White Tail Solar Project

Glare Hazard Analysis

Prepared for:
White Tail Solar, LLC

Prepared by:
Stantec Consulting Services Inc.
12075 Corporate Parkway, Suite 200
Mequon, WI 53092

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Abbreviations

deg	degrees (0 is due north, 180 is due south)
DNI	Direct Normal Irradiance
FAA	Federal Aviation Administration
FP	Flight Path (landing path from threshold to two miles out)
ft	feet
kW	kilowatt
kWh	kilowatt hour
m	meters
mi	mile
min	minutes
mrad	milliradian
OP	Observation Point (e.g. control tower, vehicle location)
PV	Photovoltaic

Glossary*

Correlate Slope Error with Surface Type?	Correlates the slope error value based on the surface material type; default value is 8.43 milliradians (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 [deg] from horizontal).
Maximum Tracking Angle (deg)	Rotation limit of panels in either direction. Full rotation is 2*maximum tracking angle. E.g. maximum tracking angle of 60 deg indicates full panel rotation range of 120 deg.
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 by at 0.5 by Forge Solar.
Offset angle of module (deg)	Additional tilt/elevation angle between the tracking axis and the panel.
Orientation of Tracking Axis (deg)	Azimuthal position of tracking axis measured clockwise from true north. Tracking systems in the northern hemisphere are typically oriented near 180 deg. Tracking systems in the southern hemisphere are typically oriented near 0 deg.
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 meters (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.

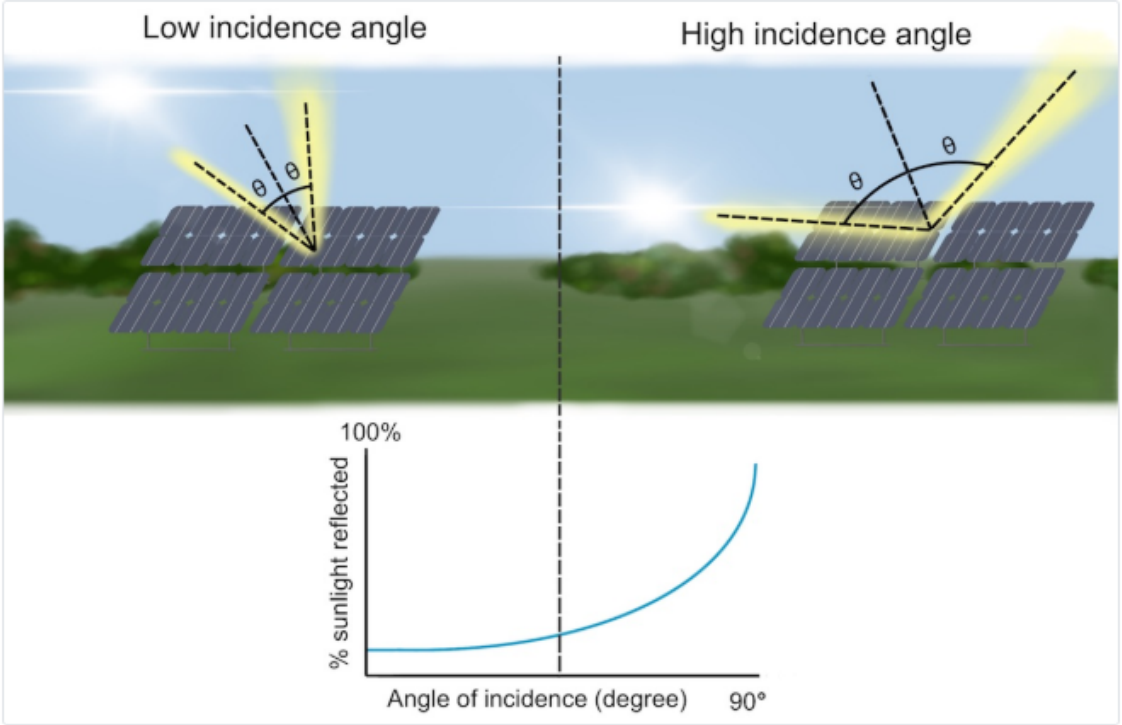
Rated Power (kW)	Power rating of the solar array - used to estimate the energy output per year of the array (optional).
Slope Error (mrad)	Accounts for beam scatter of sunlight on the array. Default is 8.43 mrads but the value may be adjusted based on the panel material type.
Subtended Angle of Sun (mrad)	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.
Tilt of Tracking Axis (deg)	The elevation angle of the tracking axis upon which panels rotate (e.g. torque tube), measured from flat ground. 0 deg implies the axis is on level, flat ground. Values between 0 and 30 deg are typical.
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., Cianan 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/

Incidence Angle Diagram from ForgeSolar.com Documentation:



PV panel reflectance depends on incidence angle between panel normal (i.e. facing) and sun position. Large incidence angle yields more reflected sunlight.

