

GLINT AND GLARE ASSESSMENT

Rooftop PV Solar Panels



**Regional Biosolids
Storage Facility
Co. Dublin**



Registered
Landscape
Architect
2017-2018

January 2018

Executive Summary

The proposed Regional Biosolids Storage Facility (RBSF), located adjacent to the R135 at Newtown, Dublin 11, shall include a roof mounted PV solar installation on one of the two storage buildings. This study aims to determine whether this installation will have any glint and glare impact upon surrounding houses, routes and the aviation activities at the nearby Dublin Airport.

Based on an in depth analysis of receptors in the landscape (dwellings and routes) surrounding the proposed development and from the aviation receptors as recommended by the Federal Aviation Authority (FAA) technical guidance, we can determine no reason to suggest that there will be any adverse impacts from the solar development at Newtown as proposed.

Introduction

Macro Works Ltd. was commissioned by J.B. Barry and Partners Ltd to prepare this glint and glare report for a proposed roof top PV Solar Installation at RBSF, to accompany the engineers design report, as part of the overall planning application.

Macro Works' relevant experience includes nineteen years of analysing the visual effects of a wide range of infrastructural and commercial development types. These include numerous solar farms and wind farms, both domestic and international. Macro Works has developed Ireland's only Glint and Glare analysis software (MWGG) in conjunction with the National University of Ireland, (NUI) Maynooth. This has been deployed for the glint and glare analysis of over 60 solar farms to date.

The receptors (features of interest) typically assessed for glint and glare for this scale of PV solar installation include residential buildings, routes (road and rail) and aviation activities. In this instance, special attention has been given to the N2 National Route located to the north and east of the site, and also to the aviation receptors of Dublin Airport, located just over 2km to the east.

Guidance

While there is a requirement by certain local authorities to assess the potential for glint and glare from proposed PV developments, there is no guidance in Ireland as yet to specifically address how or under what circumstances this should be undertaken for ground-based receptors (residential dwellings or routes) surrounding such a proposal. Despite the UK's more established solar industry it too equally lacks such guidance, however, as it has been the subject of greater debate, Macro Works has drawn from accepted practices there.

Guidelines have been prepared by the Federal Aviation Authority (FAA) to address the safety concerns of siting solar PV installations in close proximity to airports. These guidelines coupled with the FAA-endorsed Solar Glare Hazard Analysis Tool (SGHAT) are commonly regarded as the accepted industry standard by aviation authorities internationally when considering the glint and glare effects upon aviation-related receptors. Both the Irish Aviation Authority (IAA) and the Dublin Airport Authority (DAA) defer to these guidelines and the use of SGHAT for proposed PV installations in Ireland.

The IAA requires the referral to it of all solar PV development submissions within 10km of an approved airport or aerodrome. As of August 2017, the DAA has specifically expanded this extent for both Dublin Airport and Cork Airport to a radius of 15km.

Analysis Software

SGHAT

The Solar Glare Hazard Analysis Tool (SGHAT) produced by Sandia National Laboratories in the US is endorsed by the Federal Aviation Authority (FAA) and is commonly regarded as the accepted industry standard by aviation authorities internationally when considering the glint and glare effects upon aviation related receptors.

“As of the date of publication (23rd Oct 2013) of this interim policy, the FAA requires the use of the SGHAT to demonstrate compliance with the standards for measuring ocular impact stated above for any proposed solar energy system located on a federally-obligated airport. The SGHAT is a validated tool specifically designed to measure glare according to the Solar Glare Hazard Analysis Plot.”

The tool is described as follows:

“This tool determines when and where solar glare can occur throughout the year from a user-specified PV array as viewed from user-prescribed observation points. The potential ocular impact from the observed glare is also determined”

In preparing this assessment, Macro Works used the SGHAT for its analysis of aviation receptors.

The principal output from the SGHAT is a glare report per receptor that indicates the time of day and days per year that glare has the potential to occur. The plot is coloured according to the intensity of the glare per period and whether it is harmful to human vision (see Figure 2).

MWGG

The Macro Works' Glint and Glare analysis software program (MWGG) was developed by Macro Works Ltd in conjunction with the Dept. of Experimental Physics, NUI Maynooth. This collaboration has been ongoing for since early 2016 and continues to undergo updates and enhancements.

MWGG utilises the exact layout and panel parameters for a proposed development and accounts for the complex mutual screening of panels by other panels. Further, MWGG accepts complex Digital Surface Models allowing it to account for existing and enhanced screening proposals. Both circumstances can result in a significant reduction in the visibility and thus the potential for glare from particular ground-based receptor positions.

The MWGG process looks each receptor and analyses the solar reflection that occurs from each panel as the sun passes through its arc over the course of a day. This is measured for every minute of every day over the course of a year. The table and graphic outputs are similar in type to that of SGHAT. SGHAT is deferred to for solar intensity calculations.

MWGG has consistently and successfully replicated results from the FAA-approved SGHAT software (where parameters and terrains are equal) and has been utilised to assess the effects of glint and glare for more than 60 no. solar development sites throughout Ireland to date.

Due to limitations and inflexibility of the SGHAT at handling detailed development and terrain features (see Appendix E), Macro Works' MWGG has been used for all non-aviation ground-based receptors.

Development Description

The proposed installation occupies the southern rooftop portion of Storage Building A at the proposed RBSF at Newtown, Dublin 11. The facility provides treated sludge storage for the upgraded Ringsend Wastewater Treatment Plant (WwTP) and new Greater Dublin Drainage WwTP. The building rooftop is a large curved convex shape which measures approx. 107m x 60m and is approximately oriented along an east-west axis. It is proposed to install the PV panels flush to the roof on the south facing aspect (approx. 107m x 30m).

The building where the solar development is proposed is a part of a proposed large 2-building complex off the R135 just west of the N2 at Newtown/Kilshane. The area, characterized by industrial buildings and activity, is bounded by an extensive Roadstone quarry and processing plant to the south, the Northwest Business Park to the west and the Dublin Airport Logistics Park to the east. To the north, the land remains principally in arable agriculture. The site is presently bounded to the west, south and southeast by mature hedgerow vegetation. The N2 route to the east of the site follows a northwesterly direction from the M50 to Ashbourne and crosses above the R135 just to the north. As roadside planting has not fully established there are elevated perpendicular views from the N2 route across the site.

Methodology

Solar Development Layout

The proposed installation of roof mounted PV panels differs from a standard ground-based installation in that the building orientation guides the orientation of the panels (facing direction = 193 degrees from True North) and roof curvature guides the tilt of the panels (from 0.1° – 9.6°). Accounting for the roof curvature, the ‘tilt’ parameter is variable, increasing in value from the apex of the roof towards the eaves of the roof.

We have accounted for this variability by defining the roof as 9 arrays of panels (A – I) parallel to the roof apex ranging in tilt from 0.1 ° – 9.6 ° (see Figures 1 & 2). Note: As SGHAT analyses each row of panels separately it results in a lengthy report.

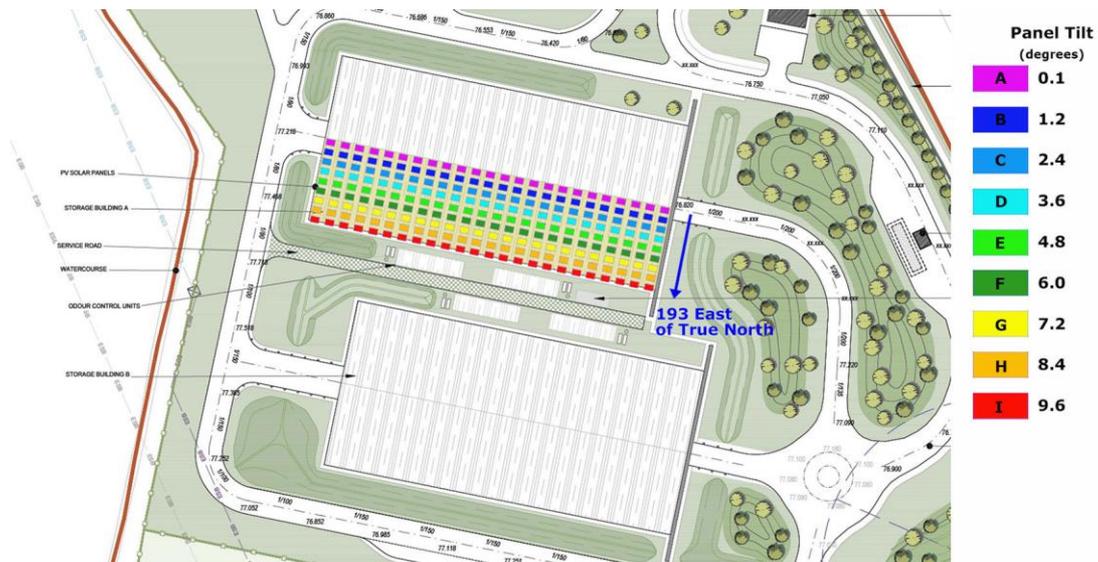


Figure 1: Orientation and tilt of the panel layout used to calculate glint and glare

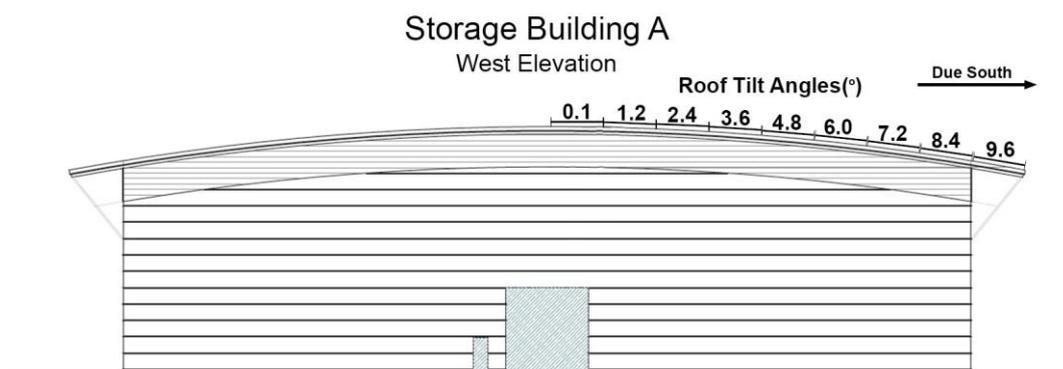


Figure 2: Tilt angles of the curved roof section of Storage Building A used to calculate glint and glare

Local Ground Receptors

In accordance with current best practice, the study area for receptors was defined by a 1.0km radius extent about the proposed PV installation. Digital Surface Model (DSM) data was procured for this area specifically for the purposes of carrying out glint and glare analysis. Such data depicts terrain as well as land cover and is particularly useful in accounting for landscape features that may have a screening effect – such as dwellings, vegetation and small undulations in landform. In this instance specifically, the DSM data had the added benefit of accurately depicting the profile and banking of the N2 route relative to the surrounding terrain. To further enhance the accuracy of the predicted results, the profile of the Storage Building B was carefully added to our surface model as this is likely to screen views of the proposed PV panels from areas to the south.

To identify those zones within the study area with the theoretical potential to be affected by glint and glare, an array of points was placed within the study area at 25m centres (25m x 25m). Each point was thoroughly tested using the MWGG for a full year of sun path reflectance (1-minute intervals).

Residential

All residential receptors and their building type (1 or 2 storey) within or in close proximity to the above zones were identified using the Eircode Geodirectory and verified by a site visit/survey. These are identified in Figure 3 below.



Figure 3: Residential receptors identified within 1km of the proposed solar PV development relative to the predicted glare pattern.

Houses H15 – H18 are located in close proximity to a small area predicted to be impacted by glare. The rear of these properties has been assessed individually for glare effects.

Routes

Taking account of the orientation of the roof section and the proposed PV panels, the routes of interest for assessment consideration are as follows:

- (a) R135 immediately to the east of the site
- (b) N2 (northbound only) to the east of the site (the orientation of the roof section renders the proposed solar PV development outside of the field of view for motorists travelling south).
- (c) Elm Road, which links the N2 with the R122 to the east of the site.

Further to our initial general assessment of glint and glare, a secondary more thorough route specific assessment was carried out that concentrated on those route sections where glint and glare was predicted to be a theoretical possibility. For this exercise, 10 x receptor points were placed at 25m intervals along each of the identified route sections – one 250m section along the R135 and another 250m section along the N2-northbound.



Figure 3: Route receptors identified within 1km of the proposed solar PV development that intersect with the predicted glare pattern.

To qualify the intensity of the reflected light that would be emitted from the solar PV panels during a period of reflectance, SGHAT analysis was carried out. The results provide us with a valid measure of the hazard level for motorists in instances where glare can be experienced.

Aviation Receptors

The Irish Aviation Authority (IAA) has indicated that all applications for PV solar arrays within a 10km radius of an airport or aerodrome should be referred to the authority for review. Dublin Airport, located approximately 2.4km to the east of the proposed installation, is the principal airport being considered in this assessment. Casement Aerodrome and Weston Airport located 14.5km and 12.5km to the southwest of the site respectively both fall outside of this threshold and will not be regarded further in this study.

Guided by the FAA *Technical Guidance for Evaluating Selected Solar Technologies on Airports* (2013), the IAA and DAA have requested appropriate glint and glare assessments to include for the following:

- (a) Glare towards the 2 mile (3.2km) approach path for runways
- (b) Glare towards any Air Traffic Control Towers (ATCTs)

Such assessment requires detailed analysis of the path of the sun throughout the year while also considering the specific position, size and angle of the solar panels relative to the following:

- a) Size and position of the airport air traffic control towers (ATCTs)
- b) Orientation of approach paths to runways of the airport

Using SGHAT as the analysis tool for aviation receptors it is important that the results confirm the following:

1. There can be no potential for any glint and glare episodes to affect any existing or planned Airport Traffic Control Tower (ATCT) cab, and
2. No potential for glare of type that will result in 'temporary after-image' or 'permanent eye damage' (shown in yellow and red respectively in Figure X) along the final approach path for any existing landing threshold or future landing thresholds (including any planned interim phases of the landing thresholds) as shown on the current FAA-approved Airport Layout Plan (ALP). The final approach path is defined as two (2) miles from fifty (50) feet above the landing threshold using a standard three (3) degree glidepath.

	Glare beyond 50 deg from pilot line-of-sight
	Low potential for temporary after-image
	Potential for temporary after-image
	Potential for permanent eye damage

Figure 2: Glare report – hazard intensity legend

Note that the glare type '*Low potential for temporary after-image*' is acceptable for approaching aircraft. It is not acceptable, however, for ATCTs.

Dublin Airport

Located approx $45^\circ - 85^\circ$ due NNE of proposed site
2.4 kms from proposed site to closest runway (Runway 10 Threshold)
4.2 kms from proposed site to new permitted ATCT

Dublin Airport is an international airport operated by the DAA. It is located approx. 10km north of Dublin in Collinstown, Fingal. It hosts 2 operational runways 10/28 and 16/34 as detailed in Figure 2. A 3rd runway is planned to the north (Reg. Ref. SID/01/09 / ABP PI06FPA0014) to help accommodate increasing passenger numbers that will run parallel to runway 10/28 to the south. This will render the 16/34 runway as a purely taxiing runway when operational.

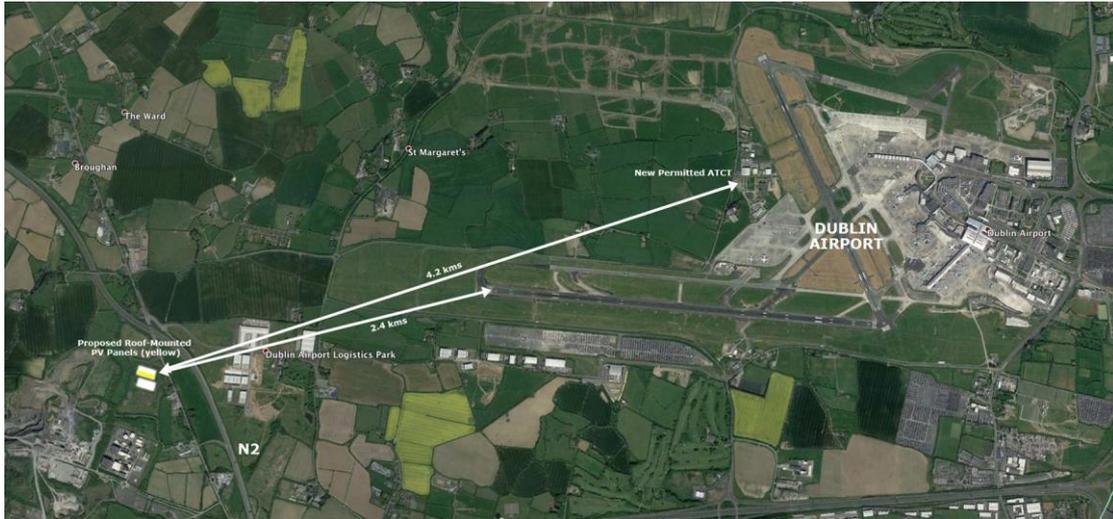


Figure 3: Location of the proposed roof-mounted PV solar panels relative to Dublin Airport

A new taller control tower was recently granted planning by ABP (Reg. Ref 04/1755 ABP PL06F217429) to cater for greater traffic volumes and allow for visibility of the new runway to the north, which would be screened from the smaller tower by airport buildings when built.

Runway Approaches

All 6 runway approaches were tested for Glint and Glare effects using the SGHAT. This includes the recently proposed northern runway (approach 10L and 28R).

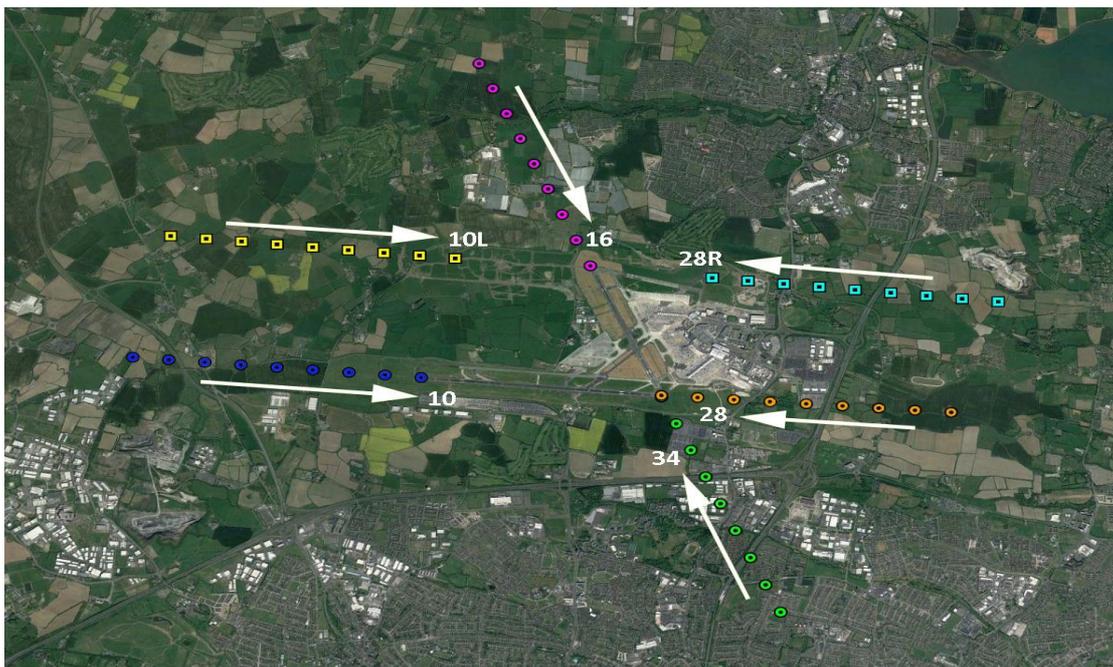


Figure 4: 2 mile approach lines to runways at Dublin Airport (at $\frac{1}{4}$ mile intervals) as assessed by SGHAT. Includes the proposed northern runways 10L and 28R.

Air Traffic Control Towers (ATCT)

Dublin airport currently has a control tower to the west of the main terminal buildings. This has viewing height of 21.9m.

The recently permitted more modern tower is due to be built in conjunction with the new proposed northern runway, by 2020. This is considerably taller with a viewing height of 75.6m and is situated close to the west of the existing tower.

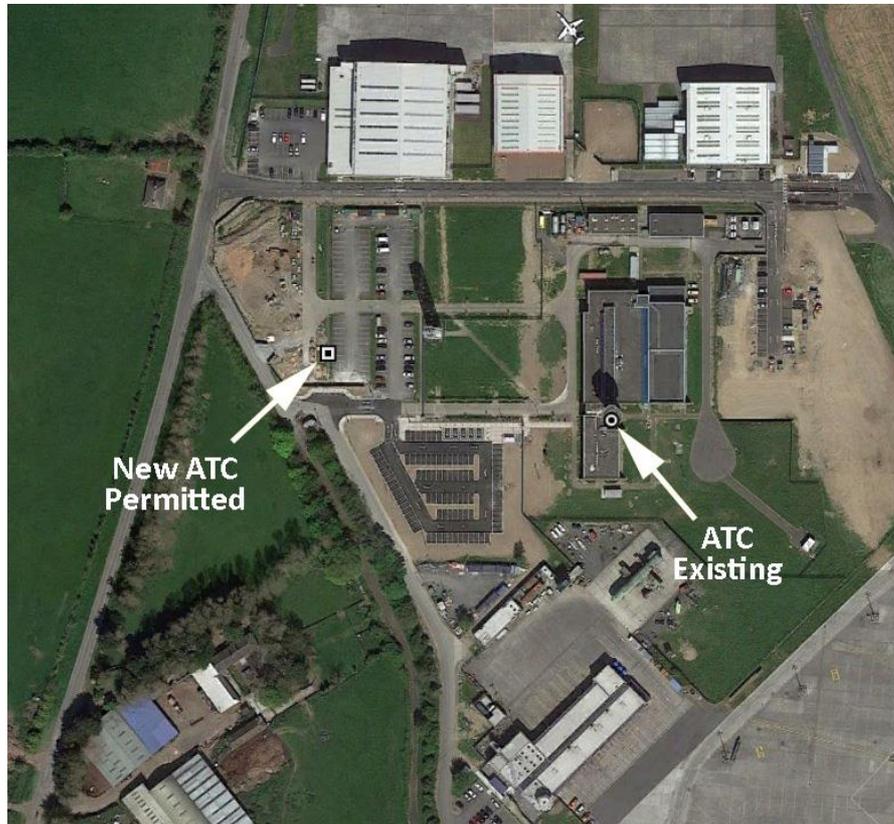


Figure 5: Air Traffic Control Towers (existing and newly permitted)

Results

Residential

Due to the elevation and orientation of the roof section to be developed with PV panels, those residences to the north of the roof apex line have no possibility of a view and thus cannot be affected by glint and glare. Through a combination of roof elevation, roof orientation and screening by the second of the 2 proposed storage buildings – the calculations have determined that none of the residences to the south have any potential to be affected by episodes of glint and glare.

Houses **H15 – H18**, located close to a zone of potential glare were specifically assessed for the effects of glare. Representative points placed immediately to the rear of each property indicate that there is no potential for any glare episode to occur (see Appendix A)

Routes

Our secondary route-specific assessment yielded a similar, albeit more precise pattern of glare impact to our initial assessment of the overall study area. Of the 20 route receptors assessed (see Appendix B) just one (1) of the receptors on the R135 (R135-5) and eight (8) of the receptors along the N2 (N2-3 – N2-9 and N2-11) were identified as having the theoretical potential to experience glare.

R135: The single point on the R135 that is predicted to be impacted by glare, has the potential to be effected for a total of 126 minutes across the months of June and July. This amounts to a maximum daily effect of 4 minutes (See Appendix B). Taking account of the roadside screening (buildings and vegetation) and assuming the typical speeds of cars (60kmph) travelling along this route, the experience of such glint effects will be momentary at worst, lasting no more than a couple of seconds. Given the light absorbing nature of modern PV panels coupled with their anti-reflective coating, this brief glint episode would be far less intense than that experienced from the glass of a building or an aluminium façade.

N2: Of the 8 points on the N2 (northbound) that are identified as being theoretically impacted by glare, all are subject to the screening afforded by the roadside mixed-species tree planting which is now approaching a leader height of 4-5m (this was not identified by the DSM as it was collected prior to the establishment of these trees). This visual barrier will be especially effective during the summer months in which glare is predicted to occur, this being the period when the foliage is flush and less visually porous. This screening effectively negates the glare episodes that are predicted to occur and will prove to be an even more effective barrier over time as the trees grow taller and the foliage becomes more dense.

In addition to the screening effect of the roadside planting, SGHAT analysis of these road points has revealed that the intensity of the glare (predicted as having the theoretical potential to impact the section of route) is of a type '*Low Potential for After-Image*'. This is acceptable by standards set by the FAA for pilots landing aircraft. It follows therefore, that such glare (located oblique to the direction of travel) should not pose any hazard of nuisance to motorists.

Further ameliorating factors include:

1. The panels causing glare are located at an angle approximately 40° – 50° to the left of the direction of travel. This is at the limit of the field of view of a motorist and should not present as a hazard or nuisance to normal driving.
2. At the times of day and year when these episodes are predicted to occur, the sun will be shining from the same direction and will be a far more intense source of light than the reflection that it is causing.

Aviation

SGHAT analysis (see Appendix C) has identified the following:

1. There will be no glare experienced by either of the Air Traffic Control Towers (ATCTs), existing or permitted.
2. There will be no glare experienced by aircraft on their approaches to runways 10L (proposed) or 16 (existing).
3. There will be glint/glare experienced by aircraft on their approaches to existing runways 10, 28 and 34 and to the proposed northern runway 28R.

In each case the glint/glare identified will be of a type 'Low Potential to Cause After-Image (flash blindness)' which is acceptable by FAA standards.

Conclusion

From our detailed analysis of this proposed PV Solar development we can state with a high level of confidence that there will be no nuisance or hazard effect upon local residences or the routes running through the study area.

In respect of local residences, the elevated nature and orientation of the PV panels coupled with the screening effect of the adjacent second storage building that is proposed, all combine to limit the area that is potentially impacted by glare episodes. The low housing density of the predominantly industrial and agricultural landscape surrounding the development site results in no house being affected.

While the N2 falls within an area highlighted by the predicted glare pattern, the northbound roadside embankment planting will serve (increasingly) to screen motorists from any nuisance that this may result in. Any glare, should it be experienced through any gap in the vegetation, has been determined to be of a low intensity (far less than that experienced from other surfaces commonly found in this environment such as glass houses and aluminium roofing) and will not present any safety hazard to motorists. Note that any glare predicted for the southbound carriageway of the N2 will fall outside of the field of view of motorists and will not present any nuisance effect.

Further, while there is the potential for glare episodes to be visible from a number of the approach paths into Dublin Airport, they are predicted to be of an intensity that is within the threshold deemed acceptable to the FAA and the Irish aviation authorities. Neither of the Air Traffic Control Towers (existing or permitted) will be affected in any way by this development.

Appendices

Appendix A – Analysis of Dwelling Receptors

Appendix B – Analysis of Route Receptors

Appendix C – Analysis of Aviation Receptors (SGHAT)

Appendix D – Relevant FAA Guidance for Aviation Receptors

The US Federal Aviation Authority (FAA) published guidance in November 2010, ‘*Technical Guidance for Evaluating Selected Solar Technologies on Airports*’ which contains most comprehensive guidance available for the assessment of Glint and Glare on airports and aviation activity. This was updated with an interim policy in 2013, ‘*FAA Review of Solar Energy System Projects on Federally Obligated Airports*’.

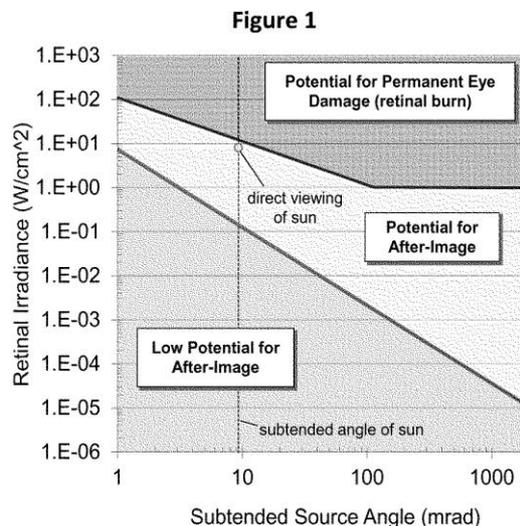
Pertinent issues from this guidance document are listed below:

Standard for Measuring Ocular Impact FAA adopts the Solar Glare Hazard Analysis lot shown in Figure 1 below as the standard for measuring the ocular impact of any proposed solar energy system on a federally-obligated airport.

To obtain FAA approval to revise an airport layout plan to depict a solar installation and/or a “no objection” to a Notice of Proposed Construction Form 7460–1, the airport sponsor will be required to demonstrate that the proposed solar energy system meets the following standards:

1. *No potential for glint or glare in the existing or planned Airport Traffic Control Tower (ATCT) cab, and*
2. *No potential for glare or “low potential for after-image” (shown in green in Figure 1) along the final approach path for any existing landing threshold or future landing thresholds (including any planned interim phases of the landing thresholds) as shown on the current FAA-approved Airport Layout Plan (ALP). The final approach path is defined as two (2) miles from fifty (50) feet above the landing threshold using a standard three (3) degree glidepath.*

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



Solar Glare Ocular Hazard Plot: The potential ocular hazard from solar glare is a function of retinal irradiance and the subtended angle (size/distance) of the glare source. It should be noted that the ratio of spectrally weighted solar illuminance to solar irradiance at the earth’s surface yields a conversion factor of ~100 lumens/W. Plot adapted from Ho et al., 2011.

Chart References: Ho, C.K., C.M. Ghanbari, and R.B. Diver, 2011, Methodology to Assess Potential Glint and Glare Hazards from Concentrating Solar Power Plants: Analytical Models and Experimental Validation, J. Solar Energy Engineering, August 2011, Vol. 133, 031021-1 – 031021-9.

Figure 8: Plot used by SGHAT to assess the ocular impact of light intensity from reflections

The SGHAT was designed to determine whether a proposed solar energy project would result in the potential for ocular impact as depicted on the Solar Glare Hazard Analysis Plot shown above.

As of the date of publication of this interim policy, the FAA requires the use of the SGHAT to demonstrate compliance with the standards for measuring ocular impact stated above for any proposed solar energy system located on a federally-obligated airport.

Appendix E – Limitations of SGHAT as they apply to this study

SGHAT has a number of documented limitations in its Users Manual. Not all of them have relevance to the results that have been calculated for this study, however, there are a couple that are important to note.

- 1: *“SGHAT does not rigorously represent the detailed geometry of a system; detailed features such as gaps between modules, variable height of the PV array, and support structures may impact actual glare results.”*

Macro Works has tested the results from SGHAT with the results from its own software. The results are in broad agreement between the 2 systems in terms of the start and end dates for glare periods and the times at which glare occurs.

Due to the intensity of the setup with our proprietary software where panel design and layout is accurately accounted for, the lines of panels are continuous without gaps and follow the undulations of the site more faithfully. The result can be marginally longer individual glare periods.

In this report we have defaulted to the longer glare periods. Other result parameters such as intensity, not dependent on period, have remained faithful to the SGHAT results.

- 2: *“SGHAT does not consider obstacles (either man-made or natural) between the observation points and the prescribed solar installation that may obstruct observed glare, such as trees, hills, buildings, etc.”*

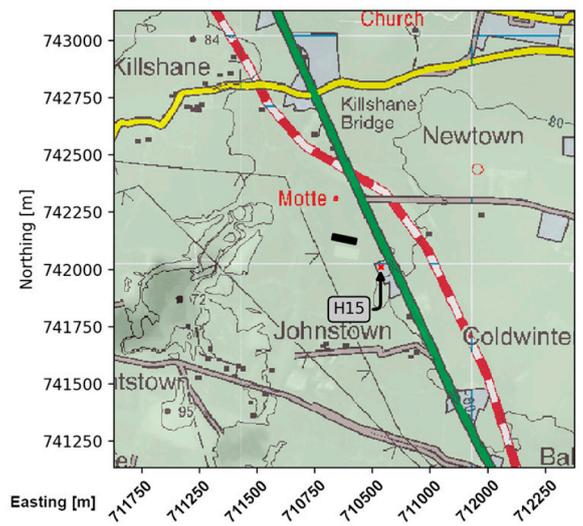
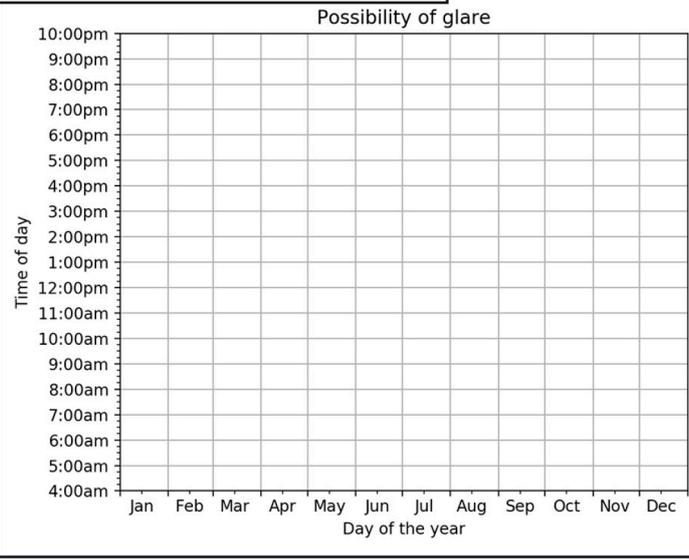
As part of our visibility and glint and glare calculations for solar sites Macro Works insists on using the best terrain input data. For this we capture the site terrain in high-resolution (25cm) to a distance of 700m from site boundary. From this data we derive a digital surface model which enables us to account for screening afforded by trees, building and any small undulations that may occur across the site. This is a system intensive process, however, it gives a far truer statement of visibility and thus glare than the bare-earth terrain employed by SGHAT.

