

June 16, 2025

Mr. J. Hunter Watkins
Terracon
50 Goldenland Court, Suite 100
Sacramento, CA 95834

Subject: Tokay High School – Glare and Lighting Study, City of Lodi, CA

Dear Mr. Watkins:

MD Acoustics, LLC (MD) has completed the photometric analysis for the lighting plan proposed for the Tokay High School project over the area encompassed by the Baseball Field and Swimming Pool located in the facilities at 1111 Century Boulevard in the City of Lodi, California. This letter report evaluates the existing light levels (foot-candles) to the preliminary lighting plan (prepared by Musco Lighting, 4/2/2025) and to the City's lighting general development standards. Also, this report presents a glare analysis to ensure that roadways are not impacted by glare as required per the City's standards. Appendix A contains lighting definitions for your convenience.

1.0 Assessment Overview

MD conducted a site visit on 06/03/25 to evaluate the existing light conditions at the project site. MD utilized an LX1330B digital illuminance/light meter that can measure from 0 to 200,000 lux (0 to 18,580 foot-candles). The existing light conditions were compared to the preliminary photometric lighting plan and the requirements outlined by the City's General Property Development and Use Standards, Section 17.14.070.

Per the City of Lodi Land Use Plan, the site has a current land use classification of Public or Quasi-Public use. Land uses surrounding the site include existing residential areas in all directions. The proposed equipment layout is shown in Appendix B.

2.0 City of Lodi Lighting Requirements

Section 17.14.070 Lighting of the City's Code outlines the following as it relates to minimum lighting requirements:

Exterior lighting on private property within the city shall comply with the requirements of this section.

- A. Exterior lighting fixtures shall not exceed a height of twenty feet or the height of the nearest building, whichever is less.
- B. Lighting shall be energy-efficient, and shielded or recessed so that direct glare and reflections are confined to the maximum extent feasible within the boundaries of the site, and shall be directed downward and away from adjoining properties and public rights-of-way.
- C. No permanently installed lighting shall blink, flash, or be of unusually high intensity or brightness, as determined by the director.
- D. All lighting fixtures shall be appropriate in scale, intensity, and height to the use they are serving.
- E. All lighting shall be properly maintained.

Therefore, the project must, at a minimum, provide sufficient lighting to satisfy the exterior code requirements. Additionally, the project shall assure that the glare impact on roadways is not significant as required per City's Development Code.

3.0 Evaluation and Findings

Some land uses are considered more sensitive to light than others, such as hotels, residential neighborhoods, and nursing homes. Although humans may observe light at 0.1 lumens, it would not make a substantial difference, especially if lighting is already present within the area of introduction. For example, approximately 400 lumens per square meter would be generally acceptable for a reading area.

According to the Illumination Engineering Society (IES), the recommended average footcandle level for a baseball field is 20 to 50 footcandles for recreational/non-broadcast and 70 to 100 footcandles for competitive/professional or broadcast.¹ Thus, a significant impact would occur if sensitive land uses (such as residences) were exposed to a substantial increase in sources of light, if that level of light was not previously present. Similarly, mobile source lighting impacts would be significant if residential or other light-sensitive uses are introduced to new light sources along roadways and driveways.

This report compares the lighting conditions to four (4) scenarios: 1) Existing lighting levels, 2) Project lighting levels, 3) Existing plus project lighting conditions, and 4) the glare impact analysis on roadways and potential glare-sensitive receptors.

Existing

MD measured the lighting levels in foot candles (at the locations shown on Exhibit A) at or close to the project site (see Exhibit A), which considers the light from vehicles along close roadways, existing residential and Public lights. The existing light levels measured between 0 to 1.5 foot candles.

Project

The project will utilize nighttime lighting for operational purposes for sport and recreational events. The updated preliminary lighting plan (dated 4.2.25 and shown in Exhibit B) shows that the project's lighting levels at the north perimeter will range between 0 and 7.2 foot-candles. Also, the lighting plan shows a perimeter wall between the project site and the existing residential uses. This increase will change the existing conditions at said residences from 0.01 to 7.2 foot-candles. This lighting impact will meet the City standards, since the direct glare and reflections are confined to the maximum extent feasible within the boundaries of the site. There is no specific limit set forth by the City's Code Section 17.14.070, and also Section 17.26.040 states that the development standards within the PF zoning district will be determined by the city through the project review process.

Existing plus Project

The project adds between 0.01 to 7.2 foot-candles to the existing light conditions at the adjacent land uses. The existing lighting conditions measured at the project's site showed a minimal lighting exposure between 0.01 to 0.05 foot-candles to the adjacent existing residential land uses adjoining the northern property line.

¹ https://waypointlighting.com/uploads/2/6/8/4/26847904/ies_recommended_light_levels.pdf

Therefore, the project exterior lighting plan has the potential to reach up to 7.2-foot candles at the northern property line between the residences. This lightning level is similar to the level recommended for a parking lot area. Also, the project lighting plan includes an integrated architectural design with the surrounding developments and considers light fixtures that are oriented downward and shielded, so glare is confined to the project parcel. Additionally, the proposed light fixtures do not blink or flash and are not of unusually high intensity or brightness.

Glare analysis

The glare analysis shows a low potential for temporary after-image effects on people at adjacent roadways, land uses, or flight paths (See Appendix C). Most of the building shell finishes, including the roof, consist of CMU walls and stucco with windows where they occur. The color scheme for buildings is mid to low-reflective coating colors, substantially reducing the impact on nearby receptors due to solar glare. The project building, as described, will have a low potential for glare impact on roadways and close receptors.

4.0 Conclusions

MD is pleased to provide this evaluation. The project exterior lighting plan meets the City's ordinance requirements; additionally, the building does not create a significant glare impact on roadways and sensitive receptors. If you have any questions regarding this analysis, please don't hesitate to call us at (805) 426-4477.

Sincerely,
MD Acoustics, LLC



Francisco Irarrazabal, MS, INCE-USA
Consultant

Exhibit A

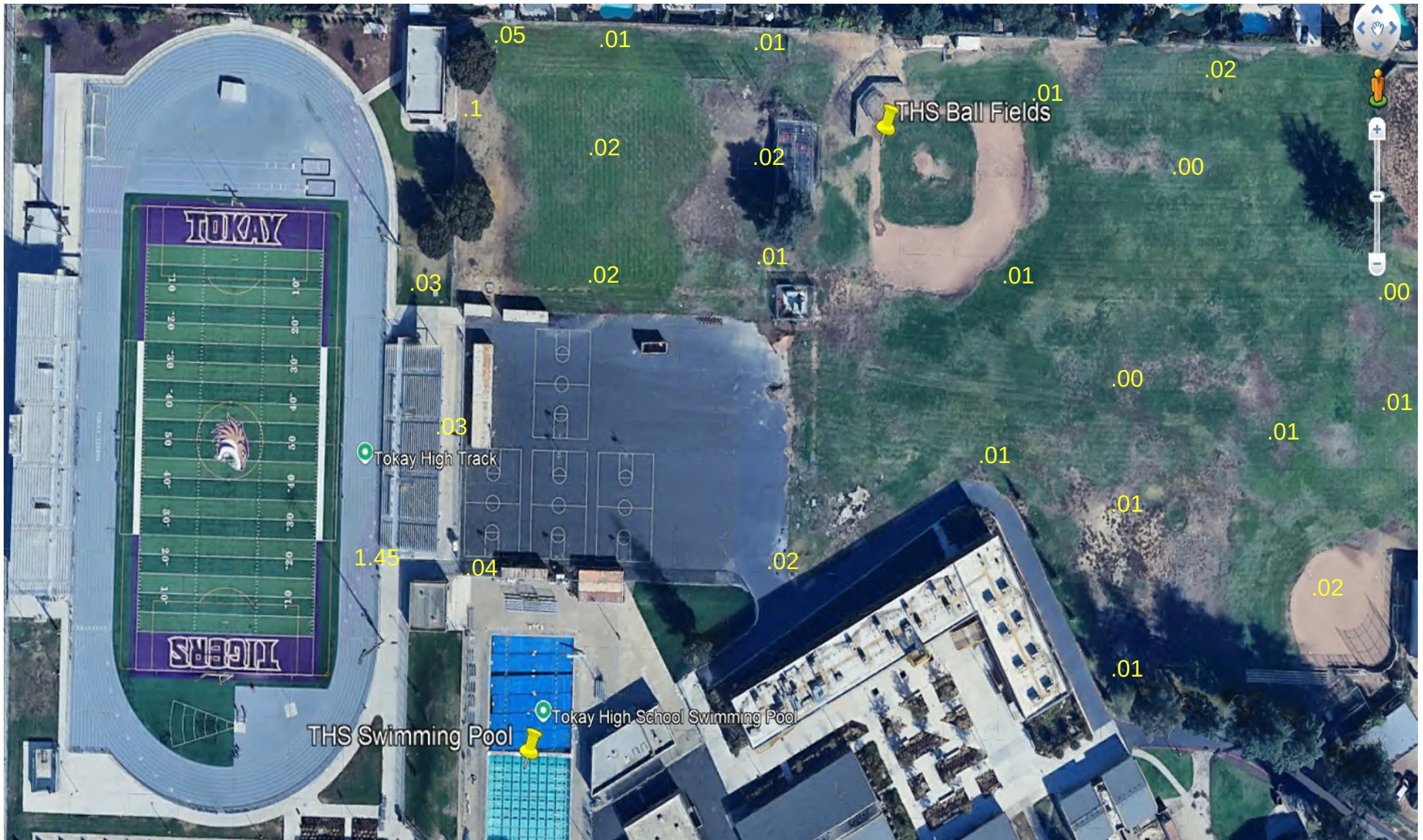


Exhibit B



Appendix A

Glossary of Lighting Terms

Glossary of Terms

Foot-Candle is a unit of illumination (now little used) equal to that given by a source of one candela at a distance of one foot (equivalent to one lumen per square foot or 10.764 lux).

Lumen is a measure of the total amount of visible light (to the human eye) from a lamp or light source. The higher the lumen rating the “brighter: the lamp will appear (Integral LED, 2015). This light, as low as 0.1 lumens is visible to the human eye, and the average household lightbulb (60 watts) emits approximately 800 lumens (at the source).

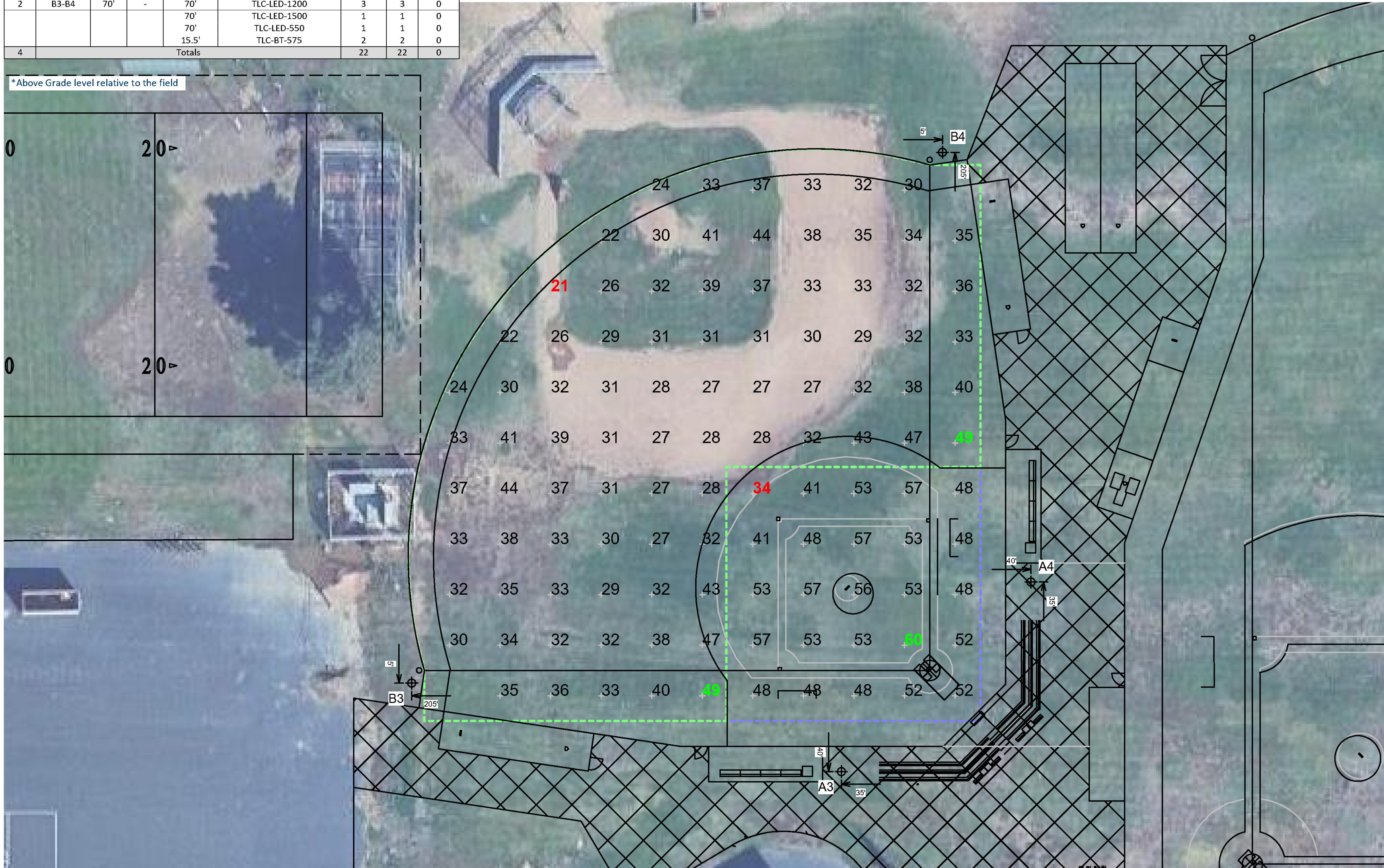
Lux is the SI unit of illuminance, equal to one lumen per square meter.

Appendix B

Project Equipment Layout

Equipment List For Areas Shown								
Pole				Luminaires				
QTY	LOCATION	SIZE	GRADE ELEVATION	ABOVE GRADE LEVEL	LUMINAIRE TYPE	QTY/POLE	THIS GRID	OTHER GRIDS
2	A3-A4	70'	-	70'	TLC-LED-1200	2	2	0
				70'	TLC-LED-900	1	1	0
				15.5'	TLC-BT-575	1	1	0
2	B3-B4	70'	-	70'	TLC-LED-1200	3	3	0
				70'	TLC-LED-1500	1	1	0
				70'	TLC-LED-550	1	1	0
				15.5'	TLC-BT-575	2	2	0
4	Totals					22	22	0

*Above Grade level relative to the field



Tokay High School Baseball And Softball Field

Lodi,CA

Grid Summary	
Name:	Softball
Size:	200'/225'/200' - basepath 60'
Spacing:	20.0' x 20.0'
Height:	3.0' above grade

Illumination Summary		
	MAINTAINED HORIZONTAL FOOTCANDLES	
	Infield	Outfield
Guaranteed Average:	50	30
Scan Average:	50.65	33.22
Maximum:	60	49
Minimum:	34	21
Avg/Min:	1.48	1.58
Guaranteed Max/Min:	2	2.5
Max/Min:	1.75	2.33
UG (adjacent pts):	1.27	1.41
CU:	0.64	
No. of Points:	25	84
LUMINAIRE INFORMATION		
Applied Circuits:	B	
No. of Luminaires:	22	
Total Load:	20.81 kW	

Guaranteed Performance: The ILLUMINATION described above is guaranteed per your Musco Warranty document and includes a 0.95 dirt depreciation factor.

