FINAL REPORT

TAELOR SOLAR PROJECT

WELD COUNTY, COLORADO

SOLAR GLARE HAZARD ASSESSMENT

RWDI #2401940

January 22, 2024

SUBMITTED TO

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1 INTRODUCTION

RWDI USA LLC (RWDI) was retained by Balanced Rock Power, LLC to undertake a Solar Glare Hazard Assessment (SGHA) for the proposed Taelor Solar Project located in Weld County, Colorado. The aim of this analysis was to predict the potential for glare from the Project on nearby dwellings, flight paths and vehicle routes. All work was completed by qualified technical staff, as detailed in Appendix A.

1.1 Objective and Regulatory Context

RWDI is not aware of specific requirements for glare from photovoltaics in Colorado. As such, we have based this assessment on standard industry best practices and RWDI's past experience in studying glare for hundreds of projects around the world. RWDI's assessment included:

- Predicting solar glare potential at any dwellings, railways, highways and other major roads within 5000 feet from the boundary of the project.
- Predicting solar glare potential at aerodromes, including the potential effect on runways, flightpaths, and air traffic control towers within 10 miles from the boundary of the project.
- Describing the time, location, duration, and intensity of solar glare predicted to be caused by the project.
- Describing the software or tools used in the assessment, the assumptions, and the input parameters utilized.
- Describing the qualification of the individual(s) performing the assessment.
- Producing a map (or maps) identifying the solar glare receptors, critical points along highways, major roadways and railways and aerodromes that were assessed.
- Producing a table that provides the expected intensity of solar glare (e.g., green, yellow, or red) and the expected duration of solar glare at each identified location.

2 PROJECT DESCRIPTION

The Project is a solar power plant that will have a grid capacity of 250 MW_{AC} consisting of solar photovoltaic (PV) panels mounted on single-axis trackers covering approximately 6.3 square miles. Surrounding land use primarily consists of cultivated agricultural land and internal access roads. A map of the Project's layout, including the dwelling receptors and routes considered as part of this assessment, is included below in Figure 1.

3 METHODOLOGY

3.1 Overview

3.1.1 Glare and Glint

Solar glare is defined as a continuous source of excessive brightness. This can be experienced by both stationary and moving observers. In common language, glint is a similar phenomenon but occurring over very brief timescales. In the interest of clarity, the word 'glare' will be used throughout this report.

