Wister Solar Project
Imperial County, California

Glare Hazard Analysis Report

Prepared for:
Ormat Wister Solar

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Abbreviations

deg	degrees (0 is due north, 180 is due south)
DNI	Direct Normal Irradiance
FP	Flight Path (landing path from threshold to two miles out)
ft	feet
kW	kilowatt
kWh	kilowatt hour
mi	mile
min	minutes
mrad	milliradian
MW	Megawatt
NM	Nautical Miles
OP	Observation Point (e.g. control tower, vehicle location)
PV	Photovoltaic
USMC	United States Marine Corps
VP	Vantage points (also known as Observation Point, OP)

Glossary*

Correlate Slope Error with Surface Type?	Correlates the slope error value based on the surface material type; default value is 8.43 mrads.
Eye Focal Length (m)	Typical distance between the cornea and the retina of the human eye, default is 0.017, though some sources indicate that the typical length is 0.022.
Glide Slope (deg)	Angle at which the plane approaches the runway during landing (default is 3 degrees from horizontal).
Maximum Tracking Angle (deg)	Value set when the rotation angle is limited in the clockwise and counterclockwise directions.
Resting Angle (deg)	Angle modules return to after maximum angle is reached.
Observation Point	A specific location, such as a control tower or vehicle, from which an observer might experience glare.
Ocular Transmission Coefficient	Related to the ability of the eye to transmit light, set at 0.5 by Forge Solar.
Tracking Axis Panel Offset (deg)	The vertical offset between the tracking axis and the panel.
Orientation of Tracking Axis (deg)	Direction of the tracking axis clockwise from true north.
Peak DNI (W/m^2)**	This value is set at 1,000 by ForgeSolar and is the amount of solar radiation per unit surface area by a surface perpendicular to the sun's rays in a straight line from the direction of the sun at its current position in the sky.
Pupil Diameter (m)	Typical pupil diameter for observer, default is 0.002 m.
PV Array Axis Tracking	Panel tracking mode, if any. Panel can be set to track along one (single) or two (dual) axis tracking. This parameter affects the positioning of the panels at every time step when the sun is up.
PV Array Panel Material	Surface material of panels, including use of anti-reflective coating (ARC). Options include: smooth glass without ARC, smooth glass with ARC, light-textured glass without ARC, light-textured glass with ARC, and deeply textured glass.
Rated Power (kW)	Power rating of the solar array - used to estimate the energy output per year of the array (optional).
Slope Error (mrad)	Accounts for beam scatter of sunlight on the array. Default is 8.43 mrads but the value may be adjusted based on the panel material type.

Subtended Angle of Sun (mrad)	The angle above horizontal at which the viewer observes the sun, default value is 9.3 mrad.
Threshold	The physical beginning of the runway. Aircraft are typically expected to be 50 ft above ground at this point.
Time Interval (min)	Time step intervals used by the program for analyses. Default is set to analyze for glare at every one minute interval throughout the year.
Timezone	Time zone difference from Greenwich Mean Time at the location of the analysis.
Tracking Axis Tilt (deg)	The elevation angle of the tracking axis. 0 degrees is facing straight up and 90 degrees is facing horizontally.
Vary Reflectivity	Varies panel reflectivity with sun position at each time step.
Maximum Downward Viewing Angle (deg)	The angle extending downward from the horizon indicating the maximum downward viewing angle from the cockpit. Used to determine whether glare is visible by the pilot along the flight path. Default is 30 degrees.

*Sources:

- Ho, Clifford, K., Cianian A. Sims, Julius E. Yellowhair. 2015. Solar Glare Hazard Analysis Tool (SGHAT) Users Manual v. 2H. Sandia National Laboratories
- https://www.ForgeSolar.com/

**Source: http://www.3tier.com/en/support/solar-prospecting-tools/what-direct-normal-irradiance-solar-prospecting/

APPENDIX
June 6, 2019

1.0 EXECUTIVE SUMMARY

Stantec utilized the web-based ForgeSolar Pro glare hazard analysis program to analyze the potential for glare from a proposed 20 MW photovoltaic solar power project as depicted in **Figures 1 and 2**. The program identifies the three (3) following types of glare (no color indicates no glare predicted):

GREEN - Low potential for temporary after-image.
YELLOW - Potential for temporary after-image.
RED - Potential for permanent eye damage.

