Sapphire Solar Farm

Environmental Impact Statement

Volume 3 - Appendices

Appendix F
Glint and Glare Assessment

PAGERPOWER

Solar Photovoltaic Glint and Glare Study

Prepared for:

Ecological Australia

Sapphire Solar Farm

December, 2017

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ADMINISTRATION PAGE

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Issue	Date	Detail of Changes
1	November, 2017	First edition
2	December, 2017	Change to receptor referencing

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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the possible effects of glint and glare from the proposed Sapphire Solar Farm located in New South Wales, Australia. This assessment pertains to the possible effects upon surrounding roads and dwellings with a high-level assessment of aviation issues. The analysis includes modelling of a tracking system that optimises the panel angle throughout the day to maximise electricity generation.

Pager Power

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

Guidance

There is limited glint and glare guidance for the assessment of proposed solar photovoltaic (PV) developments. Pager Power's methodology is based on independent studies, consultation with stakeholders and experience drawn from completion of over 250 glint and glare assessments.

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[1].

Glint and Glare

The definition of glint and glare used by Pager Power is as follows:

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

Results

General Conclusions

Glint and glare effects can only ever occur when the weather is clear and sunny. In the scenario where a solar reflection is possible towards a road user or resident in a surrounding dwelling, the individual will also be looking in the general direction of the Sun. This means the Sun and solar reflection will be visible simultaneously. The Sun is a significantly brighter source of light. Lastly, at any one location, only a particular area of solar panels will produce a solar reflection towards it. Note that not all receptors will experience a solar reflection at the same time.

Surrounding Roads

Solar reflections are theoretically possible towards approximately 7.6km of road classified as local road. Road users would be expected to be travelling at (up to) moderate speeds with a low density of traffic also expected. Any solar reflection could last for up to 20 minutes, however in reality, its duration would depend on the speed of the car travelling through the solar reflection zone. In accordance with the methodology set out in Section 3 and Appendix E, the overall expected impact upon road users with respect to safety is classified as low (at worst) where the reflecting solar panels are visible. Where the solar panels are not visible, there is no impact.

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

Surrounding Dwellings
Solar reflections are possible towards the seven surrounding dwelling receptors. At these dwellings, views of the proposed solar farm and the reflecting solar panels has not been confirmed. The solar reflections would last for up to 20 minutes per day for up to 6 months from windows with a clear view of the reflecting solar panels. The results vary per dwelling therefore see Table 3 and Appendix G for the detailed results breakdown for each dwelling. In all cases, a clear view of the reflecting solar panels at the particular time of day when a solar reflection was geometrically possible would be required. In addition, the weather would also have to be clear and sunny. In accordance with the methodology set out in Section 3 and Appendix E, the resulting impact significance is Low to Moderate. If screening removes the solar panels from view, No Impact will be possible.

Mitigation

If mitigation were to be requested, the most appropriate form would be the installation of screening in the form of vegetation.

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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 the proposed Sapphire Solar Farm located in New South Wales, Australia.

This assessment pertains to the possible effects upon surrounding roads and dwellings with a high-level assessment of aviation issues. This report contains the following:

- Solar farm 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.
- High-level aviation assessment.
- Mitigation.

1.2 Pager Power's Experience

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

1.3 Glint and Glare Definition

The definition of glint and glare can vary. The definition used by Pager Power is as follows[2]:

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

In context, glint will be witnessed by moderate to fast moving receptors whilst glare would be encountered by static or slow moving receptors with respect to a solar farm. The term 'solar reflection' is used in this report to refer to both reflection types i.e. glint and glare.

[2] This definition is in line with FAA guidance.

2 PROPOSED SOLAR FARM LOCATION AND DETAILS

2.1 Photovoltaic Panel Mounting Arrangements and Orientation

The solar panels will be mounted to the ground and fitted to a single-axis tracking system that tilts the panels from east to west throughout the day.

2.2 Tracking System

It is understood that:

- The azimuth angle of the panels will be 90 degrees in the morning and 270 degrees in the evening. During solar noon, when the Sun is directly overhead, the panels will be flat, directed immediately upwards.
- The tilt of the panels throughout the day is programmed, based on the known path of the Sun and shading considerations i.e. the tilt angle is optimised to avoid having one row of panels cast a shadow on another row.
- The range of elevation angles will be ±60°.

The panel details are illustrated in Figures 1-3 below.

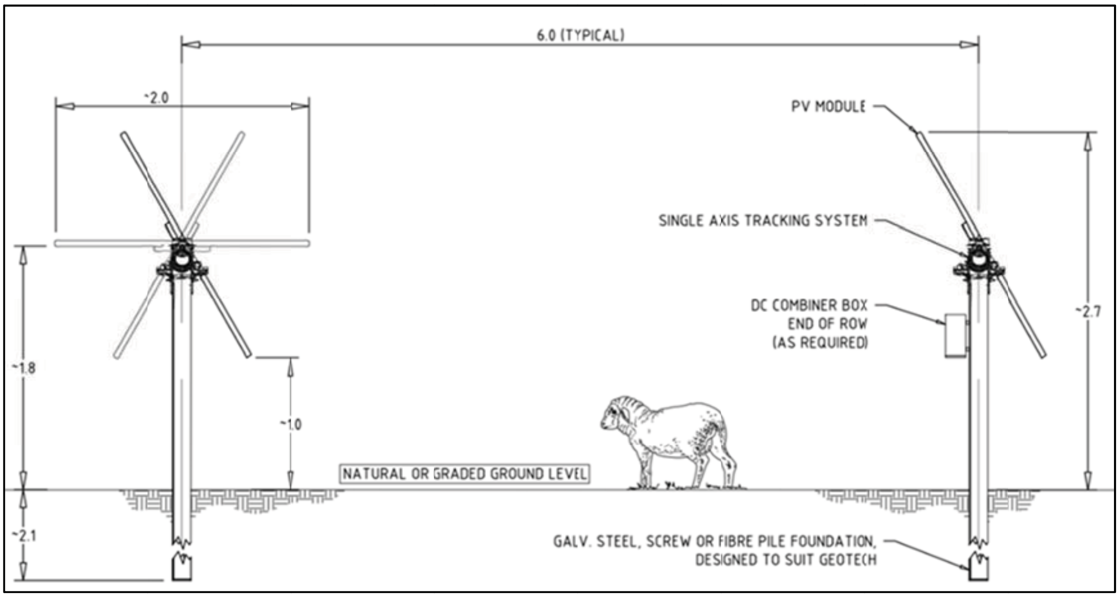

Figure 1 *Panel tracking details - 1*

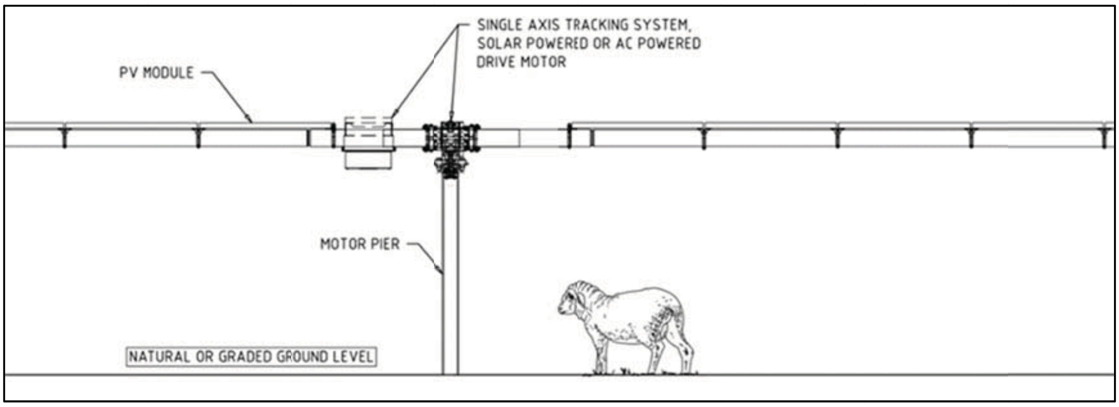

Figure 2 *Panel tracking details - 2*

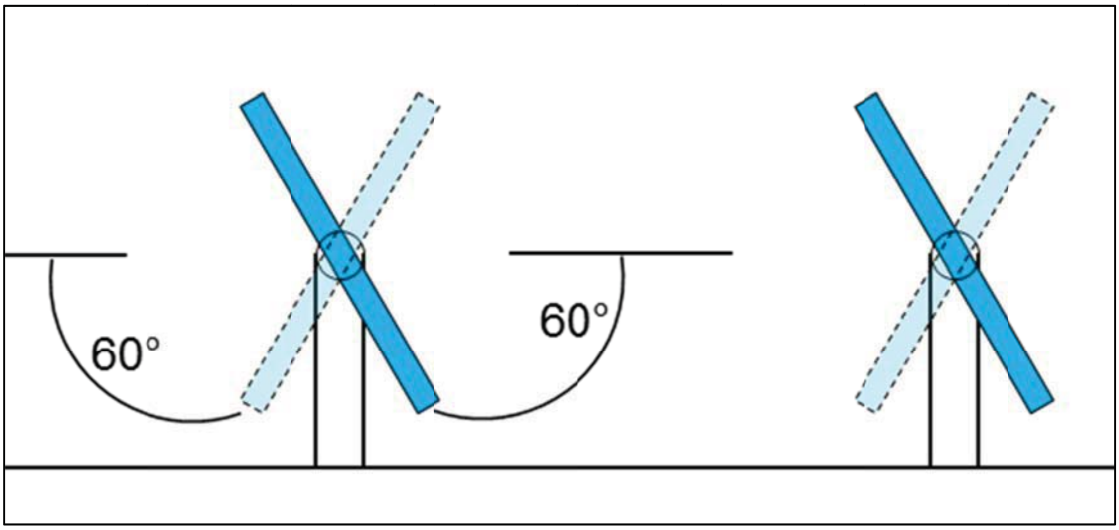

Figure 3 *Panel tracking details - 3*

Shading considerations that dictate the panel tilt. This is affected by:

- The elevation angle of the Sun.
- The vertical tilt of the panels.
- The spacing between the panel rows.

This means that early in the morning and late in the evening, the panels will not be directed exactly towards the Sun. Figure 4 below illustrates this.

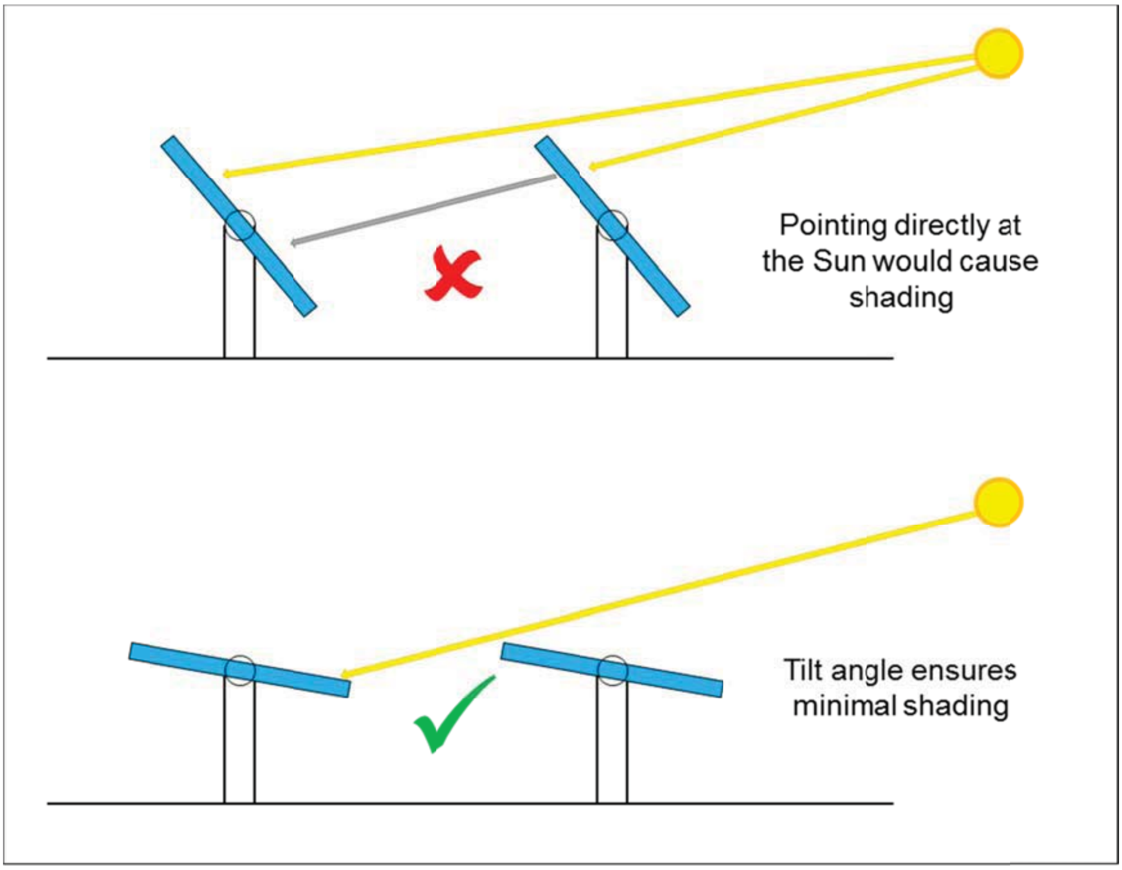

Figure 4 *Shading considerations*

Later on in the day, the panels can be directed towards the Sun without any shading issues. This is illustrated in Figure 5 below.

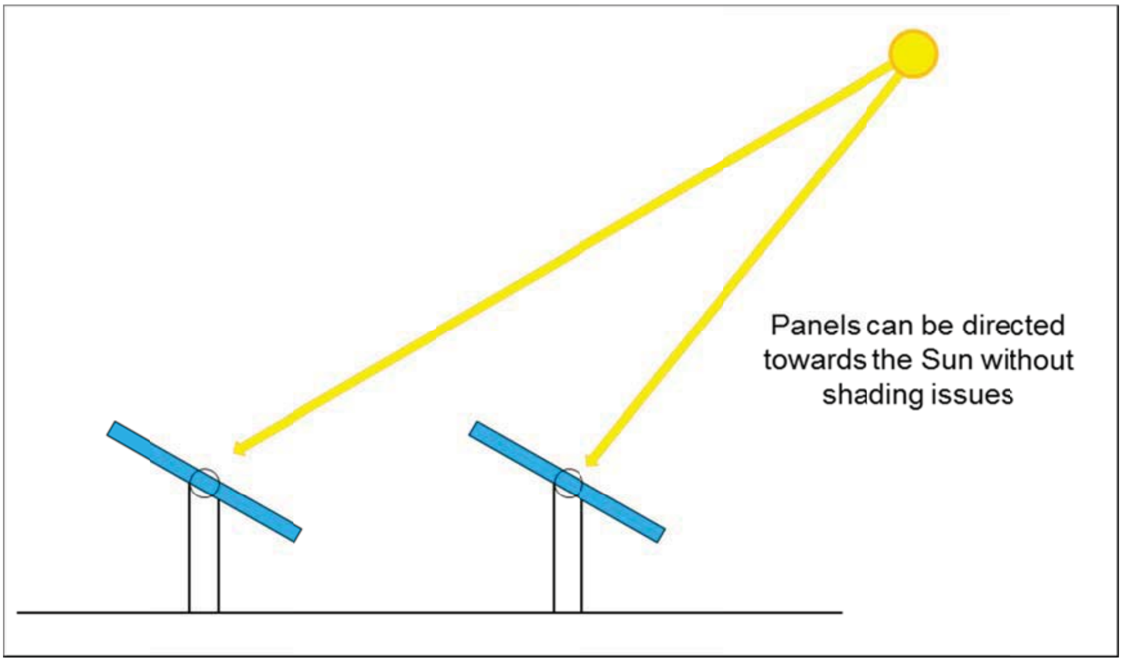

Figure 5 *Panel alignment at high solar angles*

Note that in reality the lines from the Sun to each panel would be effectively parallel due to the large separation distance. The two previous figures are for illustrative purposes only.

2.3 Proposed Solar Farm Panel Areas

Figure 6 below shows[3] the proposed panel areas.

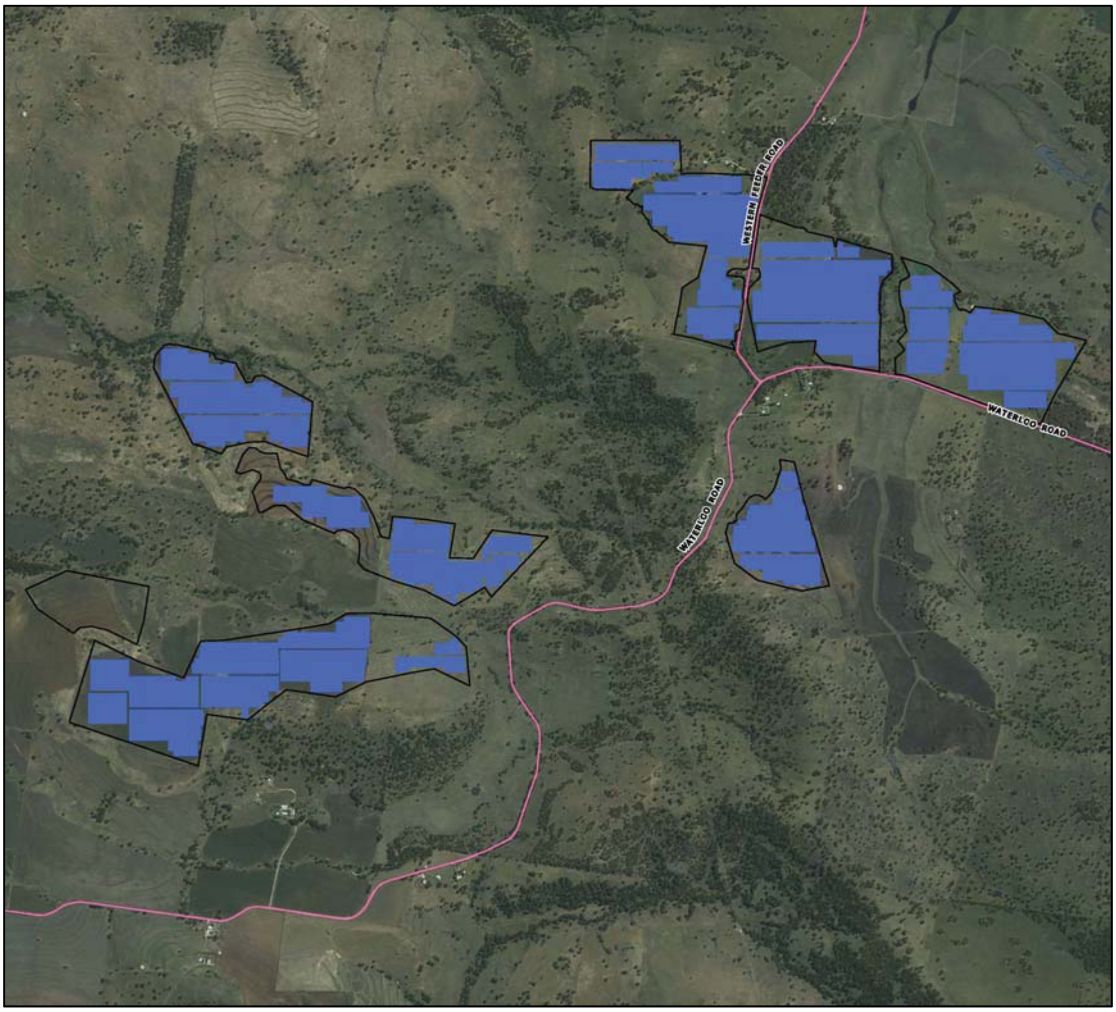

Figure 6 *Panel areas*

For the purpose of this analysis, six separate solar panel areas have been assessed.

[3] ©2017 Google/CNES/Airbus

3 GLINT AND GLARE ASSESSMENT METHODOLOGY

3.1 Guidance and Studies

Appendix A and Appendix 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:

- The results of the available studies state that 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 reflections from solar panels are equal to or less than those from water. It also shows that reflections from solar panels are significantly less intense than many other reflective surfaces which are common in an outdoor environment.

3.2 Background

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

3.3 Methodology

The assessment methodology is based on guidance, studies, previous discussions with stakeholders and Pager Power's practical experience. Information regarding the methodology of the Pager Power glint and glare assessment is presented below:

- Identify receptors in the area surrounding the proposed solar farm.
- Consider direct solar reflections from the proposed solar farm towards the identified receptors by undertaking geometric calculations – accounting for the tracker system;
- 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[4].
- 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 farm and the location of the direct sunlight with respect to the receptor's position.
- Carry out SGHAT analysis (aviation receptors only – where deemed appropriate)[5].
- Consider the solar reflection with respect to the published studies and guidance.
- Determine whether a significant detrimental impact is expected based on the methodology set out in Appendix E.

Within the Pager Power model, representative points within each solar panel area are modelled, as well as the relevant receptor locations. The result is a chart that illustrates whether a reflection can occur and the approximate duration of any effects. Calculations were undertaken at a resolution of 10 day steps with 10 minute intervals within each assessed day. Further technical details relating to the methodology of the geometric calculations can be found in Appendix C.

3.4 Assessment Limitations

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

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[4] This is generally not a significant factor for airborne receptors.
[5] In line with Federal Aviation Administration standards in the USA, which are followed by stakeholders internationally in countries including the United Kingdom, Ireland and India.

4 IDENTIFICATION OF RECEPTORS & MODELLING OVERVIEW

4.1 Ground Level Receptors – Overview

There is no legal or formal guidance with regard to the maximum distance at which glint and glare should be assessed. There is also no technical limit to the distance at which reflections could occur.

However, the significance of a reflection decreases with distance. This is 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.

A 1km buffer is therefore considered appropriate for glint and glare effects on ground-based receptors.

All ground heights have been taken from Pager Power's database, based on interpolated SRTM data.

4.2 Modelling Overview

Figure 7[6] below shows the assessed solar panel areas that have been used for modelling purposes. Coordinate data for the boundary points data is shown in Appendix F.

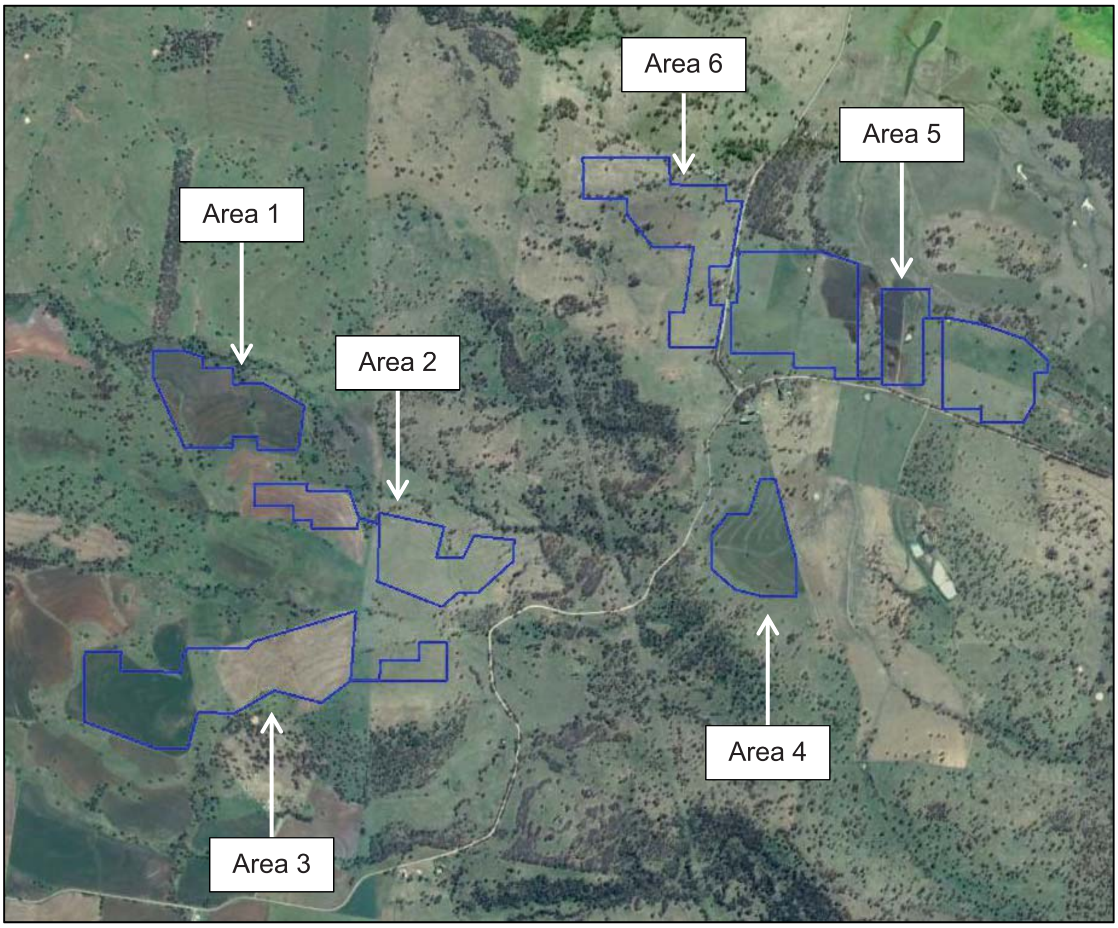

Figure 7 *Modelled points within the solar farm*

[6] Source: ©2017 Google/CNES/Airbus.

4.3 Road Receptors

Road receptors have been identified within the area surrounding proposed solar farm. The assessed lengths of road are shown in the Figure 8[7] on the following page. Approximately 200m separates each point. The co-ordinates of the assessed dwellings are presented in the Appendix F.

[7] Source: ©2017 Google/CNES/Airbus.

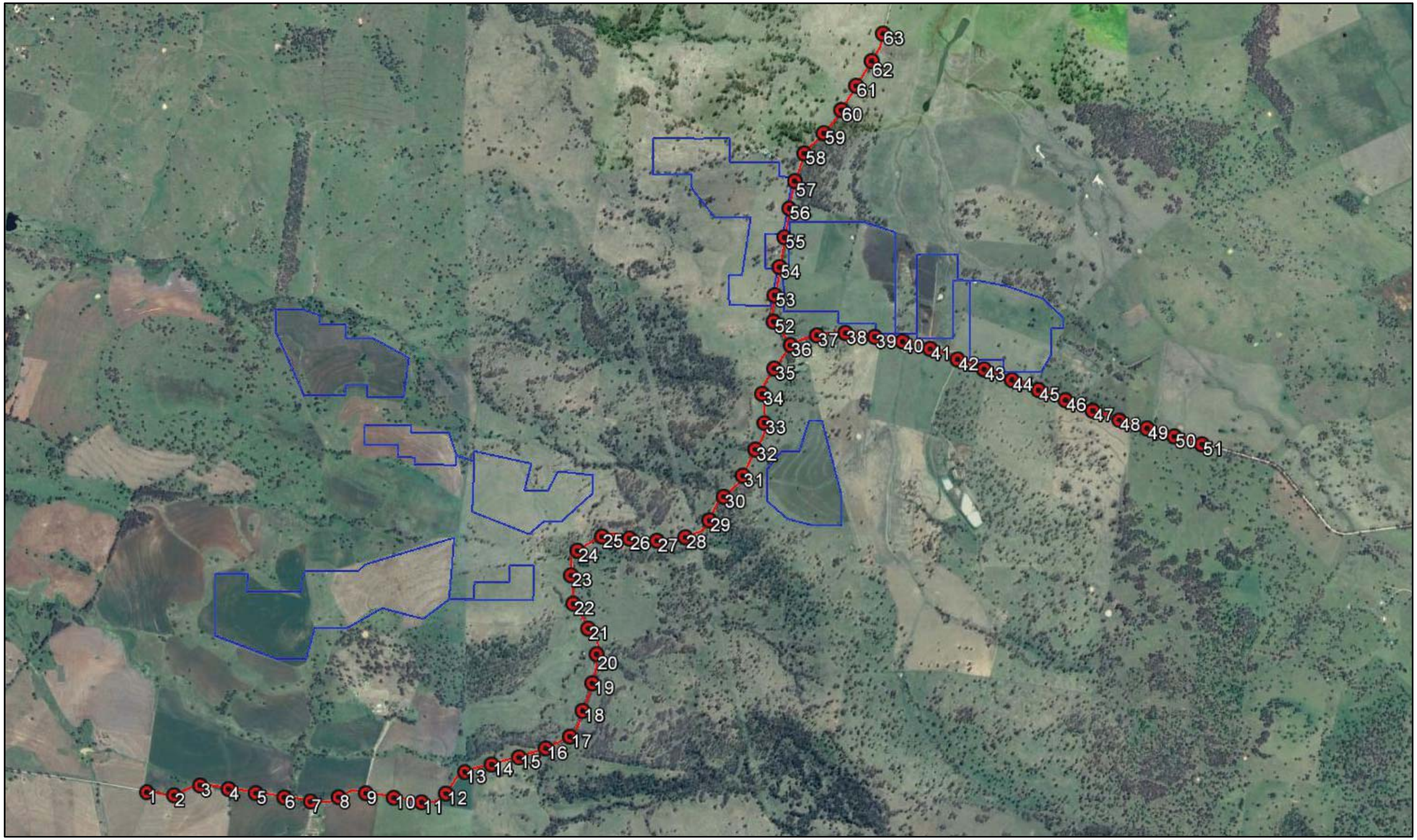

Figure 8 *Road receptors*

4.4 Dwelling Receptors

Potential dwelling receptors have been identified within the area surrounding proposed solar farm. These dwellings are shown in the Figure 9[8] below.