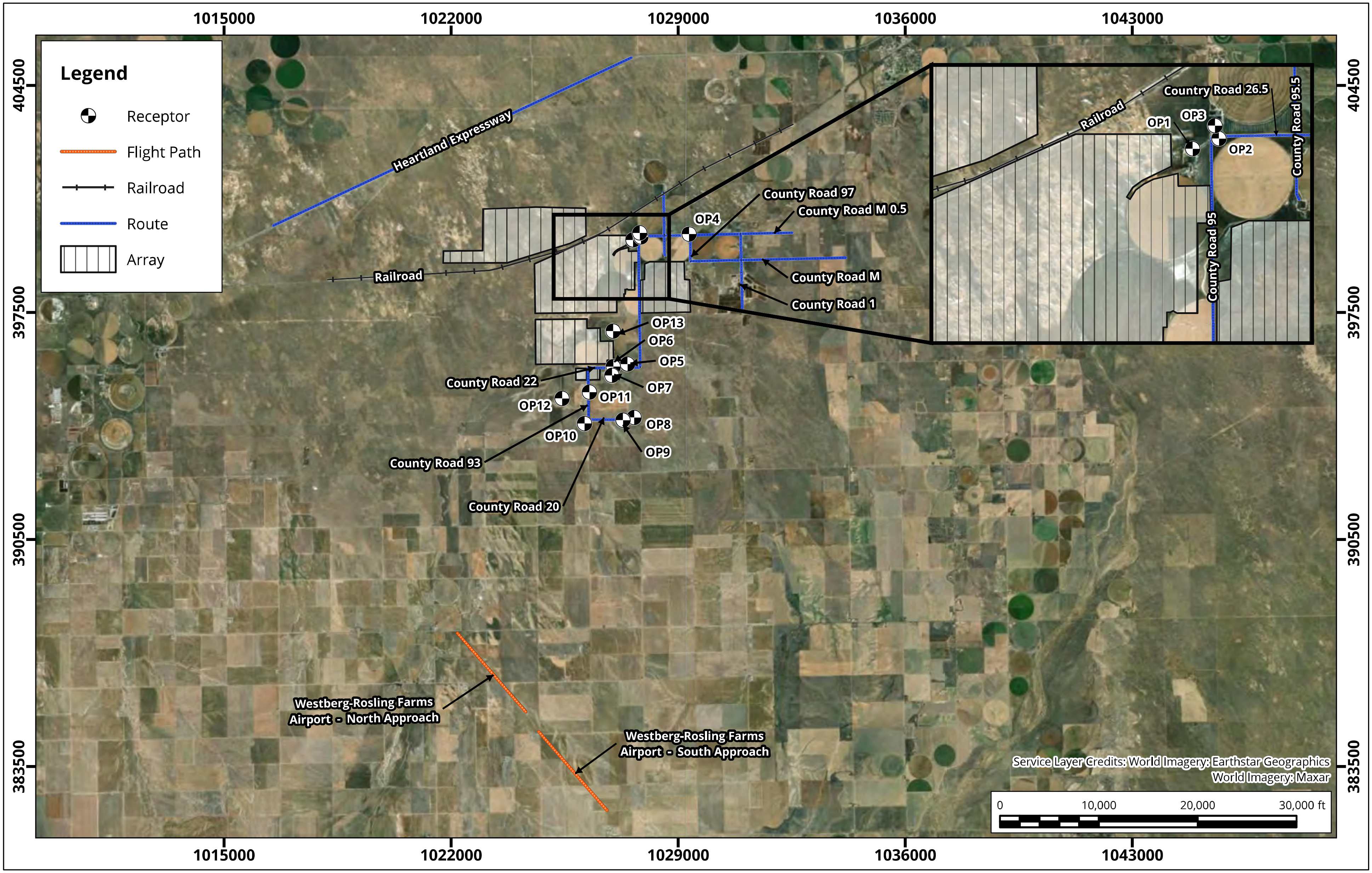
There are many ways that glare can be classified [1], however the most commonly used metric for solar glare hazard assessment is the one created by Ho et al. [2] which categorizes glare into one of the three ocular hazard color codes:

Green: Glare with low potential to cause temporary afterimage (i.e. lingering image in a viewer's eye associated with a flash of light) to a viewer prior to a typical blink response time.

Yellow: Glare with potential to cause temporary afterimage to a viewer prior to a typical blink response time.

Red: Glare with potential to cause retinal damage to a viewer prior to a typical blink response time.

Below is a sample ocular hazard plot that illustrates where common sources of light approximately fall within this framework.