Based upon the solar array parameters provided, glare from the proposed Wister Solar Project is not predicted to be visible to pilots flying planes at 5,500' above MSL. The flight path (FP) analyzed is at a heading of 270 deg, 1 to 3 Nautical Miles (NM) from the target (located 6.5 mi NE of the Wister Site). Glare is also not predicted for drivers on roads adjacent to the project. Vantage points OP2/4)& OP1/3 were analyzed for the roadways.

Note: Observation Points (OP) 2 & 4 are the same location with OP 2 at 5-ft and OP 4 at 9-ft viewing height. This also applies for OP 1 & 3; with OP 1 at 5-ft and OP 3 at 9-ft viewing height

2.0 INTRODUCTION

Stantec utilized the web-based ForgeSolar Pro glare hazard analysis program to perform the glare/glint analysis of the proposed Wister project. ForgeSolar provides a quantified assessment of (1) when and where glare will occur throughout the year for a prescribed solar installation, (2) potential effects on the human eye at locations where glare occurs, (3) a general map showing where glare is coming from within an array, and (4) the annual energy production from the photovoltaic (PV) array so that alternative designs can be compared to maximize energy production while mitigating the impacts of glare. ForgeSolar employs an interactive Google Map for site location, mapping the proposed PV array(s), and specifying observer locations or FPs. Latitude, longitude, and elevation are automatically recorded through the Google Interface, providing necessary information for sun position and vector calculations. Additional information regarding the orientation and tilt of the PV panels, reflectance, environment, and ocular factors are entered by the user.

The Project is approximately two (2) miles North East of Niland, in Imperial County, California, and adjacent to an area utilized by the USMC for training purposes. This glare study analyzes the FP provided by the USMC and two (2) observation points at ground level. If glare is found, the tool calculates the retinal irradiance and subtended angle (size/distance) of the glare source to predict potential ocular hazards ranging from temporary after-image to retinal burn. Results are presented in a plot that specifies when glare will occur throughout the year, with color codes indicating the potential ocular hazard.

The analysis included in the report were revised based on an updated conceptual site plan dated July 26, 2019.

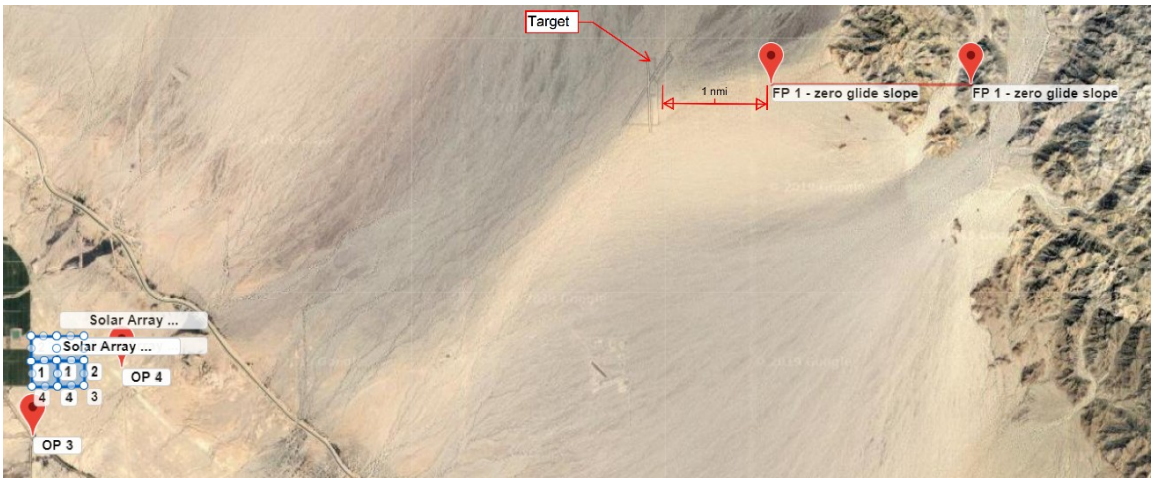


Figure 1: Wister Solar Project PV Array Layout in ForgeSolar depicting FP as requested by the USMC