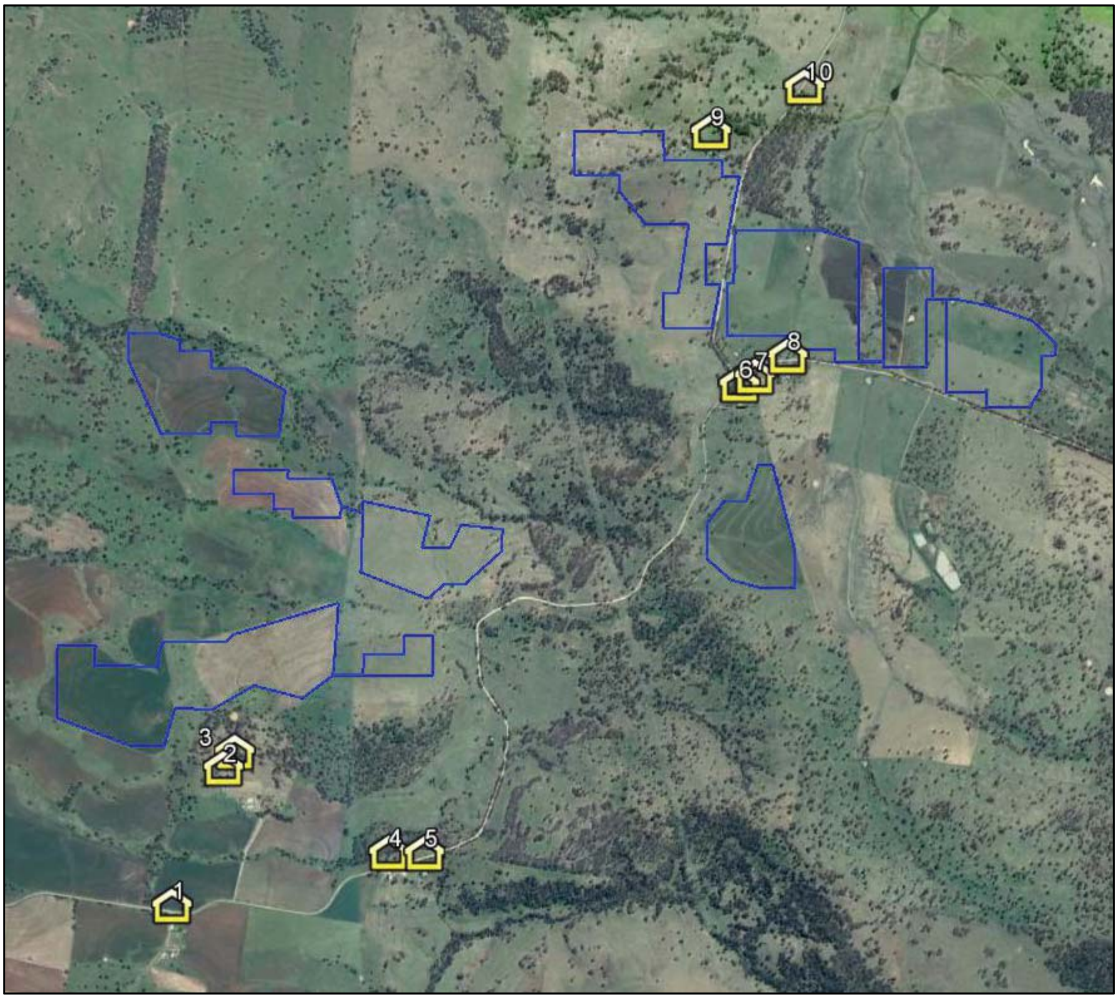

Figure 9 *Dwelling receptors*

The referencing as per the EIS is shown in Table 1 below[9].

No.	Ref. as per EIS	No.	Ref. as per EIS
01	R033	06	R014
02	R016	07	
03		08	R013
04	R015	09	R018
05		10	R017

Table 1 *Receptors as per the EIS*

The co-ordinates of the assessed dwellings are presented in the Appendix F.

[8] Source: ©2017 Google/CNES/Airbus.
[9] Note that dwellings R013, R014, R016, R018, R033, R036, and R079 are associated with the project.

4.5 Assessed Receptors

The recommended approach is to assess receptors within 1 kilometre. Figures 10[10] and 11[11] below and on the following page show the approximate 1 km buffer for the identified road[12] and dwelling[13] receptors respectively.

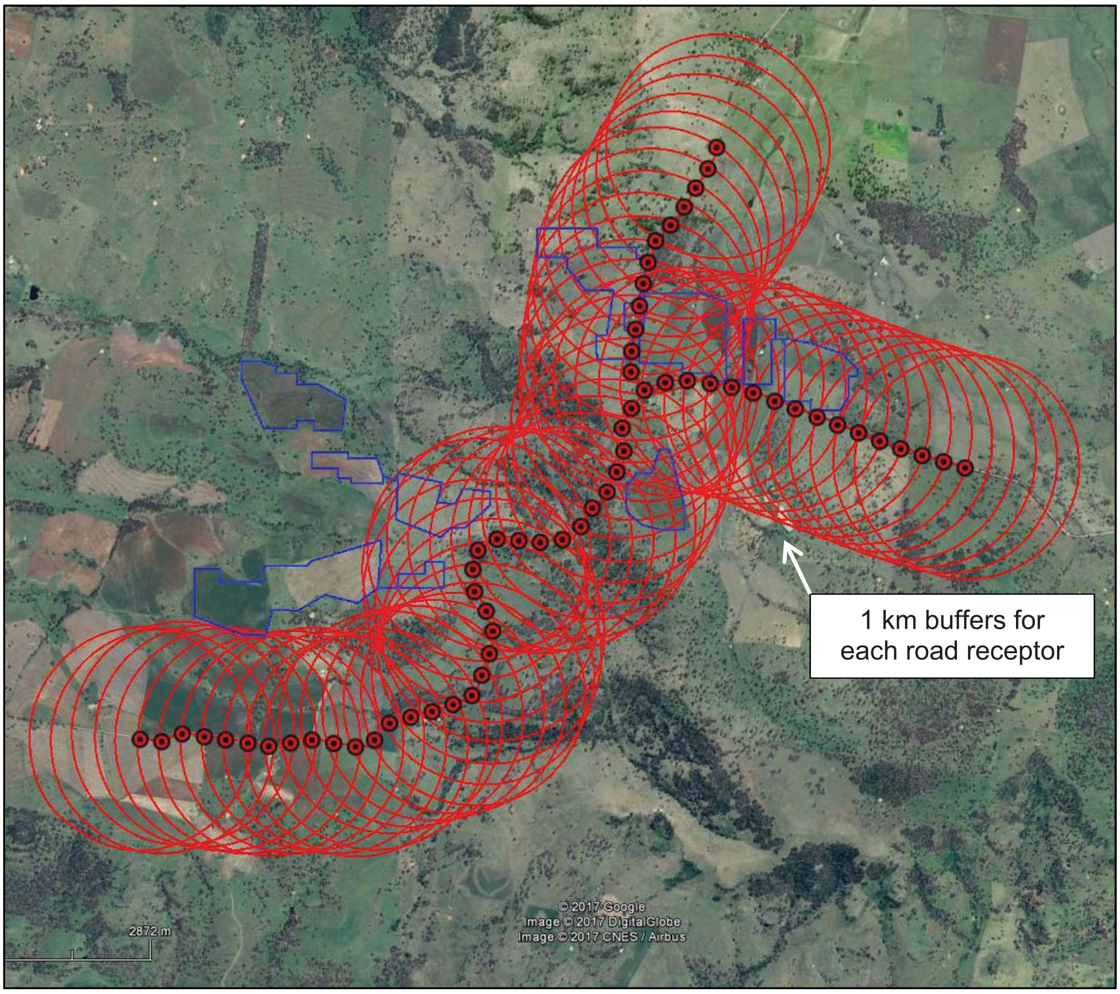

Figure 10 *Receptors and buffers – roads*

[10] Source: ©2017 Google/CNES/Airbus.
[11] Source: ©2017 Google/CNES/Airbus.
[12] Note where a solar panel area was identified within 1km of the receptor, modelling was extended to complete calculations for all solar panel reflector point/s within 1.5km of that receptor location (but still within that solar panel area). This is to ensure that the model would not miss a geometric calculation where a specific solar panel reflector point had not been generated within the solar panel area that is encompassed by the 1km buffer.
[13] For dwellings the whole area was modelled to remain conservative where the duration of the solar reflection affects the overall impact.

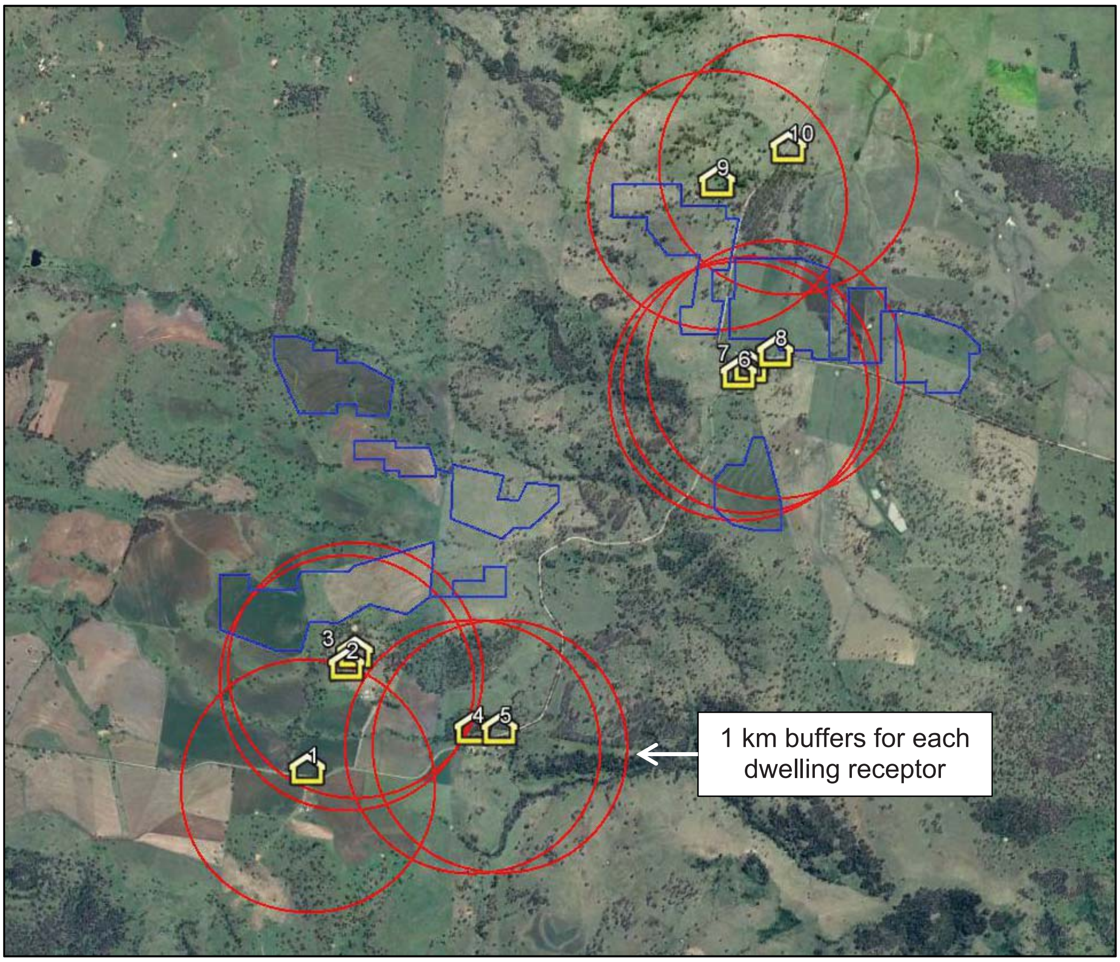

Figure 11 *Receptors and buffers - dwellings*

Table 2 below provides an overview of each receptor and the solar panel area/s that are within 1km requiring assessment.

Receptor	Panel areas with 1km	Receptor	Panel areas with 1km	Receptor	Panel areas with 1km
R1	None within 1km	R26	Areas 2, 3 and 4	R51	None within 1km
R2	None within 1km	R27	Areas 2, 3 and 4	R52	Areas 4, 5 and 6
R3	None within 1km	R28	Areas 2 and 4	R53	Areas 4, 5 and 6
R4	Area 3	R29	Areas 2 and 4	R54	Areas 5 and 6
R5	Area 3	R30	Areas 2 and 4	R55	Areas 5 and 6
R6	Area 3	R31	Area 4	R56	Areas 5 and 6
R7	Area 3	R32	Areas 4, 5 and 6	R57	Areas 5 and 6
R8	Area 3	R33	Areas 4, 5 and 6	R58	Areas 5 and 6
R9	None within 1km	R34	Areas 4, 5 and 6	R59	Areas 5 and 6

R10	None within 1km	R35	Areas 4, 5 and 6	R60	Areas 5 and 6
R11	None within 1km	R36	Areas 4, 5 and 6	R61	Areas 5 and 6
R12	None within 1km	R37	Areas 4, 5 and 6	R62	Area 6
R13	None within 1km	R38	Areas 4, 5 and 6	R63	None within 1km
R14	None within 1km	R39	Areas 4, 5 and 6	D1	None within 1km
R15	None within 1km	R40	Areas 4, 5 and 6	D2	Area 3
R16	None within 1km	R41	Areas 4 and 5	D3	Area 3
R17	Area 3	R42	Area 5	D4	None within 1km
R18	Area 3	R43	Area 5	D5	None within 1km
R19	Area 3	R44	Area 5	D6	Areas 4, 5 and 6
R20	Areas 2 and 3	R45	Area 5	D7	Areas 4, 5 and 6
R21	Areas 2 and 3	R46	Area 5	D8	Areas 4, 5 and 6
R22	Areas 2 and 3	R47	Area 5	D9	Areas 5 and 6
R23	Areas 2 and 3	R48	Area 5	D10	Areas 5 and 6
R24	Areas 2 and 3	R49	Area 5		
R25	Areas 2 and 3	R50	None within 1km		

Table 2 *Receptors with 1km of a solar panel area*

A number of representative panel locations are selected within each of the solar panel areas for modelling purposes.

4.6 Conditions for a Reflection

The model calculates the angular separation between a reflection and the line from the observer to the reflecting panel. This is illustrated in Figure 12 below.

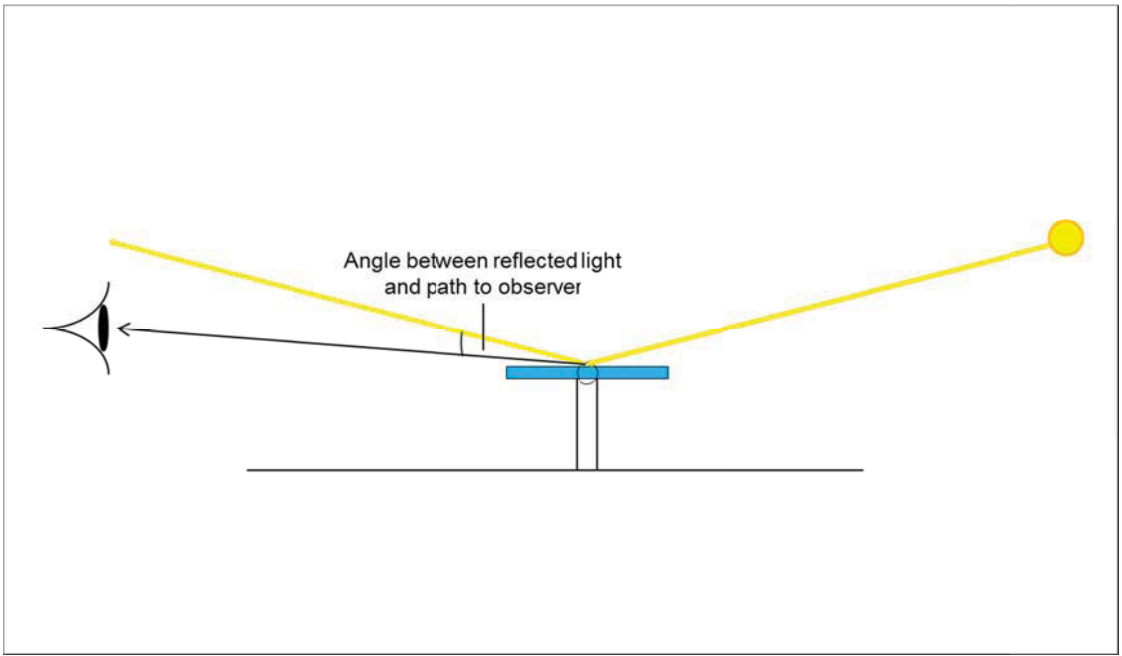

Figure 12 *Calculating reflections*

It can be seen that if the angle is zero, the observer will experience a direct reflection. Angles above zero indicate that the reflection will pass over the observer, and no reflection would be experienced. It is important to remember that:

- The Sun is not a point source, but has an angular size of approximately 0.5 degrees as seen from Earth.
- The receptor height above ground level is based on a typical value (1.5 metres for road users and 1.8 metres for dwellings). In practice this may vary by, typically[14], one or two metres.
- The terrain height above mean sea level is based on a database, and may vary in practice by a few metres.
- The modelling considers the representative panel locations only (approximately 250 metres separation).

To accommodate for the above, the model identifies scenarios where the separation angle illustrated in Figure12 is up to 10 degrees. This is considered a conservative approach.

[14] e.g. due to an observer on an upper floor.

5 GLINT AND GLARE ASSESSMENT

5.1 Results

Tables 2 and 3 in the following subsection summarises the months and times during which a solar reflection could be experienced by a receptor.

This does not mean that reflections would occur continuously between the times shown.

The range of times at which reflections are geometrically possible is generally greater than the length of time for any particular day. This is because the times of day at which reflections could start and stop vary throughout the days/months.

Note that the results show the combined effects for all modelled panel areas.

Appendix G presents the detailed modelling output in cases where effects are possible.

5.2 Modelling Results Overview – Roads

The results of the geometric calculations for the assessed surrounding roads are presented in in Table 3 below.

Receptor	Results		Conclusion
	Solar reflection possible?		
	am	pm	
4	Yes – approximately between 05:30 and 07:00 GMT+10 for parts of August until April.	No	Solar reflection geometrically possible towards these receptors.
5	Yes – approximately between 05:10 and 07:00 GMT+10 for parts of May until April.	No	
6	Yes – approximately between 05:10 and 06:50 GMT+10 for parts of February, March and April until mid-November.	No	
7	Yes – approximately between 05:10 and 06:45 GMT+10 for parts of February, March and April until mid-November.	No	
8	Yes – approximately between 05:10 and 05:45 GMT+10 for parts of February, March and April until mid-November.	No	
17	Yes – approximately between 05:10 and 05:45 GMT+10 for parts of May until September.	No	

Receptor	Results		Conclusion
	Solar reflection possible?		
	am	pm	
18	Yes – approximately between 05:10 and 05:20 GMT+10 for parts of May until mid-August.	No	Solar reflection geometrically possible towards these receptors.
19	Yes – approximately between 05:10 and 05:20 GMT+10 in early July.	No	
20	Yes – approximately between 05:10 and 06:30 GMT+10 for parts of March and May until mid-October.	No	
21	Yes – approximately between 05:10 and 06:45 GMT+10 for parts of February, March and May until November.	No	
22	Yes – approximately between 05:10 and 06:50 GMT+10 for parts of February, March and May until late November.	No	
23	Yes – approximately between 05:10 and 07:00 GMT+10 for most parts of the year.	No	
24	Yes – approximately between 05:10 and 07:00 GMT+10 for most parts of the year.	No	

Receptor	Results		Conclusion
	Solar reflection possible?		
	am	pm	
25	Yes – approximately between 05:10 and 06:10 GMT+10 for parts of March until October.	No	Solar reflection geometrically possible towards these receptors.
26	Yes – approximately between 05:10 and 05:20 GMT+10 for parts of June.	No	
27	No	No	Reflections are not predicted.
28	No	No	
29	No	No	
30	No	No	
31	No	No	
32	Yes – approximately between 05:10 and 07:00 GMT+10 all year round.	Yes – approximately between 16:50 and 18:00 GMT+10 for parts of October until mid-March.	Solar reflection geometrically possible towards these receptors.
33	Yes – approximately between 05:10 and 07:00 GMT+10 all year round.	Yes – approximately between 16:50 and 18:10 GMT+10 for parts of September until April.	
34	Yes – approximately between 05:50 and 07:00 GMT+10 for parts of September until mid-March.	Yes – approximately between 16:50 and 18:10 GMT+10 for parts of September until April.	

Receptor	Results		Conclusion
	Solar reflection possible?		
	am	pm	
35	Yes – approximately between 05:50 and 07:00 GMT+10 for parts of September until late March.	Yes – approximately between 16:50 and 18:30 GMT+10 for parts of September until early May.	Solar reflection geometrically possible towards these receptors.
36	Yes – approximately between 05:10 and 07:00 GMT+10 all year round.	Yes – approximately between 16:50 and 18:30 GMT+10 for most parts of the year.	
37	Yes – approximately between 05:10 and 07:00 GMT+10 all year round.	Yes – approximately between 17:10 and 18:50 GMT+10 for parts of February until November.	
38	Yes – approximately between 05:10 and 07:00 GMT+10 all year round.	Yes – approximately between 17:40 and 18:50 GMT+10 for parts of March until October.	
39	Yes – approximately between 05:10 and 07:00 GMT+10 all year round.	Yes – approximately between 18:10 and 18:50 GMT+10 for parts of April until August.	
40	Yes – approximately between 05:10 and 07:00 GMT+10 most parts of the year.	Yes – approximately between 18:40 and 18:50 GMT+10 for parts of May until late July.	
41	Yes – approximately between 05:10 and 07:00 GMT+10 for most parts of the year.	No	

Receptor	Results		Conclusion
	Solar reflection possible?		
	am	pm	
42	Yes – approximately between 05:10 and 07:00 GMT+10 for most parts of the year.	No	Solar reflection geometrically possible towards these receptors.
43	Yes – approximately between 05:10 and 07:00 GMT+10 all year round.	No	
44	Yes – approximately between 05:10 and 07:00 GMT+10 for most parts of the year.	No	
45	Yes – approximately between 05:10 and 07:00 GMT+10 for most parts of the year.	No	
46	Yes – approximately between 05:10 and 07:00 GMT+10 for parts of March until mid-September.	No	
47	Yes – approximately between 05:10 and 05:50 GMT+10 for parts of May until September.	No	
48	Yes – approximately between 05:10 and 05:20 GMT+10 for parts of mid-May until late June.	No	
49	No	No	Reflections are not predicted.

Receptor	Results		Conclusion
	Solar reflection possible?		
	am	pm	
52	Yes – approximately between 05:10 and 07:00 GMT+10 all year round.	Yes – approximately between 16:50 and 18:30 GMT+10 for parts of September until May.	Solar reflection geometrically possible towards these receptors.
53	Yes – approximately between 05:10 and 07:00 GMT+10 for most parts of the year.	Yes – approximately between 16:50 and 18:50 GMT+10 for most parts of the year.	
54	Yes – approximately between 05:10 and 07:00 GMT+10 for most parts of the year.	Yes – approximately between 17:00 and 18:50 GMT+10 for most parts of the year.	
55	Yes – approximately between 05:10 and 07:00 GMT+10 for most parts of the year.	Yes – approximately between 16:50 and 18:50 GMT+10 for most parts of the year.	
56	Yes – approximately between 05:10 and 06:50 GMT+10 for parts of February, March and May until late November.	Yes – approximately between 16:50 and 18:50 GMT+10 for most parts of the year.	
57	No	Yes – approximately between 16:50 and 18:50 GMT+10 for most parts of the year.	
58	No	Yes – approximately between 16:50 and 18:50 GMT+10 for most parts of the year.	

Receptor	Results		Conclusion
	Solar reflection possible?		
	am	pm	
59	No	Yes – approximately between 16:50 and 18:50 GMT+10 for most parts of the year.	Solar reflection geometrically possible towards these receptors.
60	No	Yes – approximately between 16:50 and 18:50 GMT+10 for most parts of the year.	
61	No	Yes – approximately between 16:50 and 18:50 GMT+10 for most parts of the year.	
62	No	No	Reflections are not predicted.

Table 3 *Geometric glint and glare reflection calculation results – roads*

5.3 Modelling Results Overview – Dwellings

The results of the geometric calculations for the assessed surrounding dwellings are presented in in Table 4 below.

Receptor	Results		Conclusion
	Solar reflection possible?		
	am	pm	
2	Yes – approximately between 06:00 and 07:00 GMT+10 for parts of October until March.	No	Solar reflection possible if the reflection solar panels are visible.
3	Yes – approximately between 05:00 and 07:00 GMT+10 for parts of May until April.	No	
6	Yes – approximately between 05:00 and 07:00 GMT+10 for parts of July until June.	Yes – approximately between 16:50 and 18:50 GMT+10 almost all year round.	
7	Yes – approximately between 05:10 and 07:00 GMT+10 all year round.	Yes – approximately between 16:50 and 18:50 GMT+10 almost all year round.	
8	Yes – approximately between 05:10 and 07:00 GMT+10 all year round.	Yes – approximately between 16:50 and 18:50 GMT+10 for parts of March until mid-October.	
9	No	Yes – approximately between 16:50 and 18:50 GMT+10 almost all year round.	
10	No	Yes – approximately between 16:50 and 18:50 GMT+10 almost all year round.	

Table 4 *Geometric glint and glare reflection calculation results – dwellings*

6 RESULTS DISCUSSION

6.1 Road Results

Based on a review of the geometric analysis, road users located at 42 of the assessed road locations could experience a solar reflection from the proposed solar farm (road receptor locations 4-8, 17-26, 32-48 and 52-61).

At the remaining assessed road receptor locations, no solar reflection is geometrically possible (locations 27-31, 49 and 62) – 7 locations in total. All other road receptor locations were beyond 1km from the proposed solar farm 1-3, 9-16, 50, 51 and 63).

Figure 13[15] on the following page shows the road locations that could experience a solar reflection when existing screening is considered. The total length of road that may experience a solar reflection is approximately 7.6km. In reality this is likely to be much less due to existing screening which has not been considered.

It is likely that intervening screening will reduce the duration/locations for which a solar reflection could occur because the entire solar panel area will not be visible to a receptor in one location. In some instance, the existing intervening screening may completely remove the solar panels from view.

6.1.1 Road Assessment Conclusions

Overall, a solar reflection may only be visible from approximately 7.6km of road split over three sections.

The road where a solar reflection may be visible is classified as a local road. Road users on this road would be expected to be travelling at (up to) moderate speeds with a low density of traffic. Any solar reflection could last for up to 20 minutes, however in reality, its duration would depend on the speed of the car travelling through the solar reflection zone. Note that not all of the zone will receive a solar reflection at the same time.

In accordance with Pager Power's guidance, the impact upon road users with respect to safety is therefore classified as **Low** where the reflecting solar panels are visible. Where the solar panels are not visible, no impact is expected.

In the event that a solar reflection is experienced by a road user, further comments regarding the scenario in which a solar reflection would be visible and the intensity of any solar reflection experienced are presented Section 6.3. If mitigation is to be applied, further information mitigation is provided in Section 6.4.

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[15] Source: ©2017 Google/CNES/Airbus.

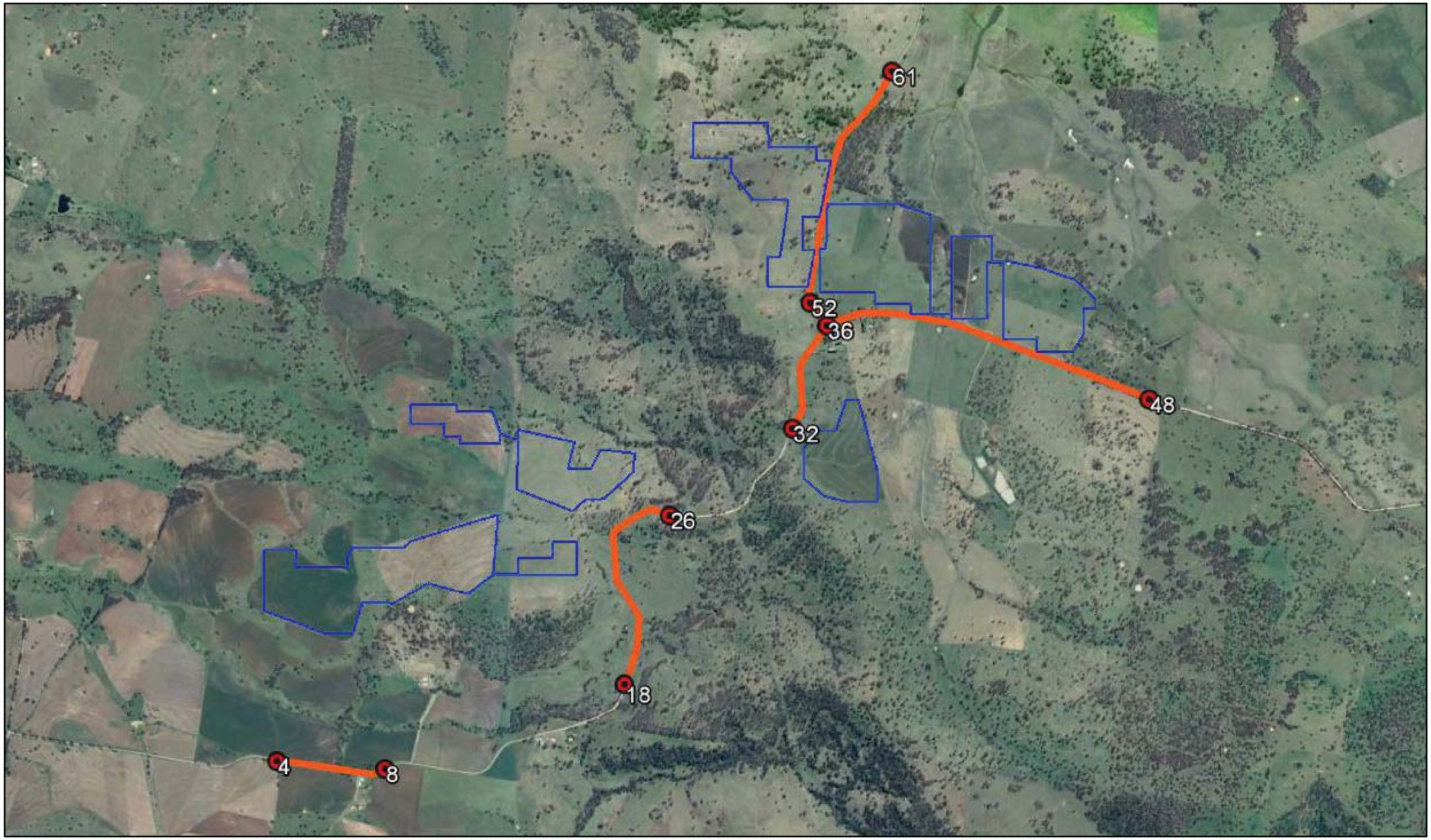

Figure 13 *Sections of road that could experience a solar reflection*

6.2 Dwelling Results

Based on a review of the geometric analysis, residents located within all seven of the assessed dwelling receptors could experience a solar reflection from the proposed solar farm (receptor locations 2, 3 and 6-10).