Map Document: C:\GIS\2401940_BalancedRockPower\P2401940_BalancedRockPower.aprx

Project Layout Showing Project Location, Routes, and Receptors

True North

Drawn by: RCL	Figure: 1	
Approx. Scale:	1:165,000	
Date Revised:	Jan 16, 2024	

Map Projection: NAD 1983 StatePlane Colorado North FIPS 0501

Balanced Rock Power - Weld County, Colorado

Project #: 2401940

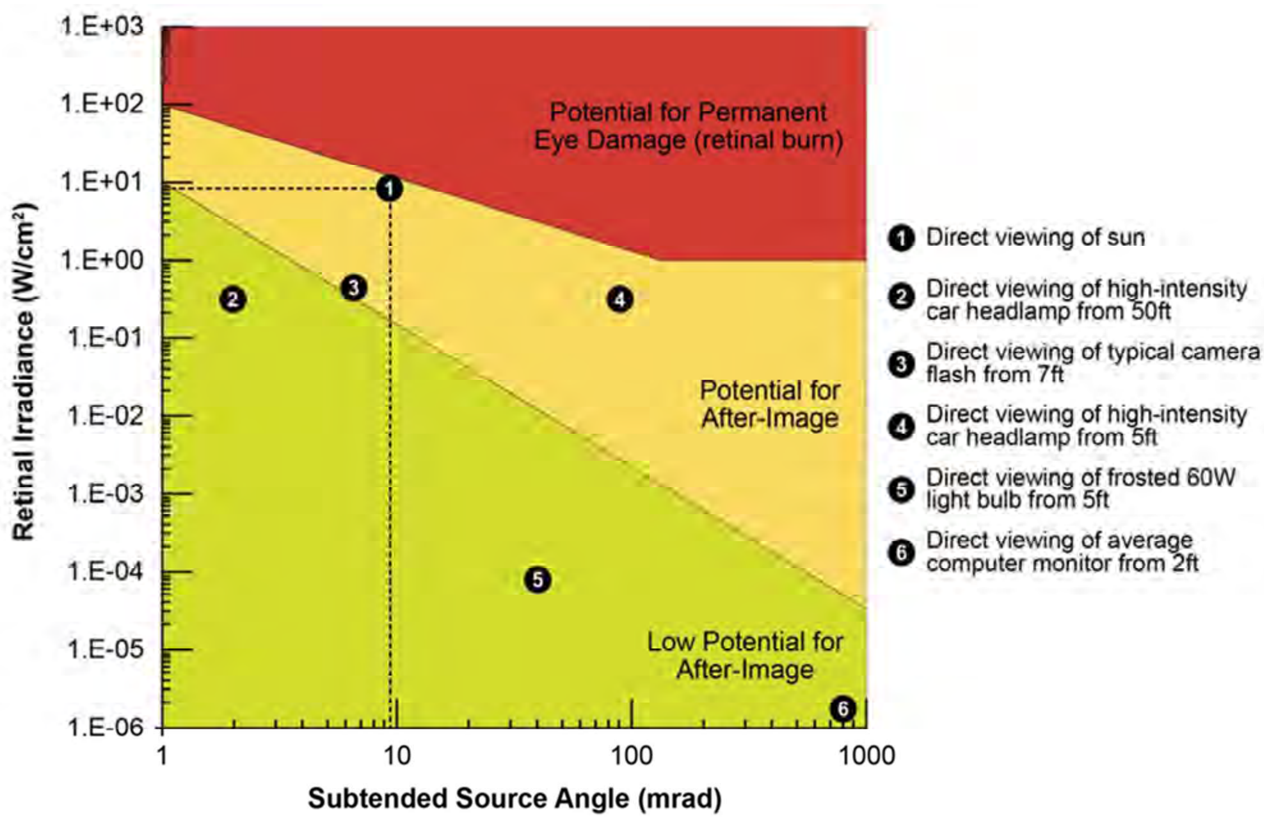


Figure 2: Ocular Hazard Plot

3.1.2 Reflectivity

The amount of visible light reflected from a solar panel depends on a variety of factors including the:

- latitude of the solar farm;
- time of year;
- solar intensity;
- presence of cloud, fog, dust or other attenuating factors in the atmosphere;
- angle of incidence at which direct sunlight strikes the panel; and
- overall reflectivity of the panel surface.

Solar panels are designed to maximize sunlight absorption and minimize reflection in order to ensure maximum electricity production. The majority of solar panels are treated with an anti-reflective coating (ARC) that further reduces the amount of sunlight that is reflected and was modelled as such in our analysis.

3.2 Identification of Receptors

The locations investigated in this analysis were chosen based on RWDI's own best practices and experience in other jurisdictions to provide an appropriately conservative assessment of glare potential.

3.2.1 Dwellings

All dwellings that exist within 5000 feet of the Project was assessed in this study. A total of 13 dwellings were found within that radius (refer to Figure 1). These dwellings were studied at two different heights (5ft and 15ft above grade) to account for views at approximately the first and second floors.