The net result of this is that SGHAT overestimates the level of exposure of sites. In many instances only a portion of the site is actually visible once screening is accounted for.

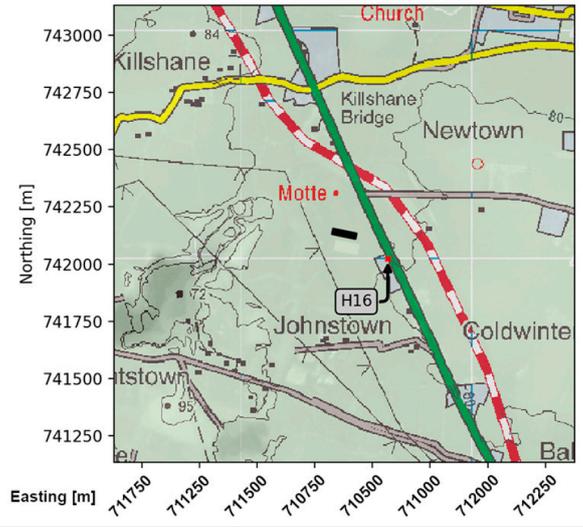
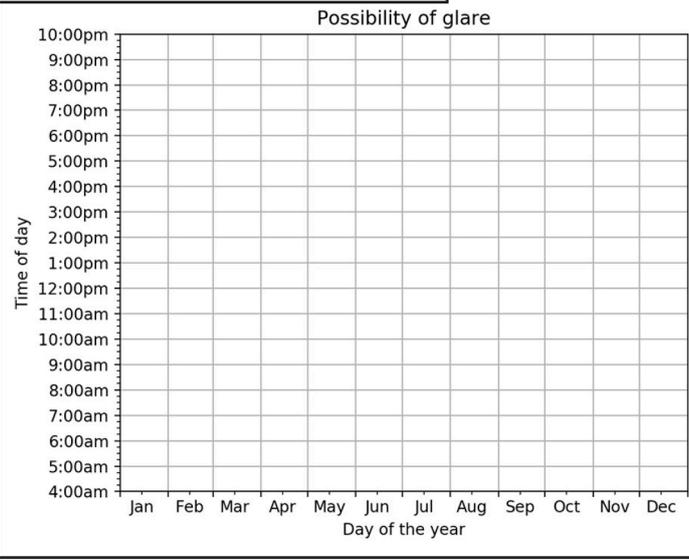
- 3: SGHAT does not account for the mutual screening of panels, i.e. front panels that screen the view of other rear panels. This can result in an exaggeration of the intensity of the glare effect and can alter the duration of glare periods. This is more so the case for lower receptors where panels have a greater capacity to screen one another.

Macro Works proprietary software takes account of this, however, this has not been a significant issue for the results of this project where the majority of views have been elevated.

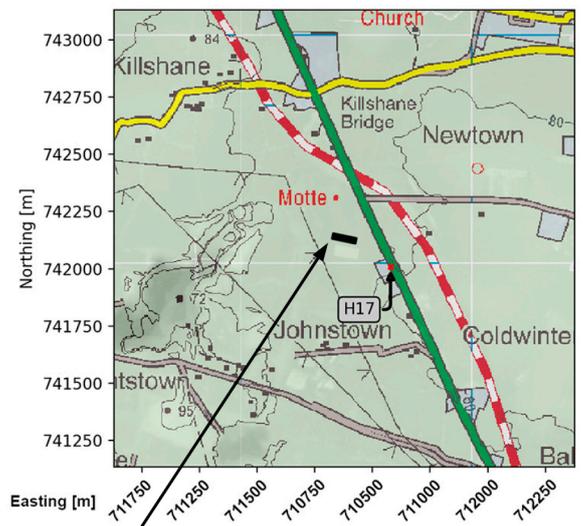
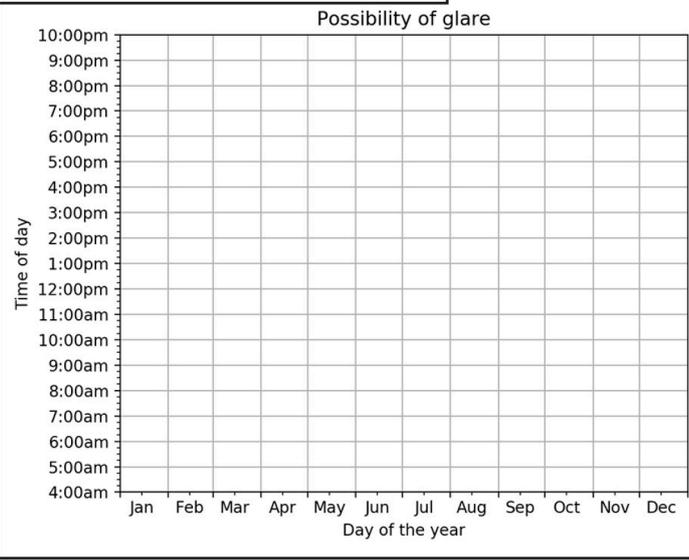
House 15



House 16



House 17

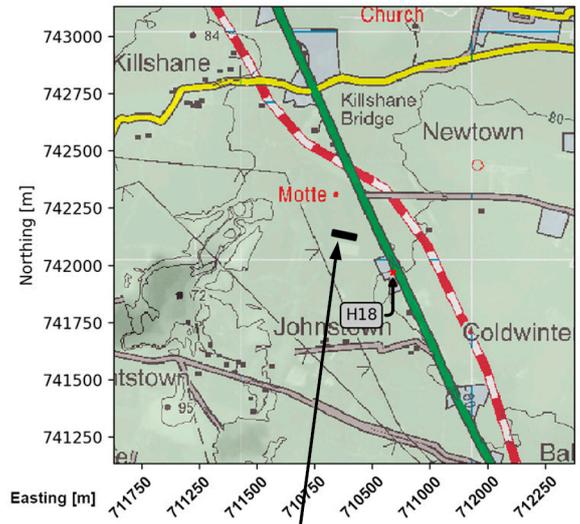
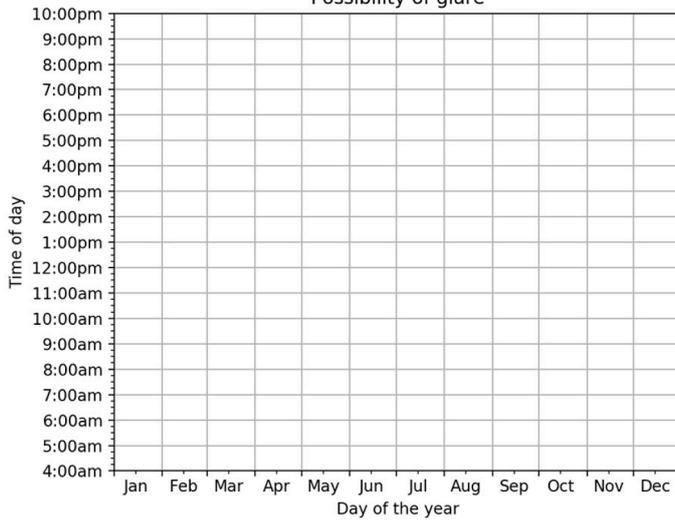


Panel Colour Legend

 glare is possible at times	 panel not visible from receptor
 glare is not possible	 panel screened from the sun
 only the rear of the panel is visible	

House 18

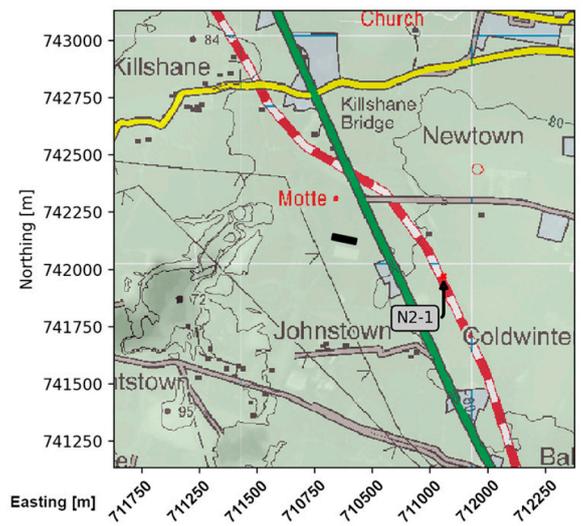
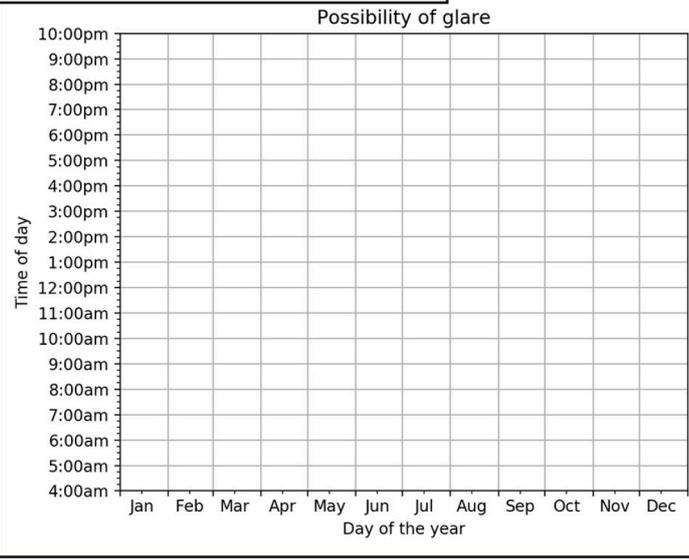
Possibility of glare



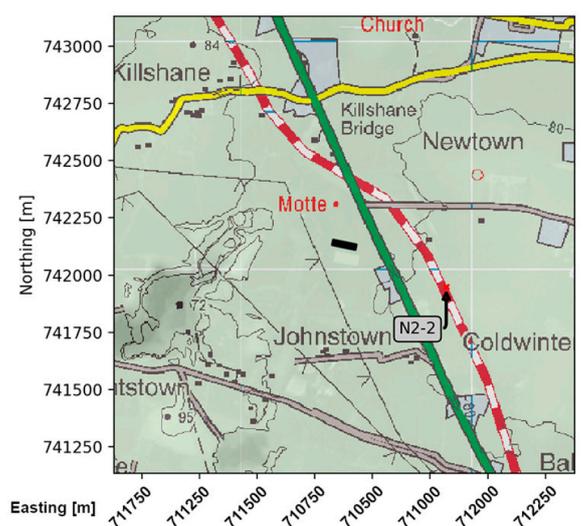
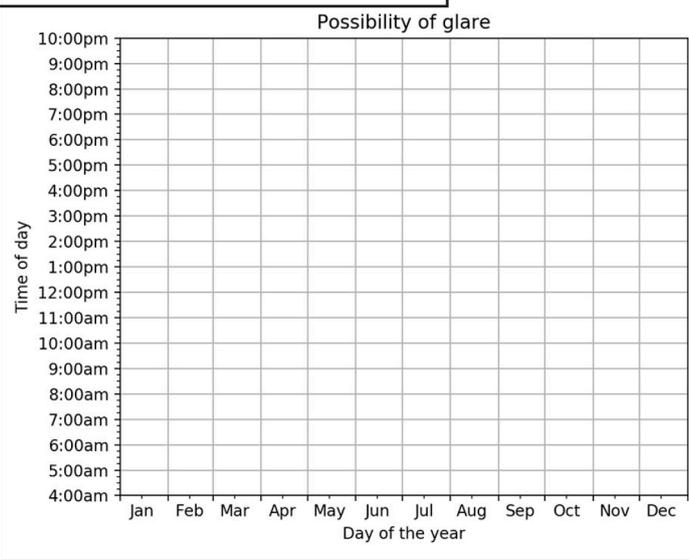
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	only the rear of the panel is visible		

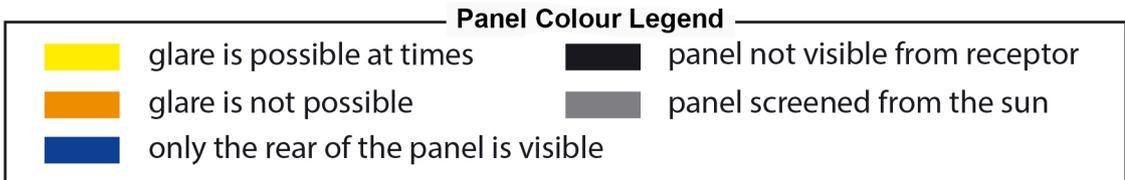
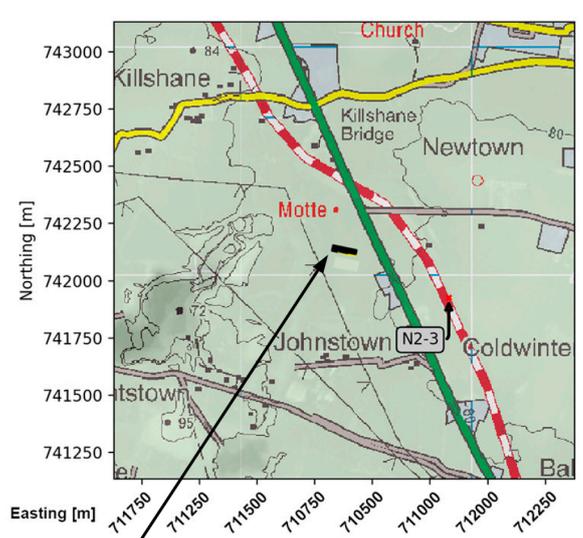
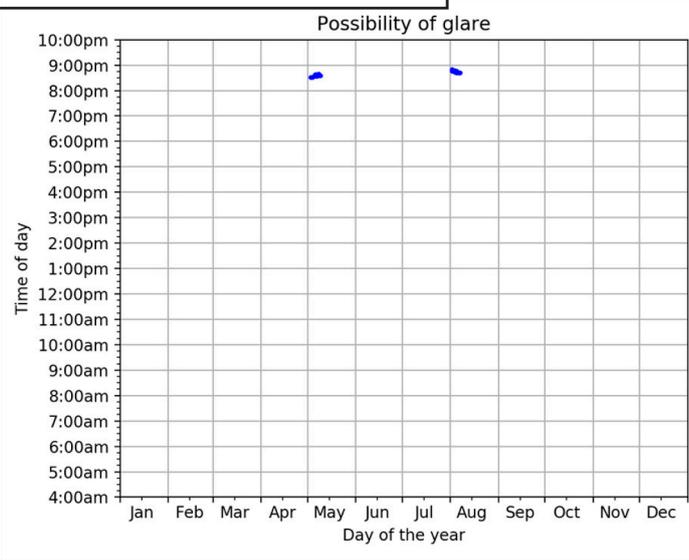
N2 Point 1



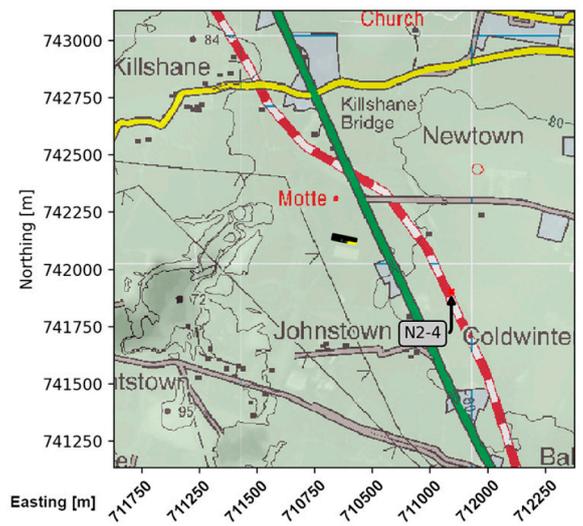
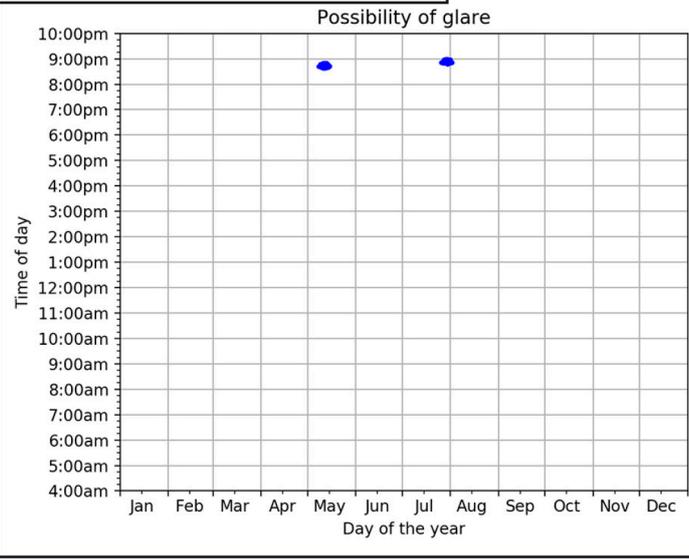
N2 Point 2



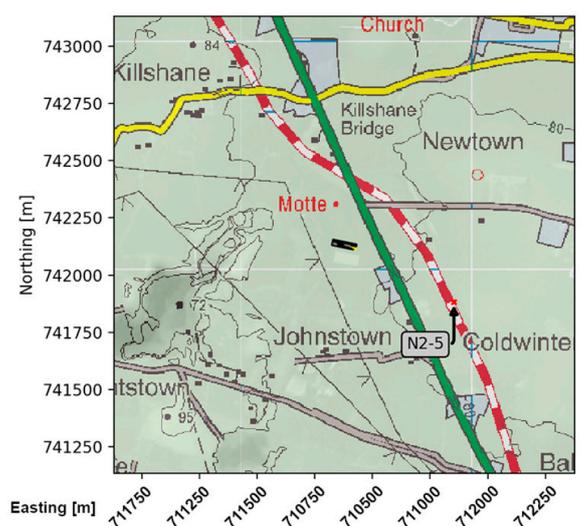
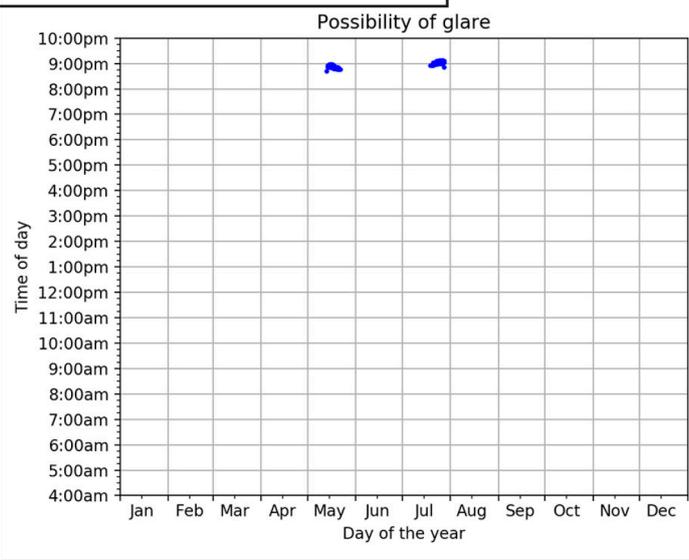
N2 Point 3



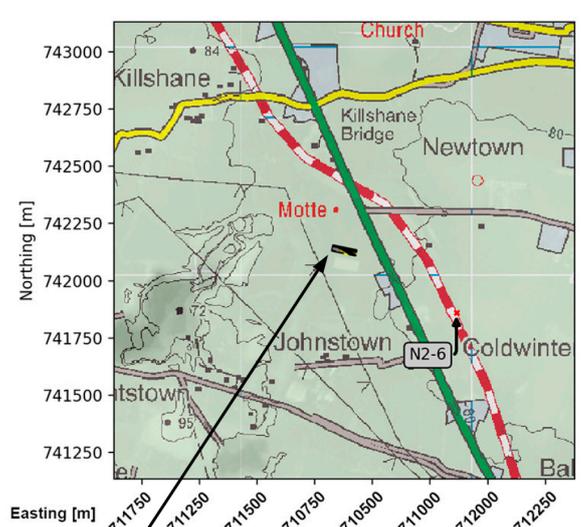
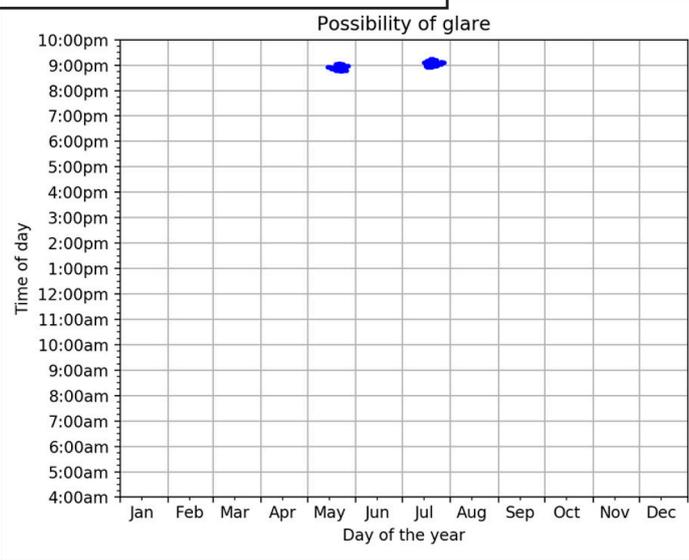
N2 Point 4



N2 Point 5



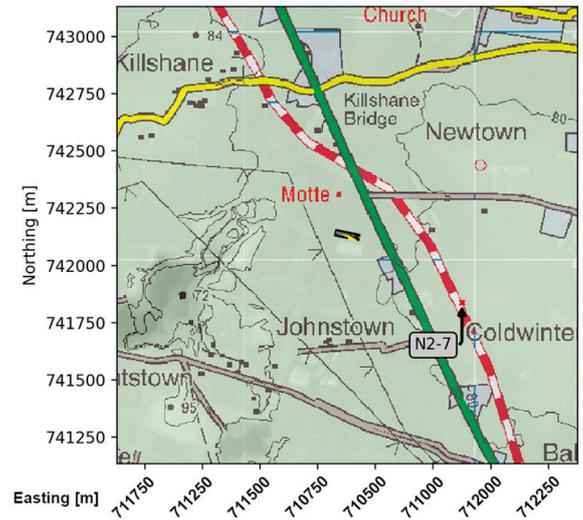
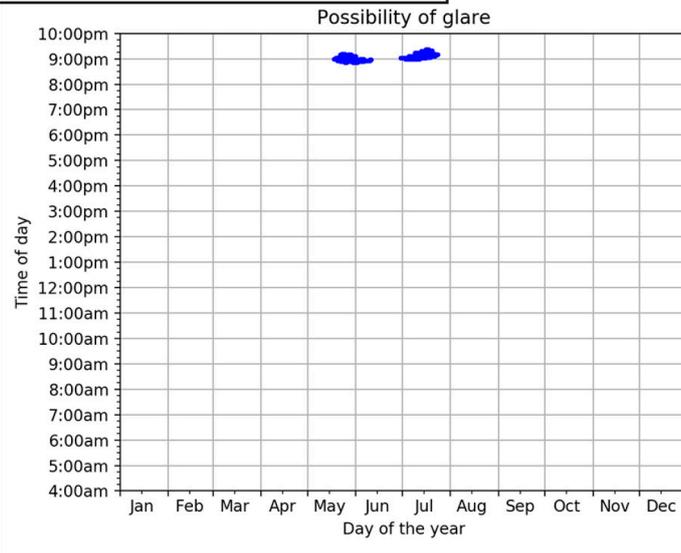
N2 Point 6



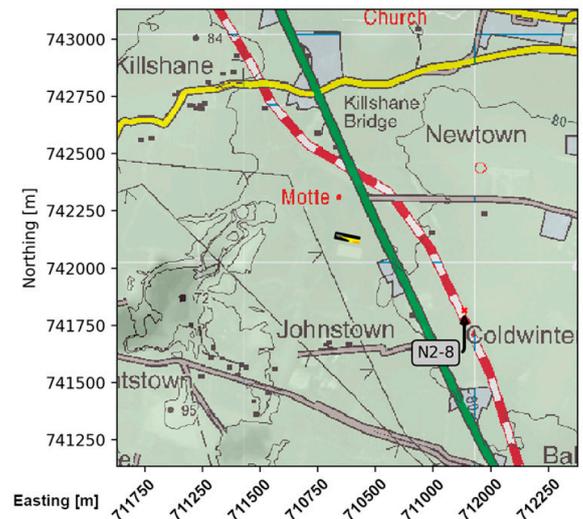
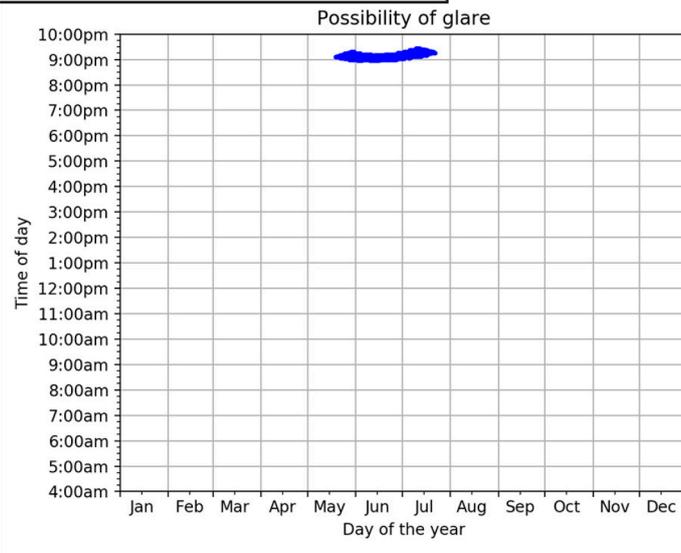
Panel Colour Legend

 glare is possible at times	 panel not visible from receptor
 glare is not possible	 panel screened from the sun
 only the rear of the panel is visible	

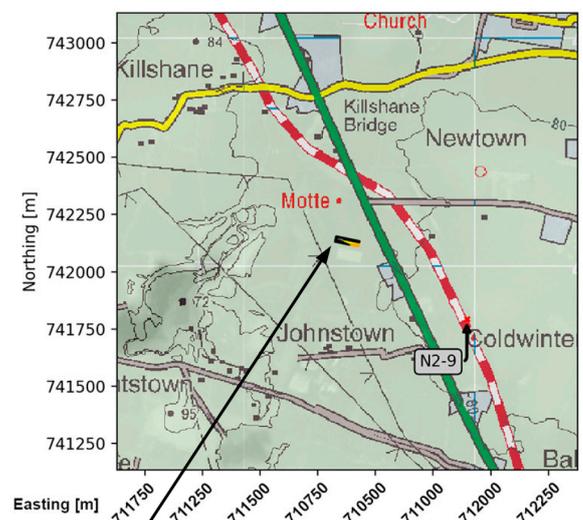
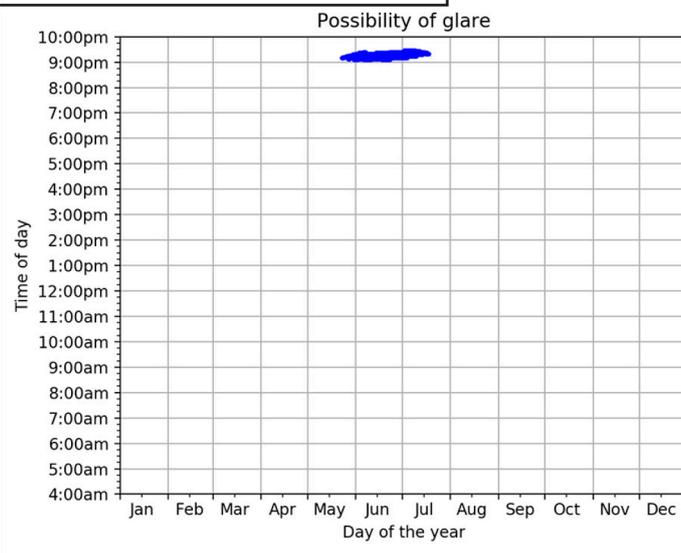
N2 Point 7



N2 Point 8



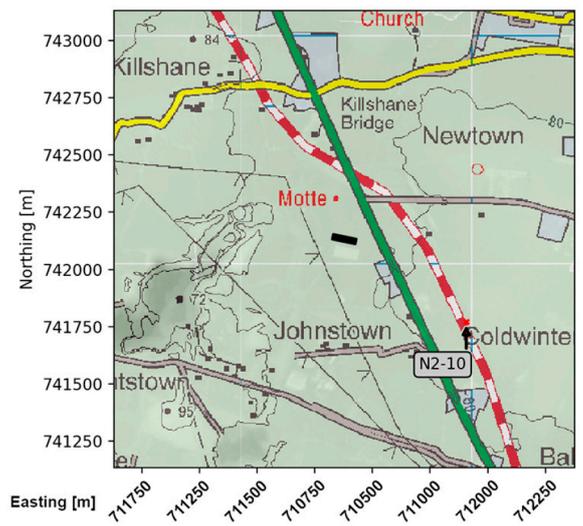
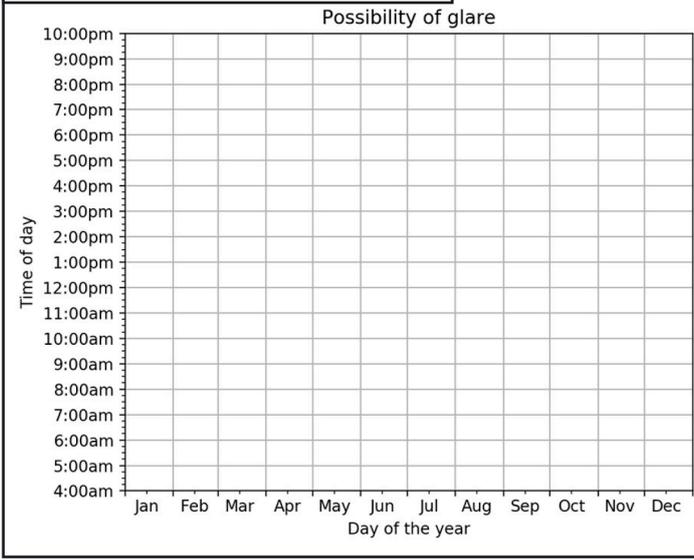
N2 Point 9



