Canadian Guidelines for Outdoor Lighting (Low-Impact Lighting)

for

Dark-Sky Protection Programs

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Edited by

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1.0 SCOPE

The goal of Dark-Sky Protection Programs (Program) is to promote the reduction in light pollution, demonstrate good ecologically sound night-time lighting practices, improve the nocturnal environment of wildlife and provide accessible locations for the general public to experience the naturally dark night sky.

There shall be no installed artificial light within a Preserve. However if the manager deems it necessary, artificial lighting shall conform to these guidelines.

This document presents the Canadian Guidelines for Outdoor Lighting (CGOL) to be used in, but not limited to, Dark-Sky Preserves™, Nocturnal Preserves™ and Urban Star Parks™ herein after referred to as Preserves. It refers to areas classified as "Lighting Zone 0, and Zone 1" (per IESNA-IDA Model Lighting Ordinance). LZ 1 has low ambient lighting levels such as small rural residential areas. LZ 0 encompasses areas that are sensitive to artificial lighting and other environmental disruptions.

This CGOL has three objectives: to limit glare and the adverse ecological impact of artificial lighting throughout the Preserve, provide technical specifications for acceptable illumination levels required for safe navigation, and it presents lighting policies that may be applied to urban areas beyond its boundaries. These will protect the Preserve from deterioration by surrounding light pollution.

Section 3.0 presents the rationale for the protection of the rural and urban night environments from the excessive use of artificial lighting. To support these guidelines, this document provides references to general research and useful web sites into the effects of nocturnal lighting on humans, flora and fauna. Additional information and references have been published in Dick[1,2].

The Canadian Guidelines for Outdoor Lighting are presented in Section 4.

Lighting hardware and signage are described in the Appendices to assist Managers and city officials in selecting compliant lighting, or to guide the modification of non-compliant lighting to make it compliant. These sections and the Appendices will also be useful to other officials who are tasked with reducing the ecological impact of urban or built infrastructure.

[1] Dick, R., Applied Scotobiology in Luminaire Design, Lighting Research and Technology, 2013; 0: 1-17, doi: 10.1177/1477153513505758

[2] Dick, R. The Biological Basis for the Canadian Guideline for Outdoor Lighting, (Series of 6-papers) JRASC, June 2020-June 2021

2.0 GLOSSARY

2.1 Abbreviations

ALAN Artificial (Anthropogenic) light at night

CARS Canadian Aviation Regulations
CFL Compact Fluorescent Lamps
CO Cut-off luminaires (>0% and <2% up-light)

FCO Full Cut-Off luminaires (0% up-light or "fully shielded", 10% of light from 80° and 90° from nadir (glare zone). This is the minimum level of shielding.

CGOL Canadian Guidelines for Outdoor Lighting

HID High Intensity Discharge lamps (LPS, HPS, MH lamps)
HPS High Pressure Sodium lamps ("yellow" coloured HID lamps)

IESNA Illumination Engineering Society of North America

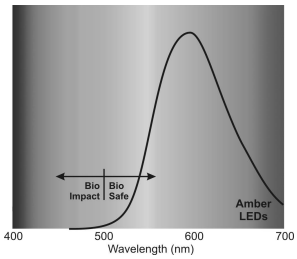
LEDs Light Emitting Diodes
LIL™ Low Impact Lighting™. Lighting that complies with these Guidelines
LPS Low Pressure Sodium lamps (monochromatic, single colour HID lamps)
LZ # Lighting Zone as per IESNA-IDA

MH Metal Halide lamps ("white" coloured HID lamps)

Preserve An area under single management that has been designated as a Dark-Sky Preserve™, Nocturnal Preserve™ or Urban Star Park™, or otherwise identified to have its nocturnal environment protected from artificial light.

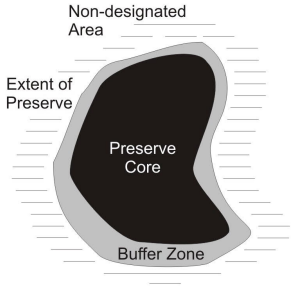
SAD Seasonal Affective Disorder
SCO Semi-Cut-off luminaires (<2% up-light)
ShCO Sharp Cut-off luminaires (0% up-light, <1% between 80-90 degrees of nadir)

2.2 Definitions



Amber – a colour of light that does not have any emissions at wavelengths shorter than 500 nm with a peak around 590 nm. Generally has a broadband yellowish colour and has less impact on night vision and circadian rhythm than other colours.

Dark Time – a period after which scheduled outdoor activity has ended and visitors are expected to minimize their activity to permit other visitors to sleep.

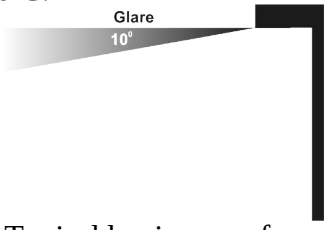


Preserve – The total area under the control of the Preserve Manager and includes the core and buffer zone.

Preserve Buffer Zone - the region within the Preserve that surrounds the Core area. The Buffer shall prevent glare and light trespass from shining from outside the Preserve into the Core area.

Preserve Core - the region under control of the Preserve Manager surrounded by the Buffer Zone.

Foot-candles (fc) - – the illuminance metric in the Imperial units of lumens/foot^2. Examples of levels are provided in Appendices A and C.



Glare Zone - sector between the horizon (90º from nadir) and 10º below the horizon.

Incandescent lamps - Lamps with tungsten filaments

Low Impact Lighting – Lighting complying with these Guidelines

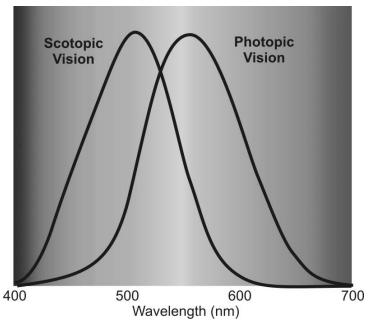
Lumens - A luminance metric unit for the amount of emitted light. Typical luminance of various lamps are listed in Appendix A and C.

Lux – the illuminance metric in the SI units of lumens/m^2. Examples of levels are provided in Appendix C.

Marker Light – used to indicate the location of a feature (not to illuminate a surface)

Nadir - the point directly below the luminaire (opposite to zenith)

Photobiology – the study of the effects of light on biological systems



Photopic Vision – vision based on the cone cells in the retina that have evolved for daytime vision and high illumination levels. Their peak sensitivity is at 555 nm.

Scotobiology – the study of the biological need for periods of darkness

Scotopic Vision - vision based on the rod cells in the retina that have evolved for night vision and low illumination levels. Their peak sensitivity is at 505 nm.

Sky Quality Meter –meter designed to measure the brightness of the night sky.

White Light - Coloured light with combined spectral components of blue, yellow and red

3.0 RATIONALE

Most people take artificial night lighting for granted. In cities it is considered to be an acceptable component of our society, and indeed many people think it is necessary for safety and security while providing an aesthetic quality to the night. Specifications and guidelines for street and roadway lighting[3] address these urban assumptions. These have lead to lighting policies that encourage the illumination of all urban areas to allow the use of human photopic (daytime) vision in virtually all populated areas (Figure 3.0.1).

