CHAPPICE LAKE SOLAR PROJECT

SOLAR GLARE HAZARD ANAYLSIS REPORT

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Prepared By:

Green Cat Renewables Canada Corporation

Prepared For:

Elemental Energy Renewables Inc.

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TABLE OF CONTENTS

1 INTRODUCTION

Green Cat Renewables has been commissioned by Elemental Energy to conduct a solar glare hazard analysis report for the proposed Chappice Lake photovoltaic (PV) solar project located northeast of Medicine Hat, Alberta.

Glint and glare refers to light reflected off smooth surfaces, either momentarily and intense (glint) or less intense for a more sustained period (glare).

The assessment considers the potential of glare impacts from the proposed solar array upon select nearby receptors including residences, roads, railways and flight paths as applicable.

Solar PV technology is specifically designed to absorb as much sunlight as possible and panels are normally covered in an anti-glare coating. Solar PV sites have been developed alongside major transport routes and close to dwellings around the world, including adjacent to road infrastructure, suggesting that solar PV technology and roads can safely coexist.

However, it is considered that the Chappice Lake Solar Project should be analyzed for safety assurances regarding the full potential impact of the installation on road users and nearby residents, in the form of a solar glare hazard analysis report.

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2 BACKGROUND INFORMATION

The potential for glint and glare from PV panels on any surrounding roads, railways, residential properties and nearby aerodromes should be 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 panel.

Glare is caused by a continuous but less intense reflection of a bright dispersed light (known as diffuse reflection) whereas glint is caused by the direct reflection of sunlight on a reflective surface (also called specular reflection). **Figure 2.1** shows these two key ways in which sunlight could potentially be reflected from a solar PV panel.

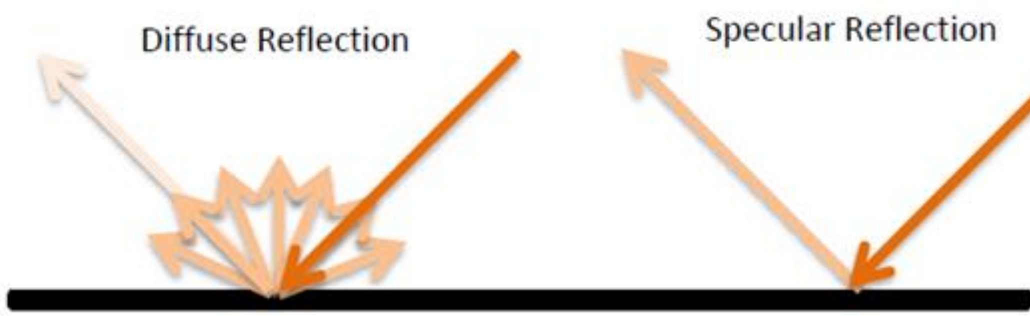

Figure 2.1 – Means by which light reflects from solar panels.

To maximize their efficiency, solar PV panels are specifically designed to absorb, not reflect, light from the sun.

The majority of solar PV panels used for commercial solar parks are manufactured with anti-reflective coatings to be as absorbent as possible in order to maximise the amount of light captured and subsequently converted to electricity. This causes solar panels to exhibit very low levels of reflectivity, and consequently, solar PV panels are substantially less reflective than non-coated glass and, in many cases, other sources of natural surfaces such as bare soil and fresh snow when facing the sun directly. This is demonstrated in **Figure 2.2**