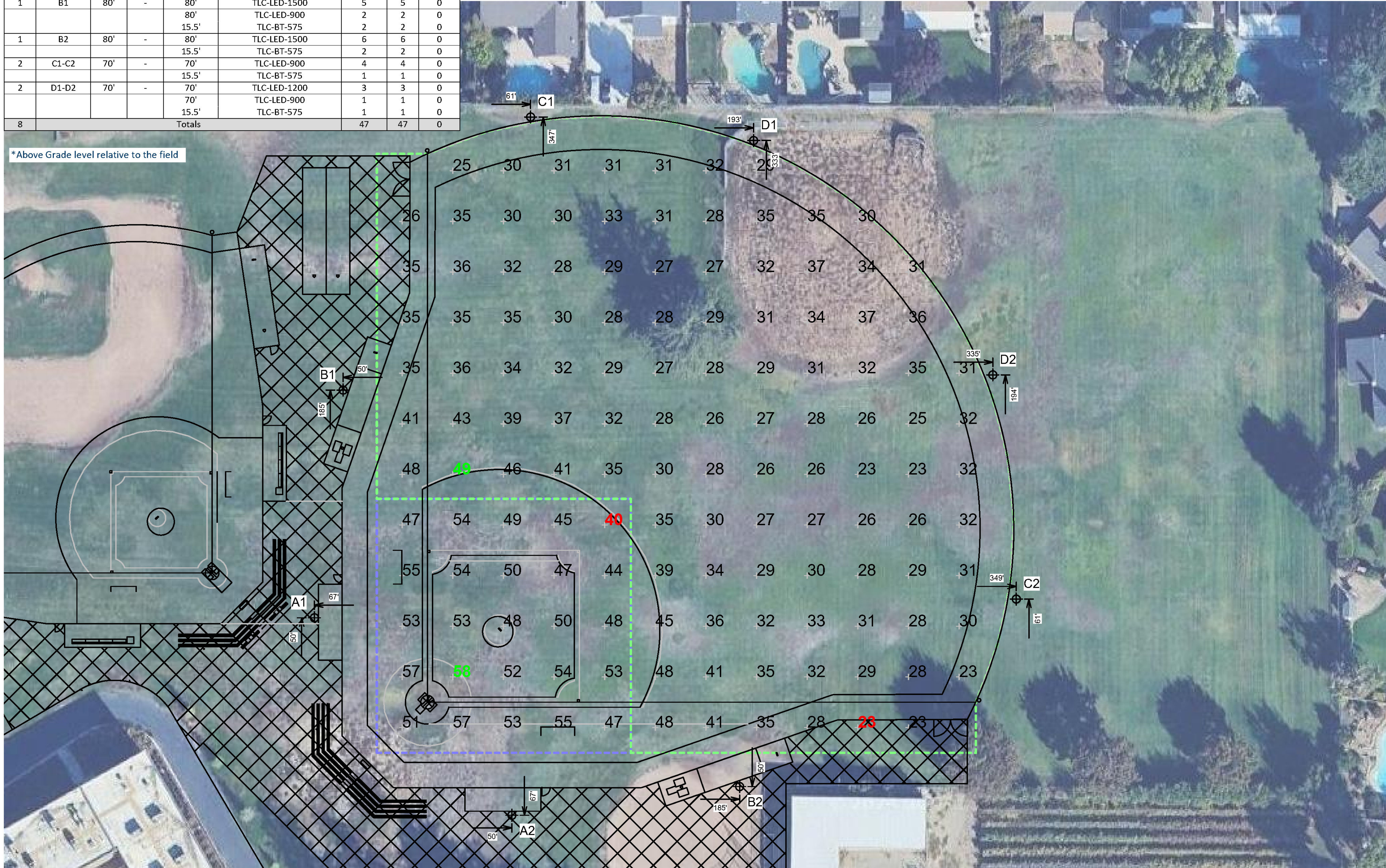
Field Measurements: Individual field measurements may vary from computer-calculated predictions and should be taken in accordance with IESNA RP-6-15.

Electrical System Requirements: Refer to Amperage Draw Chart and/or the "Musco Control System Summary" for electrical sizing.

Installation Requirements: Results assume ± 3% nominal voltage at line side of the driver and structures located within 3 feet (1m) of design locations.

Equipment List For Areas Shown								
Pole				Luminaires				
QTY	LOCATION	SIZE	GRADE ELEVATION	ABOVE GRADE LEVEL	LUMINAIRE TYPE	QTY/POLE	THIS GRID	OTHER GRIDS
2	A1-A2	70'	-	70'	TLC-LED-1200	3	3	0
				70'	TLC-LED-1500	1	1	0
				15.5'	TLC-BT-575	1	1	0
1	B1	80'	-	80'	TLC-LED-1500	5	5	0
				80'	TLC-LED-900	2	2	0
				15.5'	TLC-BT-575	2	2	0
1	B2	80'	-	80'	TLC-LED-1500	6	6	0
				15.5'	TLC-BT-575	2	2	0
2	C1-C2	70'	-	70'	TLC-LED-900	4	4	0
				15.5'	TLC-BT-575	1	1	0
2	D1-D2	70'	-	70'	TLC-LED-1200	3	3	0
				70'	TLC-LED-900	1	1	0
				15.5'	TLC-BT-575	1	1	0
8	Totals					47	47	0

*Above Grade level relative to the field



Tokay High School Baseball And Softball Field

Lodi,CA

Grid Summary	
Name:	Baseball
Size:	325'/390'/325' - basepath 90'
Spacing:	30.0' x 30.0'
Height:	3.0' above grade

	MAINTAINED HORIZONTAL FOOTCANDLES	
	Infield	Outfield
Guaranteed Average:	50	30
Scan Average:	51.02	32.04
Maximum:	58	49
Minimum:	40	23
Avg/Min:	1.28	1.39
Guaranteed Max/Min:	2	2.5
Max/Min:	1.46	2.11
UG (adjacent pts):	1.17	1.40
CU:	0.73	
No. of Points:	25	109
LUMINAIRE INFORMATION		
Applied Circuits:	A	
No. of Luminaires:	47	
Total Load:	48.68 kW	

Guaranteed Performance: The ILLUMINATION described above is guaranteed per your Musco Warranty document and includes a 0.95 dirt depreciation factor.

Field Measurements: Individual field measurements may vary from computer-calculated predictions and should be taken in accordance with IESNA RP-6-15.

Electrical System Requirements: Refer to Amperage Draw Chart and/or the "Musco Control System Summary" for electrical sizing.

Installation Requirements: Results assume ± 3% nominal voltage at line side of the driver and structures located within 3 feet (1m) of design locations.

Appendix C

Glare Analysis Report

FORGESOLAR GLARE ANALYSIS

Project: **Tokay High School**

Glare analysis for new luminaries at the sport field

Site configuration: **Tokay HS-temp-0**

Created 13 Jun, 2025

Updated 13 Jun, 2025

Time-step 1 minute

Timezone offset UTC-8

Minimum sun altitude 0.0 deg

DNI peaks at 1,000.0 W/m²

Category 100 to 500 kW

(1,000 kW / 8 acre limit)

Site ID 152023.25428

Ocular transmission coefficient 0.5

Pupil diameter 0.002 m

Eye focal length 0.017 m

Sun subtended angle 9.3 mrad

PV analysis methodology V2



Summary of Results Glare with potential for temporary after-image predicted

PV Array	Tilt	Orient	Annual Green Glare		Annual Yellow Glare		Energy
	°	°	min	hr	min	hr	kWh
PV array 1	0.0	180.0	6,627	110.5	0	0.0	-

Vertical Surface	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Vertical surface 1	13,921	232.0	603	10.1
Vertical surface 2	11,450	190.8	0	0.0
Vertical surface 3	2,257	37.6	0	0.0

Total glare received by each receptor; may include duplicate times of glare from multiple reflective surfaces.

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Route 1	12,200	203.3	0	0.0
Route 2	7,450	124.2	0	0.0
FP 1	0	0.0	0	0.0
FP 2	0	0.0	0	0.0
FP 3	0	0.0	0	0.0
FP 4	0	0.0	0	0.0
OP 1	2,509	41.8	0	0.0

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
OP 2	2,940	49.0	0	0.0
OP 3	1,228	20.5	603	10.1
OP 4	2,387	39.8	0	0.0
OP 5	1,893	31.6	0	0.0
OP 6	715	11.9	0	0.0
OP 7	66	1.1	0	0.0
OP 8	660	11.0	0	0.0
OP 9	626	10.4	0	0.0
OP 10	1,581	26.4	0	0.0

Component Data

PV Arrays

Name: PV array 1

Description: Pool simulation

Axis tracking: Fixed (no rotation)

Tilt: 0.0°

Orientation: 180.0°

Rated power: -

Panel material: Smooth glass without AR coating

Reflectivity: Vary with sun

Slope error: correlate with material



Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
1	38.110563	-121.286378	41.72	0.00	41.72
2	38.110559	-121.286120	38.26	0.00	38.26
3	38.110107	-121.286120	39.74	0.00	39.74
4	38.110105	-121.286370	39.67	0.00	39.67

Vertical Surfaces

Name: Vertical surface 1

Use smooth glass reflectivity profile? Yes

Slope error: 10.0 mrad

Lower edge height: 0 ft

Upper edge height: 32 ft

Surface glare contribution: evaluate single side

Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)
1	38.110367	-121.285547	41.01
2	38.110464	-121.285619	44.44
3	38.110825	-121.284809	42.01
4	38.110502	-121.284584	40.99

Name: Vertical surface 2

Use smooth glass reflectivity profile? Yes

Slope error: 10.0 mrad

Lower edge height: 0 ft

Upper edge height: 32 ft

Surface glare contribution: evaluate single side

Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)
1	38.109375	-121.286923	41.67
2	38.110063	-121.286920	41.62

Name: Vertical surface 3

Use smooth glass reflectivity profile? Yes

Slope error: 10.0 mrad

Lower edge height: 0 ft

Upper edge height: 20 ft

Surface glare contribution: evaluate single side

Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)
1	38.110176	-121.282650	41.74
2	38.110143	-121.282577	42.10
3	38.110027	-121.282664	43.54
4	38.110066	-121.282736	44.59
5	38.110176	-121.282650	41.74

Route Receptors

Name: Route 1

Path type: Two-way

Observer view angle: 50.0°



Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
1	38.108284	-121.288050	39.62	0.00	39.62
2	38.112791	-121.288007	41.74	0.00	41.74

Name: Route 2

Path type: Two-way

Observer view angle: 50.0°



Vertex	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
1	38.112715	-121.286473	40.46	0.00	40.46
2	38.112281	-121.286424	38.57	0.00	38.57
3	38.112205	-121.286290	39.19	0.00	39.19
4	38.112293	-121.284992	41.49	0.00	41.49
5	38.112293	-121.282621	43.66	0.00	43.66
6	38.112276	-121.282170	43.64	0.00	43.64
7	38.112129	-121.281403	44.74	0.00	44.74

Flight Path Receptors

Name: FP 1

Description:

Threshold height: 50 ft

Direction: 270.3°

Glide slope: 3.0°

Pilot view restricted? Yes

Vertical view: 30.0°

Azimuthal view: 50.0°



Point	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
Threshold	38.084083	-121.319121	26.81	50.00	76.81
Two-mile	38.083952	-121.282346	40.71	589.53	630.24

Name: FP 2

Description:

Threshold height: 50 ft

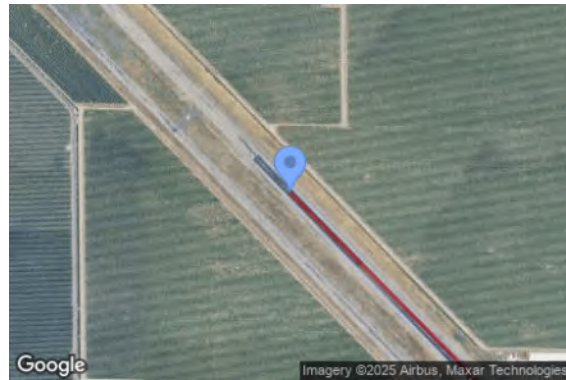
Direction: 315.1°

Glide slope: 3.0°

Pilot view restricted? Yes

Vertical view: 30.0°

Azimuthal view: 50.0°



Point	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
Threshold	38.091380	-121.357700	21.39	50.00	71.39
Two-mile	38.070914	-121.331720	20.03	604.79	624.82

Name: FP 3

Description:

Threshold height: 50 ft

Direction: 271.8°

Glide slope: 3.0°

Pilot view restricted? Yes

Vertical view: 30.0°

Azimuthal view: 50.0°



Point	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
Threshold	38.202937	-121.271267	53.88	50.00	103.88
Two-mile	38.202034	-121.234449	76.43	580.88	657.31

Name: FP 4

Description:

Threshold height: 50 ft

Direction: 314.5°

Glide slope: 3.0°

Pilot view restricted? Yes

Vertical view: 30.0°

Azimuthal view: 50.0°



Point	Latitude (°)	Longitude (°)	Ground elevation (ft)	Height above ground (ft)	Total elevation (ft)
Threshold	38.202284	-121.268653	56.81	50.00	106.81
Two-mile	38.182023	-121.242376	68.33	591.91	660.24

Discrete Observation Point Receptors

Name	ID	Latitude (°)	Longitude (°)	Elevation (ft)	Height (ft)
OP 1	1	38.112002	-121.285419	50.87	5.00
OP 2	2	38.112002	-121.284518	50.13	5.00
OP 3	3	38.111968	-121.283617	44.54	5.00
OP 4	4	38.112002	-121.282802	49.41	5.00
OP 5	5	38.111664	-121.282308	44.94	5.00
OP 6	6	38.111175	-121.282244	47.13	5.00
OP 7	7	38.112019	-121.286278	48.04	5.00
OP 8	8	38.110584	-121.282201	48.65	5.00
OP 9	9	38.110229	-121.282244	45.56	5.00
OP 10	10	38.109824	-121.282051	48.23	5.00

Glare Analysis Results

Summary of Results Glare with potential for temporary after-image predicted

PV Array	Tilt °	Orient °	Annual Green Glare		Annual Yellow Glare		Energy kWh
			min	hr	min	hr	
PV array 1	0.0	180.0	6,627	110.5	0	0.0	-

Vertical Surface	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Vertical surface 1	13,921	232.0	603	10.1
Vertical surface 2	11,450	190.8	0	0.0
Vertical surface 3	2,257	37.6	0	0.0

Total glare received by each receptor; may include duplicate times of glare from multiple reflective surfaces.

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Route 1	12,200	203.3	0	0.0
Route 2	7,450	124.2	0	0.0
FP 1	0	0.0	0	0.0
FP 2	0	0.0	0	0.0
FP 3	0	0.0	0	0.0
FP 4	0	0.0	0	0.0
OP 1	2,509	41.8	0	0.0
OP 2	2,940	49.0	0	0.0
OP 3	1,228	20.5	603	10.1
OP 4	2,387	39.8	0	0.0
OP 5	1,893	31.6	0	0.0
OP 6	715	11.9	0	0.0
OP 7	66	1.1	0	0.0
OP 8	660	11.0	0	0.0
OP 9	626	10.4	0	0.0
OP 10	1,581	26.4	0	0.0

PV: PV array 1 low potential for temporary after-image

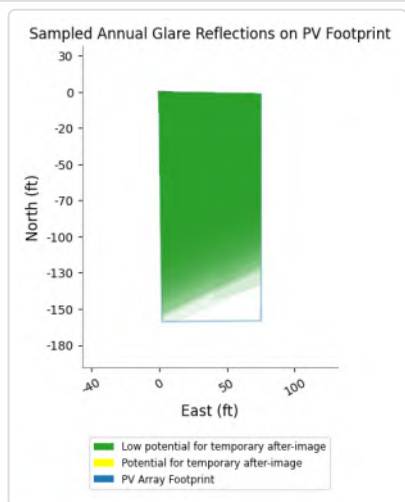
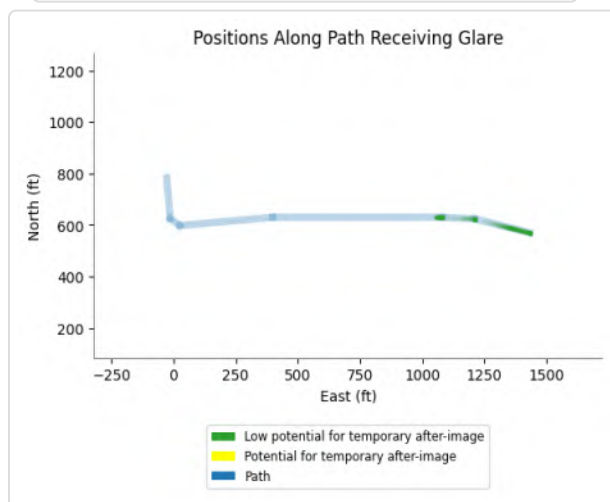
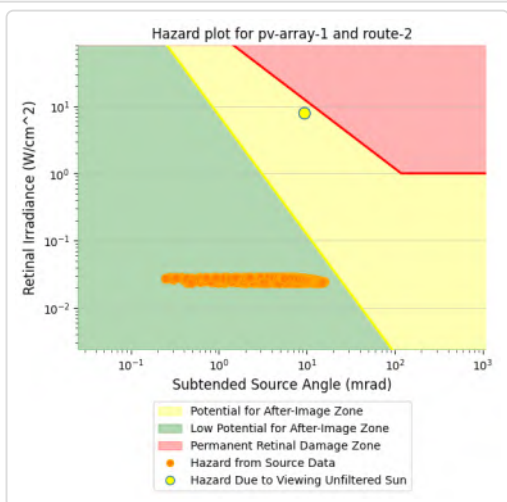
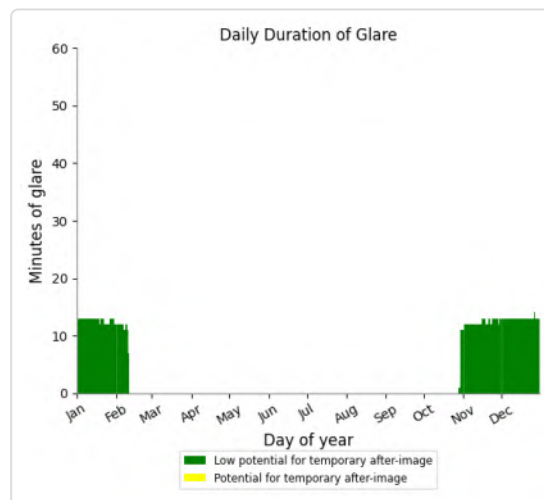
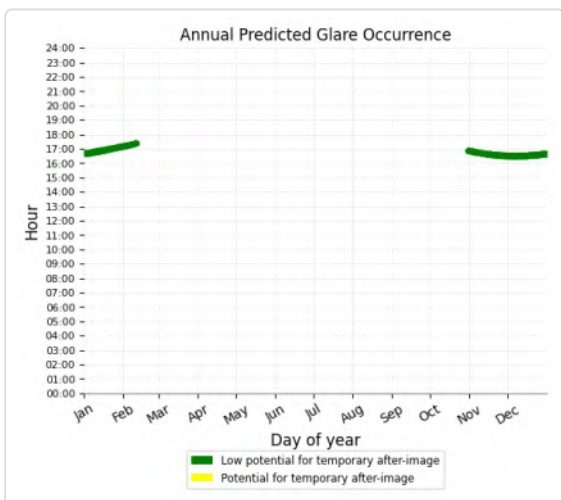
Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Route 2	1,318	22.0	0	0.0
Route 1	0	0.0	0	0.0
FP 1	0	0.0	0	0.0
FP 2	0	0.0	0	0.0
FP 3	0	0.0	0	0.0
FP 4	0	0.0	0	0.0
OP 3	439	7.3	0	0.0
OP 4	1,258	21.0	0	0.0
OP 5	928	15.5	0	0.0
OP 6	715	11.9	0	0.0
OP 8	660	11.0	0	0.0
OP 9	626	10.4	0	0.0
OP 10	683	11.4	0	0.0
OP 1	0	0.0	0	0.0
OP 2	0	0.0	0	0.0
OP 7	0	0.0	0	0.0

PV array 1 and Route: Route 2

Yellow glare: none

Green glare: 1,318 min.