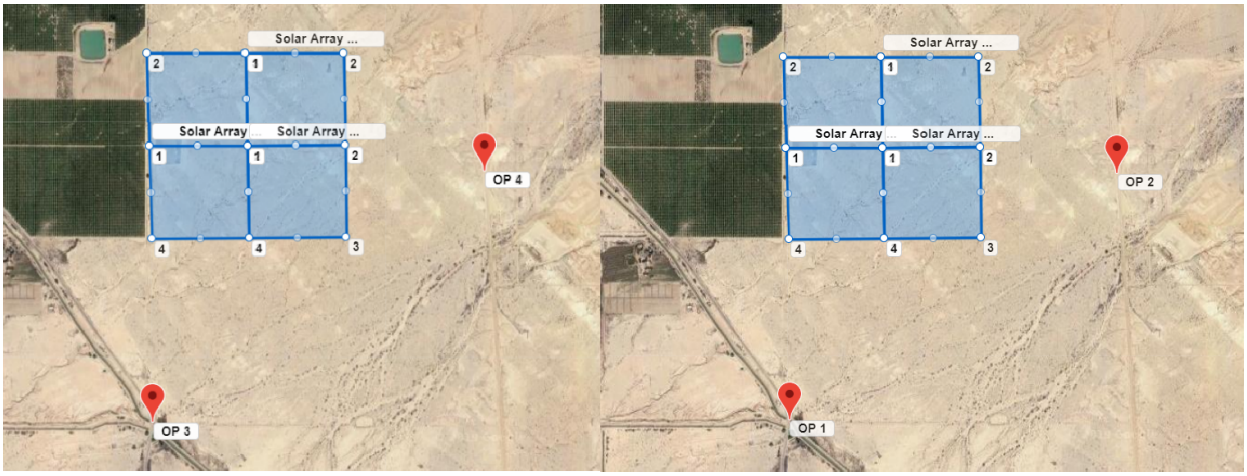


Figure 2: Wister Solar Project PV Array Layout in ForgeSolar depicting VPs at ground level

Note: The glare analysis reports included in the appendix show that four (4) arrays were used to perform the analyses. Due to the large size of the project, the accuracy of certain centroid based calculations would be reduced if the analysis was conducted as one (1) large array for the entire project. To avoid a reduction in calculation accuracy, the array was broken down into four (4) smaller arrays, which were then used to analyze the OPs and FP. The arrays were conservatively drawn slightly larger than the layouts provided.

3.0 DATA INPUT SUMMARY

The parameters used for the analyses are listed below. "Default" indicates the default parameter value set by ForgeSolar and is considered the most conservative value for the parameter. "Chosen" parameters were selected to perform the most conservative analysis with respect to glare potential.

3.1 SOLAR ARRAY

The location of the solar array and array parameters used for the analyses are based on information provided by Ormat (Client) for the Wister Solar project.

Table 1: Solar Panel Parameters Used (a detailed description of each parameter is provided in the Glossary):

Parameter	**Value Used**	**Default, Chosen, or Provided?**
Axis tracking	Single	Provided
Tracking Axis Tilt (deg)	0.0	Provided
Tracking Axis Orientation (deg)	180.0	Provided
Tracking Axis Panel Offset (deg)	0.0	Default
Maximum Tracking Angle (deg)	52.0	Provided
Resting Angle (deg)	52.0	Chosen
Rated Power (kW)	0.0 kW	Default
Vary reflectivity?	Yes	Default
Panel material	Smooth glass with ARC	Provided
Timezone offset	-8.0	Chosen

Subtended angle of sun (mrad)	9.3	Default
Peak DNI (W/m^2)	1,000	Default
Ocular transmission coefficient	0.5	Default
Pupil diameter (m)	0.002	Default
Eye focal length (m)	0.017	Default
Time interval (min)	1	Default
Correlate slope error with surface type?	Yes	Default
Slope error (mrad)	8.43	Default

It should be noted that a 'resting angle' of 52 degrees was used for the panels in the analysis. If a resting angle of 0 degrees (panels facing straight up) is used in the analysis, the program moves the panels to 0 degrees instantly once the sun drops below 52 degrees in either direction. This results in the panels facing straight up during sunrise and sunset, under which conditions the program predicts yellow glare. Panels should therefore not be 'rested' in a 0- degree position when the sun is above the horizon.

