

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
8.4	-6.311789	49.915506	37.3	-6.318116	49.914078
9.1	-6.311892	49.915554	37.4	-6.318096	49.914080
9.2	-6.311905	49.915547	38.1	-6.318064	49.914203
9.3	-6.311847	49.915487	38.2	-6.318083	49.914203
9.4	-6.311832	49.915493	38.3	-6.318067	49.914082
10.1	-6.313259	49.914155	38.4	-6.318047	49.914082
10.2	-6.313278	49.914155	39.1	-6.318377	49.914078
10.3	-6.313270	49.914072	39.2	-6.318394	49.914074
10.4	-6.313252	49.914071	39.3	-6.318345	49.913949
11.1	-6.313297	49.914121	39.4	-6.318327	49.913951
11.2	-6.313317	49.914121	40.1	-6.318327	49.914087
11.3	-6.313312	49.914073	40.2	-6.318347	49.914083
11.4	-6.313293	49.914073	40.3	-6.318294	49.913960
12.1	-6.313458	49.914127	40.4	-6.318275	49.913963
12.2	-6.313835	49.914105	41.1	-6.318293	49.913894
12.3	-6.313836	49.914093	41.2	-6.318313	49.913888
12.4	-6.313457	49.914115	41.3	-6.318175	49.913625
13.1	-6.299074	49.913882	41.4	-6.318155	49.913630
13.2	-6.299152	49.913882	42.1	-6.318247	49.913902
13.3	-6.299151	49.913872	42.2	-6.318266	49.913897
13.4	-6.299074	49.913872	42.3	-6.318128	49.913637
14.1	-6.298813	49.913949	42.4	-6.318106	49.913643
14.2	-6.298898	49.913967	43.1	-6.318056	49.913970
14.3	-6.298903	49.913958	43.2	-6.318077	49.913966
14.4	-6.298819	49.913939	43.3	-6.317990	49.913818
15.1	-6.298751	49.913883	43.4	-6.317968	49.913823
15.2	-6.298764	49.913875	44.1	-6.317997	49.913982
15.3	-6.298727	49.913848	44.2	-6.318019	49.913976
15.4	-6.298714	49.913855	44.3	-6.317937	49.913832
16.1	-6.298795	49.913855	44.4	-6.317917	49.913838
16.2	-6.298811	49.913847	45.1	-6.317811	49.913650
16.3	-6.298689	49.913761	45.2	-6.317828	49.913647
16.4	-6.298673	49.913770	45.3	-6.317805	49.913592
17.1	-6.298538	49.913730	45.4	-6.317788	49.913596

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
17.2	-6.298564	49.913722	46.1	-6.317760	49.913659
17.3	-6.298445	49.913584	46.2	-6.317777	49.913656
17.4	-6.298424	49.913592	46.3	-6.317755	49.913603
18.1	-6.298588	49.913697	46.4	-6.317738	49.913606
18.2	-6.298610	49.913690	47.1	-6.317760	49.913515
18.3	-6.298504	49.913560	47.2	-6.317780	49.913510
18.4	-6.298484	49.913567	47.3	-6.317760	49.913461
19.1	-6.298776	49.913267	47.4	-6.317740	49.913465
19.2	-6.298797	49.913261	48.1	-6.317710	49.913523
19.3	-6.298754	49.913197	48.2	-6.317731	49.913520
19.4	-6.298731	49.913205	48.3	-6.317709	49.913470
20.1	-6.298727	49.913277	48.4	-6.317690	49.913473
20.2	-6.298748	49.913272	49.1	-6.317730	49.913391
20.3	-6.298724	49.913237	49.2	-6.317753	49.913391
20.4	-6.298703	49.913241	49.3	-6.317755	49.913326
21.1	-6.298695	49.913157	49.4	-6.317736	49.913325
21.2	-6.298717	49.913149	50.1	-6.317674	49.913387
21.3	-6.298647	49.913054	50.2	-6.317695	49.913388
21.4	-6.298627	49.913061	50.3	-6.317700	49.913326
22.1	-6.298612	49.913118	50.4	-6.317681	49.913325
22.2	-6.298633	49.913112	51.1	-6.317888	49.914177
22.3	-6.298601	49.913067	51.2	-6.317911	49.914174
22.4	-6.298583	49.913073	51.3	-6.317878	49.914083
23.1	-6.298450	49.912874	51.4	-6.317856	49.914086
23.2	-6.298466	49.912869	52.1	-6.317857	49.914198
23.3	-6.298436	49.912825	52.2	-6.317876	49.914196
23.4	-6.298421	49.912830	52.3	-6.317844	49.914108
24.1	-6.298407	49.912886	52.4	-6.317825	49.914110
24.2	-6.298425	49.912880	53.1	-6.317724	49.914147
24.3	-6.298393	49.912837	53.2	-6.317736	49.914145
24.4	-6.298378	49.912843	53.3	-6.317726	49.914123
25.1	-6.298132	49.912788	53.4	-6.317680	49.914128
25.2	-6.298182	49.912774	53.5	-6.317684	49.914139
25.3	-6.298172	49.912762	53.6	-6.317718	49.914134