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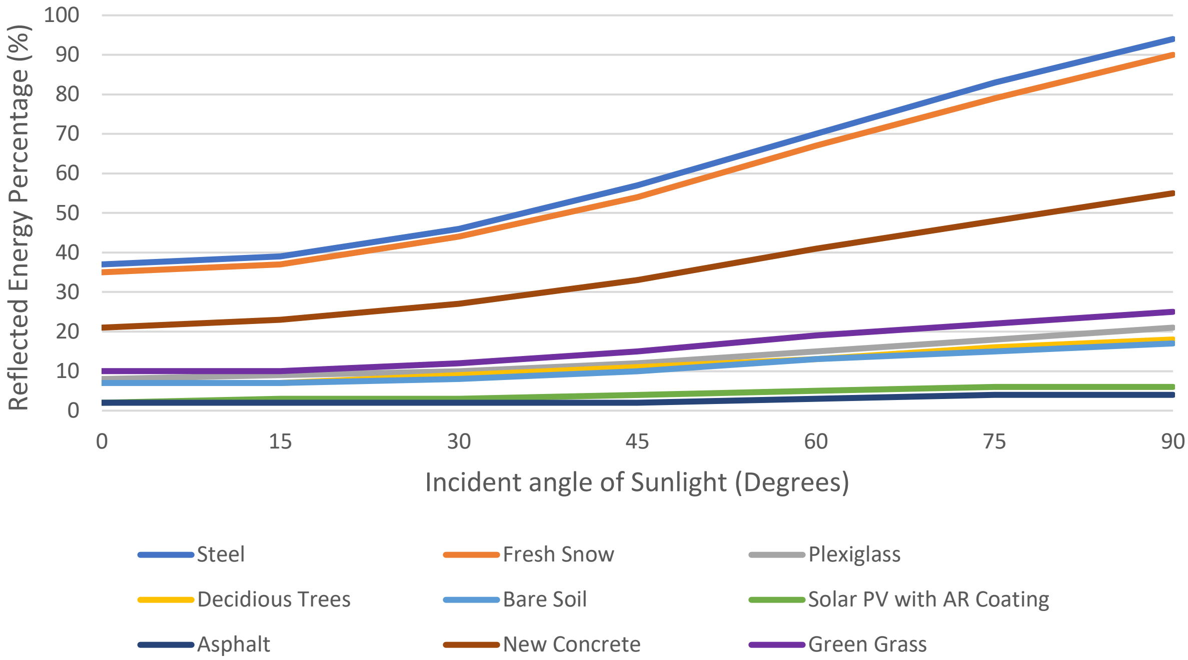

Figure 2.2 – Analysis of typical material reflectivity[1]

Calculation of potential glare requires the values for azimuth and elevation angle of the sun and the consequent angles of incidence and reflection at extreme points in the year i.e. summer solstice when the sun is highest and winter solstice when at its lowest.

The angle of incidence is the angle at which the sun strikes the panel, with the angle of reflection being equal to it. These angles give a good indication of the likely impact from direct glare since the light absorption of the PV panels is greatest when the light is incident at 0 ^{o} to the panel surface.

Figure 2.3 shows that when the sun is low in the sky (early mornings or late evenings) a higher incidence angle is formed which reflects light at a lower altitude onto the local surroundings. This is where glare can potentially occur from solar developments. Panels that face the sun directly experience low incidence angles. Typically, when angles of incidence are low, any light reflected from the panels is too high to cause potential concern to residents or motorists.

[1] Adapted from: *Burleson Consulting, I. Sacramento Solar Highways Initial Study and Mitigated Negative Declaration (July, 2011)*