Figure 14[16] below shows the dwelling receptor locations that could experience a solar reflection. This does not consider whether the solar panels may be visible to the receptor i.e. due to existing screening.

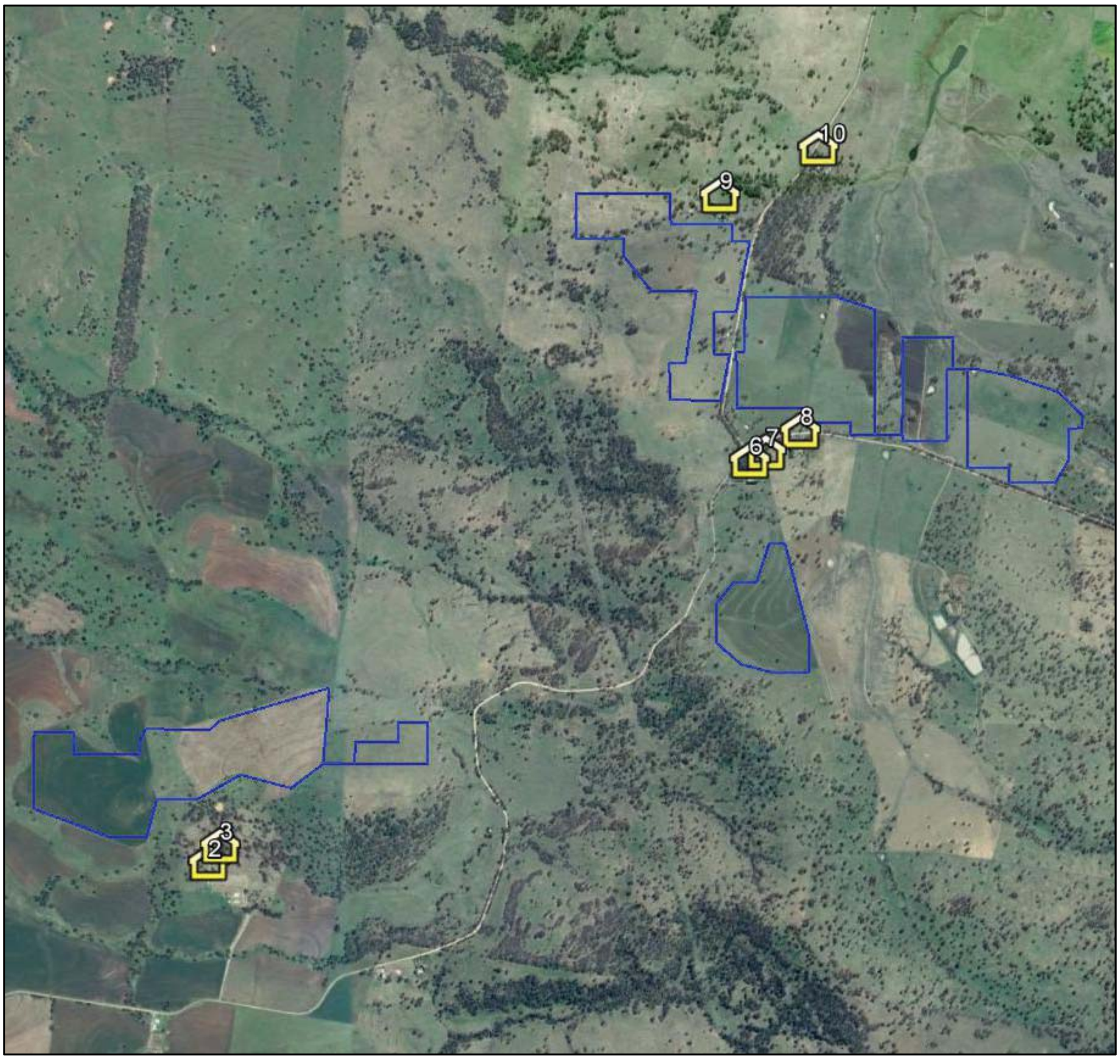

Figure 14 *Dwellings that could experience a solar reflection*

It is likely that intervening screening will reduce the duration/locations for which a solar reflection could occur because the entire solar panel area will not be visible to a receptor in one location. In some instance, the existing intervening screening may completely remove the solar panels from view.

[16] Source: ©2017 Google/CNES/Airbus.

6.2.1 Dwelling Assessment Conclusions

Overall, a solar reflection is deemed possible towards seven of the assessed surrounding dwellings. Intervening screening will likely reduce the duration and likelihood of impact however this cannot be conclusively determined based on the available imagery.

Solar reflections would last for up to 20 minutes on any one day at any one location and only from windows with a clear view of the reflecting solar panels. Solar reflections would only occur on days when the weather is clear and sunny. See Table 3 and Appendix G for the detailed results breakdown.

The potential reflections would last for more than three months a year but less than 60 minutes per day. In accordance with the methodology set out in Section 3 and Appendix E (for dwellings), the resulting impact significance is **Low** to **Moderate**. If screening removes the solar panels from view, **No Impact** will be possible.

In the event that a solar reflection is experienced by resident within a surrounding dwelling, further comments are presented in the following sub-section.

For completeness, mitigation options are presented in Section 6.4.

6.3 Results Discussion Regarding Reflections from Solar Panels

The geometric solar reflection calculations have determined that glint and glare effects are possible towards seven dwellings and three sections of road totally approximately 7.6km (worst-case). Overall, no to moderate impact upon residential amenity is expected and a low impact upon road safety is expected. Further comments are presented below regarding the scenario in which a solar reflection could be experienced by surrounding receptors.

In all scenarios where a solar reflection is geometrically possible towards surrounding roads and dwellings, direct sunlight would coincide with the solar reflection. This means that the viewer will likely be able to see the glare from the reflecting solar panels as well as the Sun directly. Therefore, in this similarly assessed scenario, even if a solar reflection from the panel is experienced by a receptor, the direct sunlight will also be experienced. It is important to note that the direct sunlight would be a significantly brighter source of light when compared to the solar reflection. Lastly, at any one location, only a particular area of solar panels will produce a solar reflection towards it. Note that not all receptors will experience a solar reflection at the same time.

A view of a solar reflection from within the assessed dwellings would only occur where there is a clear view of the reflecting solar panels at the particular time of day when a solar reflection was geometrically possible. In addition, the weather would also have to be clear and sunny. The scenario required to view a solar reflection means that the overall likelihood of viewing a solar reflection in reality would be low.

To experience a solar reflection from the road, a road user would need to be located within the reflection zones, and have a clear view of the reflecting solar panels at the particular time of day when a solar reflection was geometrically possible. In addition, the weather would also have to be clear and sunny. In all cases, the driver would then also be looking in the general direction of the Sun.

6.4 Mitigation and Recommendations

Visibility of the proposed solar farm will likely reduce the predicted impacts and therefore visibilty could be investigated further. If mitigation were to be requested, the most appropriate form would be the installation of screening in the form of vegetation.

7 HIGH LEVEL AVIATION ASSESSMENT

7.1 Overview

In some instances an aviation glint and glare assessment is required for proposed solar developments. The following section provides an overview of the surrounding aerodromes and the requirement for detailed assessment.

7.2 Surrounding Aerodromes

Table 5 below presents an overview of the identified aerodromes surrounding the proposed solar development.

Aerodrome	Distance	Assessment
Glenn Innes	~25km north east	None required
Inverell	~30km south east	None required

Table 5 *Surrounding Aerodromes*

Pager Power typically recommends an assessment when an aerodrome is within 10km of a proposed solar development. Requests for assessment have however been seen out to 30km. Both identified aerodromes are on the outer limits of this radius.

7.3 Aviation Conclusions

In the author's opinion, it is very unlikely that significant impacts upon aviation safety at either of the identified aerodromes will occur. Consultation could be undertaken to determine whether an assessment is expected by the aerodrome safeguarding team.

8 OVERALL CONCLUSIONS

8.1 Glint and Glare Assessment Scope

There is a concern that solar reflections (glint and glare) from the solar panels will create a hazard to the safety of road users, whilst also affecting residential amenity at nearby dwellings. The glint and glare assessment has therefore considered the location and heights of the panels, the receptors and the Sun as it passes across the sky through the year. In this instance, a solar panel tracking system has been assessed.

8.2 Guideline and Studies Overview

To the author's knowledge, there are no specific guidelines for examining the effect of solar reflections from solar panels with respect to residential amenity or road safety in Australia.

Notwithstanding this, well established guidelines exist in the UK (produced by the CAA[17]) and in the USA (produced by the FAA[18]) with respect to solar developments and aviation activity. Generic advice has also been provided within UK Planning Policy.

The analysis has therefore been informed by the available guidance and Pager Power's assessment experience. The approach is to identify receptors, undertake geometric reflection calculations using Pager Power's own bespoke glint and glare model, and then to compare against available solar panel reflection studies.

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[19].

8.3 Understanding Glint and Glare – General Overview

When sunlight illuminates an object, an amount of the incident light is reflected. This reflected light, when directed towards the eye of an observer, can become noticeable and cause a distraction or a nuisance. The unwanted reflection of is referred to as 'glint' (a momentary flash of bright light) or 'glare' (a continuous source of bright light). Where reflected sunlight may be visible to a receptor, it can be concluded that glint and glare effects are possible.

8.4 Road Results

Overall, a low impact upon road users (at worst) on the assessed roads is expected. The overall results and reasoning are presented below.

- Solar reflections are theoretically possible towards approximately 7.6km of road over three sections. In actuality this will be much less due to existing screening;
- The road is classified as a local road;
- Road users would be expected to be travelling at (up to) moderate speeds with a low density of traffic also expected;
- Any solar reflection could last for up to 20 minutes, however in reality, its duration would depend on the speed of the car travelling through the solar reflection zone. Note that not all of the zone will produce a solar reflection towards the road at the same time;
- In accordance with the methodology set out in Section 3 and Appendix E, the overall expected impact upon road users with respect to safety is classified as low where the reflecting solar panels are visible.

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[17] Civil Aviation Authority.
[18] Federal Aviation Administration.
[19] SunPower, 2009, SunPower Solar Module Glare and Reflectance (appendix to Solargen Energy, 2010).

8.5 Dwelling Results

Overall, a low to moderate impact upon residential amenity is expected (at worst). Where the solar panels are not visible, no impact is expected. The overall results and reasoning are presented below.

- Solar reflections are possible towards seven of the assessed dwelling receptors based on the modelling. The visibility of the reflecting solar panels cannot be confirmed based on the available imagery and therefore the conclusions are considered conservative;
- At these seven dwellings, the solar reflections would last for up to 20 minutes per day for up to 6 months. The results vary per dwelling therefore please see Table 3 and Appendix G for the detailed results breakdown for each dwelling;
- In all cases, a clear view of the reflecting solar panels at the particular time of day when a solar reflection was geometrically possible would be required. In addition, the weather would also have to be clear and sunny;
- In all scenarios where a solar reflection is geometrically possible towards the surrounding dwellings, direct sunlight would coincide with the solar reflection. Direct sunlight is significantly more intense than reflections form solar panels;
- In accordance with the methodology set out in Section 3 and Appendix E (for dwellings), the resulting impact significance is Low to Moderate. If screening removes the solar panels from view, No Impact will be possible.

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'. Whilst there is little formal guidance with regard to the assessment of this issue, Pager Power has reviewed relevant publications pertaining to glint and glare. Relevant extracts from guidance published in the UK is presented below for reference.

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[20]) 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[21] (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 farm 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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[20] http://planningguidance.planningportal.gov.uk/blog/guidance/renewable-and-low-carbon-energy/

[21] 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

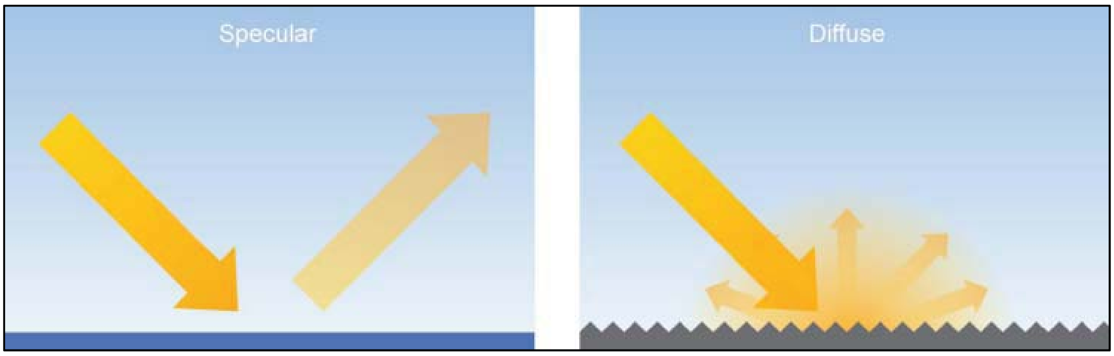
Overview

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 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[22], 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

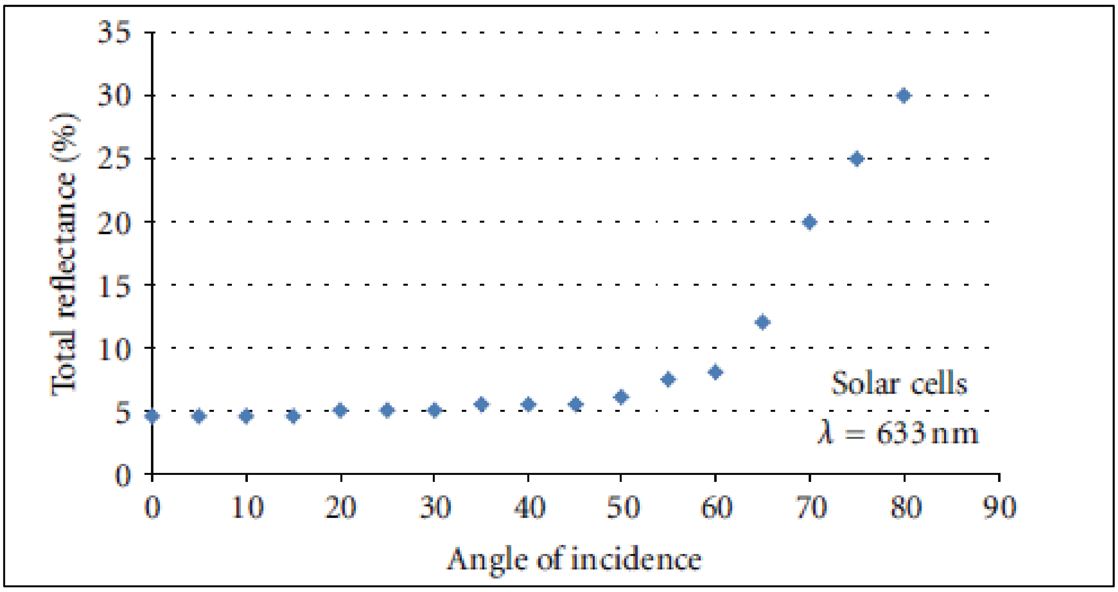
An overview of content from identified solar panel reflectivity studies is presented in the subsections below.

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*[23]". 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.

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

[23] 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"[24]

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[25] within the FAA guidance, is presented on the following page.

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

Surface	Approximate Percentage of Light Reflected[26]
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[27] 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.

[26] Extrapolated data, baseline of 1,000 W/m^2 for incoming sunlight.
[27] Technical Support, 2009. SunPower Technical Notification- Solar Module Glare and Reflectance.

APPENDIX C – PAGER POWER'S REFLECTION CALCULATIONS METHODOLOGY

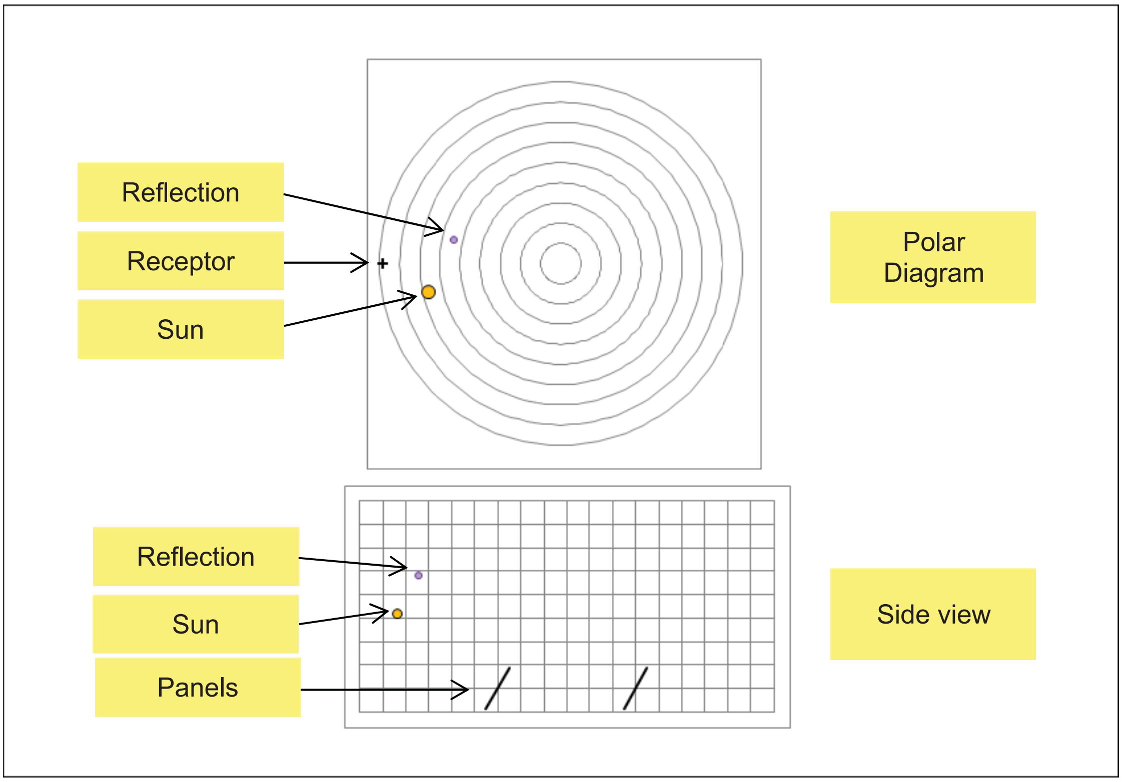
The calculations are three dimensional and complex, accounting for:

- The Earth's orbit around the Sun;
- The Earth's rotation;
- The Earth's orientation;
- The reflector's location;
- The reflector's 3D Orientation – including consideration of the tracking mechanism.

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.

A single axis system such as NexTracker rotates panels from east to west so that they face the Sun as it passes through the sky during the day. At very low solar altitudes the panels flatten so that one row of panels does not cast a shadow on the next. Pager Power's computer algorithm determines the amount of panel tilt based on (1) the predicted position of the Sun; (2) how far the panel can actually tilt - determined by the physical characteristics of the tilting mechanism and (3) the shadow that will be cast on the neighbouring row of panels.

The diagram below illustrates one step in the iterative modelling process, showing the position of the Sun, the angle of the panels and the direction of the reflection at a single point in time.



APPENDIX D – ASSESSMENT LIMITATIONS AND ASSUMPTIONS

Calculations have been undertaken for panel locations at each boundary point of the site, and the site centre. In each case, the modelled altitude of the panels is the same across the development. This is an appropriate assumption because the modelled area is relatively flat.

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 farm 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 farm are chosen in order to build a comprehensive understanding of the entire solar farm. This determines whether a reflection could ever occur at a chosen receptor. The calculations do not incorporate all of the possible panel locations within the solar farm 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 solar farm 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 E – ASSESSMENT METHODOLOGY

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

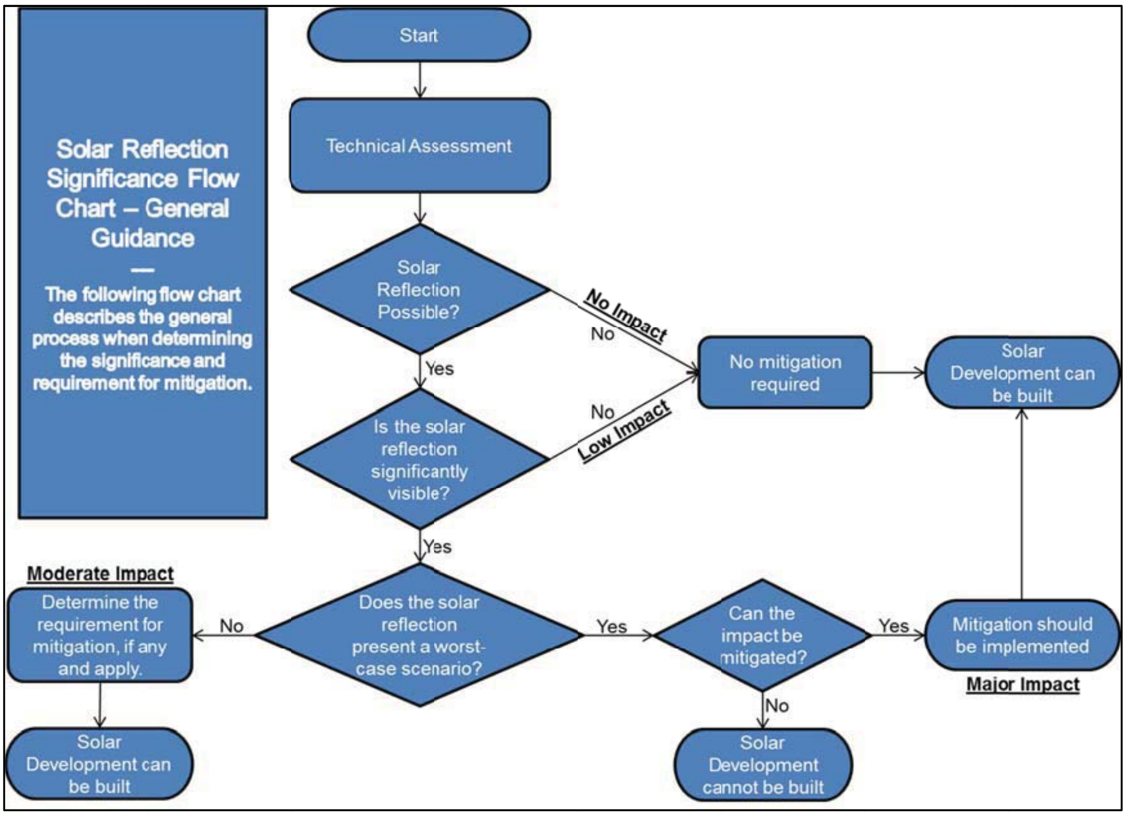
The table below presents the recommended definition of 'impact significance' in glint and glare terms and the requirement for mitigation under each.

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 – General

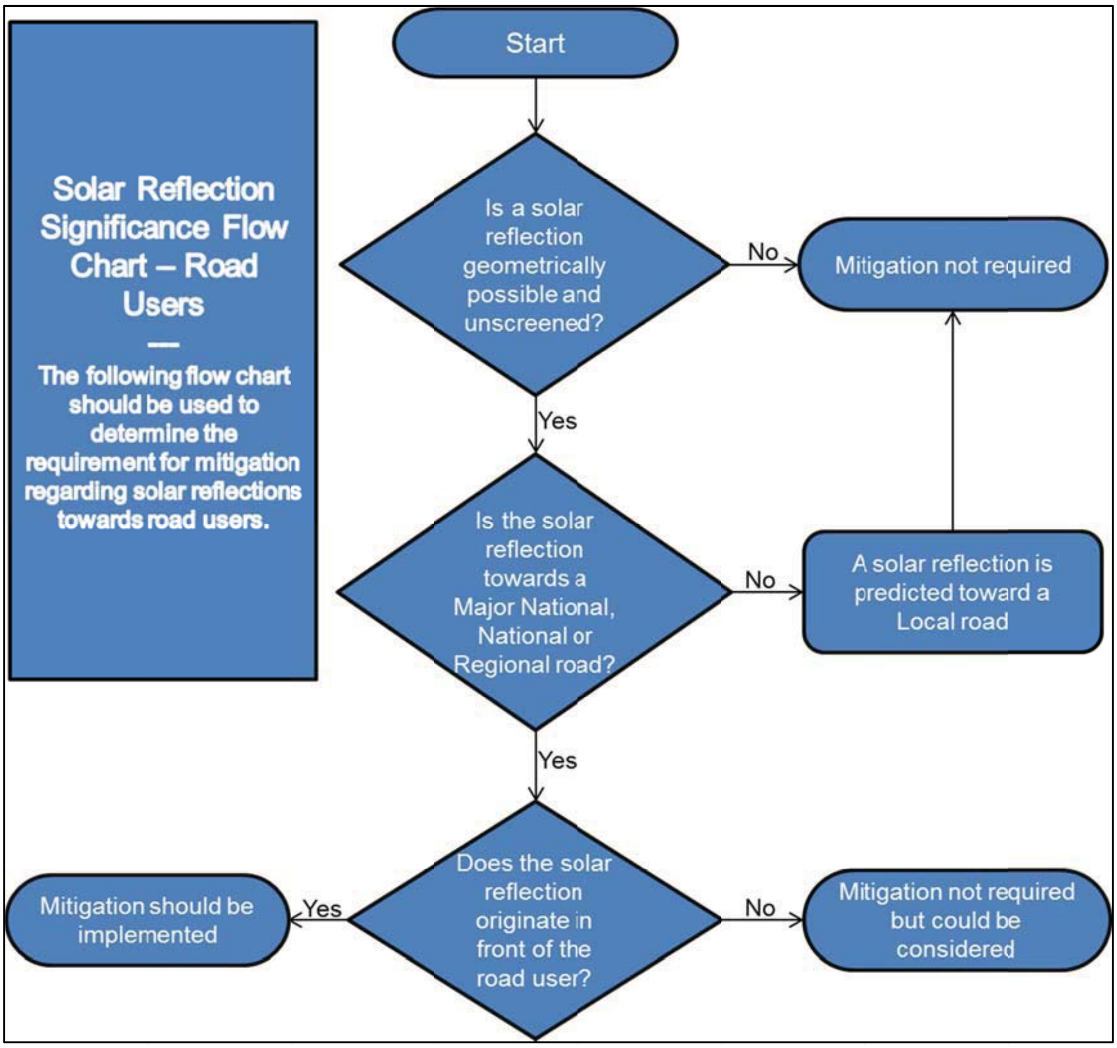
The flow chart presented below shows the general process for establishing a mitigation requirement for a glint and glare impact.



General mitigation requirement flow chart

Assessment process for road receptors

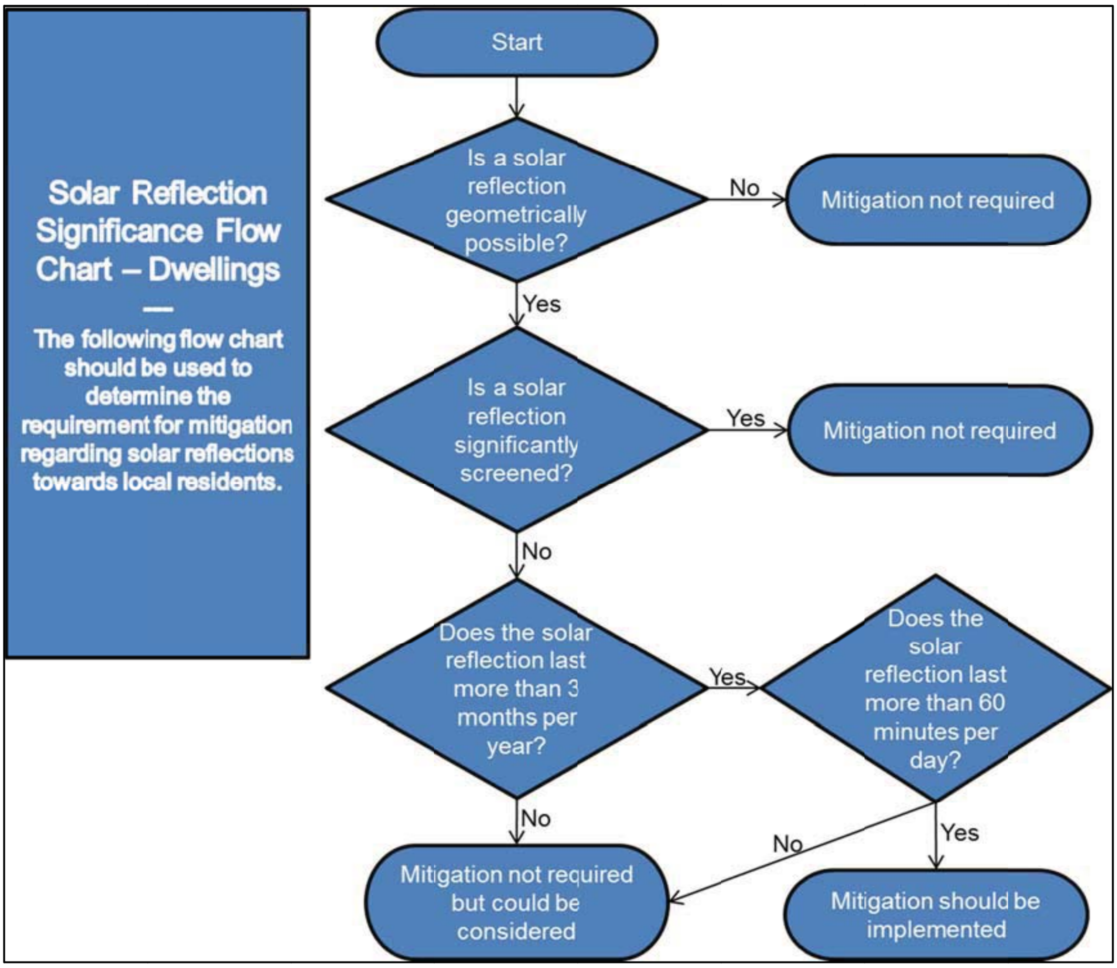
The flow chart presented below has been followed when determining the mitigation requirement for road receptors.



