Spring Coulee Solar Project

Solar Glare Hazard Analysis

Client: Solar Krafte Utilities Inc.
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Executive Summary

Solar Krafte Utilities Inc. (Solar Krafte) is developing a utility-scale solar photovoltaic (PV) project, designated as the Spring Coulee Solar Project (the Project). The Project is proposed on 175 acres of land located approximately nine kilometres southwest of the Hamlet of Spring Coulee, in Cardston County, Alberta. The Project will consist of approximately 71,000 fixed-tilt solar modules. Solar Krafte retained Green Cat Renewables Canada Corporation (GCR) to conduct a solar glare hazard analysis for the potential of glare at dwellings and along transportation routes near the Project.

GCR utilizes ForgeSolar's GlareGauge software to assess user-input PV arrays for potential glare on identified roadways, dwellings, and aviation assets. The software evaluates the occurrence of glare on a minute-by-minute basis. If glare is predicted, each minute of glare as a function of retinal irradiance and subtended angle is plotted on a hazard plot. Retinal irradiance and subtended angle predict the ocular hazard associated with the glare as either green (low potential for after-image), yellow (potential for temporary after-image), or red (potential for retinal damage). The software does not consider obstacles such as trees, hills, buildings, etc. between the PV array and glare receptor.

GCR followed the guidelines provided in the AUC's updated *Rule 007* (effective September 2021) for the receptors to be included in a solar glare assessment, but *Rule 007* does not specify any modelling parameters or glare threshold limits.[1] GCR also referred to the information provided in Zehndorfer Engineering's *Solar Glare and Glint Project Report*,[2] which was written to inform the AUC's update to *Rule 007*, and precedent set by recent AUC proceeding

GCR evaluated the area within 4,000m of the Project for aerodromes and within 800m for any other receptors. The assessment considered the following receptors near the Project:

- Two residences;
- Highway 5; and
- Four local roads.

The glare analysis indicates that the Project is not likely to have the potential to create hazardous glare conditions for the dwellings or transportation routes assessed.

The actual glare impacts that will be experienced on roads are anticipated to be only a fraction of the results presented in this report. The actual impact is expected to be less because vehicle operators will be travelling past the site, not standing still while looking at the solar PV arrays. The affected roadway is a rural gravel or dirt road that is not expected to have high traffic volumes. Since there will be fewer cars travelling along this route, the risk of the predicted glare affecting drivers is further reduced.

Glare predicted to affect dwellings is only expected to occur for short daily durations, and it is not expected to have a significant adverse effect on a resident's use of their home. Observers are also expected to simultaneously see direct sunlight originating from the same general direction as the glare, so glare impacts may be less pronounced. Some of the predicted glare is also expected to be obstructed by existing rows of trees.

[1] *AUC Rule 007: Applications for Power Plants, Substations, Transmission Lines, Industrial System Designations, Hydro Developments and Gas Utility Pipelines,* subsection 4.3.2 SP14, (March 2021).

[2] *Solar Glare and Glint Project* (Zehndorfer Engineering, September 2019).

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Table of Contents

1 Introduction

Solar Krafte Utilities Inc. (Solar Krafte) retained Green Cat Renewables Canada Corporation (GCR) to conduct a solar glare hazard analysis for the Spring Coulee Solar Project (the Project). The solar photovoltaic (PV) project is proposed on 175 acres of land located approximately nine kilometres southwest of the Hamlet of Spring Coulee, in Cardston County, Alberta. The Project will consist of approximately 71,000 fixed-tilt solar modules, with a total generation capacity of 30.8 megawatts (MW_{AC}).

The assessment considers the glare impact of the Project on dwellings and roadways within approximately 800 metres of the site. The evaluated roads include Highway 5, Range Road 242B, Range Road 243, Township Road 42, and Township Road 43A. There are no registered aerodromes within 4,000 metres of the Project. The nearest registered aerodrome is the Cardston Airport, which is about 16 km southwest of the Project. GCR conducted a high-level search for unregistered aerodromes within 4,000 metres of the Project but did not find any.

Glint and glare refer to light reflected off smooth surfaces, either momentarily and intense (glint) or less intense for a more sustained period (glare). Solar PV technology is specifically designed to absorb as much sunlight as possible and modules are generally coated in an anti-reflective coating. Solar PV sites have been developed alongside major transport routes and airports around the world, including adjacent to road infrastructure. This suggests that solar PV technology, such as the Spring Coulee Solar Project, can safely coexist with roads and airports.

It is considered that a developer, in this case Solar Krafte, should provide safety assurances regarding the full potential impact of the installation on routes, roads, and dwellings in the form of a glare assessment.

2 Background Information

The potential for glint and glare from solar PV modules on the surrounding roads, residential properties and nearby aerodromes should be fully considered when planning a solar project.

Glint and glare are both caused by the reflection of light from a surface, in this case sunlight from a solar module. Glare is caused by a continuous but less intense reflection of a bright light, whereas glint is caused by a strong, momentary reflection of sunlight. Reflections from smooth surfaces produce more direct “specular” reflections, and rougher surfaces disperse the light in multiple directions, creating “diffuse” reflections. Figure 2-1 shows these two types of reflections from a solar PV module.

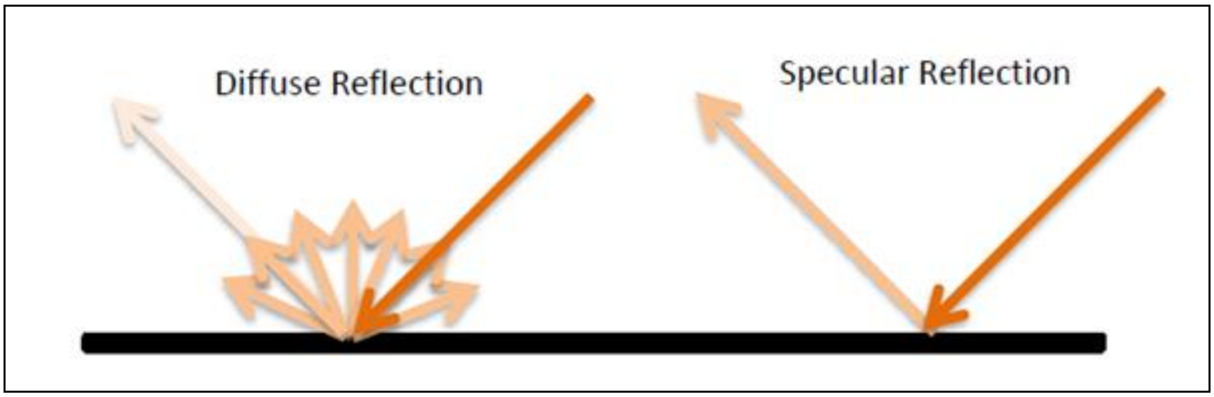

Figure 2-1 – Types of light reflection from solar modules

Calculation of potential glare requires the azimuth and elevation angle of the sun, and the consequent angles of incidence and reflection at the array, at all times throughout the year.