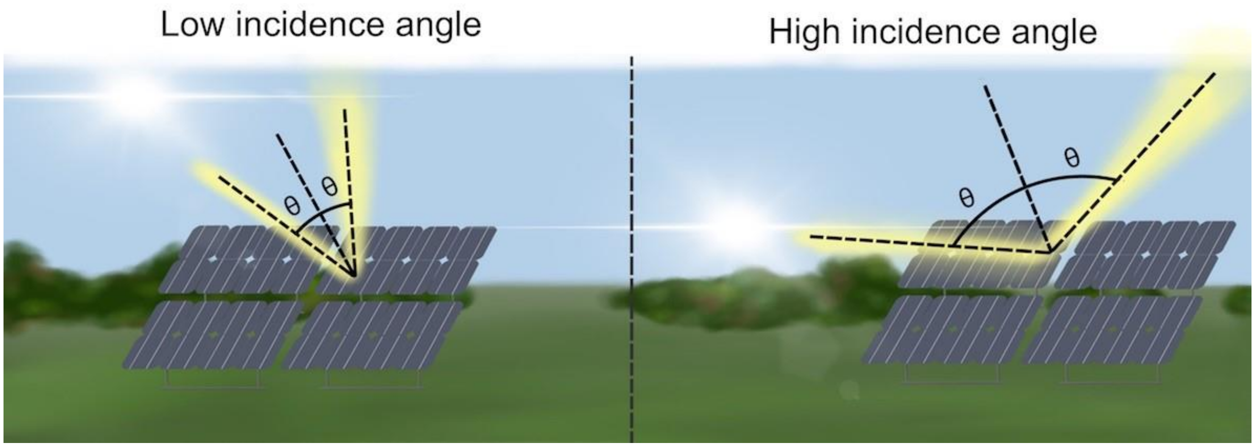

Figure 2.3–Angles of incidence relative to Sun's position

Throughout the day the sun will track across the sky, therefore the angle at which the light is incident on the panel will vary, although with a tracking system this variation is minimised. **Figure 2.4** shows the two angles required to define the orientation of the sun with respect to the solar panel and the path the light takes when incident on the panel's face.

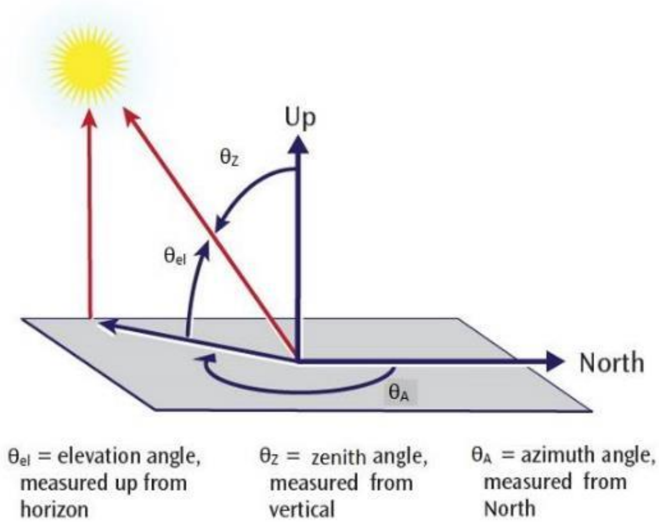

Figure 2.4 – Sun's position relative to solar panel

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

- The type of solar panel
- The panel's tilt angle
- The panel 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 site lies north-east of Medicine Hat in the north-east quarter of section 35-14-4-W4. The solar development in relation to Vale, Alberta is shown in Figure 3.1 below.

Figure 3.1 – Chappice Lake Solar site in relation to Vale, Alberta.

Chappice Lake Solar Project spans an area of approximately 160 acres with a generating capacity of up to 15 MW. It is composed of approximately 44,000 solar panels. Solar modules will be ground mounted, on flexible tracking enabled frames.

The flexible tracking frame has a tracking range of +/-55°. This assessment looks at the glare for panels elevated at an average height of 2.4m from the ground.

A cross section of the PV tables for a +/-55° tracking range of is shown in **Figure 3.2**.