PV array 1 and Route: Route 1

No glare found

PV array 1 and FP: FP 1

No glare found

PV array 1 and FP: FP 2

No glare found

PV array 1 and FP: FP 3

No glare found

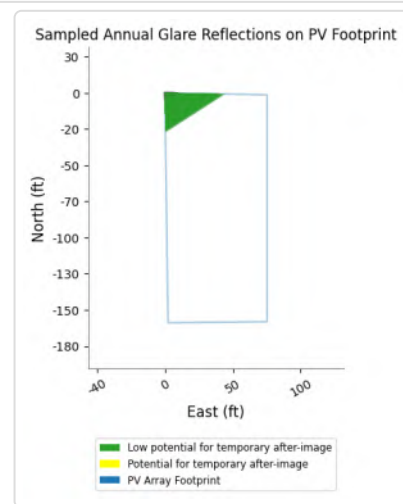
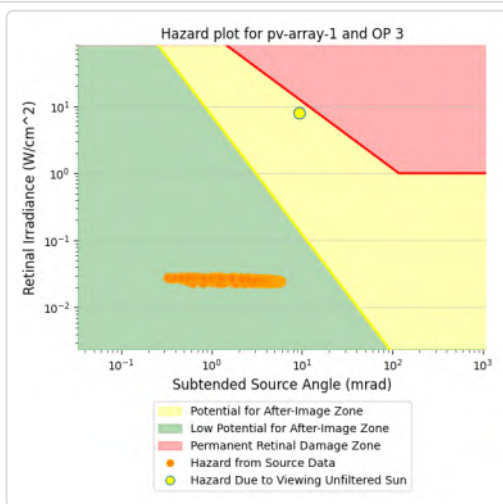
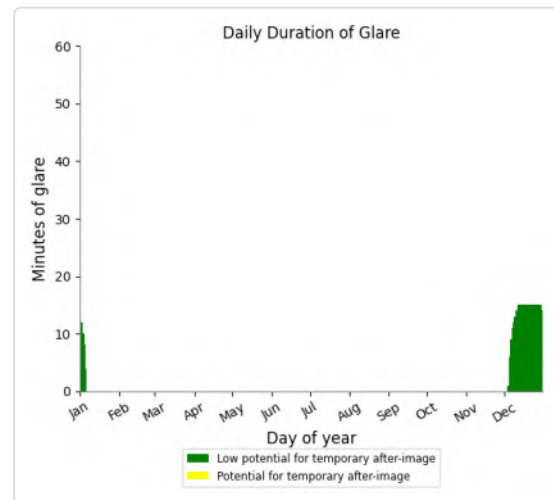
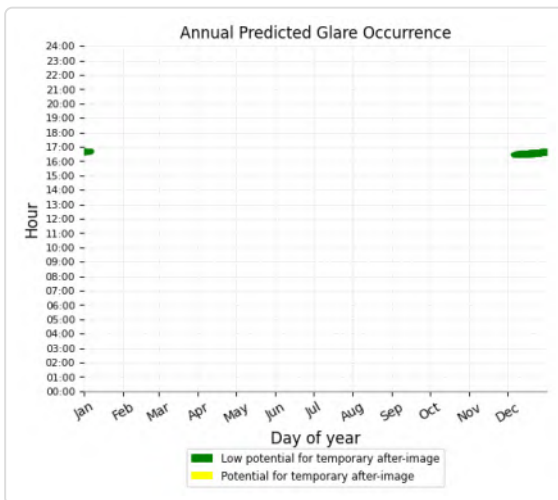
PV array 1 and FP: FP 4

No glare found

PV array 1 and OP 3

Yellow glare: none

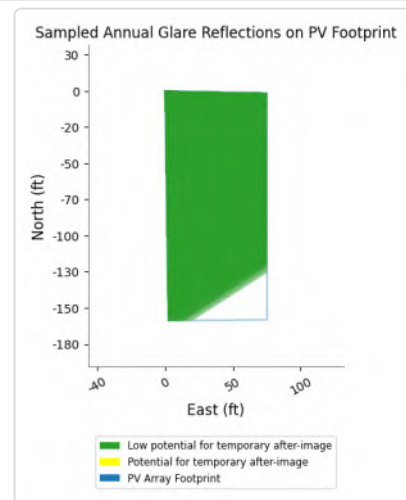
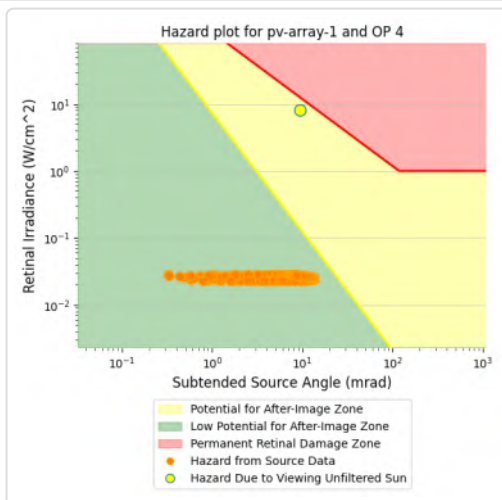
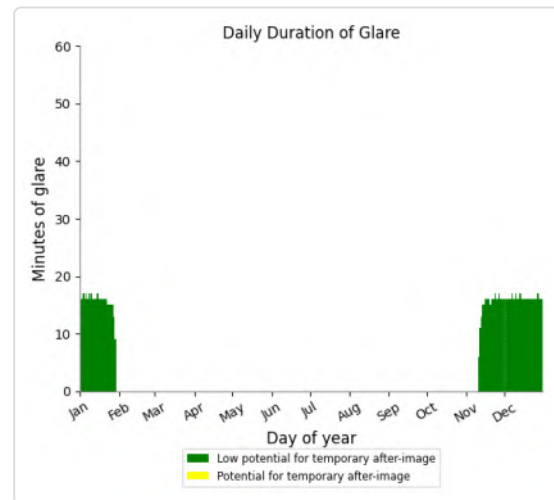
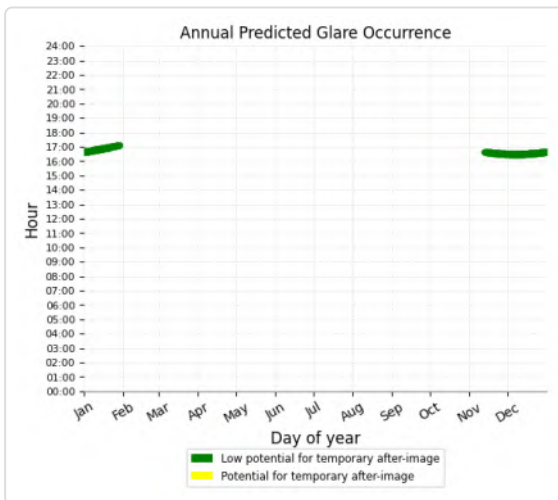
Green glare: 439 min.



PV array 1 and OP 4

Yellow glare: none

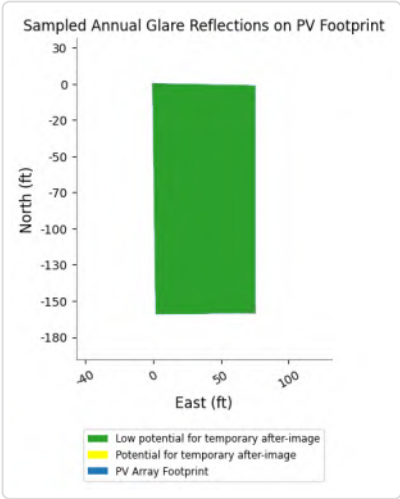
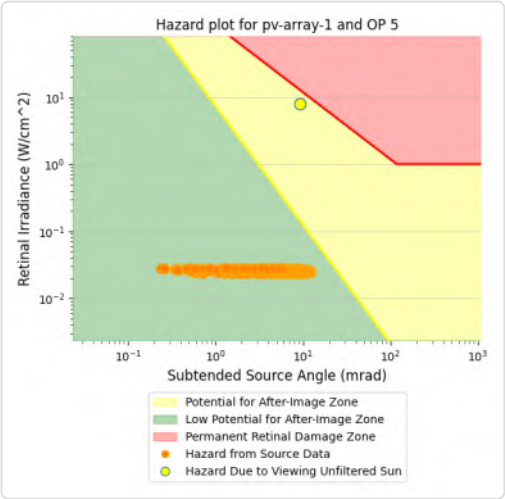
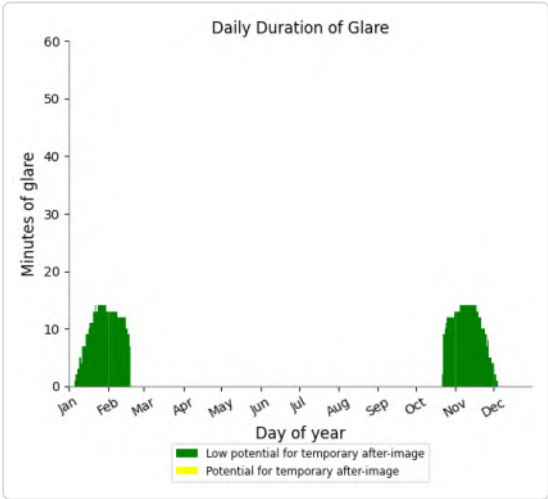
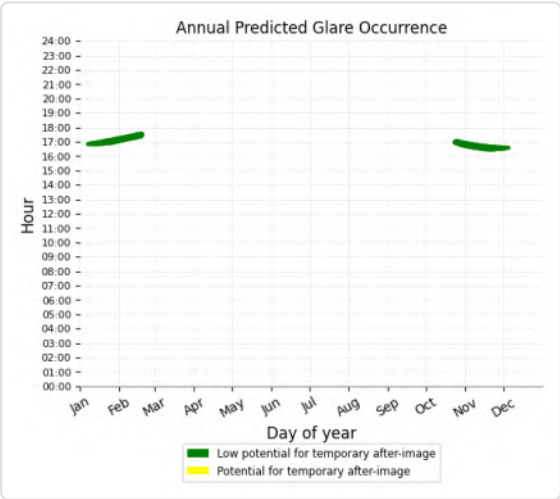
Green glare: 1,258 min.



PV array 1 and OP 5

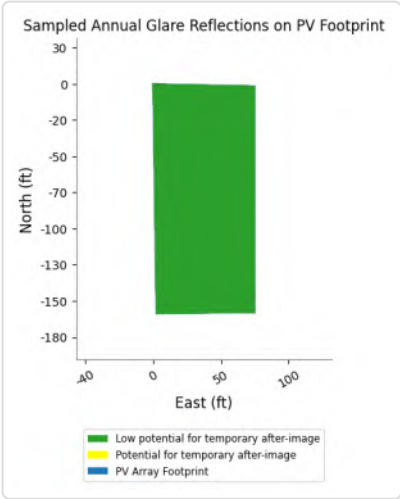
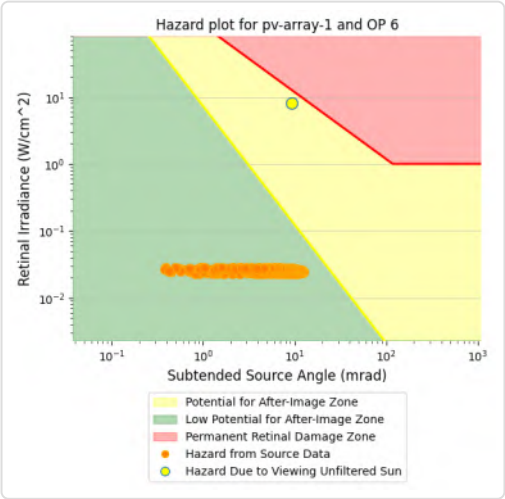
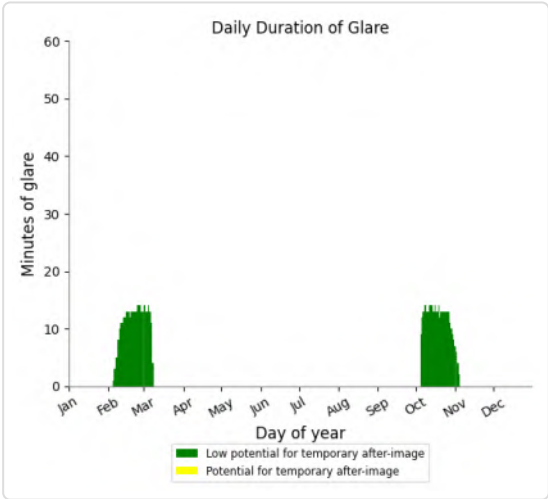
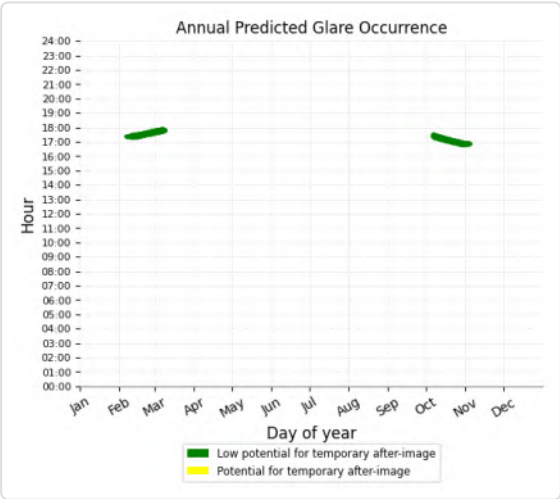
Yellow glare: none

Green glare: 928 min.



PV array 1 and OP 6

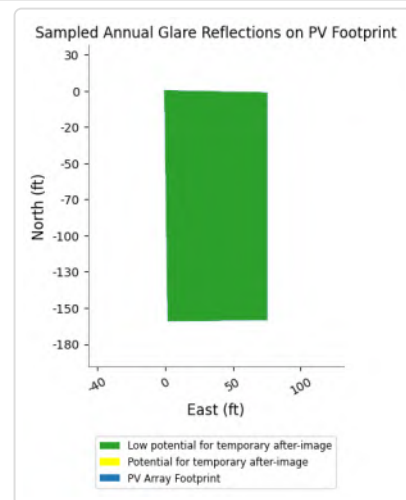
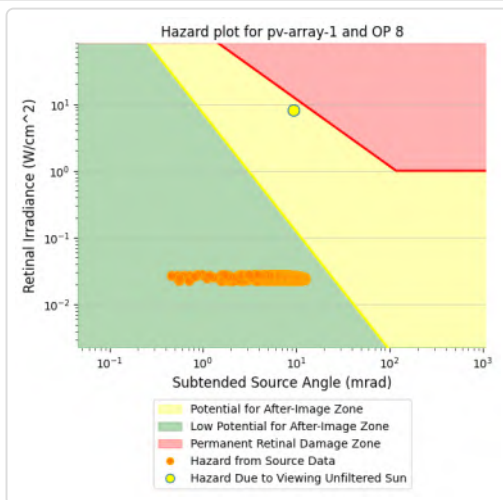
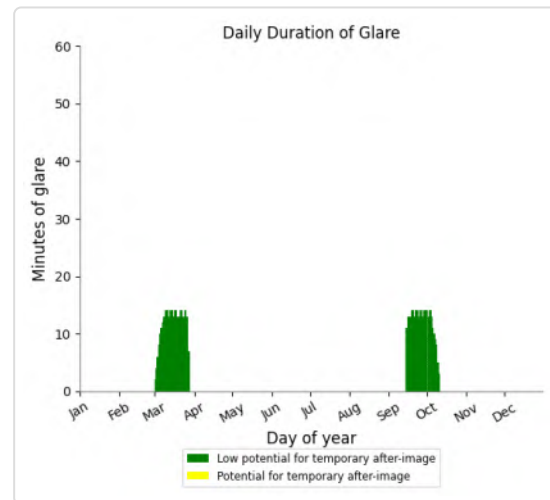
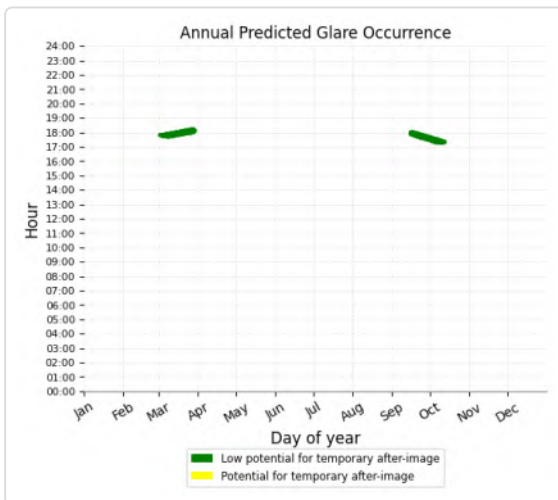
Yellow glare: none
Green glare: 715 min.