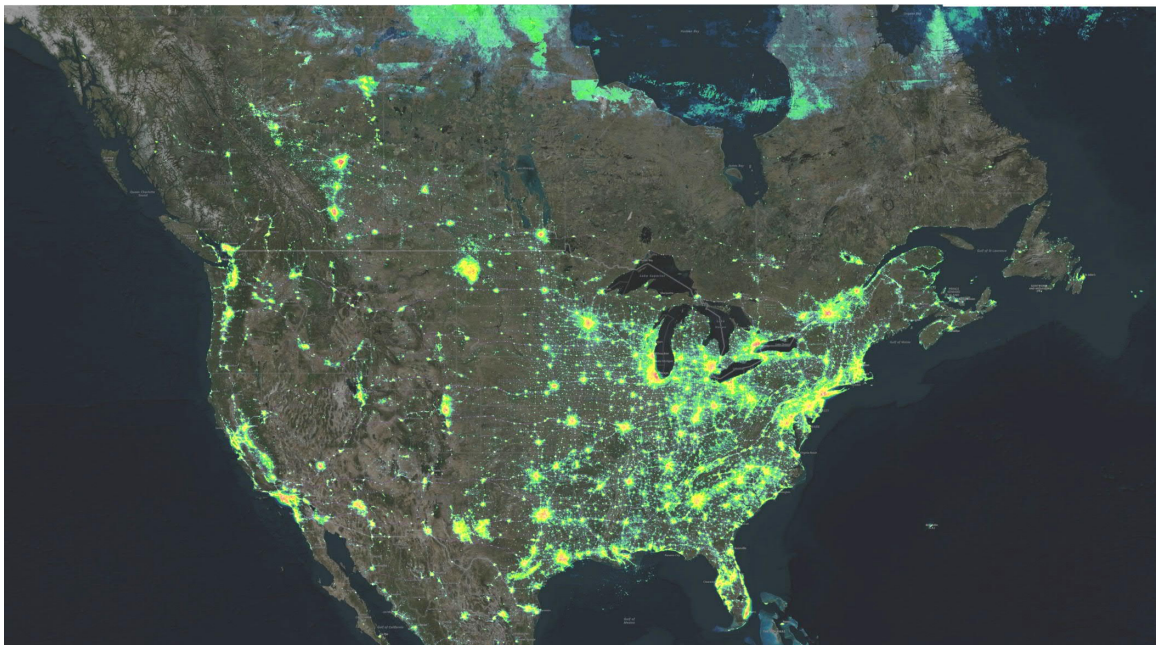


Figure 3.0.1 *Mid Latitudes at Night (http://www.lightpollutionmap.info 2019)*

The availability of electrical energy and efficient lighting fixtures have enabled the current urban lifestyle of non-stop "24-7" activity. Furthermore, the advances in lighting technology over a human lifetime have enabled the use of 10X the light with the same amount of electricity, which is exponentially increasing illumination levels by about 2.2% per year[4]. Most commercial and consumer luminaires are designed for high levels of illumination. Low intensity fixtures are primarily limited to decorative lighting such as Christmas lights.

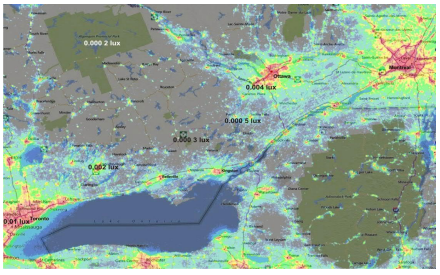
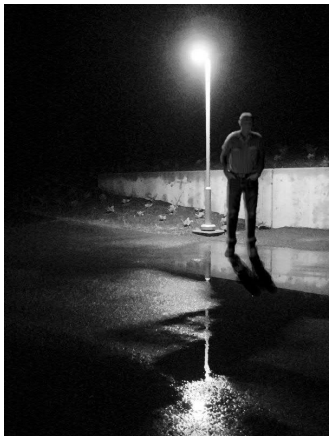


Figure 3.0.2 *Light Pollution in Southern Ontario. Illuminance (lux) values were converted from Sky Quality Meter readings made under clear skies between about 2010 and 2012. Most rural light comes from house and dusk-to-dawn lighting beside township roads and highways. (http://www.lightpollutionmap.info 2010)*

[3] Illumination Engineering Society of North American (IESNA) Handbook
[4] C. Kyba, et.al., Artificially Lit Surface of Earth at Night Increasing in Radiance and Extent Science Advances 2017;3: e1701528 November 22, 2017, http://advances.sciencemag.org/

It is now common in a city to be able to read a newspaper at night under the city's artificial sky glow. In Figure 3.0.2, the light polluted skies of Toronto are compared to "good skies" in the core of Algonquin Park (upper left) that has very dark skies. Bright red corresponds to high levels of urban sky glow.

3.1 Crime



The most prevalent reason given for light at night is to reduce crime in cities. This is generally based on the notion that more light improves visibility, and this visibility discourages criminals. Based on studies of crime statistics before and after changes in outdoor lighting, there is no clear evidence that outdoor lighting reduces crime[5]. Although there are anecdotal reports that "improved lighting" (i.e. more light) reduces crime[6], there is no evidence that crime is reduced with "more or brighter lighting"[7]. In some cases crime was simply displaced, or the altered lighting was prompted or caused by a change in use of the streets by, "…strengthening informal social control and community cohesion"[8] and this may have affected the pattern of crime.

There are different types of crime. Anecdotal studies report theft and property crime are more prevalent during daytime hours. The public's belief in the prevalence of random violence (promoted by Hollywood films) is not supported by research. Further, violent crime occurs more often in the evening and after midnight[9] between persons that know each other. Random violence is generally quite rare but is widely reported in the media.

There was an unconfirmed report that the brightly lit City of Manila found violent crime was still more prevalent on brightly lit streets after dark but increasing the presence of police was effective at reducing crime at night. They concluded that the city lights were not the deterrent to crime whereas the visible presence of the police was. A comprehensive report to Congress, by the National Institute of Justice[10] states that there is no evidence that artificial lighting deters crime. It reports that most studies are poorly designed and without controls, which undermines any conclusions to the contrary. The report states that: "We can have very little confidence that improved lighting prevents crime". Furthermore, lighting can assist criminal activity by putting the victim and the target property on display. And, the perception of safety provided by the light may have the opposite effect by encouraging unsafe behaviour.

[5] The Influence of Street Lighting on Crime and Fear of Crime, Prevention Unit Paper No. 28, Stephen Atkins, Sohail Husain and Angele Storey, 1991, ISBN 0 86252 668 X
[6] Effects of Improved Street Lighting on Crime: A Systematic Review, Home Office Research Study 251, by David P. Farrington and Brandon C. Welsh, August 2002
[7] The Indiana Council on Outdoor Lighting Education (ICOLE), P.O. Box 17351, Indianapolis, IN 46217
[8] ibid, page 2.
[9] www.bpap.org/bpap/research/DCA_briefing_dtd.pdf
[10] National Institute of Justice Grant Number 96MUMU0019 (www.ncjrs.gov/works/)

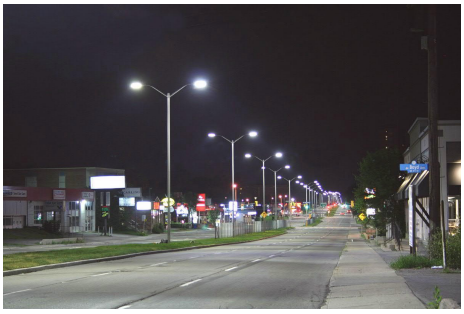
Vandalism is an example where security lighting has the opposite effect of what is generally believed. Studies conclude that lit areas are subject to more vandalism and graffiti. Anecdotal evidence[11] and more focused studies[12] support the policy of turning lights off when security staff is not around. Apparently, vandals want to see the results of the damage and for others to see it.

"Security lighting" is often given as a reason for a luminaire. However, the illumination only enables surveillance by security cameras or personnel. Without active monitoring, the light will have the opposite effect. What is being watched? A security light need only illuminate a particular area that is under surveillance. Shining the light off-site is not just wasteful, but produces glare that undermines visibility.

Security is NOT the same as safety. Best practice for security lighting is based on urban crime, whereas safety depends on visibility of hazards. In most cases illumination in Preserves is used for visitor safety and navigation. This is a different approach to lighting and that is provided by much less light. Lighting should be used only to highlight hazards, and only the hazards should be highlighted.