3.2 FLIGHT ANYALSIS:

Two (2) flight paths were analyzed for the Wister solar project (Figure 1). The first flight path is located approximately 1NM to the east of the center of the target. The heading of flight path one (1) is 270 deg. The ForgeSolar program automatically plots and analyzes points at the threshold and continuously for up to 2 miles in a straight direction (270 deg) from the threshold. The program also determines the altitude at each point based on the plane height at the threshold and the glide slope for landing. Flight path one (1) is at a constant altitude of 5,500' MSL. In addition, the analysis considered pilot visibility from the cockpit based on default values of 30 degrees for the vertical view restriction and 50 degrees for the azimuthal view restriction (Figure 1).

3.3 ROADWAYS ADJACENT TO THE SOLAR ARRAYS:

Two (2) observation points (also referred to as vantage points) were analyzed for vehicles travelling along adjacent roads. The Observation Points (OP) were chosen to correspond with Vantage Points (VP) used in the Project's Planning Documents. Potential glare to drivers was evaluated for both passenger vehicles and semi-trucks, where the passenger vehicles were assumed to have a maximum viewing height of 5 ft while the viewing height for drivers of semi-trucks was assumed to be a maximum of 9 ft. Locations of the chosen roadway routes are shown as red pins (OP 1 & 2) in Figure 2.

4.0 GLARE ANALYSES RESULTS

Stantec utilized the web-based ForgeSolar program for the glare analyses. ForgeSolar analyzed glare potential in one-minute increments throughout the year. The program identifies the three (3) following types of glare (no color indicates no glare predicted):

GREEN - Low potential for temporary after-image.
YELLOW - Potential for temporary after-image.
RED - Potential for permanent eye damage.

4.1 USMC FLIGHT PATH

Based on the input parameters described above, glare is not predicted for the USMC flight path from approximately one (1) to three (3) Nautical Miles east of the target with a heading of 270 deg at an altitude of 5,500' MSL as shown in **Figure 1**.

4.2 ROADWAYS ADJACENT TO THE SOLAR ARRAYS

Glare is also not predicted for drivers at either of the two (2) OP included in the analysis for drivers with viewing heights of 5 ft and 9 ft above ground (Figure 2).

5.0 CONCLUSIONS

Based upon the solar array parameters provided, glare is not predicted to occur from the proposed Wister Ormat Solar Project for planes approaching the target 1 NM to 3 NM away, heading 270 deg at an elevation of 5,500' MSL. Glare is also not predicted for drivers of vehicles at the OPs adjacent to the project at either 5-ft (cars and small trucks) or 9-ft (semi-trucks) viewing heights.

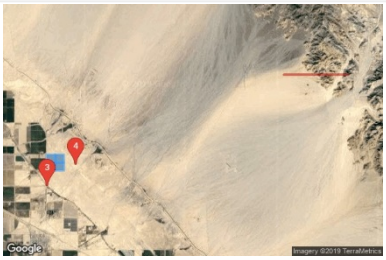
It should be noted that a 'resting angle' of 52 degrees was used for the panels in the analysis. If a resting angle of 0 degrees (panels facing straight up) is used in the analysis, the program moves the panels to 0 degrees instantly once the sun drops below 52 degrees in either direction. This results in the panels facing straight up during sunrise and sunset, under which conditions the program predicts yellow glare. Panels should therefore not be 'rested' in a 0- degree position when the sun is above the horizon.

APPENDIX

GlareGauge Glare Analysis Results

Site Configuration: Modified Site plan 25 MW 97 ac-temp-4

Project site configuration details and results.



Created **July 29, 2019 12:22 p.m.**
Updated **July 29, 2019 12:25 p.m.**
DNI **varies** and peaks at **1,000.0 W/m^2**
Analyze every **1** minute(s)
0.5 ocular transmission coefficient
0.002 m pupil diameter
0.017 m eye focal length
9.3 mrad sun subtended angle
Timezone **UTC-8**
Site Configuration ID: 29903.4971

Summary of Results No glare predicted!