3.2.2 Aerodromes

A privately owned airstrip, Westberg-Rosling Farms Airport, was identified within a 10 mile radius of the project, to the southwest. Two flight paths, designated as FP1 and FP2, have been evaluated, representing departures/approaches to/from the north and south, respectively.

3.2.3 Routes

Twelve nearby routes were assessed in this analysis: County Road 1 (RR1), County Road 26 1/2 (RR4), County Road 95.50 (RR7), County Road 97 (RR8), County Road M (RR9) and County Road M 5/10 (RR10) are located to the east of the project site. County Road 22 (RR3), County Road 93 (RR5), County Road 95 (RR6) and the Railroad (RR12) pass through the project site. County Road 20 (RR2) is located south of the Project. Heartland Expressway (RR11) is located north of the Project. These routes were assessed for glare at a height of 3.5 feet above grade, excluding RR12 which is assessed at a height of 8 feet due to the likely higher seated position of a rail conductor.

A summary of the receptors identified for the Project are presented in Table 1 below.

Table 1: Project Route Receptors and Observation Points

Receptor ID	GlareGauge Receptor Type	Details
RR1	Route	County Road 1
RR2	Route	County Road 20
RR3	Route	County Road 22
RR4	Route	County Road 26.5
RR5	Route	County Road 93
RR6	Route	County Road 95
RR7	Route	County Road 95.5
RR8	Route	County Road 97
RR9	Route	County Road M
RR10	Route	County Road M 0.5
RR11	Route	Heartland Expressway
RR12	Route	Railroad
FP1	Flight Path	Westberg-Rosling Farms Airport Approaching from/Departing to the North
FP2	Flight Path	Westberg-Rosling Farms Airport Approaching from/Departing to the South
OP1 – OP13*	Observation Point	Dwellings in the vicinity of the Project

*Note that all dwellings were studied at two different heights (5ft and 15ft above grade) to account for views at approximately the first and second floors. For the exact location of these dwellings, please refer to Appendix B.

3.3 Modelling Software

Solar glare from the proposed Project has been estimated using Forge Solar's GlareGauge assessment tool. Assumptions and limitations associated with GlareGauge are described within Section 3.3.2. All work was completed by technical staff experienced in the assessment of reflected visible light and solar energy, as detailed in Appendix A.

3.3.1 Modelling Inputs

Table 2: Model Inputs

Parameter	Value	Input Type
Axis Tracking	Single axis	Project Specific
Backtracking Method	Shade-slope	Project Specific
Tracking Axis Orientation	180 Degrees (South)	Project Specific
Maximum Tracking Angle	60 Degrees	Project Specific
Resting Angle	3 Degrees	Project Specific
Ground Coverage Ratio (GCR)	34%	Project Specific
Module Surface Material	Smooth glass with ARC	Project Specific
Rated Power	250 MW_{AC}	Project Specific
Heights Above Ground	Solar panels: 5 ft	Project Specific
	Route Receptors (RR1-RR11): 3.5 ft Rail Route Receptor (RR12): 8 ft	General
	Observation Points (OP): 5 ft and 15 ft	General
View Angle for Routes	50 Degrees	Default
View Angle for Flight Paths	30 Degrees (downward) 50 Degrees (azimuthal)	Default
Glide Slope for Flight Paths	3 Degrees	Default
Eye Focal Length	0.017 m	Default
Sun Subtended Angle	9.3 milliradians	Default

3.3.2 Model Assumptions and Limitations

Assumptions and limitations of the analysis are listed below:

- This analysis was based on information provided to RWDI up to November 29, 2023. Design changes may impact the predictions made below. Should alterations occur, the details should be communicated to RWDI so that their impact on the conclusions be investigated.
- The SGHA did not include detailed geometry of the PV panels such as gaps between the modules and as such actual glare results may be impacted.
- The SGHA assumes that the PV panel arrays are aligned with a plane defined by the heights and coordinates from Google Maps. Large, localized changes in topography cannot be directly accounted for using this method. However, based on available data such topographical changes were not noted at this site.
- The model does not account for potential screening from natural or artificial obstacles such as cloud cover, vegetation or other physical obstructions including the building envelope of any dwellings.
- The model presents results for 1-minute intervals, but vehicle drivers would travel through a particular section of road relatively quickly. As such, if glare was to occur, it would result in momentary glint rather than continuous glare being observed for a driver.
- Based on information provided to RWDI, the PV arrays consist of single axis tracking panels and the module surface material was a smooth glass with an anti-reflective coating (ARC).
- RWDI has assumed a modern backtracking approach designed to minimize panel shading and low solar elevations.
- This analysis covers the expected typical operating condition of the Project. It does not include an assessment of glare potential during maintenance or other activities that would impact panel orientation. It is assumed that such activities would not occur for prolonged periods and would not affect a large portion of the Project at any one time.
- All receptor locations were based on Google Earth imagery of the project location and were not field verified by RWDI.
- This analysis assumed reasonable and responsible behavior on the part of people in the vicinity of the Project. A reasonable and responsible person would not purposely look towards a bright reflection, purposely prolong their exposure to reflected light or heat, or otherwise intentionally try to cause discomfort/harm to themselves or others and/or damage to property.

4 RESULTS AND ANALYSIS

4.1 Assessment

The results of the analysis (summarized in Table 3 below) predicted no potential for red glare at any of locations under the assumptions described above. No yellow or green glare was predicted so long as one of the mitigation options discussed is Section 5.5 is undertaken. It is RWDI's understanding that Balanced Rock is planning to undertake mitigation.

Table 3: Potential Glare Impacts for the Project

Receptor ID	GlareGauge Receptor Type	Green Glare (min/year)	Yellow Glare (min/year)	Red Glare (min/year)
RR1	Route	0	0	0
RR2	Route	0	0	0
RR3	Route	0	0	0
RR4	Route	0	0	0
RR5	Route	0	0	0
RR6	Route	0*	0*	0
RR7	Route	0	0	0
RR8	Route	0	0	0
RR9	Route	0	0	0
RR10	Route	0	0	0
RR11	Route	0	0	0
RR12	Route	0**	0**	0
FP1	Flight Path	0	0	0
FP2	Flight Path	0	0	0
OP1 – OP13	Observation Point	0	0	0

* No glare was predicted at this receptor assuming one of the mitigation measures discussed below. Without mitigation, green and yellow glare was predicted to be possible 7,126 minutes and 1,062 minutes per year, respectively.

** No glare was predicted at this receptor assuming one of the mitigation measures discussed below. Without mitigation, green and yellow glare was predicted to be possible 809 minutes and 288 minutes per year, respectively.

4.2 Effect of Resting Angle on Predictions

The "resting angle" of a PV tracking system defines the angle up from horizontal the panels will 'rest' at when the sun is low in the sky. Shallow rest angles are common in systems with backtracking as this minimizes inter-row shadowing during the first and last hours of the day. Resting angle is also an important factor that contributes to glare potential within the GlareGauge software. This is because panels resting closer to horizontal have the potential to create glancing angle reflections when the sun is low in the sky. The reflectivity of any glass (including the exterior surface of a PV panel) is naturally increased when light strikes it in such a fashion (see Figure 3) and the low solar angle results in reflections directed more horizontally rather than vertically. Thereby, increasing the potential for glare that could affect people. As such, the analysis was also conducted for a range of resting angles to understand its impact on the glare potential of the Project.