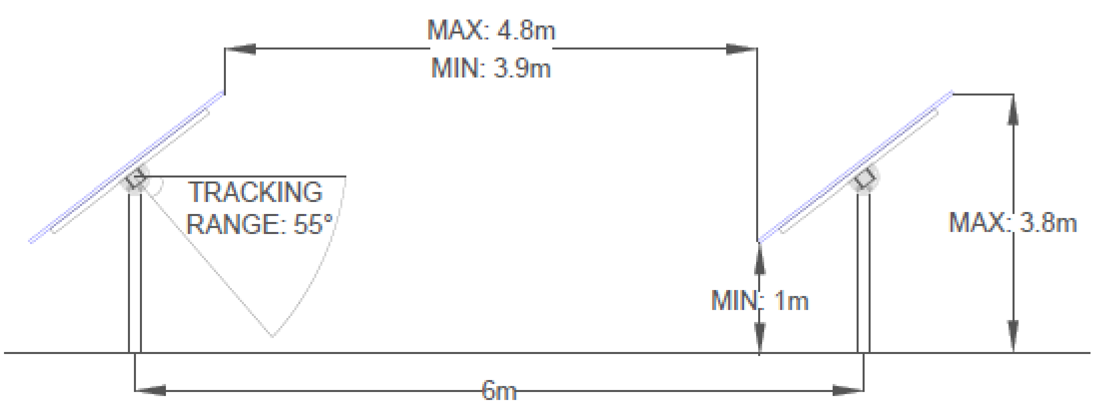

Figure 3.2 – Cross section and mounting structure dimensions

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4 LEGISLATION AND GUIDANCE

There is currently no adopted legislation and little guidance for assessing the impacts of glare from solar development. Moreover, what guidelines are available do not currently apply to impacts on dwellings and road users. Therefore, GCR has taken a conservative approach when assessing the glare impacts for the Chappice Lake Solar Project in relation to roads and dwellings based on the US Federal Aviation Administration (FAA) Technical Guidance for Evaluating Selected Solar Technologies on Airports[2]. The FAA state in the document, last updated in April 2018, that potential for glare might vary depending on site specifics such as existing land uses, location and size of the project and that a geometric analysis may be required to assess any reflectivity issues coming from the solar panels.

4.1 GEOMETRIC ANALYSIS - USE OF THE SOLAR GLARE HAZARD ANALYSIS TOOL (SGHAT)

The SGHAT is a validated tool specifically designed to estimate potential glare according to a Solar Glare Hazard Analysis Plot at a certain panel height, tilt, type and observer's location. It is accepted as the most comprehensive tool to assess potential glare impacts to road and railway users, flight paths and dwellings.

This software allows for the analysis of potential glare on flight paths, routes and stationary observation points. The FAA understands that since there are no specific standards for evaluating potential for glare from proposed projects, each development should be considered on a case-by-case basis[3]. This principal has been applied to the road route and dwelling receptors in this case.

[2] *Technical Guidance for Evaluating Selected Solar Technologies on Airports, pg. 40 (FAA, April 2018)*

[3] *Ibid*

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5 ASSESSMENT METHODOLOGY

The Glare Gauge software incorporates flight paths at a 3.2km (2-mile) approach from landing to assess glare for pilots. The Chappice Lake Project is located within 3.2km of Althen D House airstrip to the north-west of the site

In the absence of specific guidance on assessing the impacts of glare on dwellings and road users, the assessment was carried out by:

- Assessing dwellings that may have a potential to experience glare from the solar development.
- Placing route pathways on roads that are in view and nearby the project to assess for potential of glare.

The assessment was carried out utilizing Forge Solar software, Glare Gauge. Glare Gauge is a SGHAT tool which determines when and where solar glare can occur throughout the year from a PV array from any given reference points.

Note, if the panels are not visible to the individual then no glare can occur. Glare Gauge does not account for above ground obstacles or even topographic screening from vegetation and buildings. The software also assumes clear sunny days at all times and no atmospheric attenuation. Therefore, any results can be considered a conservative estimate.

5.1 COMPONENT DATA

The solar array, travel routes and observation points were plotted using an interactive Google map and inputting site specific data. The following sections provide details of the parameters specified for the analysis calculations in the Glare Gauge software.

5.1.1 PV Array

The layout and PV area were plotted on the interactive Google map as shown on **Figure 5.1** below.