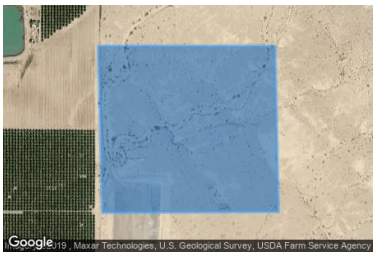
PV name	Tilt	Orientation	"Green" Glare	"Yellow" Glare	Energy Produced
	deg	deg	min	min	kWh
Solar Array Ormat Wister Project North quad 1	SA tracking	SA tracking	0	0	-
Solar Array Ormat Wister Project North quad 2	SA tracking	SA tracking	0	0	-
Solar Array Ormat Wister Project North quad 3	SA tracking	SA tracking	0	0	-
Solar Array Ormat Wister Project North quad 4	SA tracking	SA tracking	0	0	-

Component Data

PV Array(s)

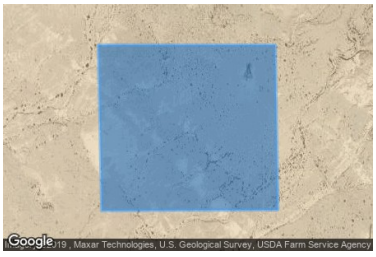
Name: Solar Array Ormat Wister Project North quad 1
Axis tracking: Single-axis rotation
Tracking axis orientation: 180.0 deg
Tracking axis tilt: 0.0 deg
Tracking axis panel offset: 0.0 deg
Maximum tracking angle: 52.0 deg
Resting angle: 52.0 deg
Rated power: -
Panel material: Smooth glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 8.43 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	ft	ft	ft
1	33.274494	-115.510350	-21.49	5.00	-16.49
2	33.278120	-115.510460	-5.86	5.00	-0.86
3	33.278119	-115.505847	7.98	5.00	12.98
4	33.274511	-115.505758	-3.48	5.00	1.52



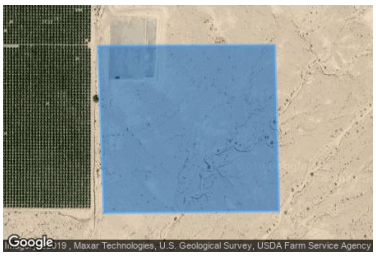
Name: Solar Array Ormat Wister Project North quad 2
Axis tracking: Single-axis rotation
Tracking axis orientation: 180.0 deg
Tracking axis tilt: 0.0 deg
Tracking axis panel offset: 0.0 deg
Maximum tracking angle: 52.0 deg
Resting angle: 52.0 deg
Rated power: -
Panel material: Smooth glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 8.43 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	ft	ft	ft
1	33.278120	-115.505845	7.98	5.00	12.98
2	33.278120	-115.501230	30.99	5.00	35.99
3	33.274529	-115.501159	9.85	5.00	14.85
4	33.274512	-115.505756	-3.48	5.00	1.52



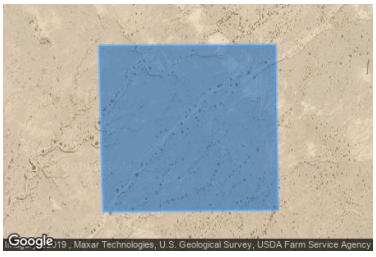
Name: Solar Array Ormat Wister Project North quad 3
Axis tracking: Single-axis rotation
Tracking axis orientation: 180.0 deg
Tracking axis tilt: 0.0 deg
Tracking axis panel offset: 0.0 deg
Maximum tracking angle: 52.0 deg
Resting angle: 52.0 deg
Rated power: -
Panel material: Smooth glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 8.43 mrad

Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	ft	ft	ft
1	33.274494	-115.510349	-21.49	5.00	-16.49
2	33.274512	-115.505756	-3.48	5.00	1.52
3	33.270909	-115.505647	-18.05	5.00	-13.05
4	33.270869	-115.510201	-29.11	5.00	-24.11