The angle of incidence is the angle at which the sun strikes the module (measured from normal/perpendicular to the surface). The angle of reflection is equal and opposite the angle of incidence. Light transmission through the glass and absorption by the PV module is greatest when the light is normal to the glass surface, while more light is reflected at shallower angles. As shown in Figure 2-2, a low incidence angle in a fixed tilt system is associated with the sun being high in the sky such that the sun’s rays are shining at close to a right angle with the module surface. The highest incidence angles will occur in the early morning and late evening when the sun is low in the sky.

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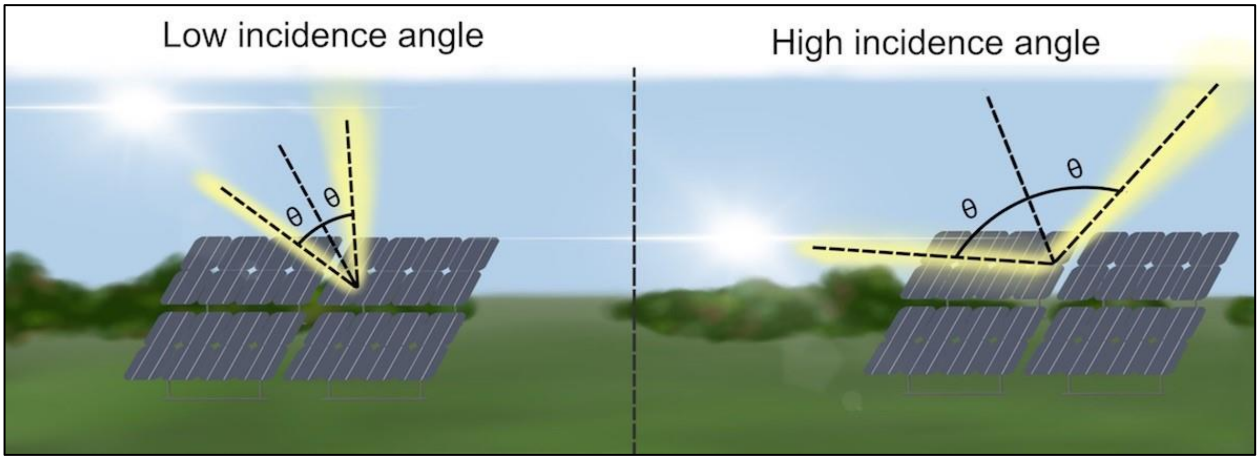

Figure 2-2 – Angles of incidence relative to the Sun's position

Throughout the day the sun will track across the sky; therefore, the angle at which the light is incident on the module will vary. Figure 2-3 shows the two angles (azimuth and elevation/zenith) required to define the orientation of the sun with respect to the solar module.

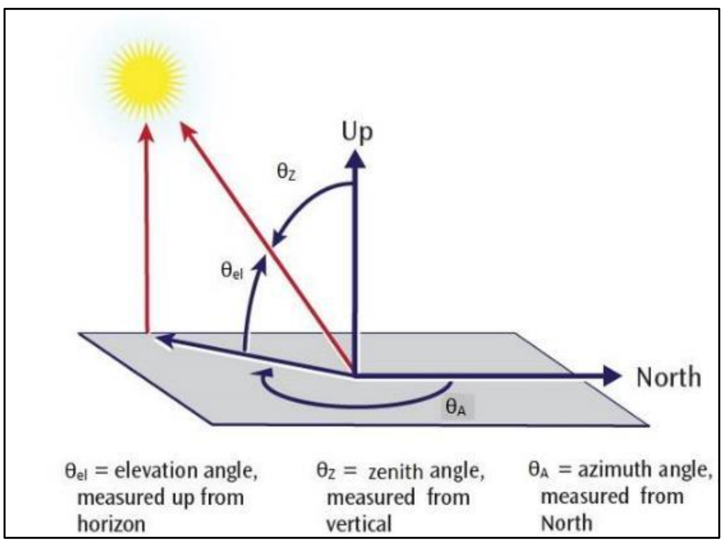

Figure 2-3 – Sun's position relative to solar module

There are many factors that affect the glare level. These include but are not limited to:

- The type of solar module
- The module's tilt angle and orientation
- Size of solar development
- Shape of solar development
- Location of solar development
- Distance between solar development and observer
- Angle to observer
- Relative height of observer

The following section describes the proposed development and the associated infrastructure in detail.

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3 Project Description

The proposed Project site is located in southern Alberta, approximately 9 km southwest of the Hamlet of Spring Coulee, in Cardston County, Alberta. The Project location is shown in **Figure 3-1**.

Figure 3-1 – Spring Coulee Solar Project Location

The Project covers an area of approximately 175 acres with a total generating capacity of 30.8 MW_{AC}. The PV modules will be mounted on fixed tilt racking secured to the ground with piles.

4 Legislation and Guidance

There is currently no adopted legislation for assessing the impacts of glare for solar energy development in Alberta or Canada, and standardized guidance only specifies what receptors to include in an assessment without specifying acceptable thresholds.

The AUC have released an update to *Rule 007* that will take effect September 1, 2021. *Rule 007* states that solar glare assessment reports must include receptors within 800m from the boundary of the project and aerodromes within 4,000m from the boundary of the project.[3] It continues to state the following requirements.

- Describe the time, location, duration, and intensity of solar glare predicted to be caused by the project.
- Describe the software or tools used in the assessment, the assumptions, and the input parameters (equipment-specific and environmental) utilized.
- Describe the qualification of the individual(s) performing the assessment.
- Identify the potential solar glare at critical points along highways, major roadways, and railways.
- Identify the potential solar glare at any aerodrome within 4,000 metres from the boundary of the project, including the potential effect on runways, flight paths and air traffic control towers.
- Include a map (or maps) identifying the solar glare receptors, critical points along highways, major roadways and railways, and aerodromes that were assessed.
- Include a table that provides the expected intensity of the solar glare (e.g., green, yellow, or red) and the expected duration of solar glare at each identified receptor, critical points along highways, major roadways and railways, and any registered and known unregistered aerodromes that were assessed.

This report will abide by: requirements in the updated *Rule 007* (effective September 2021); suggestions made in Zehndorfer Engineering's *Solar Glare and Glint Project Report* from September 2019,[4] which was written to inform the AUC's update; and precedent set by recent AUC proceedings.

As observed in the Zehndorfer document, solar glare assessments in Canada typically utilize Sandia National Laboratories' Solar Glare Hazard Analysis Tool (SGHAT) through ForgeSolar's software called GlareGauge. The Zehndorfer report notes that: "*the typical Solar Glare Assessment in Canada consists of more than just the plain SGHAT report. It describes the geometric situation, highlights glare duration and suggests glare-reducing measures.*"[5] This approach has been adopted for this assessment.