3.2 Lighting for Human Activities

Humans are a daytime species. Although we can see at night, our vision is significantly reduced compared to the daytime. In the past, starlight provided sufficient levels of illumination for most "pedestrian" activities. However our modern fast-paced and mechanized activities require better visual acuity for driving cars, riding bicycles and for highlighting urban hazards.



The human reaction time to a stimulus is a function of the illumination level[13]. For our photopic vision it is less than 0.2 seconds whereas with our scotopic (night) vision it is about 0.5 seconds, which is sufficient for a walking pace. However in the presence of illuminated roadside distractions, actual reaction times are from 1 to 3 seconds[14]. Illumination levels play only a small part in reducing driver reactions but significantly increase the distractions.

Some level of artificial lighting is required for activities at night. But this lighting must be designed to increase visibility. Paradoxically, more light can reduce visibility by creating

[11] "Darkened Streetlights Fail to Raise Crime Rate", DesMoines Register, T. Alex and T. Paluch, May 6, 2004 www.dmregister.com

[12] Effects of improved street lighting on crime: a systematic review, Home Office Research Study 251, August 2002

[13] A.L. Robert - Simple Time Reaction as a Function of Luminance for Various Wavelengths, Perception & Psychophysics, 1971, Vol.10(6)

[14] T. Triggs, W. Harris, Reaction Time of Drivers to Road Stimuli, Human Factors Report No. HFR-12, ISBN 0 86746 147 0, Monash University, Victoria Australia, June 1982

glare. This is especially true for persons over 40 years of age[15] whose visual abilities degrade with time.

For example, our sensitivity to glare increases with age, as does our chances of developing cataracts. In the face of a bright light, our iris closes down letting light into the eye only through the centre of our lens. Since cataracts begin in the centre of the lens, the vision of senior citizens can be severely degraded by glare even without fully developed cataracts. With the aging of our population, it is becoming more important to reduce glare at night.

3.3 Human Health

The proliferation of outdoor lighting has a significant impact on the health and behaviour of humans[16]. "Biological clocks control our sleep patterns, alertness, mood, physical strength, blood pressure, and other aspects of our physiology"[17]. The dominant mechanism for synchronizing this biological clock to our activity (the circadian rhythm) is the day-night contrast and the timely release of the hormone melatonin. There is considerable research on this topic. Melatonin regulates the ebb and flow of other hormones that repair the damage our bodies suffer each day. Without the timely release of these hormones, healing takes longer and our bodies are less able to fend off disease[18].

The timing or phase of the circadian rhythm also affects our behaviour. For example, Seasonal Affective Disorder (SAD) is an emotional condition experienced by travellers, and others. The symptoms of SAD can be reduced with exposure to bright light[19] in the morning as it shifts (or entrains) and resets our biological clock. However if this entrainment occurs during the late evening or at night due to artificial lighting, the biochemistry that controls our physiological well-being will be shifted away from the optimum period.

3.4 Environmental Health

Although many people are familiar with the activity of the natural world during the day (i.e. photobiology), few people are as familiar with similar activity at night. Humans are not the only species whose biological clock is controlled by day-night contrasts and the release of melatonin. Similar biological clocks are found in plants and animals wherein darkness plays a similar role[20]. Wildlife depends on the darkness of the night and the study of this dependence is called "scotobiology".

[15] Work, Aging, and Vision: Report of a Conference, ISBN-10: 0-309-07793-1
[16] Light Research Organization, Electric Power Research Institute, (www.epri.com/LRO/index.html)
[17] WebMD, March 06, 2007, www.webmd.com/cancer/news/20040908/ light-at-night-may-be-linked-to-cancer
[18] "Light at night and cancer risk", Schernhammer E, et.al., Photochem Photobiol. 2004 Apr;79(4):316-8.
[19] "Shutting Off the Night", H. Marano, Psychology Today, Sep/Oct 2002
[20] "Lighting for the Human Circadian Clock", S. M. Pauley, Medical Hypotheses (2004) 63,588–596

Research into the nocturnal environment is relatively recent compared to research into the daytime environment. This situation is changing with a growing body of literature documenting the sensitivity of the general ecology at night to artificial lighting. This mounting scientific evidence is documenting the profound impact of artificial light on the ecology of the night[21] and the degradation it causes.

Plants are affected by the colour and duration of lighting. Whether the effects are considered beneficial or not depends on whether the outcome is desired or not. Generally, artificial lighting will change natural growth patterns and may affect the resistance of plants to infestations and disease. Many plants respond to the length of the night as an indication of seasonal change. Extending light past the evening will slow or prevent the ability of some plant's biochemistry to prepare for winter. The various affects of light colour and duration, and type of plant, etc. makes sweeping conclusions impossible, however they indicate that changing the natural lit environment will change the natural ecology of the area.

3.5 Animal Behaviour

Artificial skyglow extends well beyond the city boundaries. Therefore in considering urban outdoor lighting, city officials must also consider its impact on the rural areas in the region. As with air and water pollution, light pollution is not contained by political boundaries.

Exposure to short periods of bright illumination (less than a minute) does not seem to affect the biological rhythm in animals[22]. However, longer exposures can shift (or entrain) their circadian rhythm and can modify their behavioural patterns. Minimizing the duration and extent of exposure is necessary to limit its impact.

Seasonal variations will shift the time of sunset by over four hours at mid-latitudes from roughly 16:30 hours in winter to 21:00 hours in summer (mid latitudes). During the peak of summer activities in public parks, the time of sunset can vary by over two hours (see Appendix D). In addition to this, dusk can extend the daylight by as much as an hour. The "behavioural plasticity" of animals has presumably evolved to accommodate these variations. This can be used to place appropriate limits in the schedule of lighting.

Natural lighting changes the behaviour of species at night[23]. Nocturnal mammals adapt their behaviour over the lunar month to avoid predators. This behaviour includes, in part, limiting the foraging area and carrying food back to their shelters instead of eating in the field - limiting how much they can eat[24]. They compensate for this during the dark time of the month.

[21] Ecological Consequences of Artificial Night Lighting, C. Rich, T. Longcore, Island Press, 2006, Pg. 405
[22] Ecological Consequences of Artificial Night Lighting, C. Rich, T. Longcore, Island Press, 2006, Pg. 24
[23] The Urban Wildlands Group (www.urbanwildlands.org/abstracts.html)
[24] Ecological Consequences of Artificial Night Lighting, C. Rich, T. Longcore, Island Press, 2006, Pg. 28

Predator and prey behaviour depends on the darkness of the night[25]. Illumination levels that significantly affect our biology and that of wildlife is believed to be at the level of the full Moon (0.1-lux), although the effect begins to be evident at lower light levels[26]. To put this in context, it is generally recommended by the IESNA that an urban parking lot be lighted to more than 100X the brightness of the full Moon (see Appendix A), and the distant illumination by the sky glow from a nearby city can exceed full Moon levels.

An illuminated road may separate animals from their normal foraging grounds. When headlights from passing cars temporarily blind them, their natural instinct is to wait until they can see where they are going. This can leave them in the open and vulnerable to predation. They may eventually abandon their established foraging areas for new ones, which will impact the indigenous species as they compete for resources[27].

It is well documented that some insects are drawn towards light sources. This interrupts their normal mating and foraging activities and it concentrates them within a small area thus enhancing predation[28]. They may also swarm the light fixture until they are exhausted. In one Canadian park, the resulting pile of insects has to be cleaned up in the morning[29]. The blue-light components of typical broadband (white) light are the main light attractors for insects. Using white light essentially attracts the insects to the people causing a nuisance and, since insects are vectors for disease, the white light enhances the health risk of outdoor activity[30].

3.6 Shorelines

Waterways are used for transportation and recreation. However, they are also important ecosystems that support wildlife in the water and on the lands adjacent to the shoreline. Shoreline property is valued by our society and this is causing human developments along rivers and around lakes. An increasing number of properties have shoreline lighting that illuminates the waterway.