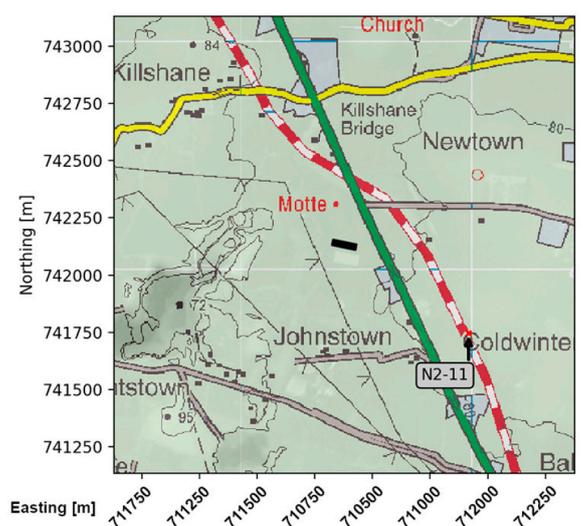
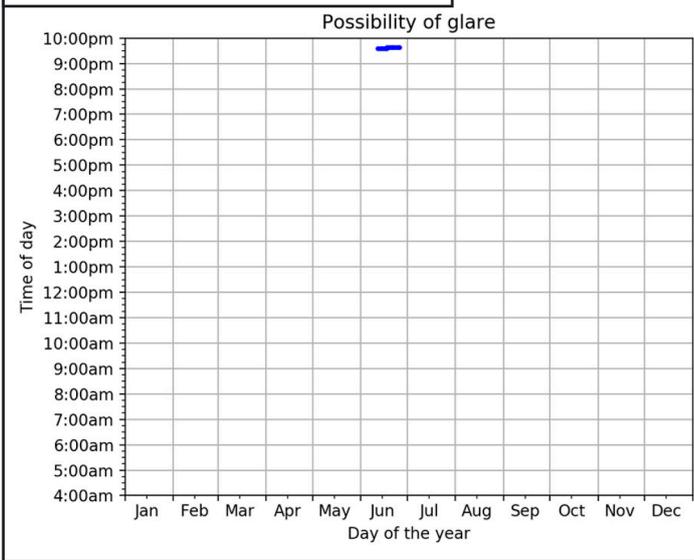
Panel Colour Legend

 glare is possible at times	 panel not visible from receptor
 glare is not possible	 panel screened from the sun
 only the rear of the panel is visible	

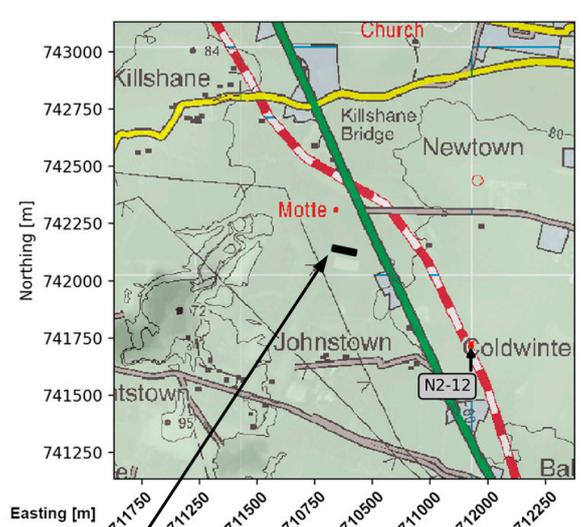
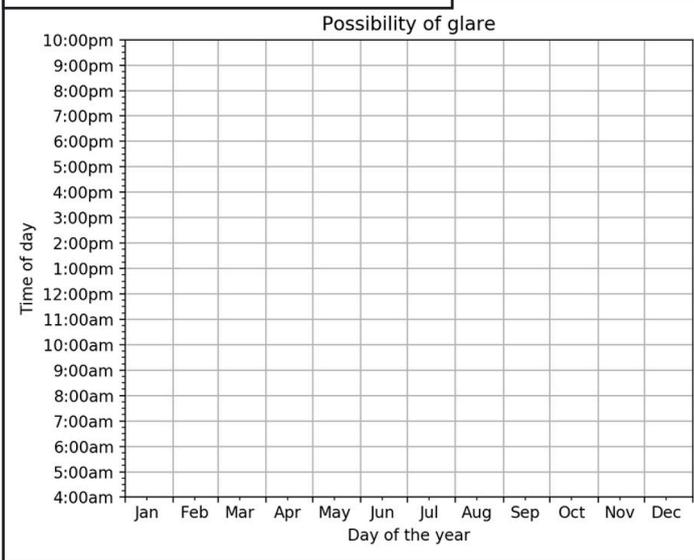
N2 Point 10



N2 Point 11



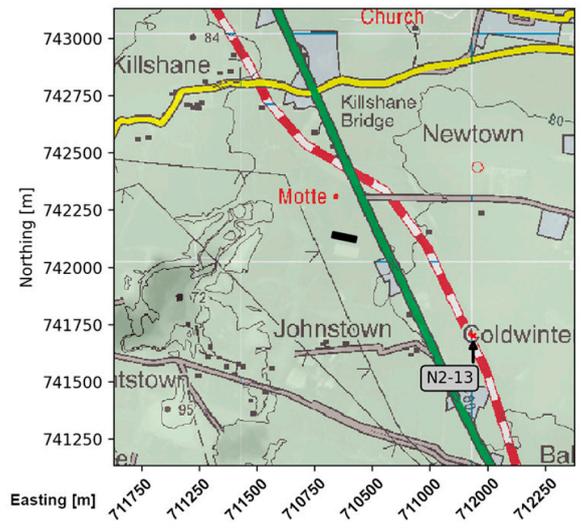
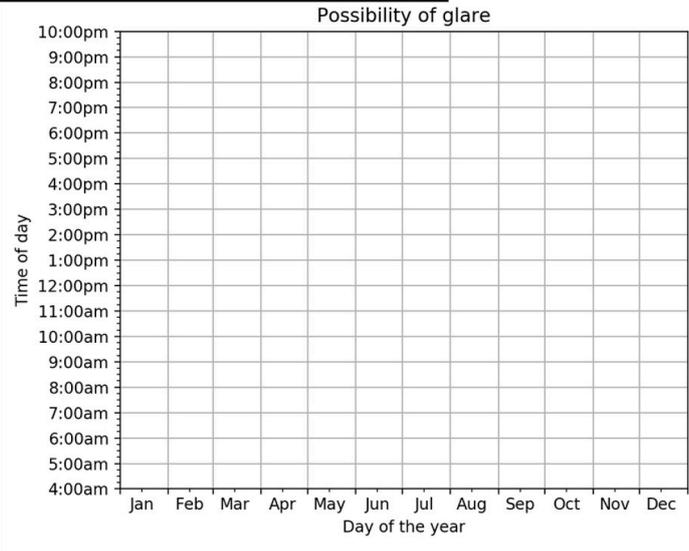
N2 Point 12



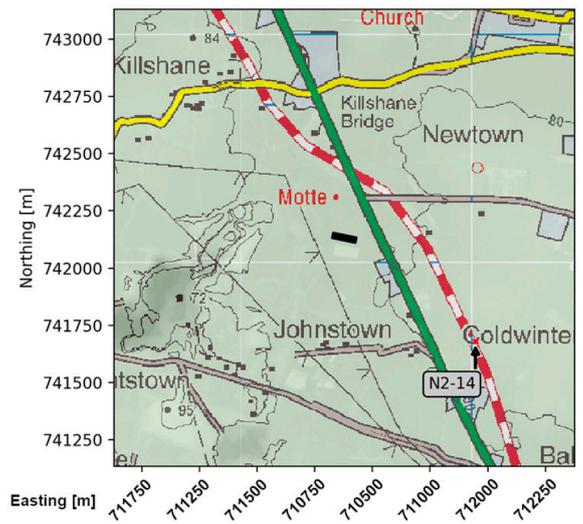
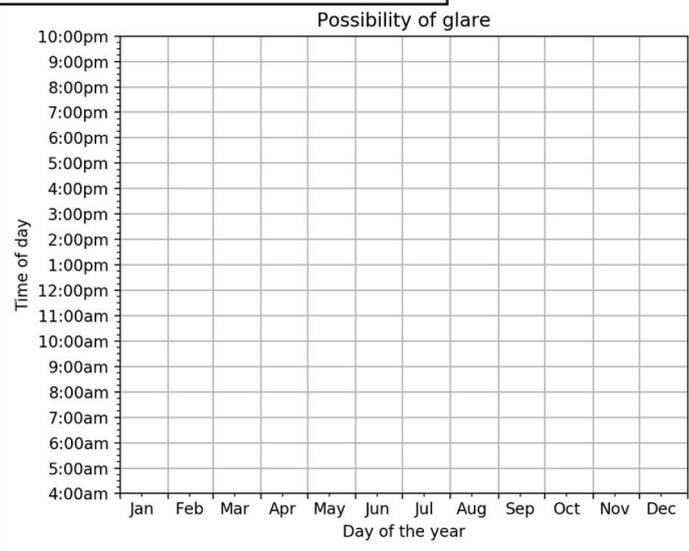
Panel Colour Legend

	glare is possible at times		panel not visible from receptor
	glare is not possible		panel screened from the sun
	only the rear of the panel is visible		

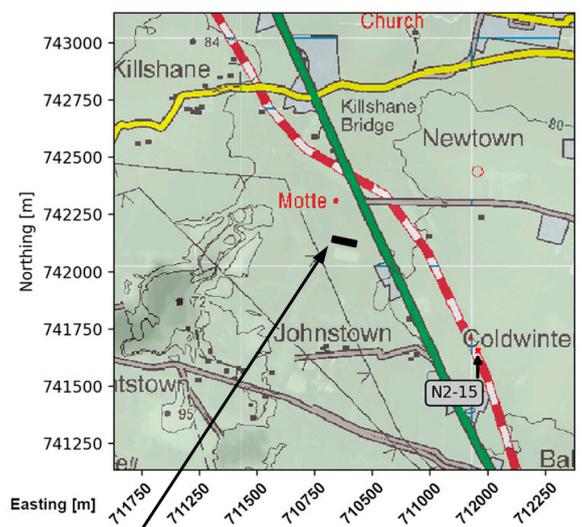
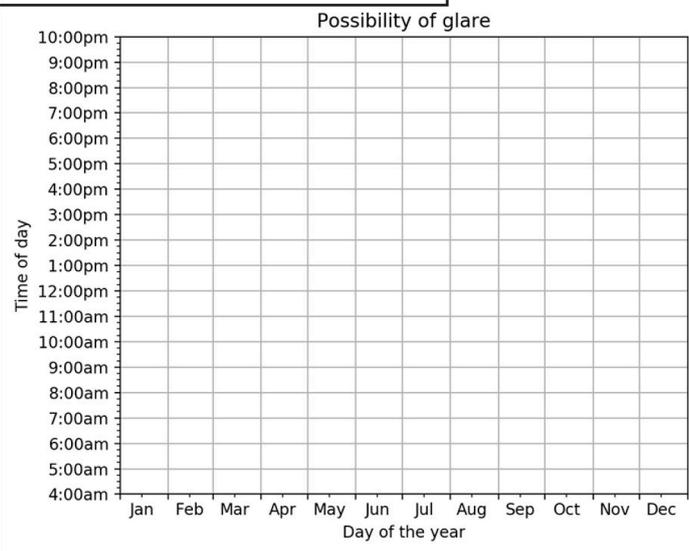
N2 Point 13



N2 Point 14



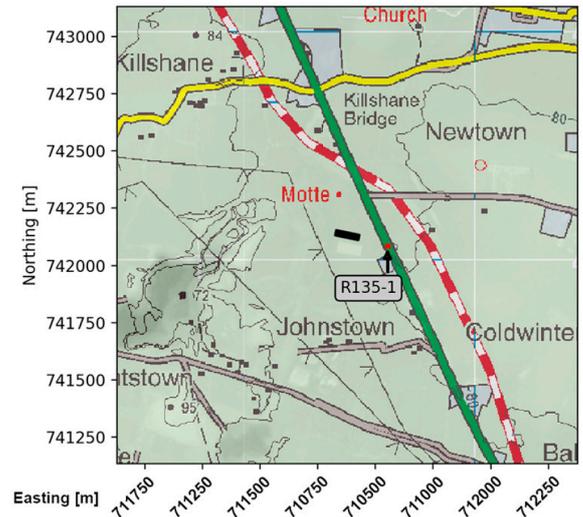
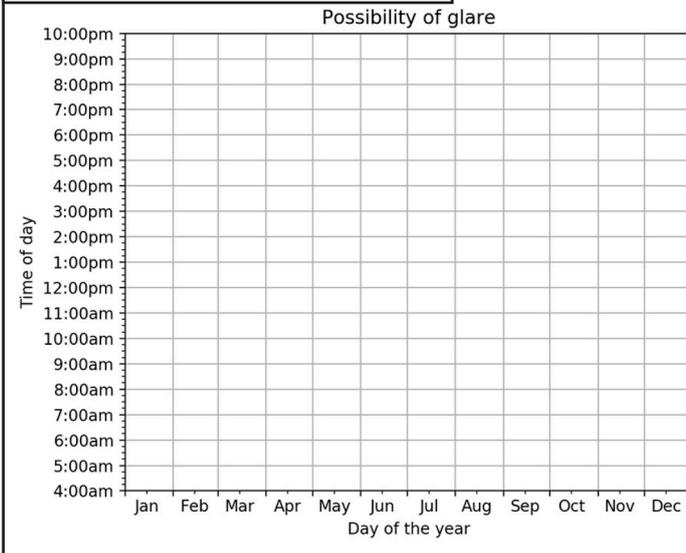
N2 Point 15



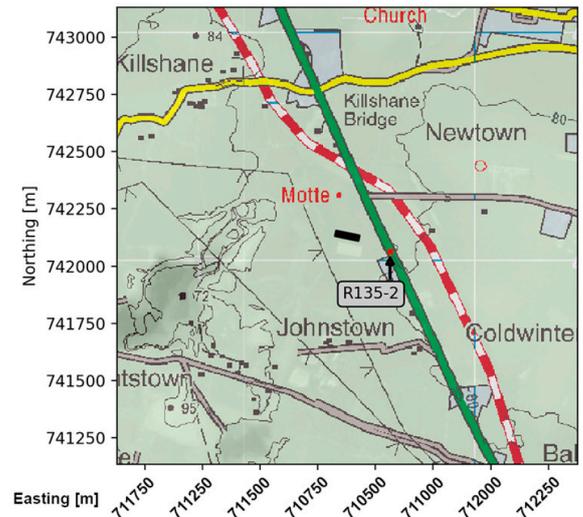
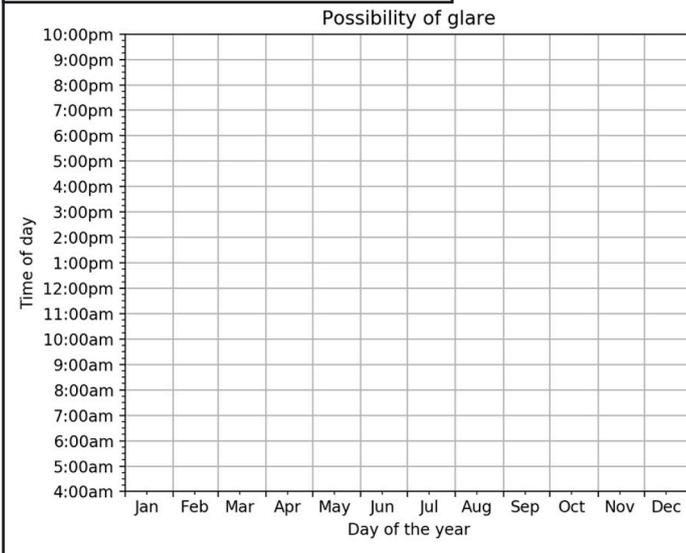
Panel Colour Legend

- glare is possible at times
- glare is not possible
- only the rear of the panel is visible
- panel not visible from receptor
- panel screened from the sun

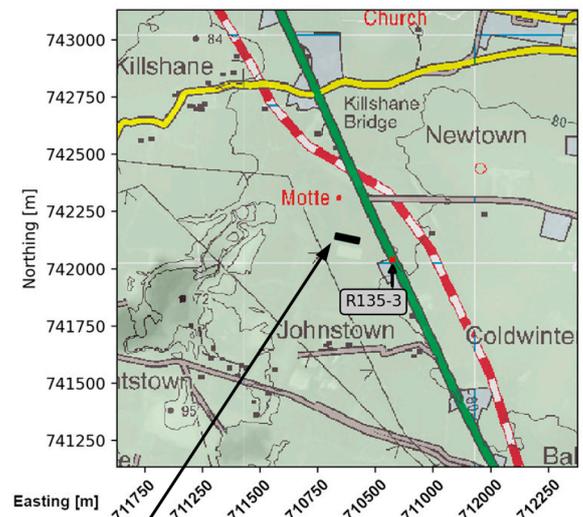
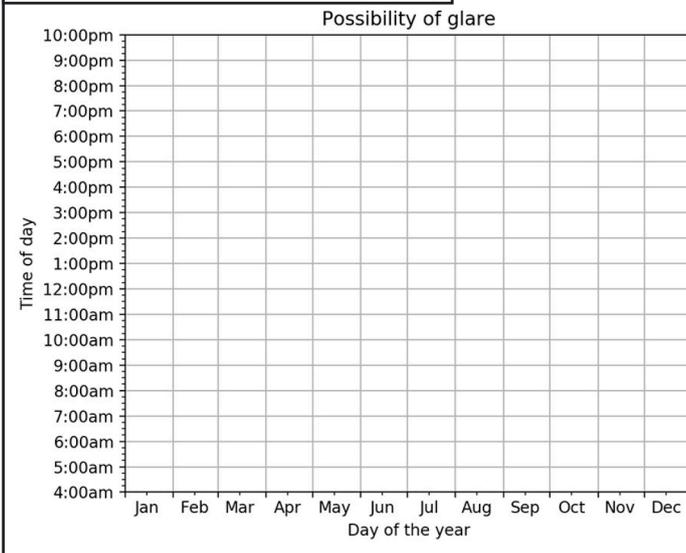
R135 Point 1



R135 Point 2



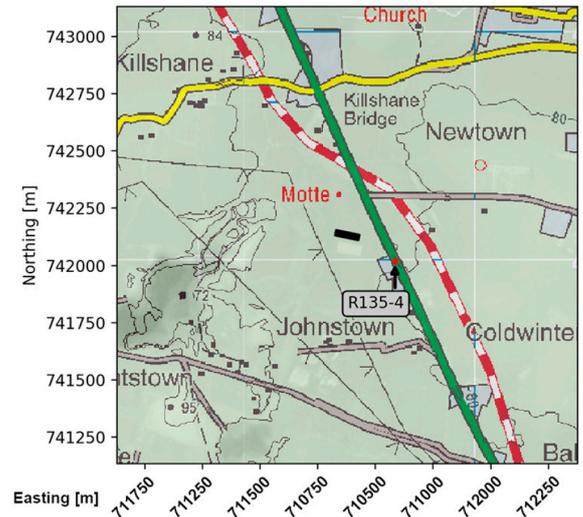
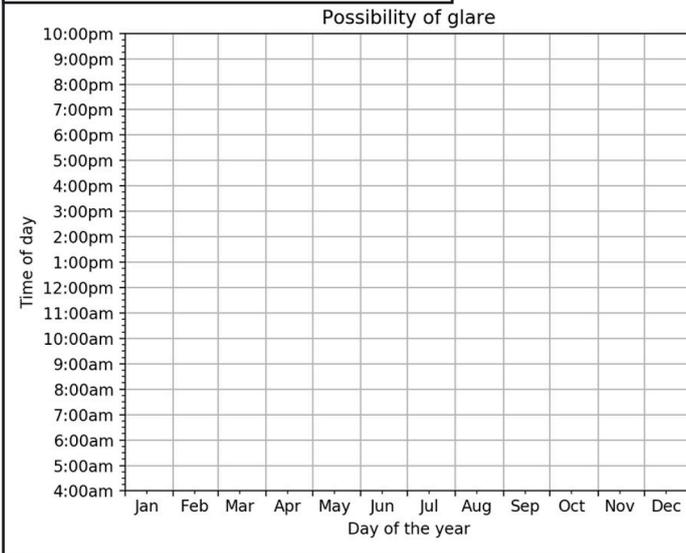
R135 Point 3



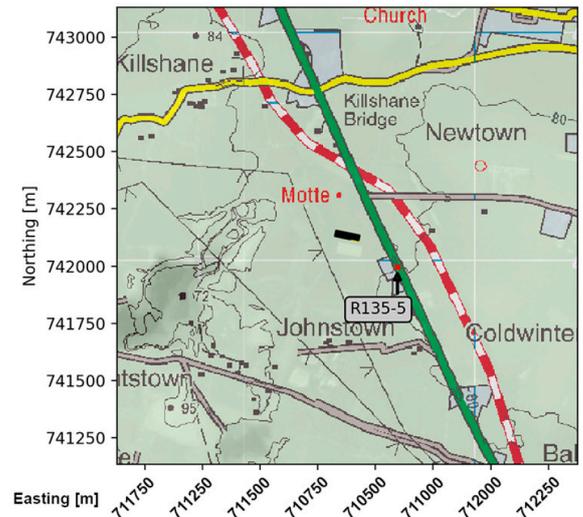
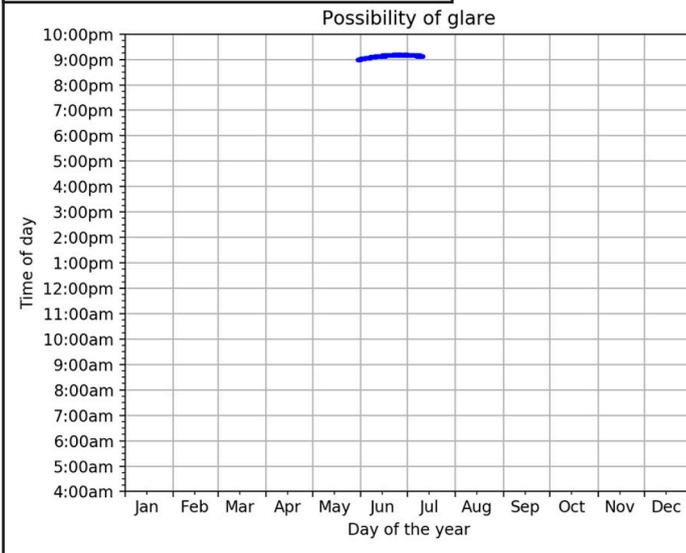
Panel Colour Legend

- glare is possible at times
- glare is not possible
- only the rear of the panel is visible
- panel not visible from receptor
- panel screened from the sun

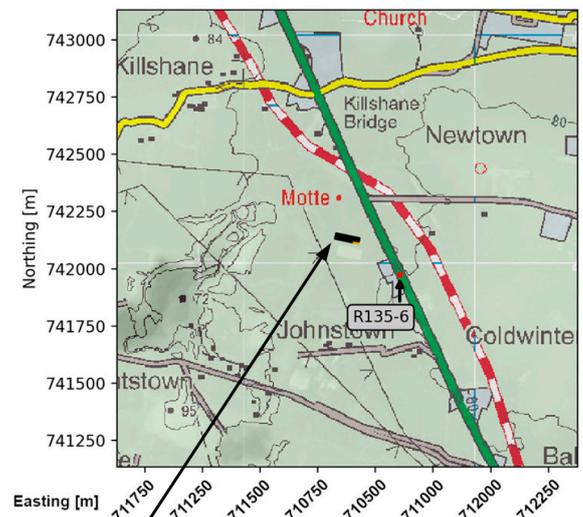
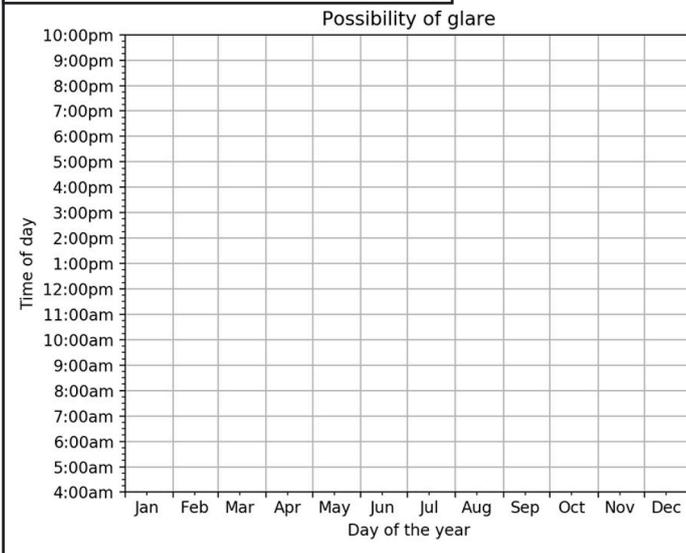
R135 Point 4



R135 Point 5



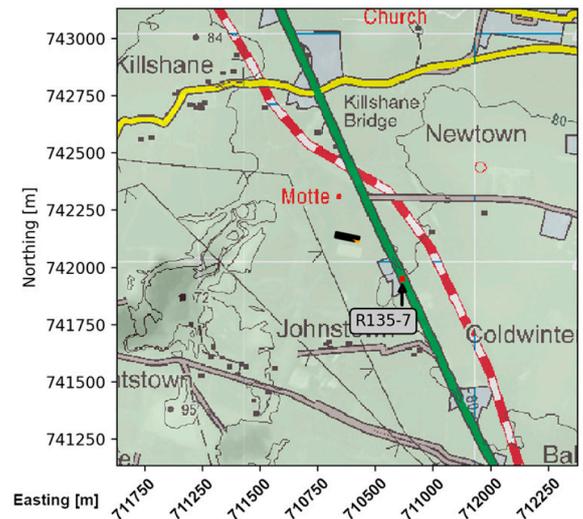
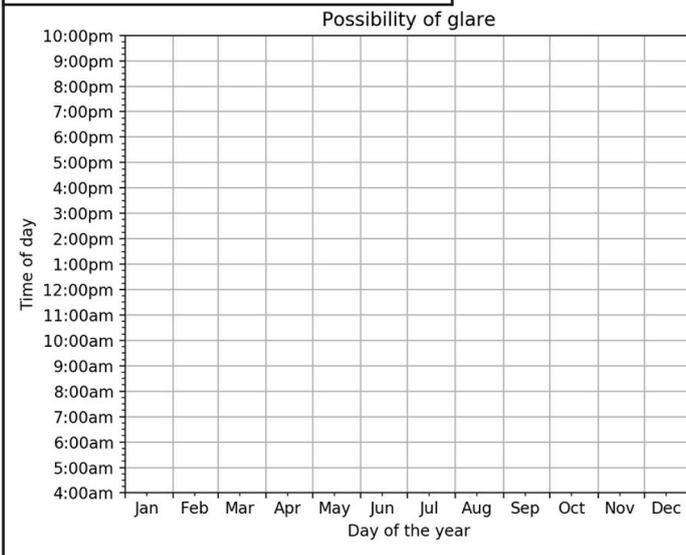
R135 Point 6



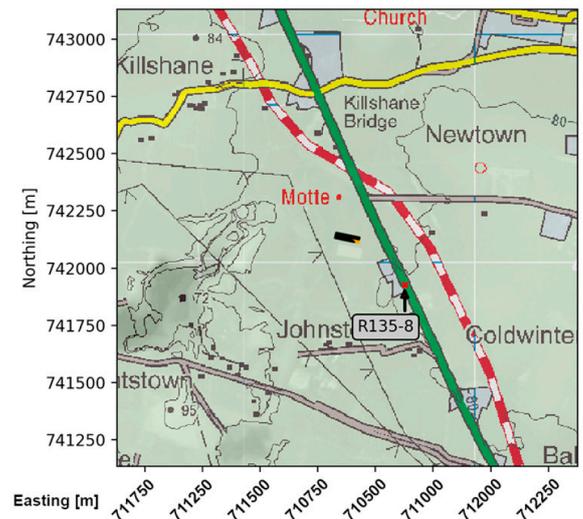
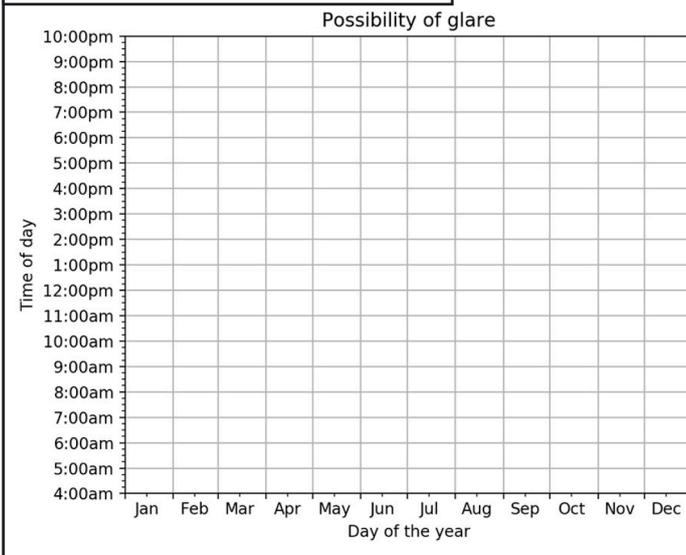
Panel Colour Legend

- glare is possible at times
- glare is not possible
- only the rear of the panel is visible
- panel not visible from receptor
- panel screened from the sun

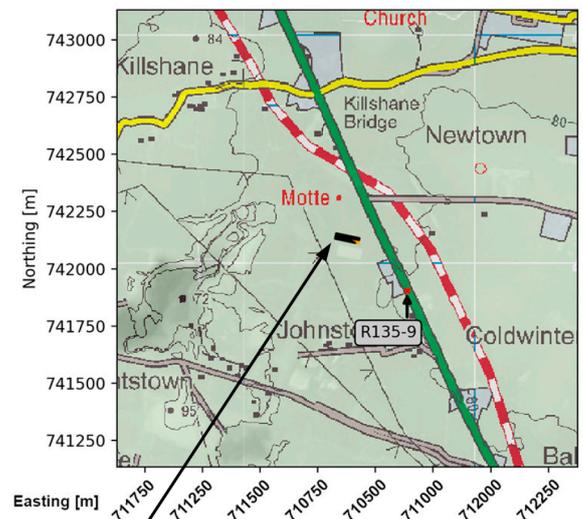
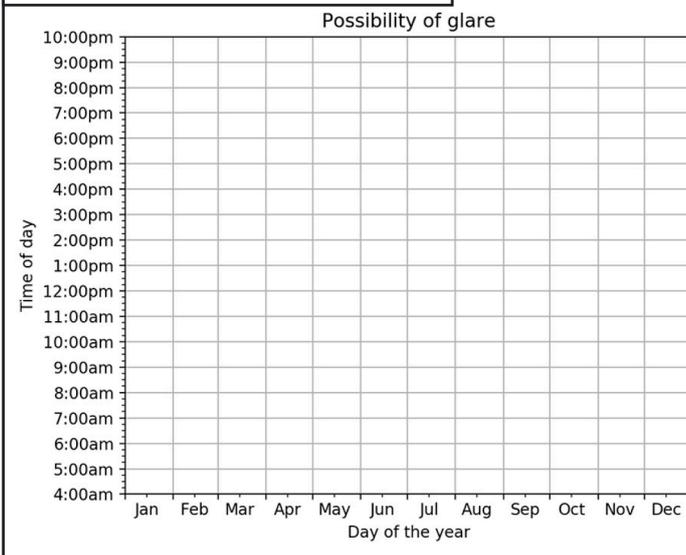
R135 Point 7



R135 Point 8



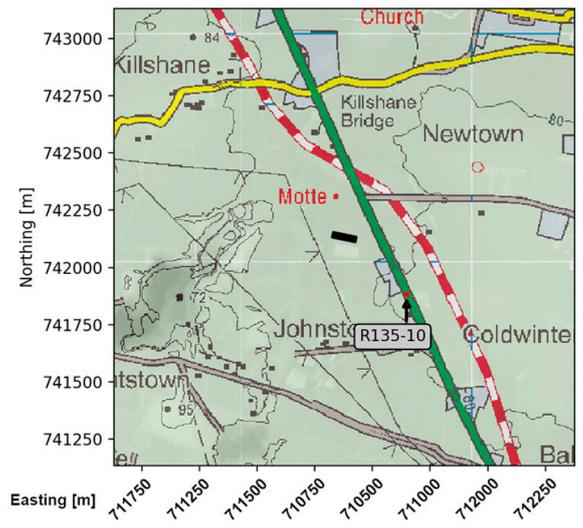
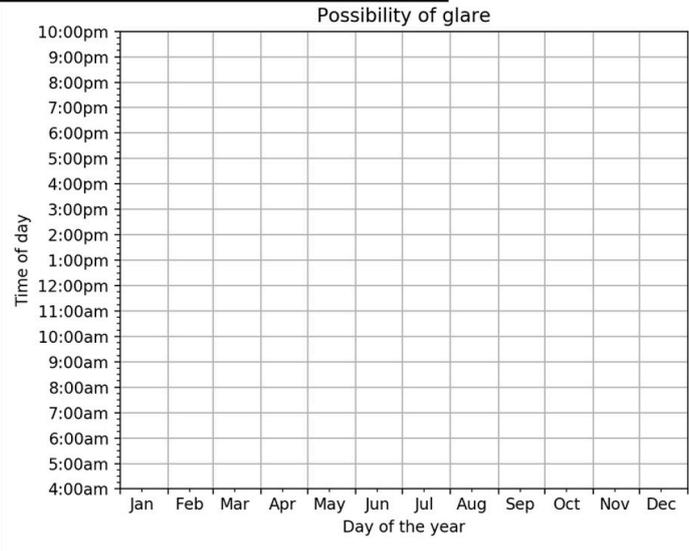
R135 Point 9