The Zehndorfer report also comments that: "*with respect to dwellings, geometrical considerations can be useful. The inclination angle towards a window makes a difference, because light rays perpendicular towards the glass will penetrate the window, while window recesses will shade flat-angled rays of light.*"[6]

[3] AUC Rule 007*: Applications for Power Plants, Substations, Transmission Lines, Industrial System Designations, Hydro Developments and Gas Utility Pipelines,* subsection 4.3.2 SP14, (March 2021).

[4] *Solar Glare and Glint Project* (Zehndorfer Engineering, September 2019).

[5] *Solar Glare and Glint Project* (Zehndorfer Engineering, September 2019) PDF page 8.

[6] *Solar Glare and Glint Project* (Zehndorfer Engineering, September 2019) PDF page 6.

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In addition to Zehndorfer's report, the US Federal Aviation Administration (FAA) have provided the Technical Guidance for Evaluating Selected Solar Technologies on Airports.[7] This document, last updated in April 2018, states that potential for glare might vary depending on site specifics such as existing land uses, location and size of the project. A geometric analysis may be required to assess any reflectivity issues coming from the solar modules. FAA guidelines have also been informed by the 2015 study, Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach, by Rogers, et al. This study concludes that glare of sufficient size and intensity in an airplane pilot's view, within ±25° of heading, may have an adverse impact on the pilot's ability to read their instruments or land their plane. The study also indicates that glare beyond ±50° of heading is not likely to impair a pilot.[8]

4.1 Geometric Analysis – Use of the Solar Glare Hazard Analysis Tool

The SGHAT is a validated tool specifically designed to estimate potential glare according to a Solar Glare Hazard Analysis Plot at a certain module height, tilt, type, and observer location. ForgeSolar's GlareGauge/SGHAT software allows for the analysis of potential glare on flight paths, routes, and stationary observation points. It is widely accepted as the most comprehensive tool to assess potential glare impacts on receptors near solar power projects. The Zehndorfer report reviewed several glare software packages that may be used to assess solar PV glare, including ForgeSolar's GlareGauge/SGHAT. The report does not make a specific recommendation, but the findings suggest that the SGHAT is the most accessible tool of those evaluated, and the most robust with respect to the output information.[9]

[7] *Technical Guidance for Evaluating Selected Solar Technologies on Airports* (FAA, April 2018), pg. 40.
[8] *Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach* (Rogers, J. A., et al., July 2015).
[9] *Solar Glare and Glint Project* (Zehndorfer Engineering, September 2019).

5 Assessment Methodology

The SGHAT is configured to enable an analysis on flight paths using a 2-mile approach to a runway when landing. No airports were reported within 4,000m of the Project, so no airplane flight paths were included in this assessment.

For ground-based routes, the Zehndorfer report recommends modelling the FOV within ±15° from the vehicle operator's heading.[10] This covers the region where a person's vision will be most focussed, which is the critical area of concern. A more conservative ±25° FOV can also be modelled to identify routes that may be peripherally impacted by glare. This wider FOV is based on the information presented in the Rogers FAA report for airplane pilots, adapted to suit vehicle operators using ground-based routes. Both passenger and commercial vehicles are considered in the analysis.

In line with AUC *Rule 007*'s updated guidelines (effective September 2021) for choosing receptors to include in a solar glare analysis, the assessment evaluated:

- Two residences;
- Highway 5; and
- Four local roads.

Note, if the modules are not visible to the individual receptor, then no glare can be observed at that receptor.

5.1 Assessment Input Parameters

The solar arrays, observation points, and transportation routes were plotted using an interactive Google map, and site-specific data was entered into the software prior to modelling. The following sections provide details of the parameters specified for the analysis calculations in the GlareGauge software.

5.1.1 PV Array

The general PV array areas were plotted on the interactive Google map as shown in **Figure 5-1.** The Project was split into four sub-arrays to avoid conflict between complex array geometry and software calculation limitations, while also providing additional detail in areas with greater topographical variation. The modelled sub-array includes more land than the proposed PV array coverage, which results in a more conservative analysis.

[10] *Solar Glare and Glint Project* (Zehndorfer Engineering, September 2019).

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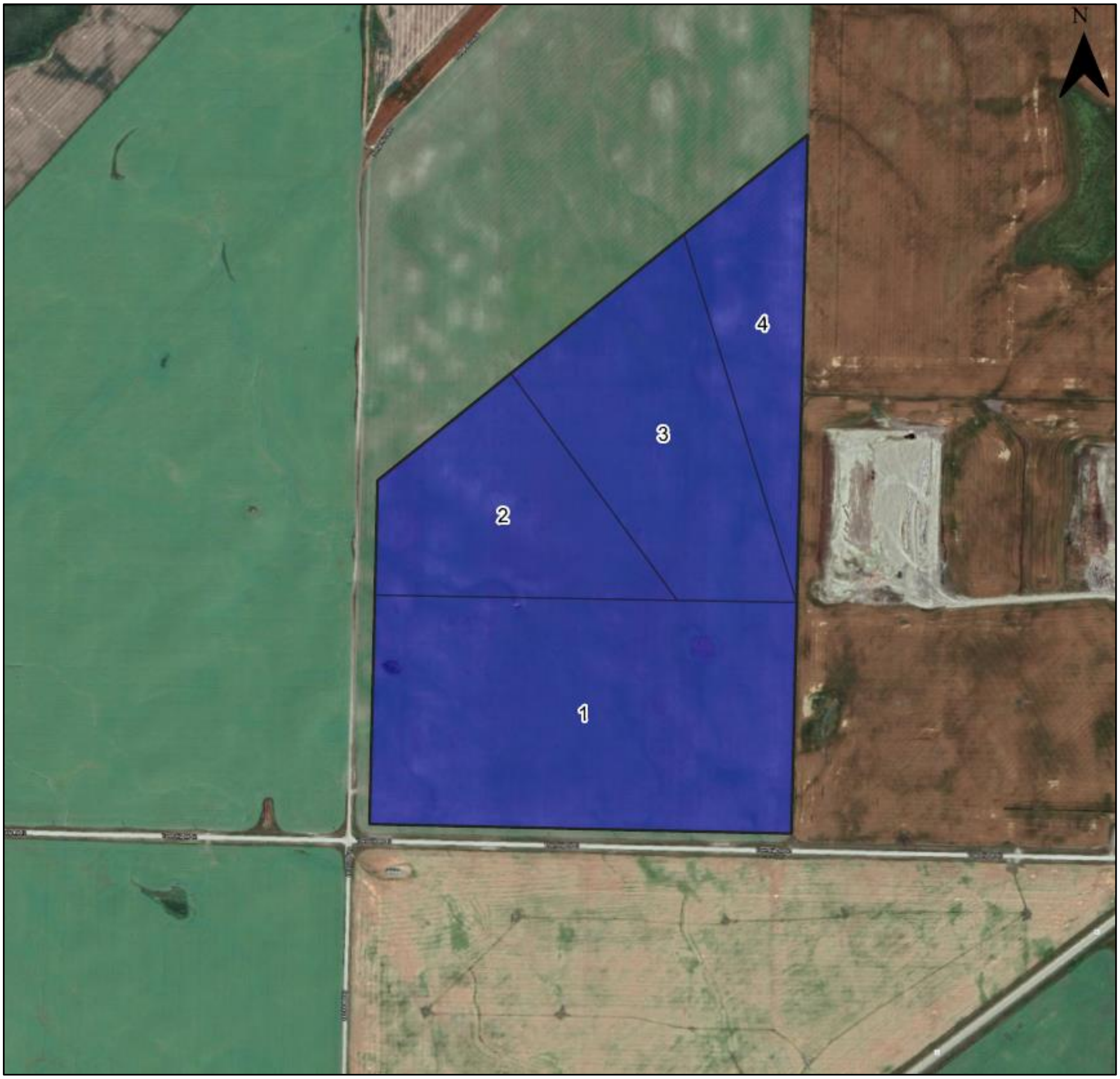