Source: ForgeSolar, 2021

EXECUTIVE SUMMARY

Stantec utilized the web-based ForgeSolar glare hazard analysis program to analyze the potential for glare from a proposed photovoltaic solar power project as depicted in **Figure 1**. The program identifies the three 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 on the solar array parameters provided, glare is not predicted to occur from the proposed White Tail Solar Project (Project) at seven airports (**Table 1**) and two air traffic control towers (ATCTs) located within 10 miles of the Project (**Figure 2**). Glare is not predicted for drivers of vehicles on eight roads (**Table 2**) analyzed adjacent to the project at either five-foot (cars and small trucks) or nine-foot (semi-trucks) viewing heights (**Figure 3**). Glare is also not predicted for the 41 buildings analyzed adjacent to the project site (primarily residences) (**Figure 3**). All routes, flight paths and buildings were also analyzed using five-foot, nine-foot and 12-foot panel heights. Note that all elevations used as inputs for the analysis are above ground level (AGL) heights. Additionally, The glare analysis was conducted without factoring the screening effects of existing or proposed landscaping along Project property boundaries.

*****It should be noted that a 'resting angle' of 60 degrees was used for the panels in the analysis. If a resting angle of 0 degrees (panels horizontal/facing straight up) is used in the analysis, the program moves the panels to 0 degrees instantly once the sun drops below 60 degrees in either direction. This results in the panels being horizontal/facing straight up during sunrise and sunset, under which conditions the program predicts extensive green and yellow types of glare. Panels should therefore not be 'rested' in a 0- degree position when the sun is close to the horizon (near dawn and dusk daylight hours) (See Incidence Angle diagram in Glossary above).***

Under typical operating conditions, panels for this project will not be at 0 degrees during sunrise and sunset and, therefore, will not generate glare. Based on this analysis, it is predicted the proposed Project does not have the potential for causing glare impacts on nearby airports or adjacent roadways and buildings.

1.0 INTRODUCTION

Stantec utilized the web-based ForgeSolar glare hazard analysis program for the glare analysis. This interactive tool provides a quantified assessment of (1) when and where glare will occur throughout the year for a prescribed solar installation and (2) potential effects on the human eye at locations where glare occurs.

ForgeSolar employs an interactive Google map for site location, mapping the proposed PV array(s), and specifying observer locations, vehicular travel routes, or flight paths. 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.