PV array 1 and OP 8

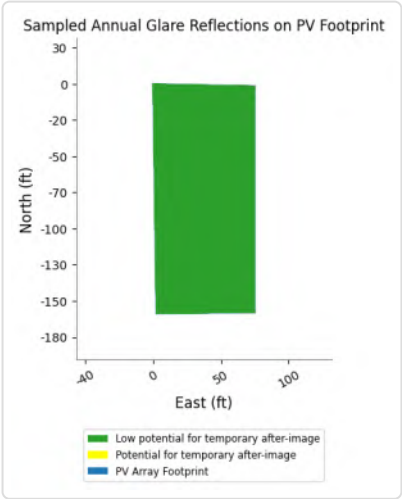
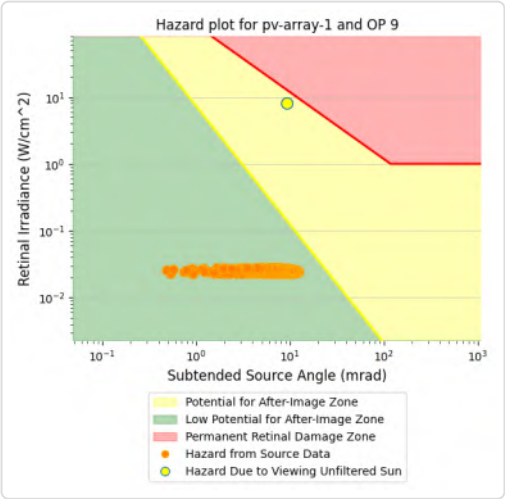
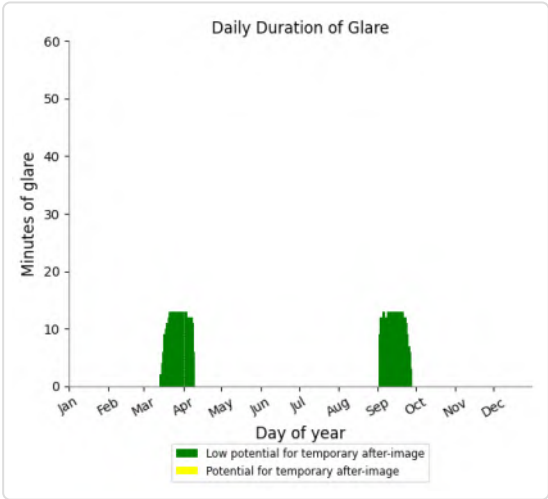
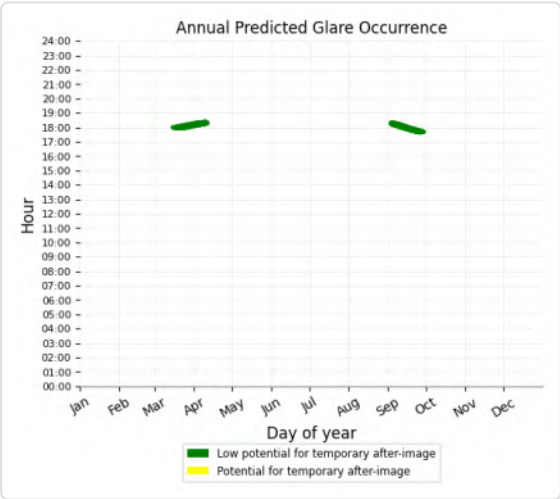
Yellow glare: none

Green glare: 660 min.



PV array 1 and OP 9

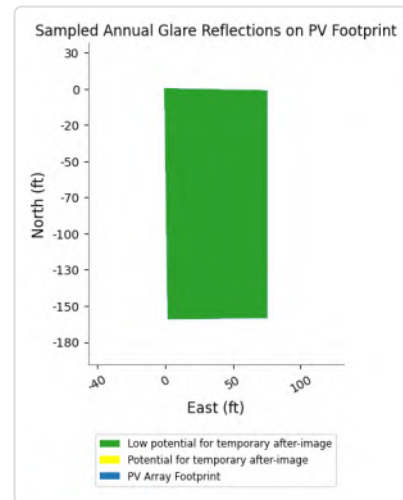
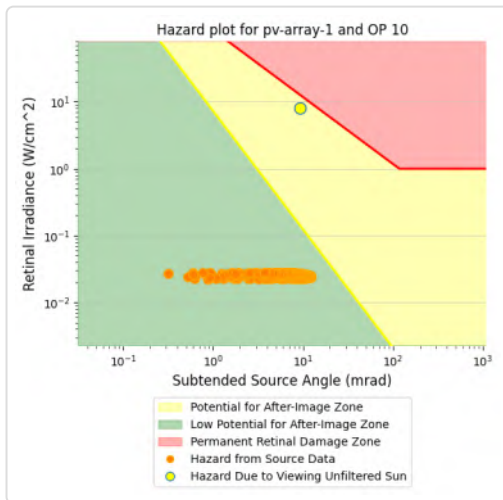
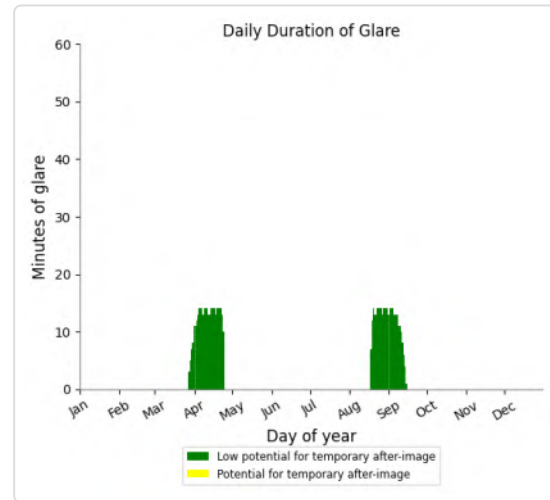
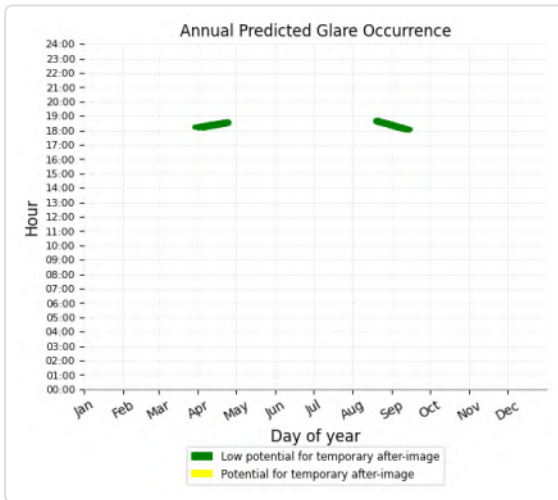
Yellow glare: none
Green glare: 626 min.



PV array 1 and OP 10

Yellow glare: none

Green glare: 683 min.



PV array 1 and OP 1

No glare found

PV array 1 and OP 2

No glare found

PV array 1 and OP 7

No glare found

VS: Vertical surface 1

VS Face: 1-2 low potential for temporary after-image

Receptor results ordered by category of glare

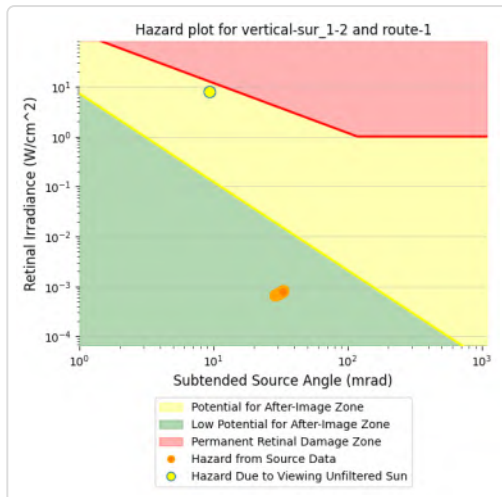
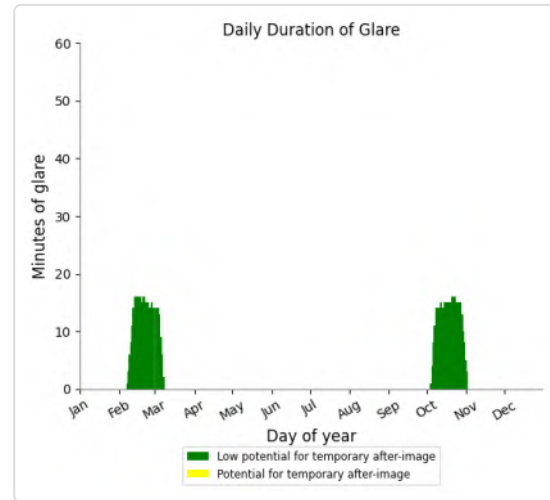
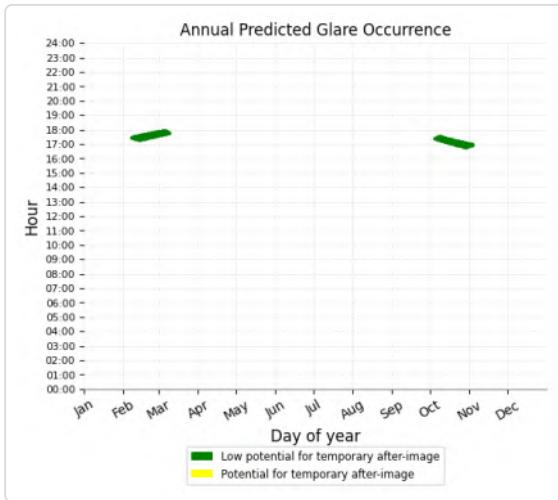
Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Route 1	750	12.5	0	0.0
Route 2	0	0.0	0	0.0
FP 1	0	0.0	0	0.0
FP 2	0	0.0	0	0.0
FP 3	0	0.0	0	0.0
FP 4	0	0.0	0	0.0
OP 1	0	0.0	0	0.0
OP 2	0	0.0	0	0.0
OP 3	0	0.0	0	0.0
OP 4	0	0.0	0	0.0
OP 5	0	0.0	0	0.0
OP 6	0	0.0	0	0.0
OP 7	0	0.0	0	0.0
OP 8	0	0.0	0	0.0
OP 9	0	0.0	0	0.0
OP 10	0	0.0	0	0.0

Route 1

Receptor type: Route

0 minutes of yellow glare

750 minutes of green glare



Route 2

Receptor type: Route

No glare found

FP 1

Receptor type: 2-mile Flight Path

No glare found

FP 2

Receptor type: 2-mile Flight Path

No glare found

FP 3

Receptor type: 2-mile Flight Path

No glare found

FP 4

Receptor type: 2-mile Flight Path

No glare found

OP 1

Receptor type: Observation Point

No glare found

OP 2

Receptor type: Observation Point

No glare found

OP 3

Receptor type: Observation Point
No glare found

OP 4

Receptor type: Observation Point
No glare found

OP 5

Receptor type: Observation Point
No glare found

OP 6

Receptor type: Observation Point
No glare found

OP 7

Receptor type: Observation Point
No glare found

OP 8

Receptor type: Observation Point
No glare found

OP 9

Receptor type: Observation Point
No glare found

OP 10

Receptor type: Observation Point
No glare found

VS Face: 2-3 potential temporary after-image

Receptor results ordered by category of glare

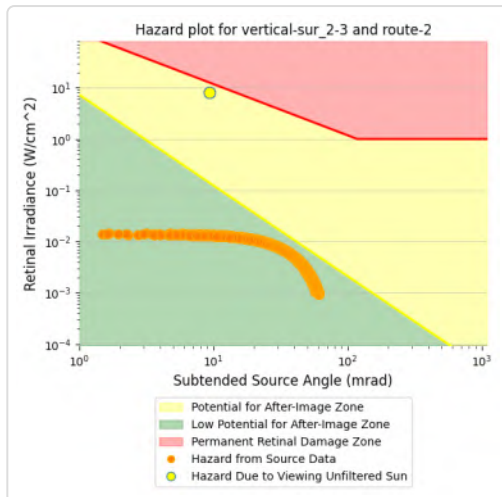
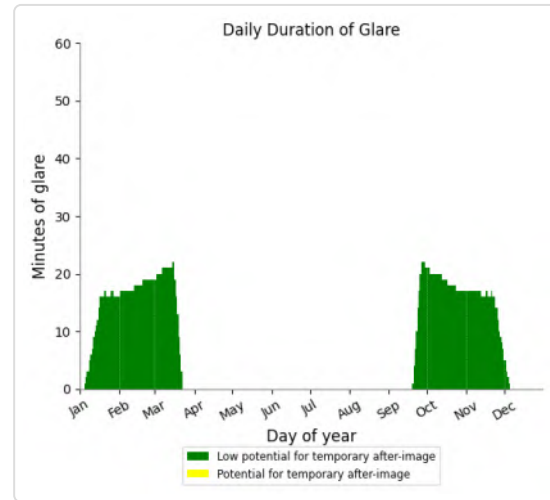
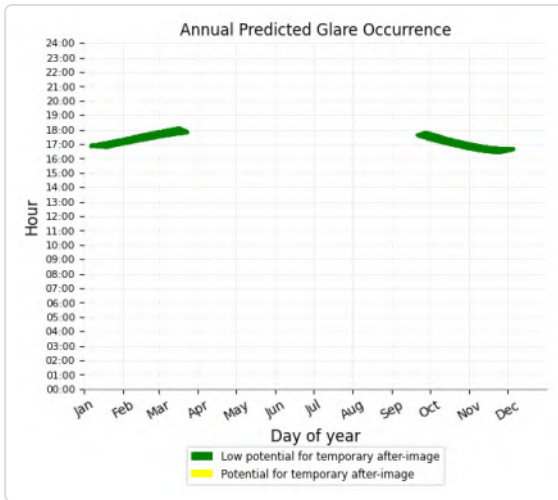
Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Route 2	2,436	40.6	0	0.0
Route 1	0	0.0	0	0.0
FP 1	0	0.0	0	0.0
FP 2	0	0.0	0	0.0
FP 3	0	0.0	0	0.0
FP 4	0	0.0	0	0.0
OP 3	0	0.0	603	10.1
OP 1	2,470	41.2	0	0.0
OP 2	2,223	37.0	0	0.0
OP 4	220	3.7	0	0.0
OP 5	0	0.0	0	0.0
OP 6	0	0.0	0	0.0
OP 7	0	0.0	0	0.0
OP 8	0	0.0	0	0.0
OP 9	0	0.0	0	0.0
OP 10	0	0.0	0	0.0

Route 2

Receptor type: Route

0 minutes of yellow glare

2,436 minutes of green glare



Route 1

Receptor type: Route

No glare found

FP 1

Receptor type: 2-mile Flight Path

No glare found

FP 3

Receptor type: 2-mile Flight Path

No glare found

FP 2

Receptor type: 2-mile Flight Path

No glare found

FP 4

Receptor type: 2-mile Flight Path

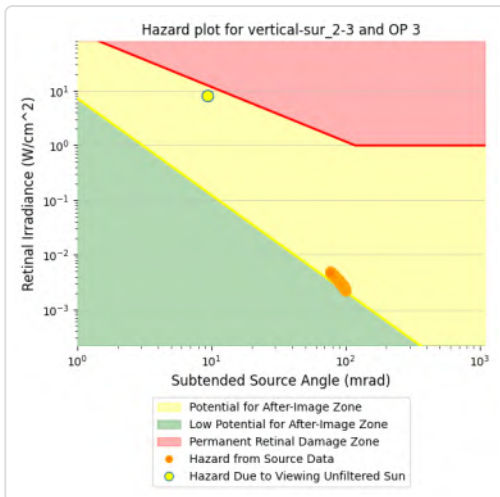
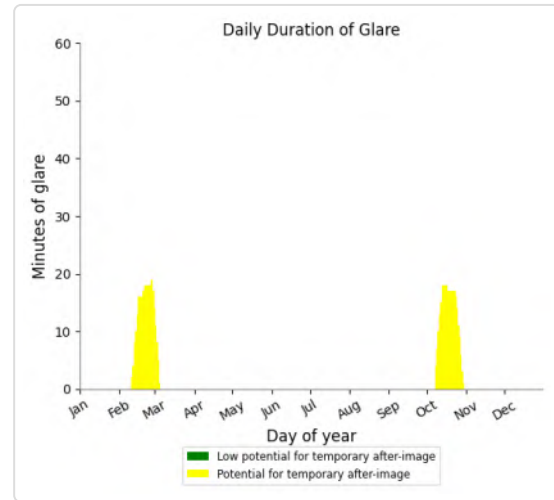
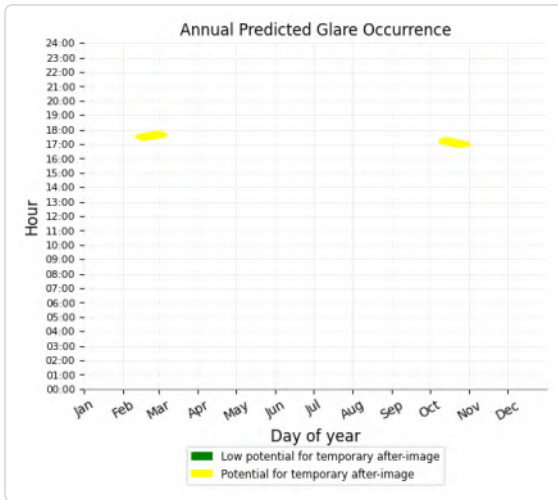
No glare found