Figure 5-1– General PV array areas plotted in GlareGauge Software

The Project details in Table 5-1 were specified in the model.

Table 5-1 – PV Array Specified Parameters

Required Inputs	Specified Parameters	Description
Axis Tracking	None	Modules are mounted on fixed tilt racking
Orientation	180° (south)	Azimuthal position measured from true north
Fixed Tilt Angle	30°	Fixed tilt angle of modules
Module Surface Material	Smooth glass with anti-reflective coating	Surface material of modules
Minimum Module Height Above Ground	0.6m	Approximate height at the bottom of the array
Maximum Module Height Above Ground	2.9m	Approximate height at the top of the array

Solar PV modules are designed to maximize light absorption and conversion to electricity. Specifying different types of glass and coatings used on the modules can affect a system's energy production and glare potential. Smooth glass with anti-reflective coatings will generally reflect less light, i.e., create less glare, than uncoated glass. Incorporating texture into the glass surface will also help diffuse incident light, reducing the intensity of the reflection.

Both the minimum and maximum module heights are modelled to show the variance in potential glare from different parts of the arrays. Longer durations of glare are often predicted for the bottom module elevation than the top, but the lower parts of arrays are more likely to be visually screened by other rows of arrays in practice (which is not modelled by GlareGauge). Glare results are not additive between the evaluated heights, and glare time frames predicted for each height typically coincide.

The elevation variation across the site is ranging from 1,125m to 1,142m above mean sea level (AMSL). Further review of Google elevation data shows that the land is sloping downward toward the north and west in particular, with the southeast corner of the site being the highest elevation point. The elevation is generally lower in north and west of the site, but a high point exists in the boundary between sub-array 2 and 3, as shown in **Figure 5-1**, that forms a small hill. The sub-array layout was intentionally plotted to account for this hill.

5.1.2 Route Paths

Five route paths were evaluated for glare impacts from the Project in this assessment, including a highway and four local roads. Sections of Highway 5, Range Road 242B, Range Road 243, Township Road 42, and Township Road 43A near the Project boundary were modelled as two-way routes to represent vehicles travelling in both possible directions. **Figure 5-2** shows the routes in relation to the Project.

Two horizontal viewing angles were evaluated for motorists: ±15° and ±25° (30° and 50° total FOV). The ±15° range encompasses the region where a person's vision will be most focussed, which is the critical area of concern.[11] The ±25° range is a more conservative view that indicates the routes that may be impacted by glare. The road routes were set at 1.5m elevation to represent the typical height of passenger vehicles and 3.0m to represent the typical height of commercial trucks. Commercial vehicles are typically more susceptible to glare than passenger vehicles due to their increased height.

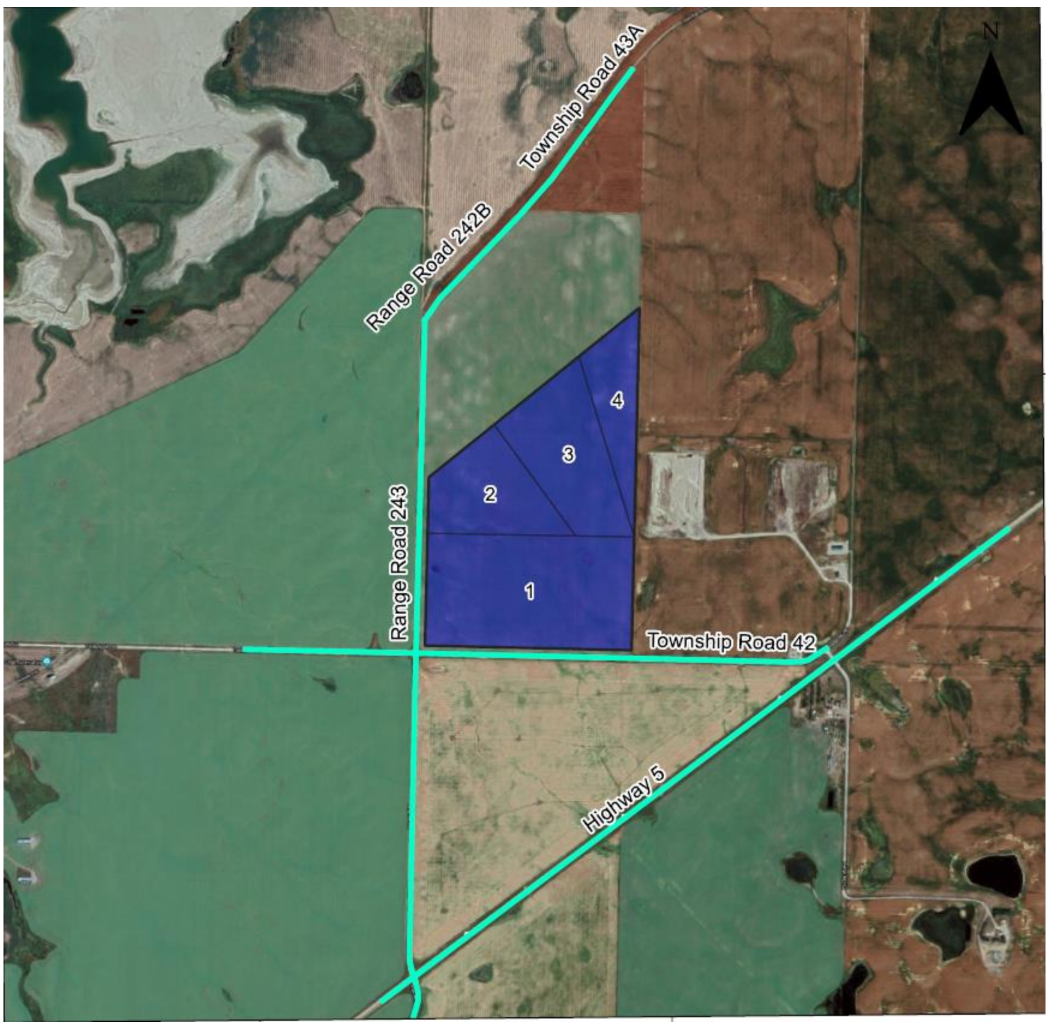

Figure 5-2 – Roads near the Project

[11] *Solar Glare and Glint Project* (Zehndorfer Engineering, September 2019).