Figure 5.1 –Site Layout plotted on Glare Gauge software

Table 5-1 details project specific modeling parameters utilized in the assessment:

Table 5-1 PV Array Specified Parameters

Required Inputs	Specified Parameters	Description
Axis Tracking	Single	Deploys a tracking system orientated one-way
Tilt of Tracking Axis	0°	Elevation angle of the tracking axis with 0° being faced up (flat) parallel to the ground
Orientation	180° (south)	Azimuthal position of the tracking axis measured from true north
Max Tracking Angle	55°	Rotation limit of panels in each direction
Resting Angle	55°	Rotation angle of modules outside of the determined range
Offset Angle	0°	Additional elevation angle between tracking axis and the panel
Panel Material	Smooth glass with anti-reflective coating	Surface material of panels
Height Above Ground	2.4m	Panel centroid

The elevation across the site varies with the lowest point of the site reaching 764.0m AOD and the highest at 771.0m AOD.

5.2 GLARE ANALYSIS PROCEDURE

Effects from glare are subjective depending on a person's ocular parameters and size/distance from the glare source, for example, the SGHAT tool has a generalized approach to specify the type of eye hazard that can be produced because of glare. The results of the assessment will be interpreted, analysed and reported on to assist decision makers in identifying any unacceptable effects and to outline potential mitigations that could be applied.

The SGHAT User's Manual v 3.0[4] 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 color codes are based on a red, yellow and green structure to categorize the level of danger 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. 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 potential for temporary after-image; and
- Red: Glare is present with potential for permanent eye damage.

For clarification, an after image 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 level of glare is derived using the graph below which plots the level of irradiance against the angle, which is occupied by the glare in the field of view.

SGHAT have developed a plot to accurately quantify the intensity of light hitting the eye to the size/distance from the glare source. This is divided into the three regions of glare described above: red; yellow; and

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

green. This allows a visual comparison of glare coming from a solar development with directly viewing the sun unfiltered. **Figure 5.2** highlights this plot, differentiating the types of glare possible.