From the human stand point; shoreline lighting makes it very difficult to navigate the channel. Glare from unshielded lights prevents boater's eyes from becoming dark adapted. At night, a boater will only be able to see the points of light along the shore rendering the channel markers and floating hazards very difficult to see. Clearly, glare along the shoreline obscures hazards and should be reduced.

[25] ibid., Chapter 2
[26] ibid., Chapter 11
[27] Ecological Consequences of Artificial Night Lighting, C. Rich, T. Longcore, Island Press, 2006
[28] ibid., Chapter 13
[29] Anecdotal reports from Parks Canada, 2011
[30] A. Barghini, B. de Medeiros, Artificial Lighting as a Vector Attractant and Cause of Disease Diffusion, doi: 10.128/ehp.1002115, August 2010, National Institute of Environmental Health Sciences, US Dept. of Health and Human Services

Illuminated shorelines also impact fish and aquatic plants[31]. Some fish are attracted to the light from their natural feeding depths. The increase in the concentration of small fish increases the hunting efficiency of predators. Although the behaviour of the nocturnal predator may not be compromised by artificial light, the ability of its prey to recognize the danger and to escape will affect their survival. This alters the ecological balance leading to unforeseen consequences.

3.7 Cultural Impact

There is a cultural imperative to protect the darkness of the night sky. Throughout recorded history (about 6,000 years) stargazing and astronomy have been a focus of stories and mythologies. Those who have seen a dark sky are impressed by the serene majesty of the celestial sphere. It comes as no surprise that all civilizations have the constellations and asterisms woven into their culture.

This is a fading experience for most people. After stepping outside from a lit room to under a dark rural sky, our initial count of a few stars with our photopic vision increases a hundred fold after only 10 minutes. This may be followed by another order of magnitude after less than an hour as our eyes become fully dark-adapted. However, urban sky glow overwhelms the faint stars, and the glare from discrete light fixtures prevents our eyes from becoming dark-adapted. These limit the number of stars we can see from many thousands to less than a few hundred. The consequence is that most people do not look up - because the view is only darkness. Our current generation is the first for whom much less than half the population has seen a star-filled night sky. Most children have never seen the Milky Way.

With urban-style lighting in parks and campgrounds, visitors are less able to see the night sky that motivated our ancestors. By adhering to these Guidelines, visitors will be welcomed by the view of the night sky and will hear the sounds of the nocturnal animals, and these Guidelines will help preserve the ecological integrity of the area.

3.8 Spectrum of ALAN

As discussed earlier, and as specified in Section 4 and summarized in Appendix L, only non-white light sources are permitted in Preserves. However conversion to compliant lighting can be relatively easy (see Appendix K).

Most lamps are based on incandescent, HPS, florescent and LED bulbs. Incandescent bulbs emit a broadband "warm" white light with a correlated colour temperature (CCT) of about 2700K. HPS lamps have a "spiky" amber spectrum. Although the colour "looks" yellow, it contains 10% blue light (<500 nm).

LEDs are available in a range of colours but they can be classified as white or amber. (Warm-white light has less blue, but it is still “white”.) White-light LED luminaires are available with correlated colour temperatures (CCT) from 2700K to 5000K LEDs. However the amount of blue in these lamps can vary considerably with CCT and between

[31] Ecological Consequences of Artificial Night Lighting, C. Rich, T. Longcore, Island Press, 2006, Part V

companies from less than 10% to almost 40%. The amber LEDs (CCT ~1800K to 2200K) emit virtually no blue light.

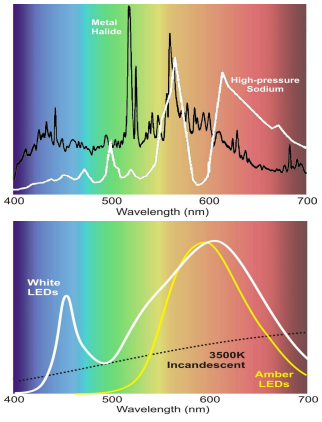


Figure 3.8 Spectra of Common Lamps
A lamps spectrum depends on the physics of light emission and can have either a "spiky" or banded spectrum or a smoothly varying spectrum. Incandescent lamps (~2700K tungsten filament) have a smooth spectrum that illuminates all coloured surfaces very well. All other spectra only illuminate certain colours, which reduces the colour rendering. Although amber LEDs (White minus Blue) do not cover the full range of colours, it provides fair rendering due to its smooth broad emission. It is generally the blue-light component that causes the biological impact.

White light is not permitted in Preserves because of its impact on wildlife, vision and its high scattering properties in smoke and fog. Blue light affects the circadian rhythm of plants and animals - artificially altering their biology, and it provides subconscious lighting cues that may lead to inappropriate seasonal and foraging behaviours. For example some plants base their preparation for winter on the length of the night, which can be artificially shortened by artificial light, leading to a delay in dropping leaves and reduced winter survival.

White light with blue spectral components also attracts approximately 50% more insects than amber light. Apart from being a nuisance, insects can carry diseases that may be transmitted to park visitors.

If 3000K LEDs must be used, no more than 1% of the total emitted light shall be emitted in the "glare zone" between 90-80 degrees from nadir (ShCO requirements, Section 310). And, the illumination level must be less than 40% the levels specified in Chapter 4. (This accounts for the difference between photopic lumens and scotopic lumens.) This will help preserve night vision and limit the extent of the ecological impact.

The blue light components increase the impact of glare – up to 10X that of amber light. And when unshielded, white LEDs undermine our night vision. With a compromised night vision, we are less able to see into dim areas - reducing safety by limiting our awareness of the surroundings (creating hazards) and affecting our ability to navigate at night. This lack of visibility also reduces our sense of safety and security.

The role of artificial light is to either mark a location at night (a marker light) or to make a surface visible. Once the light is emitted from a lamp or scattered off a surface, it may contribute to light pollution.

3.9 Luminance

The amount of light we see is “luminance”. It is the light that enters our eyes, and if it is excessive we perceive it as glare. The amount of incident light per unit area is the surface “illuminance”. This illuminated surface then reflects or scatters the light into our eyes,

which we perceive as, once again, the surface luminance. It is the light source and the reflected surface "luminance" that affects the vision and biology of animals and people.

If a lamp is to illuminate a large surface then the luminance of the lamp must be considerably greater than the illuminated surface because it is much smaller than the surface. For example the light source of a streetlight may have an area of 40 cm^2 (0.004 m^2) but it must illuminate 240 m^2 of road surface, so the luminance of the lamp must be about 60,000X brighter than the apparent luminance of the road. And, the road surface may only reflect 5% of this light. So although the road surface has a modest brightness, the lamp will be "brilliant".

If not shielded, the apparent brilliance of the lamp scatters in our eyeglasses and optics of our eyes to reduce contrast and undermine our ability to see. The luminance of a light source (a lamp or a brightly illuminated surface) is what attracts insect and affects the biology and behaviour of other animals.

This is why shields are so important (Section 3.11) otherwise we are both "distracted" by the direct lamplight, and the glare undermines our vision into to dimmer areas. There are three celestial objects that put the luminance of lights into a practical perspective.

During twilight, the planet Venus is a brilliant object and hard to ignore - it casts shadows! However it is low in the sky after twilight and tends to be obscured by vegetation near the horizon. Another celestial object that "gets the attention" of city dwellers is the star Sirius. It is seen in the dark winter sky and is only 1/10 the luminance of Venus (1 cd/m^2 compared to 0.1 cd/m^2)

In contrast, the full Moon is much brighter at about 4,500 cd/m^2 and a streetlight can have the luminance of 4-million cd/m^2. The light of the crescent Moon affects the behaviour of different types of animals[32], and a luminance of several-times the light of the full Moon affects our biology[33,34], and by similarity that of other animals. These numbers put natural and engineered luminous objects into perspective.