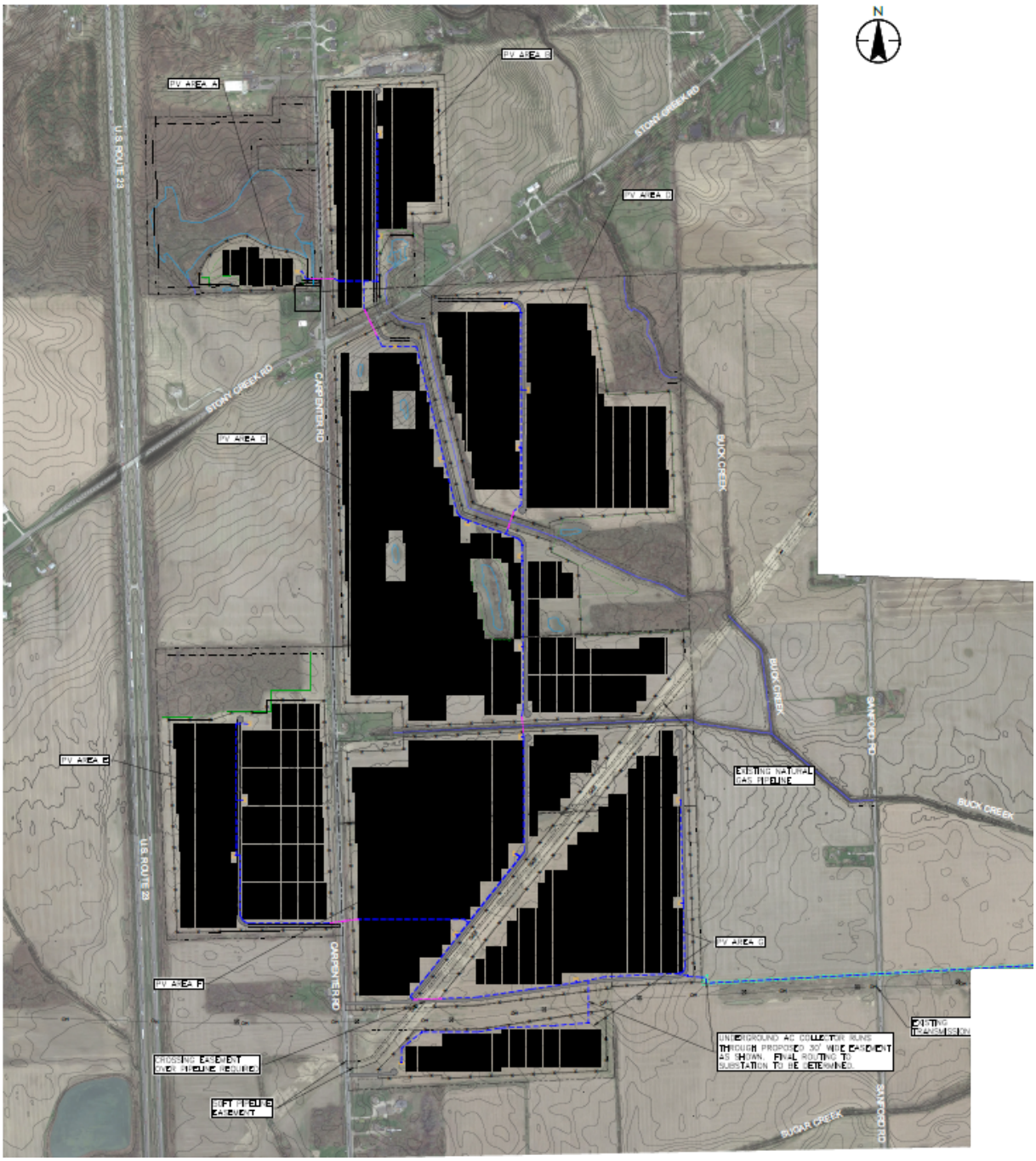
If glare is found, the tool calculates the retinal irradiance and subtended angle (size/distance) of the glare source to predict potential ocular hazards ranging from temporary after-image to retinal burn. The results are presented in a plot that specifies when glare will occur throughout the year, with color codes indicating the potential ocular hazard.

The Project is in the Charter Township of York, Washtenaw County, Michigan, approximately eight miles south-southeast of the City of Ann Arbor. The site is located within 10 miles of seven active airports (**Table 1, Figure 2**). This glare study analyzes potential glare for landing paths all airports, two air traffic control towers (ATCT)s, and for drivers of vehicles with a five-foot (cars and small trucks) and nine-foot (semi-truck) viewing height on eight roadways adjacent to the Project (**Table 2, Figure 3**). In Figure 3, light, blue lines depict the examined roadways, and the numbered dots represent the analyzed location along the roadway. Heights for the ATCTs at Ann Arbor Municipal Airport and Willow Run Airport are not provided on airport diagrams found via AirNav[1] and, therefore, a conservative height of 100 feet was assumed for each. The analysis also included a determination of potential glare to viewers at 41 unique buildings (primarily residences) in the vicinity of the Project location at 25-ft viewing heights (**Figure 3**). The red, numbered balloons (e.g., OP xx) in Figure 3 represent the 41 building locations for the glare analysis. The blue-shaded parcels depict the approximate proposed project PV areas. All routes, flight paths and homes were analyzed using five-foot, nine-foot, and 12-foot panel heights.

NOTE: The arrays used in the analysis program were drawn to be larger than the actual planned and designed arrays shown in Figure 1 in order to be conservative in the glare analysis by analyzing more area than the panels will actually occupy. This <u>in no way implies</u> that that planned PV arrays are larger or different from the actual planned and designed arrays shown in Figure 1.