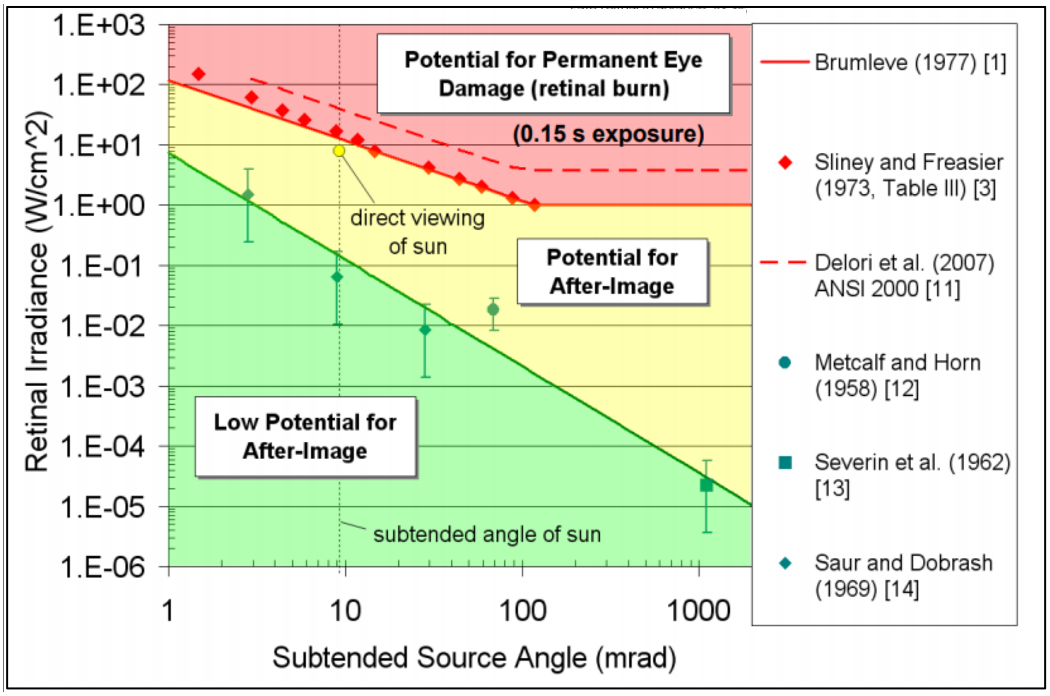

Figure 5.2 – Hazard plot depicting the retina effects of light

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 can occur when both the retinal irradiance and subtended angle is large enough to ultimately cause retinal burn. This is highlighted in the red region. The yellow section highlights a potential for a temporary after-image. The size and impact of the after-image is dependant upon the subtended source angle[5]. If both the retinal irradiance and subtended angle are small, then the hazard will be in the green section where there is very low potential for after-image.

[5] *Evaluation of glare at the Ivanpah Solar Electric Generating System, C.K. Ho et al., Elsevier Ltd., 2015*

5.3 RECEPTORS

5.3.1 Althen D House Airstrip

The nearest airport facility to the proposed project is the Althen D House Airstrip. It is located approximately 2.2km northwest of the solar project. This airport has one registered runway oriented north-south, which is the main runway at the airport. A glare assessment has been carried out for the north-south potential flight paths, shown in **Figure 5.3** below. The runway threshold points were specified using the Google map interface.

Figure 5.3 – Althen D House Airstrip proximity to Chappice Lake Solar site

The SGHAT tool utilizes the FAA earlier version on recommended guidance from its interim policy in 2013[6]. This is a 2-mile approach from the threshold point that is automatically calculated, based on a 3° glide slope and a 15m (50ft) threshold point height.

[6] *Interim Policy, FAA Review of Solar Energy System Projects on Federally Obligated Airports, 2013*

Flight path line of site for pilot visibility is also calculated at this stage. The angle below the horizon indicating the field of view of the pilot in the cockpit from the flight path, also called the maximum downward viewing angle, was set to 30°. The azimuthal viewing angle for the pilots, which is the horizontal angle from the front of the aircraft parallel with the horizon was set to 50°, giving a 100° field of view. Glare occurring beyond these field of views was not considered.

The viewing angle may be potentially mitigated if the angle of glare is greater than 25° from the driver's centre of view[7]. This analysis has set the viewing angle to the far more conservative 50° (100° total field of view) which is the angle beyond which minimal impairment of aircraft pilots due to yellow glare would be expected[8].

[7] *FAA – Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach, 2015, pg 10*

[8] *FAA – Evaluation of Glare as a Hazard for General Aviation Pilots on Final Approach, 2015*

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5.3.2 Road Route Paths

Two local road routes have been evaluated for glare impacts from the Chappice Lake Project. These roads are the nearest to the site and thus deemed to present the worst-case scenario for glare on road users.

A conservative viewing of 50° (100° total field of view), which is the angle beyond which minimal impairment of aircraft pilots due to yellow glare would be expected[9], was also utilized when assessing ground-based route paths. This angle has been taken to be appropriate, and similarly conservative, for road users in the area, in the absence of any other specific guidelines.

Range Road 43 and Township Road 150 were inputted into the software as they are closest to the proposed development from the west and north, respectively. **Figure 5.4**, highlights the roads in relation to the Chappice Lake Project.