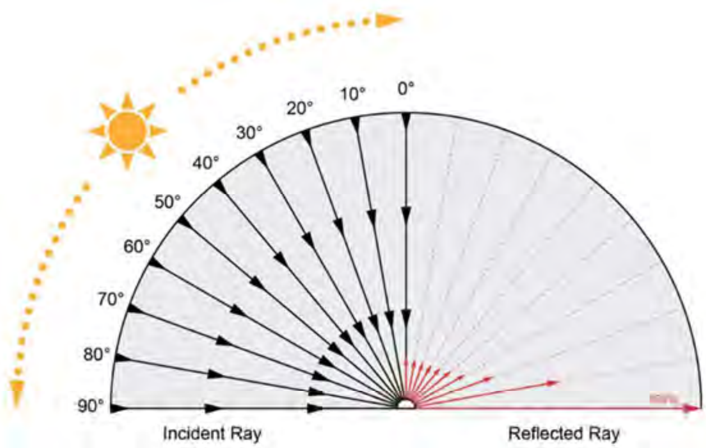


Figure 3: Schematic Illustrating Reflectivity vs. Incidence Angle

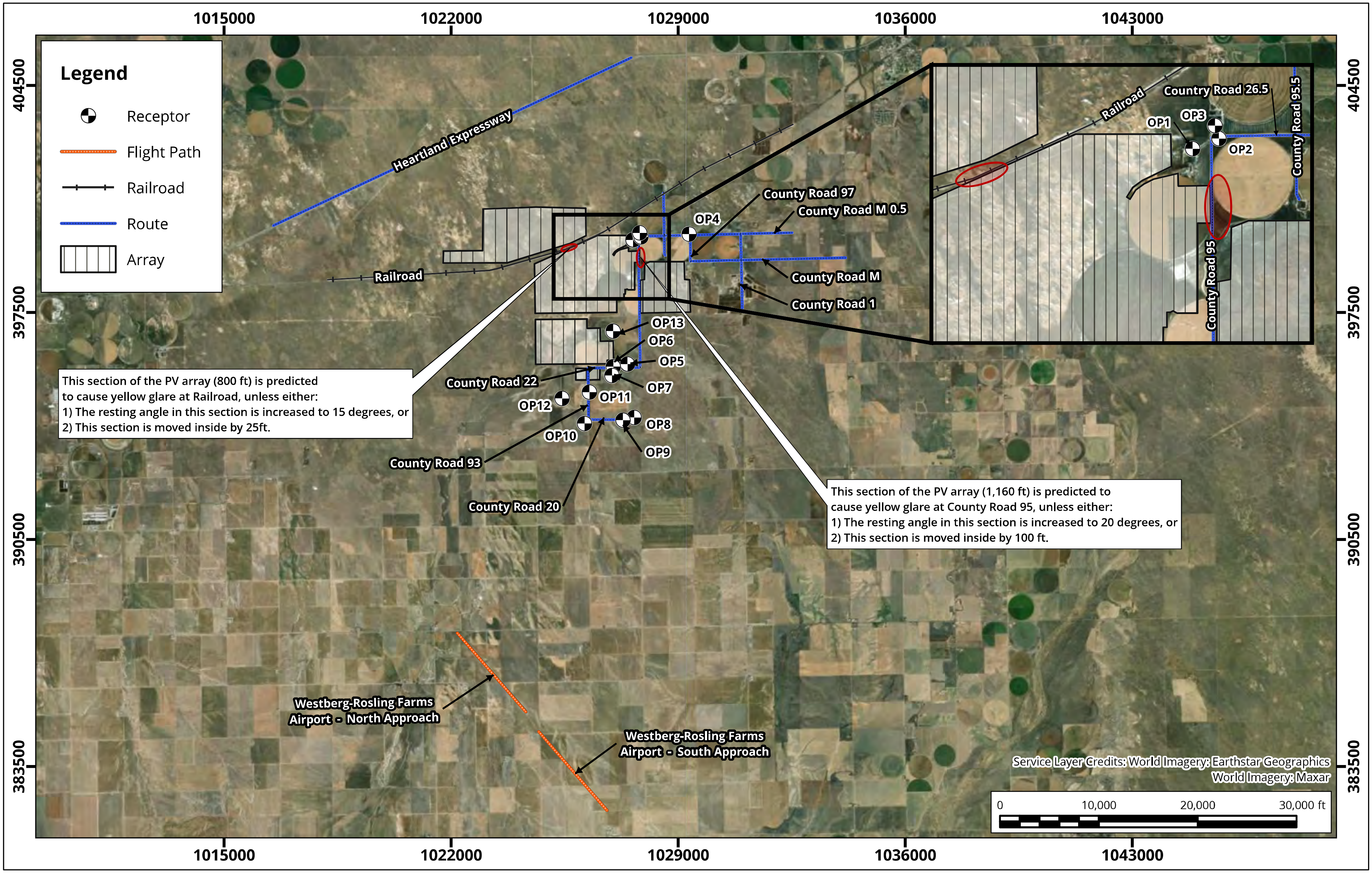
Table 4: Number of Receptors Receiving Glare at Different Resting Angles