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
25.4	-6.298122	49.912776	54.1	-6.317565	49.914153
26.1	-6.298145	49.913268	54.2	-6.317665	49.914140
26.2	-6.298161	49.913262	54.3	-6.317660	49.914124
26.3	-6.298127	49.913228	54.4	-6.317559	49.914137
26.4	-6.298108	49.913236	55.1	-6.317133	49.914188
27.1	-6.298186	49.913247	55.2	-6.317230	49.914179
27.2	-6.298203	49.913241	55.3	-6.317226	49.914165
27.3	-6.298170	49.913211	55.4	-6.317127	49.914176
27.4	-6.298153	49.913218	56.1	-6.317118	49.914430
28.1	-6.297705	49.913020	56.2	-6.317298	49.914439
28.2	-6.297725	49.913015	56.3	-6.317300	49.914421
28.3	-6.297700	49.912978	56.4	-6.317123	49.914412
28.4	-6.297679	49.912982	57.1	-6.316997	49.914404
29.1	-6.297751	49.913006	57.2	-6.317046	49.914408
29.2	-6.297771	49.913001	57.3	-6.317046	49.914396
29.3	-6.297749	49.912968	57.4	-6.316998	49.914393

Additional Panel Areas

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
58.1	-6.280297	49.923089	64.2	-6.306358	49.914711
58.2	-6.280392	49.923023	64.3	-6.306524	49.91453
58.3	-6.280374	49.923010	64.4	-6.306479	49.914514
58.4	-6.280277	49.923074	65.1	-6.306414	49.914726
59.1	-6.280339	49.923108	65.2	-6.30657	49.914548
59.2	-6.280426	49.923044	65.3	-6.306533	49.914535
59.3	-6.280407	49.923032	65.4	-6.30637	49.914712
59.4	-6.280317	49.923096	66.1	-6.30777	49.916154
60.1	-6.280449	49.92316	66.2	-6.307928	49.916056
60.2	-6.280543	49.923098	66.3	-6.307884	49.916026
60.3	-6.280529	49.923084	66.4	-6.307724	49.916124
60.4	-6.280429	49.923147	67.1	-6.295501	49.914967
61.1	-6.280478	49.923179	67.2	-6.2957	49.914964
61.2	-6.280572	49.923121	67.3	-6.295701	49.914887
61.3	-6.280555	49.923108	67.4	-6.295933	49.914884

ID	Longitude (°)	Latitude (°)	ID	Longitude (°)	Latitude (°)
61.4	-6.280462	49.923166	67.5	-6.295932	49.914676
62.1	-6.289318	49.920819	67.6	-6.295507	49.914677
62.2	-6.289358	49.920804	68.1	-6.294777	49.91423
62.3	-6.289283	49.920724	68.2	-6.294816	49.914231
62.4	-6.289247	49.920738	68.3	-6.294845	49.914045
63.1	-6.289373	49.920792	68.4	-6.294809	49.914044
63.2	-6.289397	49.920781	69.1	-6.294714	49.914103
63.3	-6.28933	49.920705	69.2	-6.294776	49.914105
63.4	-6.289303	49.920719	69.3	-6.294784	49.914042
64.1	-6.306308	49.914696	69.4	-6.294724	49.914041