Animals have evolved under the natural lights, so we presume the ecosystem will tolerate this amount of luminance even as bright as the full Moon. However streetlights are roughly 1,000X brighter than the full Moon. In the absence of more specific studies, it is reasonable to limit the luminance of light fixtures that are used to illuminate an area, as seen from beyond the target area, to at least less than the crescent Moon (500 cd/m^2).

[32] Benoit-Bird, K., Au, W., Wisdom, D. (2009) Nocturnal Light and Lunar Cycle Effects on Diel Migration of Micronekton, Limnology and Oceanography, 54(5), 1789–1800 2009

[33] Dauchy, R., et.al., (2010) Dark-Phase Light Contamination Disrupts Circadian Rhythms in Plasma Measures of Endocrine Physiology and Metabolism in Rats, Comparative Medicine, Vol. 60, No 5 October 2010 Pages 348–356

[34] Dauchy, R., et.al., (2014) Circadian and Melatonin Disruption by Exposure to Light at Night Drives Intrinsic Resistance to Tamoxifen Therapy in Breast Cancer, Cancer Research; 74(15) August1, 2014, DOI: 10.1158/0008-5472.CAN-13-3156

Shielding is not appropriate in applications where the purpose of the light is to mark a location (marker light). In these cases, the luminance should be less than 1 cd/m^2 so as to limit debilitating glare. This is about 3X the luminance of the surface of an urban residential street.

Lamps are rated by how many "lumens" of light they emit, so how many lumens are permissible?

A candle emits light in almost every direction, but many modern lights direct the light forward – doubling its apparent luminance for a given total amount of emitted light. More specifically for a marker light, a modern directional lamp such as an LED should be limited to about 6 lumens (a 1/16 W LED).

A brighter field of view (ambient light) will require a brighter LED to get the same attention. For a marker light near an illuminated asphalt road, to get the same contrast of Venus against a tree line, a directional LED would need to be 30X brighter (2W LED marker light)[35, 36].

3.10 Luminaire Shields

Shielding luminaires is critical for cutting widespread glare that is otherwise visible for "as far as the eye can see". Shielding improves visibility and prevents the light's impact on the environment beyond the target area.

Unshielded lights will illuminate a very large area, however the illumination level more than 2 mounting heights from nadir is, quite literally, negligible - <1/10 that at nadir, and contributes little to good visibility. The useful spread of the light is only about 1.5 X mounting height from nadir. (This is due to the cosine law and the 1/r^2 law, which are shown the accompanying figure.) So any light that shines beyond this distance primarily produces glare and wastes energy.

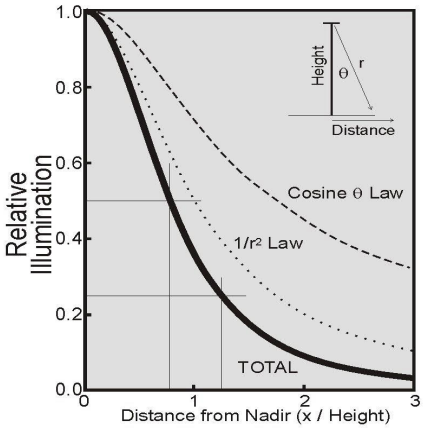


Figure 3.10.1 Distribution of light from a luminaire. For a simple luminaire, the illumination decreases with distance from the nadir of the luminaire. There two reasons for this: the illumination dims with distance (1/r^2), and the angle the light hits the ground gets lower (cosine law). The combination of these limits the practical illumination out to less than 2 mounting heights from nadir. Thus a luminaire that shines light farther than this distance contributes only glare, which reduces visibility.

[35] Puschnig, J., Posch, T., Uttenthaler, S., Night Sky Photometry and Spectroscopy Performed at the Vienna University Observatory, JQSRT, April 2013 arXiv:1304.7716v1 [astro-ph.IM] 29 Apr 2013

[36] Assumes a DSP sky brightness of 21.3 mag/s^s, a tree albedo of 0.15 and an asphalt road luminance of 0.3 cd/m^2

The light that shines within 10° below the horizon can undermine our night vision more than 100 meters away and can affect the aesthetic appearance of the night. Full cut-off fixtures (or fully-shielded fixtures) limit the amount of light in this glare zone to <10% while Sharp Cut-Off fixtures limit it to <1%. (See Figure 3.10.2).

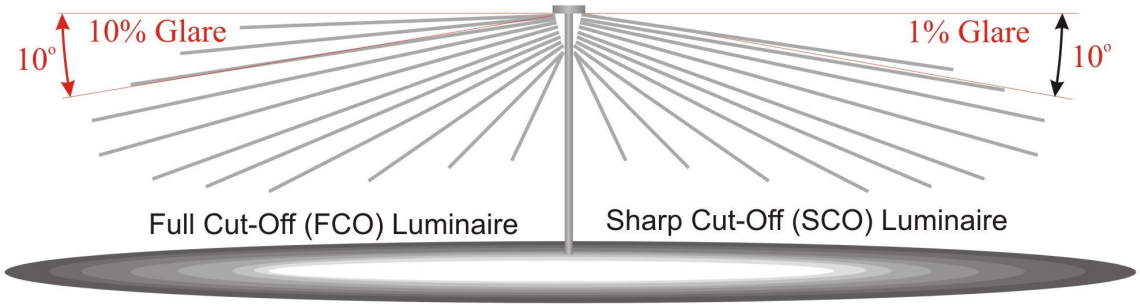


Figure 3.10.2 Comparison of FCO and ShCO shielding. FCO shielding permits 10% of the total emitted light to shine within 10-degrees below the horizon. ShCO shielding reduces this to only 1% and significantly reduces this glare.

To expand the target area with more useful light requires appropriately designed optics to "throw light" from nadir into the periphery but still limit the light in this glare zone to <10%.

Because of the spectral effects discussed in Section 3.8, white-light lamps require at least Sharp Cut-Off shielding for them to reduce the effective glare to that of amber light. Existing commercial luminaires approach FCO but extra shields may be required to convert them into Sharp Cut-Off. FCO LED luminaires tend to have the LEDs close to the bottom of the fixture (Figure 3.10.3) whereas ShCO LED luminaires tend to have the LEDs recessed well inside the housing (Figure 3.10.4).

Mirror surfaces or bright coatings on the shields are effective at redirecting the light from the glare zone down into the target area to produce a more effective light fixture and increases visibility across the illuminated area, and even beyond by helping to preserve our night vision. This increases our “sense of place” and “situation awareness”, and thereby increases our safety and security.

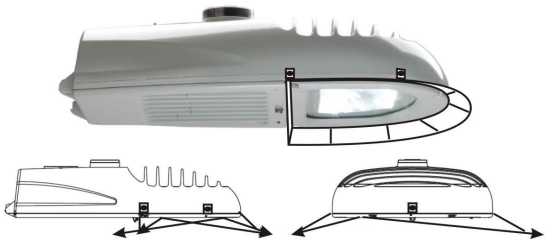


Figure 3.10.3 *Sketch of luminaire shield. This is a sketch of what a sheet metal shield could look like. The shape is based on earlier shields that were used on non cut-off cobra lights. The front and back surfaces limit light trespass.*

Figure 3.10.4 Sharp Cut-off Design. LEDs are well recessed above the window. Only the diffuse light from the optics is visible from a distance thus reducing glare.

3.11 Scheduling of Light

Humans are the only creatures that want light at night, so it must only be used if and when there is human activity in the area. After this activity the lights should be dimmed or turned off.

Some Preserves define a “Dark or Quiet Time” when outdoor activity and lighting is discouraged so other visitors may sleep, typically beginning 2-hours after sunset. Wildlife can also accommodate this limited extension of twilight. So these Guidelines suggest dimming or turning off lights at the beginning of their Dark Time.

There are four uses for outdoor lighting.

Navigation	- assists in wayfinding
Safety	- renders hazards more visible
Security	- assists personnel to protect persons and property
Aesthetics	- illuminates a cultural display

The norms of urban areas should not apply in a Preserve. Artificial light should be used “sparingly” for navigation. The role of artificial light at night is to only identify hazards and wayfinding for pedestrian activities, which require relatively low illumination levels.