Resting Angle	GlareGauge Receptor Type	Green Glare	Yellow Glare	Red Glare
0°	Routes	10	9	**0**
	Flight Paths	**0**	**0**	**0**
	Observation Points	8	4	**0**
3°	Routes	2	2	**0**
	Flight Paths	**0**	**0**	**0**
	Observation Points	**0**	**0**	**0**
20°	Routes	**0**	**0**	**0**
	Flight Paths	**0**	**0**	**0**
	Observation Points	**0**	**0**	**0**

5 CONCLUSIONS

Based on the GlareGauge analysis, RWDI can draw the following conclusions:

1. The Taelor Solar Project was not predicted to create red glare at any of the studied receptor locations.
2. Assuming a resting angle of 3°, yellow glare was predicted on County Road 95 (RR6) from a section of the array just west of the road (refer to Figure 4). The PV panels in this section, (approximately 1,160 feet long and 100 feet wide), were predicted to cause yellow glare between 3:30 pm and 4:30 pm MST from early November to early February. This amounts to yellow glare being possible in approximately 0.4% of the daytime annually.
3. Assuming the same resting angle, yellow glare was predicted on the Railroad (RR12) from a section of the array just south of the track (refer to Figure 4). The PV panels in this section, (approximately 800 feet long and 25 feet wide), were predicted to cause yellow glare between 6:00 am and 8:00 am MST from late October to mid-February. This amounts to yellow glare being possible in approximately 0.11% of the daytime annually.
4. In both cases the potential for yellow glare was predicted in a small fraction of the year and predicted to emanate from small, localized areas of the Project.
5. Several options are possible to reduce or eliminate the yellow glare predicted by these simulations:
    a. Increasing the rest angle of the PV panels in the areas highlighted in Figure 3 to direct reflections upwards and away from traffic. The simulations indicated that rest angles of 15° and 20° would be needed to eliminate the potential for yellow glare on the railway and County Road 95 respectively.
    b. Eliminating the PV panels in these areas, essentially increasing the setback from the road and railway.
    c. Planting dense trees/hedges between the PV panels and the road and railway or creating some other opaque obstruction to obscure the view of the specific areas shown in Figure 3 from drivers.



Solar Glare Assessment Overview - Drivers and Dwellings

Receptors, Site Orientation, and Routes Assessed

Predicted Annual Minutes of Glare at Resting Angle of PV Array = 3°, except at highlighted sections

Map Projection: NAD 1983 StatePlane Colorado North FIPS 0501

Balanced Rock Power - Weld County, Colorado

True North

Project #: 2401940

Drawn by: RCL	Figure: 4
Approx. Scale: 1:165,000	
Date Revised: Jan 16, 2024	

Map Document: C:\GIS\2401940_BalancedRockPower\P2401940_BalancedRockPower.aprx

6 REFERENCES

1. Danks, R., Good, J., and Sinclair, R., "Assessing reflected sunlight from building facades: A literature review and proposed criteria." Building and Environment, 103, 193-202, 2016.
2. Ho, C., Ghanbari, C. and Diver, R., "Methodology to Assess Potential Glint and Glare Hazards from Concentrating Solar Power Plants: Analytical Models and Experimental Validation," Journal of Solar Energy Engineering, vl. 133, no. 3, 2011.