5.1.3 Dwellings

Two dwellings were assessed within approximately 800m of the Project boundary. Dwellings were modelled at 4.5m above ground to represent the worst-case scenario where an observer can see the Project from a second-storey window. The model assumes that receptors have an unobstructed view of the arrays, i.e., the view is not affected by any part of the building being evaluated. **Figure 5-3** shows the dwellings in relation to the Project.

Figure 5-3 – Dwellings near the Project

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5.1.4 Other Assumptions

The following assumptions have been made in setting the parameters for this analysis:

- 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 that may mitigate impacts. This includes buildings, tree cover and geographic obstructions.
- The glare hazard determination relies on several approximations including observer eye characteristics, angle of view, and typical blink response time. Actual values may differ.
- Hazard zone boundaries shown in the Glare Hazard plot are an approximation and visual aid. Actual ocular impact outcomes encompass a continuous, not discrete, spectrum.
- Glare analysis does not account for change in weather patterns. It is assessed as clear sunny skies throughout the year.
- To increase accuracy of modelling results, parts of the array may be divided into sub-sections if the footprint covers a large surface area with drastic elevation changes, or to avoid concave outlines.
- Default parameters, as alluded to in the following section, highlight ocular metrics used in this assessment as has been acceptable according to the Sandia National Laboratories methodology on assessing potential glint and glare hazards.[12] These are shown below in **Table 5-2.**

Table 5-2 – Default Parameters

Glare Gauge Parameters	
Direct Normal Irradiance, DNI (amount of solar radiation received in a collimated beam on a surface normal to the sun during a 60-minute period)	Varies and peaks at 1000 W/m2
Ocular Transmission Coefficient (absorption of radiation within the eye before it reaches the retina)	0.5
Pupil Diameter (Typical daylight adjusted length)	0.002m
Eye Focal Length (distance where rays intersect in the eye)	0.017m
Sun Subtended Angle	9.3 mrad

[12] Ho, C.K., C.M. Ghanbari and R.B. Diver, 2011, *Methodology to Assess Potential Glint and Glare Hazards from Concentrating Solar Power Plants: Analytical Models and Experimental Validation*, Journal of Solar Energy Engineering-Transactions of the ASME, 133 (3)

5.2 Glare Analysis Procedure

GCR calculated the potential glare for observation points and route receptors using the SGHAT. Although effects from glare are subjective, depending on variables such as a person's ocular parameters and size/distance from the glare source, the SGHAT has a generalized approach to specify the hazard that glare may produce. GCR's commentary on the levels of glare found and related sources of mitigation, if required, are intended to help decision makers evaluate potential impacts.

The SGHAT User's Manual v3.0[13] states that: "*If glare is found, the tool calculates the retinal irradiance and subtended source 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 simple, easy-to-interpret plot that specifies when glare will occur throughout the year, with color codes indicating the potential ocular hazard.*"

The colour codes are based on a red, yellow, and green structure to categorize the level of risk to a person's eyes. Glare classification is dependent on the glare intensity and the apparent size of the glare area as viewed from the eye. The severity of glare is proportional to the effects of an after-image, which can be described as a lingering image of glare in the field-of-view, or a flash blindness when observed prior to a typical blink response time. The descriptions for each category are as follows:

- Green: Glare is present but there is a low potential for temporary after-image;
- Yellow: Glare is present with the potential for temporary after-image; and
- Red: Glare is present with the potential for permanent eye damage.

The level of glare is derived using the graph below that plots the level of irradiance against the angle that is occupied by the glare in the field-of-view.

ForgeSolar have developed a plot to categorize glare based on its intensity at the eye and its size in the observer's field-of-view. The plot is divided into the red, yellow, and green regions described above. The hazard associated with directly viewing the sun unfiltered is also plotted for comparison. **Figure 5-4** shows an example of the hazard plot.

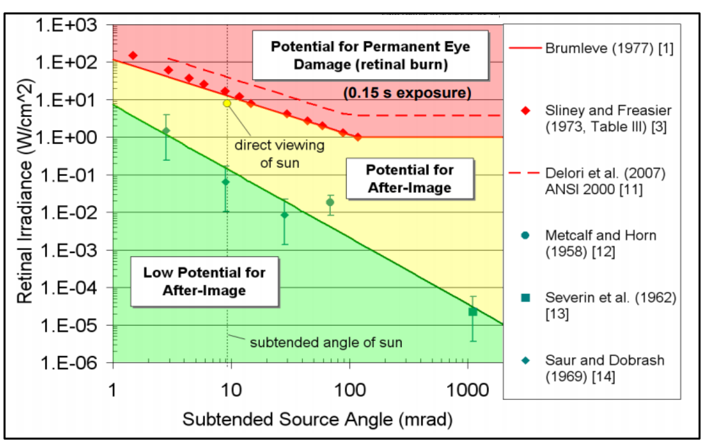

Figure 5-4 – Hazard plot depicting the retinal effects of light

[13] *Solar Glare Hazard Analysis Tool (SGHAT) User's Manual v 3.0, Ho and Sims, Sandia National Laboratories, 2016.*

Ho et al. developed a model to estimate potential impacts to eyesight with regards to retinal irradiance (amount of light entering the eye and reaching the retina) and subtended source angle (the size of the glare divided by the distance from the emitting source). Significant damage, including retinal burn, may occur at high retinal irradiances and large subtended angles. This is highlighted in the red region. The yellow section denotes the potential for a temporary after-image. The size and impact of the after-image is dependent upon the subtended source angle.[14] At a low retinal irradiance and small subtended angle, the hazard will be in the green section where there is very low potential for after-image.

5.2.1 Limitations

The SGHAT will convert the footprint of a concave polygon to a convex polygon.[15] For example, an array that is in the shape of a 'C' has a concave section and GlareGauge will modify the 'C' shape into a semi-circle. By closing the 'C' shape, the size of the PV array is increased thus potentially over-estimating the size of the array, and consequently over-predicting the glare effects. This change in geometry is required by the glare-check algorithm during analysis. PV arrays with significant concavities should be modelled as multiple arrays to avoid over-estimating the size of the PV array and the resultant glare. The limitations of the software have been carefully considered to ensure the PV array is not concave in order to represent the glare impacts as accurately as possible.