Road receptor mitigation requirement flow chart

Assessment process for dwelling receptors

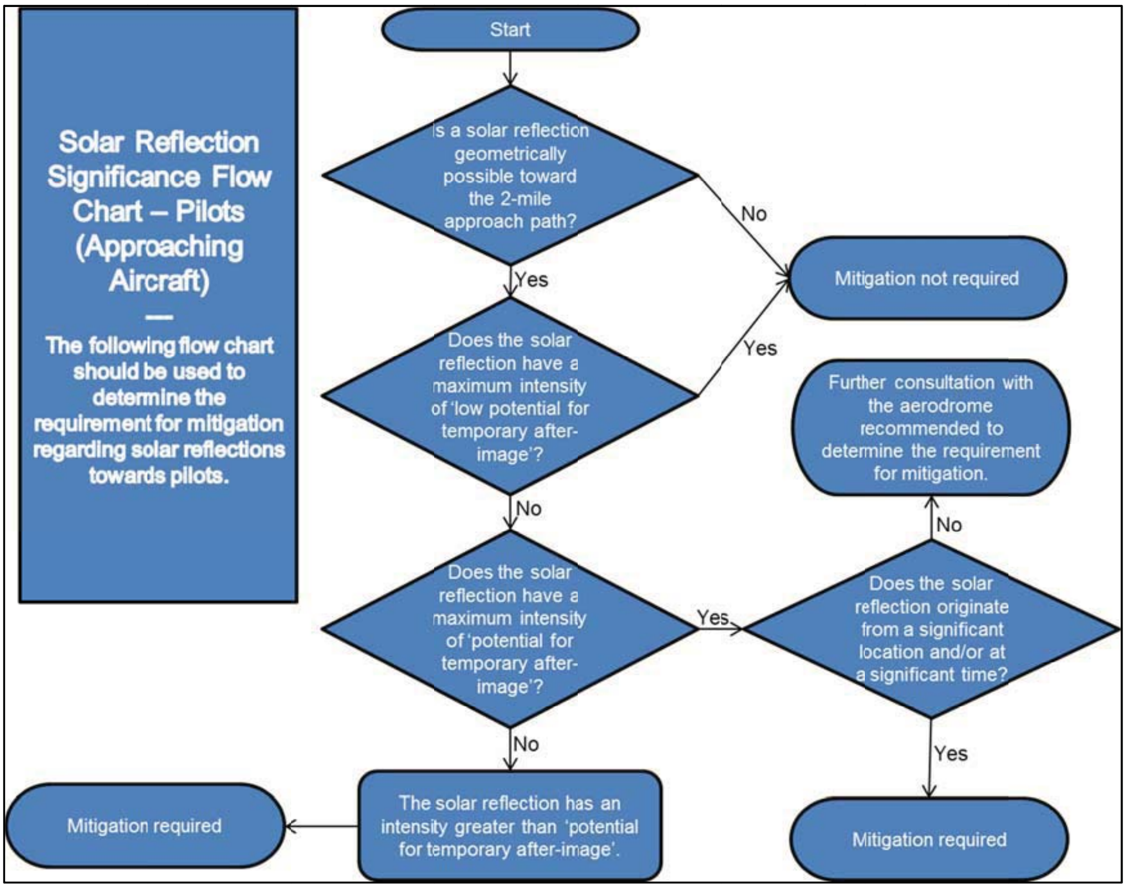
The flow chart presented below has been followed when determining the mitigation requirement for dwelling receptors.



Dwelling receptor mitigation requirement flow chart

Assessment process for aviation receptors (pilots)

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



Airborne aviation receptor mitigation requirement flow chart

APPENDIX F – COORDINATE DATA

Road Receptors

No.	Long. (°)	Lat. (°)	Z amsl (m)	No.	Long. (°)	Lat. (°)	Z amsl (m)
01	151.3785	-29.7343	816.1	33	151.4235	-29.711	996.5
02	151.3805	-29.7345	816.3	34	151.4234	-29.7092	994.1
03	151.3824	-29.7339	817.9	35	151.4242	-29.7076	984.2
04	151.3845	-29.7341	825.4	36	151.4254	-29.7061	978.7
05	151.3865	-29.7343	826.8	37	151.4273	-29.7055	971.2
06	151.3886	-29.7346	830.8	38	151.4294	-29.7054	960.2
07	151.3905	-29.7349	832.9	39	151.4315	-29.7056	953.7
08	151.3926	-29.7346	830.8	40	151.4335	-29.7059	950.8
09	151.3946	-29.7343	832.1	41	151.4355	-29.7064	950.0
10	151.3966	-29.7346	834.5	42	151.4374	-29.707	952.4
11	151.3986	-29.7349	839.2	43	151.4393	-29.7076	959.6
12	151.4004	-29.7343	843.0	44	151.4413	-29.7083	963.3
13	151.4018	-29.733	846.3	45	151.4432	-29.7089	965.9
14	151.4038	-29.7325	854.0	46	151.4451	-29.7096	973.4
15	151.4058	-29.732	858.7	47	151.4471	-29.7102	974.4
16	151.4077	-29.7314	866.1	48	151.449	-29.7108	972.0
17	151.4095	-29.7307	871.6	49	151.451	-29.7114	967.9
18	151.4104	-29.7291	873.8	50	151.453	-29.7119	961.8
19	151.4111	-29.7273	875.6	51	151.4549	-29.7124	964.8
20	151.4114	-29.7255	869.0	52	151.4242	-29.7047	977.4
21	151.4108	-29.7239	873.0	53	151.4243	-29.703	970.1
22	151.4097	-29.7223	882.0	54	151.4246	-29.7013	965.2
23	151.4096	-29.7205	900.5	55	151.425	-29.6994	961.0
24	151.4101	-29.719	919.2	56	151.4253	-29.6976	958.5
25	151.4119	-29.7181	940.5	57	151.4258	-29.6959	957.7
26	151.4139	-29.7182	952.2	58	151.4265	-29.6942	956.4
27	151.4158	-29.7184	951.8	59	151.4278	-29.6929	956.7
28	151.4179	-29.7181	959.8	60	151.4291	-29.6915	952.0
29	151.4196	-29.7171	965.5	61	151.4302	-29.6899	949.1
30	151.4206	-29.7156	972.5	62	151.4313	-29.6884	948.9
31	151.422	-29.7143	980.5	63	151.4321	-29.6867	951.0

No.	Long. (°)	Lat. (°)	Z amsl (m)	No.	Long. (°)	Lat. (°)	Z amsl (m)
32	151.4229	-29.7127	991.6				

Dwelling Receptors

No.	Ref. as per EIS	Long. (°)	Lat. (°)	Z amsl (m)
01	R033	151.3906	-29.7356	837.5
02	R016	151.3939	-29.7282	854.5
03		151.3946	-29.7274	862.6
04	R015	151.4041	-29.7328	853.1
05		151.4063	-29.7328	855.4
06	R014	151.4256	-29.7078	983.1
07		151.4265	-29.7074	981.3
08	R013	151.4285	-29.7063	969.5
09	R018	151.4239	-29.6944	960.5
10	R017	151.4296	-29.692	951.6

Panel Area One

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
01	151.3879	-29.7038	09	151.3973	-29.7094
02	151.3898	-29.7038	10	151.3947	-29.7094
03	151.3911	-29.7042	11	151.3947	-29.7086
04	151.3911	-29.7048	12	151.3931	-29.7086
05	151.393	-29.7048	13	151.3931	-29.7092
06	151.393	-29.7057	14	151.39	-29.7092
07	151.3951	-29.7057	15	151.3879	-29.7052
08	151.3976	-29.7069	16		

Panel Area 1 Reference Points

Reflector	Longitude (°)	Latitude (°)	Z (ground height) (m)
R1	151.3962	-29.7094	861.79
R2	151.39	-29.7076	832.21
R3	151.392	-29.7076	840.26
R4	151.3941	-29.7076	849.31
R5	151.3962	-29.7076	845.26
R6	151.39	-29.7058	825.00
R7	151.392	-29.7058	829.00
R8	151.3941	-29.7058	835.00

Reflector	Longitude (°)	Latitude (°)	Z (ground height) (m)
R9	151.3879	-29.704	826.27
R10	151.39	-29.704	826.73

Panel Area Two

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
01	151.3945	-29.7112	14	151.4088	-29.7172
02	151.3979	-29.7112	15	151.4075	-29.7173
03	151.3979	-29.7117	16	151.4065	-29.718
04	151.4006	-29.7117	17	151.4024	-29.7166
05	151.4012	-29.7131	18	151.4025	-29.7135
06	151.4024	-29.7135	19	151.4011	-29.7131
07	151.4025	-29.7128	20	151.4011	-29.7137
08	151.4066	-29.7136	21	151.3982	-29.7137
09	151.4061	-29.7153	22	151.3982	-29.7132
10	151.4078	-29.7153	23	151.397	-29.7132
11	151.4086	-29.7141	24	151.397	-29.7124
12	151.4111	-29.7144	25	151.3945	-29.7124
13	151.4111	-29.7155			

Panel Area 2 Reference Points

Reflector	Longitude (°)	Latitude (°)	Z (ground height) (m)
R1	151.4028	-29.7162	883.04
R2	151.4049	-29.7162	887.09
R3	151.4069	-29.7162	882.50
R4	151.409	-29.7162	896.92
R5	151.4028	-29.7144	876.41
R6	151.4049	-29.7144	879.32
R7	151.409	-29.7144	883.14
R8	151.4111	-29.7144	891.81
R9	151.3986	-29.7126	878.21
R10	151.4007	-29.7126	875.10

Panel Area Three

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
01	151.3836	-29.7206	13	151.4051	-29.721
02	151.3859	-29.7206	14	151.4051	-29.72
03	151.3859	-29.7216	15	151.4068	-29.72
04	151.3898	-29.7217	16	151.4068	-29.7221
05	151.3898	-29.721	17	151.4007	-29.7221
06	151.3902	-29.7204	18	151.3988	-29.7233

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
07	151.394	-29.7204	19	151.3958	-29.7227
08	151.3946	-29.72	20	151.3933	-29.7239
09	151.401	-29.7183	21	151.3909	-29.7239
10	151.4007	-29.7221	22	151.3902	-29.7259
11	151.4025	-29.7221	23	151.3881	-29.7259
12	151.4026	-29.721	24	151.3836	-29.7245

Panel Area 3 Reference Points

Reflector	Longitude (°)	Latitude (°)	Z (ground height) (m)
R1	151.3898	-29.7259	852.31
R2	151.3836	-29.7241	851.63
R3	151.3857	-29.7241	855.49
R4	151.3877	-29.7241	860.80
R5	151.3898	-29.7241	863.21
R6	151.3836	-29.7223	848.36
R7	151.3857	-29.7223	855.22
R8	151.3877	-29.7223	854.08
R9	151.3898	-29.7223	862.31
R10	151.3919	-29.7223	872.36
R11	151.394	-29.7223	878.84
R12	151.396	-29.7223	884.00
R13	151.3981	-29.7223	895.82
R14	151.4002	-29.7223	910.29
R15	151.3919	-29.7205	872.67
R16	151.394	-29.7205	873.09
R17	151.396	-29.7205	880.04
R18	151.3981	-29.7205	884.20
R19	151.4002	-29.7205	890.92
R20	151.4064	-29.7205	896.42
R21	151.4002	-29.7187	876.76

Panel Area Four

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
01	151.4267	-29.711	06	151.4251	-29.717
02	151.4276	-29.711	07	151.4237	-29.716
03	151.429	-29.7155	08	151.4237	-29.714

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
04	151.429	-29.7174	09	151.4246	-29.7129
05	151.4269	-29.7174	10	151.426	-29.7129

Panel Area 4 Reference Points

Reflector	Longitude (°)	Latitude (°)	Z (ground height) (m)
R1	151.4278	-29.7174	966.79
R2	151.4237	-29.7156	969.35
R3	151.4258	-29.7156	964.00
R4	151.4278	-29.7156	958.84
R5	151.4258	-29.7138	963.83
R6	151.4278	-29.7138	958.21
R7	151.4278	-29.712	962.39

Panel Area Five

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
01	151.4254	-29.6985	17	151.4407	-29.7079
02	151.4306	-29.6985	18	151.4407	-29.7071
03	151.4329	-29.6991	19	151.4383	-29.7071
04	151.4329	-29.7054	20	151.4383	-29.7022
05	151.4345	-29.7054	21	151.437	-29.7022
06	151.4345	-29.7005	22	151.437	-29.7058
07	151.4374	-29.7005	23	151.4345	-29.7058
08	151.4374	-29.7021	24	151.4344	-29.7055
09	151.4387	-29.7021	25	151.4315	-29.7055
10	151.4409	-29.7025	26	151.4315	-29.7048
11	151.4435	-29.7033	27	151.4288	-29.7048
12	151.4449	-29.7045	28	151.4288	-29.7041
13	151.4449	-29.7051	29	151.4248	-29.7041
14	151.4441	-29.7051	30	151.4248	-29.7013
15	151.4441	-29.7068	31	151.4253	-29.7013
16	151.4433	-29.7079			

Panel Area 5 Reference Points

Reflector	Longitude (°)	Latitude (°)	Z (ground height) (m)
R1	151.4414	-29.7079	961.6
R2	151.4393	-29.7061	953.47

Reflector	Longitude (°)	Latitude (°)	Z (ground height) (m)
R3	151.4414	-29.7061	954.45
R4	151.4435	-29.7061	957.01
R5	151.4289	-29.7043	956.18
R6	151.431	-29.7043	953.05
R7	151.4352	-29.7043	948.2
R8	151.4393	-29.7043	950.85
R9	151.4414	-29.7043	951.41
R10	151.4434	-29.7043	952.47
R11	151.4248	-29.7025	965.14
R12	151.4269	-29.7025	959.95
R13	151.4289	-29.7025	954
R14	151.431	-29.7025	950.99
R15	151.4352	-29.7025	948.98
R16	151.4393	-29.7025	949.3
R17	151.4269	-29.7007	956.64
R18	151.4289	-29.7007	951.82
R19	151.431	-29.7007	948.05
R20	151.4352	-29.7007	946
R21	151.4372	-29.7007	946.37
R22	151.4269	-29.6989	951
R23	151.4289	-29.6989	948.26
R24	151.431	-29.6989	949.3
R25	151.4253	-29.7013	962.06
R26	151.4248	-29.7013	964.94
R27	151.4248	-29.7041	971.82
R28	151.4288	-29.7041	957.03
R29	151.4288	-29.7048	959.94
R30	151.4315	-29.7048	953
R31	151.4315	-29.7055	953.58
R32	151.4344	-29.7055	950.23
R33	151.4345	-29.7058	950.25
R34	151.437	-29.7058	950
R35	151.437	-29.7022	948.05
R36	151.4383	-29.7022	949.56
R37	151.4383	-29.7071	954.63

Reflector	Longitude (°)	Latitude (°)	Z (ground height) (m)
R38	151.4407	-29.7071	957.5
R39	151.4407	-29.7079	961.65
R40	151.4433	-29.7079	964.75
R41	151.4441	-29.7068	958.69
R42	151.4441	-29.7051	953.15
R43	151.4449	-29.7051	956.08
R44	151.4449	-29.7045	953.3
R45	151.4435	-29.7033	952.67
R46	151.4409	-29.7025	948.1
R47	151.4387	-29.7021	949.63
R48	151.4374	-29.7021	948.83
R49	151.4374	-29.7005	946.68
R50	151.4345	-29.7005	947
R51	151.4345	-29.7054	950
R52	151.4329	-29.7054	952.25
R53	151.4329	-29.6991	947.44
R54	151.4306	-29.6985	950.45
R55	151.4254	-29.6985	957.98
R56	151.4253	-29.7013	962.06

Panel Area Six

No.	Longitude (°)	Latitude (°)	No.	Longitude (°)	Latitude (°)
01	151.4155	-29.6933	11	151.4239	-29.7037
02	151.421	-29.6933	12	151.421	-29.7037
03	151.421	-29.6948	13	151.4209	-29.7018
04	151.4246	-29.6948	14	151.4218	-29.7018
05	151.4246	-29.6957	15	151.4225	-29.6982
06	151.4256	-29.6957	16	151.4199	-29.6982
07	151.4248	-29.6993	17	151.4183	-29.6964
08	151.4235	-29.6993	18	151.4183	-29.6956
09	151.4235	-29.7014	19	151.4155	-29.6955
10	151.4244	-29.7014			

Panel Area 6 Reference Points

Reflector	Longitude (°)	Latitude (°)	Z (ground height) (m)
R1	151.4217	-29.7037	984.5

Reflector	Longitude (°)	Latitude (°)	Z (ground height) (m)
R2	151.4238	-29.7037	977.45
R3	151.4217	-29.7019	977.13
R4	151.4238	-29.7019	968.24
R5	151.4238	-29.6983	965.59
R6	151.4196	-29.6965	973.77
R7	151.4217	-29.6965	976
R8	151.4238	-29.6965	966.38
R9	151.4155	-29.6947	950.25
R10	151.4176	-29.6947	955.87
R11	151.4196	-29.6947	962.58
R12	151.4155	-29.6955	948.87
R13	151.4183	-29.6956	966.1
R14	151.4183	-29.6964	968.93
R15	151.4199	-29.6982	978.15
R16	151.4225	-29.6982	973.9
R17	151.4218	-29.7018	976.24
R18	151.4209	-29.7018	977.54
R19	151.421	-29.7037	986.83
R20	151.4239	-29.7037	976.1
R21	151.4244	-29.7014	965.28
R22	151.4235	-29.7014	969.38
R23	151.4235	-29.6993	967.29
R24	151.4248	-29.6993	961.81
R25	151.4256	-29.6957	957.48
R26	151.4246	-29.6957	959.03
R27	151.4246	-29.6948	958.55
R28	151.421	-29.6948	966.38
R29	151.421	-29.6933	949
R30	151.4155	-29.6933	943
R31	151.4155	-29.6955	948.87

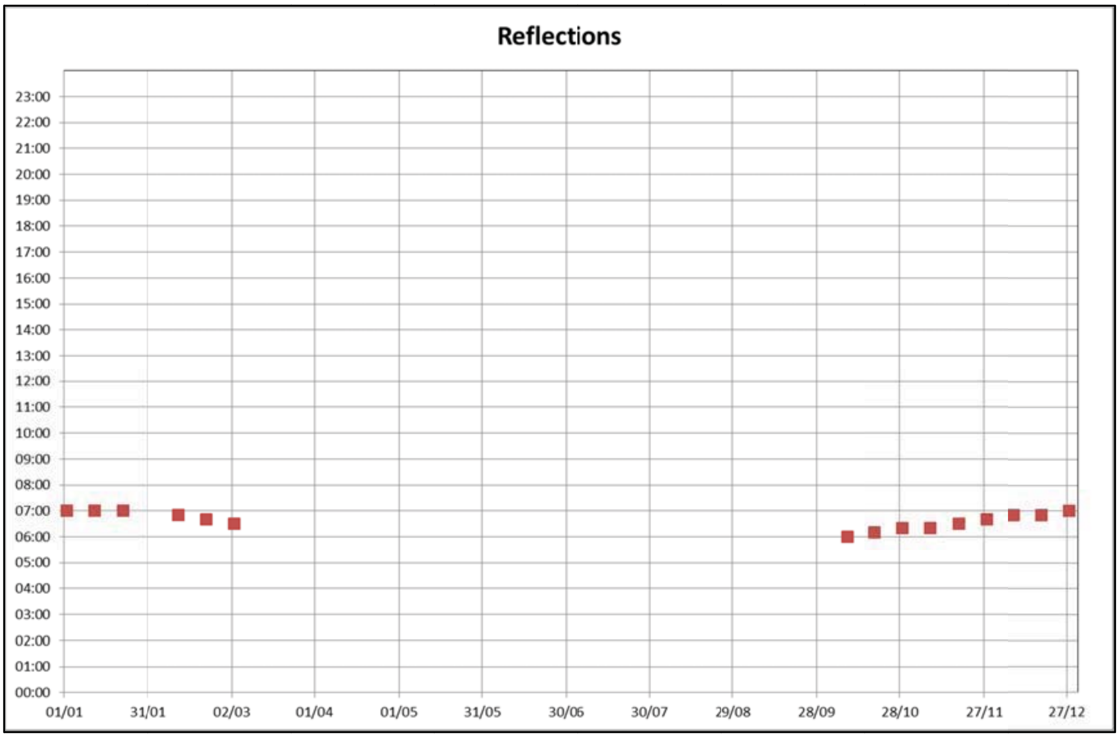
APPENDIX G – GEOMETRIC CALCULATION RESULTS

The charts for the receptors are shown on the following pages. Each chart shows the reflection date/time graph. The brown icons indicate the dates and times at which geometric reflections are possible. This is based on a 10 degree criteria (discussed in Section 4.6). The results are combined for all assessed points within the proposed solar farm.

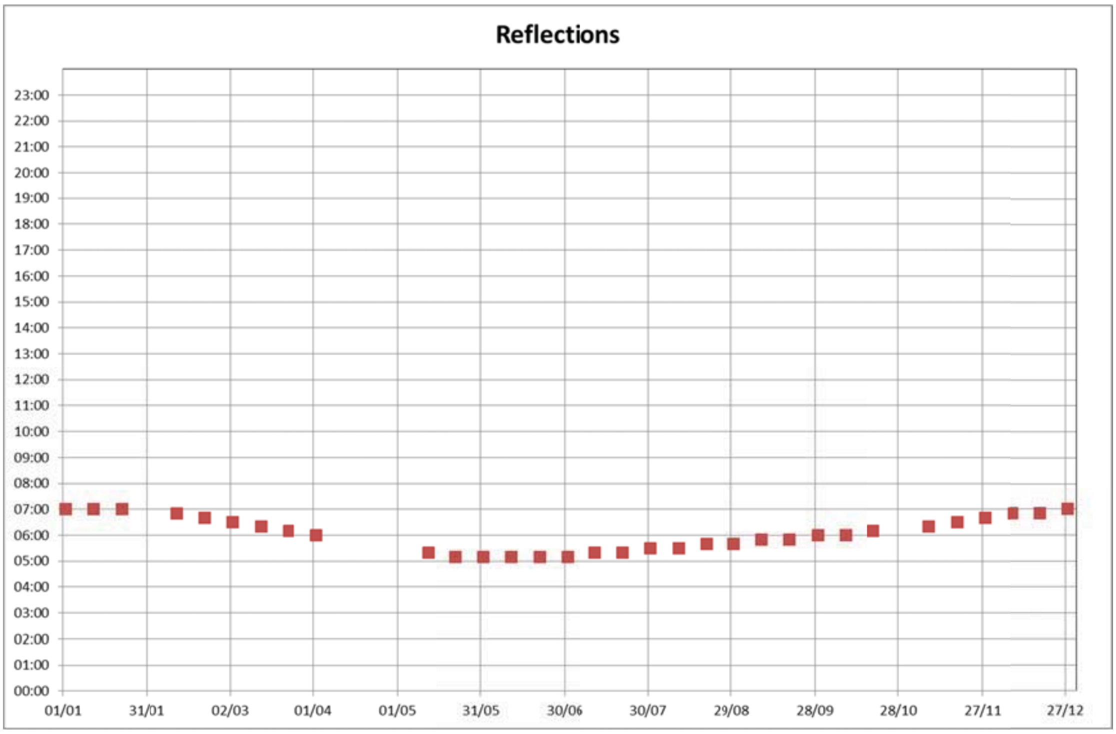
Dwelling Receptors

The glint and glare charts at the receptors where a solar reflection is geometrically possible, not considering existing screening, are presented below.