ATC tower

Longitude (°)	Latitude (°)
-6.294748	49.91429

Approach 14

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
01	-6.294483	49.915336	06	-6.312730	49.929070
02	-6.298130	49.918080	07	-6.316380	49.931820
03	-6.301780	49.920830	08	-6.320030	49.934570
04	-6.305430	49.923580	09	-6.323680	49.937310
05	-6.309080	49.926320			

Approach 32

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
01	-6.289039	49.911236	06	-6.270760	49.897510
02	-6.285370	49.908490	07	-6.267110	49.894760
03	-6.281710	49.905750	08	-6.263450	49.892020
04	-6.278060	49.903000	09	-6.259800	49.889270
05	-6.274410	49.900260			

Approach 09

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
01	-6.295400	49.913278	06	-6.323450	49.912390
02	-6.301000	49.913100	07	-6.329060	49.912210
03	-6.306610	49.912930	08	-6.334670	49.912040
04	-6.312220	49.912750	09	-6.340280	49.911860
05	-6.317840	49.912570			

Approach 27

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
01	-6.288433	49.913506	06	-6.260380	49.914400
02	-6.282820	49.913690	07	-6.254770	49.914570
03	-6.277210	49.913860	08	-6.249150	49.914750
04	-6.271600	49.914040	09	-6.243540	49.914930
05	-6.265990	49.914220			

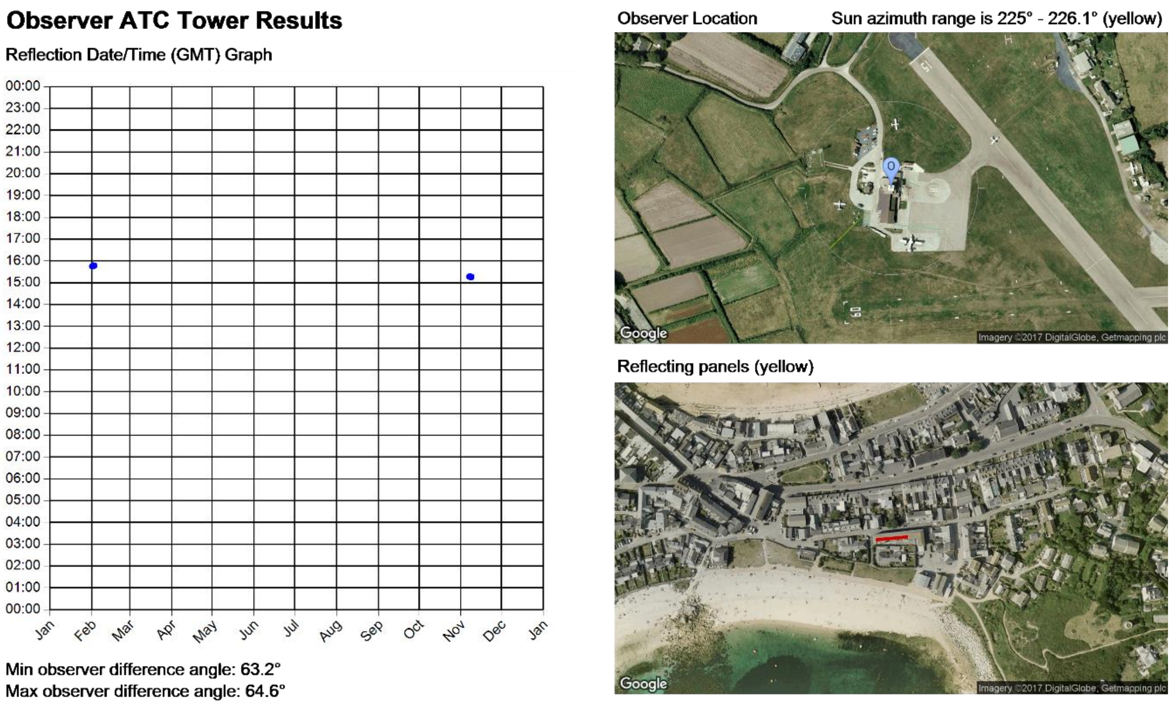
APPENDIX H – GEOMETRIC CALCULATION RESULTS

The charts for selected receptors are shown on the following pages. Each chart shows:

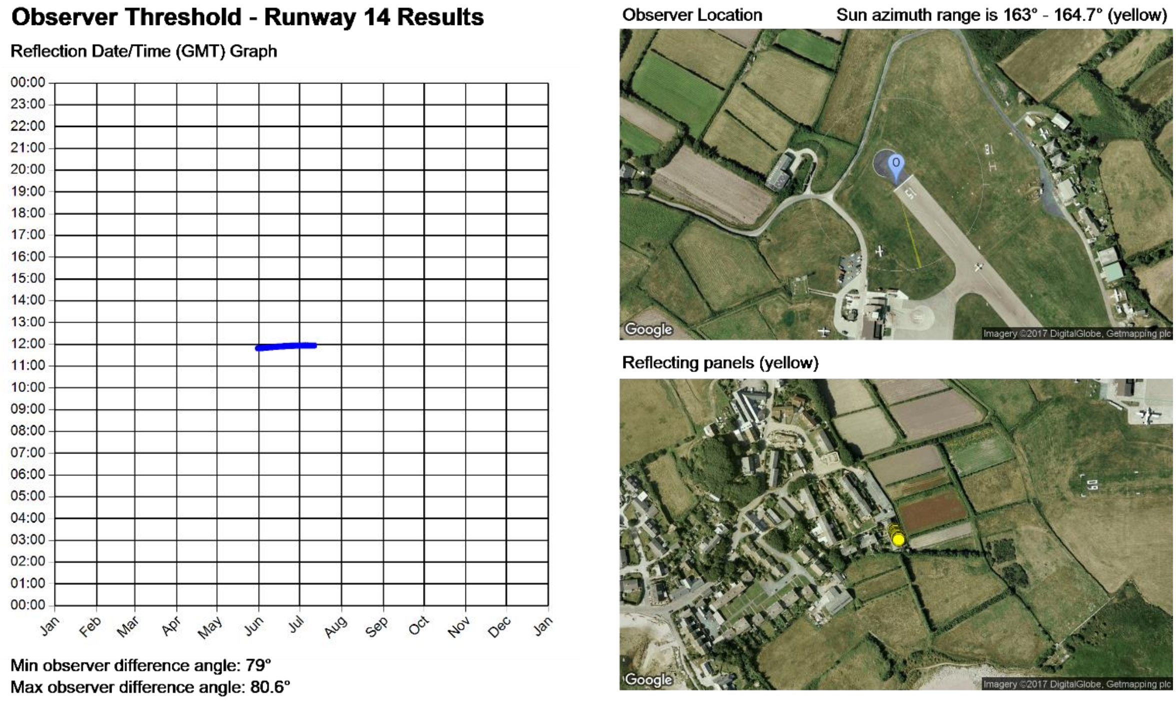
- The receptor (observer) location – top right image. This also shows the azimuth range of the Sun itself at times when reflections are possible. If sunlight is experienced from the same direction as the reflecting panels, the overall impact of the reflection is reduced as discussed within the body of 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.

It is not practical to present every single chart due to the amount of data – this can be provided on request. A cross-section of results are presented here covering each approach path, the ATC tower and development areas in each of the four zones.