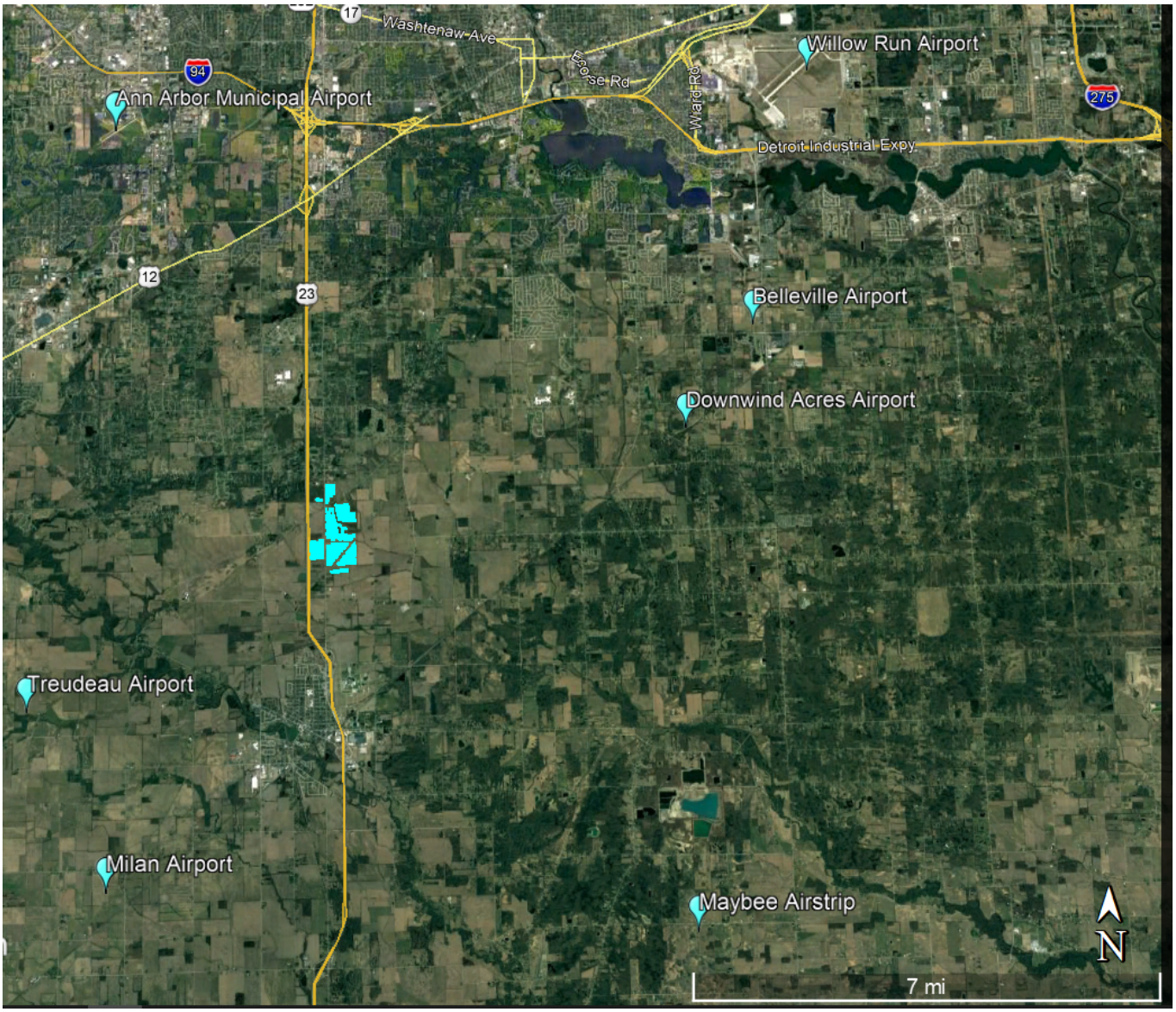
[1] https://www.airnav.com

Figure 1 - White Tail Solar Project PV Array layout



Source: White Tail Solar, LLC

Figure 2 – PV Array (blue) and Airports Analyzed



Source: Google Earth imagery, December 2016

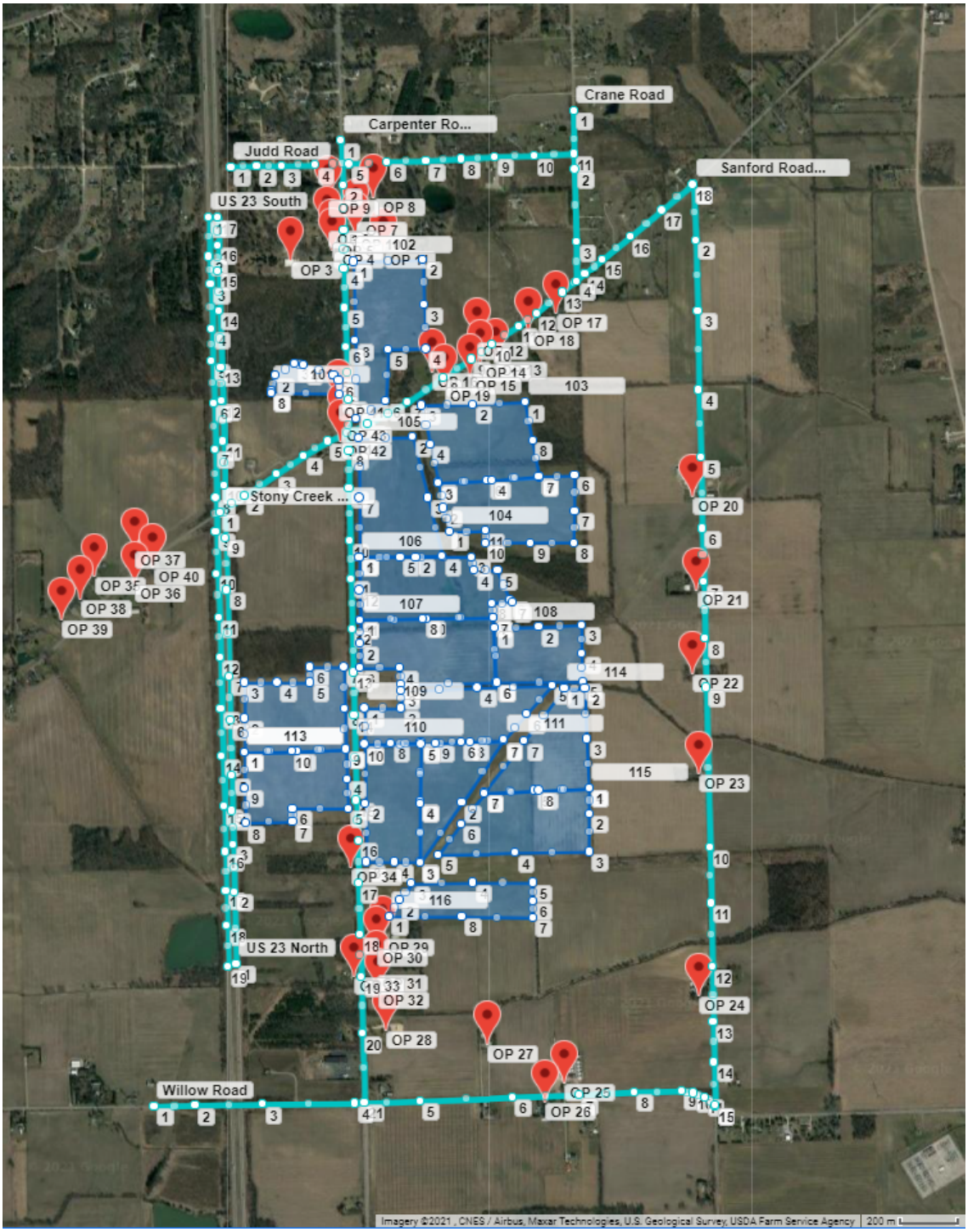
Table 1 – Airports and Approach Paths/Runways Analyzed for Glare

Airport Name	Approach Paths/Runways Analyzed	Air Traffic Control Tower?
Ann Arbor Municipal Airport	Runways 9, 24, 30 and 12	Yes
Willow Run Airport	Runways 5R, 5L, 23R and 23L	Yes
Belleville Airport	Southeast and Northwest approaches	No
Maybee Airstrip	Southbound and Northbound approaches	No
Downwind Acres Airport	Northeast and Southwest approaches	No
Milan Airport	Southbound and Northbound approaches	No
Trudeau Airport	Eastbound and Westbound approaches	No

Table 2 – Roadways Adjacent to Project Analyzed for Glare

Roadway Name	One-Way or Two-Way
Carpenter Road	Two-Way
Crane Road	Two-Way
Judd Road	Two-Way
Sanford Road	Two-Way
Stony Creek Road	Two-Way
US 23 North	One-Way
US 23 South	One-Way
Willow Road	Two-Way

Figure 3 – PV Array and Buildings and Roadways Analyzed



Source: ForgeSolar, Google Earth Imagery, March 2020

(Note: the colors above are used to simply depict locations and do not represent glare)

2.0 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. "Provided" parameters are Project specific information provided by the client.