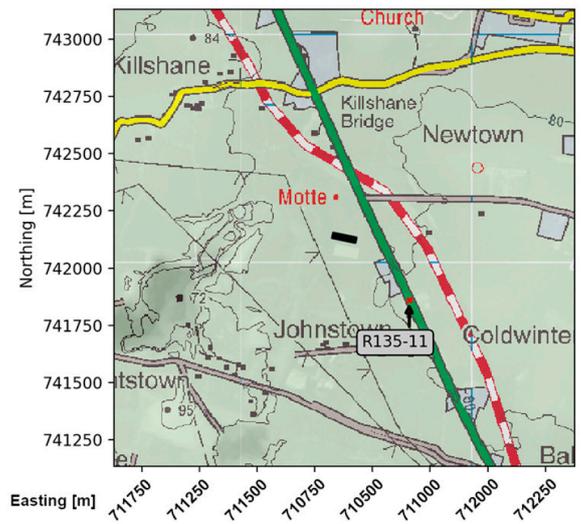
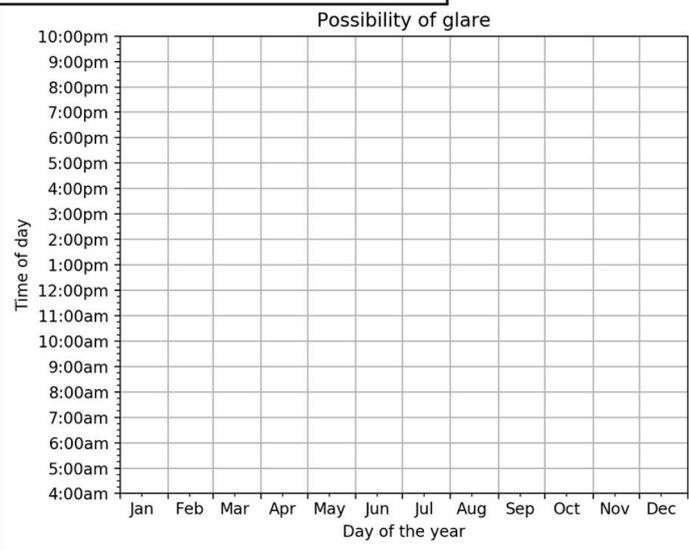
Panel Colour Legend

- glare is possible at times
- glare is not possible
- only the rear of the panel is visible
- panel not visible from receptor
- panel screened from the sun

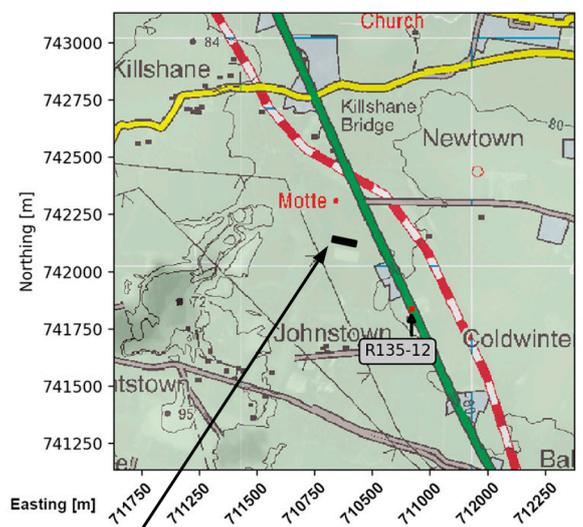
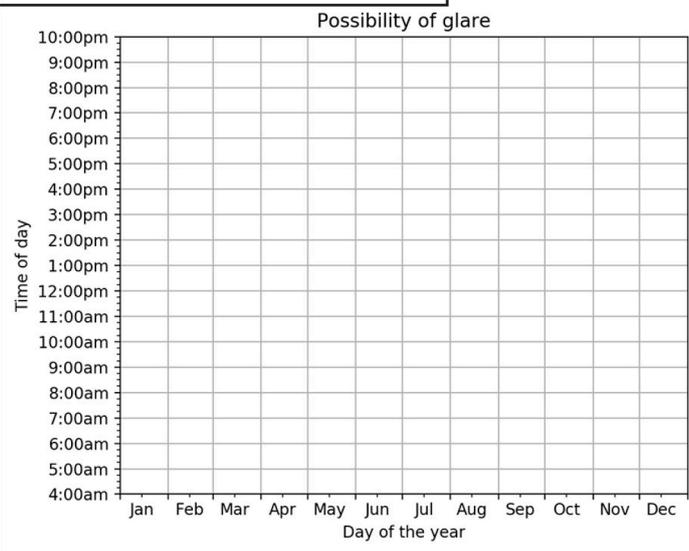
R135 Point 10



R135 Point 11



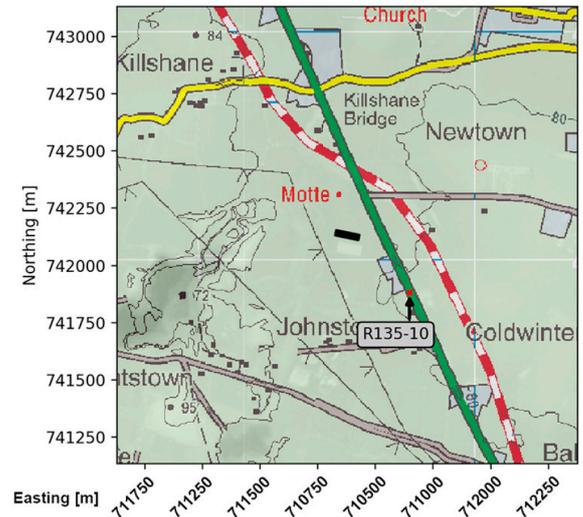
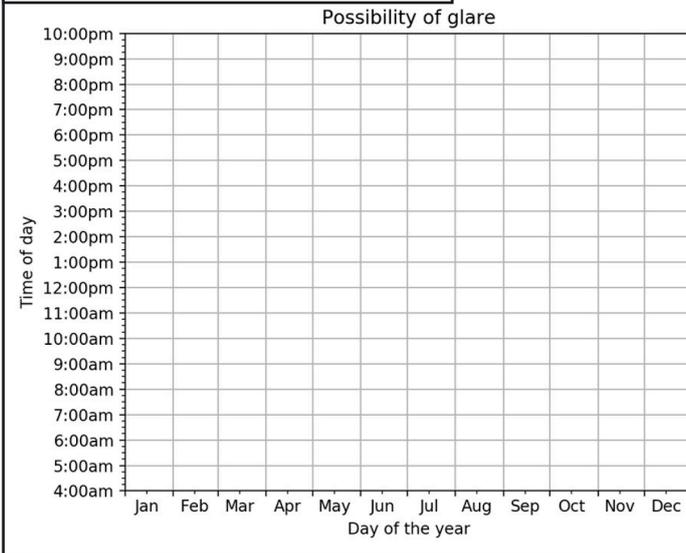
R135 Point 12



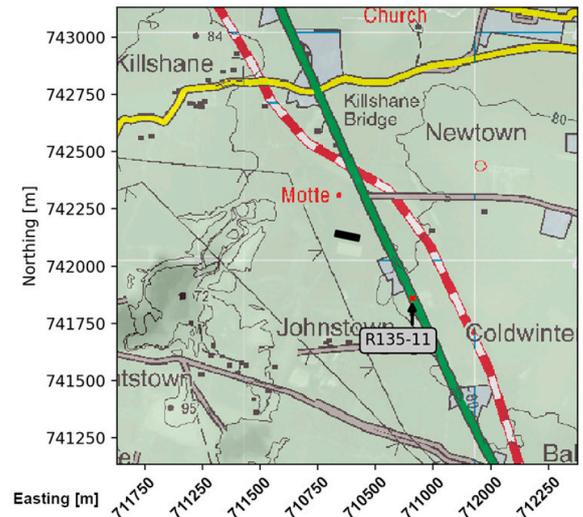
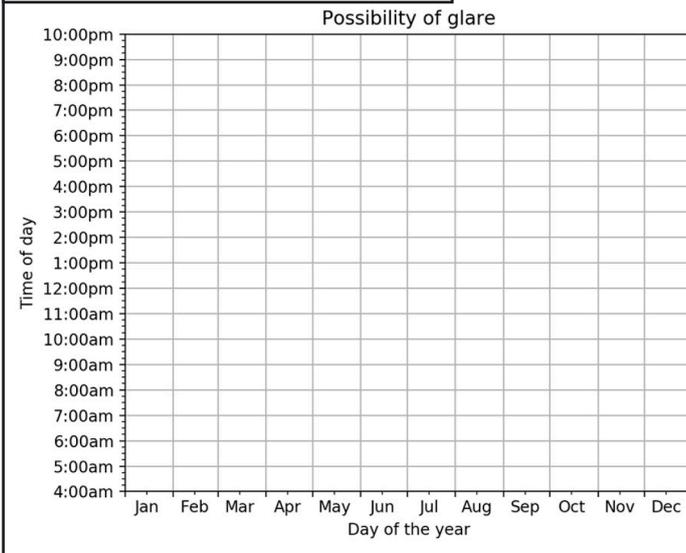
Panel Colour Legend

- glare is possible at times
- panel not visible from receptor
- glare is not possible
- panel screened from the sun
- only the rear of the panel is visible

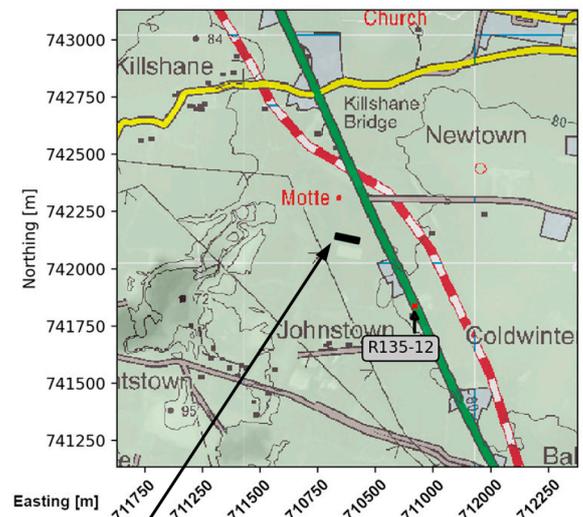
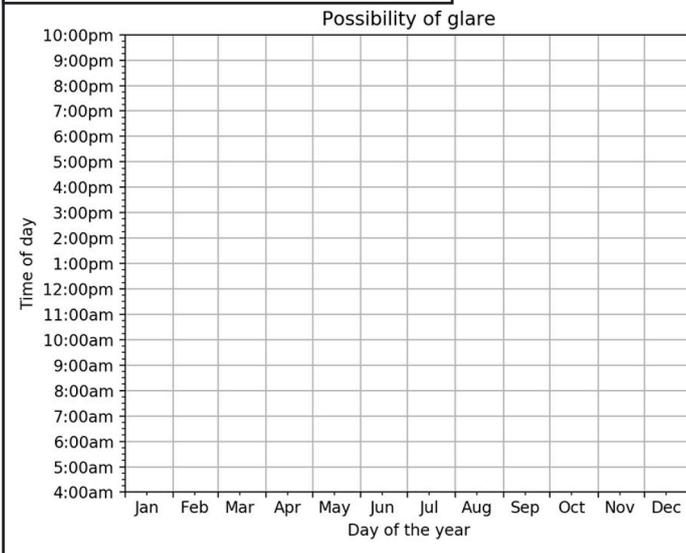
R135 Point 13



R135 Point 14



R135 Point 15



Panel Colour Legend

- glare is possible at times
- glare is not possible
- only the rear of the panel is visible
- panel not visible from receptor
- panel screened from the sun

FORGESOLAR GLARE ANALYSIS

Project: **Dublin Airport**

Site configuration: **DUBLIN AIRPORT - RBSF Roof**

Analysis conducted by Nikolas Hennessy (nik@macroworks.ie) at 16:26 on 31 Jan, 2018.

U.S. FAA 2013 Policy Adherence

The following table summarizes the policy adherence of the glare analysis based on the 2013 U.S. Federal Aviation Administration Interim Policy 78 FR 63276. This policy requires the following criteria be met for solar energy systems on airport property:

- No "yellow" glare (potential for after-image) for any flight path from threshold to 2 miles
- No glare of any kind for Air Traffic Control Tower(s) ("ATCT") at cab height.
- Default analysis and observer characteristics (see list below)

ForgeSolar does not represent or speak officially for the FAA and cannot approve or deny projects. Results are informational only.

COMPONENT	STATUS	DESCRIPTION
Analysis parameters	PASS	Analysis time interval and eye characteristics used are acceptable
Flight path(s)	PASS	Flight path receptor(s) do not receive yellow glare
ATCT(s)	PASS	Receptor(s) marked as ATCT do not receive glare

Default glare analysis and observer eye characteristics are as follows:

- Analysis time interval: 1 minute
- Ocular transmission coefficient: 0.5
- Pupil diameter: 0.002 meters
- Eye focal length: 0.017 meters
- Sun subtended angle: 9.3 milliradians

FAA Policy 78 FR 63276 can be read at <https://www.federalregister.gov/d/2013-24729>

SITE CONFIGURATION

Analysis Parameters

DNI: peaks at 1,000.0 W/m²
Time interval: 1 min
Ocular transmission coefficient: 0.5
Pupil diameter: 0.002 m
Eye focal length: 0.017 m
Sun subtended angle: 9.3 mrad
Site Config ID: 14596.2021

PV Array(s)

Name: Section A
Axis tracking: Fixed (no rotation)
Tilt: 0.0°
Orientation: 193.0°
Rated power: -
Panel material: Smooth glass with AR coating
Reflectivity: Vary with sun
Slope error: correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.417557	-6.323648	77.30	15.10	92.40
2	53.417530	-6.323656	77.30	15.10	92.40
3	53.417743	-6.325207	77.30	15.10	92.40
4	53.417772	-6.325201	77.30	15.10	92.40

Name: Section B

Axis tracking: Fixed (no rotation)

Tilt: 1.0°

Orientation: 193.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.417530	-6.323659	77.30	15.00	92.30
2	53.417501	-6.323667	77.30	15.00	92.30
3	53.417719	-6.325215	77.30	15.00	92.30
4	53.417744	-6.325209	77.30	15.00	92.30

Name: Section C

Axis tracking: Fixed (no rotation)

Tilt: 2.0°

Orientation: 193.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.417501	-6.323667	77.30	14.90	92.20
2	53.417474	-6.323681	77.30	14.90	92.20
3	53.417687	-6.325234	77.30	14.90	92.20
4	53.417719	-6.325220	77.30	14.90	92.20

Name: Section D

Axis tracking: Fixed (no rotation)

Tilt: 3.0°

Orientation: 193.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.417474	-6.323683	77.30	14.70	92.00
2	53.417449	-6.323691	77.30	14.70	92.00
3	53.417663	-6.325242	77.30	14.70	92.00
4	53.417685	-6.325234	77.30	14.70	92.00

Name: Section E

Axis tracking: Fixed (no rotation)

Tilt: 4.0°

Orientation: 193.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.417449	-6.323694	77.30	14.50	91.80
2	53.417423	-6.323705	77.30	14.50	91.80
3	53.417637	-6.325252	77.30	14.50	91.80
4	53.417663	-6.325247	77.30	14.50	91.80

Name: Section F

Axis tracking: Fixed (no rotation)

Tilt: 6.0°

Orientation: 193.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.417423	-6.323710	77.30	14.20	91.50
2	53.417394	-6.323718	77.30	14.20	91.50
3	53.417610	-6.325258	77.30	14.20	91.50
4	53.417637	-6.325258	77.30	14.20	91.50

Name: Section G

Axis tracking: Fixed (no rotation)

Tilt: 7.0°

Orientation: 193.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.417394	-6.323718	77.30	13.90	91.20
2	53.417366	-6.323726	77.30	13.90	91.20
3	53.417583	-6.325271	77.30	13.90	91.20
4	53.417607	-6.325260	77.30	13.90	91.20

Name: Section H

Axis tracking: Fixed (no rotation)

Tilt: 8.0°

Orientation: 193.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.417366	-6.323726	77.30	13.40	90.70
2	53.417338	-6.323737	77.30	13.40	90.70
3	53.417559	-6.325285	77.30	13.40	90.70
4	53.417580	-6.325274	77.30	13.40	90.70

Name: Section I

Axis tracking: Fixed (no rotation)

Tilt: 9.0°

Orientation: 193.0°

Rated power: -

Panel material: Smooth glass with AR coating

Reflectivity: Vary with sun

Slope error: correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
1	53.417337	-6.323737	77.30	13.00	90.30
2	53.417311	-6.323745	77.30	13.00	90.30
3	53.417533	-6.325290	77.30	13.00	90.30
4	53.417559	-6.325285	77.30	13.00	90.30

Flight Path Receptor(s)

Name: 10L Runway

Flight path map

Description: None

Threshold height: 15 m

Direction: °

Glide slope: 3.0°

Pilot view restricted? Yes

Vertical view: 30.0°

Azimuthal view: 120.0°

Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.436880	-6.280253	71.90	15.20	87.10
Two-mile	53.439822	-6.328592	74.90	180.90	255.80

Name: 10L_Runway 2-4M

Description: None

Threshold height: 15 m

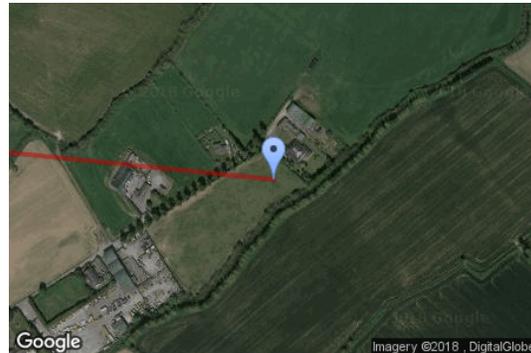
Direction: °

Glide slope: 3.0°

Pilot view restricted? Yes

Vertical view: 30.0°

Azimuthal view: 120.0°



Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.439800	-6.328661	255.80	15.20	271.00
Two-mile	53.442721	-6.377008	255.80	183.90	439.70

Name: 10 Runway

Description: None

Threshold height: 15 m

Direction: °

Glide slope: 3.0°

Pilot view restricted? Yes

Vertical view: 30.0°

Azimuthal view: 120.0°



Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.422405	-6.289520	74.00	15.30	89.30
Two-mile	53.425327	-6.337846	80.30	177.60	257.90

Name: 10 Runway 2-4M
Description: None
Threshold height: 15 m
Direction: °
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 120.0°



Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.425318	-6.337856	257.90	15.30	273.20
Two-mile	53.428240	-6.386186	257.90	184.00	441.90

Name: 16 Runway
Description: None
Threshold height: 15 m
Direction: °
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 120.0°



Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.436699	-6.261764	66.50	15.20	81.70
Two-mile	53.463138	-6.281428	69.70	180.70	250.40

Name: 16 Runway 2-4M
Description: None
Threshold height: 15 m
Direction: °
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 120.0°



Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.463143	-6.281433	250.40	15.20	265.60
Two-mile	53.489576	-6.301132	250.40	183.90	434.30

Name: 28R Runway
Description: None
Threshold height: 15 m
Direction: °
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 120.0°



Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.435084	-6.240975	65.50	15.30	80.80
Two-mile	53.432097	-6.192645	34.00	215.50	249.50

Name: 28R Runway 2-4M
Description: None
Threshold height: 15 m
Direction: °
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 120.0°



Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.432099	-6.192652	34.00	15.30	49.30
Two-mile	53.429127	-6.144323	5.90	212.00	217.90

Name: 28 Runway
Description: None
Threshold height: 15 m
Direction: °
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 120.0°



Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.420299	-6.251111	62.00	15.20	77.20
Two-mile	53.417517	-6.202763	41.90	204.00	245.90

Name: 28 Runway 2-4M
Description: None
Threshold height: 15 m
Direction: °
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 120.0°



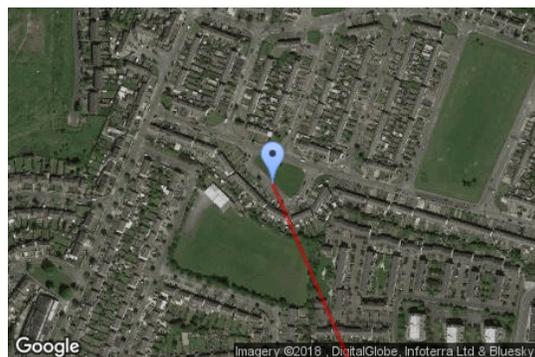
Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.417522	-6.202769	245.90	15.30	261.20
Two-mile	53.414751	-6.154423	245.90	183.90	429.80

Name: 34 Runway
Description: None
Threshold height: 15 m
Direction: °
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 120.0°



Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.420211	-6.249810	62.20	15.30	77.50
Two-mile	53.393680	-6.230504	49.00	197.10	246.10

Name: 36 Runway 2-4M
Description: None
Threshold height: 15 m
Direction: °
Glide slope: 3.0°
Pilot view restricted? Yes
Vertical view: 30.0°
Azimuthal view: 120.0°



Point	Latitude (°)	Longitude (°)	Ground elevation (m)	Height above ground (m)	Total elevation (m)
Threshold	53.393625	-6.230493	246.10	15.30	261.40
Two-mile	53.367090	-6.211214	246.10	184.00	430.10

Discrete Observation Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (m)	Height (m)
ATCT 1	1	53.428489	-6.262201	65.90	21.90
ATCT 2	2	53.428937	-6.264259	65.60	75.60

Map image of ATCT 1



Map image of ATCT 2



GLARE ANALYSIS RESULTS

Summary of Glare

PV Array Name	Tilt	Orient	"Green" Glare	"Yellow" Glare	Energy
	(°)	(°)	min	min	kWh
Section A	0.0	193.0	4,600	0	-
Section B	1.0	193.0	4,423	0	-
Section C	2.0	193.0	4,333	0	-
Section D	3.0	193.0	3,991	0	-
Section E	4.0	193.0	3,809	0	-
Section F	6.0	193.0	3,305	0	-
Section G	7.0	193.0	3,229	0	-
Section H	8.0	193.0	3,134	0	-
Section I	9.0	193.0	2,794	0	-

Total annual glare received by each receptor

Receptor	Annual Green Glare (min)	Annual Yellow Glare (min)
10L Runway	0	0
10L_Runway 2-4M	2879	0
10 Runway	3489	0

Receptor	Annual Green Glare (min)	Annual Yellow Glare (min)
10 Runway 2-4M	16358	0
16 Runway	0	0
16 Runway 2-4M	0	0
28R Runway	223	0
28R Runway 2-4M	104	0
28 Runway	355	0
28 Runway 2-4M	546	0
34 Runway	4304	0
36 Runway 2-4M	5360	0
None	0	0
None	0	0

Results for: Section A

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	0	0
10L_Runway 2-4M	691	0
10 Runway	580	0
10 Runway 2-4M	1627	0
16 Runway	0	0
16 Runway 2-4M	0	0
28R Runway	187	0
28R Runway 2-4M	104	0
28 Runway	207	0
28 Runway 2-4M	140	0
34 Runway	474	0
36 Runway 2-4M	590	0
ATCT 1	0	0
ATCT 2	0	0

Flight Path: 10L Runway

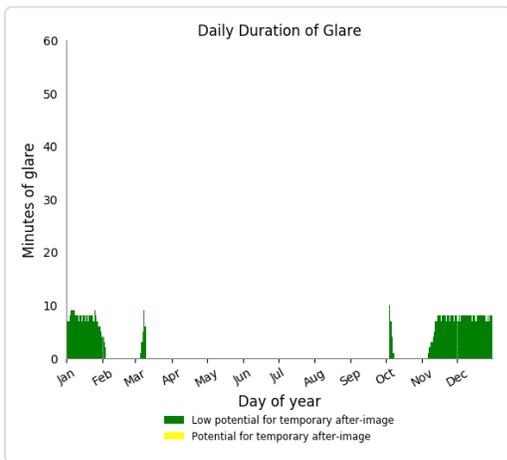
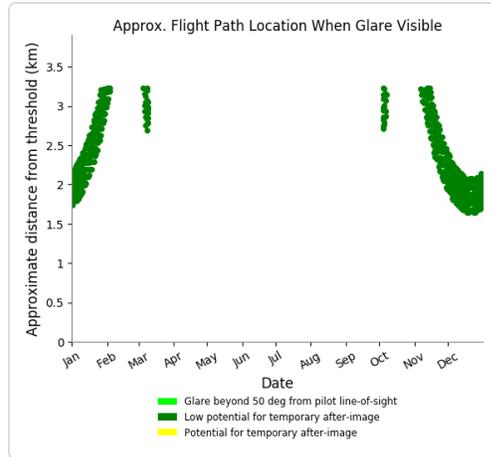
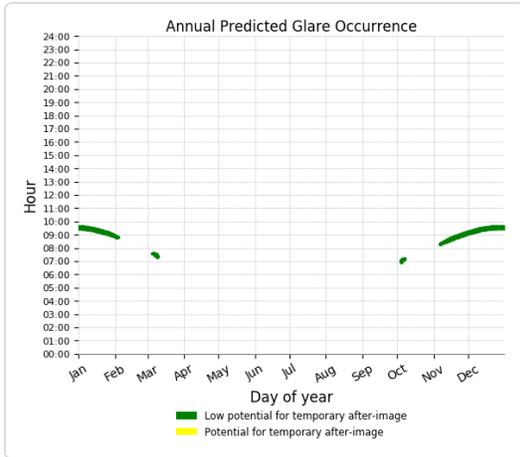
0 minutes of yellow glare

0 minutes of green glare

Flight Path: 10L_Runway 2-4M

0 minutes of yellow glare

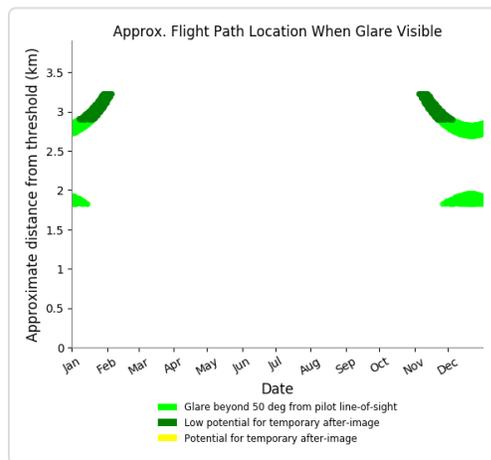
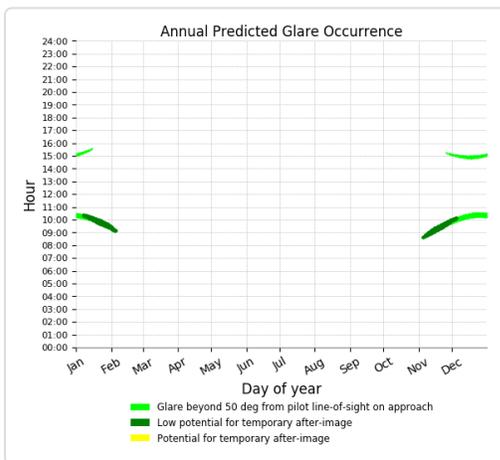
691 minutes of green glare

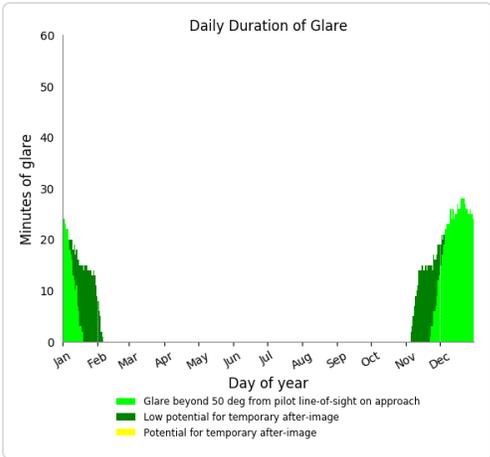


Flight Path: 10 Runway

0 minutes of yellow glare

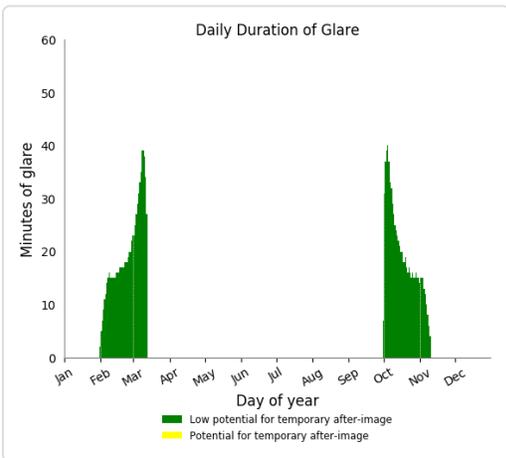
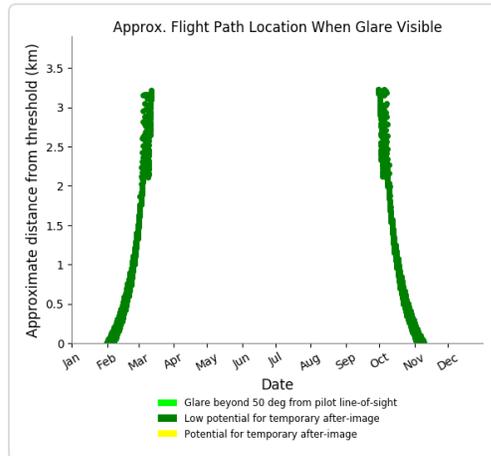
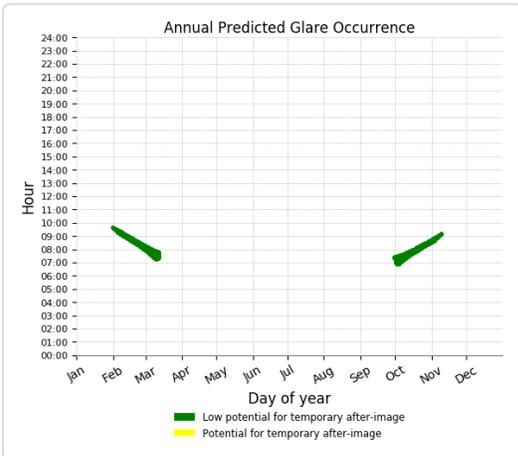
580 minutes of green glare





Flight Path: 10 Runway 2-4M

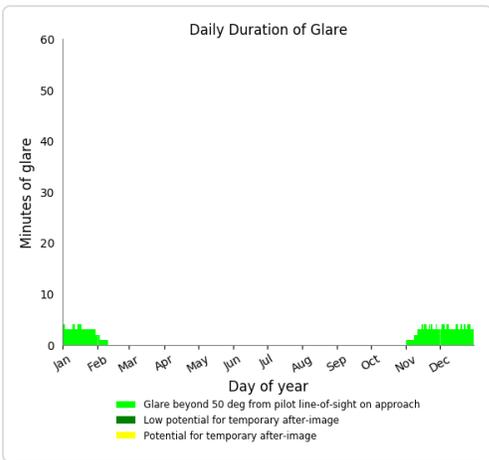
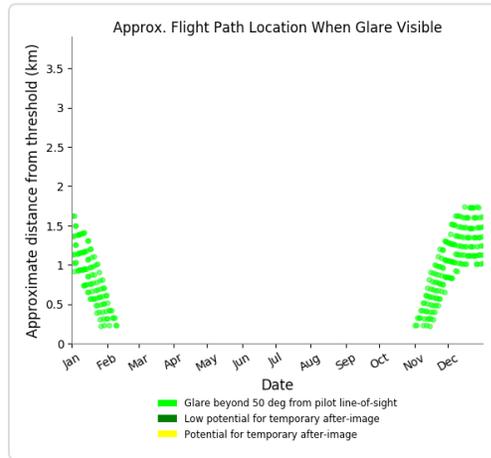
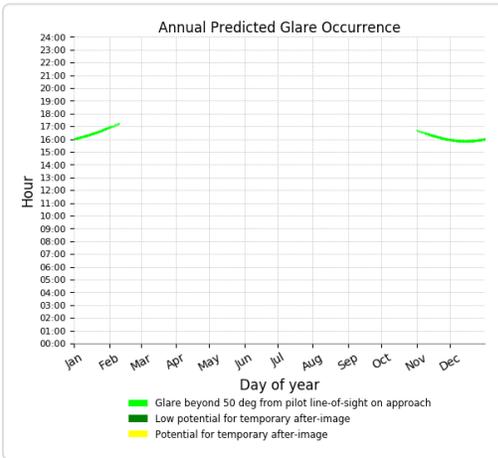
0 minutes of yellow glare
 1627 minutes of green glare