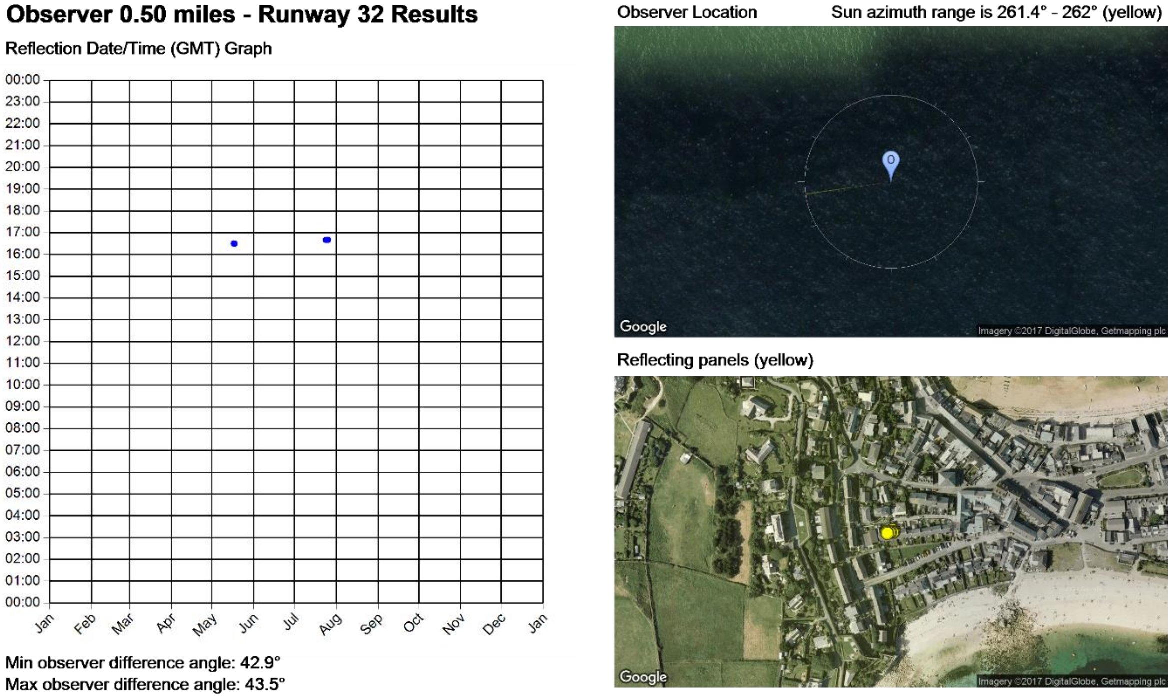
ATC Tower from Area 12 – Pager Power Model



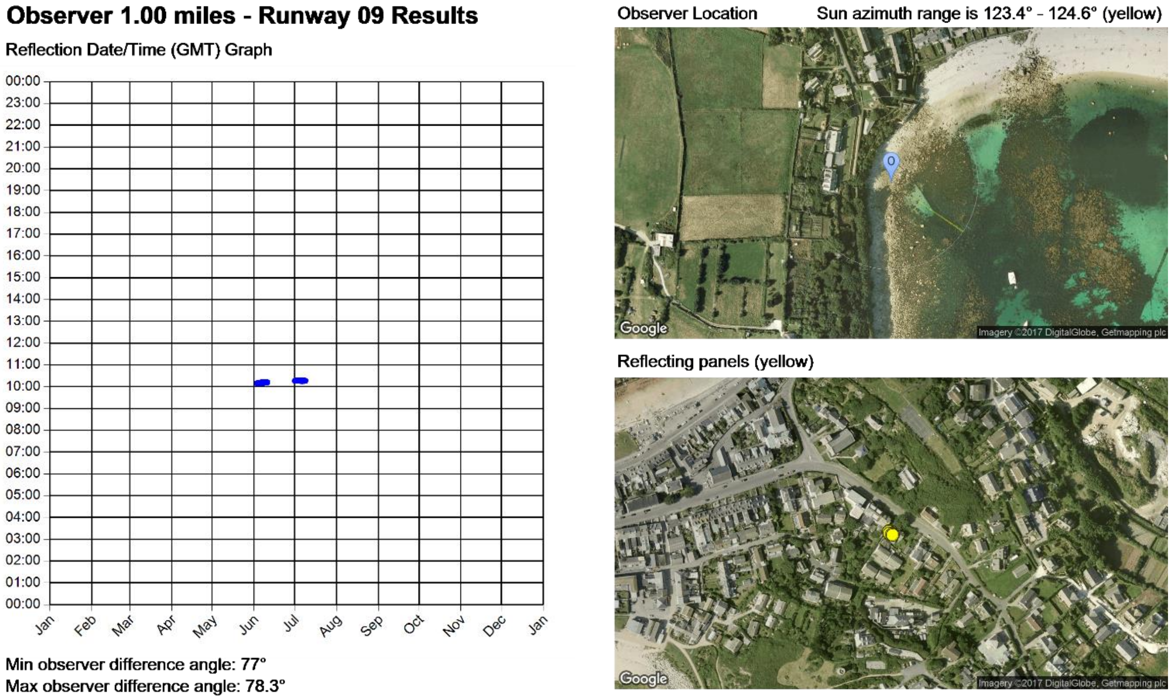
Approach 14 from Area 32 – Pager Power Model