There are usually no security personnel that to regular security sweeps or CCTV monitoring of lit areas throughout the night. Therefore, the security "best practices that require vigilance are not practical and may even aid in theft and vandalism security.

3.12 Summary

Artificial lighting that is installed for human activity alters the natural environment. Currently, this environmental degradation supported by outdated urban Best Practice and this should not be applied to Preserves.

It is clearly shown in published research, that artificial outdoor lighting affects the ecology by disrupting food webs, animal biology and behaviours. Although the actual mechanisms for these disruptions are not always clear, this does not weaken the evidence for the damaging impact of artificial light on the ecosystem and the need to minimize it.

There is growing evidence for the degradation of human health with the illumination of the night – particularly the blue components in white light that may be contributing to the increases in chronic diseases.

Education is the key to reducing this degradation by ALAN. Establishing Preserves is an obvious way to help inform the public about the virtues of a dark night, and will show its vitality. Demonstrating compliant outdoor lighting in Preserves, will show the importance of reducing artificial light at night in their home cities.

Wildlife has no voice and cannot control their environment. We must act on their behalf. Both parks, cities and citizens must take action and advocate against changing their habitat.

4.0 GUIDELINES FOR OUTDOOR LIGHTING

Chapter 3 explained the need to reduce light pollution. The information and tables in this section present the quantitative limits to outdoor lighting in Preserves. In all cases, artificial light at night is considered “contamination” that must be prevented or at least minimized.

Since the goals of the Dark Sky Programs are to promote and protect the night environment, these Canadian Guidelines for Outdoor Lighting (CGOL) apply to all Preserves. They give priority to the ecology, not urban lighting “Best Practice”.

We should not assume the current installed light is necessary. Before determining what type of lighting should be installed or retrofitted, it is important to ask the basic question; "Is the light necessary?" If there is no current need for artificial lighting, it should be removed rather than replaced – regardless of the technology.

This chapter provides guidelines that should be followed to minimize light pollution within a Preserve and to protect its ecological integrity. It is recommended that the Preserve adopt similar equipment with low ecological impact to minimize the cost and complexity of inventory, repairs, replacements and re-purposing.

Where necessary for basic safety and navigation:

1. Illumination should not exceed the specified levels.
2. The affected area of illumination should be as small as practical.
3. The duration of the illumination should be as short as practical. And,
4. Light fixtures should emit a minimum of blue spectral components (i.e. white light is not permitted).

What is “practical” depends upon the specific facilities in the area and the technology available at the time.

Illumination levels specified in this document are lower than what is used in urban areas for which most luminaires have been designed and may limit the type of light sources that may be used. However the specified illumination levels are close to those recommended by the Illumination Engineering Society. The main differences are the added requirement for shielding, amber light and scheduling of the light, which is not addressed in most urban guidelines.

Although High Intensity Discharge (HID) and CFL lamps are very efficient, they may emit more light than is recommended in these guidelines. To address this, incandescent lights may be used for short periods of time or modern amber LED fixtures may be installed that permit sufficient dimming.

Amber light is available with a number of commercially available products. For example, an incandescent or CFL light bulb can be replaced with amber "bug lights". Several

lighting companies manufacture and market amber LED luminaires[37], or amber filters[38] can be used to remove the blue-light components. See also Section 3.8.

These guidelines address the different types of facilities for pedestrian and vehicle traffic. Managers have the discretion to assess what levels are most appropriate for each built facility within the limits outlined in this chapter. Lighting is limited to provide only what is required for visitor navigation in built up areas. The artificial lighting is restricted to those selected areas and for the periods of human activity unless otherwise noted.

Managers may define Dark Time that is suitable for their facility. In this document, Dark Time is assumed to be begin 2-hours after sunset. Appendix D contains a reference table with the approximate times of sunset for parks in southern Canada (+50° latitude).

The following tenets have been used in developing these guidelines.

1. Buildings require illumination only when open or available to the public. After the office is closed to the public, all lighting visible from the outside should be turned off.

2. To save energy and minimize the duration and extent of light pollution, lit pathways should be illuminated only when pedestrians are in transit. All reasonable effort should be made to turn off lighting when pedestrian traffic is low or is no longer expected.

3. To minimize the impact of artificial lighting on the ecosystem, the areas covered by this guidelines should provide only enough light needed for a safe transition between lit structures and the surrounding unlit area, and to assist in navigation.

4. To minimize the ecological impact of light pollution, the extent of illumination should be strictly limited to only the area of current human activity.

5. To limit the duration of light exposure on the ecosystem and to save energy, light activated timing circuits should turn off outdoor lighting on or before the beginning of Dark Time or to the end of scheduled activity.

6. Where vehicle and pedestrian traffic is at a low speed or infrequent, retro-reflective signage should be used instead of installed lighting fixtures.

The IESNA BUG Designation System (Back-light, Up-light and Glare) that defines luminaire shielding is in Table 4.0. BUG lighting zone definitions are in Appendix F.

Table 4.0 BUG System Designation for Preserve Compliant Luminaires

BVH **BH, BM, BL**	<1% <10%, or as required	**FVH** **FH, FM, FL**	<2% As required	**UH, UL**	0%

[37] www.savingourstars.org/amberleds, Accessed July 2021
[38] www.bhphotovideo.com/c/product/43872-REG/Rosco_RS1511_15_Filter_Deep.html, Accessed July 2021

In addition to these guidelines, compliant luminaires described using the "abbreviated" BUG designation should be B=0, U=0 and G=0.

In all cases, full cut-off (FCO) or sharp cut-off (ShCO) luminaires should be used to prevent light scattering beyond the immediate area of the light fixture. Further, the colour of this light shall be amber with minimal blue (short wavelength) content.

4.1 Buildings

This guideline identifies five building classifications. Illumination levels and luminaire types for various buildings are listed in Table 4.1. Managers should also consult Appendix C and J for guidance in meeting the recommended illumination levels.

4.1.1 Administration Buildings

Administration buildings are defined as those with private offices and will generally be closed after dark. Illumination of the main doorway, and especially any steps leading to the main door, may be required after sunset in the late autumn, winter and early spring.

After hours, either all interior lighting should be turned off, or window and door blinds should be used to prevent interior light from shining outside. Light activated (sunset) or timing circuits should turn off all outdoor lighting within 30 minutes of the office being closed. Manual reset switches or motion detectors may be used to extend this period for late-working staff by a pre-programmed duration of typically less than 1-hour.

4.1.2 Public Buildings

Public buildings are defined as those open to the public during business hours and may also contain private offices. After hours, either all interior lighting should be turned off, or window and door blinds should be used to prevent interior light from shining outside. All outdoor lighting should be turned off within 30 minutes of the building being closed. Exterior lighting should be limited to the main door area and steps. Light activated (sunset) or timing circuits should turn the lighting on after sunset and off after a period of time specified by the Manager and subject to the building use.

If toilet, washroom and shower facilities are available throughout the night, FCO or ShCO fixtures should be used to illuminate the entrance and any steps leading to the doorway. The down light from the wall-mounted luminaire may be used as the door "marker light".

Interior lighting in these facilities must also be considered. Excessive interior lighting levels can produce serious glare through the windows that will impair exterior visibility. After sunset, interior lighting should use amber (bug lights) or red lamps, or amber filters whenever possible. Light levels, measured horizontally at the floor level, should not exceed 10 lux.

4.1.3 Retail Outlets

It is assumed retail stores will have higher pedestrian traffic than most other areas and illumination may be required while they remain open for business after dark.

Window coverings should be used so that interior lighting will not shine outside 30 minutes after sunset. Exterior light is permitted, but is restricted to FCO or ShCO fixtures illuminating the ground around the door. Exterior lighting should be turned off within 30 min. after business hours.