Name: Solar Array Ormat Wister Project North quad 4
Axis tracking: Single-axis rotation
Tracking axis orientation: 180.0 deg
Tracking axis tilt: 0.0 deg
Tracking axis panel offset: 0.0 deg
Maximum tracking angle: 52.0 deg
Resting angle: 52.0 deg
Rated power: -
Panel material: Smooth glass with AR coating
Vary reflectivity with sun position? Yes
Correlate slope error with surface type? Yes
Slope error: 8.43 mrad

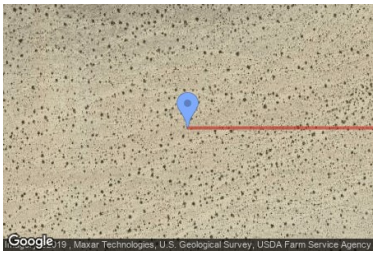
Vertex	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	ft	ft	ft
1	33.274513	-115.505755	-3.48	5.00	1.52
2	33.274531	-115.501159	9.85	5.00	14.85
3	33.270949	-115.501102	-0.27	5.00	4.73
4	33.270910	-115.505646	-18.05	5.00	-13.05



2-Mile Flight Path Receptor(s)

Name: FP 1 - zero glide slope at 5500 MSL
Description:
Threshold height : 4876 ft
Direction: 270.0 deg
Glide slope: 0.0 deg
Pilot view restricted? Yes
Vertical view restriction: 30.0 deg
Azimuthal view restriction: 50.0 deg

Point	Latitude	Longitude	Ground elevation	Height above ground	Total elevation
	deg	deg	ft	ft	ft
Threshold	33.314551	-115.381791	624.26	4876.01	5500.27
2-mile point	33.314551	-115.347152	1564.57	3935.70	5500.27



Discrete Observation Receptors

Number	Latitude	Longitude	Ground elevation	Height above ground	Total Elevation
	deg	deg	ft	ft	ft
OP 1	33.263714	-115.510158	-47.01	9.00	-38.01
OP 2	33.273511	-115.494633	40.49	9.00	49.49
OP 3	33.263710	-115.510160	-47.01	5.00	-42.01
OP 4	33.273510	-115.494630	40.49	5.00	45.49

PV Array Results

Solar Array Ormat Wister Project North quad 1

Component	Green glare (min)	Yellow glare (min)
FP: FP 1 - zero glide slope at 5500 MSL	0	0
OP: OP 1	0	0
OP: OP 2	0	0
OP: OP 3	0	0
OP: OP 4	0	0

Solar Array Ormat Wister Project North quad 2

Component	Green glare (min)	Yellow glare (min)
FP: FP 1 - zero glide slope at 5500 MSL	0	0
OP: OP 1	0	0
OP: OP 2	0	0
OP: OP 3	0	0
OP: OP 4	0	0