OP 3

Receptor type: Observation Point

603 minutes of yellow glare

0 minutes of green glare

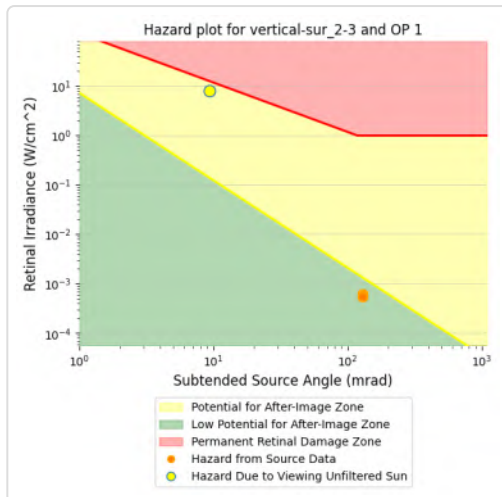
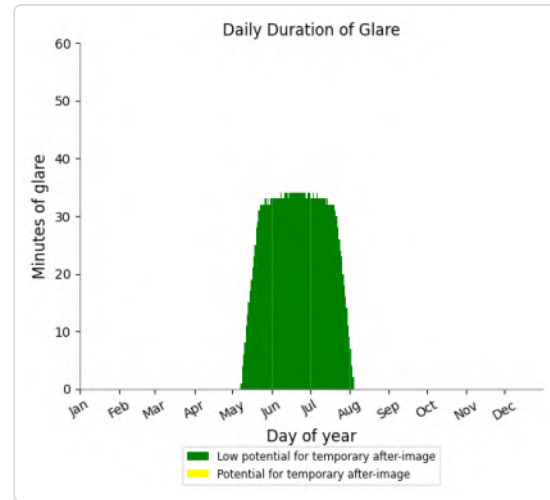
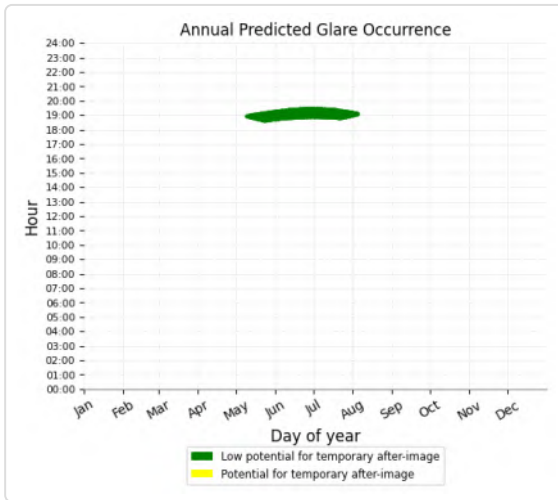


OP 1

Receptor type: Observation Point

0 minutes of yellow glare

2,470 minutes of green glare

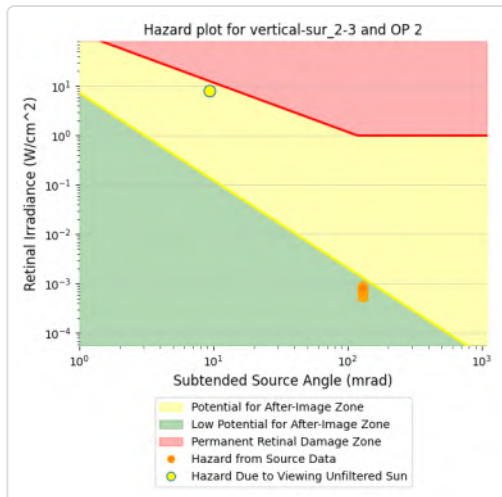
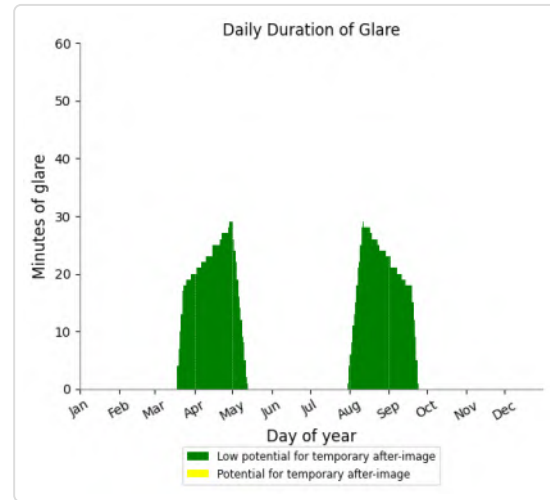
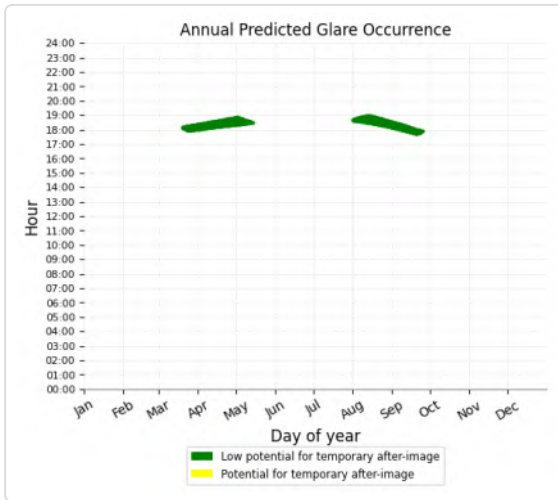


OP 2

Receptor type: Observation Point

0 minutes of yellow glare

2,223 minutes of green glare

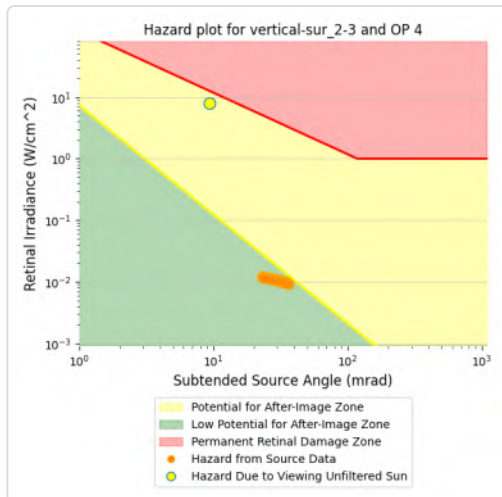
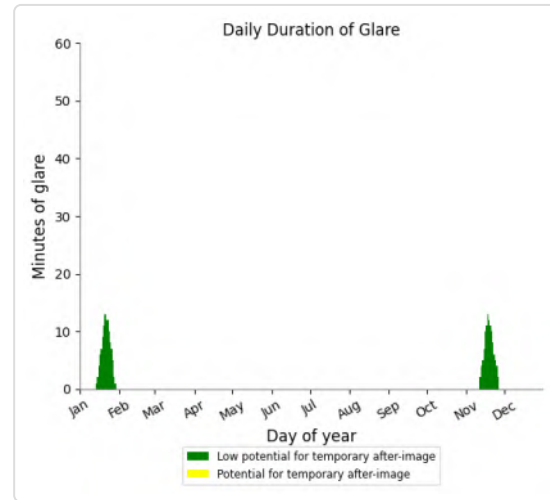
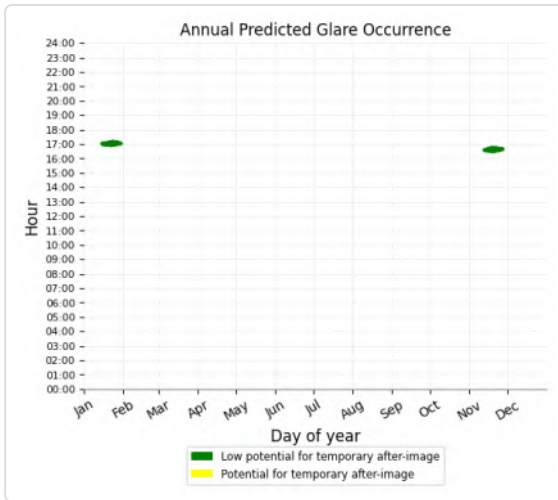


OP 4

Receptor type: Observation Point

0 minutes of yellow glare

220 minutes of green glare



OP 5

Receptor type: Observation Point

No glare found

OP 7

Receptor type: Observation Point

No glare found

OP 9

Receptor type: Observation Point

No glare found

OP 6

Receptor type: Observation Point

No glare found

OP 8

Receptor type: Observation Point

No glare found

OP 10

Receptor type: Observation Point

No glare found

VS Face: 3-4 low potential for temporary after-image

Receptor results ordered by category of glare

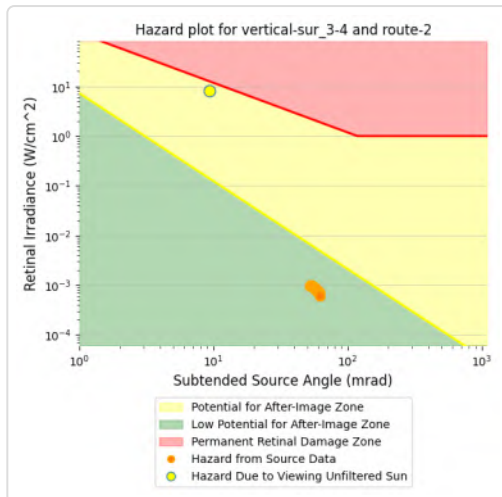
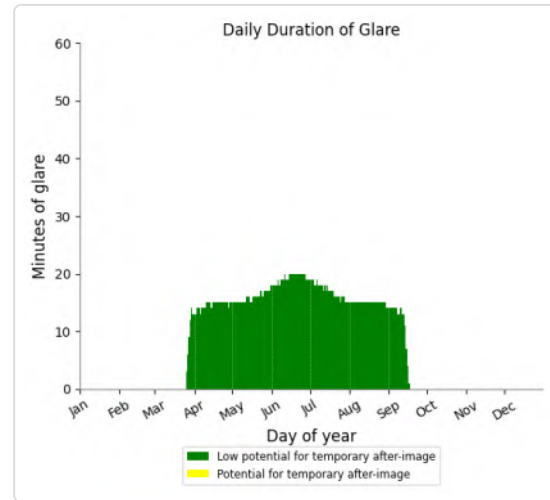
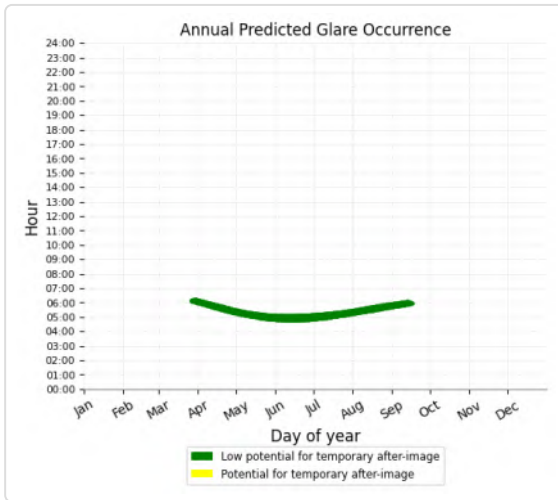
Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Route 2	2,754	45.9	0	0.0
Route 1	0	0.0	0	0.0
FP 1	0	0.0	0	0.0
FP 2	0	0.0	0	0.0
FP 3	0	0.0	0	0.0
FP 4	0	0.0	0	0.0
OP 2	670	11.2	0	0.0
OP 3	688	11.5	0	0.0
OP 4	745	12.4	0	0.0
OP 5	965	16.1	0	0.0
OP 1	0	0.0	0	0.0
OP 6	0	0.0	0	0.0
OP 7	0	0.0	0	0.0
OP 8	0	0.0	0	0.0
OP 9	0	0.0	0	0.0
OP 10	0	0.0	0	0.0

Route 2

Receptor type: Route

0 minutes of yellow glare

2,754 minutes of green glare



Route 1

Receptor type: Route

No glare found

FP 1

Receptor type: 2-mile Flight Path

No glare found

FP 3

Receptor type: 2-mile Flight Path

No glare found

FP 2

Receptor type: 2-mile Flight Path

No glare found

FP 4

Receptor type: 2-mile Flight Path

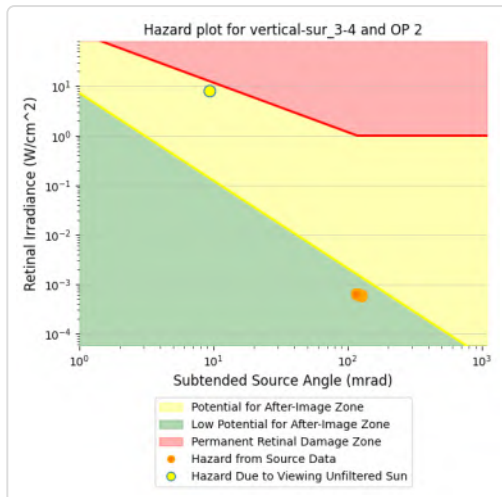
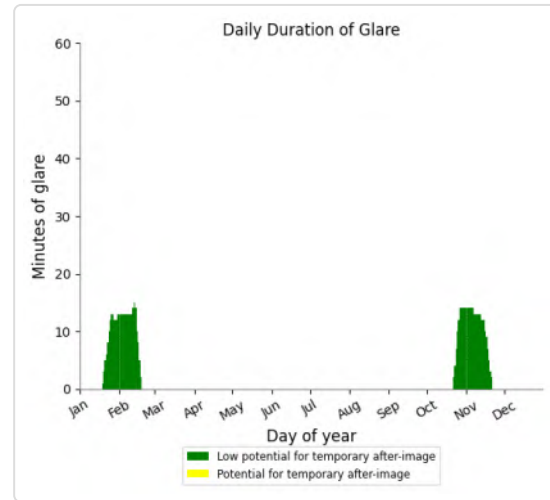
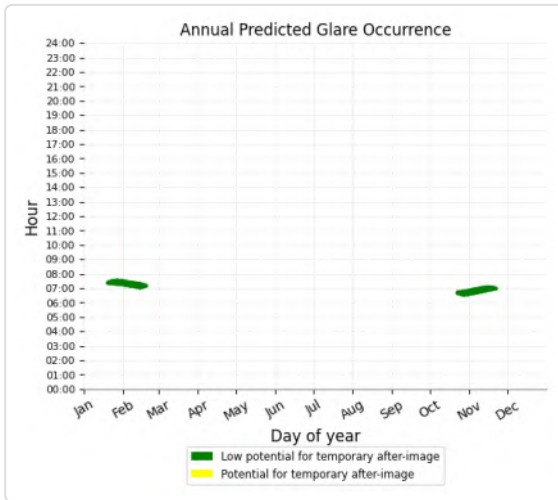
No glare found

OP 2

Receptor type: Observation Point

0 minutes of yellow glare

670 minutes of green glare

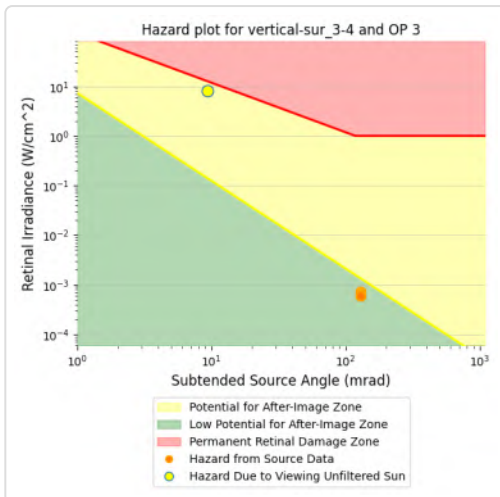
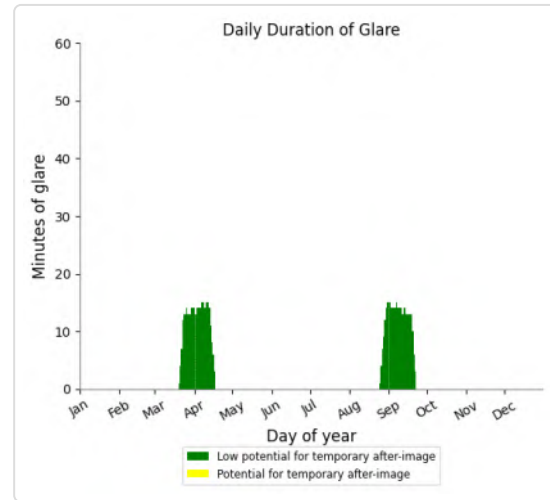
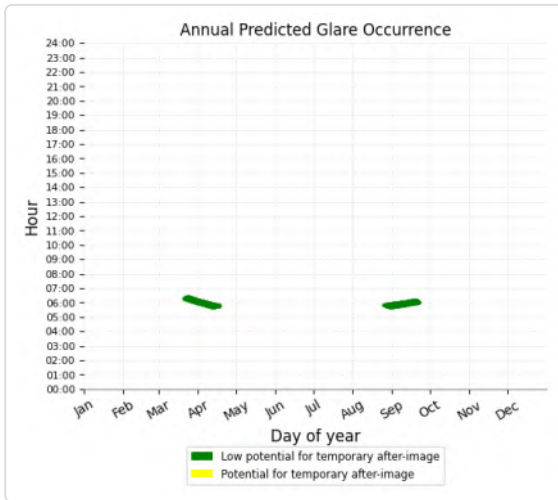