4.1.4 Vending Machines

Vending machines should be shielded within an enclosed space and their lights should not shine directly outside through doorways or windows. Where practical, these machines should be enclosed in existing public buildings. Figure 4.1.4 shows an example of a dedicated vending machine enclosure. Only FCO or ShCO fixtures should be used to illuminate the area outside the entrances. The extent of the outside illuminated ground area is restricted to less than 5 metres from the entrance to allow a transition out of the illuminated space.

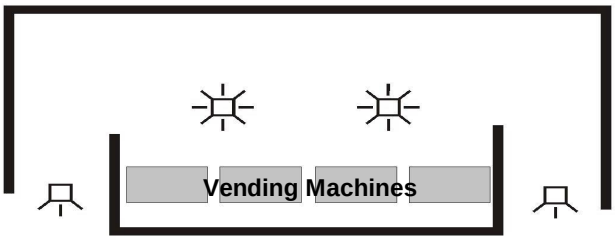


Figure 4.1.4 – Sample Vending Machine Enclosure

Doorway lighting should be turned off or dimmed within two hours of sunset. Interior lighting may remain on at the owner's discretion.

Table 4.1 Building Illumination Guidelines (Maximum Values)

4.1 Area	Type	Light*	Level (lux)**	Height	Curfew
4.1.1 Admin. Bldgs.	FCO ShCO	Amber Incandescent, CFL or LED, Filtered	~3 lux	2.5 m	Yes
4.1.2 Public Bldgs. (Toilet, Washroom, Shower Facilities)	Marker FCO ShCO	Amber Incandescent, CFL or LED, Filtered	~3 lux	2.5 m	No
4.1.3 Retail Stores	FCO ShCO	Amber Incandescent, CFL or LED, Filtered	~3 lux	2.5 m	Yes
4.1.4 Vending Machine	FCO ShCO	Amber Incandescent, CFL or LED, Filtered	~3 lux	2.5 m	Yes

* Wattages for individual lamp types are not specified due to differences in efficacy.
** 2 lux = illumination by clear sky about 20 minutes after sunset. Levels may be increased to 5 lux with Sharp Cut-off Shielding and 3:1 uniformity over area.

4.2 Parking Lots

Generally, parking lots have less traffic at night than during the day. However, they may require lighting due to scheduled after-dusk activities. This lighting may be necessary until gate closure or Dark Time, which ever occurs later. The illumination levels are listed in Table 4.2.

Where required, pole mounted FCO or ShCO luminaires should be placed at least a distance of one pole-height from the extreme corners of the parking lot and distributed evenly along the perimeter with an approximate pole spacing of no less than 4-times the luminaire height. Their light distribution pattern should be "full forward" and aimed into the lot. This is symbolically shown in Figure 4.2. Larger parking lots may have poles located within the parking lot area.

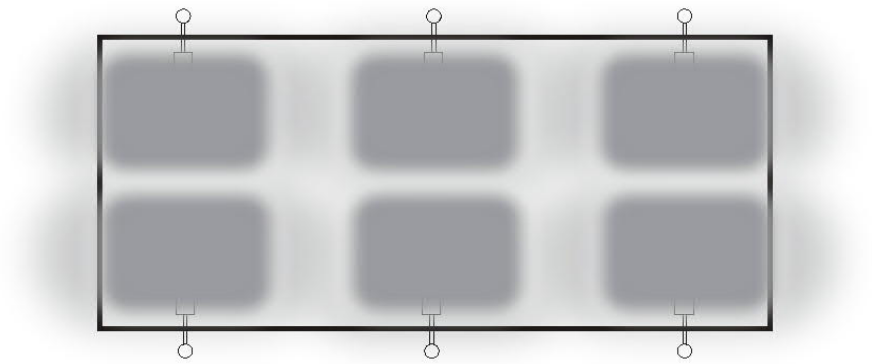


Figure 4.2 Parking Lot Lighting

4.2.1 Administration Parking Lots

Administrative personnel will generally leave when offices close. These luminaires should be turned off within 30 minutes of the office closure. A timing circuit should control the lights with a manual reset (an extra hour) for late-working employees.

4.2.2 Visitor Parking Lots (Large)

Larger parking lots (spaces for approximately more than 10 cars) may require better visibility than smaller lots due to higher pedestrian and vehicle traffic densities. These lots may be illuminated at the discretion of the Manager. However illumination levels should not exceed the limits listed in Table 4.2.

Table 4.2 Parking Lot Illumination Guidelines (Maximum Values)

4.2 Parking Area	Type	Light	Level (lux)	Height	Curfew
4.2.1 Administration Lot	FCO ShCO	LPS, HPS or Amber CFL or LED, Filtered	~3	6 m	Yes
4.2.2 Visitor Lot < 10 cars	N/A	None	N/A	N/A	N/A
4.2.3 Visitor Lot > 10 cars	FCO ShCO	LPS, HPS or Amber CFL or LED, Filtered	~3	6 m	Yes

N/A – not applicable

4.2.3 Visitor Parking Lots (Small)

Generally small lots (less than 10 cars) experience little traffic and should not be illuminated.

4.3 Roadways

Intersections are some of the most dangerous areas for drivers and pedestrians. Drivers of high-speed vehicles require sufficient time to react when they approach an intersection (approximately 3 second reaction time before brakes are applied). Therefore, major intersections should be marked with luminaires, signage or both. Illumination of adjacent areas should be minimized to avoid distracting drivers and to limit ecological impact.

Where federal and provincial highway standards take precedence, the minimum-allowable illumination in the standard should be used. Where federal or provincial roadways run through Preserves, lighting of these roadways should be evaluated. If lighting will affect the quality of the Preserve, then the Manager should request the government to use light fixtures that will most closely comply with the these guidelines.

Federal and provincial standards for roadway lighting refer to illumination levels, so FCO and ShCO shielding can and should be used. Similarly, roadway requirements permit amber-coloured light, so white light should not be used. As a minimum, the Manager should form an agreement with the government so that they are asked to advise on the type of luminaires that are selected.

Table 4.3 Roadway Illumination Guidelines (Maximum Values)

4.3 Roadways	Type	Light	Level (lux)	Height	Curfew
4.3.1 Class 1-3 roadways	None	N/A	N/A	N/A	N/A
4.3.2 Class 1-3 roads & intersections	SCO Marker	LPS, HPS or Amber CFL or LED, Filtered	~3	6 m	No
4.3.3 Class 4-6 Roads & intersections	Signage only	N/A	N/A	N/A	N/A

N/A – not applicable

4.3.1 Class 1 to Class 3

Class 1 to Class 3 roadways are subject to high traffic volumes (Class 1) to medium traffic volumes (Class 3). Due to the high traffic speeds and volumes, marker lighting may be required to alert drives well in advance of an intersection.

To ensure they are visible to approaching traffic, these marker lights may be semi cut-off (SCO) luminaires with a Type II distribution pattern (illumination along the major road). They should be oriented to minimize illumination beyond the side of the road. Additional shields may be used to prevent light from shining out of the right-of-way.

Retro-reflective signage should be used for all other intersections between the Class 1 to 3 roadways and lesser roadways. Illuminated signage should not be permitted (see Section 4.8).

4.3.2 Class 4 to Class 6

Class 4 to Class 6 roadways have low traffic volumes with class 6 roads seeing occasional and local traffic. They may provide access to large areas of the Preserve and see infrequent use of after hours. These roads and intersections should use retro reflective signage to minimize the ecological impact.

4.4 Pathways

Only those paths the Manager considers appropriate should be illuminated.

Pathways and sidewalks provide a relatively level surface for pedestrian traffic, and aid in site navigation. Visibility is necessary for navigation but excessive illumination will prevent pedestrians from seeing off the path for situation awareness. Although visitors might use flashlights, additional pathway lighting may be required to guide visitors to public events and facilities.