Flight Path: 16 Runway

0 minutes of yellow glare

0 minutes of green glare



Flight Path: 16 Runway 2-4M

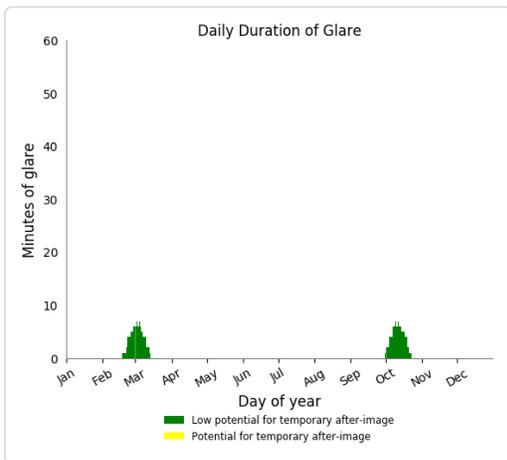
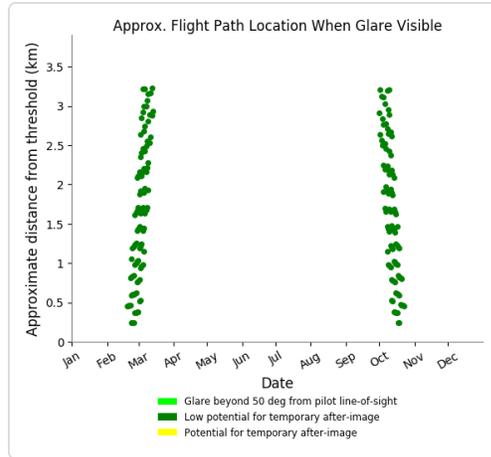
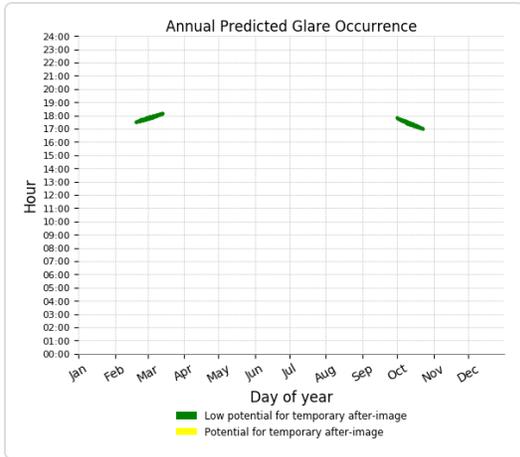
0 minutes of yellow glare

0 minutes of green glare

Flight Path: 28R Runway

0 minutes of yellow glare

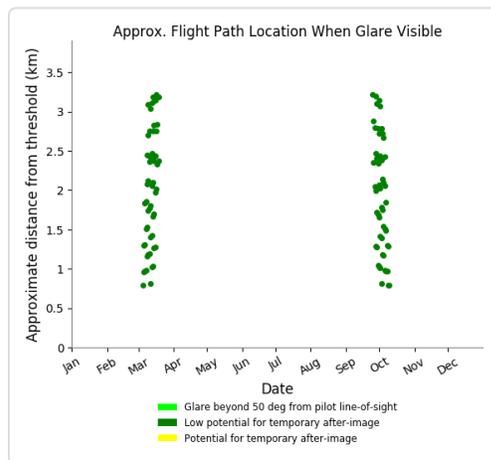
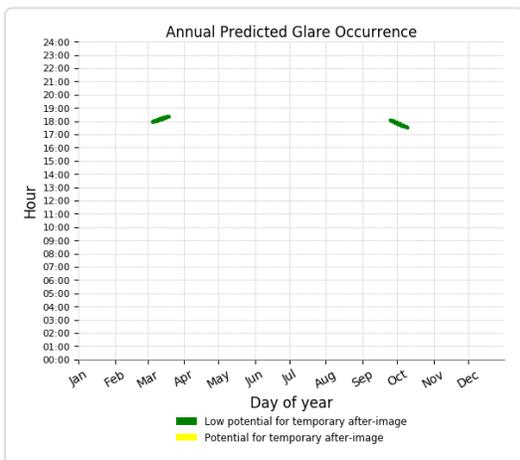
187 minutes of green glare

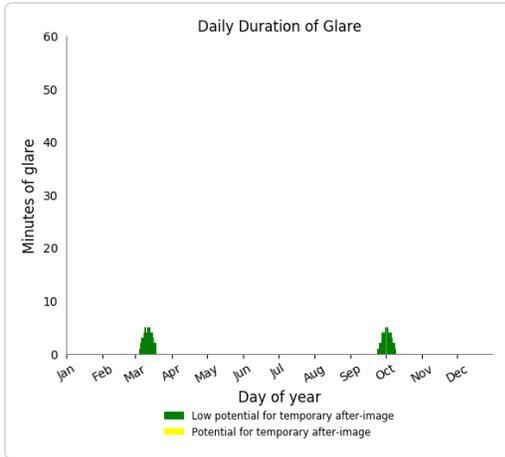


Flight Path: 28R Runway 2-4M

0 minutes of yellow glare

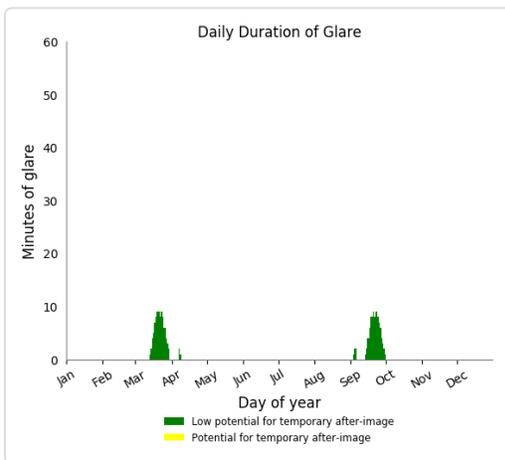
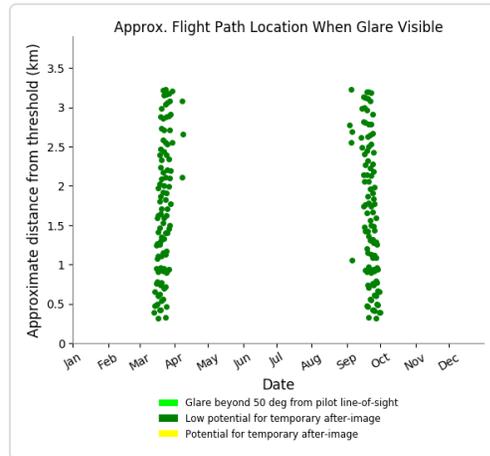
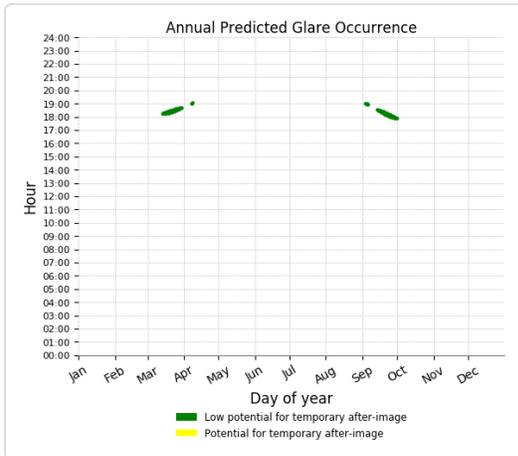
104 minutes of green glare





Flight Path: 28 Runway

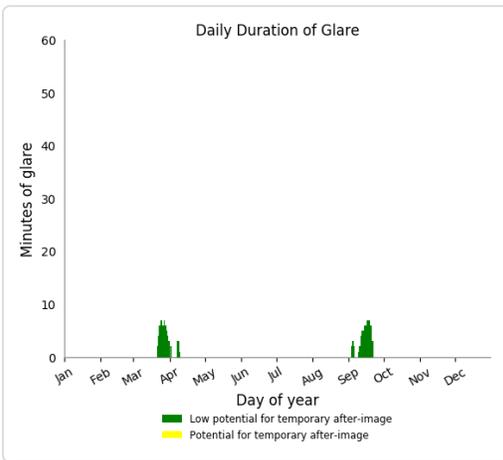
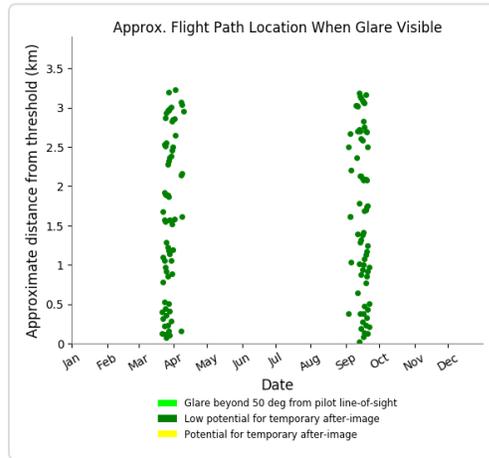
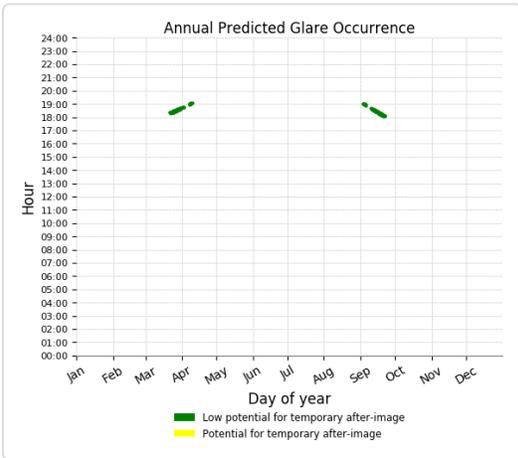
0 minutes of yellow glare
 207 minutes of green glare



Flight Path: 28 Runway 2-4M

0 minutes of yellow glare

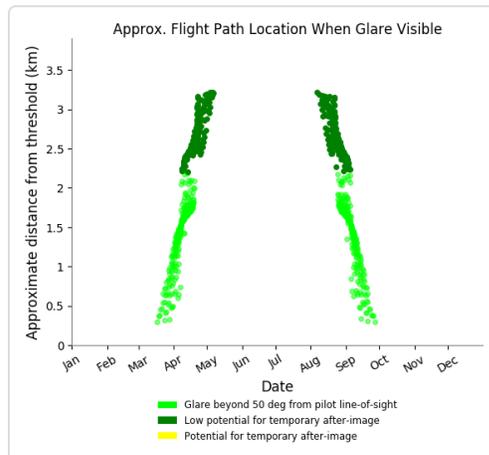
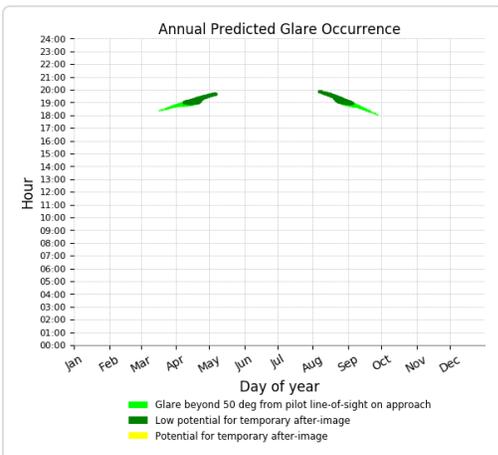
140 minutes of green glare

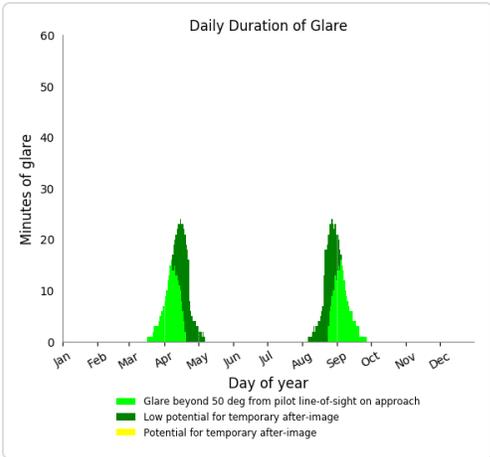


Flight Path: 34 Runway

0 minutes of yellow glare

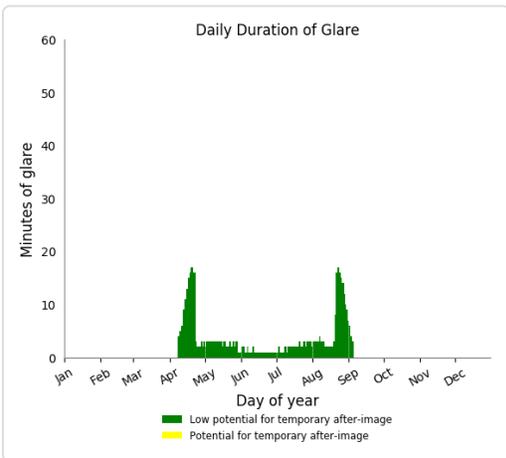
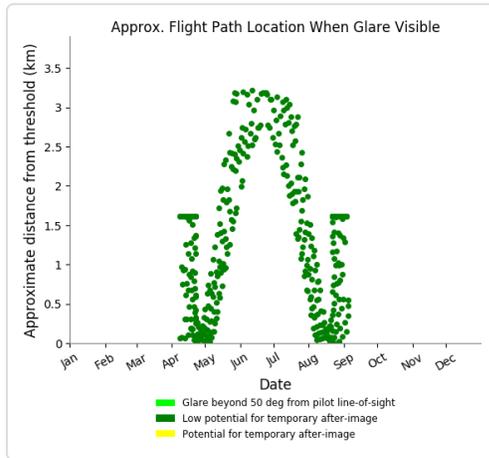
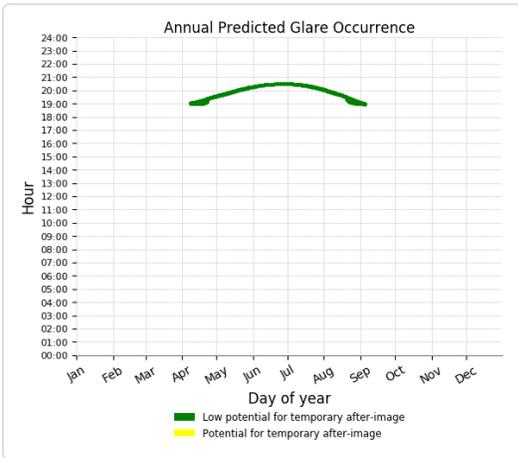
474 minutes of green glare





Flight Path: 36 Runway 2-4M

0 minutes of yellow glare
 590 minutes of green glare



Point Receptor: ATCT 1

0 minutes of yellow glare

0 minutes of green glare

Point Receptor: ATCT 2

0 minutes of yellow glare

0 minutes of green glare

Results for: Section B

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	0	0
10L_Runway 2-4M	606	0
10 Runway	780	0
10 Runway 2-4M	1669	0
16 Runway	0	0
16 Runway 2-4M	0	0
28R Runway	36	0
28R Runway 2-4M	0	0
28 Runway	113	0
28 Runway 2-4M	138	0
34 Runway	477	0
36 Runway 2-4M	604	0
ATCT 1	0	0
ATCT 2	0	0

Flight Path: 10L Runway

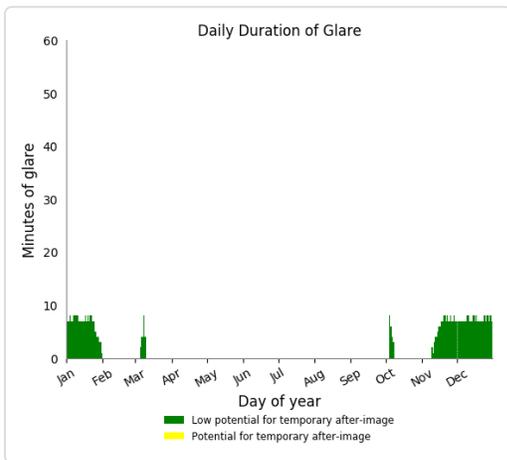
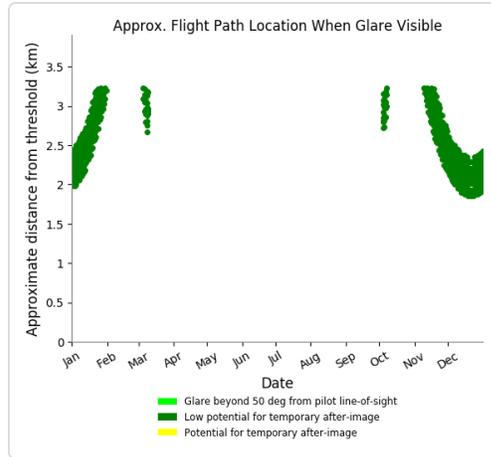
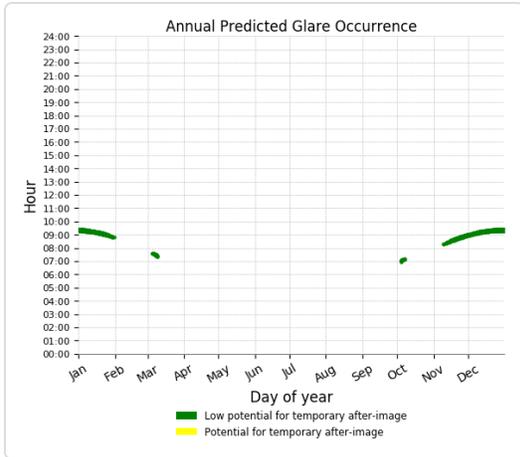
0 minutes of yellow glare

0 minutes of green glare

Flight Path: 10L_Runway 2-4M

0 minutes of yellow glare

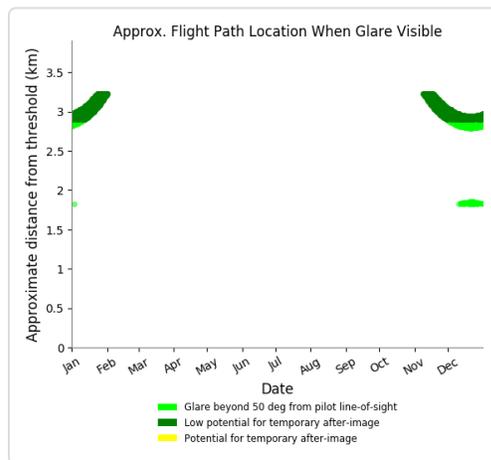
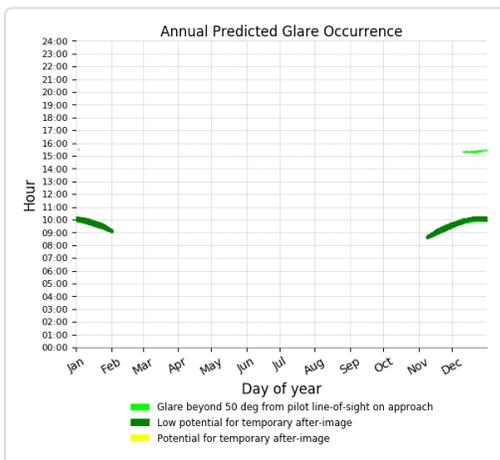
606 minutes of green glare

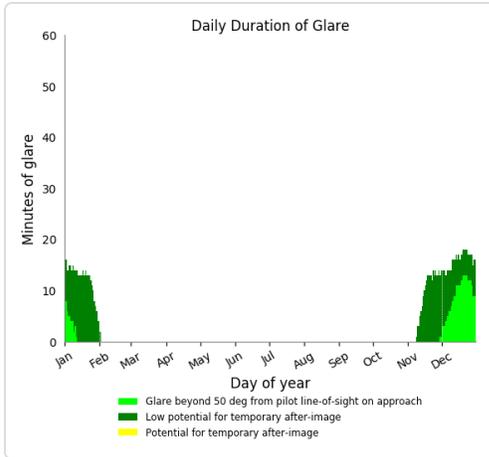


Flight Path: 10 Runway

0 minutes of yellow glare

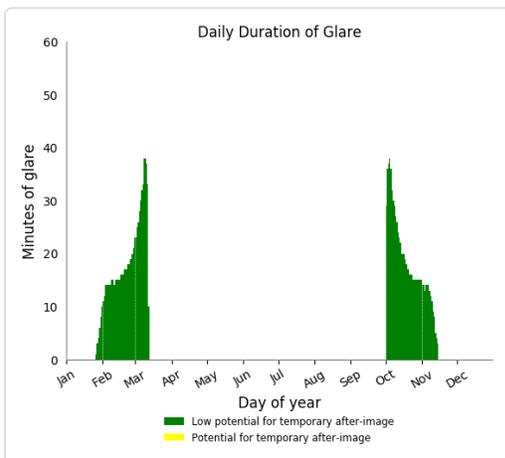
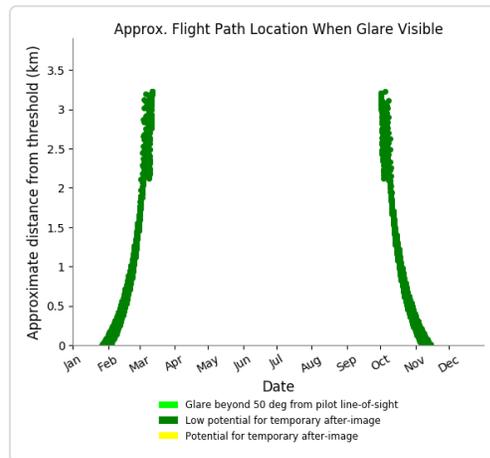
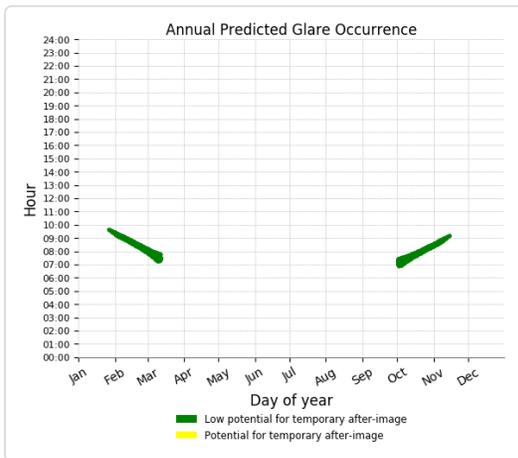
780 minutes of green glare





Flight Path: 10 Runway 2-4M

0 minutes of yellow glare
 1669 minutes of green glare



Flight Path: 16 Runway

0 minutes of yellow glare

0 minutes of green glare

Flight Path: 16 Runway 2-4M

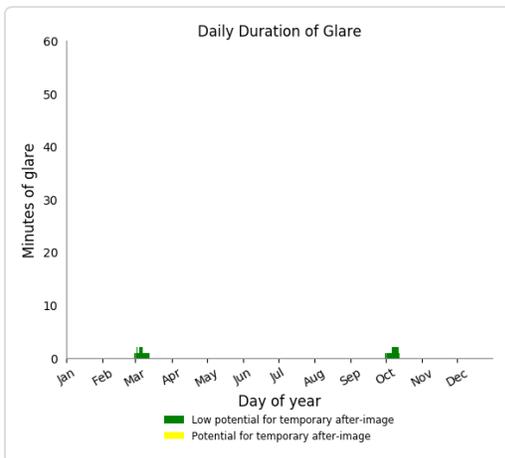
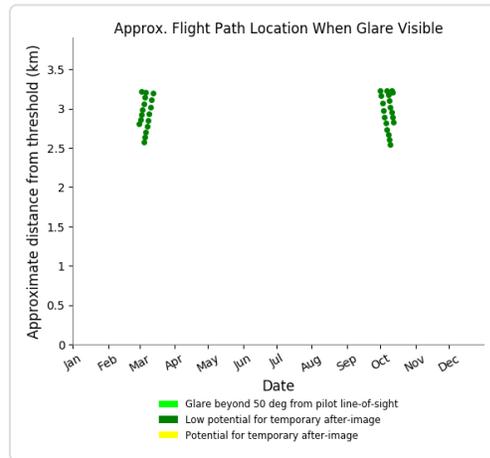
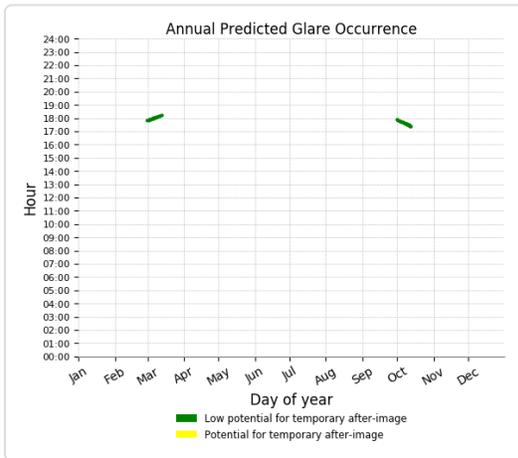
0 minutes of yellow glare

0 minutes of green glare

Flight Path: 28R Runway

0 minutes of yellow glare

36 minutes of green glare



Flight Path: 28R Runway 2-4M

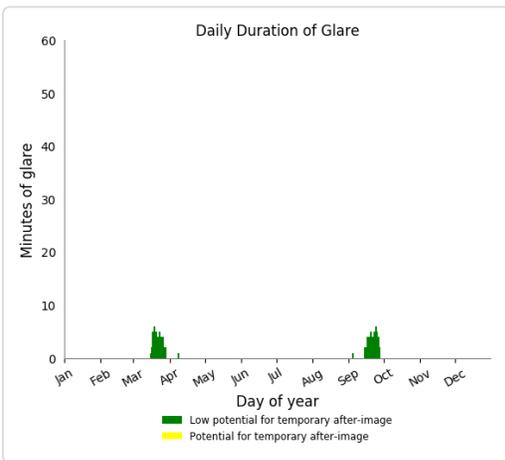
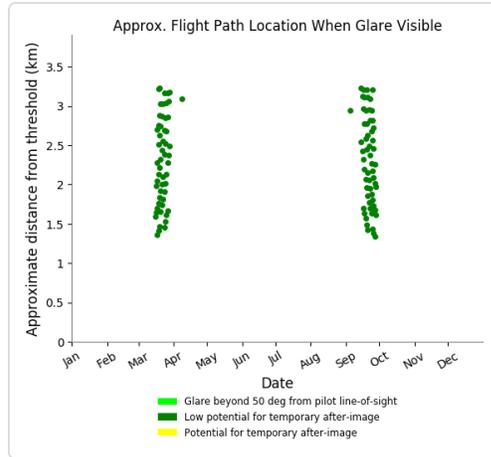
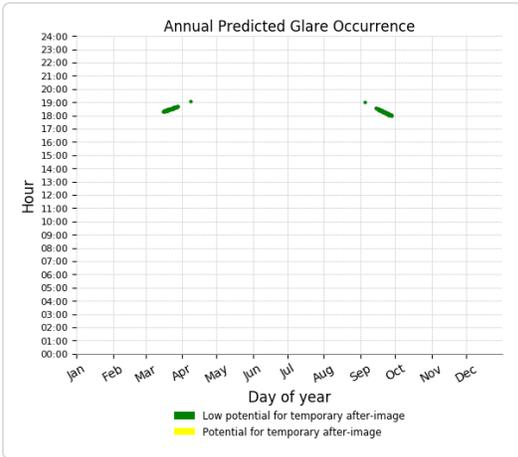
0 minutes of yellow glare

0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare

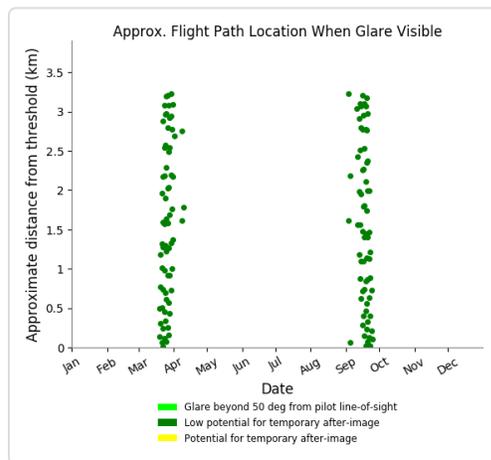
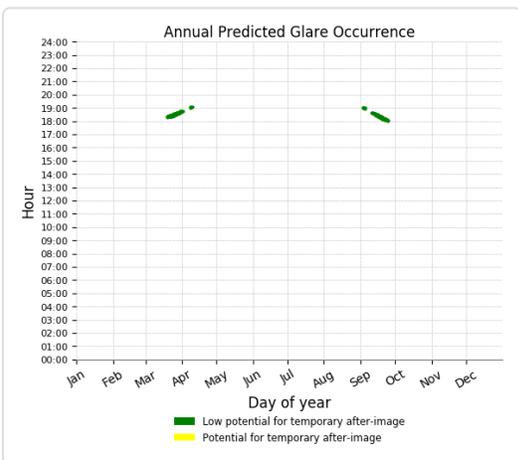
113 minutes of green glare

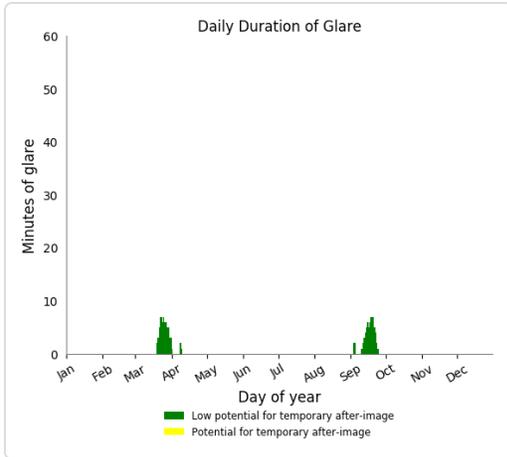


Flight Path: 28 Runway 2-4M

0 minutes of yellow glare

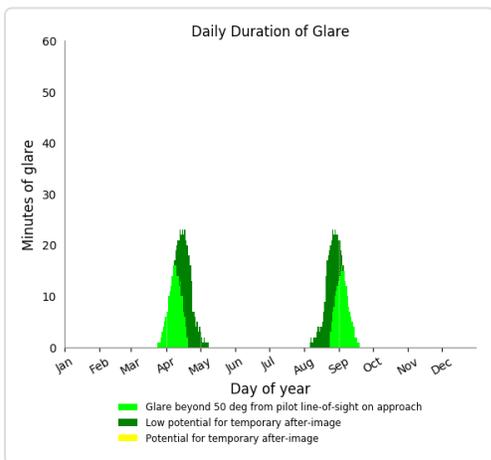
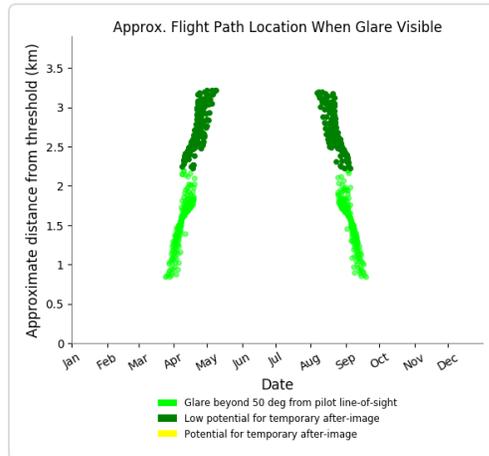
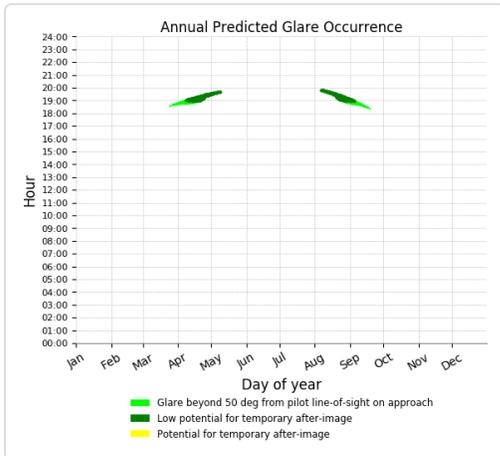
138 minutes of green glare