Approach 32 from Area 54 – Pager Power Model



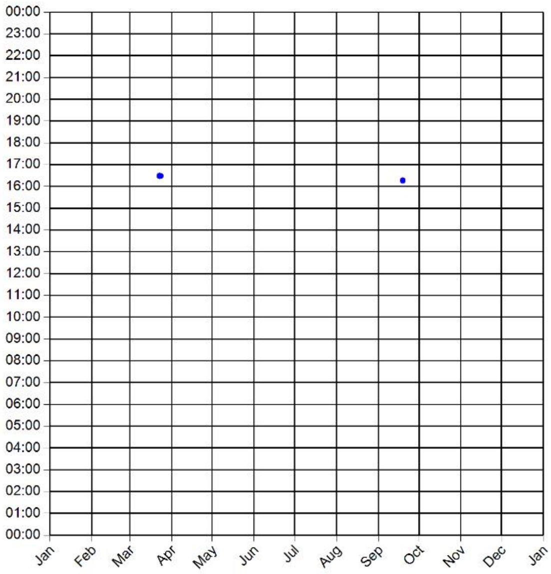
Approach 09 from Area 02 – Pager Power Model



Approach 27 from Area 30 – Pager Power Model

Observer 0.75 miles - Runway 27 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 29.8°
Max observer difference angle: 30.4°

Observer Location Sun azimuth range is 246.2° - 246.7° (yellow)

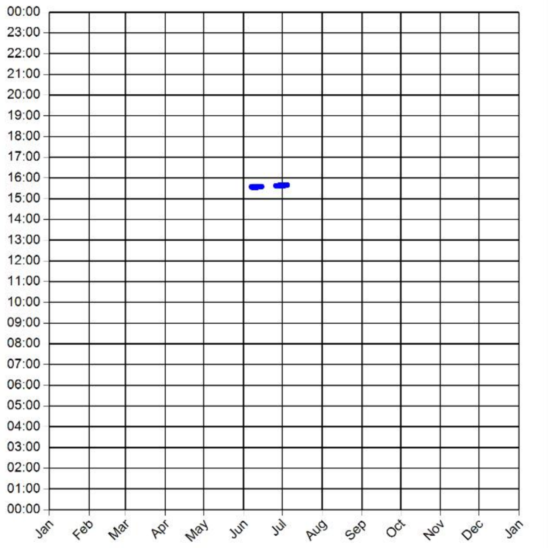
Reflecting panels (yellow)

Scenarios for Intensity Calculations

Area 12

Observer 2.00 miles - Runway 32 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 75.9°
Max observer difference angle: 76.7°

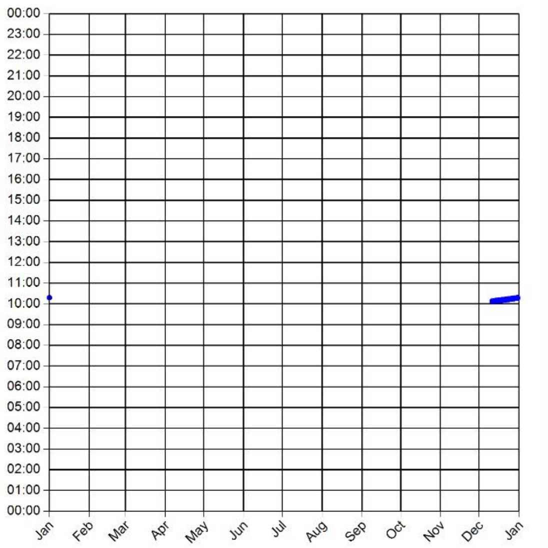
Observer Location Sun azimuth range is 251.4° - 252.2° (yellow)

Reflecting panels (yellow)

Area 17

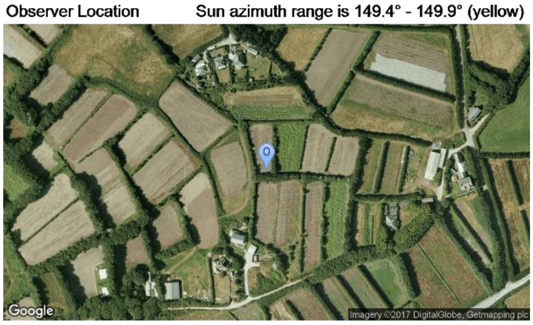
Observer 0.50 miles - Runway 14 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 21.2°
Max observer difference angle: 22°