Solar Array Ormat Wister Project North quad 3

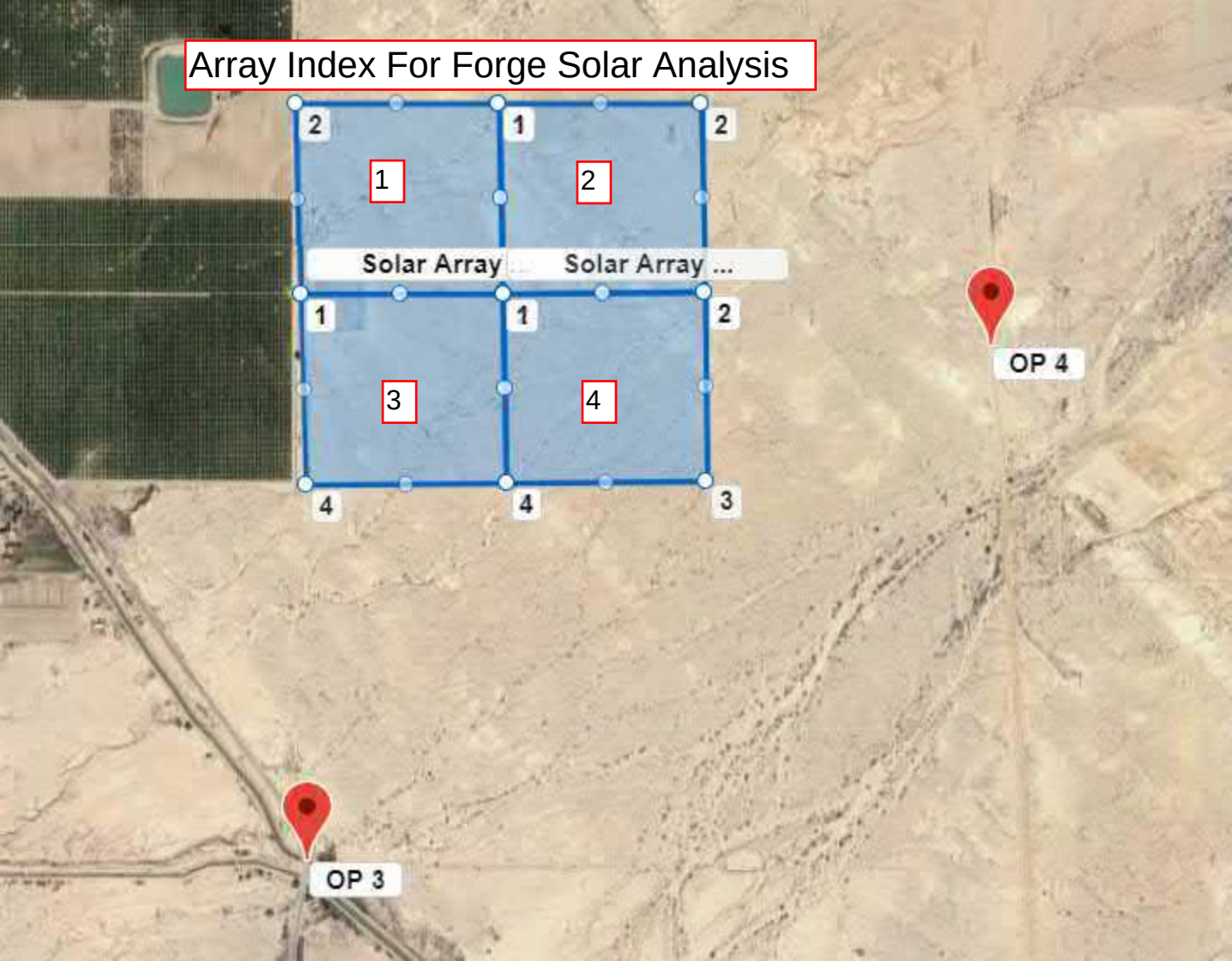
Component	Green glare (min)	Yellow glare (min)
FP: FP 1 - zero glide slope at 5500 MSL	0	0
OP: OP 1	0	0
OP: OP 2	0	0
OP: OP 3	0	0
OP: OP 4	0	0

Solar Array Ormat Wister Project North quad 4

Component	Green glare (min)	Yellow glare (min)
FP: FP 1 - zero glide slope at 5500 MSL	0	0
OP: OP 1	0	0
OP: OP 2	0	0
OP: OP 3	0	0
OP: OP 4	0	0