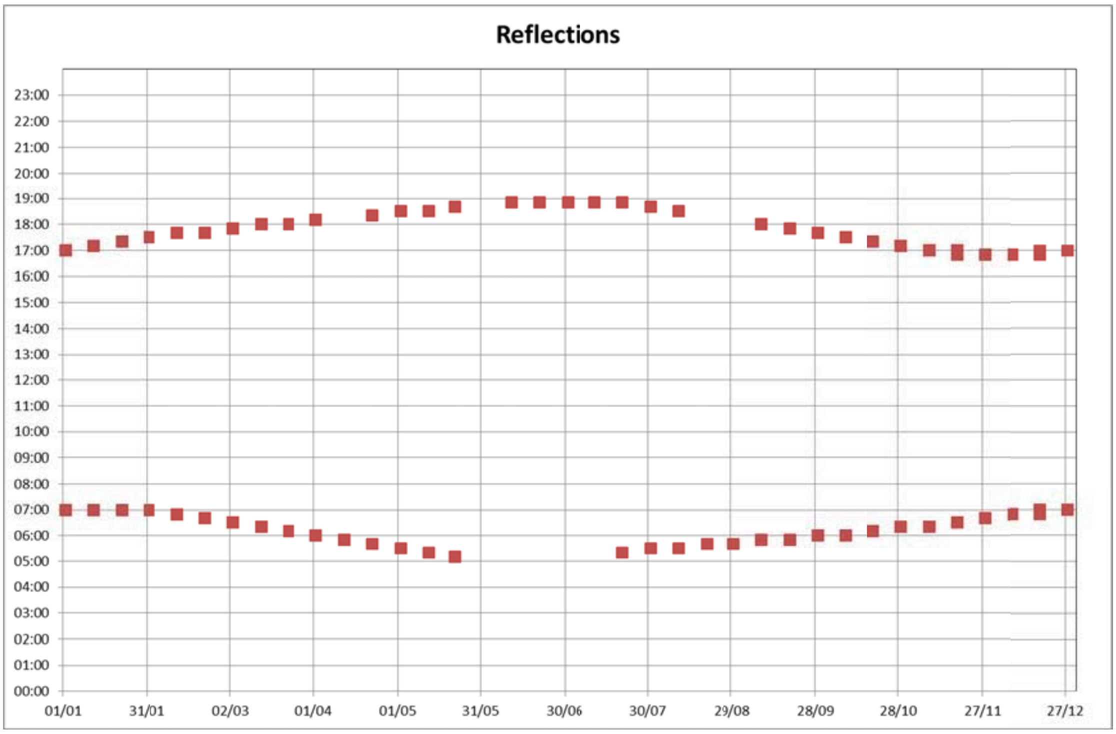
Dwelling 2



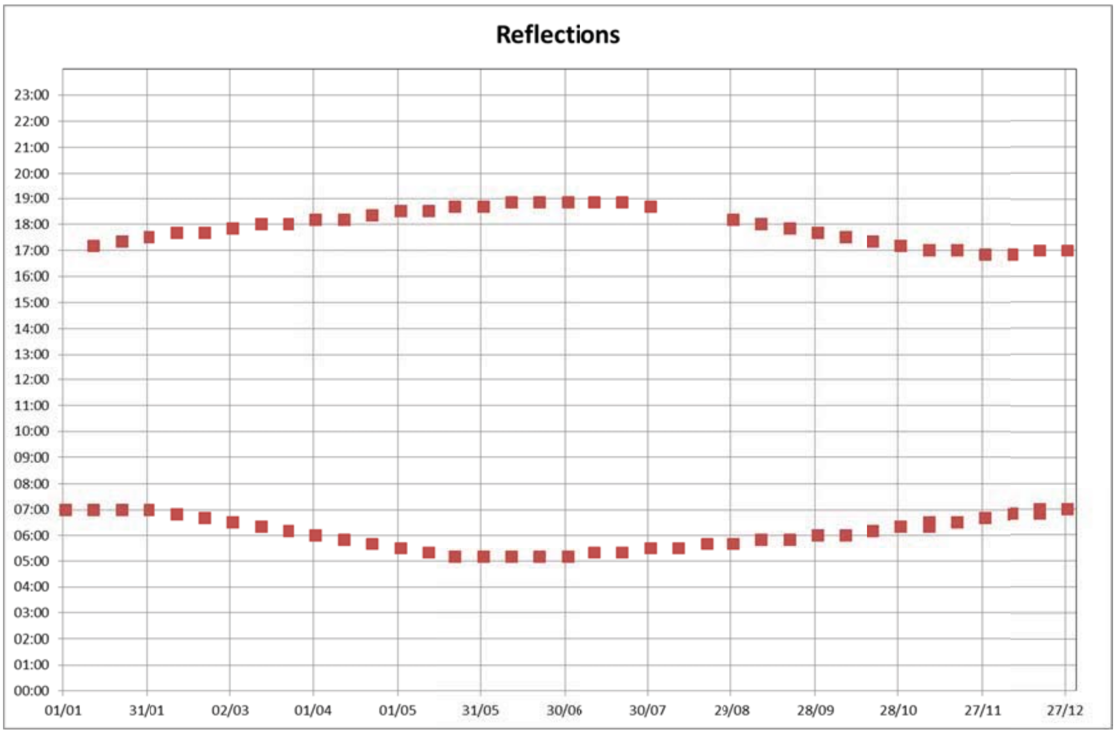
Dwelling 3



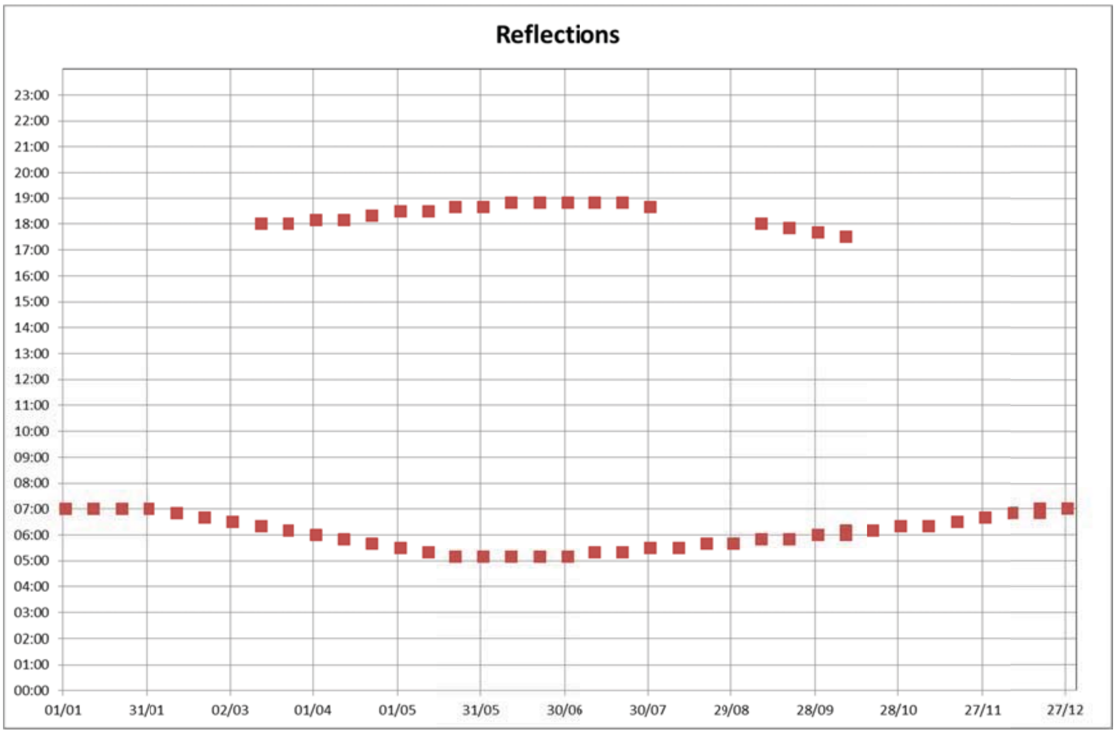
Dwelling 6



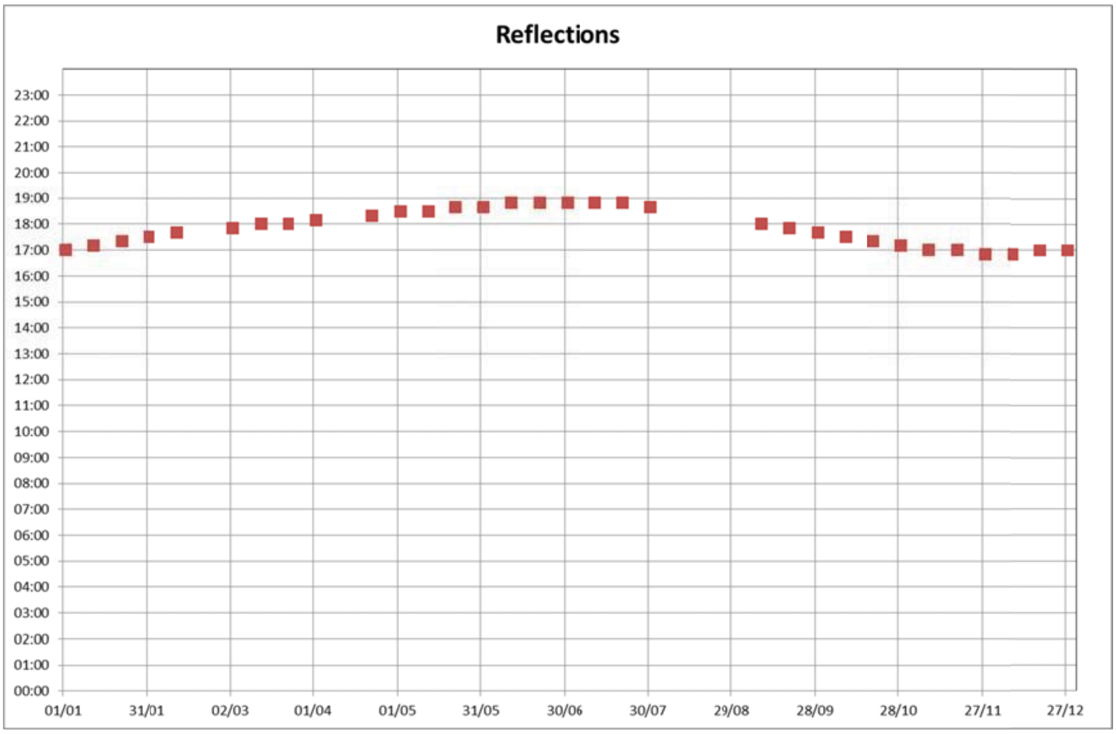
Dwelling 7



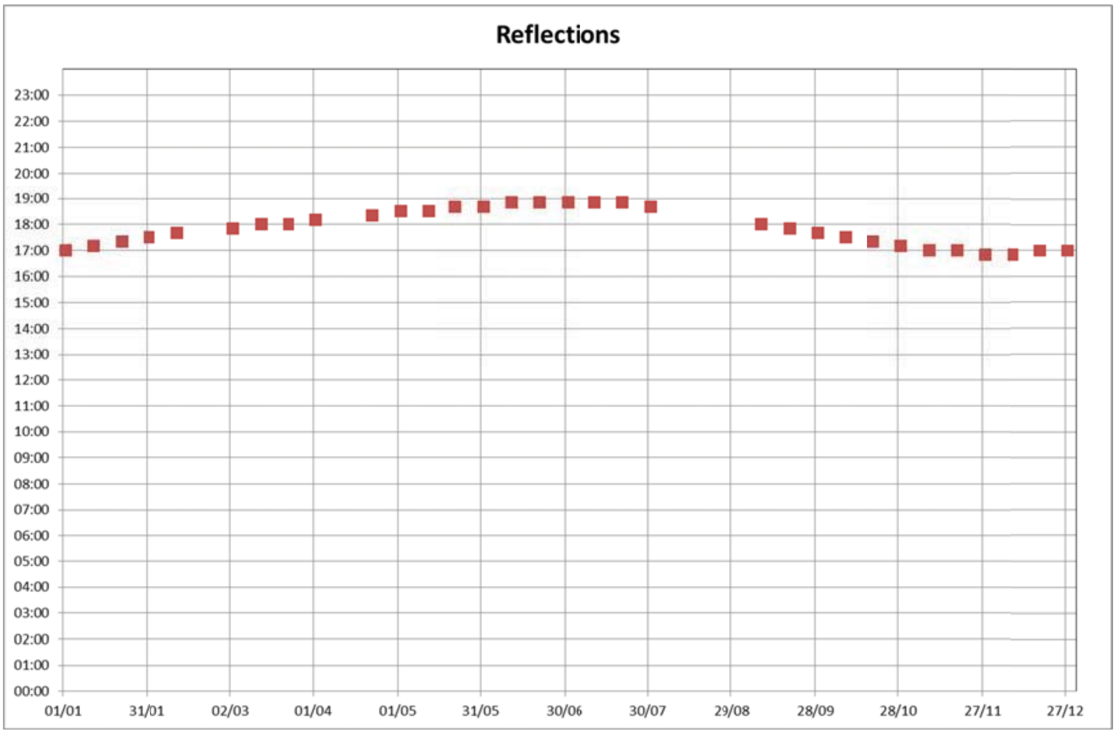
Dwelling 8



Dwelling 9



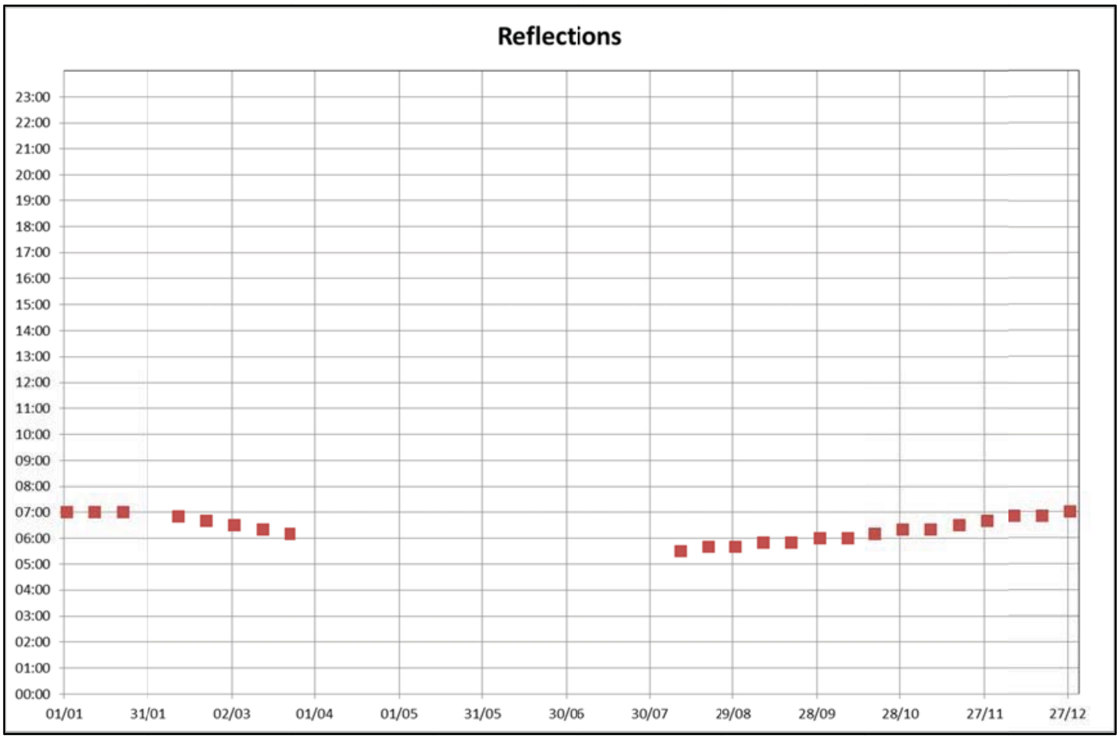
Dwelling 10



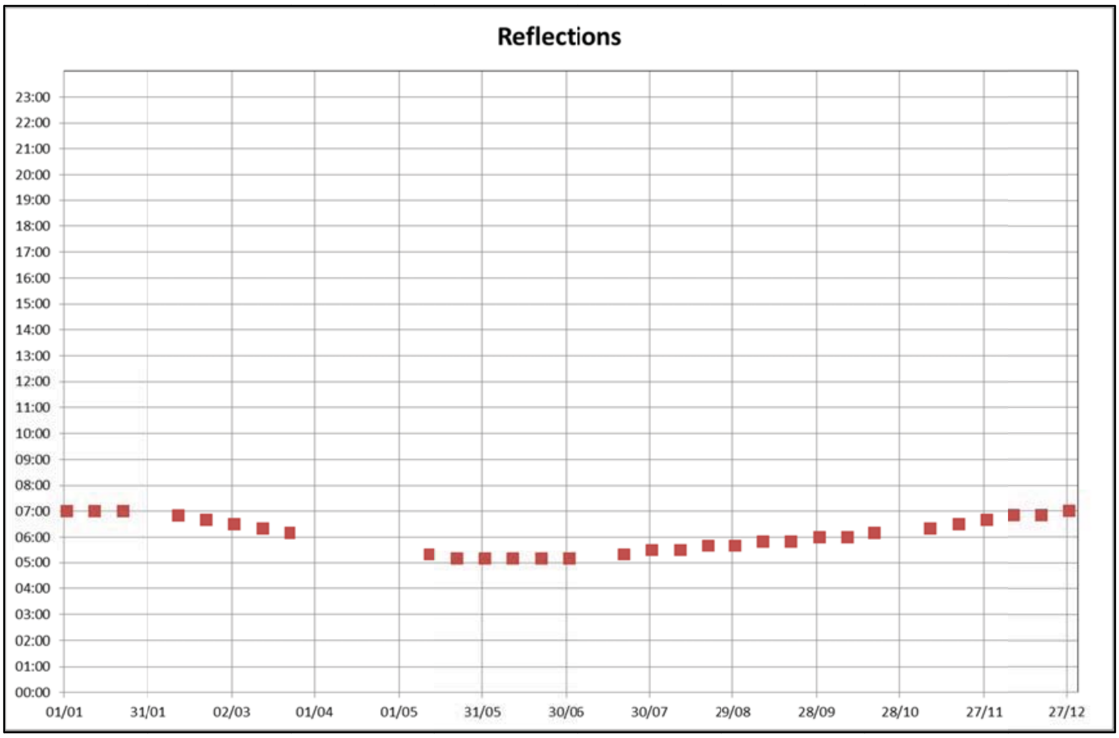
Road Receptors

The glint and glare charts at the receptors where a solar reflection is geometrically possible, not considering existing screening, are presented below.

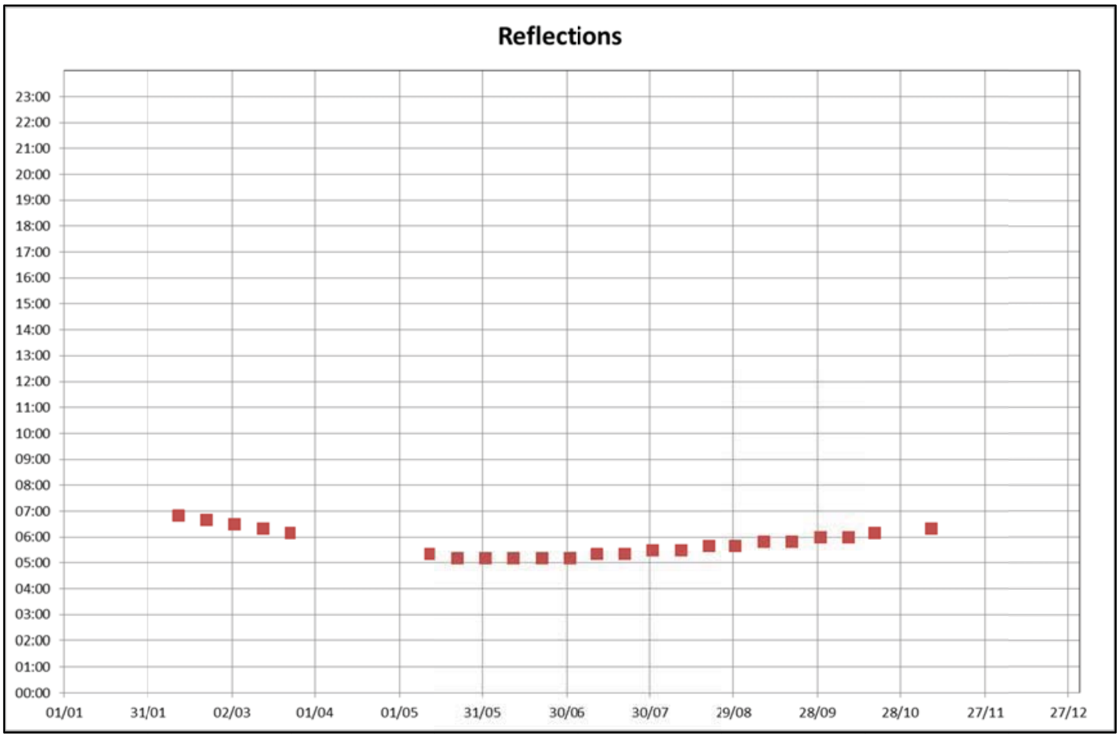
Road 4



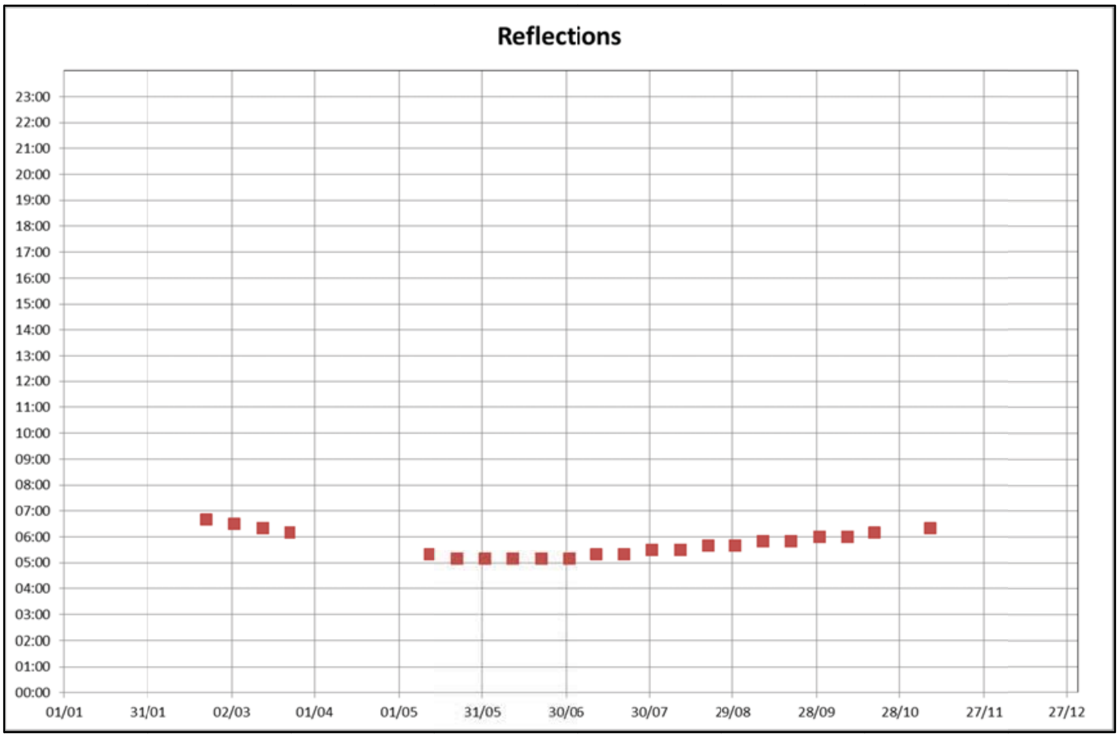
Road 5



Road 6


Reflections
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
01/01
31/01
02/03
01/04
01/05
31/05
30/06
30/07
29/08
28/09
28/10
27/11
27/12

Road 7


Reflections
23:00
22:00
21:00
20:00
19:00
18:00
17:00
16:00
15:00
14:00
13:00
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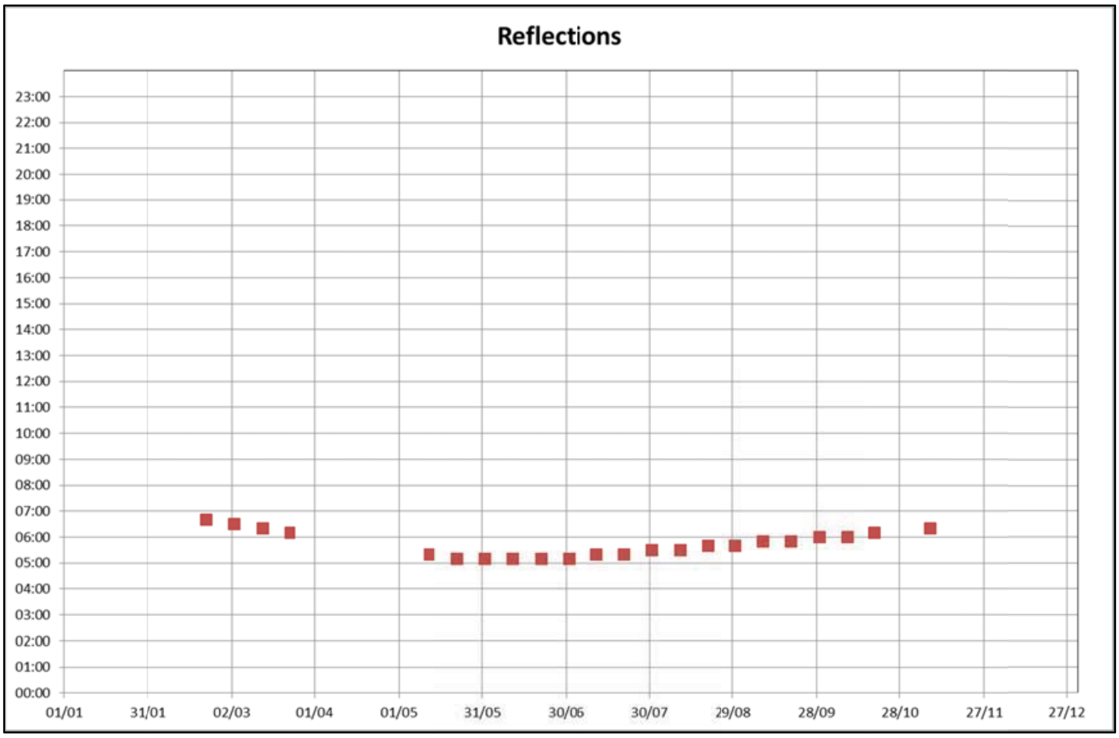
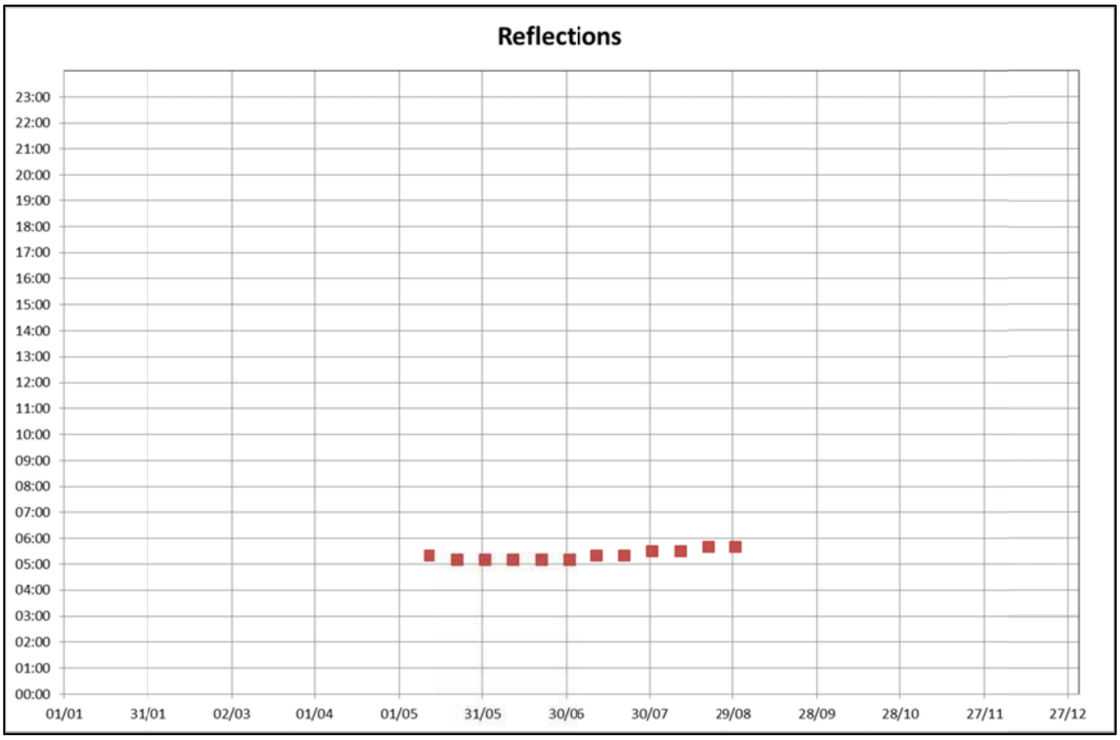
11:00
10:00
09:00
08:00
07:00
06:00
05:00
04:00
03:00
02:00
01:00
00:00
01/01
31/01
02/03
01/04
01/05
31/05
30/06
30/07
29/08
28/09
28/10
27/11
27/12