2.1 SOLAR ARRAY

The location of the solar array and array parameters used for the analyses are based on information provided by White Tail Solar, LLC. The analyses described in **Table 3** below were conducted using five-foot, nine-foot, and 12-foot panel heights.

Table 3: 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)	60.0	Provided
Resting Angle (deg)	60.0	Provided
Rated Power (kW)	Not Used	NA
Vary reflectivity?	Yes	Default
Panel material	Smooth glass with Anti-Reflective Coating	Provided

Timezone offset	-5	Based on site location
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

2.2 AIRPORT LANDING PATHS AND AIR TRAFFIC CONTROL TOWERS (ATCTS)

A total of 18 approach paths for airport and grass airstrip runways were analyzed for glare (**Table 1**). Flight paths used for the analyses were based on locating a point at the center of the estimated runway thresholds for the runways and grass landing strips using aerial photography, and indicating a flight/landing path direction extending outward from the center of the runway. The ForgeSolar program automatically plots and analyzes points at the threshold and continuously for up to two miles in a straight direction 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.

The flight path input values used were the Federal Aviation Administration (FAA) standard 50-foot altitude at the threshold and a 3-degree glide slope. In addition, the analysis considered pilot visibility from the cockpit, and the default values of 30 degrees for the vertical view restriction and 50 degrees for the azimuthal view restriction for pilots were used. Because FAA ATCT tower heights at eye level are not publicly published due to safety measures, a conservative height estimate of 100 feet was used for towers located at each airport. These are included as Observation Points (OPs) 1 and 2 in the glare analysis reports.

2.3 ROADWAYS AND PROPERTIES LOCATED ADJACENT TO THE SOLAR ARRAYS

This analysis included potential glare to vehicles travelling on eight roads in the vicinity of the Project site (**Table 2**). The ForgeSolar program sets the default viewing angle of the array at 50 degrees from the driver's direct line of sight (when looking forward). The FAA has determined that glare beyond 50 degrees from the line of sight will have no impact on the viewer[2].

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 five feet while the viewing height for drivers of semi-trucks was assumed to be a maximum of nine feet. The location of the routes analyzed are shown as blue-green route lines on **Figure 3**.

Potential glare to viewers from 41 unique buildings (primarily residences) located in the vicinity of the Project site was also analyzed at a 25-foot viewing height.

3.0 GLARE ANALYSES RESULTS

Stantec utilized the web-based ForgeSolar program for the glare analysis. ForgeSolar was used to analyze glare potential in one-minute increments throughout the year and the program identifies the three 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

The Appendix depicts the ForgeSolar results. As depicted in the graphical portions of these results, none of the colors are present and therefore, no potential for glare is predicted.

3.1 AIRPORT LANDING PATHS AND ATCTS

Glare is not predicted for planes landing at any of the 18 approach paths for the seven airports shown in **Figure 2** above. Glare is not predicted for the ATCTs located at the Ann Arbor Municipal Airport or the Willow Run Airport.

3.2 ROADWAYS AND BUILDINGS LOCATED ADJACENT TO THE SOLAR ARRAYS

Glare is not predicted for drivers along the eight roadways analyzed (**Table 2**) adjacent to the Project for drivers with viewing heights of five feet (cars and small trucks) or nine feet (semi-trucks)

[2] Rogers, J. A., et al. (2015). Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach, Federal Aviation Administration (link)

above ground. Glare is also not predicted for the 41 unique buildings (primarily residences) analyzed at 25-foot viewing heights for this Project, as shown in **Figure 3**.

4.0 CONCLUSIONS

Based on the solar array parameters provided, glare is not predicted for planes landing, or for observers in the two ATCTs at the seven airports located within 10 miles of the project site. Glare is also not predicted for drivers of vehicles on eight roadways adjacent to the project site, at either five-foot (cars and small trucks) or nine-foot (semi-trucks) viewing heights, nor for 41 buildings (primarily residences) with 25-foot viewing heights. All viewpoints were analyzed at five-foot, nine-foot and 12-foot panel heights.

Based on this analysis, it is predicted the proposed Project does not have the potential for causing glare impacts on nearby airports or adjacent roadways and buildings.

APPENDIX

(Available upon Request)