Appendix I: Light Impact Assessment

Prepared for:

North Atlantic Refining Corp.
29 Pippy Pl, St. John's, NL
A1B 3X2

Prepared by:

GHD
1118 Topsail Road, Mount Pearl, NL
A1B 3N7

Legal Disclaimer

This report has been prepared by GHD for North Atlantic Refining Corp (North Atlantic) and may only be used and relied on by North Atlantic for the purpose agreed between GHD and North Atlantic. GHD otherwise disclaims responsibility to any person other than North Atlantic arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

If this report is required to be accessible in any other format, this can be provided by GHD upon request and at an additional cost if necessary.

GHD has prepared this report on the basis of information provided by North Atlantic and others who provided information to GHD, which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

Table of Contents

List of Tables

List of Figures

List of Acronyms and Abbreviations

d	Distance to receptor
E	Illuminance
GHD	GHD Limited
HGP	Hydrogen Generation Plant
HP	Hydrogenation Plant
ILE	The Institution of Lighting Engineers
kV	kilovolt
LED	Light Emitting Diode
lm	lumen
LOHC	Liquid Organic Hydrogen Carrier
m	meter
m²	Square meter
MW	megawatt
NL	Newfoundland and Labrador
North Atlantic	North Atlantic Refining Corp.
PA	Project Area
S	Area of the given surface
the Project	Wind to Hydrogen Project
W	watt
Φ	Luminous flux
%	percent

1.0 Introduction

North Atlantic Refining Corp. (North Atlantic) is proposing to undertake the development of a Wind to Hydrogen project (the Project) on the Isthmus of Avalon Region in Newfoundland and Labrador (NL). This Project will entail the development, construction, operation and eventual decommissioning of a 324-megawatt (MW) Wind Farm consisting of 45 wind turbines on an undeveloped peninsula situated between Sunnyside and Deer Harbour. The Wind Farm will provide renewable electricity via a 138 kV transmission line to a newly developed Hydrogen Generation Plant (HGP), from where generated hydrogen will be transported to a Hydrogenation Plant (HP) for transformation into a Liquid Organic Hydrogen Carrier (LOHC), which will then be shipped from North Atlantic's port facilities to international markets for use in various decarbonization technologies.

GHD Limited (GHD) has undertaken an analysis of the proposed lighting installations for the Project. The Project Area (PA) is in a rural area that has portions that are barren, wooded, as well as nearby the water. The impacts of the proposed Project activities on nearby sensitive receptors were quantified and compared with the guidelines published by The Institution of Lighting Engineers (ILE) in the document entitled "Guidance Notes for the Reduction of Obtrusive Light" (ILE, 2011). There are currently no regulations in NL related to light from industrial operations.

Definitions

Light trespass is defined as the spilling of light beyond the boundary of the property or area being lit and is primarily a concern at night. Excess obtrusive light can be a nuisance to others, wastes electricity, and indirectly results in unnecessary emissions of greenhouse gases. Light trespass, or light pollution, can also negatively impact the surrounding ecosystem by disrupting the habits of native species. As such, it is important to understand the potential light impacts from this development, and to endeavor to minimize them.

Luminous flux is the quantity of the energy of the light emitted per second in all directions. The unit of luminous flux is lumen (lm).

Illuminance refers to the amount of light that covers a surface. If Φ is the luminous flux and S is the area of the given surface, then the illuminance E is determined by $E = \Phi/S$. Illumination is quantified in terms of lux, which represents the illuminance on a one square metre (m^2) surface when uniformly illuminated by 1 lumen of luminous flux.

A residence that may experience an objectionable encroachment of light over the property line is referred to as a residential receptor or sensitive receptor. This undesirable light spill may include the entry of unwanted light through windows, or direct line of sight to bright light sources.