An unavoidable limitation of the SGHAT is that a *"random number of 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 [air traffic control towers]."*[16]

[14] *Evaluation of glare at the Ivanpah Solar Electric Generating System (C.K. Ho et al., Elsevier Ltd., 2015).*
[15] *ForgeSolar "Help" page.* Retrieved August 16, 2021.
[16] *ForgeSolar "Help" page.* Retrieved August 16, 2021.

6 Assessment of Impact

The following section presents the findings of the glare assessment. The results are factual based on the model parameters used, which are considered to be conservative and as reasonable as possible. The updated AUC *Rule 007* (effective September 2021) provides guidelines for the receptors to be included in a solar glare assessment, but modelling parameters and glare threshold limits are not specified. Therefore, this analysis also considers the principles laid out in the Zehndorfer Engineering Report[17] and recent AUC proceedings, as described in **Section 5**.

The GlareGauge software considers the glare potential for a full one-year period in one-minute intervals to account for the variations between seasons, DNI, and sun angle.

6.1 Route Path Results

The tables on the following pages present the glare results for the route paths assessed from the minimum and maximum module heights. Results are shown for passenger and commercial road vehicles at 1.5m and 3.0m above ground, respectively. Results in **Table 6-1** used a ±15° FOV, which was modelled to capture potential glare within a vehicle operator's critical visual range. Results in **Table 6-2** were evaluated with a ±25° horizontal FOV to highlight routes that may experience glare from an extended visual range. Equivalent levels of glare within ±15° will have a greater impact on the observer than glare outside that range.

[17] *Solar Glare and Glint Project (Zehndorfer Engineering, September 2019).*

Table 6-1 – Annual route path glare levels for passenger and commercial vehicles, +/-15° FOV

Component	Green Glare (min/year)		Yellow Glare (min/year)		Red Glare (min/year)	
Module Height	0.6m	2.9m	0.6m	2.9m	0.6m	2.9m
Highway 5 (passenger)	0	0	0	0	0	0
Highway 5 (commercial)	0	0	0	0	0	0
Range Road 242B (passenger)	0	0	0	0	0	0
Range Road 242B (commercial)	0	0	0	0	0	0
Range Road 243 (commercial)	0	0	0	0	0	0
Range Road 243 (passenger)	0	0	0	0	0	0
Township Road 42 (commercial)	0	0	5,744	5,341	0	0
Township Road 42 (passenger)	0	0	5,491	3,758	0	0
Township Road 43A (commercial)	0	0	0	0	0	0
Township Road 43A (passenger)	0	0	0	0	0	0

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Table 6-2 – Annual route path glare levels for passenger and commercial vehicles, +/-15° FOV

Component	Green Glare (min/year)		Yellow Glare (min/year)		Red Glare (min/year)	
Module Height	0.6m	2.9m	0.6m	2.9m	0.6m	2.9m
Highway 5 (passenger)	0	0	0	0	0	0
Highway 5 (commercial)	0	0	0	0	0	0
Range Road 242B (passenger)	0	0	0	0	0	0
Range Road 242B (commercial)	0	0	0	0	0	0
Range Road 243 (commercial)	0	0	0	0	0	0
Range Road 243 (passenger)	0	0	0	0	0	0
Township Road 42 (commercial)	0	0	12,478	11,260	0	0
Township Road 42 (passenger)	0	7	11,590	8,835	0	0
Township Road 43A (commercial)	0	0	0	0	0	0
Township Road 43A (passenger)	0	0	0	0	0	0

Township Road 42 is directly adjacent to the southern edge of the Project, coming within approximately 40m of the nearest arrays. Drivers of commercial vehicles on this road are expected to be the most-impacted receptors on roadways near the Project, with drivers of passenger vehicles predicted to observe slightly less annual yellow glare.

Considering the more critical ±15° FOV, observers driving along this road are expected to see yellow glare for a maximum of 5,744 minutes/year. The glare is predicted from late March to mid May and late July to September around 06:50 MST for up to 37 minutes per morning. The glare is also predicted around 18:15 MST for up to 37 minutes per evening.[18] No glare is predicted to occur for commercial vehicles on Township Road 42 within the ±15° FOV between mid May and late July, or between late September and late March.

[18] These results apply to a portion of the route, not just a single point along the road. The results describe a time period during which a vehicle operator may see glare from the Project arrays, but it is highly unlikely that an observer will be affected by the glare for the full duration. A vehicle operator will only see a fraction of the glare since they will be travelling past the area, not standing still while looking at the solar PV arrays.

The following figures represent the predicted glare within the ±15° FOV of commercial vehicle drivers travelling along Township Road 42 from the bottom of the arrays. Figure 6-1 shows the daily time periods during which glare is predicted, and Figure 6-2 shows the daily duration of predicted glare.

Figure 6-3 presents the glare hazard plot for glare expected to affect the ±15° FOV of commercial drivers on this route. The hazard plot shows that the glare seen from the route will have approximately nine times the subtended angle as the sun, but it will be around 700 times dimmer than the sun. The glare is also around two orders of magnitude below the threshold for glare that has the potential to cause permanent eye damage at the same subtended angle. Glare at this level may temporarily affect a driver's vision, but it is not expected to create a hazardous situation. The glare for this route is expected to originate from the south half of the Project, though further arrays are likely to be obstructed from view by nearer arrays.

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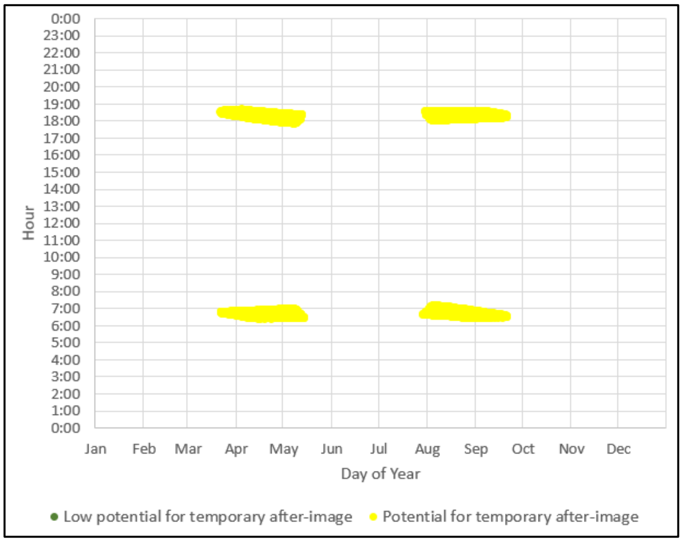