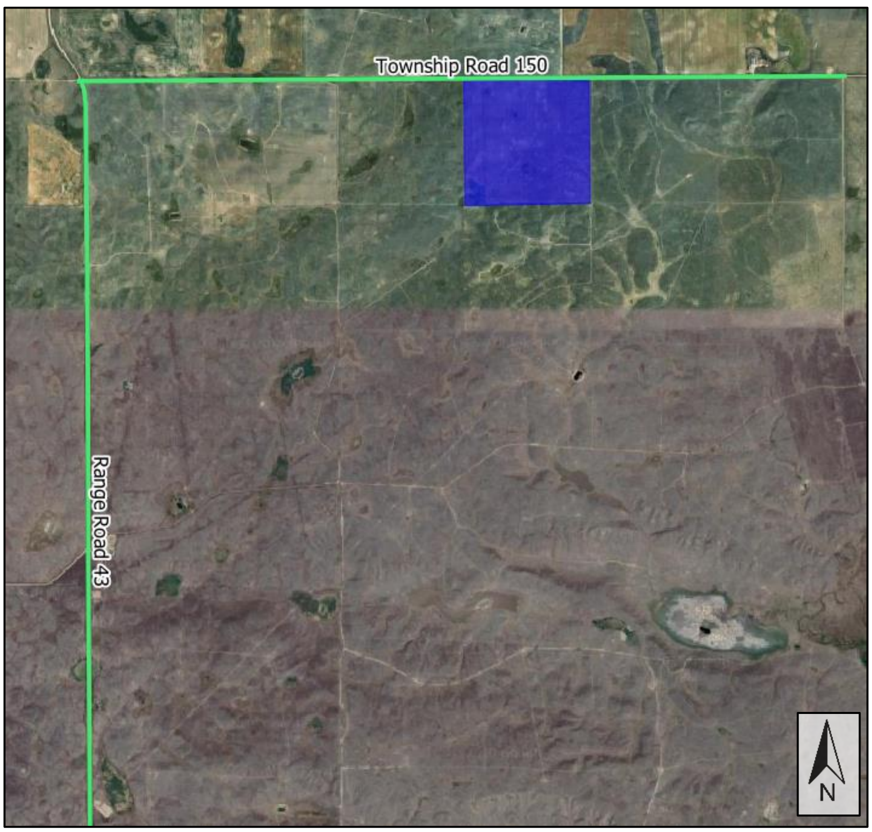

Figure 5.4 – Roads assessed in relation to the Chappice Lake Solar Project

The route receptor was set at 1.2m to represent the typical height of an individual seated in a passenger vehicle, and 3.0m to represent commercial vehicles.

[9] *Ibid*

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5.3.3 Dwellings

One dwelling is located close to the development and was assessed, no other dwellings were deemed to be susceptible to impacts from potential glare. **Figure 5.5** highlights the dwellings within the study area and their respective locations to the site.

Figure 5.5 – Resident along the Chappice Lake Solar Project

No site visit was conducted to determine the height of the property. As such, a conservative approach was taken, and the observation height of the dwelling was set at 4.5m as a two-storey structure.

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5.3.4 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 glare source and receptors which 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.
- This project has PV arrays encompassing a large surface area. For more accurate information regarding expected glare, some parts would need to be divided up into sub-sections.
- 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[10]. These are shown below in **Table 5-2.**

Table 5-2 Default Parameters

Parameters Inputted into Glare Gauge	
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/m^2
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

[10] *Sliney, D.H. and B.C. Freasier, 1973, Evaluation of Optical Radiation Hazards, Applied Optics, 12(1), p. 1-24.*

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6 ASSESSMENT OF IMPACT

The following section presents the findings of the glare assessment.

Results are informational only and open to interpretation. The software accounts for a year worth of glare in one-minute intervals to allow for the variations between seasons, DNI and sun angle.

6.1 FLIGHT PATH RESULTS

There are no impacts of glare onto users of the Althen D House Airstrip predicted from the Chappice Lake Solar Project. **Table 6-1** below highlights that neither flight path is predicted to experience any glare resultant of the Chappice Lake Solar Project.

Table 6-1 Annual Route Path Glare Levels

Flight Path	Green Glare (min)	Yellow Glare (min)	Red Glare (min)
Flight Path Main Runway (Northbound)	0	0	0
Flight Path Main Runway (Southbound)	0	0	0

6.2 ROUTE PATH RESULTS

Table 6-2 below highlights the predicted glare from the Chappice Lake Solar Project onto assessed roads.