Effects of light on fauna are not well understood and are generally described qualitatively. Some insects are attracted by nighttime lighting. Bats may follow these insects into human-occupied areas in order to hunt. Nighttime lights can adversely affect birds which fly at night and can increase the incidence of bird impacts on buildings (especially highly reflective buildings or glass buildings where interior lighting may confuse birds). Nocturnal animals may be adversely affected by excessive light in the nighttime hours.

Nocturnal animals which may be affected by nighttime light, changing their movement patterns or activities, include owls, mink, badgers, bats, coyotes, wolves, mice, opossums, raccoons, foxes, skunks, mountain lions (cougar). Deer and moose prefer dawn and dusk hours, both of which may be affected by Project lighting, but the effects of Project lighting are likely to be less significant to hunting practices than general human activity. Deer and moose prefer to avoid people, if possible, and may modify their behaviour/distribution due to the presence of Project activities, regardless of lighting.

1.1 Purpose of this Report

The purpose of this report is to present the method of assessment, results, and best management practices of the light impact assessment for the Project.

2.0 Baseline Conditions

The ILE has developed an Environmental Zone classification system whereby the existing ambient light levels at a site are used to determine the recommended maximum amount of light trespass to nearby receptors. The classification for rural areas, small villages, or relatively dark urban locations is "E2 Low district brightness areas". Based upon this classification, the light trespass limit at an offsite receptor after curfew (typically considered to be 11 p.m.) is 1 lux, which is the accepted equivalent to moonlight.

Furthermore, the ILE trespass limit at an offsite receptor before curfew is 5 lux.

Project lighting will be limited to the amount necessary to ensure safe and efficient operation, with the recognition that excessive lighting can be disruptive to wild species, local residents, and businesses. Light pollution will be reduced by installing downward-facing lights on buildings, wind turbine bases, and access roads. Wherever possible, ground-level external lights on buildings and wind turbine bases will be pointed downward and shall use motion or heat sensors when possible and permitted by relevant codes and the authority with jurisdiction. Only direct and focused light will be used for worker safety. Wind turbines and meteorological tower lighting levels will be at a minimum allowed by Transport Canada

for aeronautical safety, and white or red strobe lights may be used with the minimum intensity and flashes per minute allowable.

Bird collisions with Project lighting and subsequent mortality are expected to be rare and unlikely to have significant impact on migrating bird populations. However, efforts will be made to minimize the effects of lighting on migrating birds. No monitoring is being proposed.

3.0 Proposed Lighting

The Project includes lighting at the HGP and HP, and the wind turbines. These locations have been assessed to evaluate the potential impact on the surrounding area.

Since the exact locations of the equipment/lights are unknown, the closest location compared to the receptor was used for the purposes of the calculations. Since the specific equipment type to be used throughout the Project is not yet determined, estimates were based on the assumption that standard equipment will be used.

Navigation light fixtures will be installed on some wind turbines as per the requirements of Transport Canada Standard 621 - Obstruction Marking and Lighting (Canadian Aviation Regulations) (Transport Canada, 2021). The number of lights will be determined by Transport Canada based on the final layout and design.

4.0 Sensitive Receptors

For the purposes of the evaluation, the closest sensitive receptor to the wind turbines, and the HGP and HP were selected for the evaluation. The nearest residential receptors were identified in each direction around the property and work areas.

Figure I-4.0-1 provides the locations of all these receptors and the locations of the proposed Project activities.