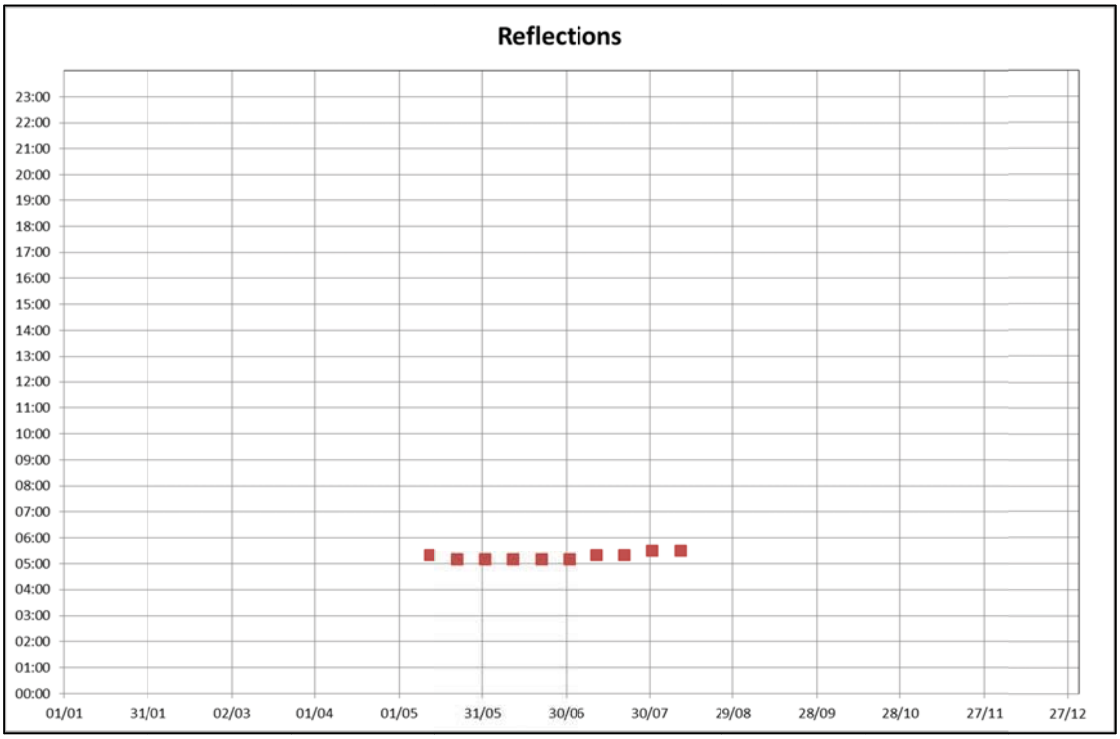
Road 8



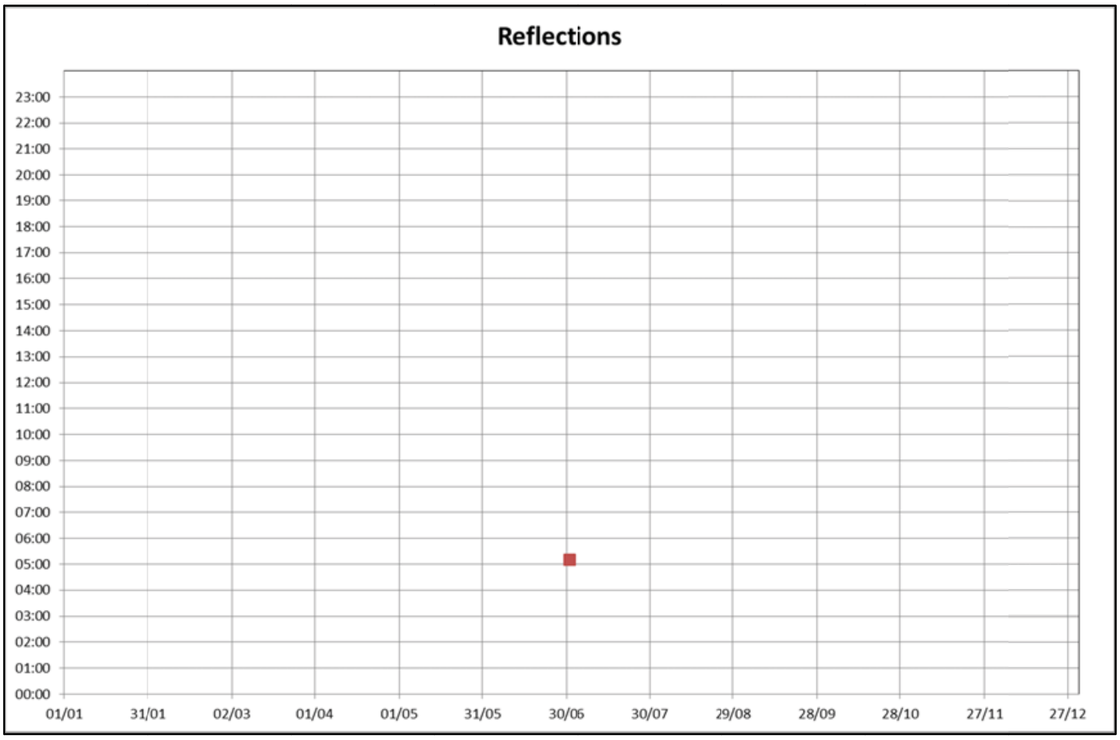
Road 17



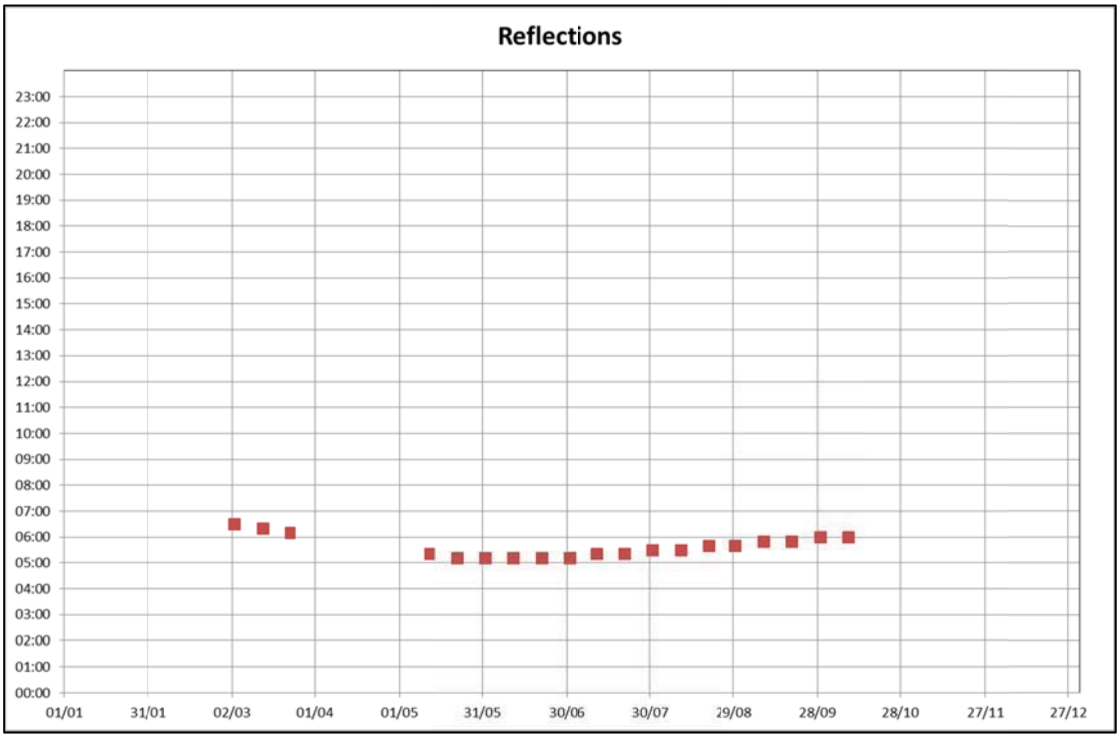
Road 18



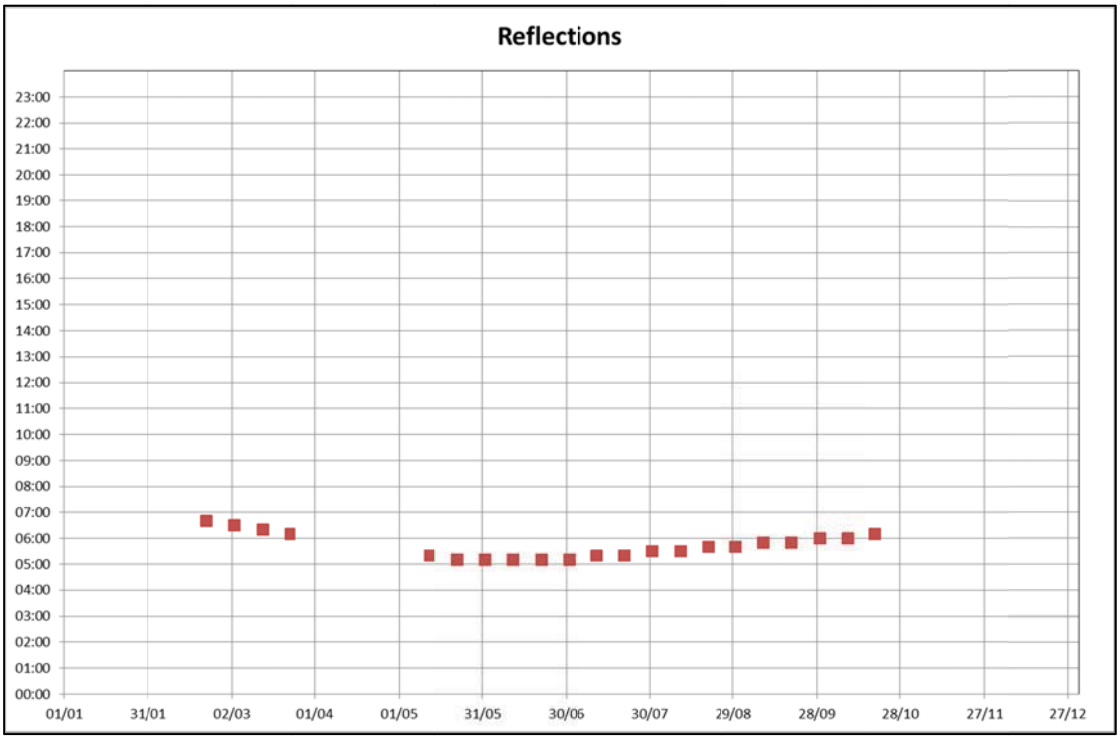
Road 19



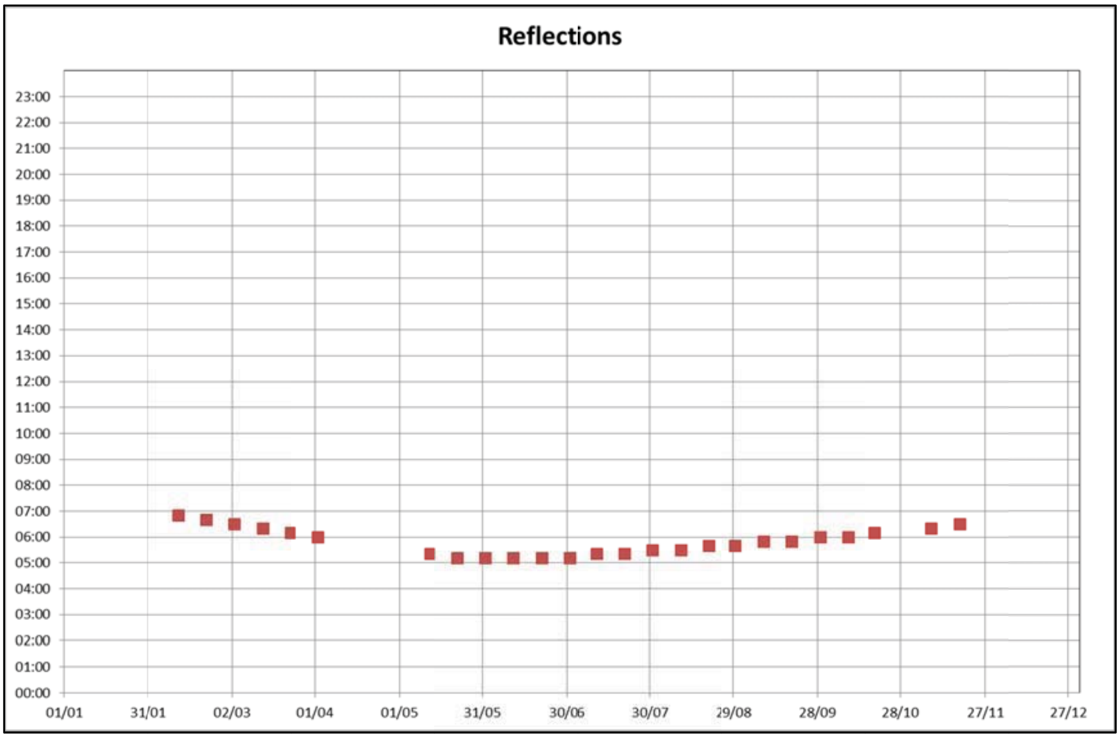
Road 20



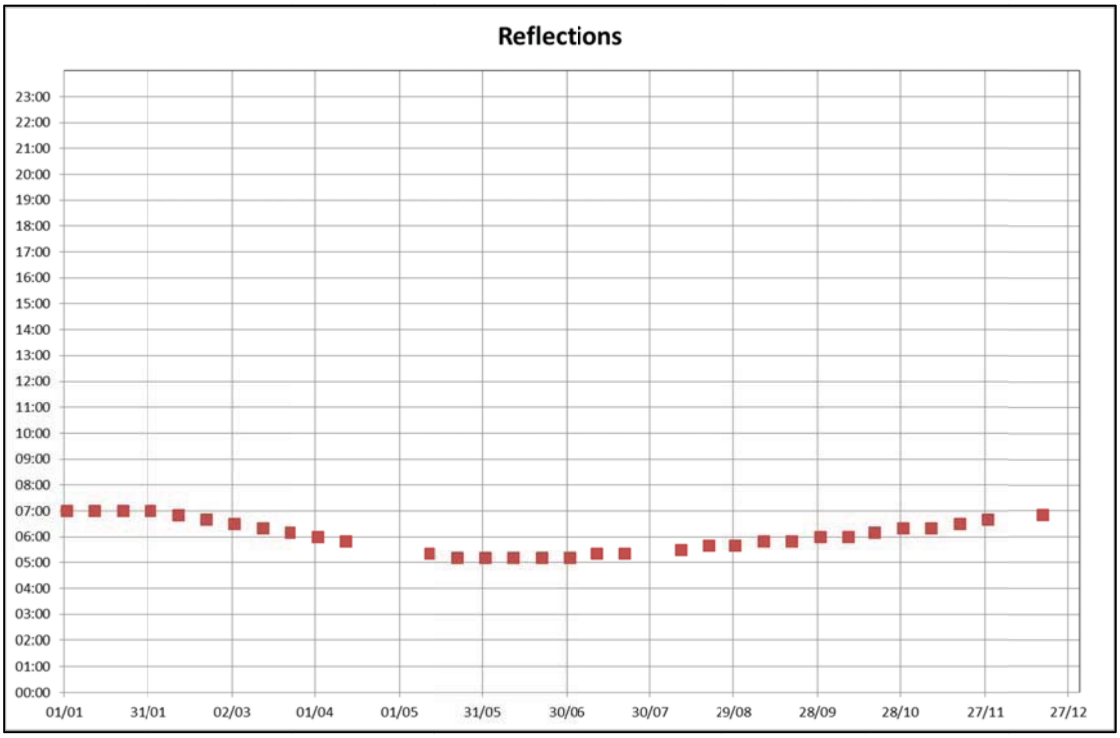
Road 21



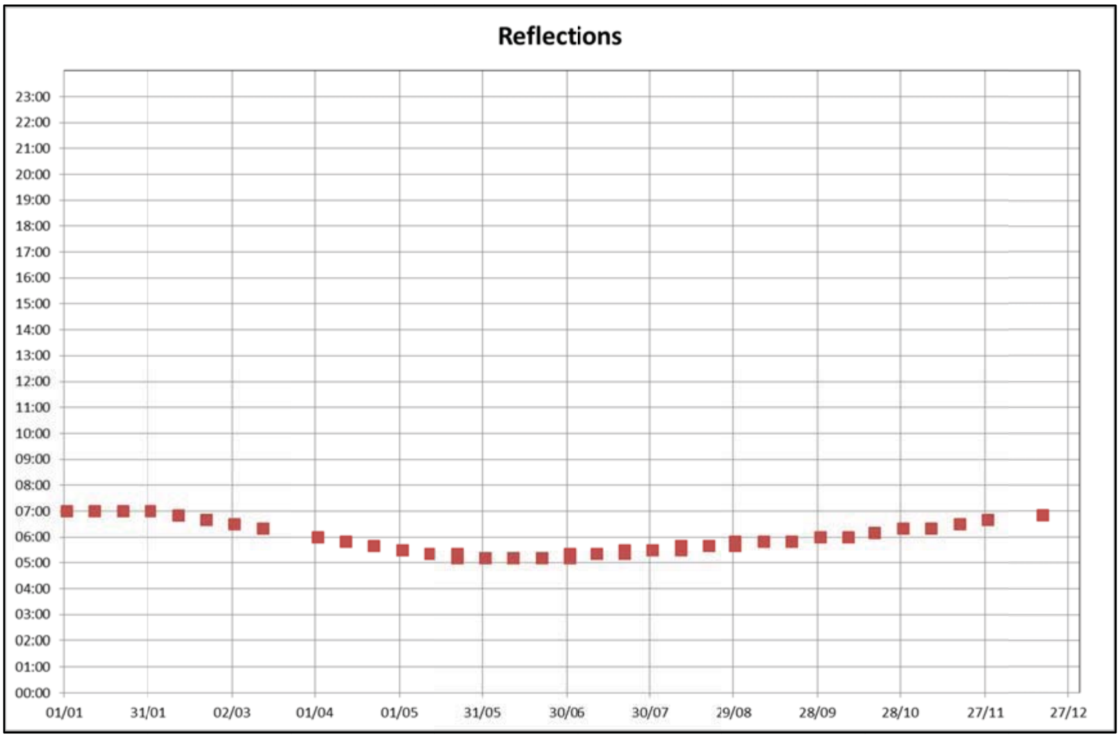
Road 22



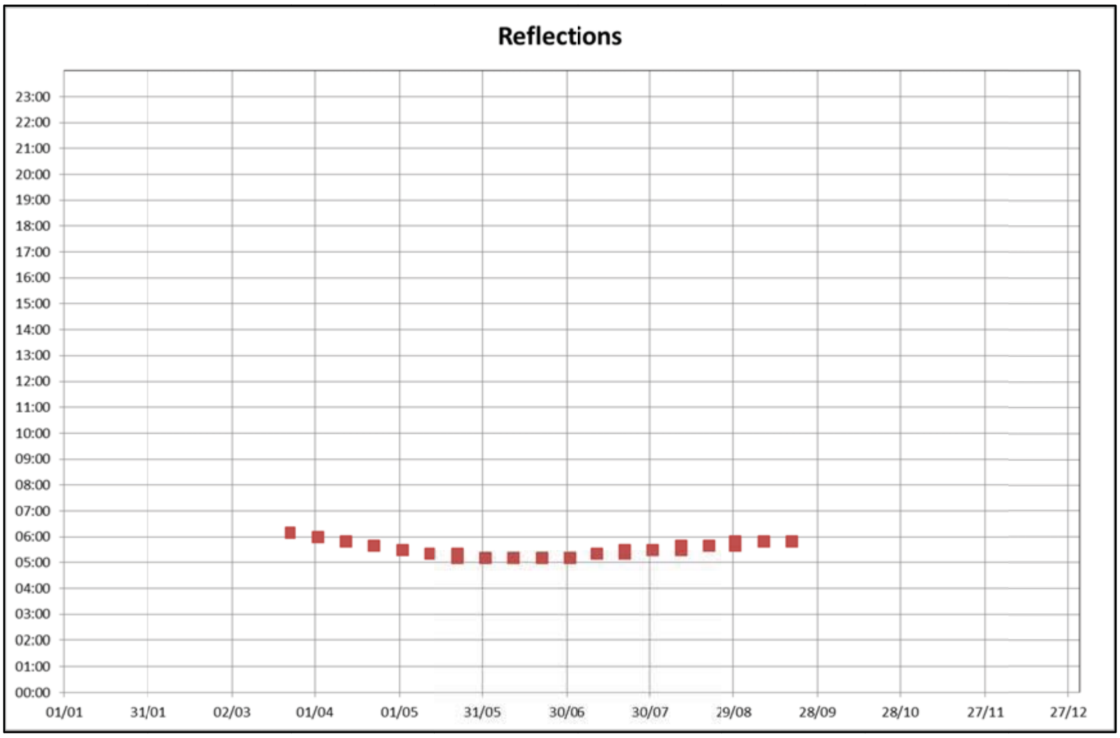
Road 23



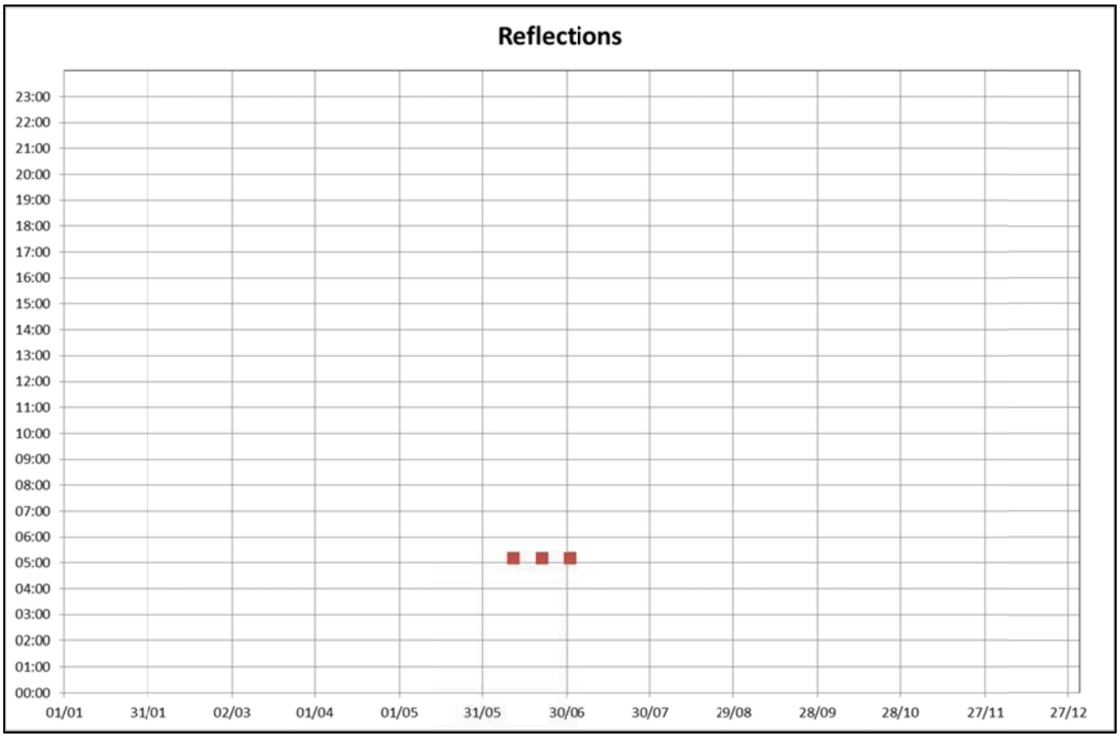
Road 24



Road 25



Road 26



Road 27

No solar reflection geometrically possible.

Road 28

No solar reflection geometrically possible.

Road 29

No solar reflection geometrically possible.

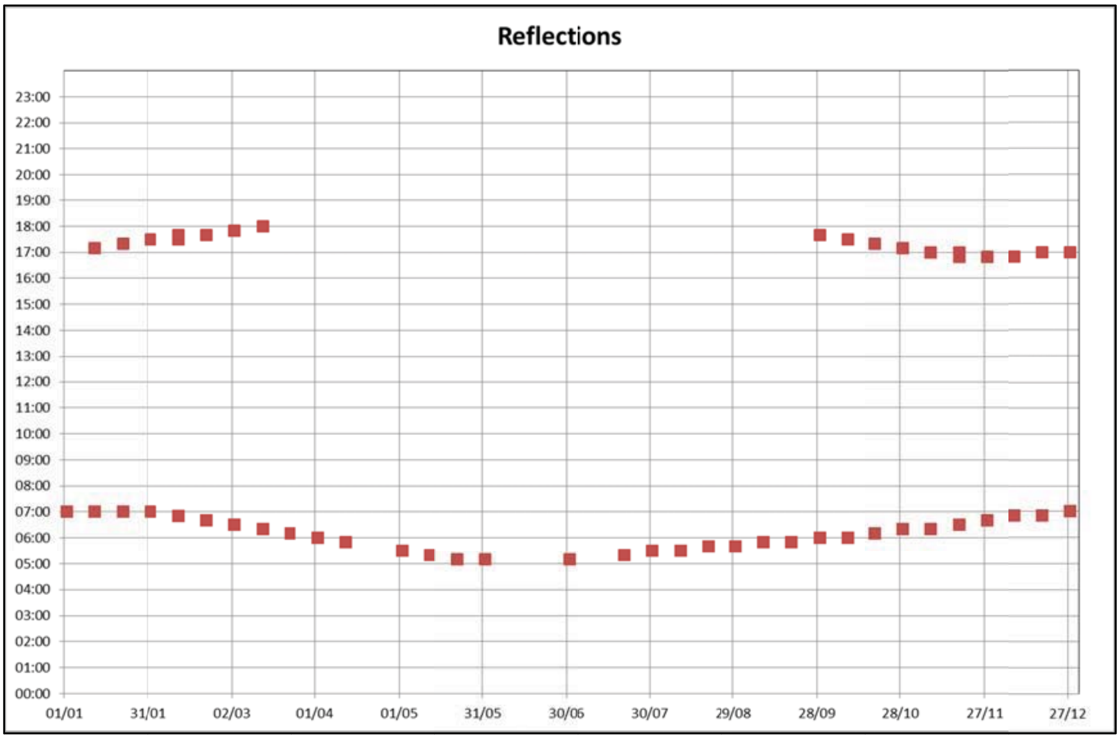
Road 30

No solar reflection geometrically possible.

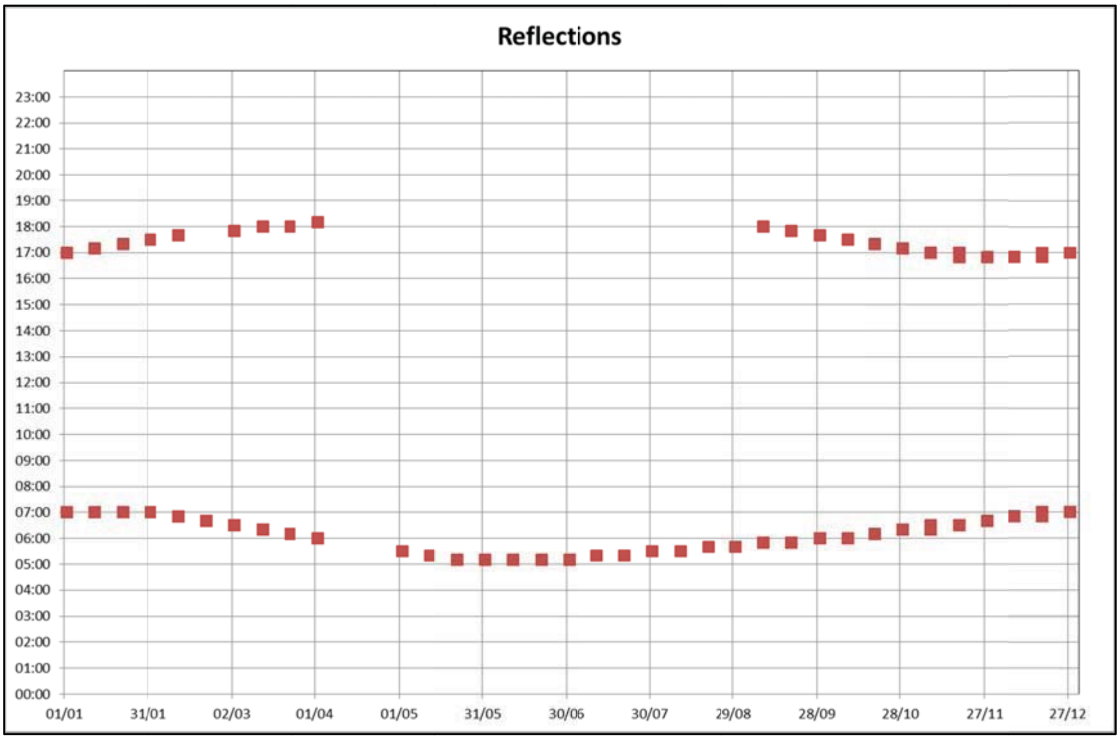
Road 31

No solar reflection geometrically possible.