Observer Location Sun azimuth range is 149.4° - 149.9° (yellow)

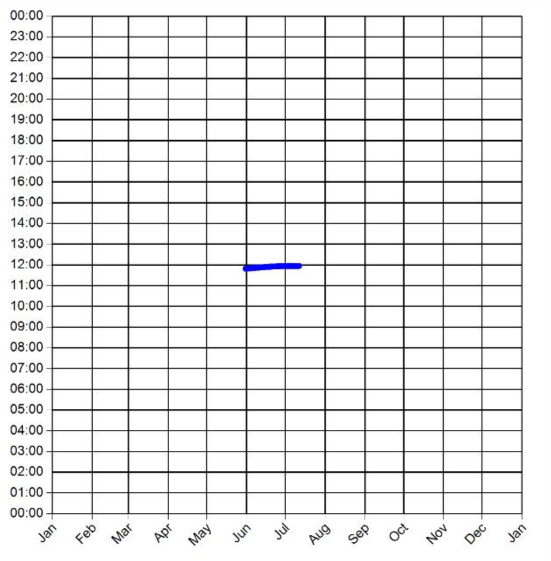


Reflecting panels (yellow)

Area 32

Observer Threshold - Runway 14 Results

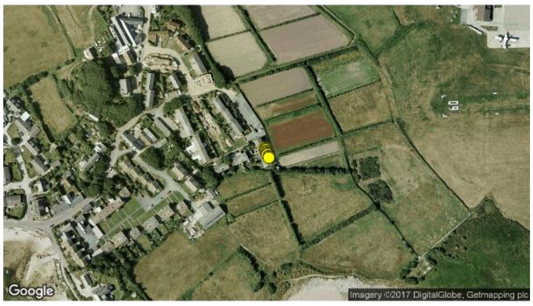
Reflection Date/Time (GMT) Graph



Min observer difference angle: 79°
Max observer difference angle: 80.6°

Observer Location | Sun azimuth range is 163° - 164.7° (yellow)

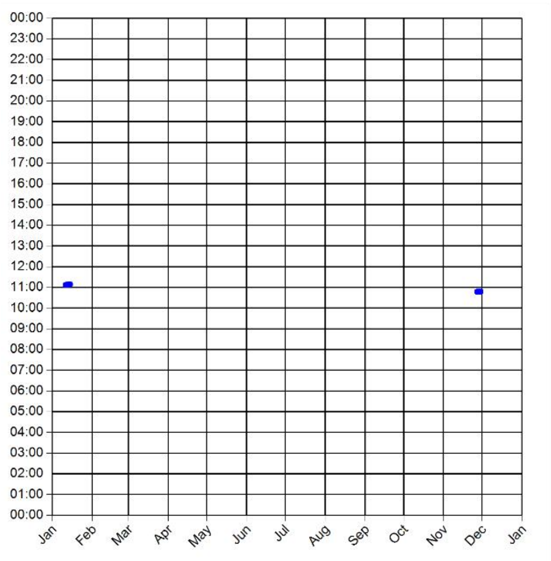
Reflecting panels (yellow)



Area 42

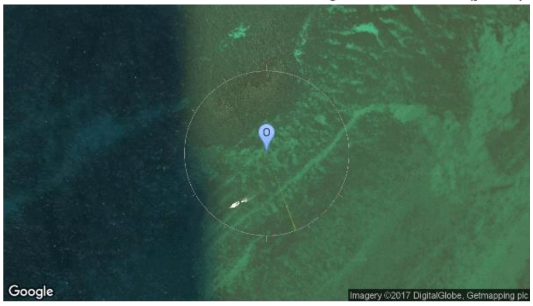
Observer 1.75 miles - Runway 14 Results

Reflection Date/Time (GMT) Graph



Min observer difference angle: 26.4°
Max observer difference angle: 27.3°

Observer Location | Sun azimuth range is 159° - 159.6° (yellow)



Reflecting panels (yellow)

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