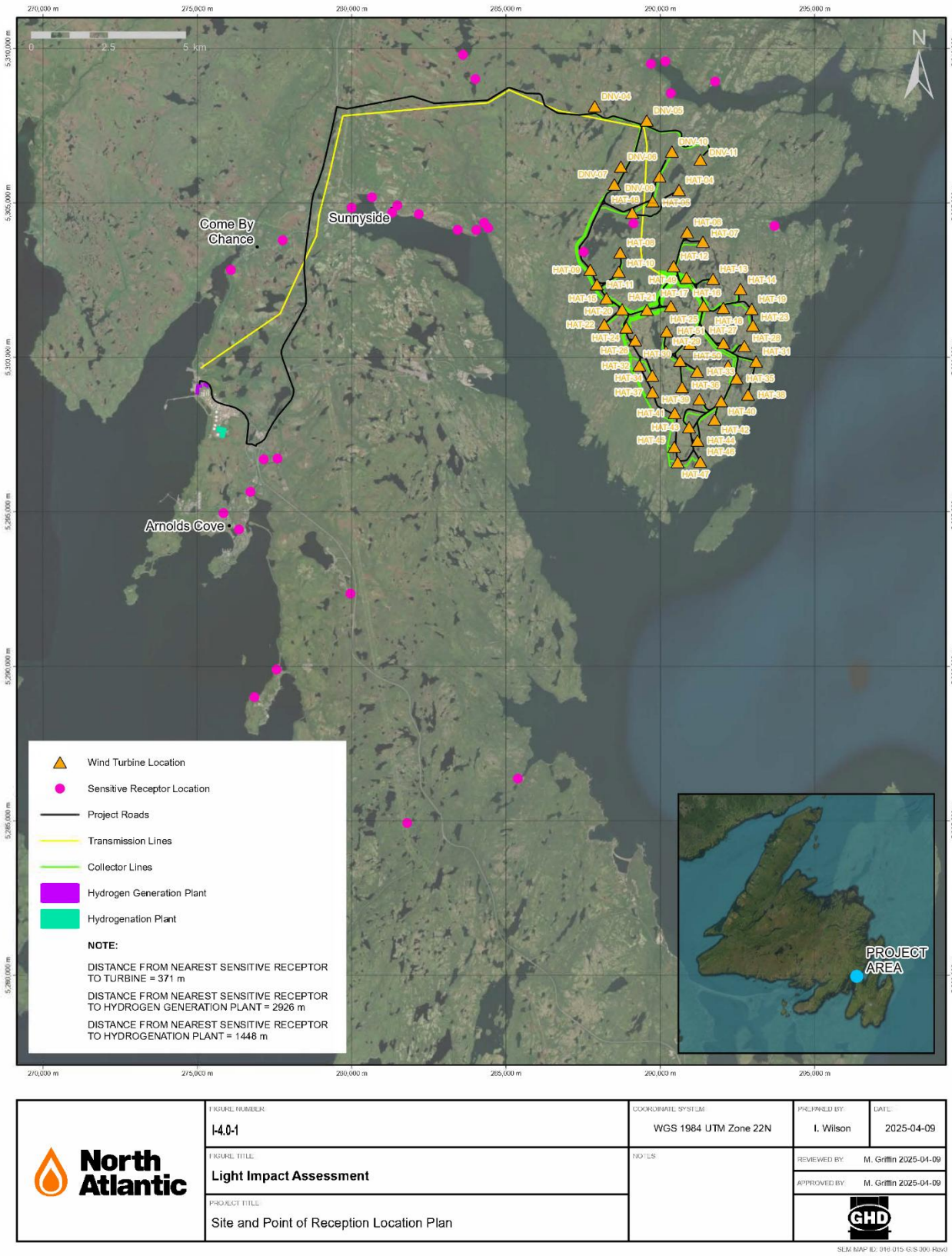

Figure I-4.0-1 Site and point of reception location plan.

5.0 Method of Assessment

GHD completed the assessment based on the equipment list that was expected based on similar projects. From known information about the power output of the installations and typical efficiencies, the luminous flux of each light source was calculated:

$$\text{Luminous Flux (lm)} = \text{Power Output (watts)} \times \text{Efficiency } \left(\frac{\text{lumens}}{\text{watt}}\right)$$

The power output of the proposed lighting was known from manufacturer information, and the efficiency was based on typical industry published values, as presented in the Table I-5.0-1.

Table I-5.0-1 Typical efficiency for lights.