Flight Path: 34 Runway

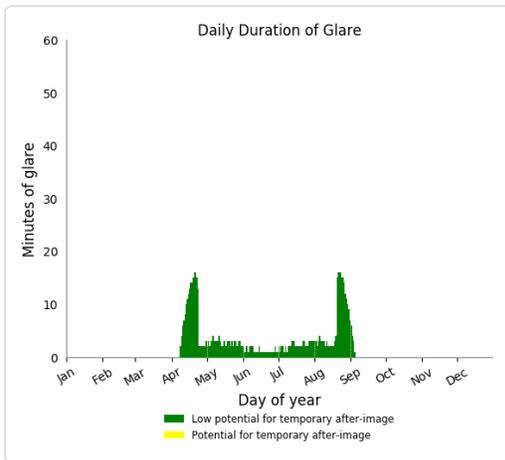
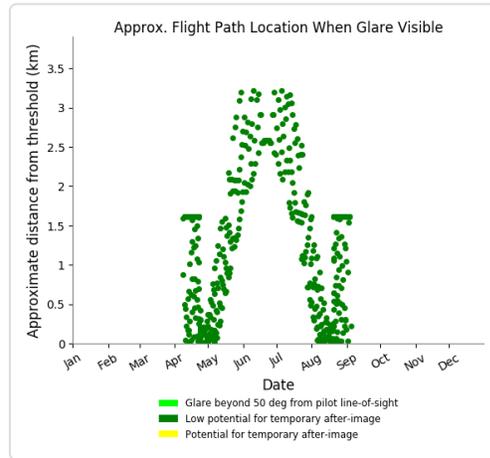
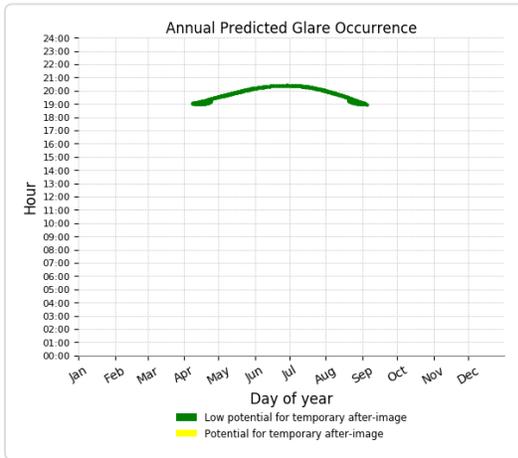
0 minutes of yellow glare
 477 minutes of green glare



Flight Path: 36 Runway 2-4M

0 minutes of yellow glare

604 minutes of green glare



Point Receptor: ATCT 1

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: ATCT 2

0 minutes of yellow glare
0 minutes of green glare

Results for: Section C

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	0	0
10L_Runway 2-4M	536	0
10 Runway	815	0
10 Runway 2-4M	1709	0

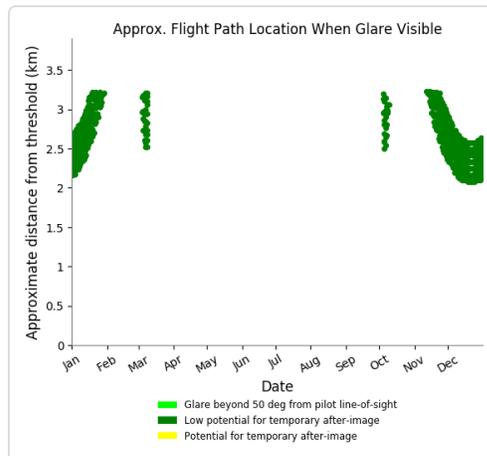
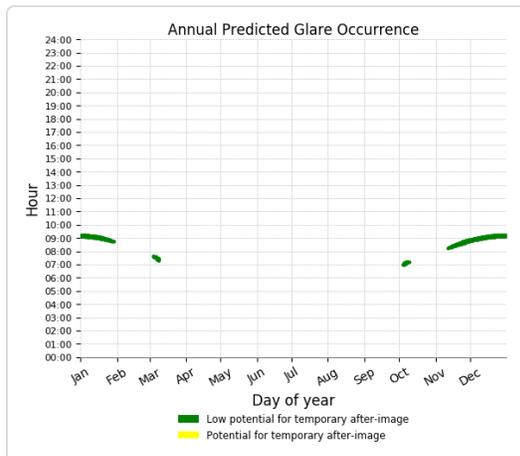
Receptor	Green Glare (min)	Yellow Glare (min)
16 Runway	0	0
16 Runway 2-4M	0	0
28R Runway	0	0
28R Runway 2-4M	0	0
28 Runway	35	0
28 Runway 2-4M	151	0
34 Runway	472	0
36 Runway 2-4M	615	0
ATCT 1	0	0
ATCT 2	0	0

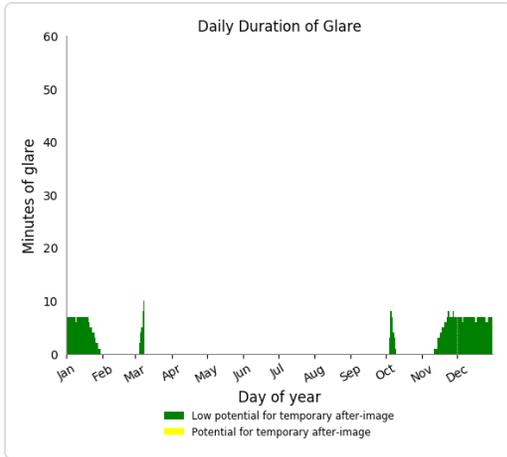
Flight Path: 10L Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 10L_Runway 2-4M

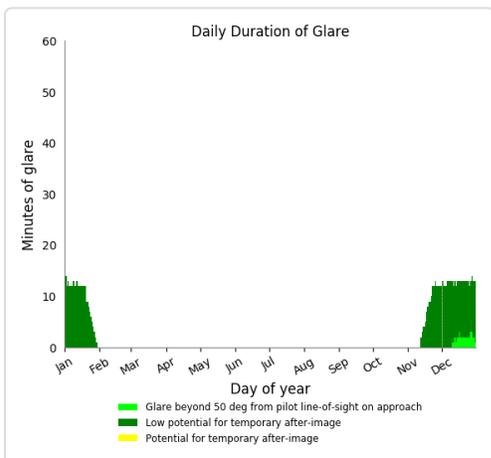
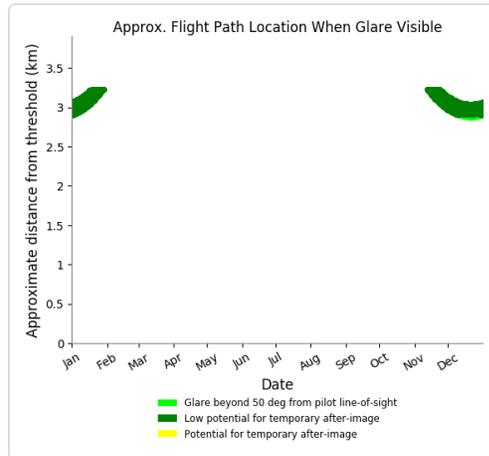
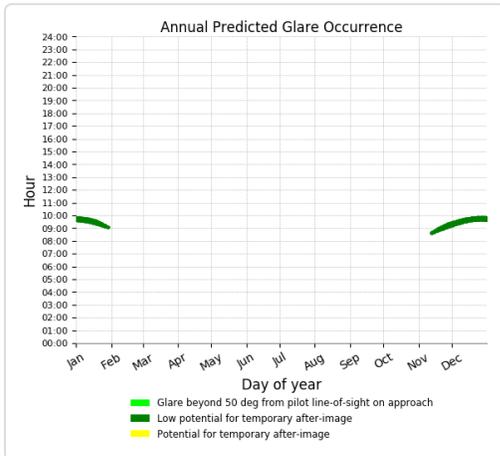
0 minutes of yellow glare
536 minutes of green glare





Flight Path: 10 Runway

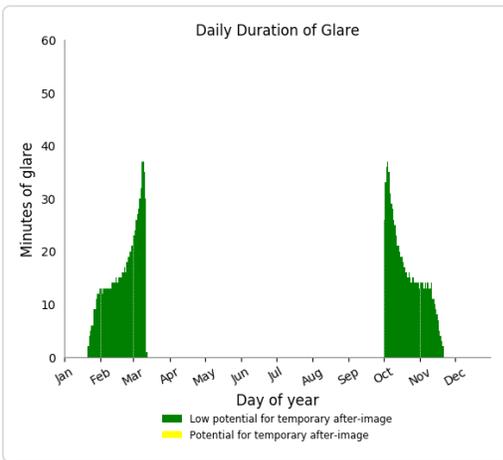
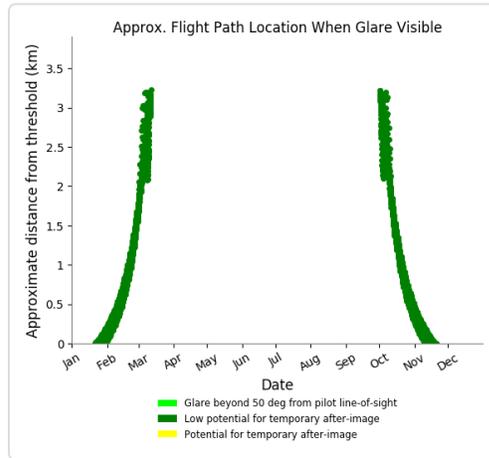
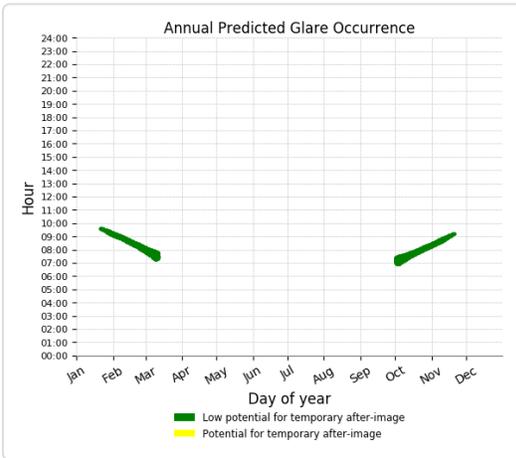
0 minutes of yellow glare
 815 minutes of green glare



Flight Path: 10 Runway 2-4M

0 minutes of yellow glare

1709 minutes of green glare



Flight Path: 16 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 16 Runway 2-4M

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28R Runway

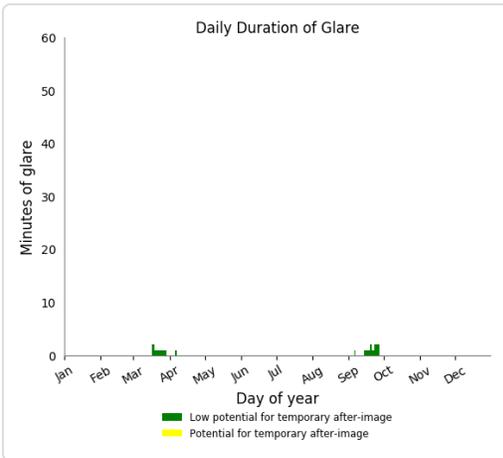
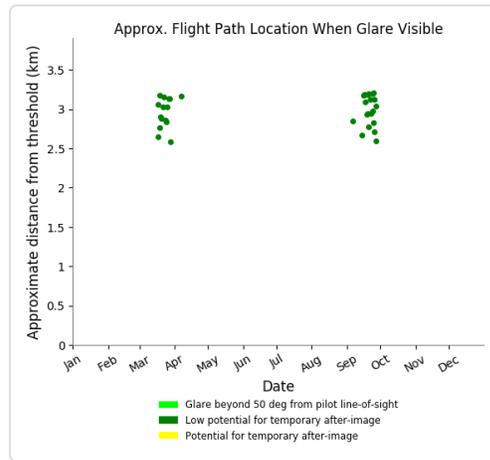
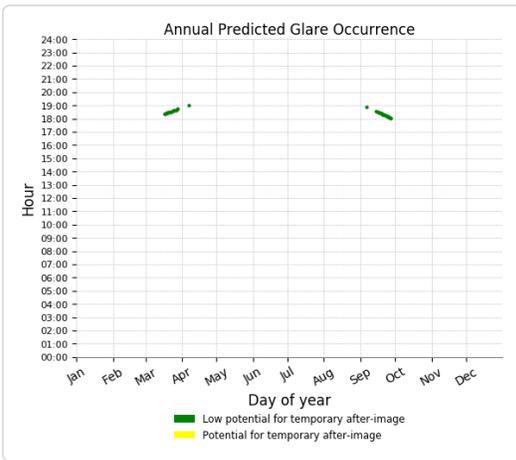
0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28R Runway 2-4M

0 minutes of yellow glare
0 minutes of green glare

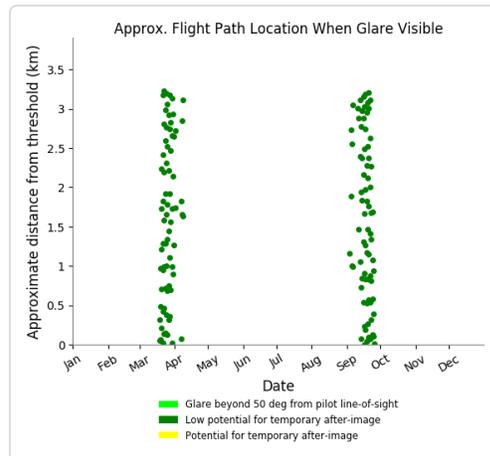
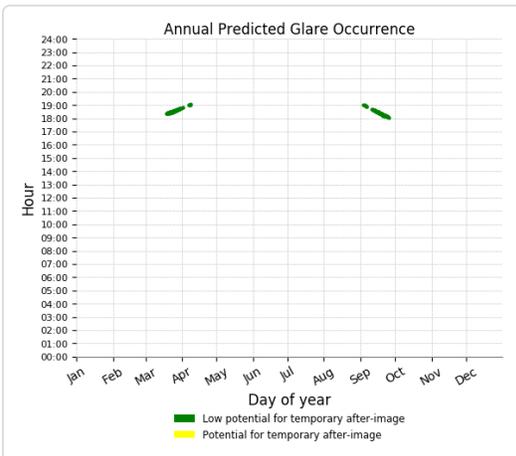
Flight Path: 28 Runway

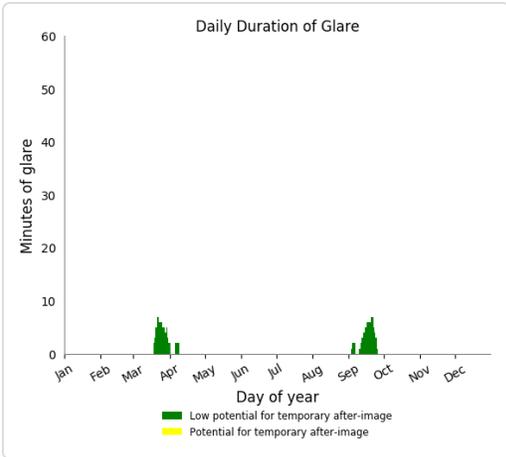
0 minutes of yellow glare
 35 minutes of green glare



Flight Path: 28 Runway 2-4M

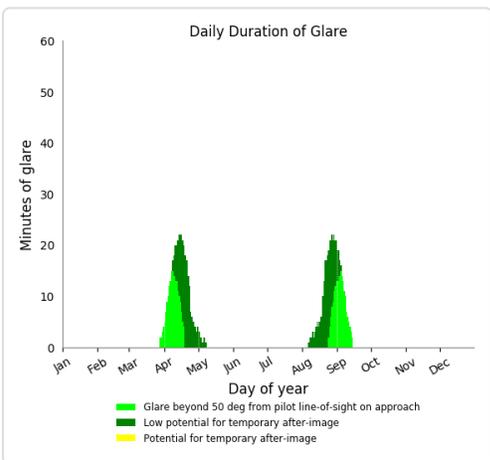
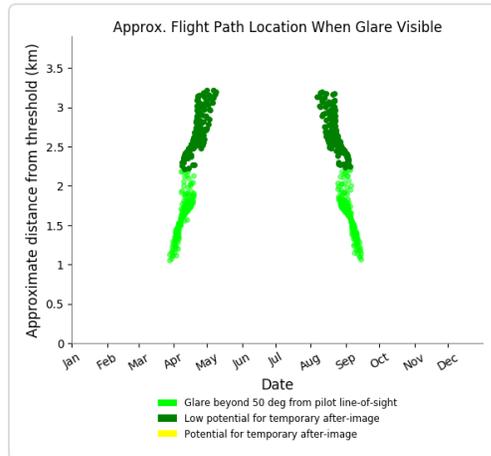
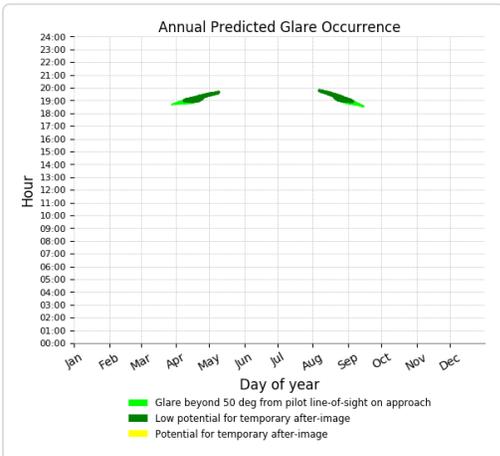
0 minutes of yellow glare
 151 minutes of green glare





Flight Path: 34 Runway

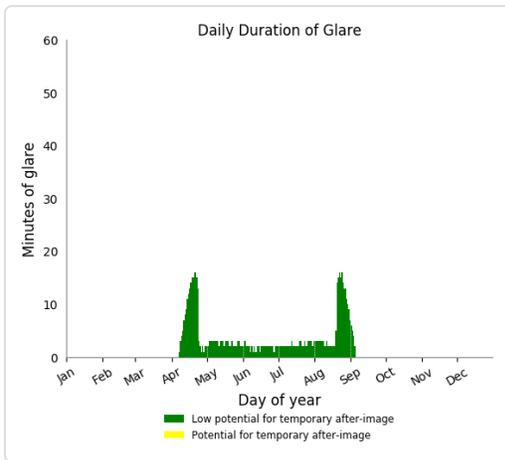
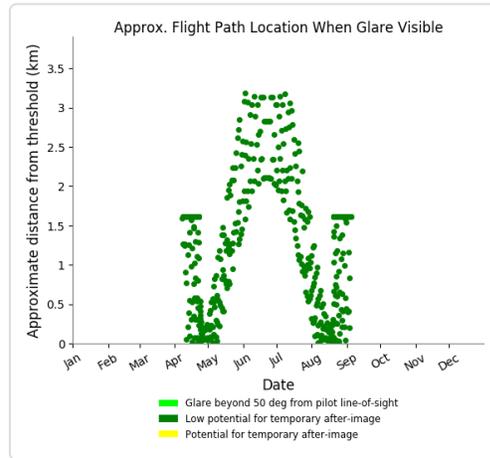
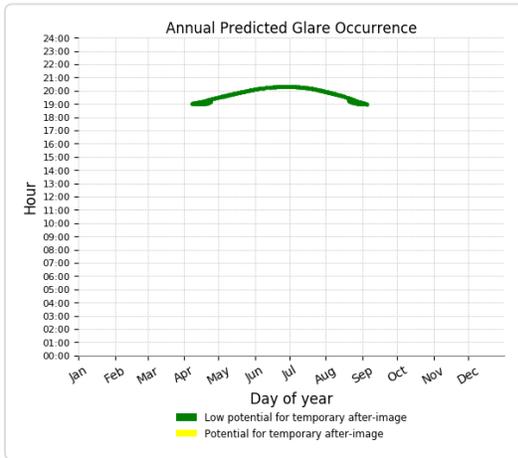
0 minutes of yellow glare
 472 minutes of green glare



Flight Path: 36 Runway 2-4M

0 minutes of yellow glare

615 minutes of green glare



Point Receptor: ATCT 1

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: ATCT 2

0 minutes of yellow glare
0 minutes of green glare

Results for: Section D

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	0	0
10L_Runway 2-4M	455	0
10 Runway	652	0
10 Runway 2-4M	1725	0

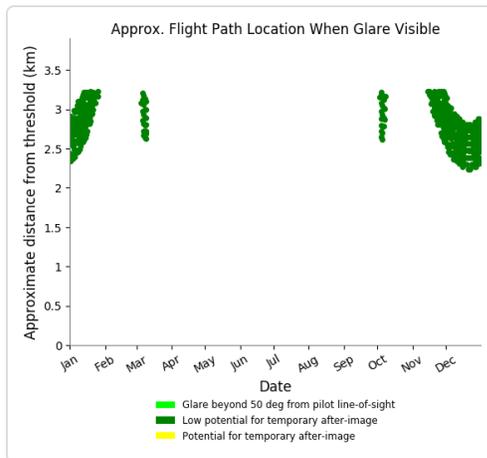
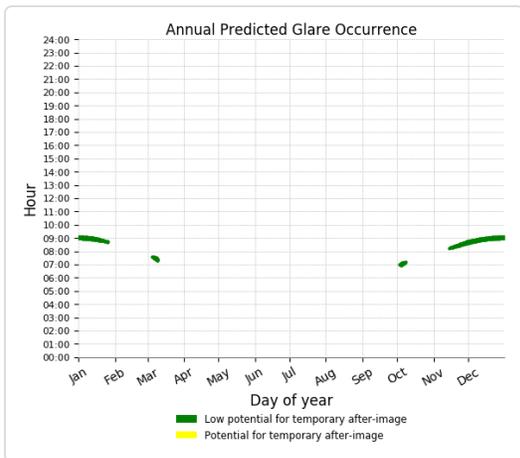
Receptor	Green Glare (min)	Yellow Glare (min)
16 Runway	0	0
16 Runway 2-4M	0	0
28R Runway	0	0
28R Runway 2-4M	0	0
28 Runway	0	0
28 Runway 2-4M	93	0
34 Runway	474	0
36 Runway 2-4M	592	0
ATCT 1	0	0
ATCT 2	0	0

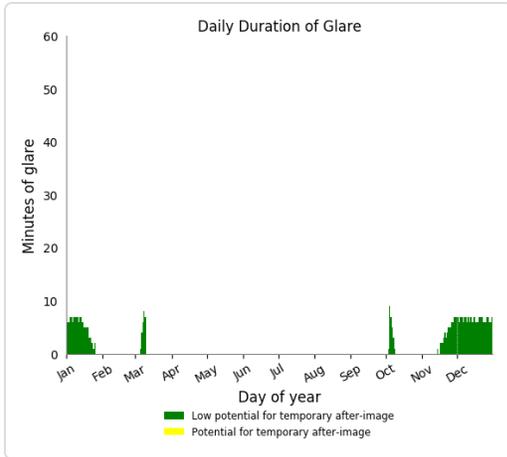
Flight Path: 10L Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 10L_Runway 2-4M

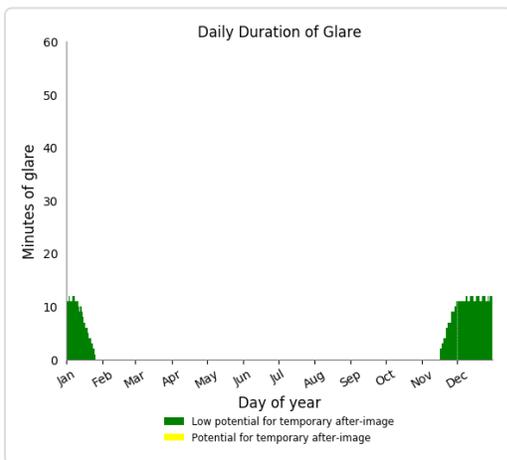
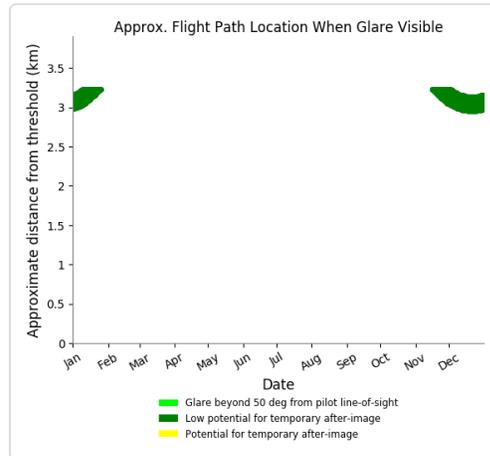
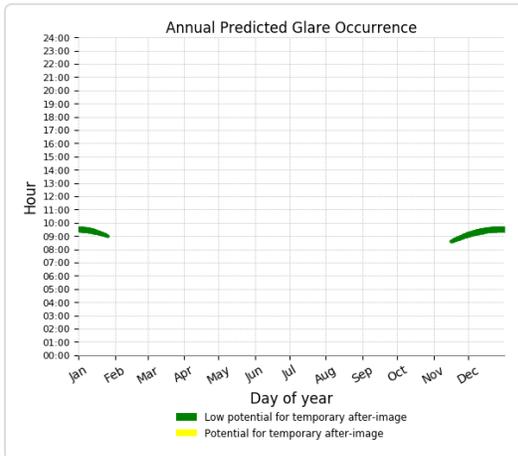
0 minutes of yellow glare
455 minutes of green glare





Flight Path: 10 Runway

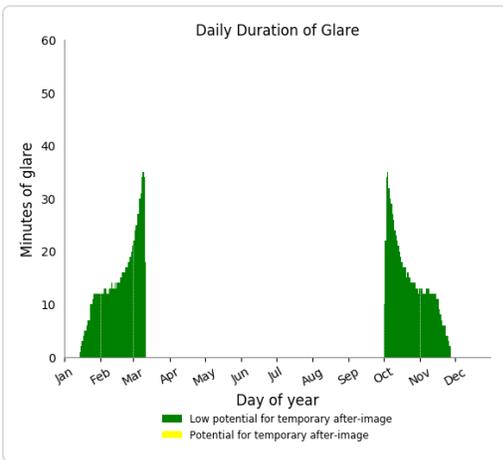
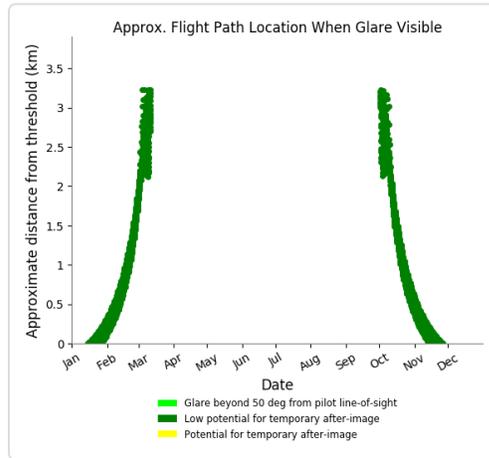
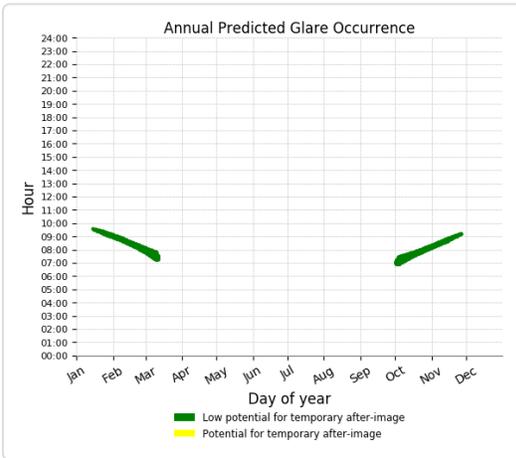
0 minutes of yellow glare
 652 minutes of green glare



Flight Path: 10 Runway 2-4M

0 minutes of yellow glare

1725 minutes of green glare



Flight Path: 16 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 16 Runway 2-4M

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28R Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28R Runway 2-4M

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28 Runway

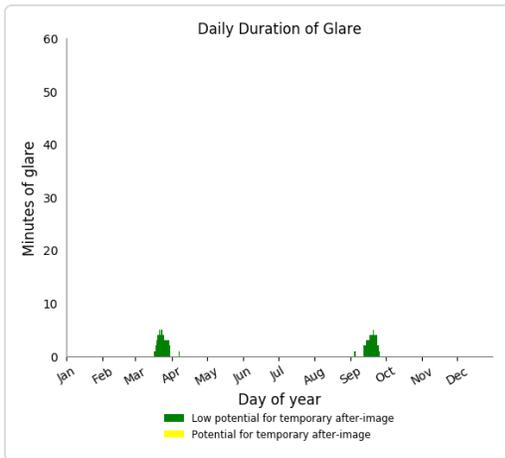
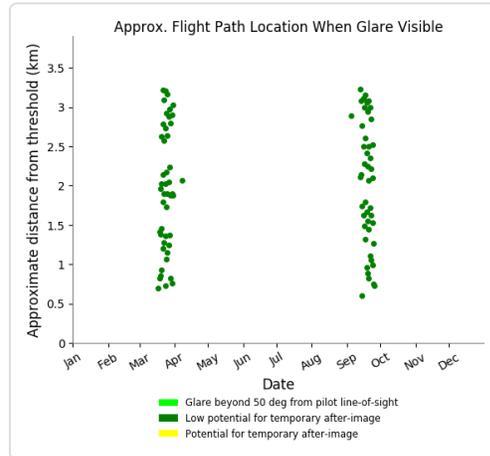
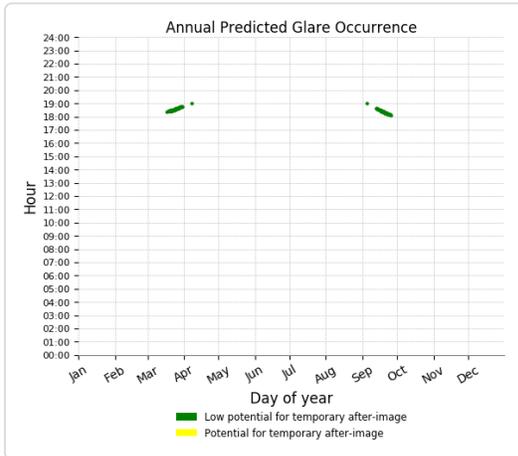
0 minutes of yellow glare

0 minutes of green glare

Flight Path: 28 Runway 2-4M

0 minutes of yellow glare

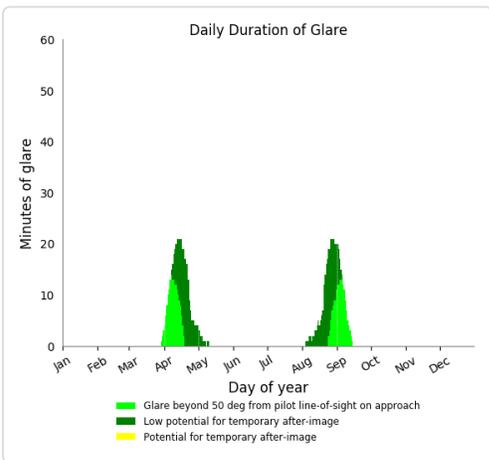
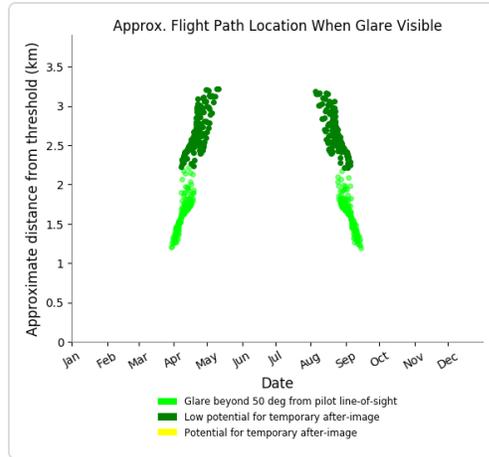
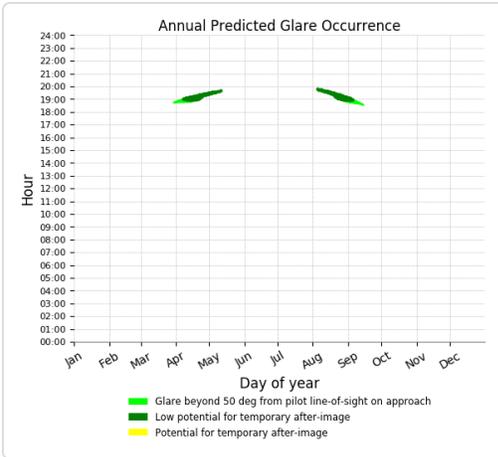
93 minutes of green glare



Flight Path: 34 Runway

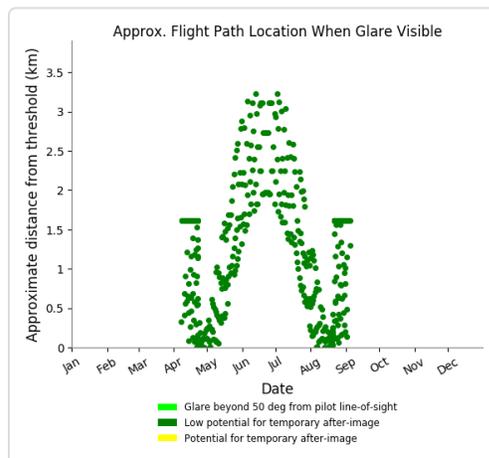
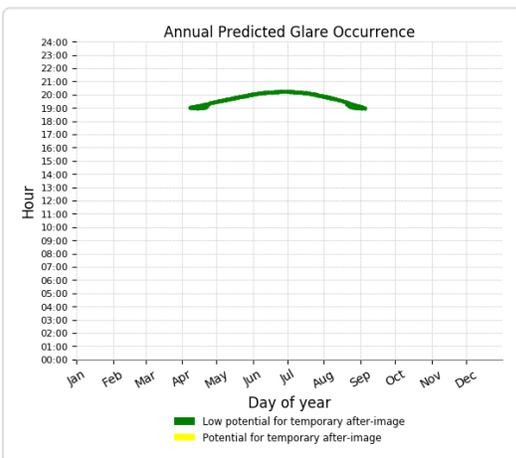
0 minutes of yellow glare