Table 6-2 Annual Route Path Glare Levels

Component	Green Glare (min)		Yellow Glare (min)		Red Glare (min)	
Vehicle Height	1.2	3.0	1.2	3.0	1.2	3.0
Range Road 43	0	0	0	0	0	0
Township Road 150	0	0	0	0	0	0

None of the roads assessed are expected to experience red glare (permanent eye damage), yellow glare (potential for temporary after-image), or green glare (low potential for temporary after-image effects) from the Chappice Lake Solar Project. Both commercial and passenger vehicles were assessed at 3.0m and 1.2m, respectively.

6.3 DWELLING RESULTS

Table 6-3 below presents the findings of glare analysis on the one assessed dwelling.

Table 6-3 Annual Dwelling Glare Levels

Component	Green Glare (min)	Yellow Glare (min)	Red Glare (min)
D1	0	0	0

No red, yellow, or green glare was expected at any of the assessed dwellings from the Chappice Lake Solar Project.

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6.4 FURTHER ANALYSIS

Though developing solar farms is still relatively new in Alberta, the International Energy Agency forecast that solar electricity will account for 27% of the world's energy mix by 2050[11]. Due to the access requirements for construction and maintenance of solar development, facilities at times have no other option but to be built near existing road or airport infrastructure.

Figure 6.1 shows the commissioned 7.9MW Borrego Sacramento International Airport Solar Project developed by Borrego Solar in Sacramento, CA. The project utilizes a NEXTracker PV tracking system which tracks the sun's path form east to west over the course of the day and has been in operation since December 2017. NEXTracker provided the PV tracker system which tracks the sun's path from east to west over the course of the day[12].

Figure 6.2 shows the commissioned Windsor Solar Project developed by Windsor Solar LP in Ontario, Canada where a 50MW system has been installed near the Windsor Airport and intersecting local roads, which has been in operation since 2015.

Figure 6.1 – Borrego Sacramento International Airport Solar Project

Figure 6.2 – Windsor Solar Project in Ontario, Canada

[11] *CanSIA Roadmap 2020: Powering Canada's Future with Solar Electricity*

[12] *NEXTracker and Borrego Solar Deliver One of.* (n.d.). Retrieved November 21, 2019, from NEXTracker: https://www.nextracker.com/wp-content/uploads/2018/04/NEXT_CaseStudy_SacrementoAirport_0318-v7-digital.pdf

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7 CONCLUSION

Solar panels are specifically designed to absorb light rather than reflect it. The panels typically reflect 2-4% of sunlight that comes in contact with it which is considerably less than other natural surfaces such as water, bare soil and snow.

There is a shortage of guidance, policy or regulation on assessing the impacts of glint and glare from solar facilities. The most relevant technical guidance available was the Federal Aviation Administration (FAA), FAA Review of Solar Energy System Projects on Federally Obligated Airports (2018).

The assessment of the site was undertaken using Glare Gauge software. The results are based on the assumptions and limitations set out in **Section 5.3.4.** The site was a modeled as single-axis tracking solar panels with a range of +/-55°. None of the route paths and observation points show red glare (potential for permanent eye-damage), or yellow glare (potential for temporary after image) or green glare (low potential for temporary after-image).

The Althen D House Airstrip is situated 2.2km from the Chappice Lake Solar Project. It has one main runway for northbound and southbound flights. There was no green, yellow or red glare associated with the Airstrip.

Local roads, Range Road 43 and Township Road 150, have been modelled as the most representative case for potential glare. The height of drivers was assumed to be 1.2m to reflect passenger vehicles and 3.0m to reflect commercial vehicles. Neither Range Road 43 nor Township Road 150 are expected to experience any green, yellow or red glare.

One dwelling observation point was evaluated located north-east of the solar project. The height of the residence was set to 4.5m (two-storey dwelling). The dwelling was not predicted to experience red or yellow or green glare.

In summary, the proposed Chappice Lake Solar Project is not predicted to result in any glare on the evaluated receptors and, overall, poses negligible potential for hazardous conditions to all receptors assessed.

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