Type of Light	Typical Efficiency (lumens/watt)
LED	58 - 113
Compact Fluorescent	70
Linear Fluorescent	108
Incandescent	15
Halogen	20
High Pressure Sodium	100

Sample Calculation:

The standard equipment for the HGP and HP, and the wind turbines are provided in Table I-5.0-2. The number and type of lights and their power output are also provided in Table I-5.0-2. The luminous flux of the crane can be calculated as follows:

$$\text{Power Output} = 1 \text{ crane } \times 6\frac{\text{Lights}}{\text{crane}} \times 65\frac{\text{W}}{\text{Light}} = 390 \text{ W}$$

$$\text{Luminous Flux} = 390 \text{ W } \times 20\frac{\text{lumens}}{\text{W}} = 7{,}800 \text{ lumens}$$

After determining luminous flux estimates for each light source, the impacts of the incident light at the identified sensitive receptors can be determined.

Table I-5.0-2 indicates the estimated distance to the sensitive receptors from these sources. The illuminance level at a receptor is equal to the combined total from each light source. It has been conservatively assumed that 100 percent of the incident light will reach the receptor due to the rocky

barren landscape near the wind turbines. The following equation was used to estimate the illuminance contribution from each light source:

$$E = \frac{\phi}{d^2}$$

Where:

E = illuminance (lux)

ϕ = luminous flux (lm)

d = distance to the receptor (m)

Sample Calculation:

The luminous flux from the crane that will be used at the Hydrogen Generation and HP is estimated at 7,800 lm. The distance to the closest receptor from the HGP and HP is approximately 1,448 m. The illuminance contribution from the HGP and HP to the closest receptor can be estimated as follows:

$$\text{Illuminance} = \frac{7{,}800 \text{ lumens}}{(1{,}448 \text{ m})^2} = 3.72 \times 10^{-3} \text{ lux}$$

This method was used to determine the estimated illuminance at the closest receptor from the wind turbines as well.

The light assessment for the PA, including the HGP and HP, and the wind turbines, is summarized in Table I-5.0-2. Table I-5.0-2 identifies all expected light sources at each Project location. Table I-5.0-3 compares the measured illuminance levels to the pre-curfew limit of 5 lux, while Table I-5.0-4 evaluates post curfew activities against the post-curfew illuminance criterion of 1 lux.

For the purposes of this assessment, pre-curfew was assumed to be before 11 PM and post-curfew was between 11 PM and 7 AM.

Table I-5.0-2 Light source summary tables.

Percentage of incident lumens assumed to reach the receptor considering directionality and line of site obstructions: **100%**

								Closest Receptor	
Area	**Source (2)**			**Type of Light**	**Power (watts)**	**Quantity**	**Total Power (watts)**	**Luminous Flux (1) (lumens)**	**Approx. Distance (m)**	**Illuminance (1) (lux)**
Hydrogen Facility (5)		Quantity of Units	No. Of Lights per Unit							
	Truck	1	4	Halogen	65	4	260	5,200	1,448	2.48E-03
	Backhoe	2	6	Halogen	65	12	780	15,600	1,448	7.44E-03
	Crane	1	6	Halogen	65	6	390	7,800	1,448	3.72E-03
	Dump Truck	3	4	Halogen	65	12	780	15,600	1,448	7.44E-03
	Dozer	3	6	Halogen	65	18	1170	23,400	1,448	1.12E-02
	Excavator	3	6	Halogen	65	18	1,170	23,400	1,448	1.12E-02
	Grader	2	6	Halogen	65	12	780	15,600	1,448	7.44E-03
	Haul Truck	2	4	Halogen	65	8	520	10,400	1,448	4.96E-03
	Loader	3	6	Halogen	65	18	1,170	23,400	1,448	1.12E-02
	Roller	2	6	Halogen	65	12	780	15,600	1,448	7.44E-03
	Articulated Truck	1	6	Halogen	65	6	390	7,800	1,448	3.72E-03
	Skid Steer	2	6	Halogen	65	12	780	15,600	1,448	7.44E-03
	Lube Truck	2	4	Halogen	65	8	520	10,400	1,448	4.96E-03
	Service Truck	2	4	Halogen	65	8	520	10,400	1,448	4.96E-03
	Water Truck	3	4	Halogen	65	12	780	15,600	1,448	7.44E-03
	Vacuum Truck	1	4	Halogen	65	4	260	5,200	1,448	2.48E-03
	Turbine Lights (4)	1	4	LED	85	4	340	6,800	7,850	1.10E-04
	Turbine Lights (4)	1	4	LED	85	4	340	6,800	7,850	1.10E-04
	Flare	1	1	Flare	-	-	-	85,000 (3)	1,448	4.05E-02
	Mobile Floodlights	10	1	Floodlight	350	10	3,500	70,000	1,448	3.34E-02
	Polemount Lights	60	1	LED	75	60	4,500	90,000	1,448	4.29E-02