OP 3

Receptor type: Observation Point

0 minutes of yellow glare

688 minutes of green glare

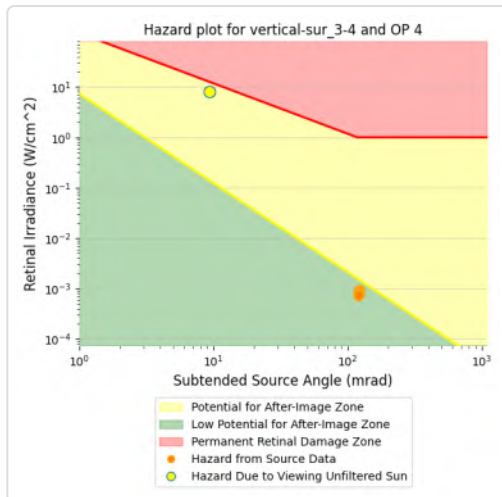
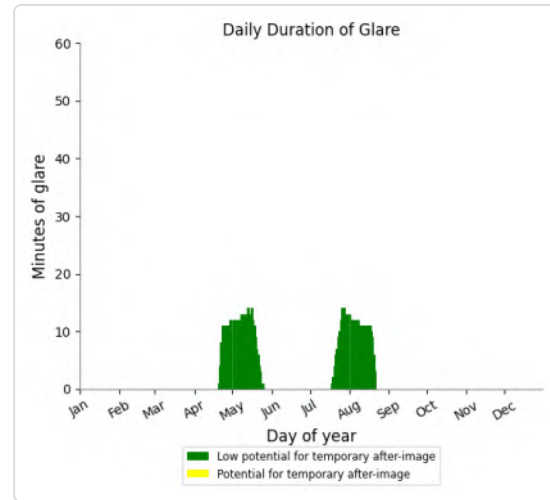
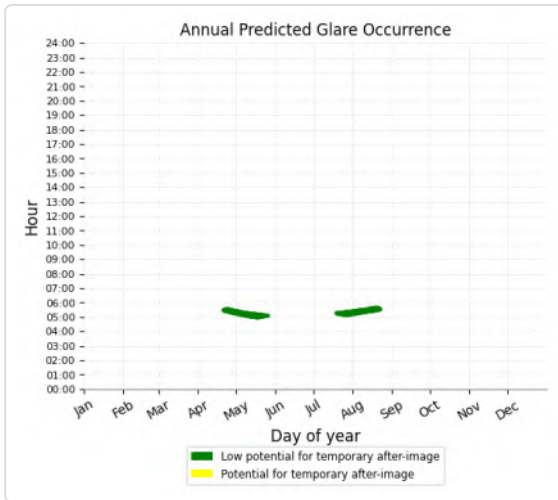


OP 4

Receptor type: Observation Point

0 minutes of yellow glare

745 minutes of green glare

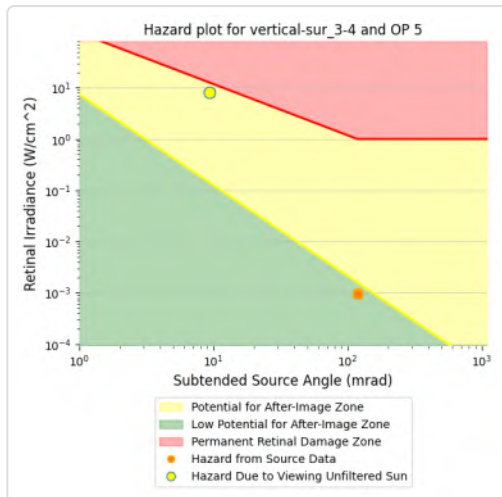
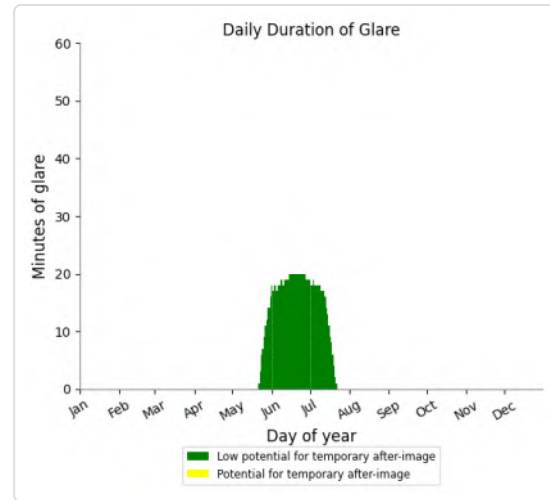
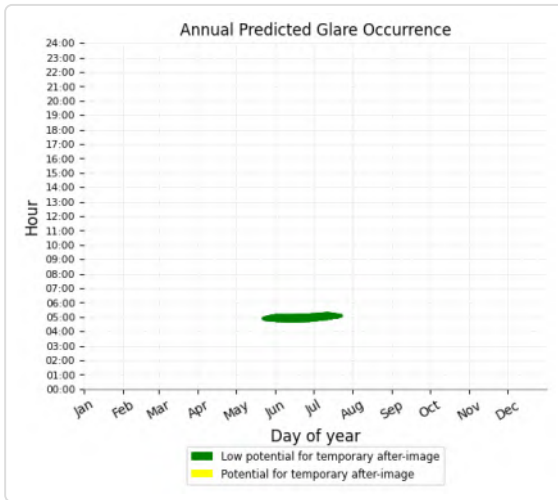


OP 5

Receptor type: Observation Point

0 minutes of yellow glare

965 minutes of green glare



OP 1

Receptor type: Observation Point

No glare found

OP 6

Receptor type: Observation Point

No glare found

OP 7

Receptor type: Observation Point

No glare found

OP 8

Receptor type: Observation Point

No glare found

OP 9

Receptor type: Observation Point

No glare found

OP 10

Receptor type: Observation Point

No glare found

VS: Vertical surface 2

VS Face: 1-2 low potential for temporary after-image

Receptor results ordered by category of glare

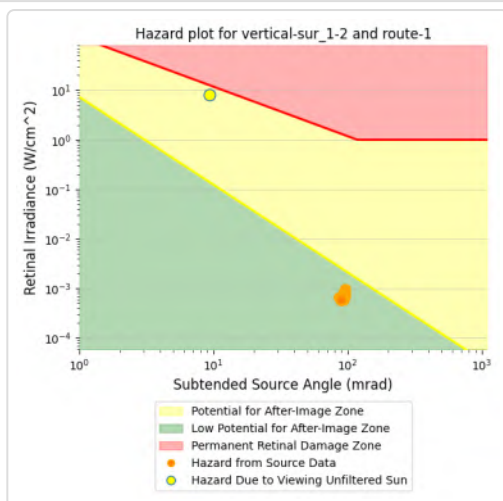
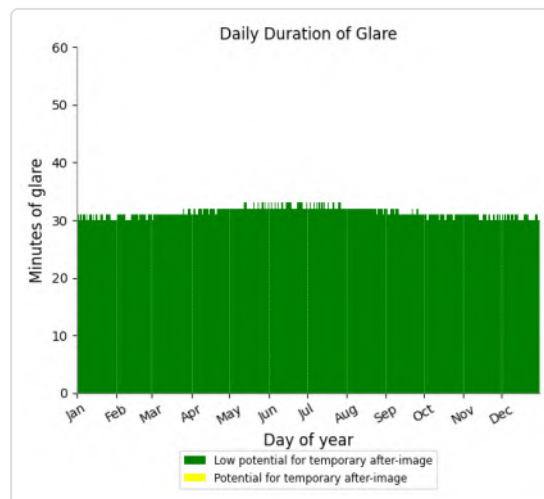
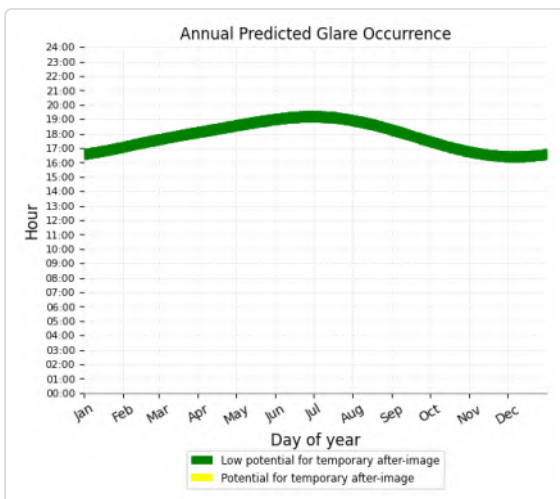
Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Route 1	11,450	190.8	0	0.0
Route 2	0	0.0	0	0.0
FP 1	0	0.0	0	0.0
FP 2	0	0.0	0	0.0
FP 3	0	0.0	0	0.0
FP 4	0	0.0	0	0.0
OP 1	0	0.0	0	0.0
OP 2	0	0.0	0	0.0
OP 3	0	0.0	0	0.0
OP 4	0	0.0	0	0.0
OP 5	0	0.0	0	0.0
OP 6	0	0.0	0	0.0
OP 7	0	0.0	0	0.0
OP 8	0	0.0	0	0.0
OP 9	0	0.0	0	0.0
OP 10	0	0.0	0	0.0

Route 1

Receptor type: Route

0 minutes of yellow glare

11,450 minutes of green glare



Route 2

Receptor type: Route

No glare found

FP 1

Receptor type: 2-mile Flight Path

No glare found

FP 2

Receptor type: 2-mile Flight Path

No glare found

FP 3

Receptor type: 2-mile Flight Path

No glare found

FP 4

Receptor type: 2-mile Flight Path

No glare found

OP 1

Receptor type: Observation Point

No glare found

OP 2

Receptor type: Observation Point

No glare found

OP 3

Receptor type: Observation Point
No glare found

OP 4

Receptor type: Observation Point
No glare found

OP 5

Receptor type: Observation Point
No glare found

OP 6

Receptor type: Observation Point
No glare found

OP 7

Receptor type: Observation Point
No glare found

OP 8

Receptor type: Observation Point
No glare found

OP 9

Receptor type: Observation Point
No glare found

OP 10

Receptor type: Observation Point
No glare found

VS: Vertical surface 3

VS Face: 1-2 low potential for temporary after-image

Receptor results ordered by category of glare

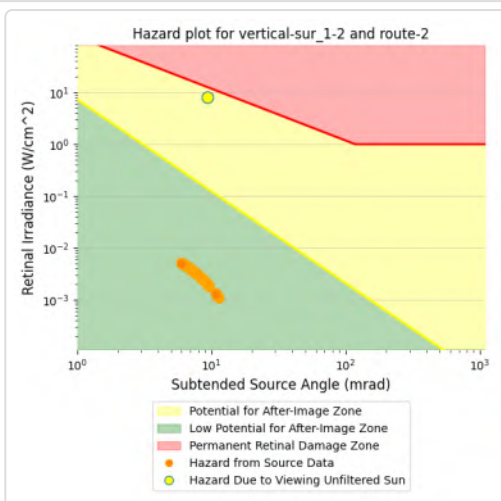
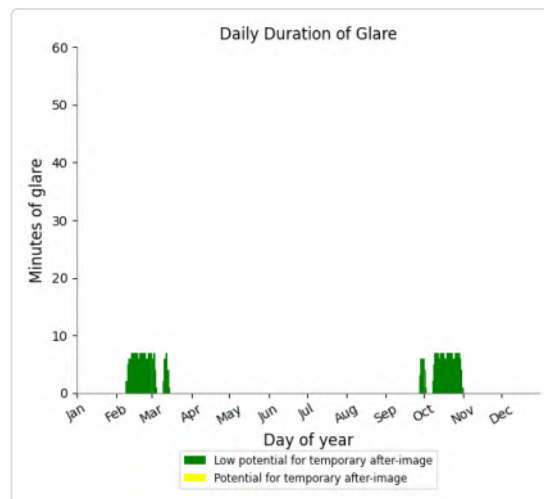
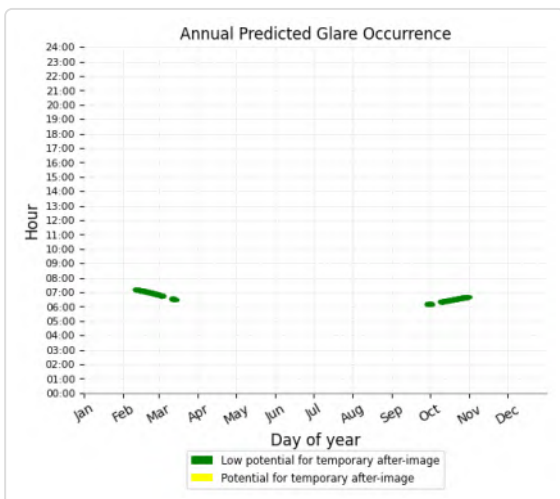
Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Route 2	361	6.0	0	0.0
Route 1	0	0.0	0	0.0
FP 1	0	0.0	0	0.0
FP 2	0	0.0	0	0.0
FP 3	0	0.0	0	0.0
FP 4	0	0.0	0	0.0
OP 1	3	0.1	0	0.0
OP 2	7	0.1	0	0.0
OP 3	29	0.5	0	0.0
OP 4	76	1.3	0	0.0
OP 7	2	0.0	0	0.0
OP 5	0	0.0	0	0.0
OP 6	0	0.0	0	0.0
OP 8	0	0.0	0	0.0
OP 9	0	0.0	0	0.0
OP 10	0	0.0	0	0.0

Route 2

Receptor type: Route

0 minutes of yellow glare

361 minutes of green glare



Route 1

Receptor type: Route

No glare found

FP 1

Receptor type: 2-mile Flight Path

No glare found

FP 3

Receptor type: 2-mile Flight Path

No glare found

FP 2

Receptor type: 2-mile Flight Path

No glare found

FP 4

Receptor type: 2-mile Flight Path

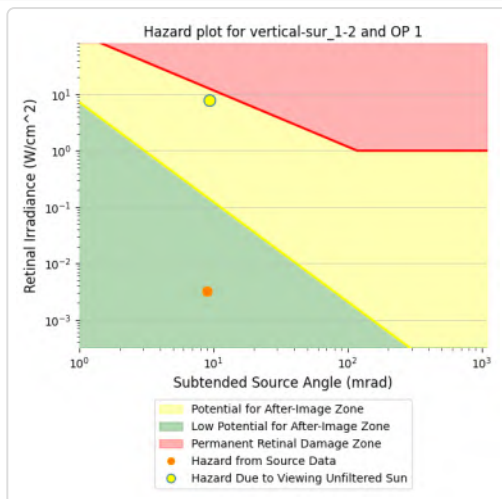
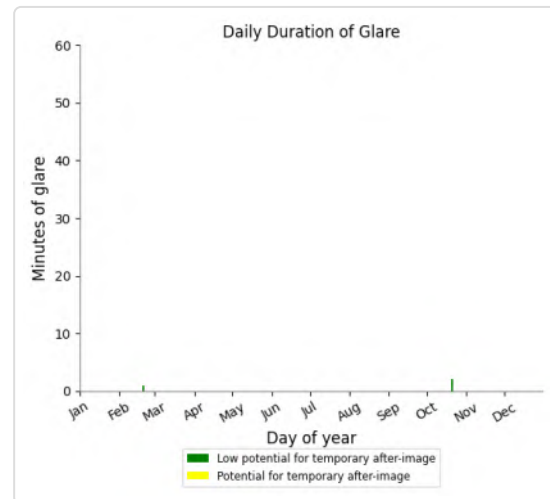
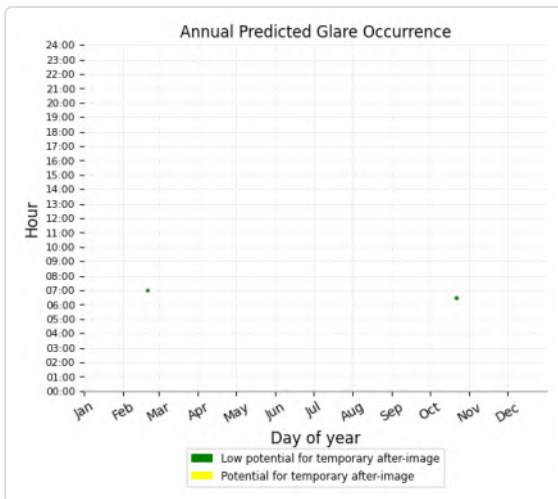
No glare found

OP 1

Receptor type: Observation Point

0 minutes of yellow glare

3 minutes of green glare

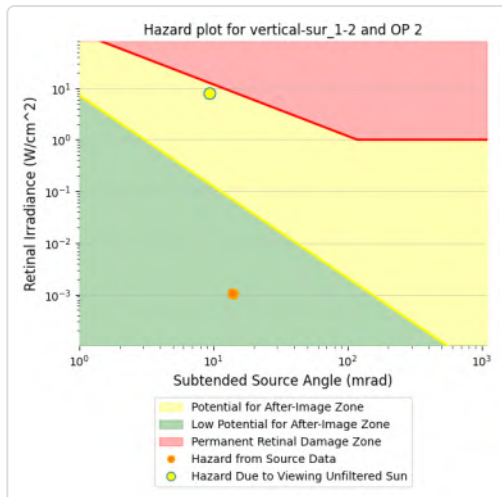
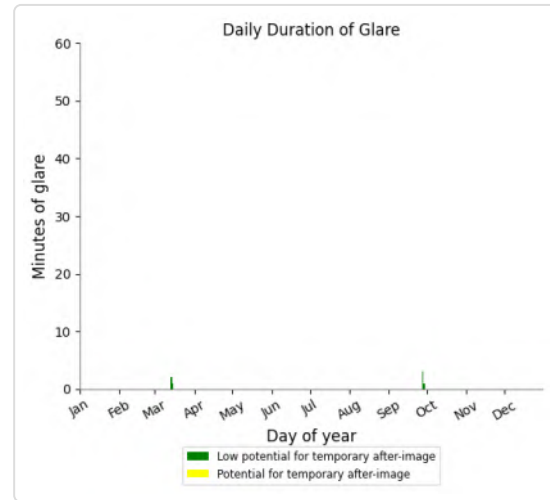
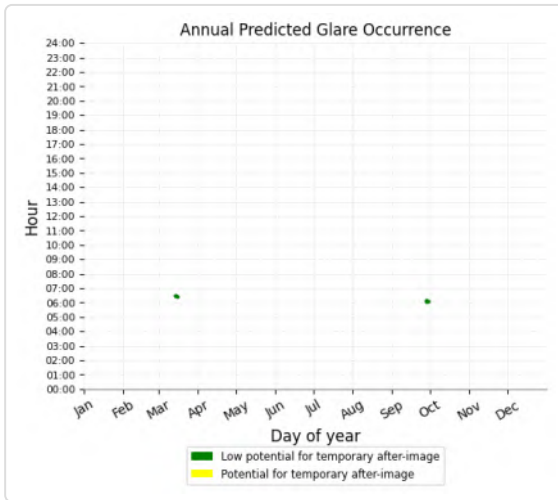