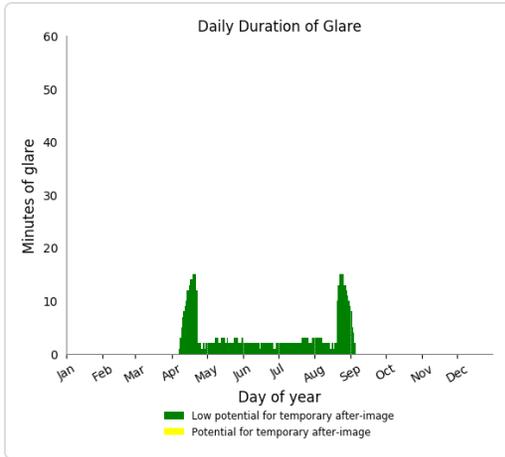
474 minutes of green glare



Flight Path: 36 Runway 2-4M

0 minutes of yellow glare
592 minutes of green glare





Point Receptor: ATCT 1

0 minutes of yellow glare
 0 minutes of green glare

Point Receptor: ATCT 2

0 minutes of yellow glare
 0 minutes of green glare

Results for: Section E

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	0	0
10L_Runway 2-4M	396	0
10 Runway	478	0
10 Runway 2-4M	1824	0
16 Runway	0	0
16 Runway 2-4M	0	0
28R Runway	0	0
28R Runway 2-4M	0	0
28 Runway	0	0
28 Runway 2-4M	24	0
34 Runway	485	0
36 Runway 2-4M	602	0
ATCT 1	0	0
ATCT 2	0	0

Flight Path: 10L Runway

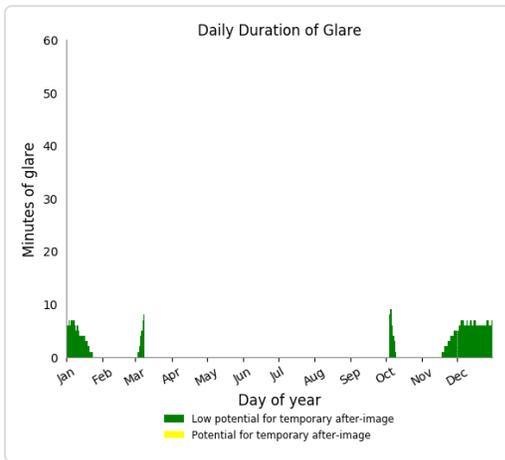
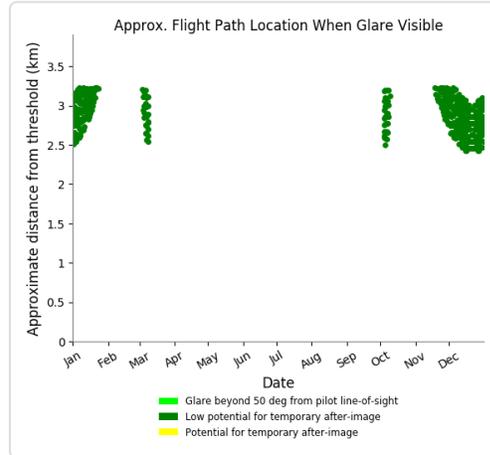
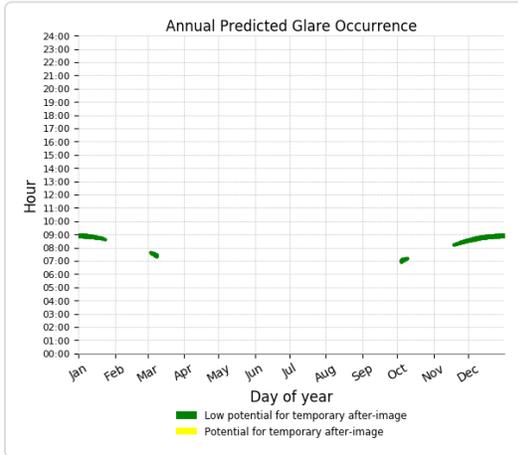
0 minutes of yellow glare

0 minutes of green glare

Flight Path: 10L_Runway 2-4M

0 minutes of yellow glare

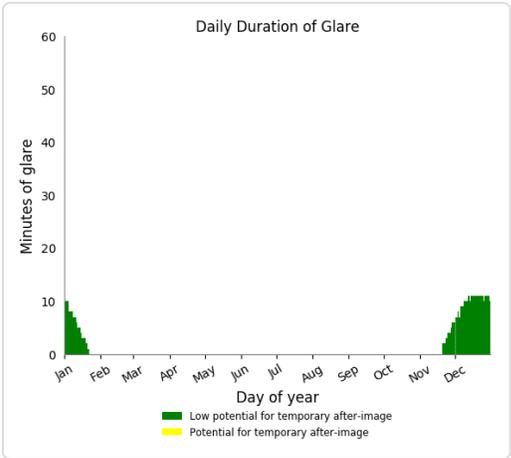
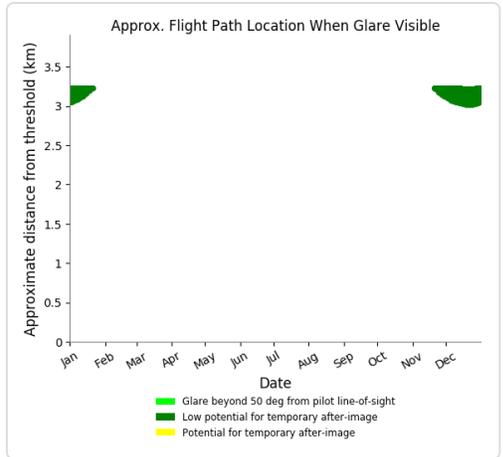
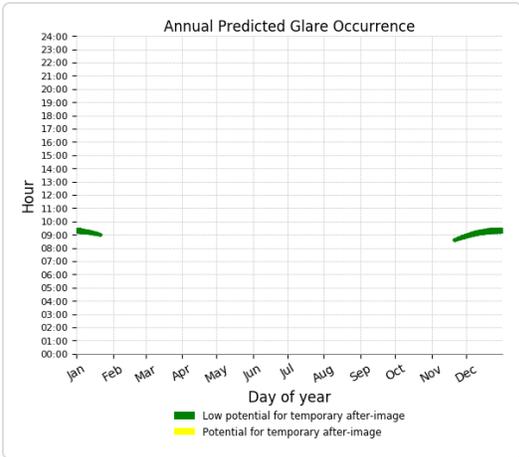
396 minutes of green glare



Flight Path: 10 Runway

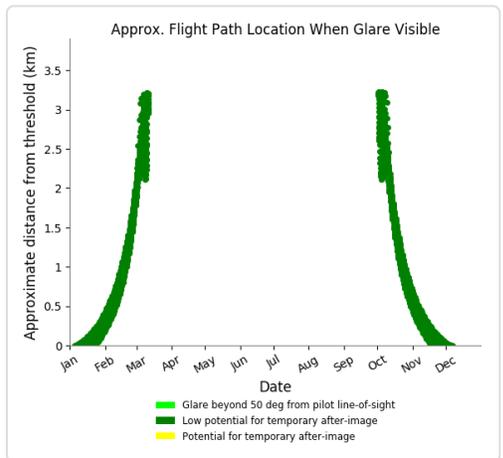
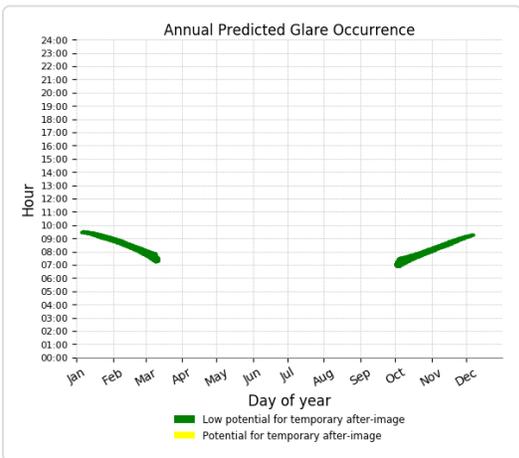
0 minutes of yellow glare

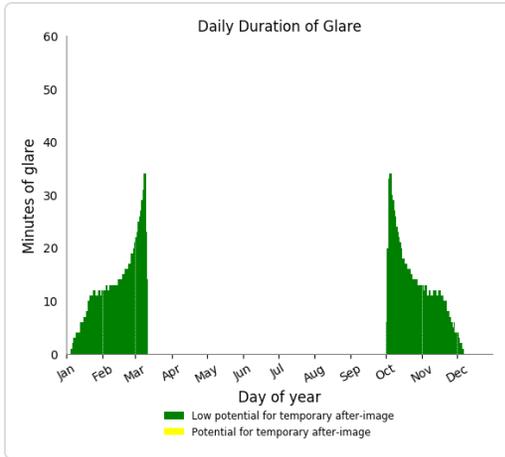
478 minutes of green glare



Flight Path: 10 Runway 2-4M

0 minutes of yellow glare
1824 minutes of green glare





Flight Path: 16 Runway

0 minutes of yellow glare
 0 minutes of green glare

Flight Path: 16 Runway 2-4M

0 minutes of yellow glare
 0 minutes of green glare

Flight Path: 28R Runway

0 minutes of yellow glare
 0 minutes of green glare

Flight Path: 28R Runway 2-4M

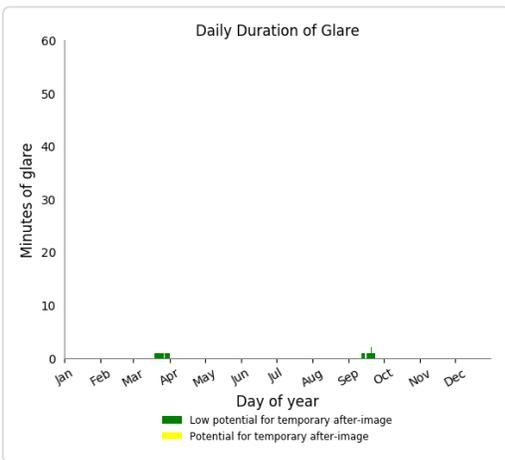
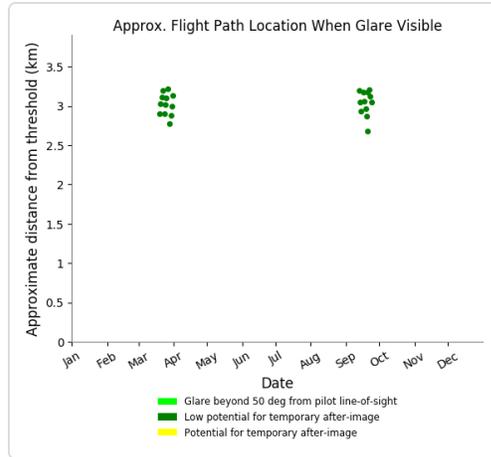
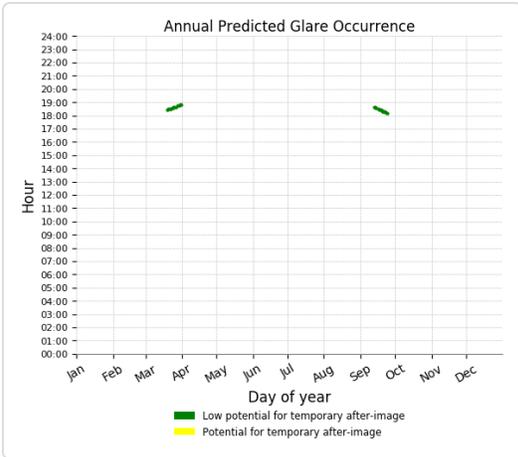
0 minutes of yellow glare
 0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare
 0 minutes of green glare

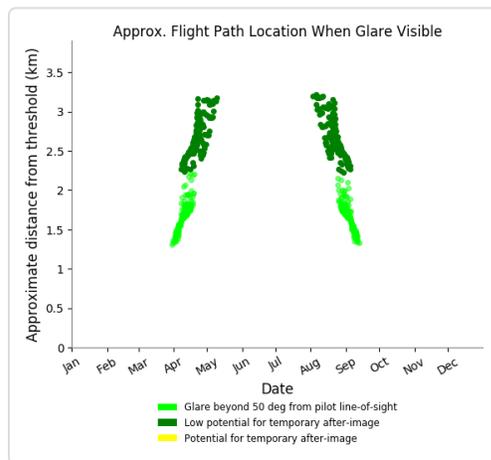
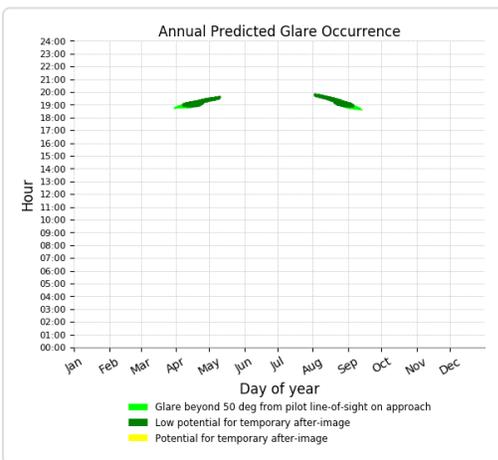
Flight Path: 28 Runway 2-4M

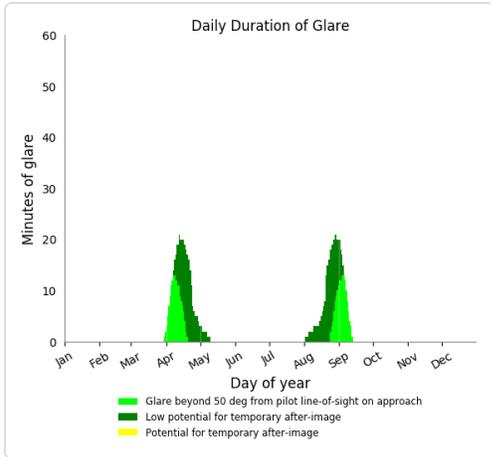
0 minutes of yellow glare
 24 minutes of green glare



Flight Path: 34 Runway

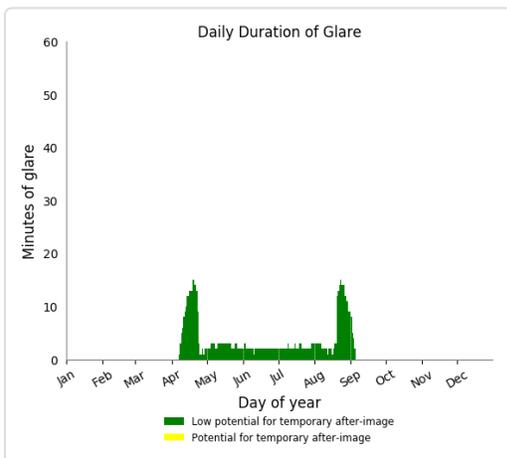
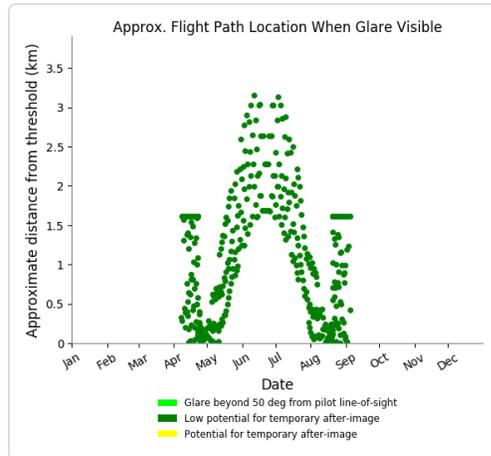
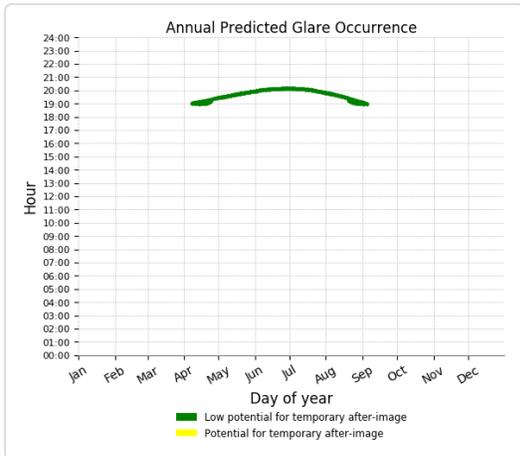
0 minutes of yellow glare
485 minutes of green glare





Flight Path: 36 Runway 2-4M

0 minutes of yellow glare
 602 minutes of green glare



Point Receptor: ATCT 1

0 minutes of yellow glare

0 minutes of green glare

Point Receptor: ATCT 2

0 minutes of yellow glare

0 minutes of green glare

Results for: Section F

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	0	0
10L_Runway 2-4M	44	0
10 Runway	140	0
10 Runway 2-4M	2060	0
16 Runway	0	0
16 Runway 2-4M	0	0
28R Runway	0	0
28R Runway 2-4M	0	0
28 Runway	0	0
28 Runway 2-4M	0	0
34 Runway	472	0
36 Runway 2-4M	589	0
ATCT 1	0	0
ATCT 2	0	0

Flight Path: 10L Runway

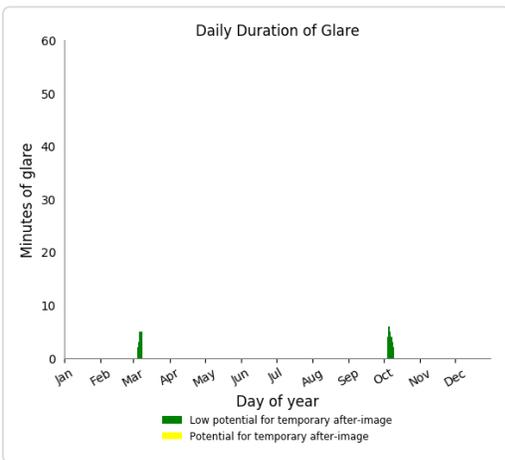
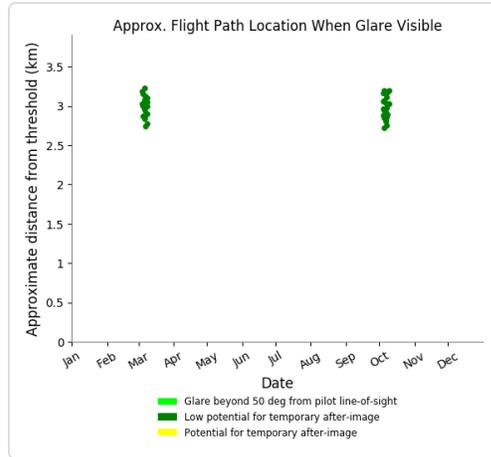
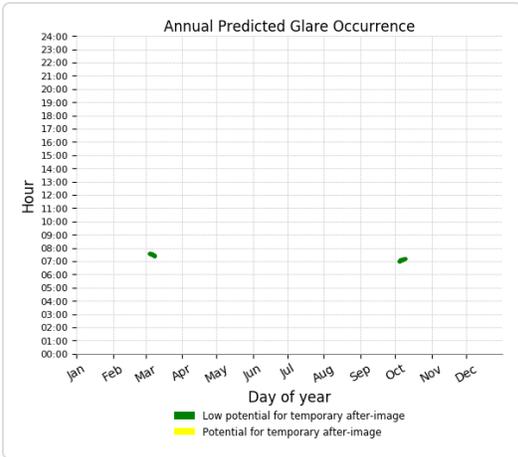
0 minutes of yellow glare

0 minutes of green glare

Flight Path: 10L_Runway 2-4M

0 minutes of yellow glare

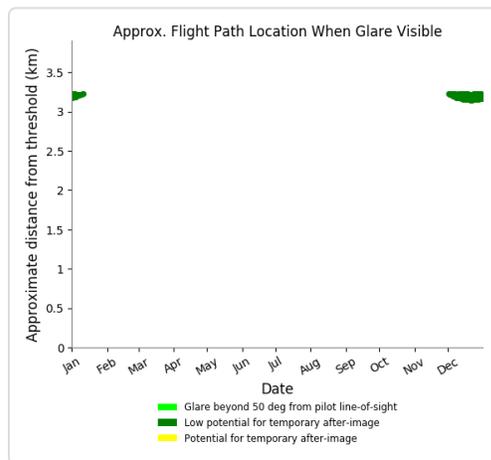
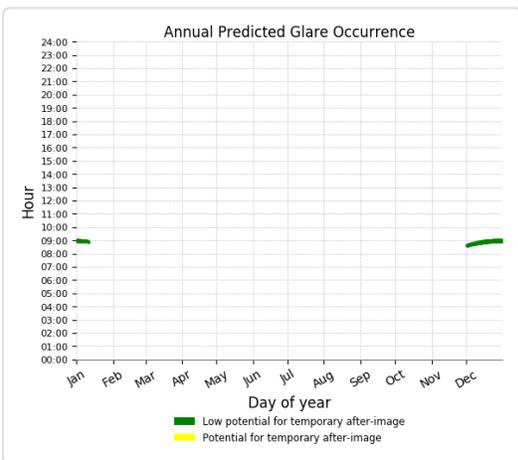
44 minutes of green glare

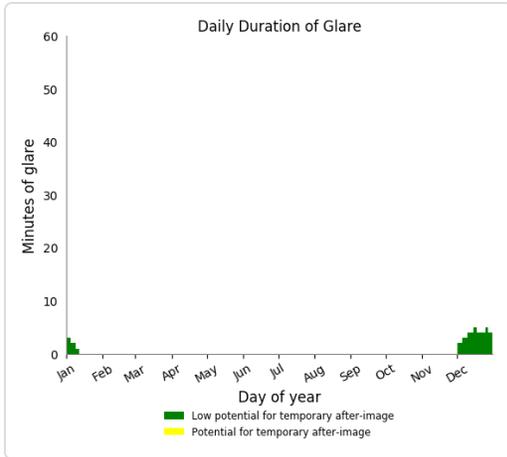


Flight Path: 10 Runway

0 minutes of yellow glare

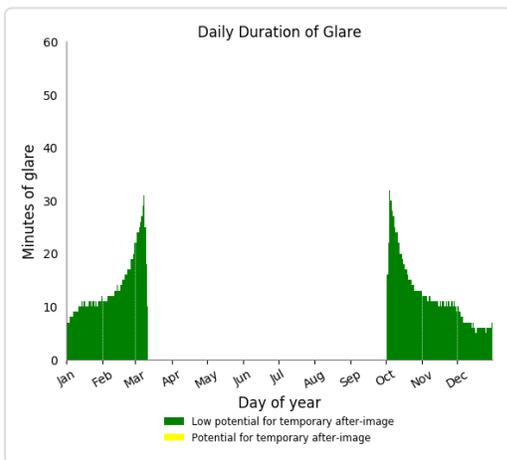
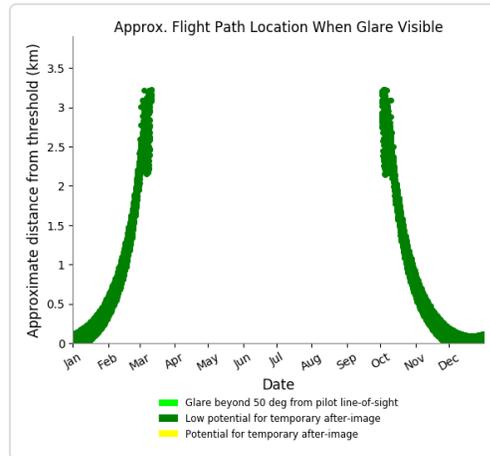
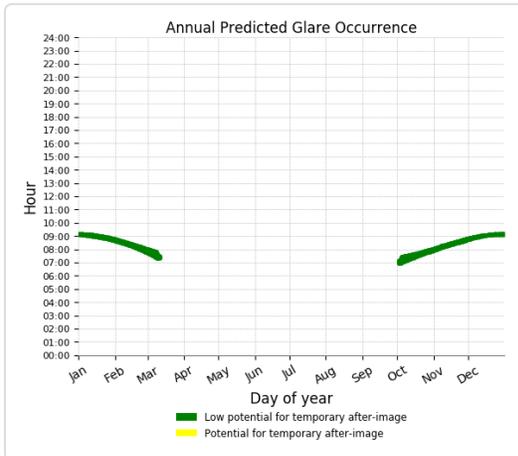
140 minutes of green glare





Flight Path: 10 Runway 2-4M

0 minutes of yellow glare
 2060 minutes of green glare



Flight Path: 16 Runway

0 minutes of yellow glare

0 minutes of green glare

Flight Path: 16 Runway 2-4M

0 minutes of yellow glare

0 minutes of green glare

Flight Path: 28R Runway

0 minutes of yellow glare

0 minutes of green glare

Flight Path: 28R Runway 2-4M

0 minutes of yellow glare

0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare

0 minutes of green glare

Flight Path: 28 Runway 2-4M

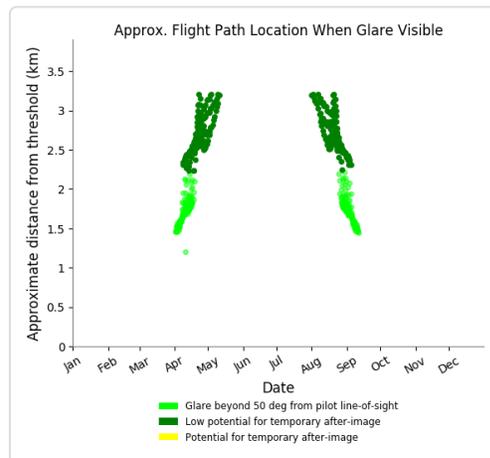
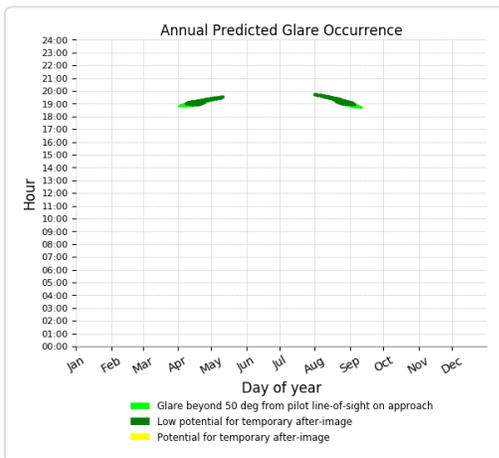
0 minutes of yellow glare

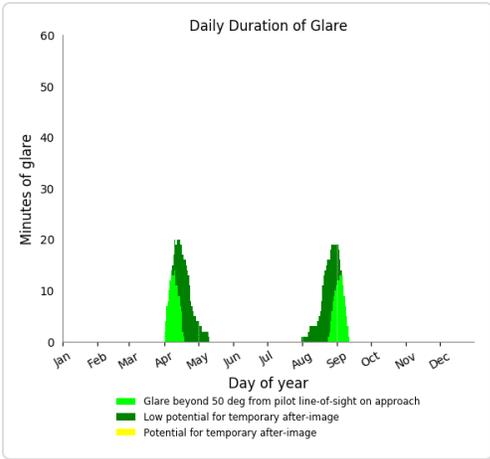
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare

472 minutes of green glare

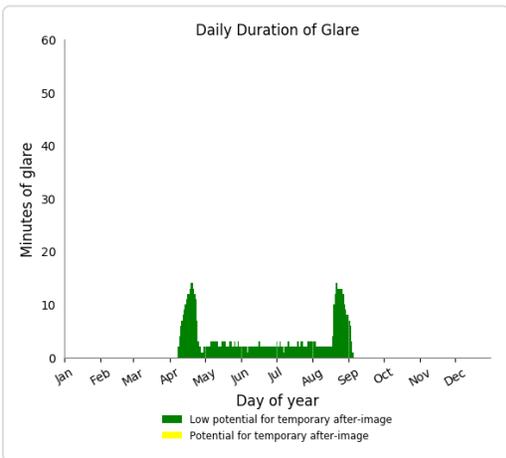
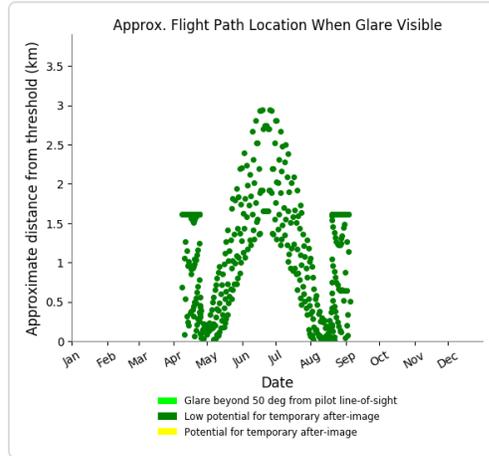
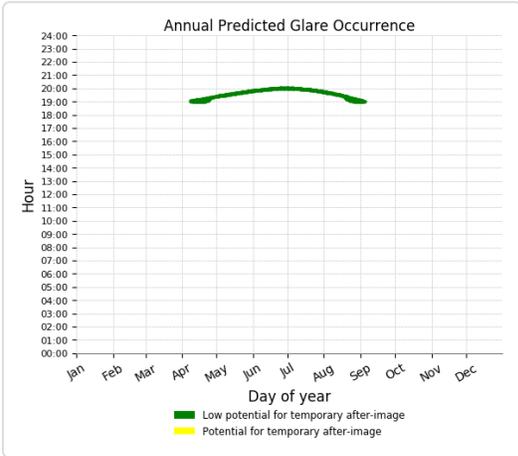




Flight Path: 36 Runway 2-4M

0 minutes of yellow glare

589 minutes of green glare



Point Receptor: ATCT 1

0 minutes of yellow glare

0 minutes of green glare

Point Receptor: ATCT 2

0 minutes of yellow glare

0 minutes of green glare

Results for: Section G

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	0	0
10L_Runway 2-4M	44	0
10 Runway	44	0
10 Runway 2-4M	2073	0
16 Runway	0	0
16 Runway 2-4M	0	0
28R Runway	0	0
28R Runway 2-4M	0	0
28 Runway	0	0
28 Runway 2-4M	0	0
34 Runway	477	0
36 Runway 2-4M	591	0
ATCT 1	0	0
ATCT 2	0	0

Flight Path: 10L Runway

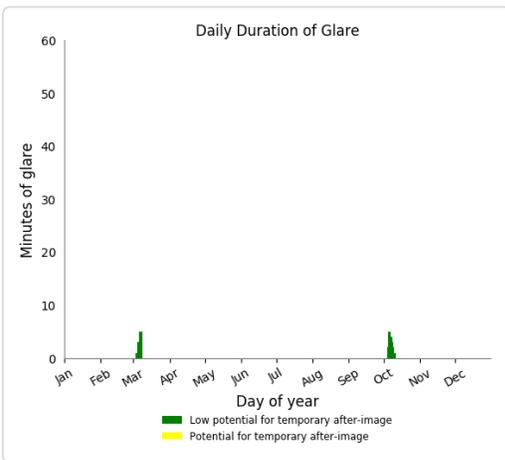
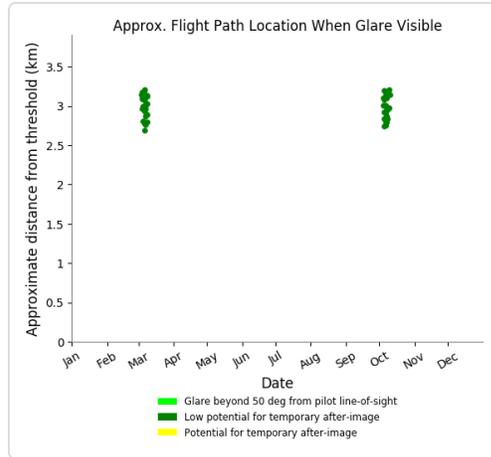
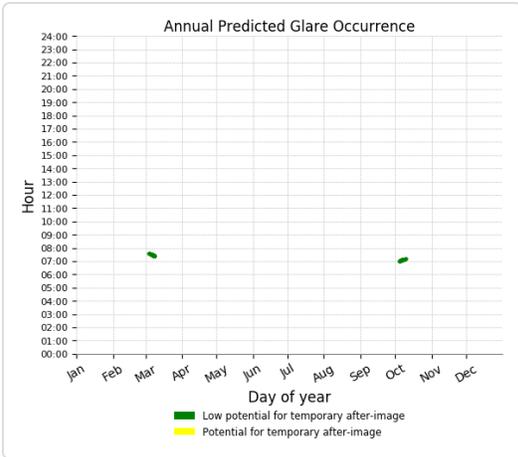
0 minutes of yellow glare