POST-CURFEW	**Total:**	2.22E-01
PRE-CURFEW	**Total:**	2.22E-01

Area	Source (2)			Type of Light	Power (watts)	Quantity	Total Power (watts)	Luminous Flux (1) (lumens)	Closest Receptor	
									Approx. Distance (m)	Illuminance (1) (lux)
Wind Turbines Receptor 9		Quantity of Units	No. Of Lights per Unit							
HAT-48	Site Truck	3	4	Halogen	65	12	780	15,600	371	1.13E-01
	Grader	1	6	Halogen	65	6	390	7,800	371	5.67E-02
	Turbine Lights (4)	1	4	LED	85	4	340	6,800	371	4.94E-02
	Turbine Lights (4)	1	4	LED	85	4	340	6,800	371	4.94E-02
	Excavator	1	6	Halogen	65	6	390	7,800	371	5.67E-02
HAT-05	Site Truck	3	4	Halogen	65	12	780	15,600	970	1.66E-02
	Grader	1	6	Halogen	65	6	390	7,800	970	8.29E-03
	Turbine Lights (4)	1	4	LED	85	4	340	6,800	970	7.23E-03
	Turbine Lights (4)	1	4	LED	85	4	340	6,800	970	7.23E-03
	Excavator	1	6	Halogen	65	6	390	7,800	970	8.29E-03
HAT-08	Site Truck	3	4	Halogen	65	12	780	15,600	1,018	1.51E-02
	Grader	1	6	Halogen	65	6	390	7,800	1,018	7.53E-03
	Turbine Lights (4)	1	4	LED	85	4	340	6,800	1,018	6.56E-03
	Turbine Lights (4)	1	4	LED	85	4	340	6,800	1,018	6.56E-03
	Excavator	1	6	Halogen	65	6	390	7,800	1,018	7.53E-03
DNV-07	Site Truck	3	4	Halogen	65	12	780	15,600	1,430	7.63E-03
	Grader	1	6	Halogen	65	6	390	7,800	1,430	3.81E-03
	Turbine Lights (4)	1	4	LED	85	4	340	6,800	1,430	3.33E-03
	Turbine Lights (4)	1	4	LED	85	4	340	6,800	1,430	3.33E-03
	Excavator	1	6	Halogen	65	6	390	7,800	1,430	3.81E-03
HAT-10	Site Truck	3	4	Halogen	65	12	780	15,600	1,610	6.02E-03
	Grader	1	6	Halogen	65	6	390	7,800	1,610	3.01E-03
	Turbine Lights (4)	1	4	LED	85	4	340	6,800	1,610	2.62E-03
	Turbine Lights (4)	1	4	LED	85	4	340	6,800	1,610	2.62E-03
	Excavator	1	6	Halogen	65	6	390	7,800	1,610	3.01E-03

POST-CURFEW	**Total:**	4.56E-01
PRE-CURFEW	**Total:**	4.56E-01

Notes

(1) Illuminance = Luminous Flux/square of distance travelled; therefore 1 Lux = 1 lumen/m^2.