7 GENERAL STATEMENT OF LIMITATIONS

This report entitled Taelor Solar Project – Solar Glare Hazard Assessment (dated January 22, 2024 was prepared by RWDI USA LLC ("RWDI") for Balanced Rock Power, LLC ("Client"). The findings and conclusions presented in this report have been prepared for the Client and are specific to the project described herein ("Project"). The conclusions and recommendations contained in this report are based on the information available to RWDI when this report was prepared.

Because the contents of this report may not reflect the final design of the Project or subsequent changes made after the date of this report, RWDI recommends that it be retained by Client during the final stages of the project to verify that the results and recommendations provided in this report have been correctly interpreted in the final design of the Project.

The conclusions and recommendations contained in this report have also been made for the specific purpose(s) set out herein. Should the Client or any other third party utilize the report and/or implement the conclusions and recommendations contained therein for any other purpose or project without the involvement of RWDI, the Client or such third party assumes any and all risk of any and all consequences arising from such use and RWDI accepts no responsibility for any liability, loss, or damage of any kind suffered by Client or any other third party arising therefrom.

Finally, it is imperative that the Client and/or any party relying on the conclusions and recommendations in this report carefully review the stated assumptions contained herein and to understand the different factors which may impact the conclusions and recommendations provided.

APPENDIX A
PRACTITIONER BIOGRAPHIES

Ryan Danks, B.A.Sc., P.Eng. Technical Director/Associate Principal

Ryan Danks specializes in creating tools and methodologies to predict how the built environment will interact with climate. From preventing dangerous solar glare to tracking germs through air ducts and understanding wind flow around the next generation of extremely large telescopes, Ryan's ability to understand and simulate multifaceted physical processes yields answers to even the most sophisticated questions. His process may be complex, but the outcome is simple: comfortable, sustainable spaces in and around our clients' structures and facilities. In addition to the impressive results he delivers for clients, Ryan helps us stay at the leading edge of building science through his contributions to our building-science R&D practice. Among other things, Ryan is the lead developer of our Climate-Aware Design Toolkit, which includes the Eclipse solar modeling engine and the Oasis thermal comfort estimator.

Ryan has experience in urban glare analysis, thermal comfort, daylight availability/shadow analysis internationally and is a registered Professional Engineer in both Ontario and Alberta. He is also a member of the International Building Performance Simulation Association (IBPSA) Canadian Chapter, Canada Green Building Council, Facade Tectonics Institute and frequently presents at conferences on solar issues and glare in the built environment.

Abdul Malik Huzaifa, M.A.Sc. Technical Coordinator

Malik brings to his work a valuable combination of technical training and research experience. He is a strong communicator and a creative problem-solver, he excels at translating the findings of his analyses into clear, actionable reports. Malik is fluent in many aspects of our solar practice; he has a holistic perspective that enables him to collaborate effectively and deliver useful results and insights for colleagues and clients alike.

APPENDIX B
OBSERVATION POINT LOCATIONS

Receptor ID	Receptor Type	Latitude (°)	Longitude (°)
OP1	Observation Point	40.180741	-104.170725
OP2	Observation Point	40.181557	-104.167829
OP3	Observation Point	40.182654	-104.168244
OP4	Observation Point	40.182131	-104.150408
OP5	Observation Point	40.146296	-104.173392
OP6	Observation Point	40.145643	-104.178538
OP7	Observation Point	40.143202	-104.179064
OP8	Observation Point	40.131442	-104.171261
OP9	Observation Point	40.130733	-104.175320
OP10	Observation Point	40.129972	-104.189241
OP11	Observation Point	40.138649	-104.187307
OP12	Observation Point	40.137021	-104.197229
OP13	Observation Point	40.155510	-104.178414