Figure 6-1 – Annual predicted glare occurrence for TwpRd42C, ±15° FOV

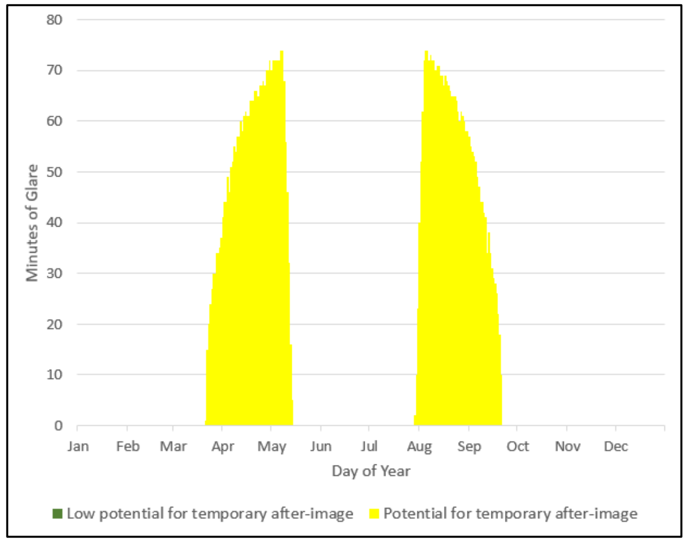

Figure 6-2 – Daily duration of glare for TwpRd42C, ±15° FOV

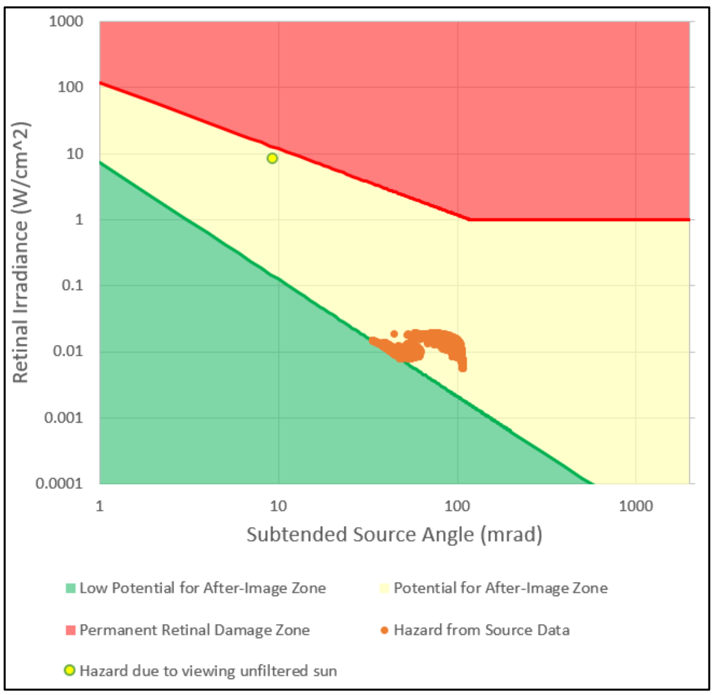

Figure 6-3 – Hazard plot for TwpRd42C, ±15° FOV

The predicted glare is split into distinct morning and evening periods because both directions of travel were modelled for each route. Drivers travelling east may see glare during the morning, while drivers travelling west may see glare during the evening. The glare originates from the same general direction as the sun for these periods and directions of travel, so the glare impact may be eclipsed by the direct effects of the sun. Aerial and street-level imagery shows that Township Road 42 is a dirt or gravel road that is not expected to see much use. Since there will be fewer cars travelling along this route, the chances of a driver passing through the affected area and seeing the glare are reduced.

6.2 Dwelling Results

The dwellings were assessed at 4.5m above ground to represent an observer viewing the Project from a second-storey window. **Table 6-3** below provides the glare results for the dwellings assessed at the array minimum and maximum heights. The dwelling identifier from the associated noise impact assessment (NIA) is indicated in parentheses.

Table 6-3 – Annual glare levels for dwellings near the Project

Component	Green Glare (min/year)		Yellow Glare (min/year)		Red Glare (min/year)	
Module Height	0.6m	2.9m	0.6m	2.9m	0.6m	2.9m
D1	29	12	4,698	4,681	0	0
D2	0	0	2,576	2,705	0	0

A review of Google Streetview and satellite imagery at D2 found that the property has vegetation between the receptor and the array, which may screen some of the predicted glare. This suggests that the annual glare seen at D2 may be less than the results predicted by the SGHAT model. Presence of the vegetation was not confirmed onsite.

A review of Google satellite imagery at D1 found that the property has no existing tree screening. D1 is located approximately 750m east of the Project. Observers at this location are expected to see yellow glare for a maximum of 4,698 minutes/year. The glare is predicted from late March to September around 18:20 MST for up to 30 minutes/day. The glare originates from the same general direction as the sun for these periods, so the glare impact may be eclipsed by the direct effects of the sun. The differences in glare from the higher module elevations than the lower elevations are very minimal at this receptor.

The following figures represent the predicted glare for D1 from the bottom of the arrays. **Figure 6-4** shows the daily time periods during which glare is predicted, and **Figure 6-5** shows the daily duration of predicted glare.

Figure 6-6 presents the glare hazard plot for glare expected to affect D1. The hazard plot shows that the glare seen from D1 will have approximately six times the subtended angle as the sun, but it will be around 800 times dimmer than the sun. The glare is also around two orders of magnitude below the threshold for glare that has the potential to cause permanent eye damage at the same subtended angle. Glare at this level is not expected to create a hazardous situation, or have a significant adverse impact on residents. The glare at D1 is expected to originate from the center of the Project, mostly from sub-arrays 2 and 3. With the ground sloping up from west to east, the arrays in far left are likely to be visually screened by other rows of arrays that are in the east closer to the receptor and potentially by the ground itself.