OP 2

Receptor type: Observation Point

0 minutes of yellow glare

7 minutes of green glare

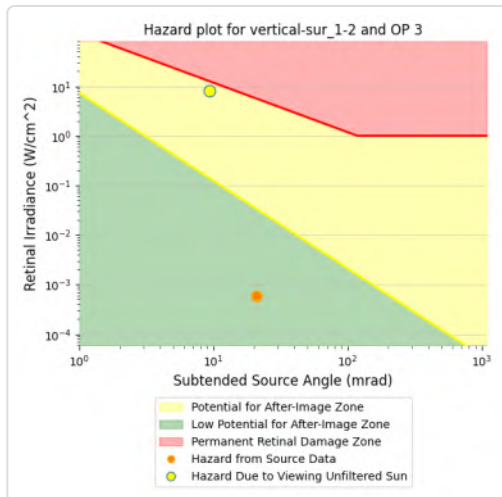
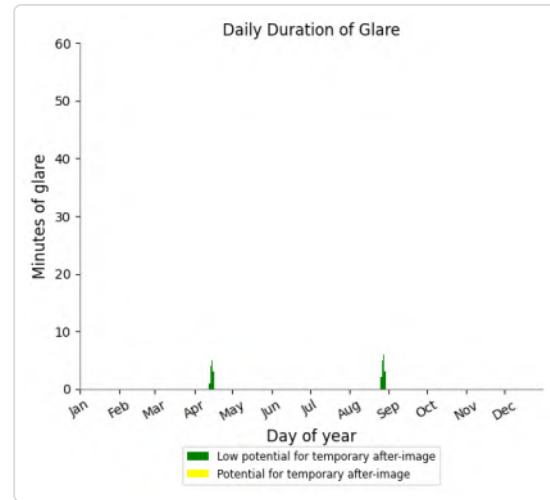
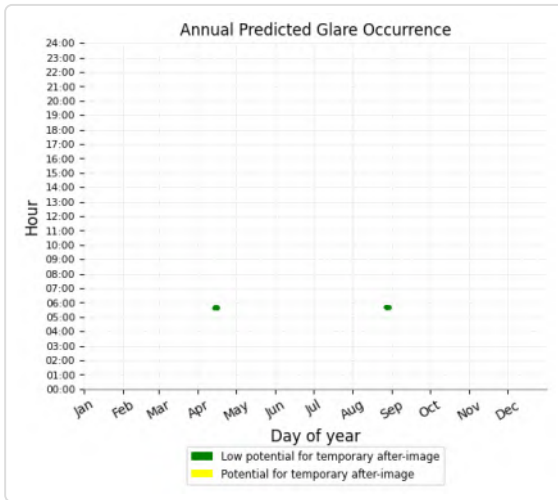


OP 3

Receptor type: Observation Point

0 minutes of yellow glare

29 minutes of green glare

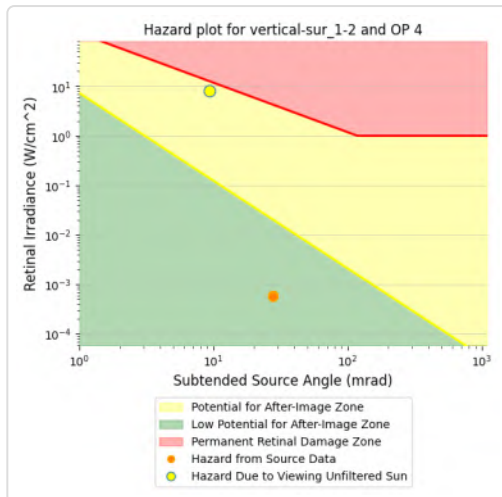
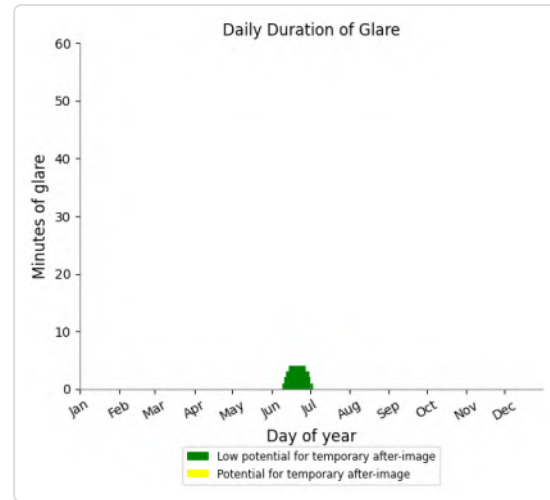
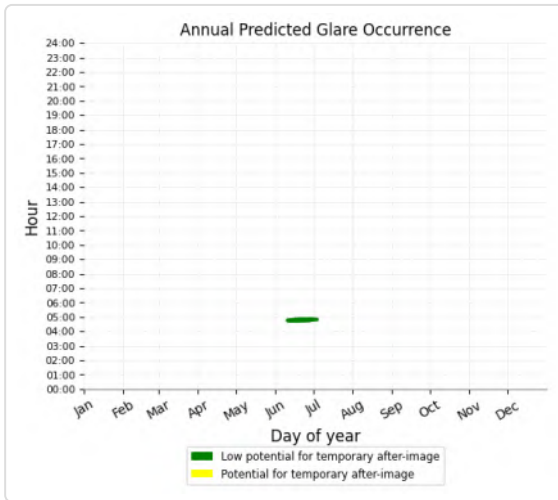


OP 4

Receptor type: Observation Point

0 minutes of yellow glare

76 minutes of green glare

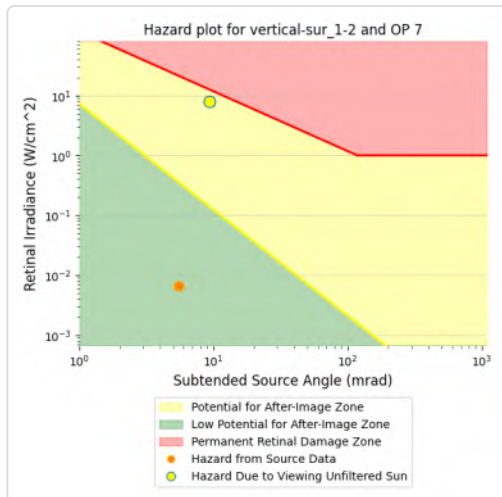
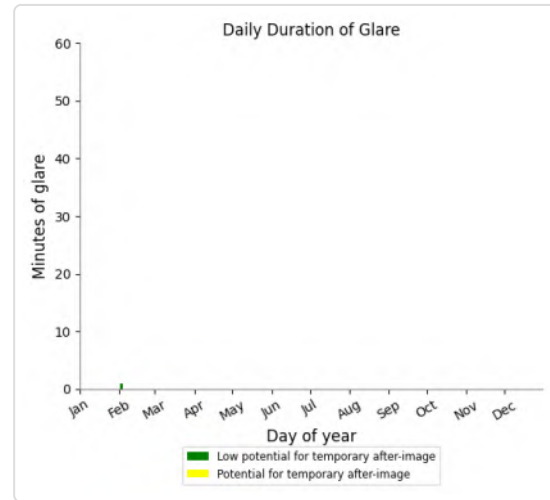
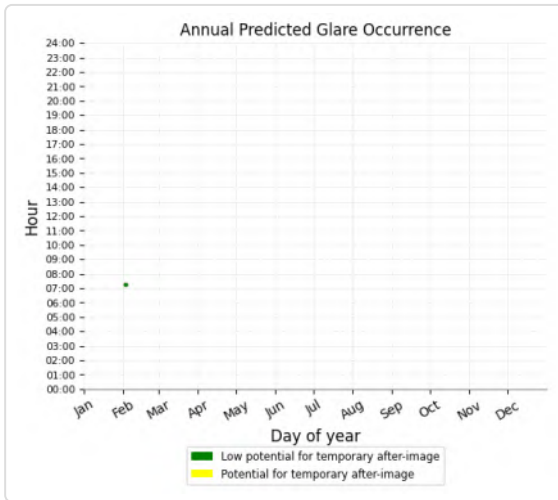


OP 7

Receptor type: Observation Point

0 minutes of yellow glare

2 minutes of green glare



OP 5

Receptor type: Observation Point

No glare found

OP 6

Receptor type: Observation Point

No glare found

OP 8

Receptor type: Observation Point

No glare found

OP 9

Receptor type: Observation Point

No glare found

OP 10

Receptor type: Observation Point

No glare found

VS Face: 2-3 low potential for temporary after-image

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Route 1	0	0.0	0	0.0
Route 2	0	0.0	0	0.0
FP 1	0	0.0	0	0.0
FP 2	0	0.0	0	0.0
FP 3	0	0.0	0	0.0
FP 4	0	0.0	0	0.0
OP 10	898	15.0	0	0.0
OP 1	0	0.0	0	0.0
OP 2	0	0.0	0	0.0
OP 3	0	0.0	0	0.0
OP 4	0	0.0	0	0.0
OP 5	0	0.0	0	0.0
OP 6	0	0.0	0	0.0
OP 7	0	0.0	0	0.0
OP 8	0	0.0	0	0.0
OP 9	0	0.0	0	0.0

Route 1

Receptor type: Route

No glare found

Route 2

Receptor type: Route

No glare found

FP 1

Receptor type: 2-mile Flight Path

No glare found

FP 2

Receptor type: 2-mile Flight Path

No glare found

FP 3

Receptor type: 2-mile Flight Path

No glare found

FP 4

Receptor type: 2-mile Flight Path

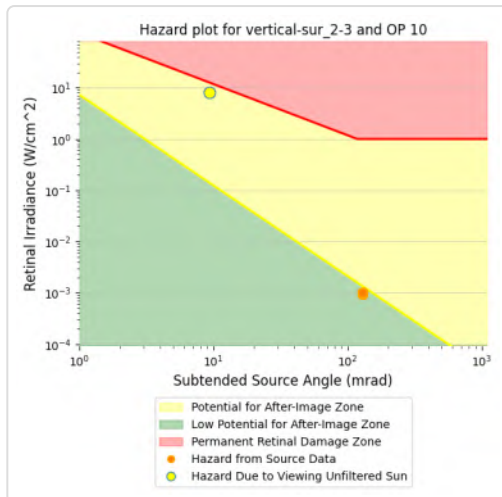
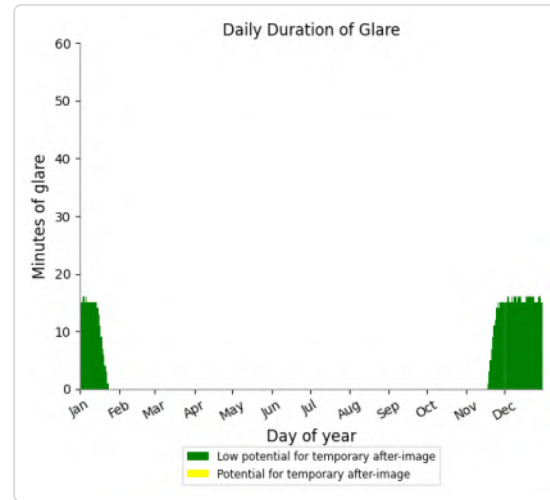
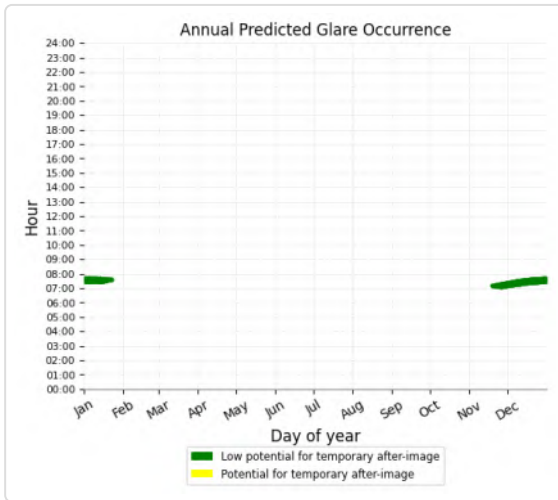
No glare found

OP 10

Receptor type: Observation Point

0 minutes of yellow glare

898 minutes of green glare



OP 1

Receptor type: Observation Point

No glare found

OP 2

Receptor type: Observation Point

No glare found

OP 3

Receptor type: Observation Point

No glare found

OP 4

Receptor type: Observation Point

No glare found

OP 5

Receptor type: Observation Point

No glare found

OP 6

Receptor type: Observation Point

No glare found

OP 7

Receptor type: Observation Point

No glare found

OP 8

Receptor type: Observation Point

No glare found

OP 9

Receptor type: Observation Point

No glare found

VS Face: 3-4 no glare found

Receptor results ordered by category of glare

Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Route 1	0	0.0	0	0.0
Route 2	0	0.0	0	0.0
FP 1	0	0.0	0	0.0
FP 2	0	0.0	0	0.0
FP 3	0	0.0	0	0.0
FP 4	0	0.0	0	0.0
OP 1	0	0.0	0	0.0
OP 2	0	0.0	0	0.0
OP 3	0	0.0	0	0.0
OP 4	0	0.0	0	0.0
OP 5	0	0.0	0	0.0
OP 6	0	0.0	0	0.0
OP 7	0	0.0	0	0.0
OP 8	0	0.0	0	0.0
OP 9	0	0.0	0	0.0
OP 10	0	0.0	0	0.0

Route 1

Receptor type: Route

No glare found

Route 2

Receptor type: Route

No glare found

FP 1

Receptor type: 2-mile Flight Path

No glare found

FP 2

Receptor type: 2-mile Flight Path

No glare found

FP 3

Receptor type: 2-mile Flight Path

No glare found

FP 4

Receptor type: 2-mile Flight Path

No glare found

OP 1

Receptor type: Observation Point

No glare found

OP 2

Receptor type: Observation Point

No glare found

OP 3

Receptor type: Observation Point
No glare found

OP 4

Receptor type: Observation Point
No glare found

OP 5

Receptor type: Observation Point
No glare found

OP 6

Receptor type: Observation Point
No glare found

OP 7

Receptor type: Observation Point
No glare found

OP 8

Receptor type: Observation Point
No glare found

OP 9

Receptor type: Observation Point
No glare found

OP 10

Receptor type: Observation Point
No glare found

VS Face: 4-5 low potential for temporary after-image

Receptor results ordered by category of glare

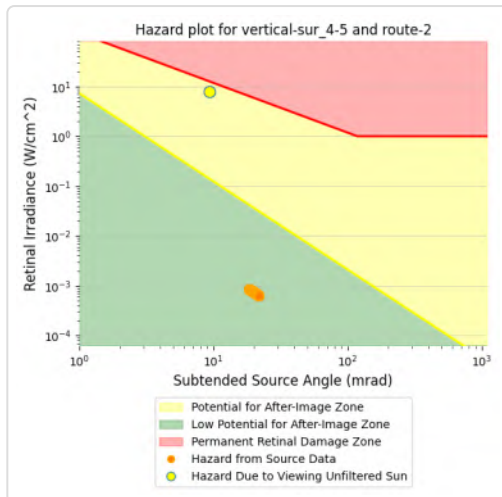
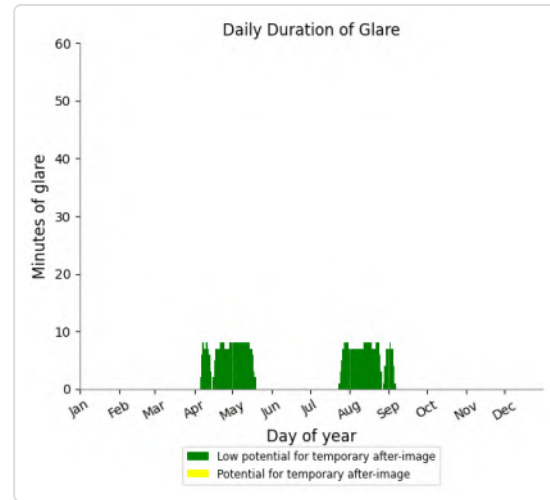
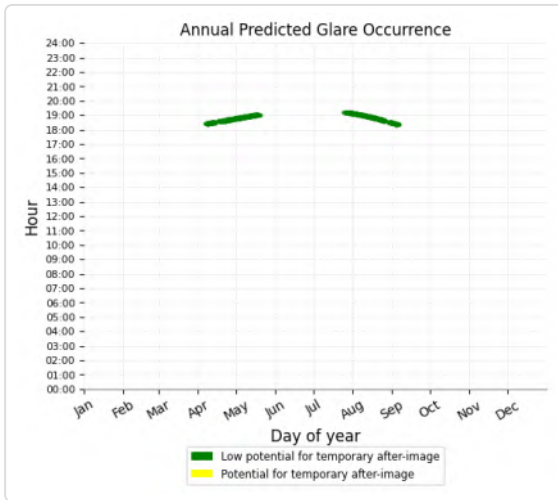
Receptor	Annual Green Glare		Annual Yellow Glare	
	min	hr	min	hr
Route 2	581	9.7	0	0.0
Route 1	0	0.0	0	0.0
FP 1	0	0.0	0	0.0
FP 2	0	0.0	0	0.0
FP 3	0	0.0	0	0.0
FP 4	0	0.0	0	0.0
OP 1	36	0.6	0	0.0
OP 2	40	0.7	0	0.0
OP 3	72	1.2	0	0.0
OP 4	88	1.5	0	0.0
OP 7	64	1.1	0	0.0
OP 5	0	0.0	0	0.0
OP 6	0	0.0	0	0.0
OP 8	0	0.0	0	0.0
OP 9	0	0.0	0	0.0
OP 10	0	0.0	0	0.0