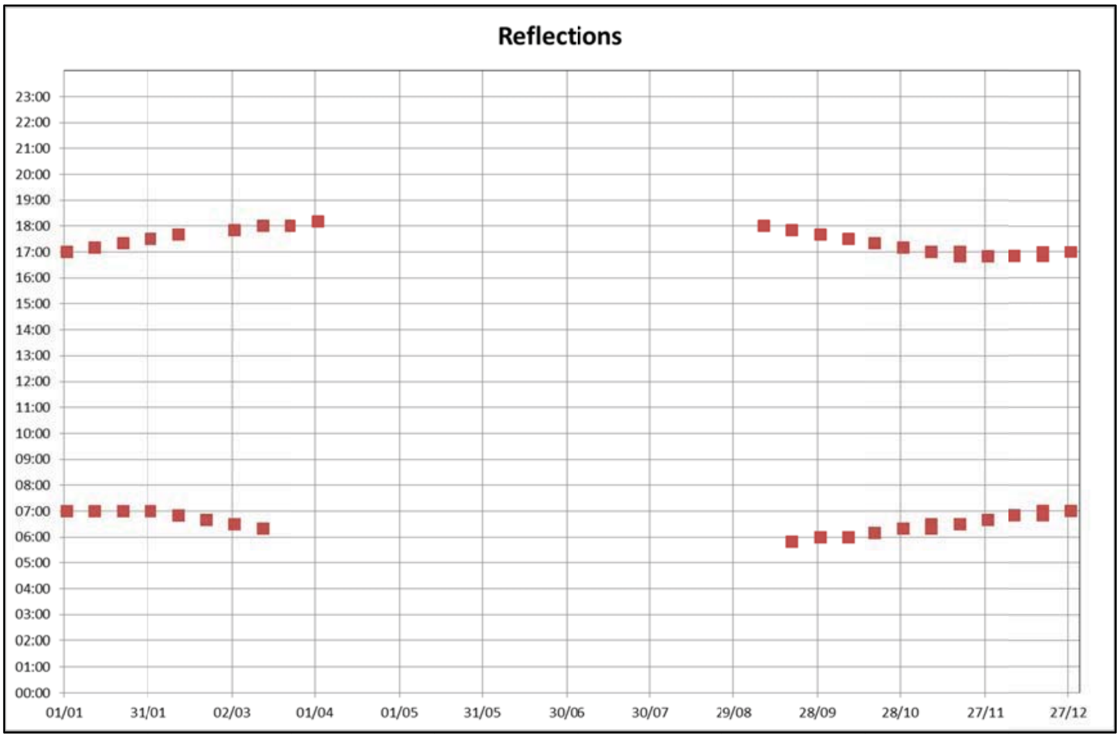
Road 32



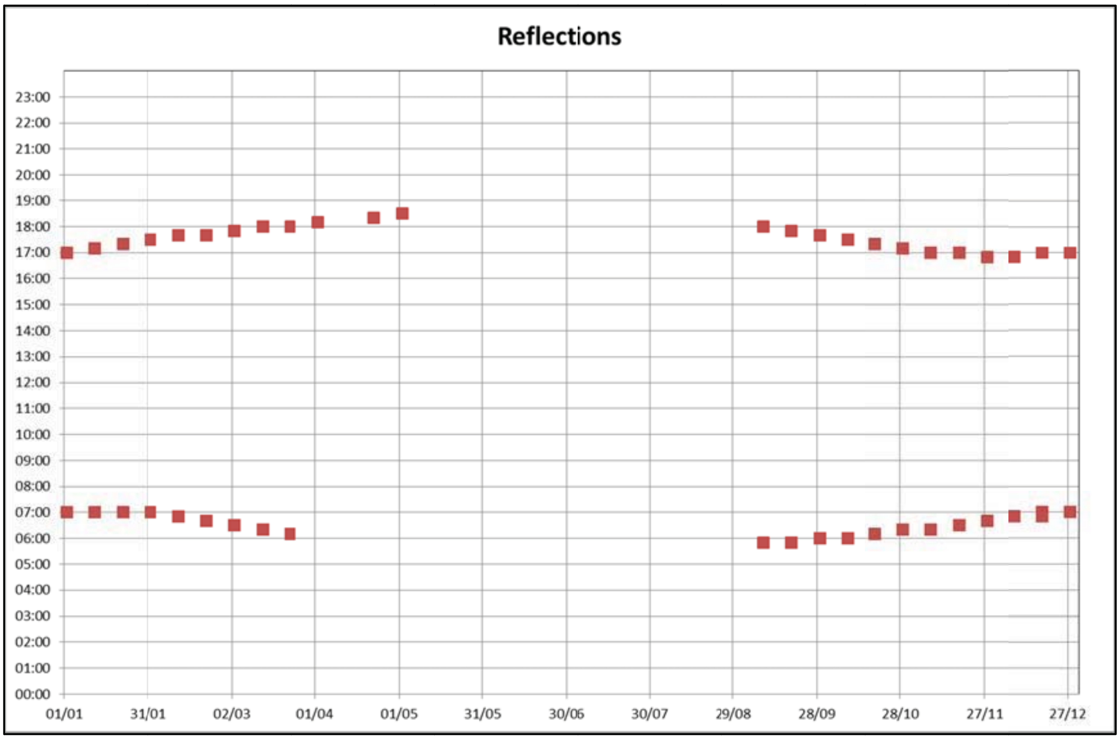
Road 33



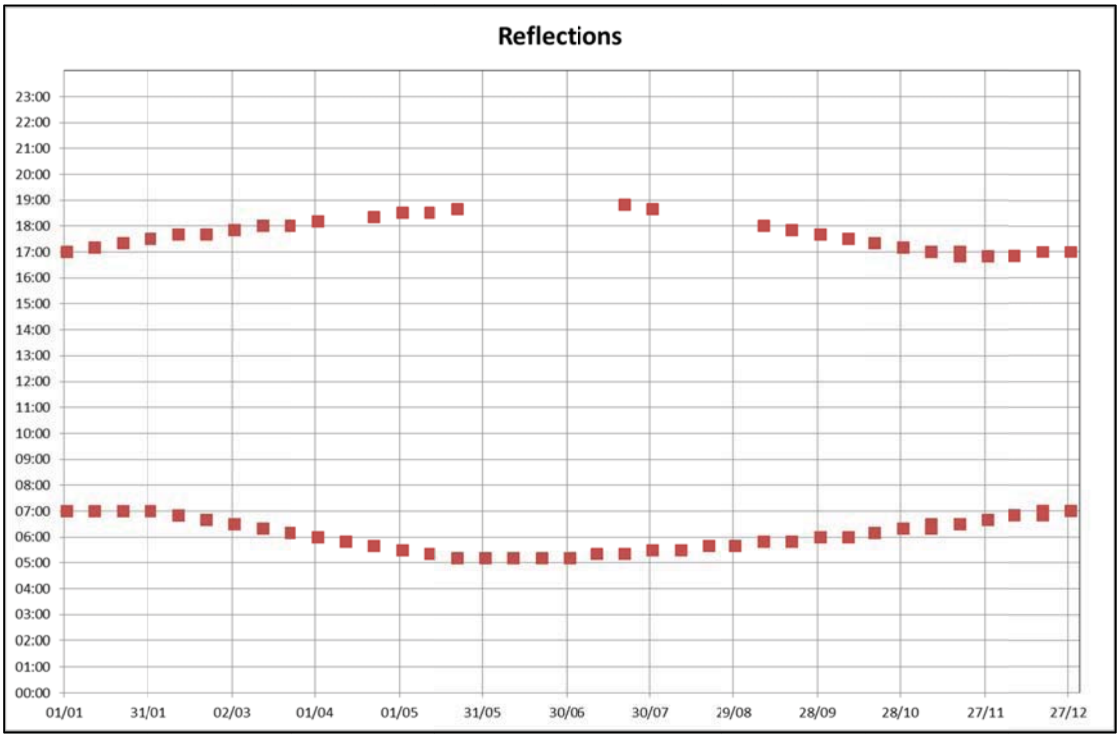
Road 34



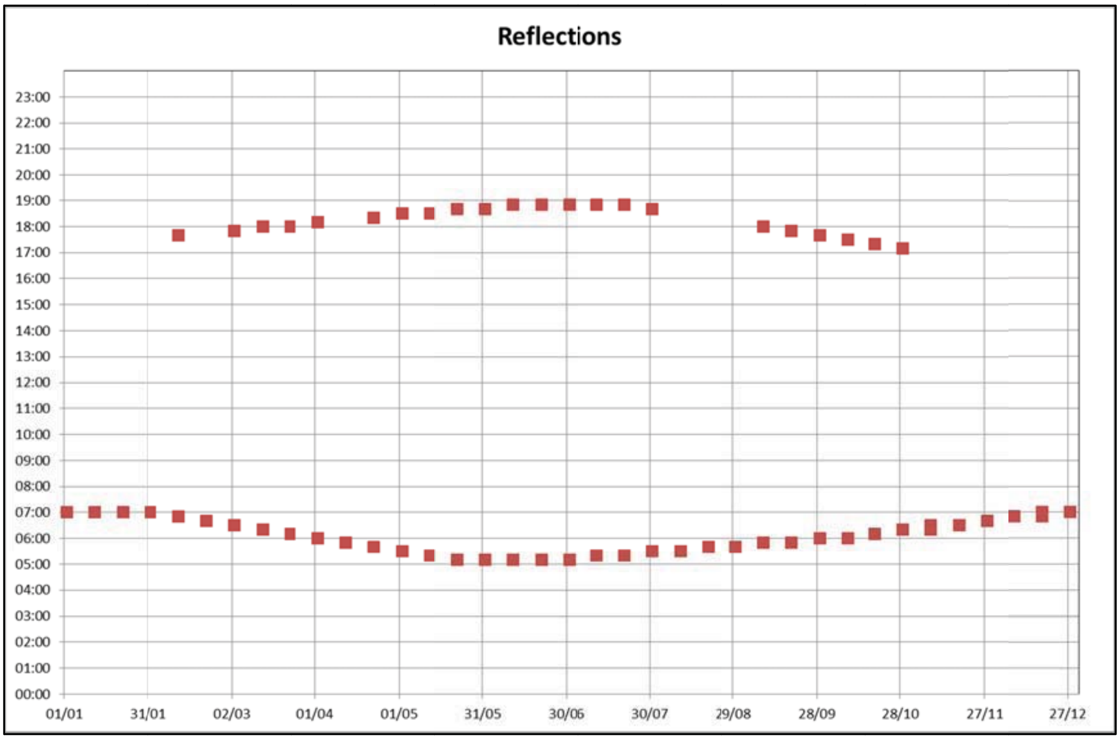
Road 35



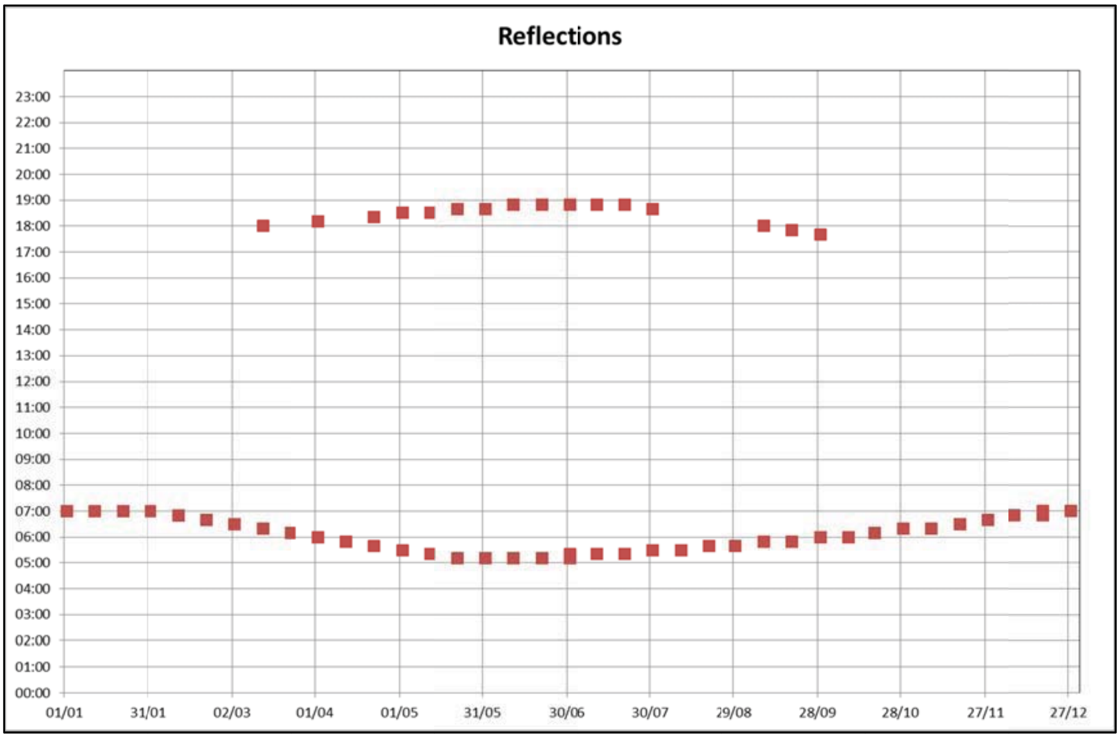
Road 36



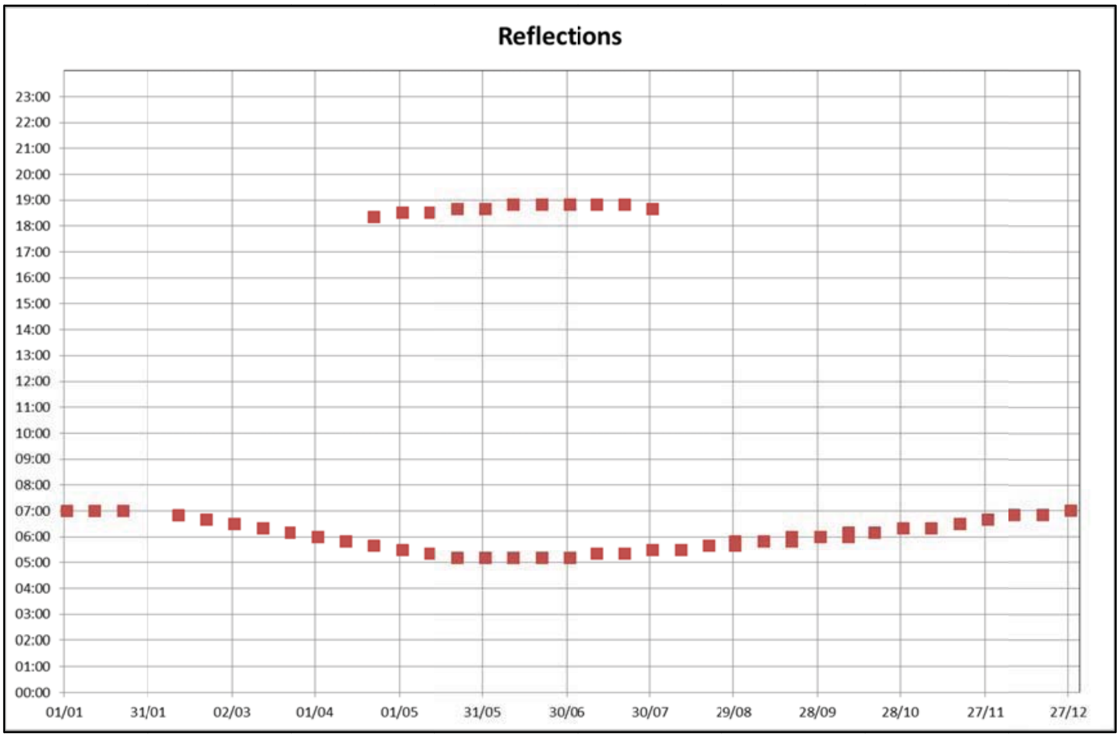
Road 37



Road 38



Road 39



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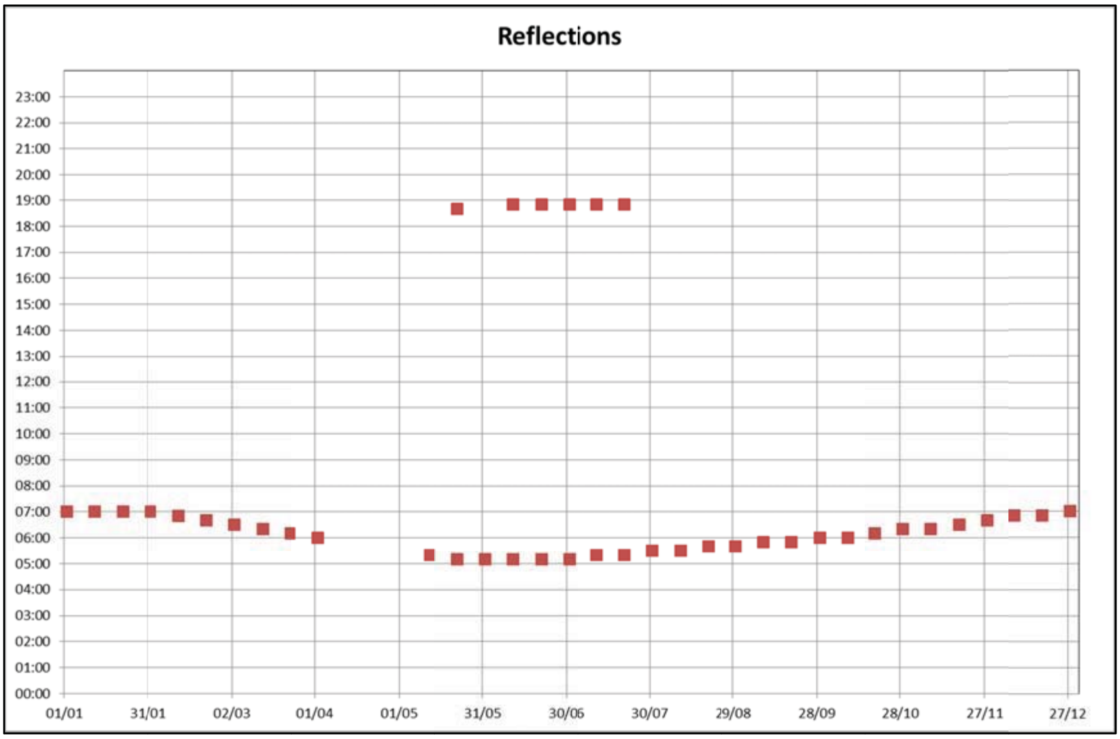
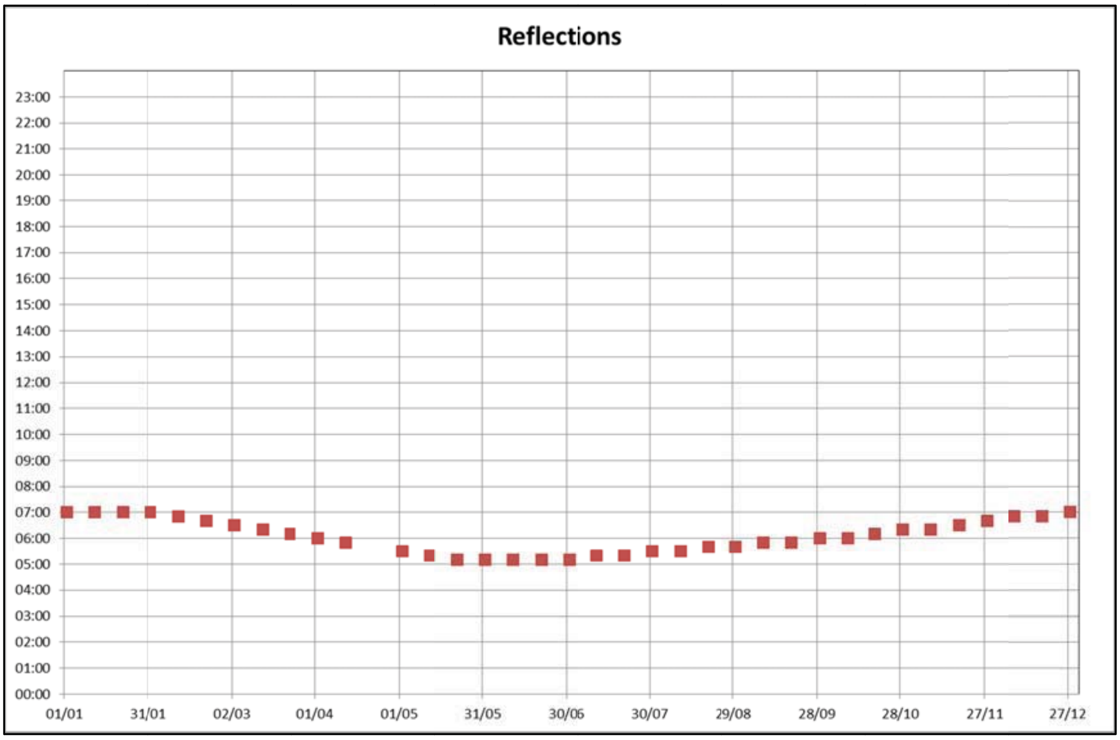
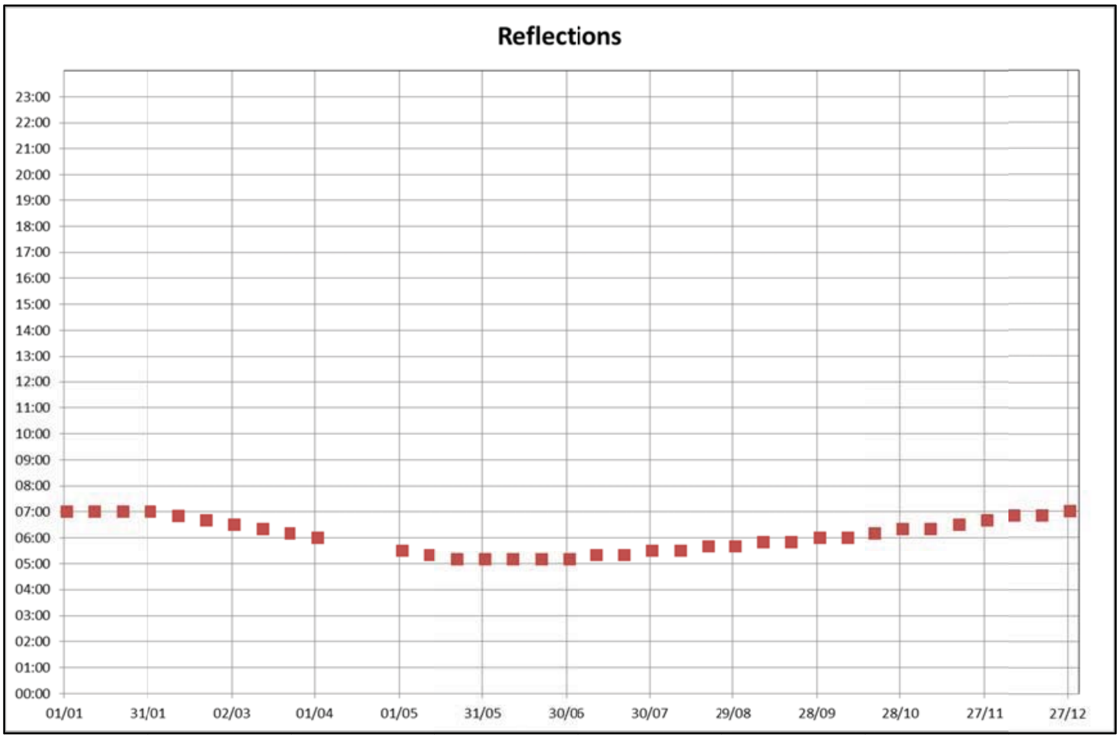