0 minutes of green glare

Flight Path: 10L_Runway 2-4M

0 minutes of yellow glare

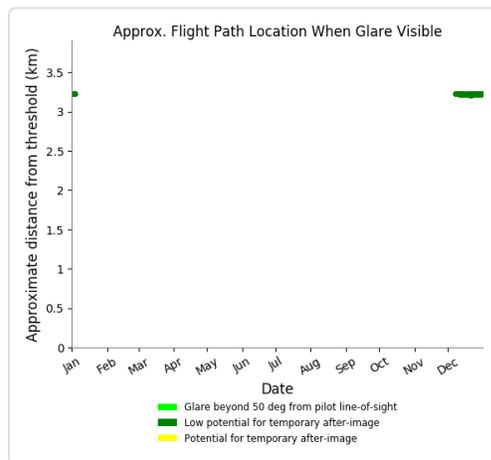
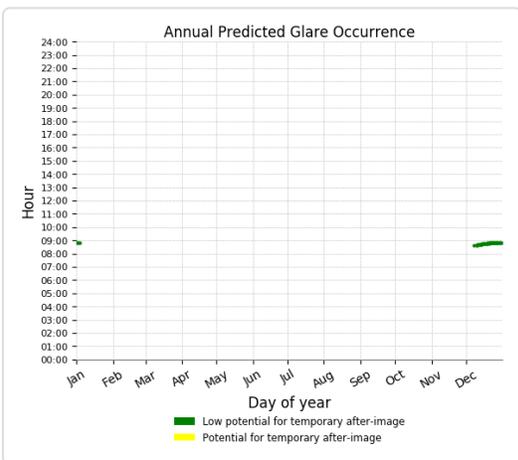
44 minutes of green glare

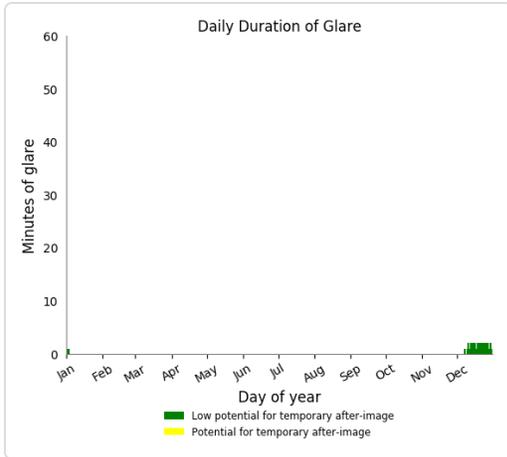


Flight Path: 10 Runway

0 minutes of yellow glare

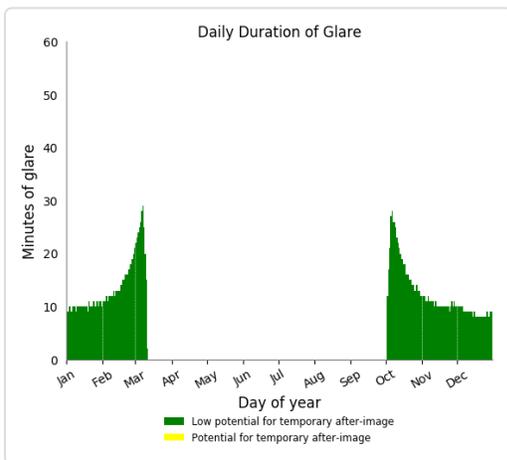
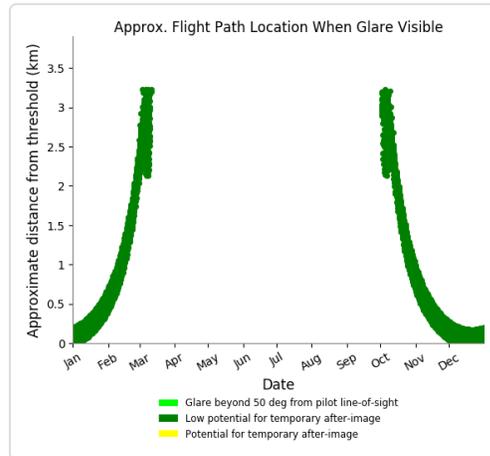
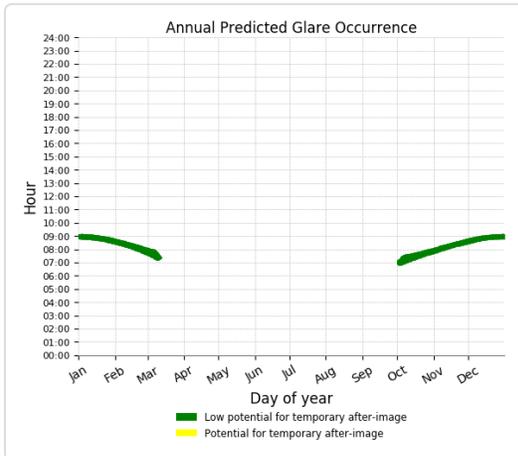
44 minutes of green glare





Flight Path: 10 Runway 2-4M

0 minutes of yellow glare
 2073 minutes of green glare



Flight Path: 16 Runway

0 minutes of yellow glare

0 minutes of green glare

Flight Path: 16 Runway 2-4M

0 minutes of yellow glare

0 minutes of green glare

Flight Path: 28R Runway

0 minutes of yellow glare

0 minutes of green glare

Flight Path: 28R Runway 2-4M

0 minutes of yellow glare

0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare

0 minutes of green glare

Flight Path: 28 Runway 2-4M

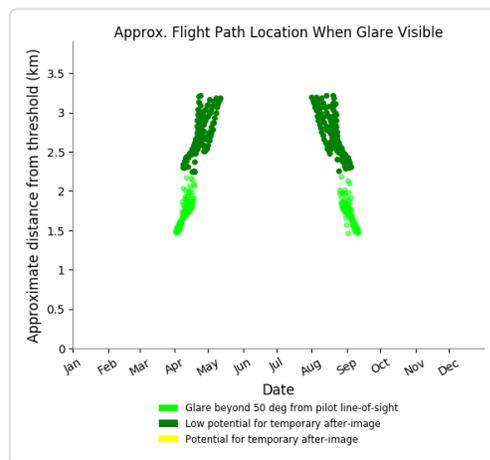
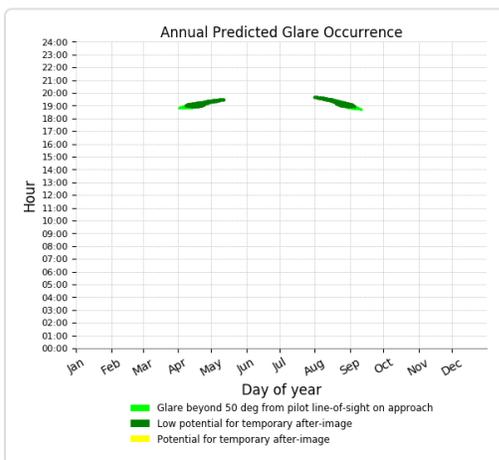
0 minutes of yellow glare

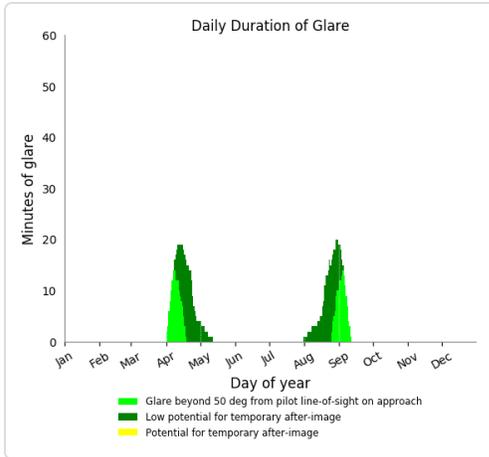
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare

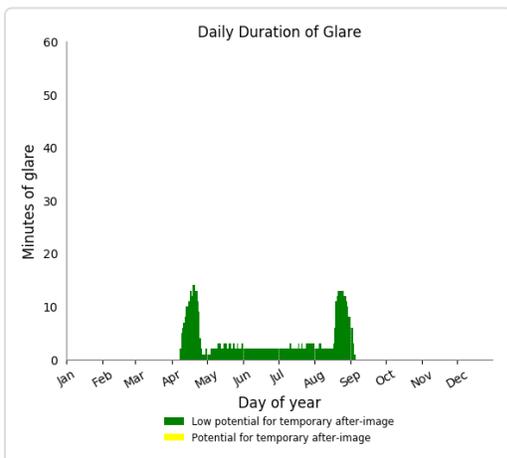
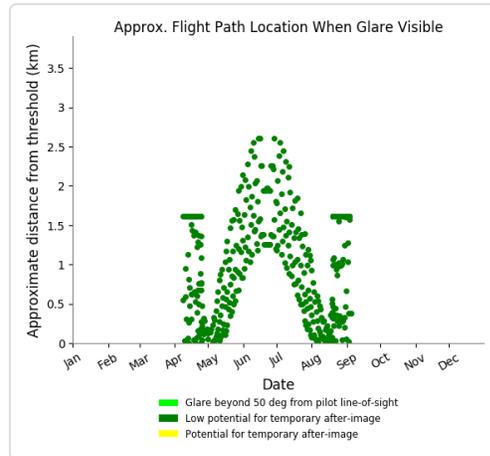
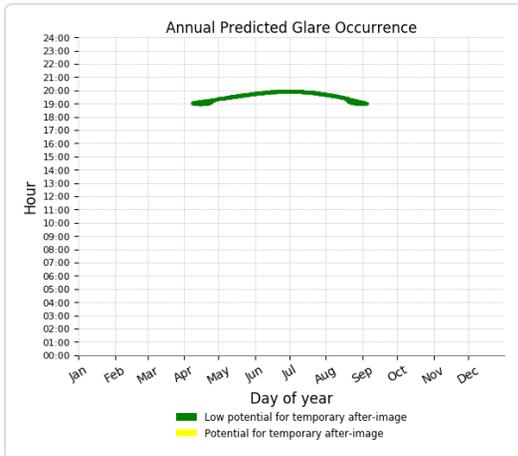
477 minutes of green glare





Flight Path: 36 Runway 2-4M

0 minutes of yellow glare
 591 minutes of green glare



Point Receptor: ATCT 1

0 minutes of yellow glare

0 minutes of green glare

Point Receptor: ATCT 2

0 minutes of yellow glare

0 minutes of green glare

Results for: Section H

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	0	0
10L_Runway 2-4M	58	0
10 Runway	0	0
10 Runway 2-4M	2002	0
16 Runway	0	0
16 Runway 2-4M	0	0
28R Runway	0	0
28R Runway 2-4M	0	0
28 Runway	0	0
28 Runway 2-4M	0	0
34 Runway	483	0
36 Runway 2-4M	591	0
ATCT 1	0	0
ATCT 2	0	0

Flight Path: 10L Runway

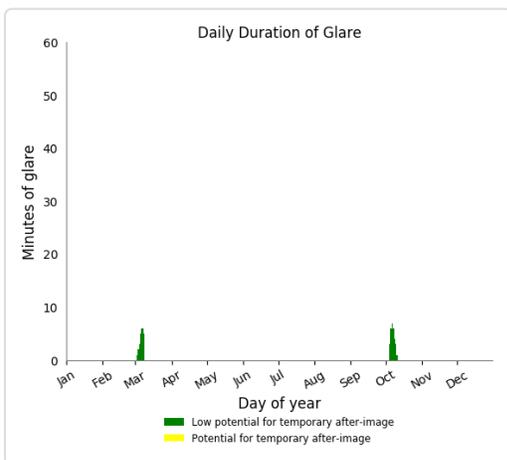
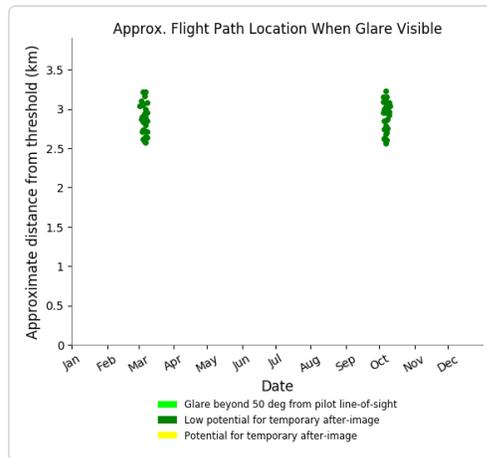
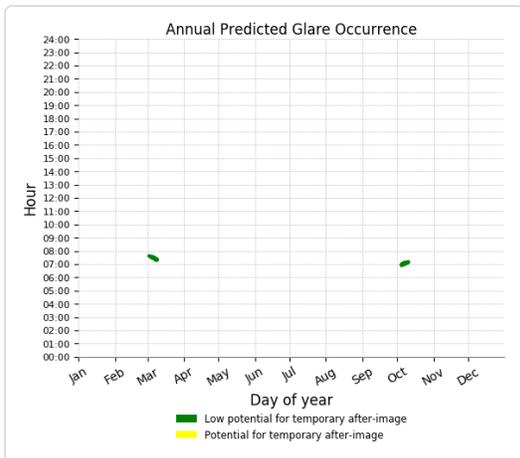
0 minutes of yellow glare

0 minutes of green glare

Flight Path: 10L_Runway 2-4M

0 minutes of yellow glare

58 minutes of green glare

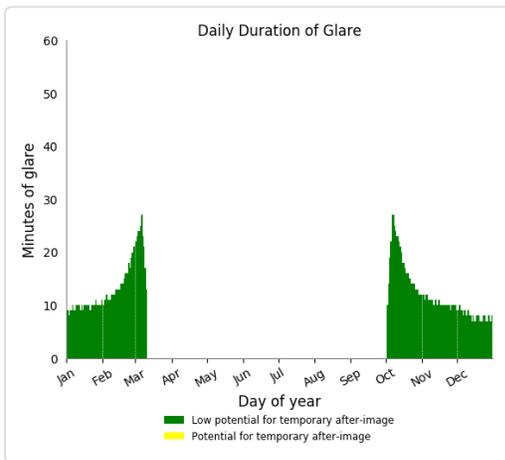
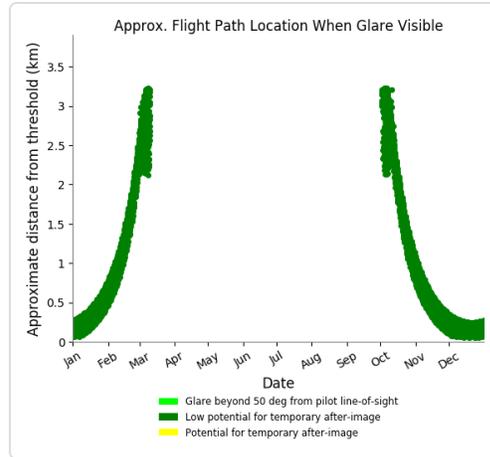
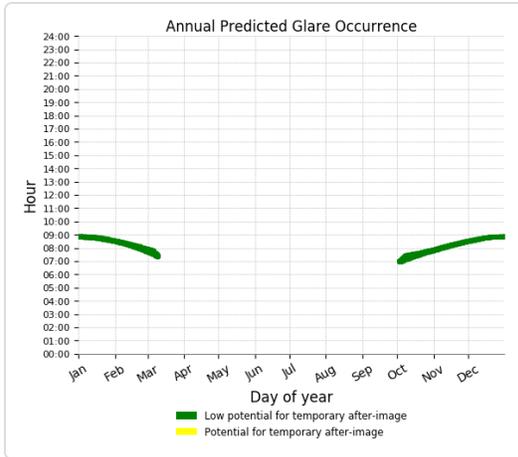


Flight Path: 10 Runway

0 minutes of yellow glare
 0 minutes of green glare

Flight Path: 10 Runway 2-4M

0 minutes of yellow glare
 2002 minutes of green glare



Flight Path: 16 Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 16 Runway 2-4M

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28R Runway

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28R Runway 2-4M

0 minutes of yellow glare
0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare

0 minutes of green glare

Flight Path: 28 Runway 2-4M

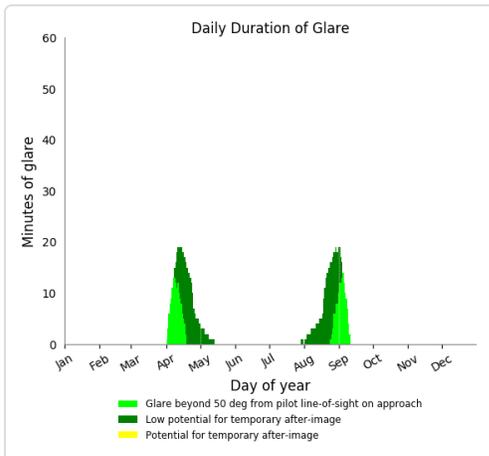
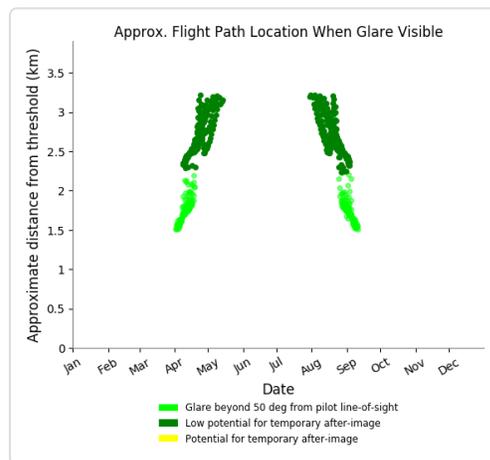
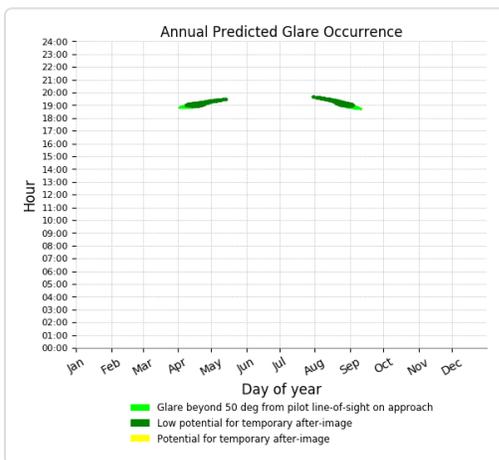
0 minutes of yellow glare

0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare

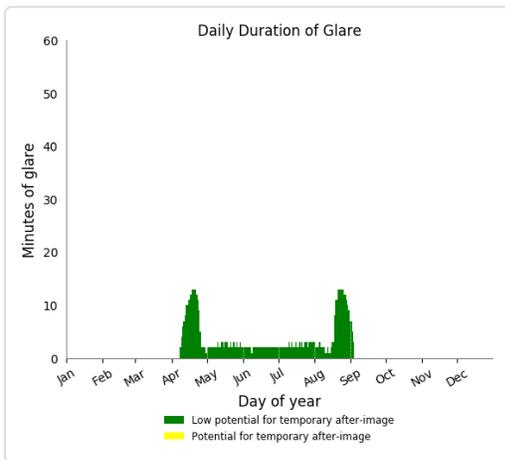
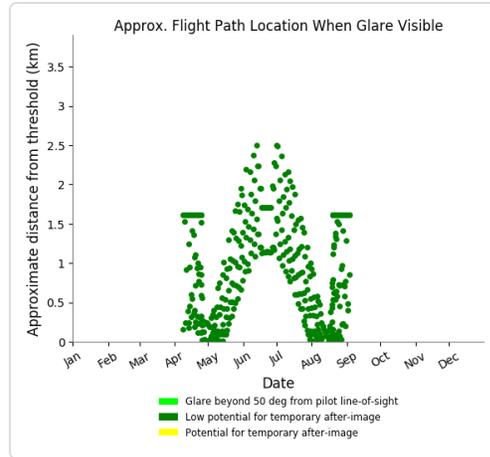
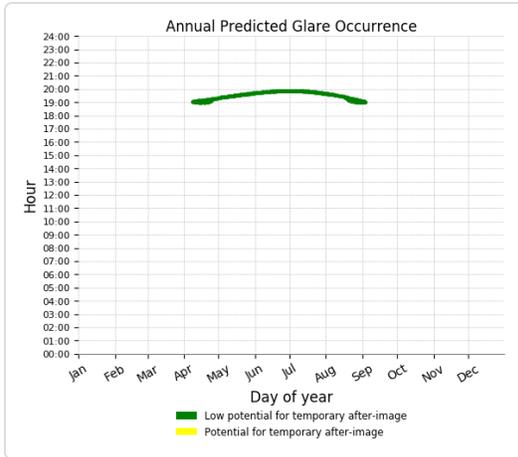
483 minutes of green glare



Flight Path: 36 Runway 2-4M

0 minutes of yellow glare

591 minutes of green glare



Point Receptor: ATCT 1

0 minutes of yellow glare
0 minutes of green glare

Point Receptor: ATCT 2

0 minutes of yellow glare
0 minutes of green glare

Results for: Section I

Receptor	Green Glare (min)	Yellow Glare (min)
10L Runway	0	0
10L_Runway 2-4M	49	0
10 Runway	0	0
10 Runway 2-4M	1669	0
16 Runway	0	0

Receptor	Green Glare (min)	Yellow Glare (min)
16 Runway 2-4M	0	0
28R Runway	0	0
28R Runway 2-4M	0	0
28 Runway	0	0
28 Runway 2-4M	0	0
34 Runway	490	0
36 Runway 2-4M	586	0
ATCT 1	0	0
ATCT 2	0	0

Flight Path: 10L Runway

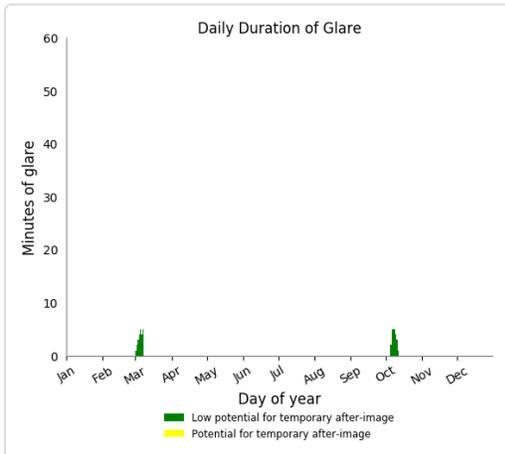
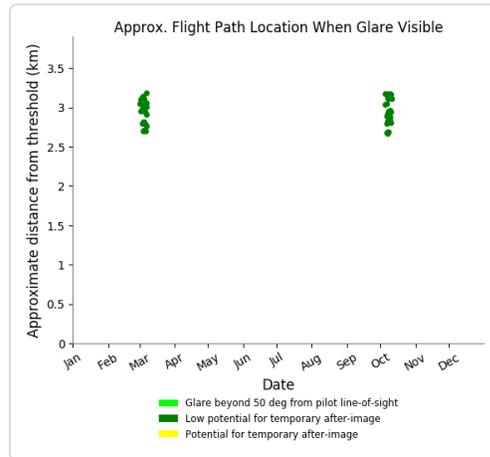
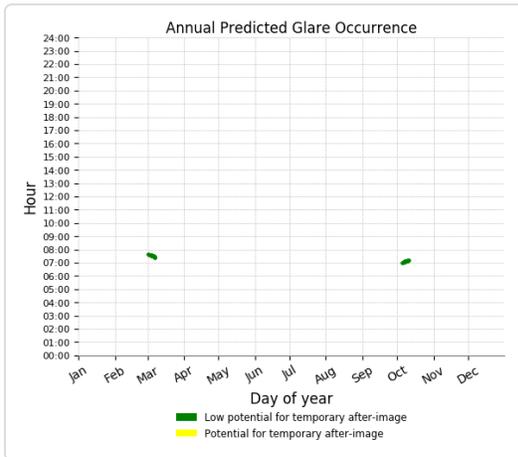
0 minutes of yellow glare

0 minutes of green glare

Flight Path: 10L_Runway 2-4M

0 minutes of yellow glare

49 minutes of green glare



Flight Path: 10 Runway

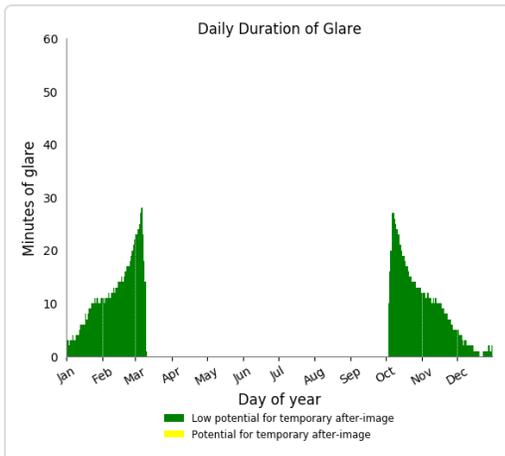
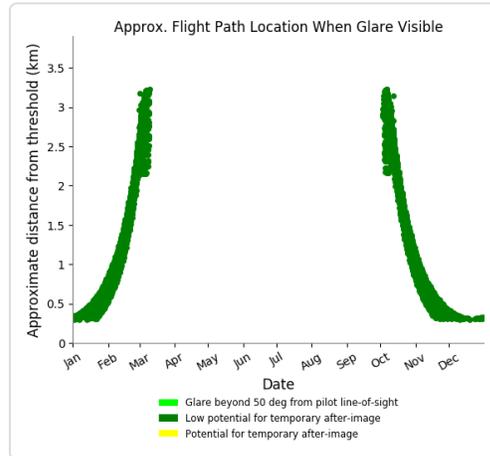
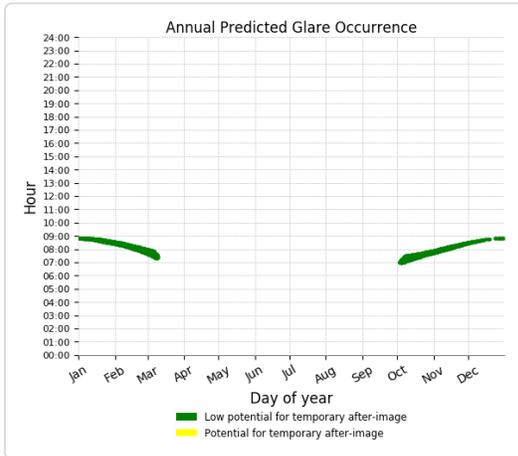
0 minutes of yellow glare

0 minutes of green glare

Flight Path: 10 Runway 2-4M

0 minutes of yellow glare

1669 minutes of green glare



Flight Path: 16 Runway

0 minutes of yellow glare

0 minutes of green glare

Flight Path: 16 Runway 2-4M

0 minutes of yellow glare

0 minutes of green glare

Flight Path: 28R Runway

0 minutes of yellow glare

0 minutes of green glare

Flight Path: 28R Runway 2-4M

0 minutes of yellow glare

0 minutes of green glare

Flight Path: 28 Runway

0 minutes of yellow glare

0 minutes of green glare

Flight Path: 28 Runway 2-4M

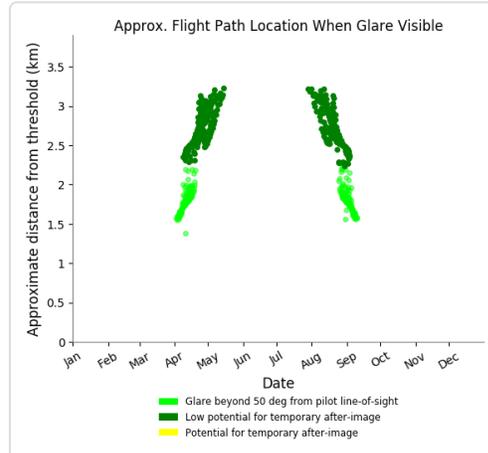
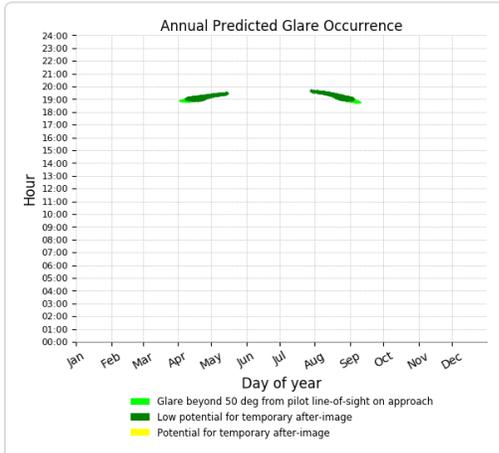
0 minutes of yellow glare

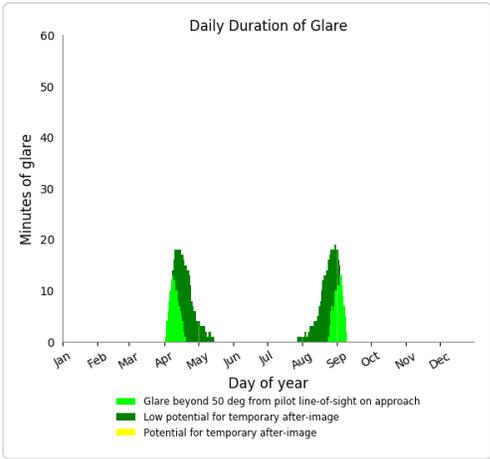
0 minutes of green glare

Flight Path: 34 Runway

0 minutes of yellow glare

490 minutes of green glare

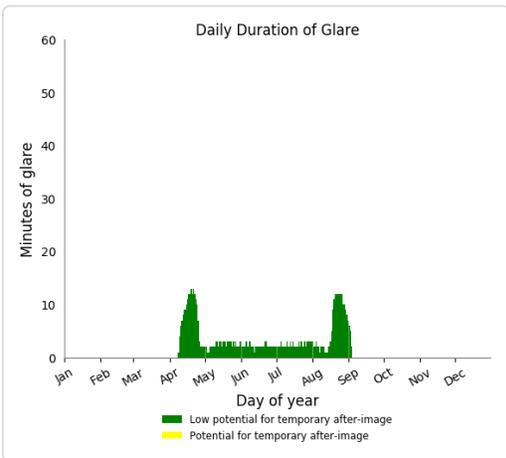
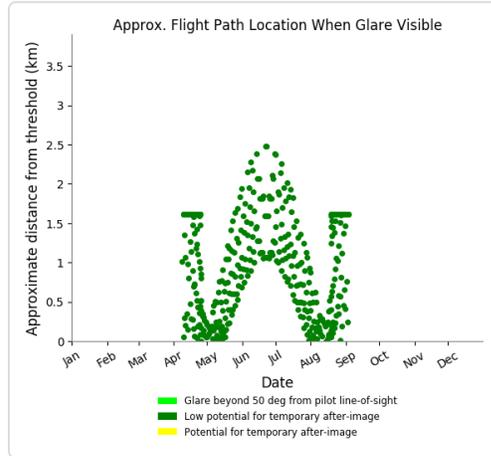
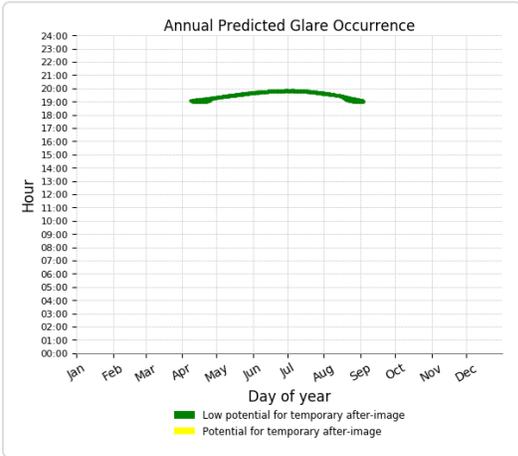




Flight Path: 36 Runway 2-4M

0 minutes of yellow glare

586 minutes of green glare



Point Receptor: ATCT 1

0 minutes of yellow glare

0 minutes of green glare

Point Receptor: ATCT 2

0 minutes of yellow glare

0 minutes of green glare

Assumptions

"Green" glare is glare with low potential to cause an after-image (flash blindness) when observed prior to a typical blink response time.

"Yellow" glare is glare with potential to cause an after-image (flash blindness) when observed prior to a typical blink response time.

Times associated with glare are denoted in Standard time. For Daylight Savings, add one hour.

Glare analyses do not account for physical obstructions between reflectors and receptors. This includes buildings, tree cover and geographic obstructions.

The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual values may differ.

Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid based on aggregated research data. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.

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