Route 2

Receptor type: Route

0 minutes of yellow glare

581 minutes of green glare



Route 1

Receptor type: Route

No glare found

FP 1

Receptor type: 2-mile Flight Path

No glare found

FP 3

Receptor type: 2-mile Flight Path

No glare found

FP 2

Receptor type: 2-mile Flight Path

No glare found

FP 4

Receptor type: 2-mile Flight Path

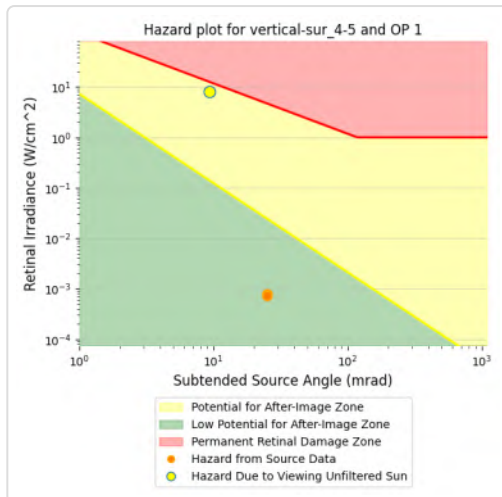
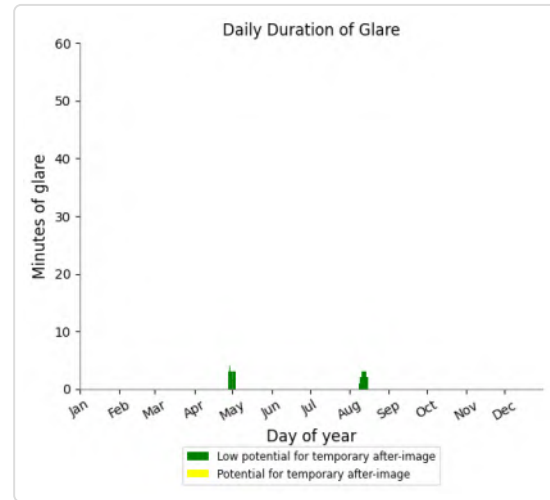
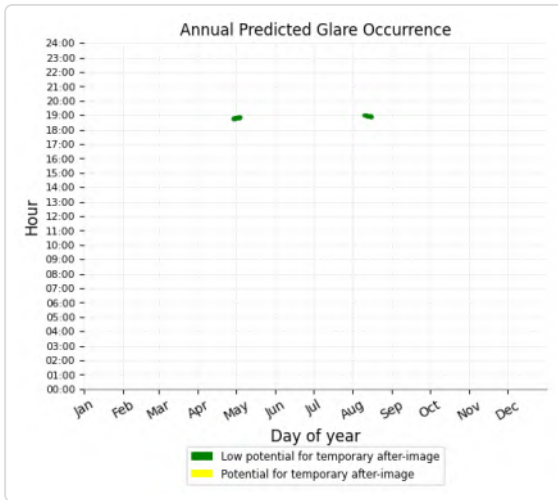
No glare found

OP 1

Receptor type: Observation Point

0 minutes of yellow glare

36 minutes of green glare

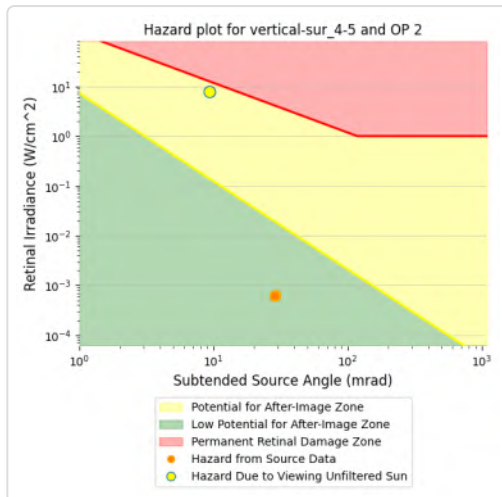
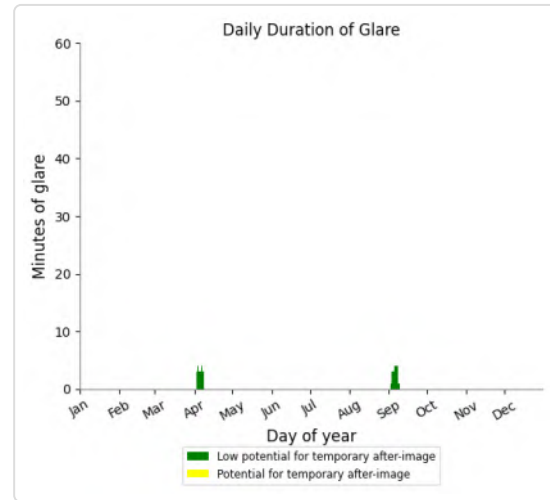
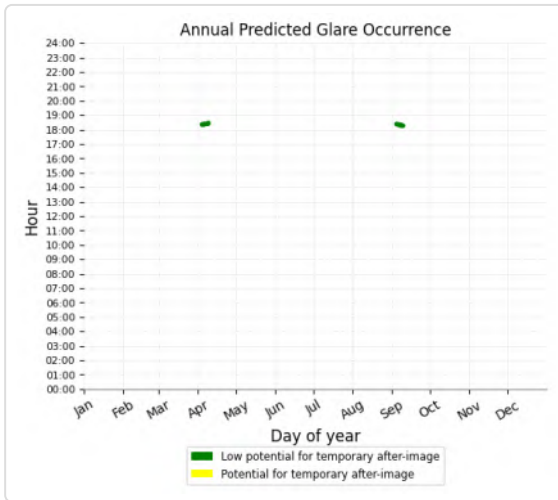


OP 2

Receptor type: Observation Point

0 minutes of yellow glare

40 minutes of green glare

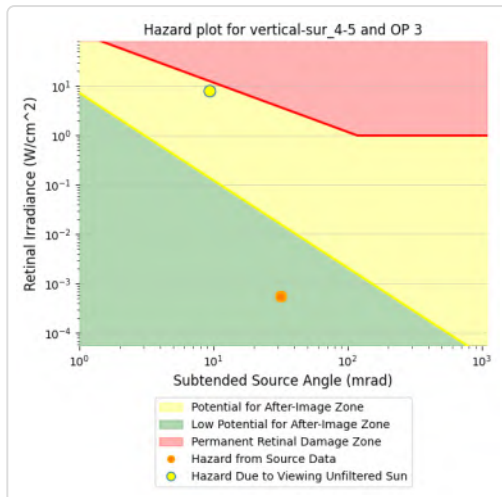
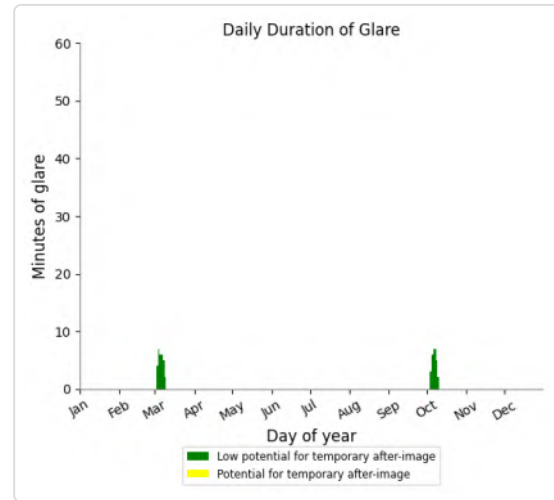
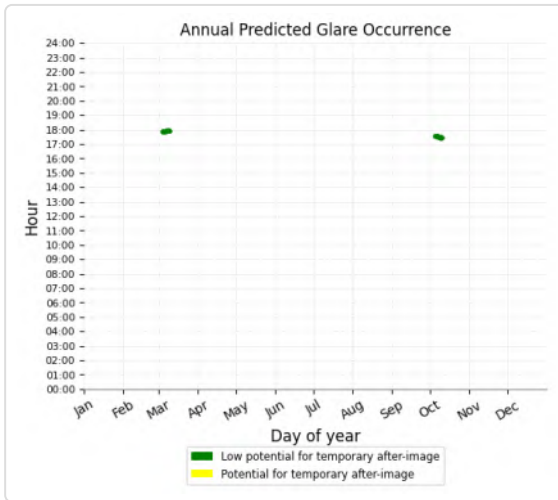


OP 3

Receptor type: Observation Point

0 minutes of yellow glare

72 minutes of green glare

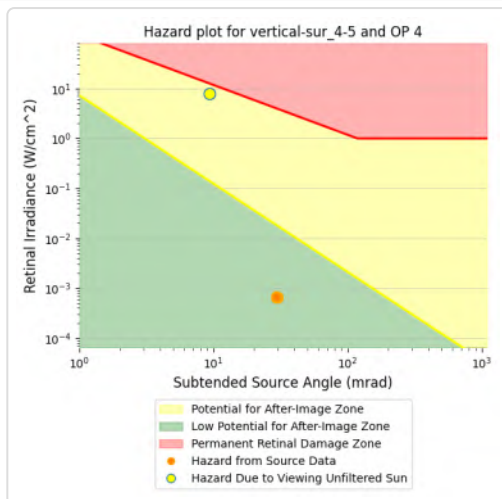
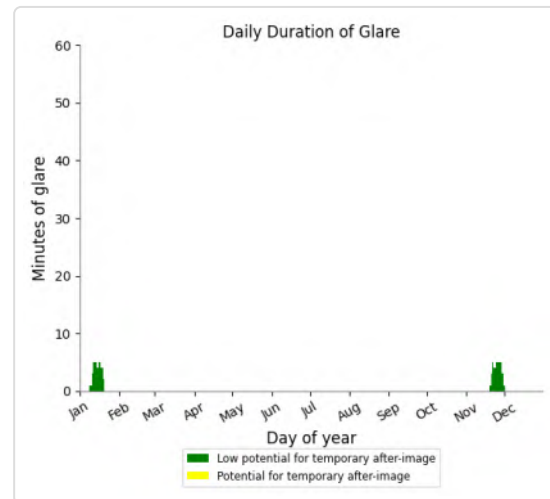
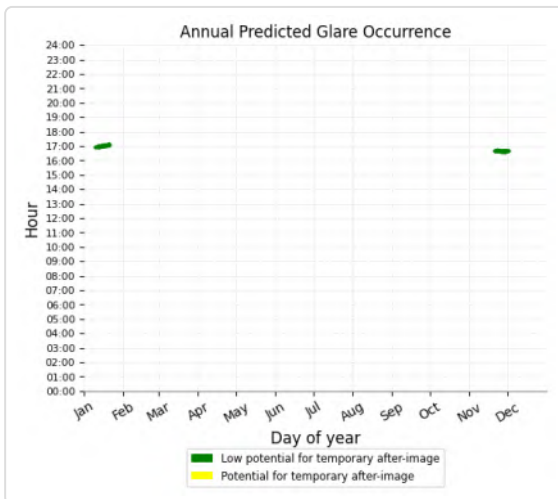


OP 4

Receptor type: Observation Point

0 minutes of yellow glare

88 minutes of green glare

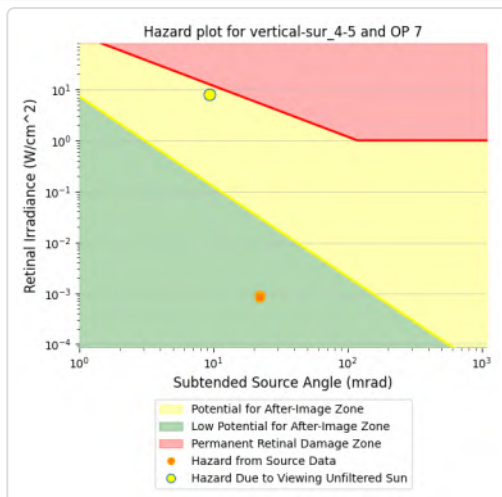
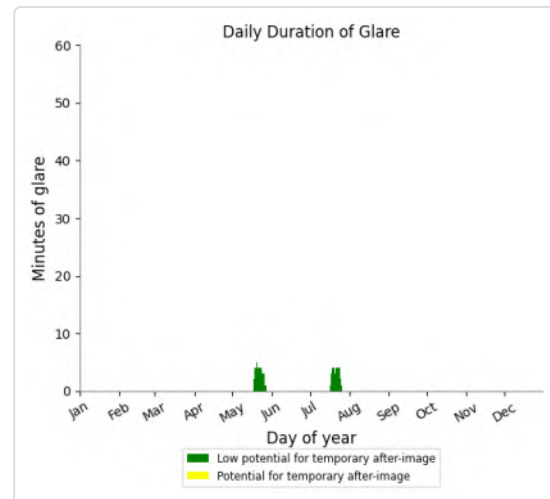
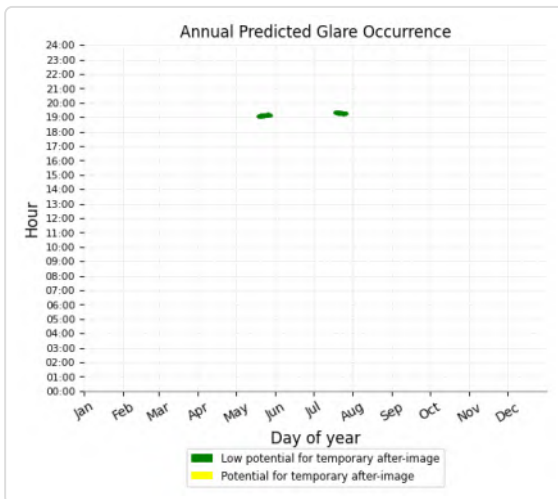


OP 7

Receptor type: Observation Point

0 minutes of yellow glare

64 minutes of green glare



OP 5

Receptor type: Observation Point

No glare found

OP 6

Receptor type: Observation Point

No glare found

OP 8

Receptor type: Observation Point

No glare found

OP 9

Receptor type: Observation Point

No glare found

OP 10

Receptor type: Observation Point

No glare found

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.

The algorithm does not rigorously represent the detailed geometry of a system; detailed features such as gaps between modules, variable height of the PV array, and support structures may impact actual glare results. However, we have validated our models against several systems, including a PV array causing glare to the air-traffic control tower at Manchester-Boston Regional Airport and several sites in Albuquerque, and the tool accurately predicted the occurrence and intensity of glare at different times and days of the year.

Several V1 calculations utilize the PV array centroid, rather than the actual glare spot location, due to algorithm limitations. This may affect results for large PV footprints. Additional analyses of array sub-sections can provide additional information on expected glare. This primarily affects V1 analyses of path receptors.

Random number computations are utilized by various steps of the annual hazard analysis algorithm. Predicted minutes of glare can vary between runs as a result. This limitation primarily affects analyses of Observation Point receptors, including ATCTs. Note that the SGHAT/ ForgeSolar methodology has always relied on an analytical, qualitative approach to accurately determine the overall hazard (i.e. green vs. yellow) of expected glare on an annual basis.

The analysis does not automatically 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.

The subtended source angle (glare spot size) is constrained by the PV array footprint size. Partitioning large arrays into smaller sections will reduce the maximum potential subtended angle, potentially impacting results if actual glare spots are larger than the sub-array size. Additional analyses of the combined area of adjacent sub-arrays can provide more information on potential glare hazards. (See previous point on related limitations.)

The variable direct normal irradiance (DNI) feature (if selected) scales the user-prescribed peak DNI using a typical clear-day irradiance profile. This profile has a lower DNI in the mornings and evenings and a maximum at solar noon. The scaling uses a clear-day irradiance profile based on a normalized time relative to sunrise, solar noon, and sunset, which are prescribed by a sun-position algorithm and the latitude and longitude obtained from Google maps. The actual DNI on any given day can be affected by cloud cover, atmospheric attenuation, and other environmental factors.

The ocular hazard predicted by the tool depends on a number of environmental, optical, and human factors, which can be uncertain. We provide input fields and typical ranges of values for these factors so that the user can vary these parameters to see if they have an impact on the results. The speed of SGHAT allows expedited sensitivity and parametric analyses.

The system output calculation is a DNI-based approximation that assumes clear, sunny skies year-round. It should not be used in place of more rigorous modeling methods.

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.

Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.

Refer to the Help page at www.forgesolar.com/help/ for assumptions and limitations not listed here.

Default glare analysis parameters and observer eye characteristics (for reference only):

- 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

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