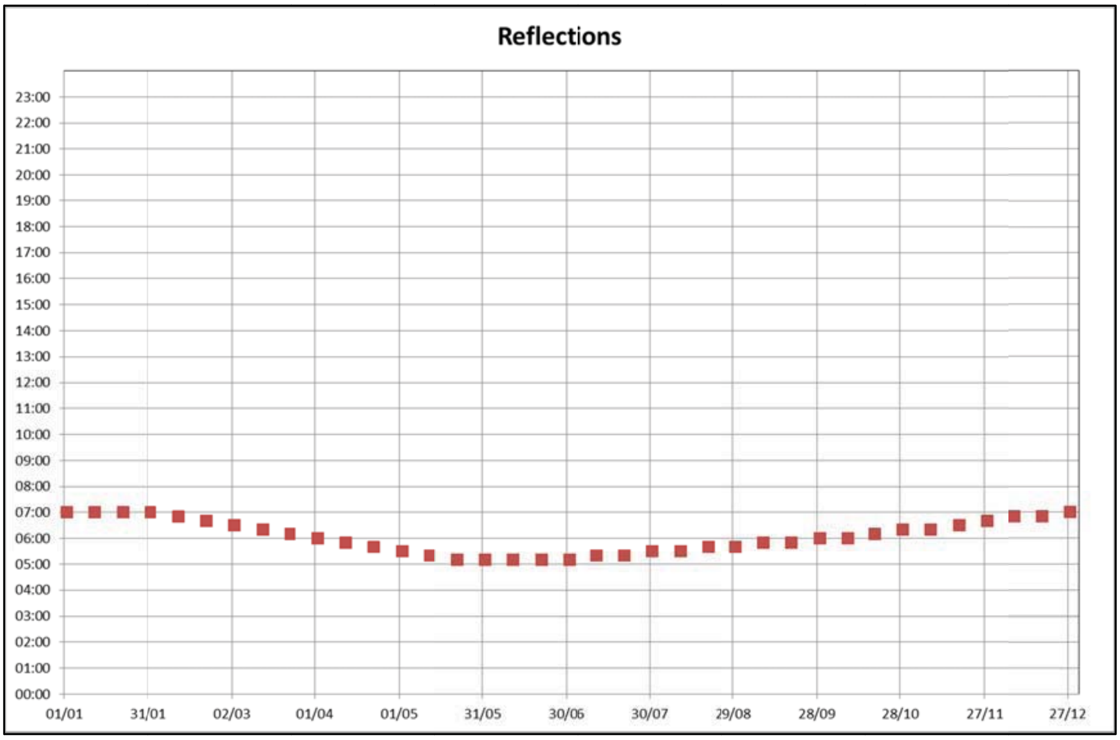
Road 41



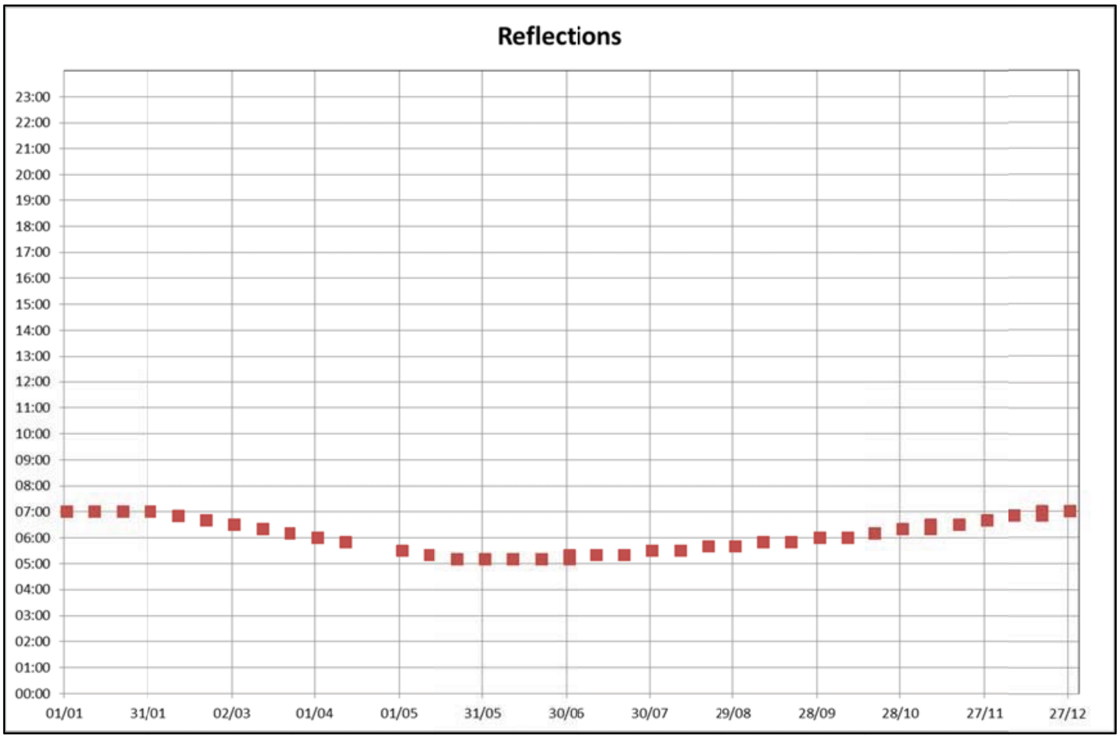
Road 42



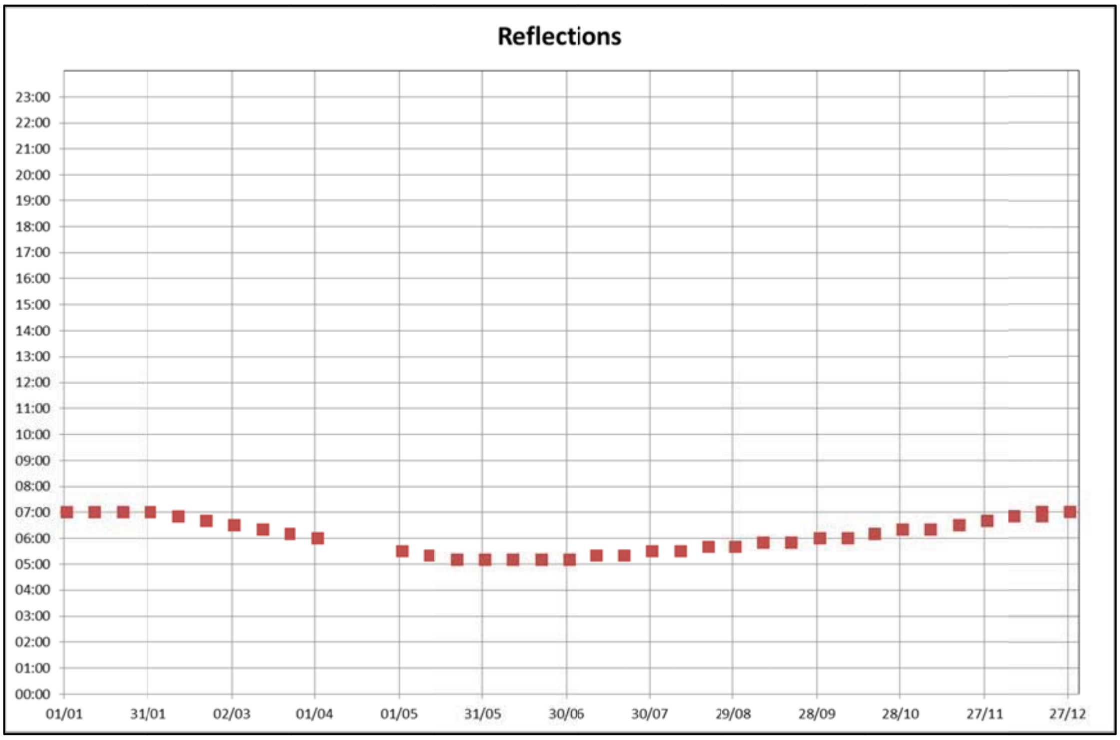
Road 43



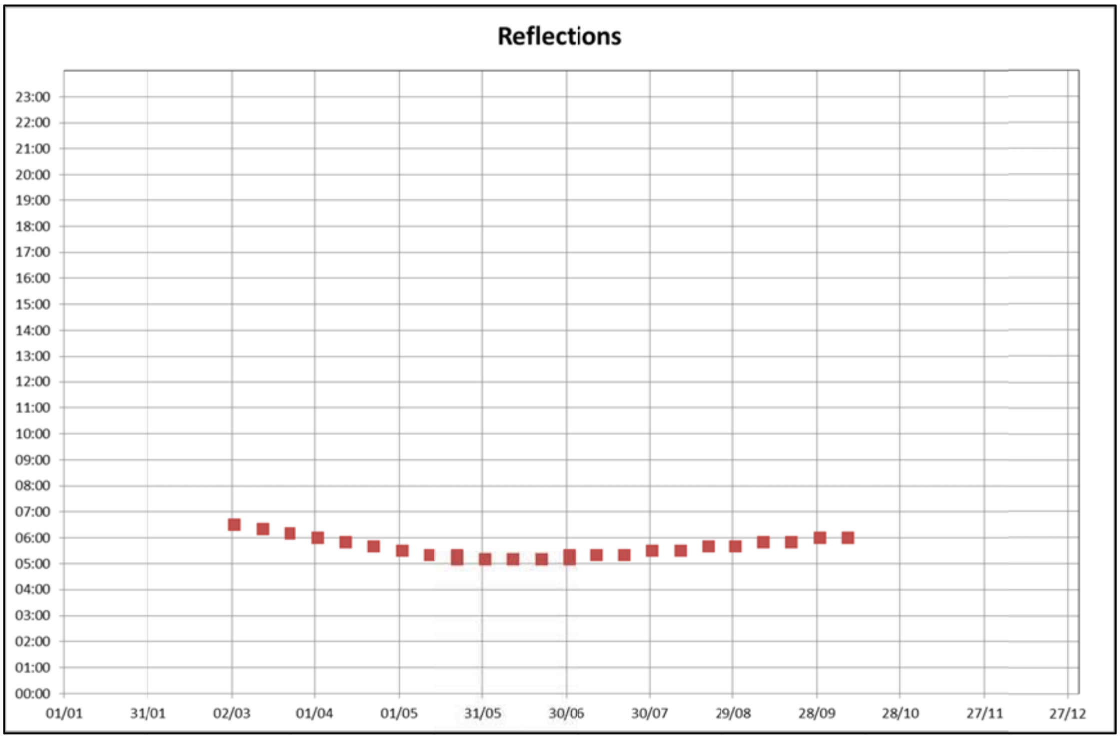
Road 44



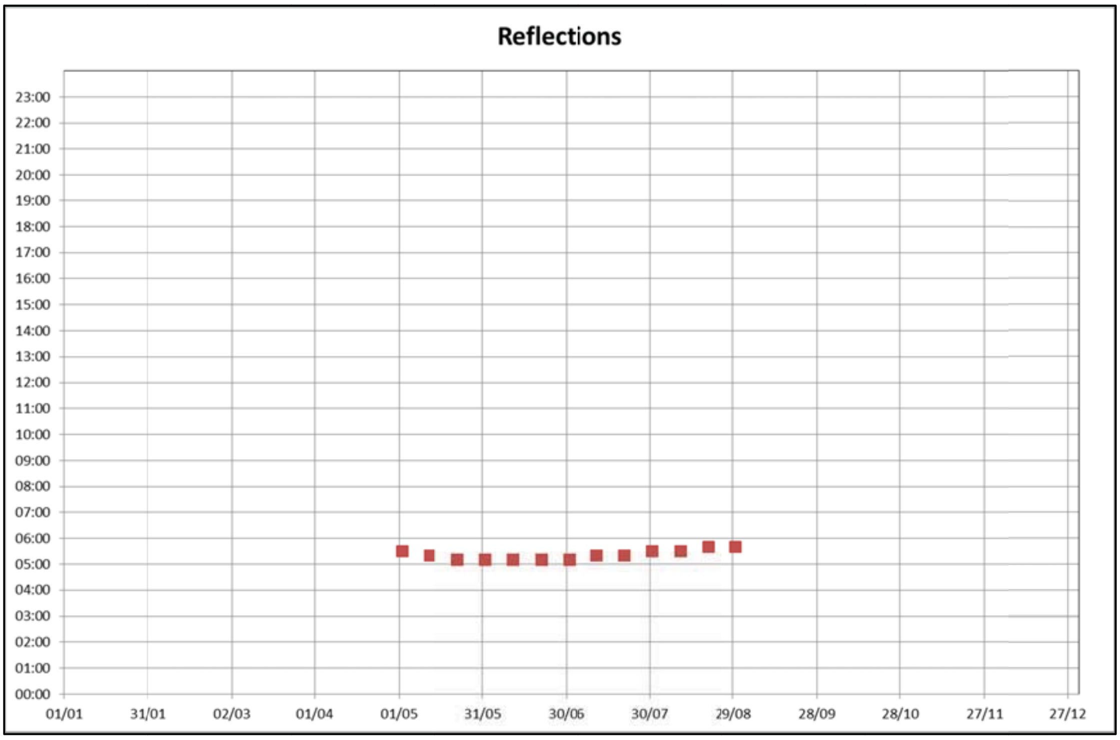
Road 45



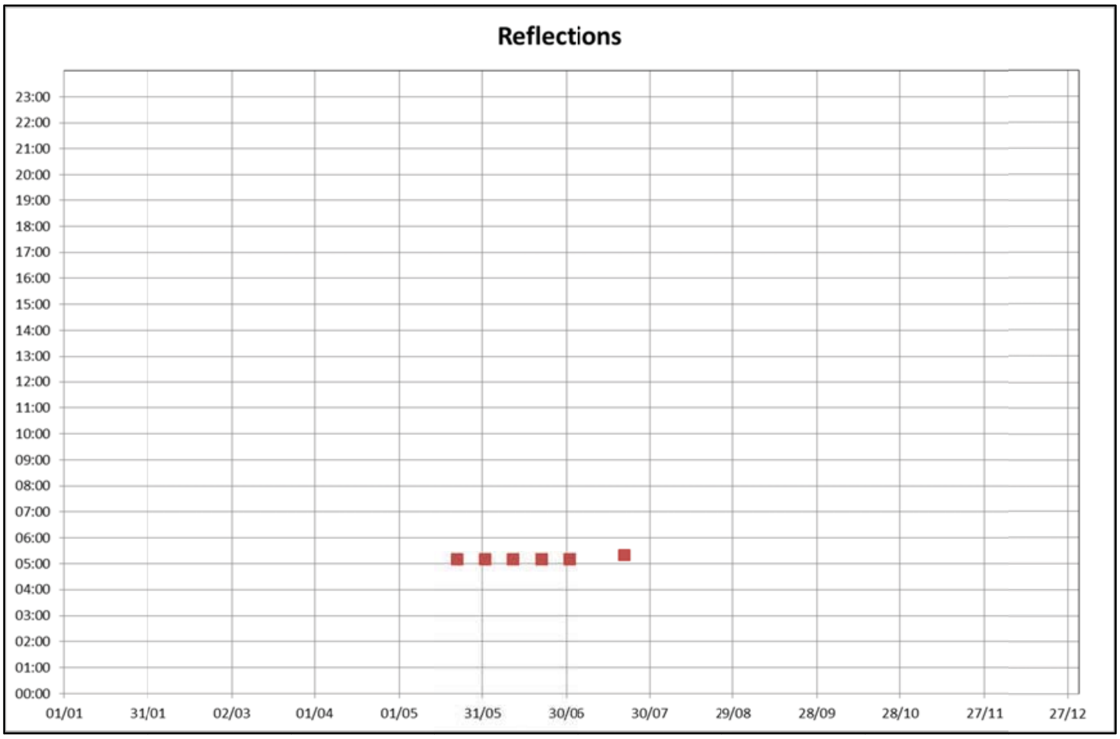
Road 46



Road 47



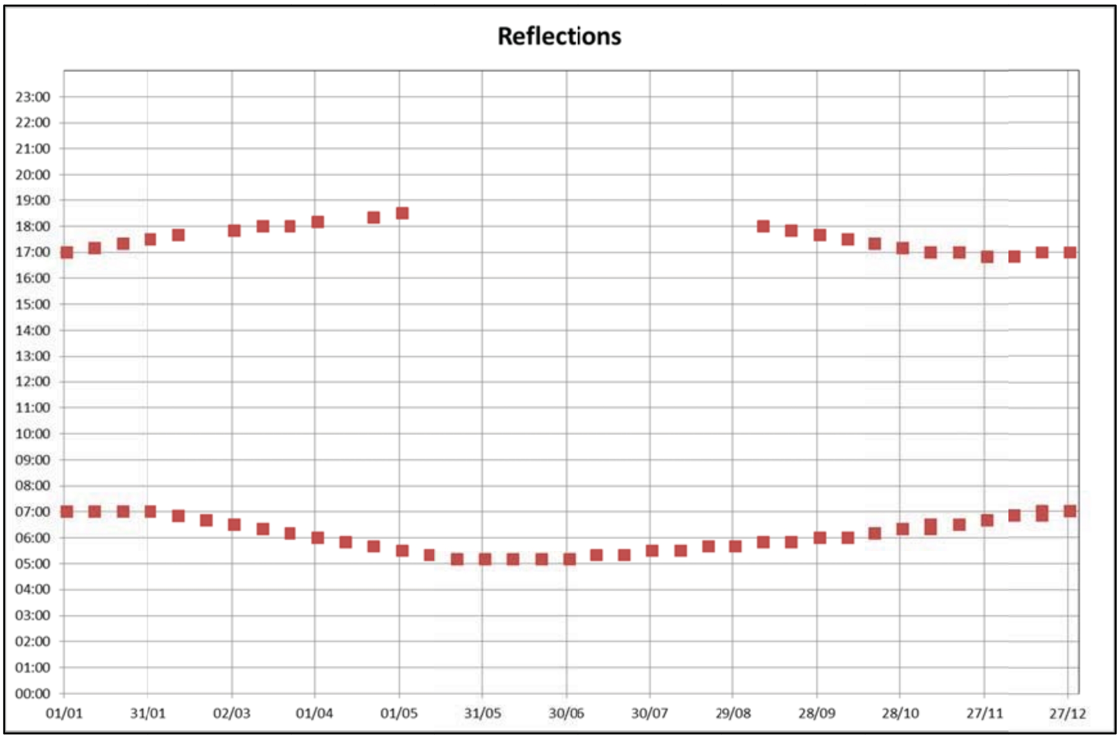
Road 48



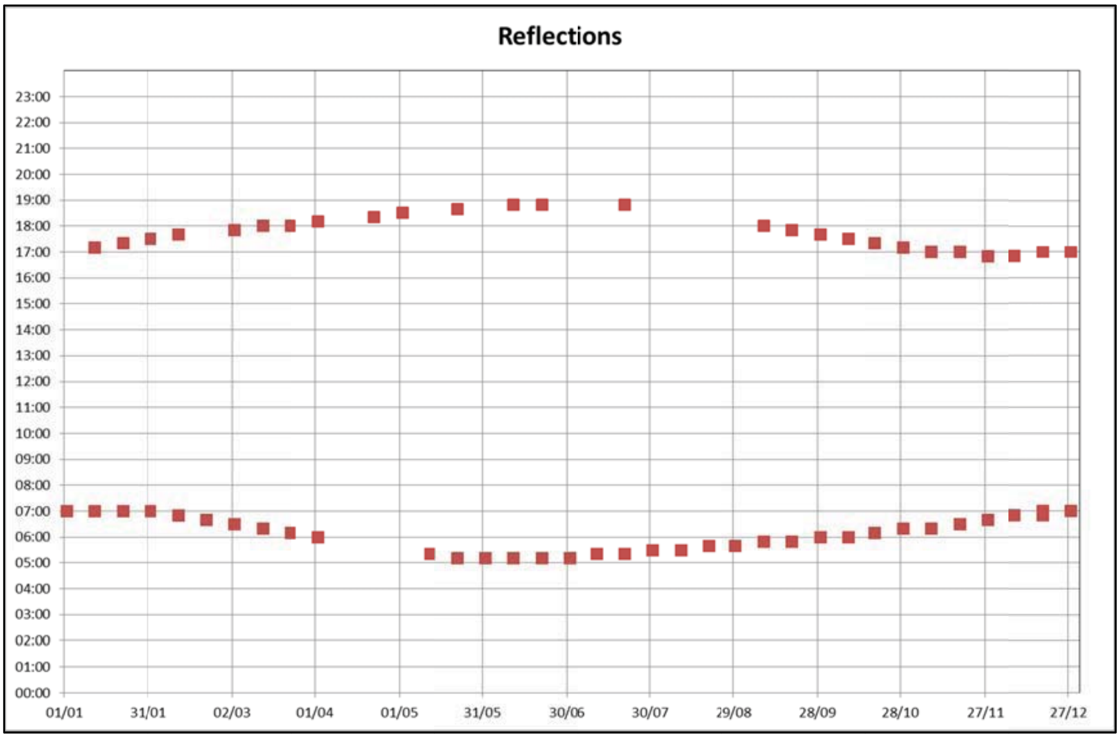
Road 49

No solar reflection geometrically possible.

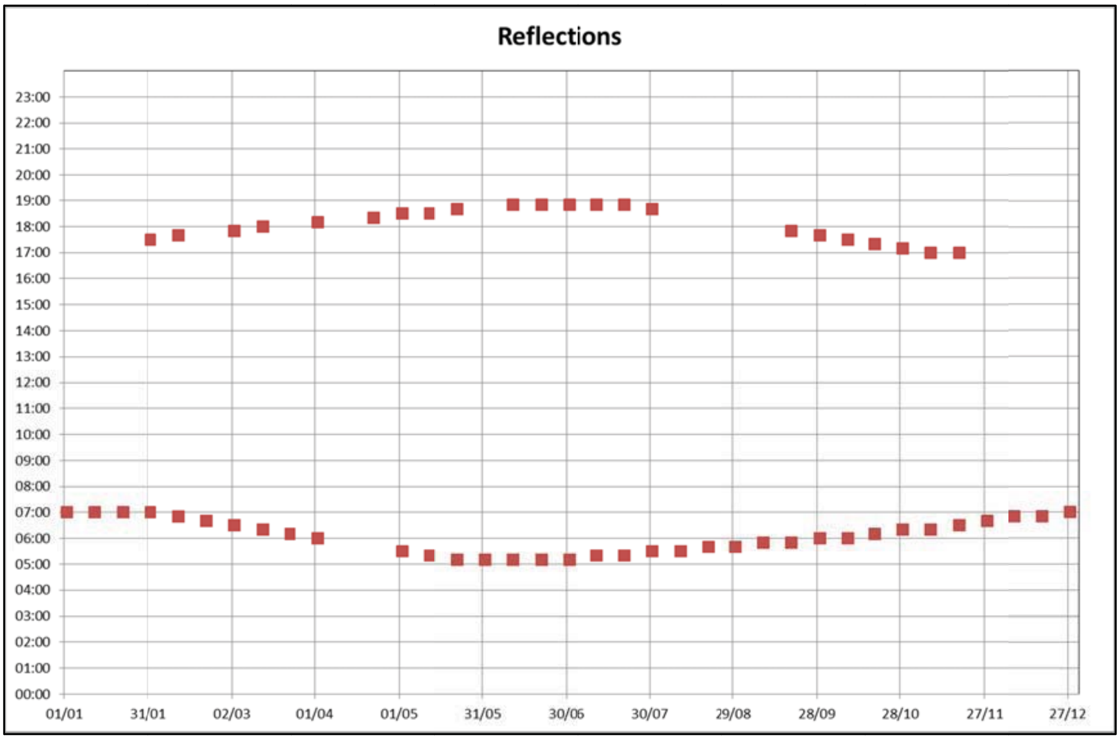
Road 52



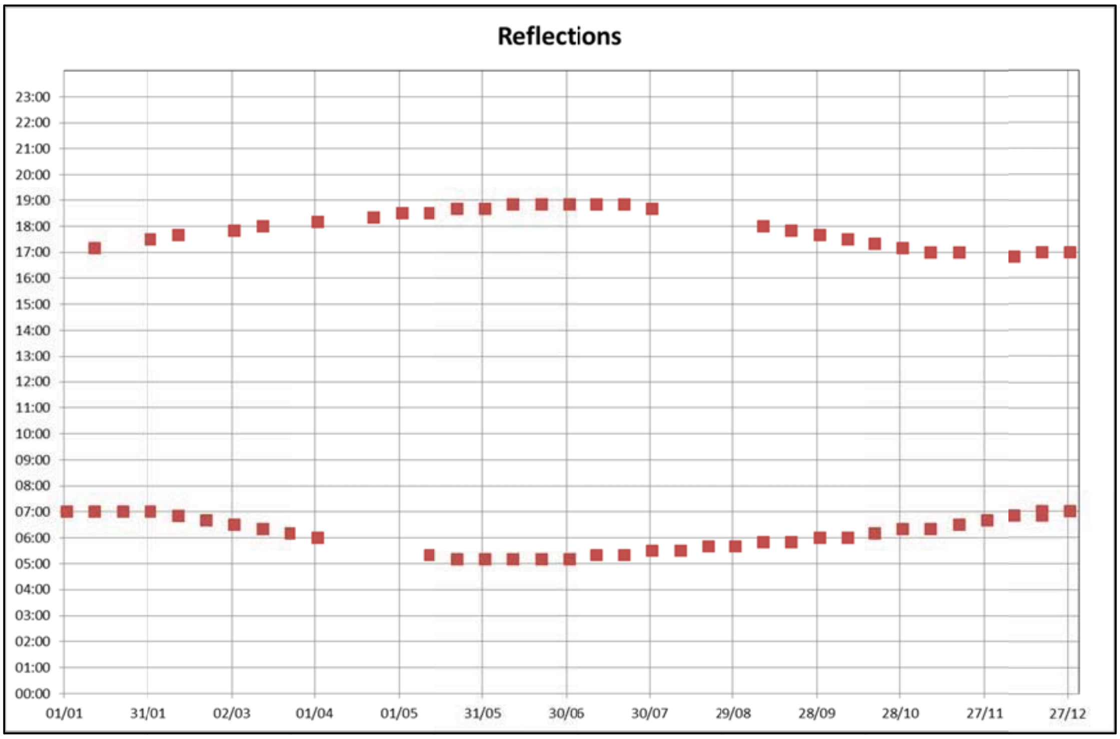
Road 53



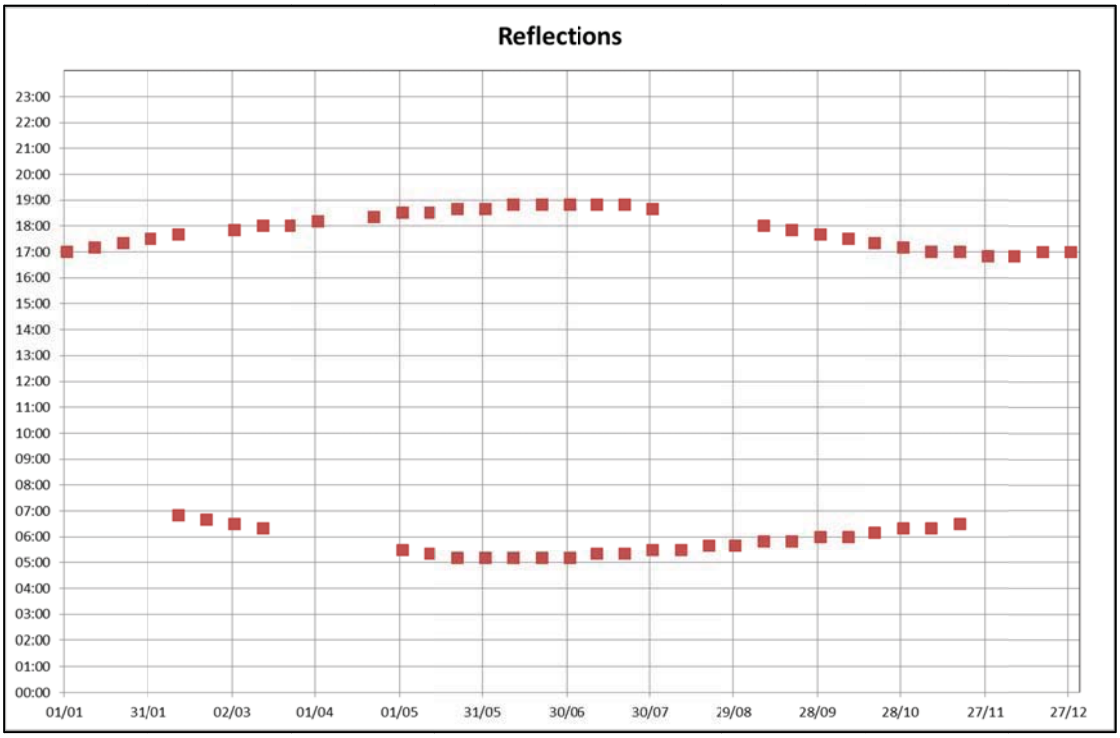
Road 54



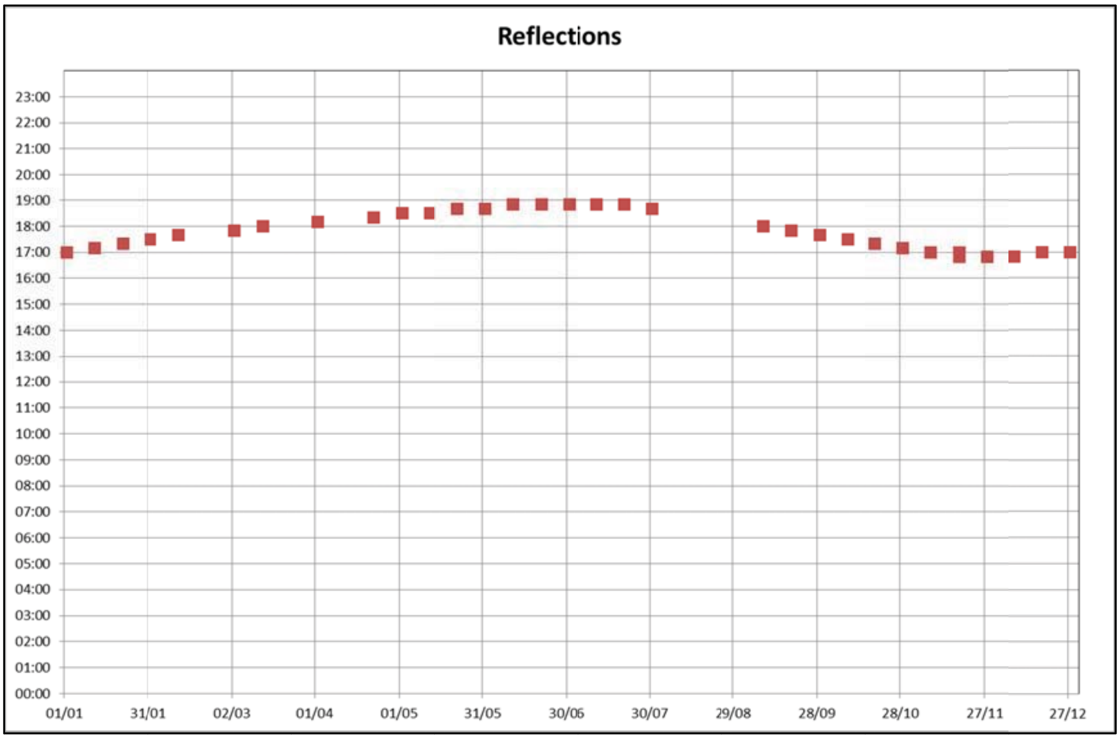
Road 55



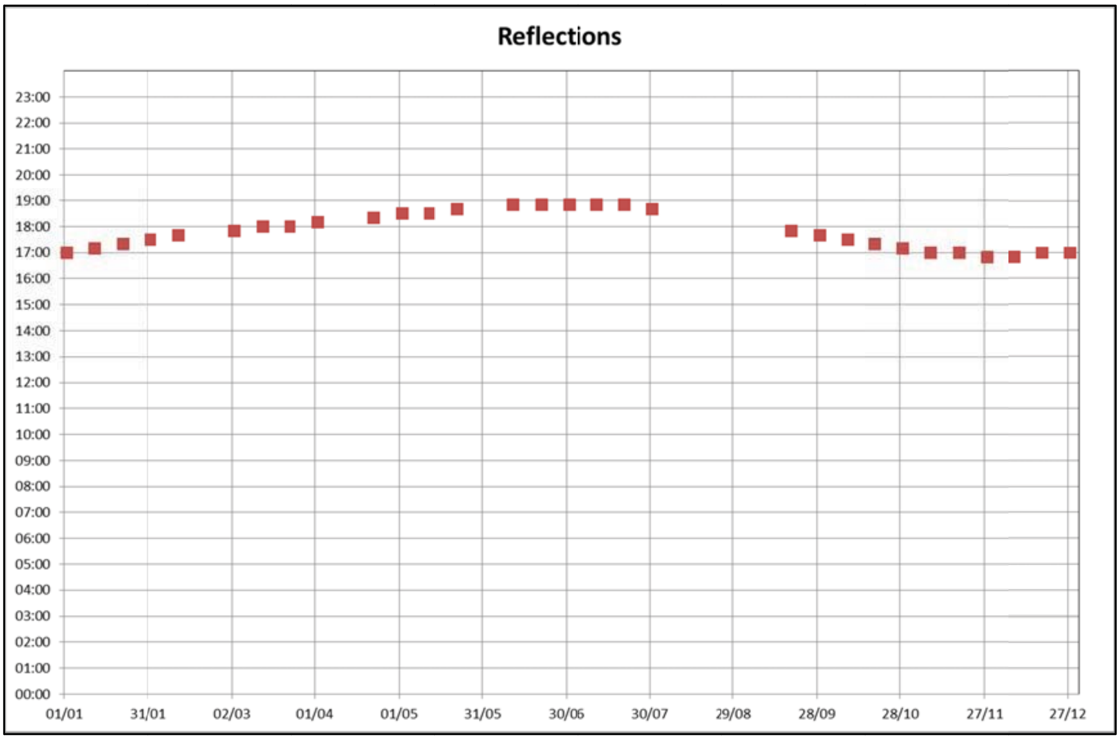
Road 56



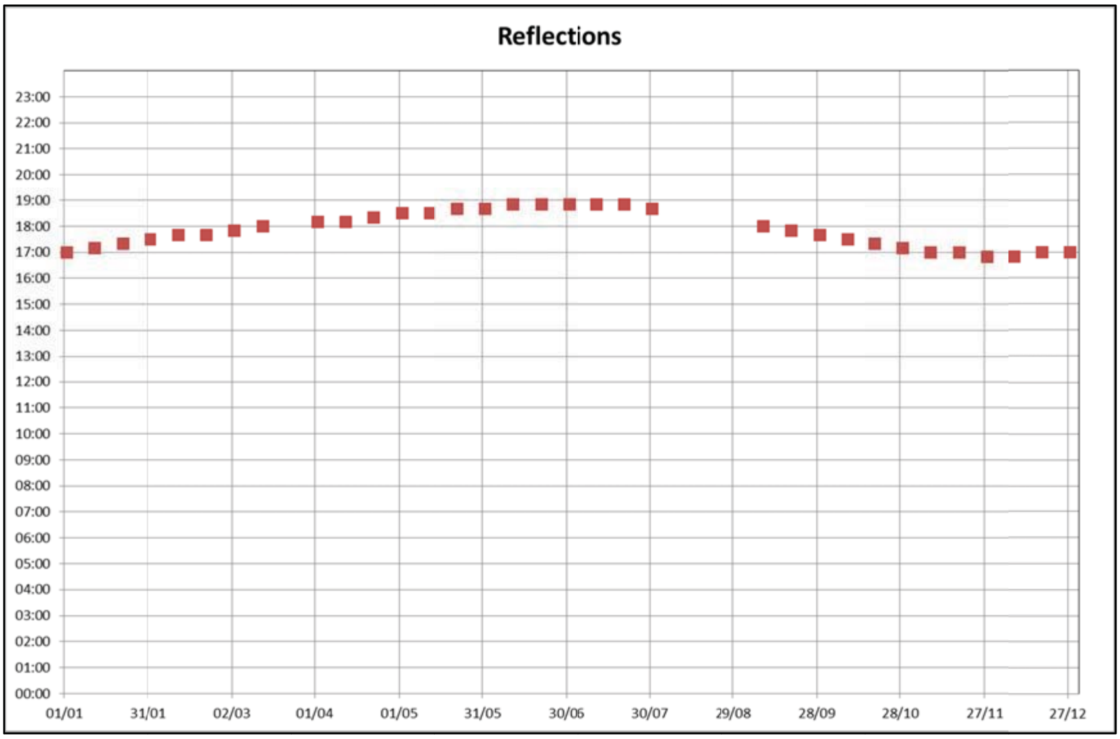
Road 57



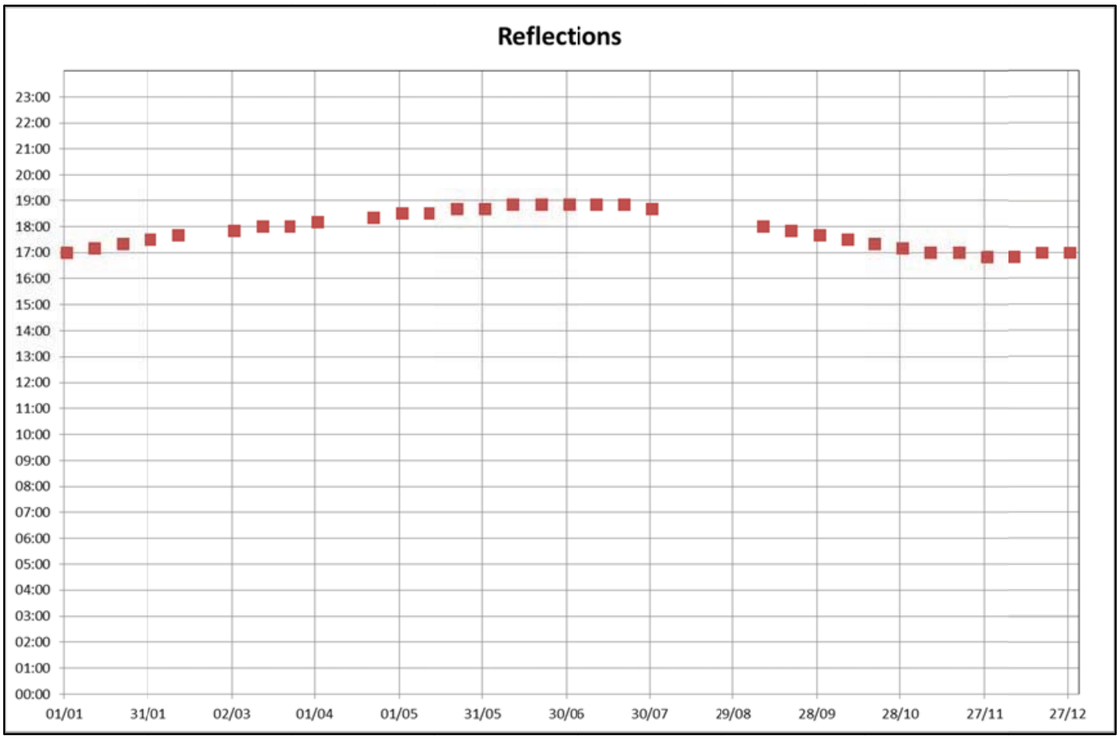
Road 58



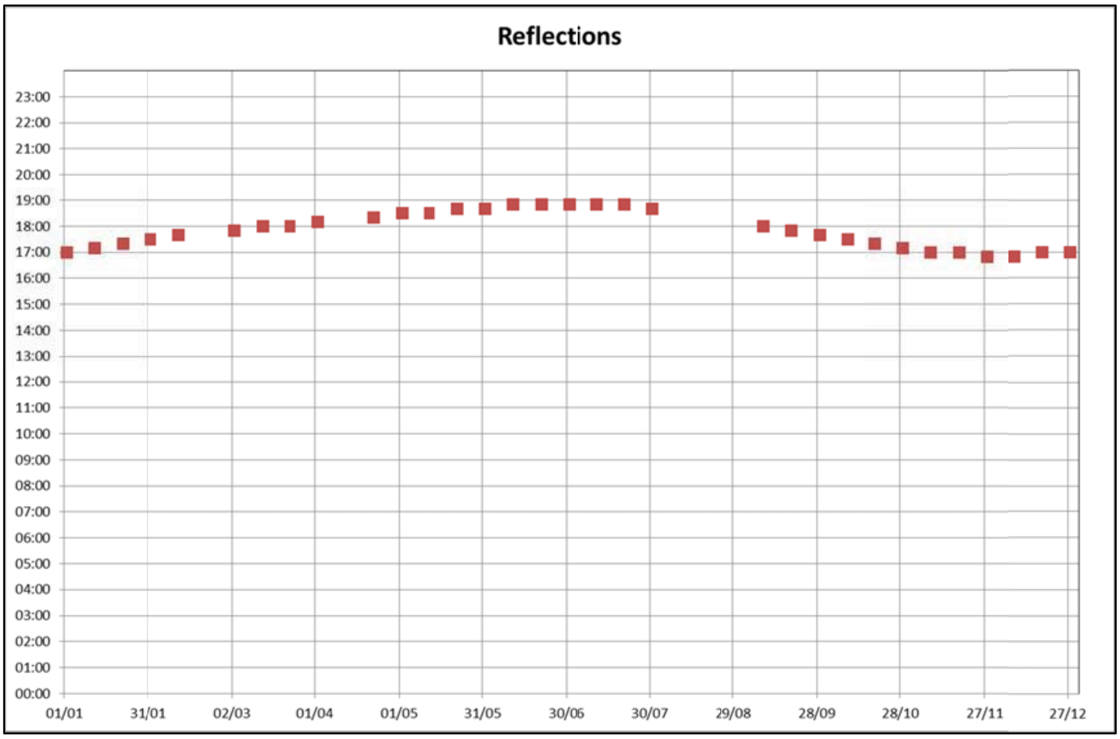
Road 59



Road 60



Road 61



Road 62

No solar reflection geometrically possible.

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