(2) Mobile equipment with headlights was assumed to be stationary for simplicity. It was assumed that each piece of equipment has 6 mounted halogen lamp lights, 65 watts each. Equipment list assumed based on similar projects.

(3) Estimate

(4) The five closest turbines have been included in the evaluation. Based on the evaluation the turbines located at greater distances would have a negligible impact on the overall results and have not been included.

(5) The light sources from the hydrogen plant and hydrogen generation plant are expected to be similar. The worst case sources were evaluated to the most impacted receptor.

Table I-5.0-3 Comparison of light levels at receptors – pre-curfew operations.

Receptor	Facility Illuminance (lux) Pre-Curfew (2)	Wind Turbine Illuminance (lux) Pre-Curfew (2)	ILE Guidance Limit (1) Pre-Curfew (2) (lux)	Percentage of Criteria (3) Pre-Curfew (%)
Closest Receptor	**2.22E-01**	**4.56E-01**	5	9.11%

Notes
(1) Based on a classification of the area as Environmental Zone E2- Low district brightness areas (ILE, 2011).
(2) Curfew = the time after which stricter requirements for the control of obtrusive light 'will apply. If not defined by the local planning authority, the ILE suggests 11:00 p.m. (ILE, 2011). Obtrusive Light,
"Table 1-Obtrusive Light Limitations for Exterior Lighting Installations").
(3) Based on conservative assumption of no reduced light due to directionality and line of site obstructions.

Table I-5.0-4 Comparison of light levels at receptors – post-curfew operations.

Receptor	Facility Illuminance (lux) Post-Curfew (2)	Wind Turbine Illuminance (lux) Post-Curfew (2)	ILE Guidance Limit (1) Post-Curfew (2) (lux)	Percentage of Criteria (3) Post-Curfew (%)
Closest Receptor	2.22E-01	4.56E-01	1	45.55%

Notes
(1) Based on a classification of the area as Environmental Zone E2- Low district brightness areas (ILE, 2011)).
(2) Curfew = the time after which stricter requirements for the control of obtrusive light 'will apply. If not defined by the local planning authority, the ILE suggests 11:00 p.m. (ILE, 2011). Obtrusive Light,
"Table 1-Obtrusive Light Limitations for Exterior Lighting Installations"
(3) Based on conservative assumption of no reduced light due to directionality and line of site obstructions.

6.0 Results and Discussion

The calculated light levels at the identified sensitive receptors are below the limits recommended by the ILE guidelines during both pre- and post-curfew conditions, as shown in Tables I-5.0-3 and I-5.0-4, respectively.

The predicted illuminance levels represent the worst-case operating conditions of the Project. The assessment considers when all of the equipment is operating at the same time and at the closest location to the receptor. The areas surrounding the wind turbines are predominantly rocky and barren, offering minimal obstruction to light. In contrast, the HGP and HP PA is characterized woodland, ponds, and wetlands. These features, along with topographic variation in the landscape, contribute to a substantial reduction in light transmission beyond the Project footprint. For screening purposes, a conservative assumption was made that 100 percent of light from the HGP and HP PA would reach nearby receptors. However, the combination of uneven terrain and the presence of surrounding vegetation will significantly attenuate light before it reaches these receptors. Additionally, there will be more lighting associated with equipment and structural components within the HGP and HP PA, in comparison to the Wind Farm PA.

7.0 Best Management Practices

Routine monitoring of the light levels at the PAs, once constructed and operational, using a light meter will enable a comparison between actual and theoretical values.

8.0 References

ILE. (2011). Guidance notes for the reduction of obtrusive light (GN01:2011).

Transport Canada. (2021). *Standard 621 – Obstruction marking and lighting*. Canadian Aviation Regulations (CARs). Retrieved from https://tc.canada.ca/en/corporate-services/acts-regulations/list-regulations/canadian-aviation-regulations-sor-96-433/standards/standard-621-obstacle-marking-lighting-canadian-aviation-regulations-cars