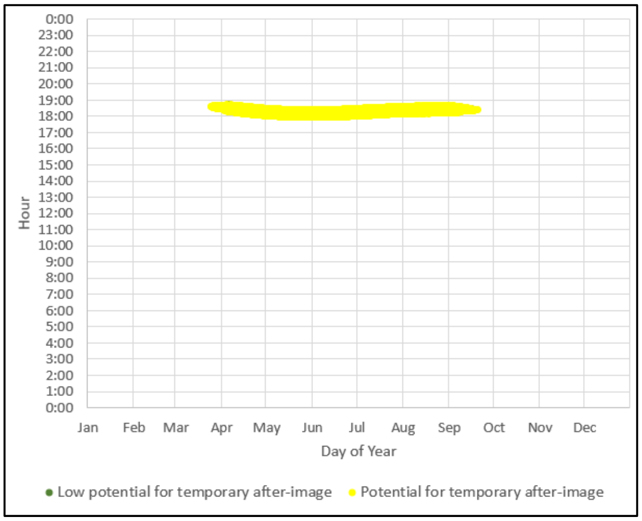

Figure 6-4 – Annual predicted glare occurrence for D1

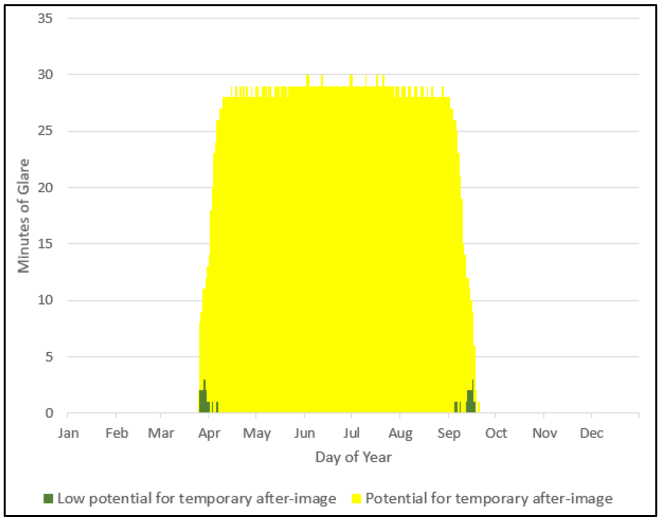

Figure 6-5 – Daily duration of glare for D1

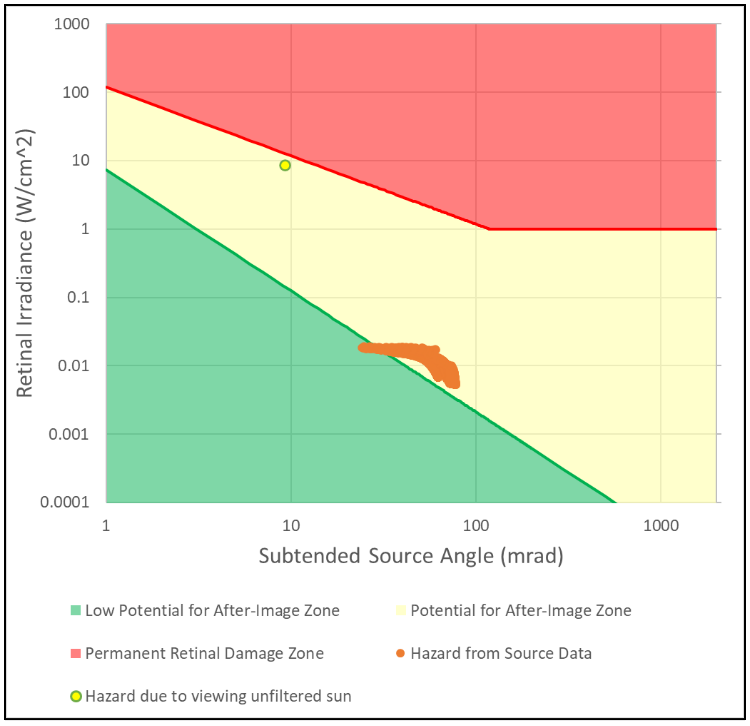

Figure 6-6 – Hazard plot for D1

7 Summary

Solar modules are specifically designed to absorb light rather than reflect it. Moreover, most modules are now manufactured with anti-reflective coatings that help further mitigate the intensity of reflections.

The assessment of the Spring Coulee Solar Project was undertaken using GlareGauge software. The results are based on the assumptions and limitations set out in previous sections of this report. The arrays were modelled at the minimum and maximum module elevations with a 30° fixed tilt angle, oriented due south.

The ground-based route paths assessed for glare impacts included both directions of travel on Highway5, Range Road 242B, Range Road 243, Township Road 42, and Township Road 43A within approximately 800m of the Project. The road routes were modelled at both passenger vehicle and commercial vehicle heights. All routes were evaluated with a horizontal viewing angle of ±15° to capture potential glare within a vehicle operator's critical visual range, as well as ±25° to identify routes that may observe peripheral glare.

Highway 5, Range Road 242B, Range Road 243, and Township Road 43A are not expected to observe glare at any level from the Project. Township Road 42 is expected to observe yellow glare between March to mid May and late July to September in the morning and evening, depending on the direction of travel. It is highly unlikely that an observer will be affected by the full duration of glare in the predicted periods. Vehicle operators will only see a fraction of the predicted glare since they will be travelling past the site, not standing still while looking at the solar PV arrays. Based on satellite imagery, Township Road 42 is a rural gravel or dirt road that is not expected to have high traffic volumes. The level of glare predicted along the transportation routes may temporarily affect a driver's vision, but it is not expected to create hazardous conditions.

There are two dwellings within approximately 800m of the Project and were evaluated in this assessment. Dwellings were evaluated at a height of 4.5m above ground to represent an observer looking out a second-floor window toward the Project to provide a conservative analysis. Observers in dwellings D2 are expected to observe short daily durations of glare from the Project and have vegetation between the receptor and the array that may screen some of the predicted glare. The more impacted receptor, D1, is expected to observe yellow glare in the evenings between late March and September. The glare originates from a direction similar to the sun during these periods, so the direct sunlight may lessen the perceived glare impact. The level of glare predicted at the observation points is not expected to create hazardous conditions or have a significant adverse effect on a resident's use of their home.

8 Conclusion

In conclusion, the Spring Coulee Solar Project is not likely to have the potential to create hazardous glare conditions for the dwellings or roads assessed. The actual glare impacts that will be experienced in the field along ground-based routes are anticipated to be only a fraction of the results presented in this report. The actual impact is expected to be less because vehicle operators will be travelling past the site, not standing still while looking at the solar PV arrays. Glare predicted to affect dwellings is only expected to occur for short daily durations, and it is not expected to have a significant adverse effect on a resident's use of their home. Observers are also expected to simultaneously see direct sunlight originating from the same general direction as the glare, so glare impacts may be less pronounced.

9 Glare Practitioners' Information

Table 9-1 summarizes the information of the co-authors and technical reviewer of the solar glare hazard analysis.

Table 9-1 – Summary of practitioners' information

Name	Justin Lee	Jason Mah	Cameron Sutherland
Title	Assistant Glare Analyst	Renewable Energy EIT	Technical Director
Role	Glare Analyst, Co-Author	Glare Analyst, Co-Author	Technical Reviewer, Co-Author
Experience	• Experience with glare modelling in Forge Solar. • Analyst on multiple assessments for Solar Energy projects in Alberta.	• Analyst on 30+ glare assessments in Alberta and the USA • Technical support for AUC information requests and hearings • BSc Chemical Engineering	• Expert witness experience in technical solar development in Canada for Brooks II Solar Project, East Strathmore Solar Project, and Fox Coulee Solar Project • Technical oversight, technical review, or authorship of 30+ glare assessments for 20+ proceedings in Alberta • MSci Physics • MSc Renewable Energy Systems Technology

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