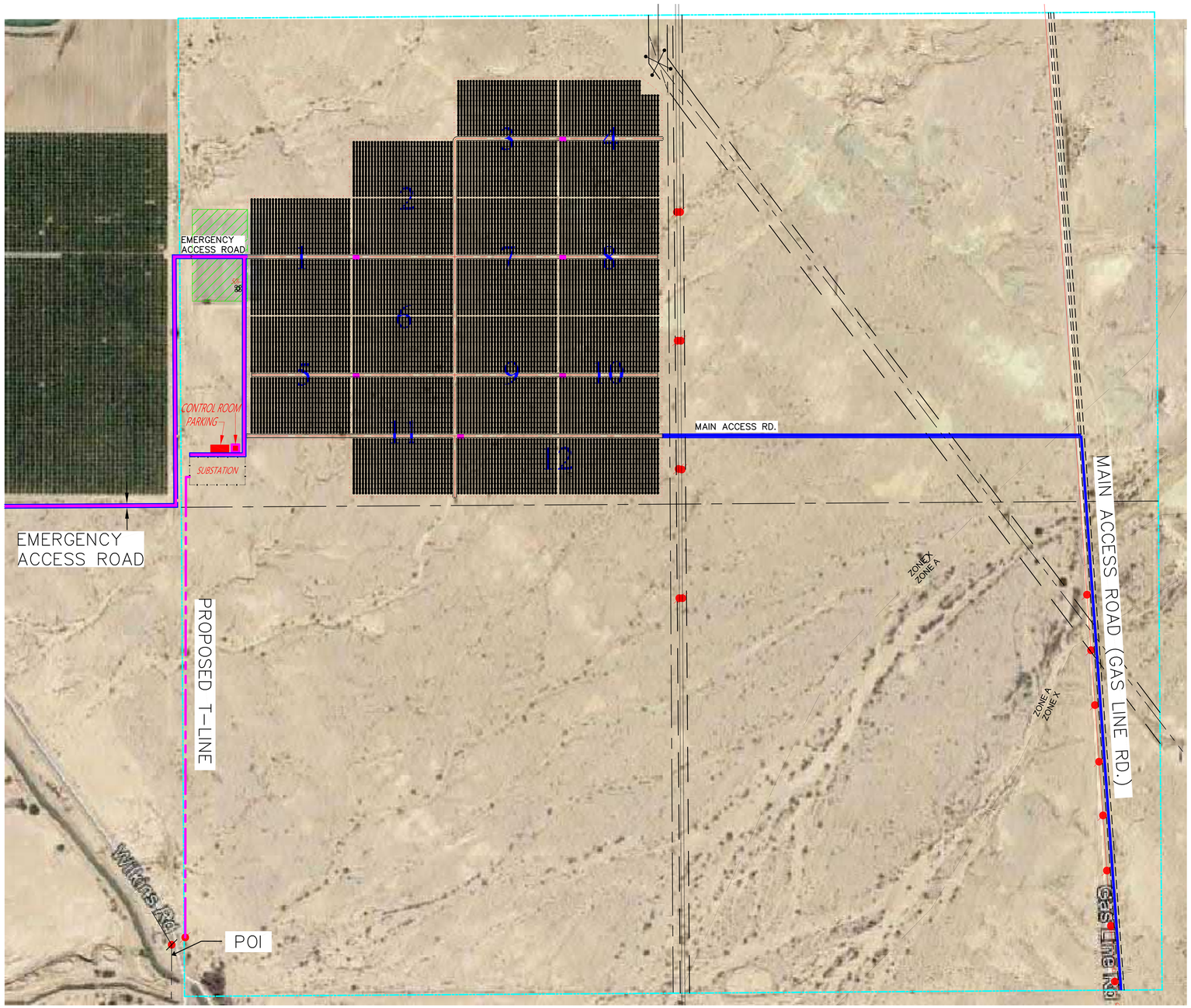
Assumptions

- 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.
- Detailed system geometry is not rigorously simulated.
- The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual values and results may vary.
- Several 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.
- 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.)
- Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass continuous, not discrete, spectrum.
- Glare locations displayed on receptor plots are approximate. Actual glare-spot locations may differ.
- Glare vector plots are simplified representations of analysis data. Actual glare emanations and results may differ.
- Refer to the **Help page** for assumptions and limitations not listed here.


Array Index For Forge Solar Analysis
2
1
2
1
2
Solar Array
Solar Array ...
1
1
2
3
4
4
4
3
OP 4
OP 3

TOPOGRAPHICAL & SITE PLAN - 25 MW-DC Solar Project

COUNTY OF IMPERIAL, STATE OF CALIFORNIA



NORTH

SCALE: 1"=300'

300 0 300 600

GRAPHIC SCALE

LEGEND:

- PROPERTY LINE
- PROPOSED CHAIN LINK FENCE
- PROPOSED INVERTER LOCATION
- MAIN ACCESS ROAD
- EMERGENCY ACCESS ROAD
- LAYDOWN/TEMP OFFICE LOCATION

SOLAR FIELD
97.11± ACRES

25 MW-DC

SINGLE AXLE TRACKING

370 Watts Solar Panel

ORMAT

WISTER SOLAR PROJECT 25MW

TOPOGRAPHICAL PLAN

OWNER: ORMAT

Ed.Barajas

DATE: 06/26/2019

SHEET: 1 OF: 1