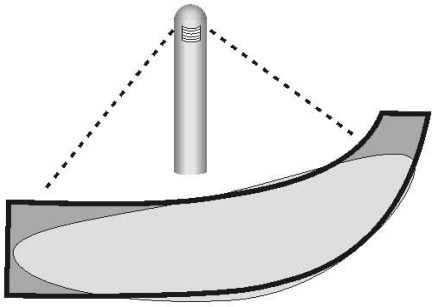
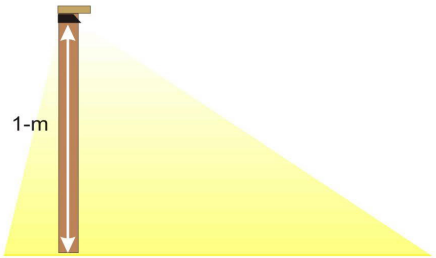
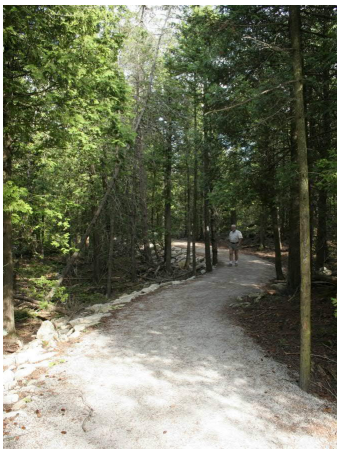


Figure 4.4.1 Bollard Luminaire

Paths are also used by wildlife. Therefore, pathway lighting should be restricted to only those paths near buildings, parking lots and campgrounds.



Since overhead FCO and ShCO luminaires will illuminate areas much wider than the path, low wattage bollard lighting, or railing mounted lighting, should be used such that the light is directed down and along the path. Fixtures should be shielded or lensed such that the illumination is approximately limited to the path width.



Pathways should use white or light coloured crushed stone (limestone) to help reflect ambient light. Asphalt has a very dark surface that requires 5X more light than more natural surface treatments.

Generally, individuals walking along a pathway will have left the area after a minute or so (a distance of 30 metres) unless they remain for an activity. To minimize unnecessary light exposure, motion detectors should be used to turn on the string of lights and timing circuits to turn them off after a few minutes. Detectors may be installed at the entrances to pathways or at the limits to the lit portion of the path.

Passive fluorescent markers may be used to mark the extent and direction of the pathway when the lights are off. These may be mounted on bollards or in the pathway surface.

The closeness of the luminaires to the ground necessitates very low intensity lights. This limits the current available products to low wattage incandescent bulbs and amber, or filtered LEDs. Low-brightness CFL Lamps are too bright for this purpose.

1. Whenever possible, pathways in the Preserve should not be illuminated. If deemed necessary by the Manager, specific pathways may be illuminated, or lined with white or yellow paint, or have fluorescent markers.
2. Illuminated pathways should have FCO or ShCO shielded fixtures, mounted on low-height poles, railings or bollards to restrict the extent of the illuminaiton.
3. Pathway lighting should be turned off during the Dark Time lighting curfew. Retro-reflective markers or florescent markers on the bollards/railing may be used to assist pedestrians after Dark Time.
4. Main pathways leading to all-night facilities may be illuminated throughout the night at the discretion of the Manager but shall be limited to Table 4.4.

Table 4.4 Pathway Illumination Guidelines (Maximum Values)

4.4 Pathways	Type	Light	Level (lux)	Height	Curfew
4.4.1 Pathways	None	None	N/A	N/A	N/A
4.4.2 Illuminated Paths	FCO ShCO	Amber Incandescent or LED, Filtered	~1 lux	1 m	Yes
4.4.3 Main Pathways	FCO ShCO	Amber Incandescent or LED, Filtered	~1 lux	1 m	No

N/A – not applicable

4.5 Shorelines

This section provides guidance to managers for reducing the impact of lighting along a waterway. Shorelines facilities consist of docks, jetties, lock facilities, boat launching areas, beaches, homes, cottages and undeveloped lands. Direct illumination of the shallow water near shore alters the behaviour of aquatic species and the foraging patterns of land species and insects.

These guidelines are relatively general due to the limited authority of managers over some of these properties.

1. Park personnel should inform the owners and users of shoreline property of the impact artificial light has on the ecology of the water and adjacent lands.
2. Property owners should be advised to shield all outdoor lighting to comply with FCO or ShCO requirements and to turn off this lighting when they go to bed.
3. Shoreline lighting should consist of amber or red light. Blue and white lights are not permitted.

4. Light fixtures should be prohibited within ten metres of a shoreline unless the Manager deems them necessary. Overhead luminaires that shine into the water are not permitted.
5. High traffic areas and areas near machinery (lock facilities) may require higher levels of illumination at the discretion of the Manager.
6. There shall be curfews when there are no boat arrivals or departures, or when the machinery is not being used and turned off.

Table 4.5 Shoreline Illumination Guidelines (Maximum Values)					
4.5 Waterways	Type	Light	Level (lux)	Height	Curfew
4.5.1 General Areas	N/A	None	N/A	N/A	N/A
4.5.2 Dock Bollards	FCO ShCO	Amber Incandescent or LED, Filtered	~1 lux	1m	Limited
4.5.3 Lock Facilities	FCO ShCO	Amber Incandescent or LED, Filtered	~3 lux	6 m	Limited

N/A – not applicable

4.6 Colour or Spectrum of Illumination

All outdoor illumination shall be amber. Illumination described as "warm", "warm white", or Dark Sky Friendly are not necessarily compliant. If 3000K LEDs must be used, no more than 1% of the total emitted light shall be emitted in the "glare zone" between 90-80 degrees from nadir (ShCO requirements). And, the illumination level must be less than 40% the levels specified in this chapter. (This accounts for the difference between photopic lumens and scotopic lumens.) This will help preserve night vision and limit the extent of the ecological impact.

4.7 Luminance Limits

The previous tables refer to the illumination levels – how much light falls on the surface. Too much light shining on a surface can reflect enough light to create glare. The specification in the previous tables will minimize surface glare while providing enough illumination to see the ground. But the brightness of the light source if not shielded, or when used as a “Marker Light” will also create glare, and should be limited.

We can approximate the limiting light that will be noticed as a marker light in a range of ambient light levels. As discussed in section 3.10, we specify 0.1 cd/m^2 to 1 cd/m^2 as a reasonable range based on natural light sources. A light of 0.1 cd/m^2 that is produced by a 0.01W LED will be easily seen from 10’s of meter away. Table 4.7 lists more powerful LEDs will attract or demand attention.

Table 4.7.1 Luminance of Marker Lights (Amber LEDs)	
Mark a Location	6-10 Lumens (0.1W)
Attract Attention	60-100 Lumens (1W)
Demand Attention (affects night vision)	600-1000 Lumens (10W)

Wall mounted luminaires may have enough backlight t o illuminate the mounting surface. This surface can act as a broad marker light that is “easier on the eyes” than a point source. Table 4.7.2 provides approximate brightness and approximate powers of LEDs that will provide reasonable surface illumination to mark a location. These values assume a surface with a light coloured paint. A dark colour (brown) may allow more illumination for the same prominence.

Table 4.7.2 Luminance of Marker “Surface” (Amber LEDs)	
Mark a Location	5-10 Lumens (0.1W)
Attract Attention	10-20 Lumens (0.2W)
Demand Attention (affects night vision)	20-50 Lumens (0.5W)

These power levels for amber LEDs are suitable for small off-grid solar systems precluding the need to install high voltage power lines.

4.8 Scheduling Illumination

Way-finding requires very little light (0.1-1 lux), but unshielded fixtures undermine this because the glare prevents the visibility of trees and other landmarks. Some Preserves have a defined a Dark Time during which all unnecessary lighting should be turned off.

Dark Time typically begins 2-hours after sunset. The Manager may identify safety-critical lighting that should remain on but in a significantly dimmed level.

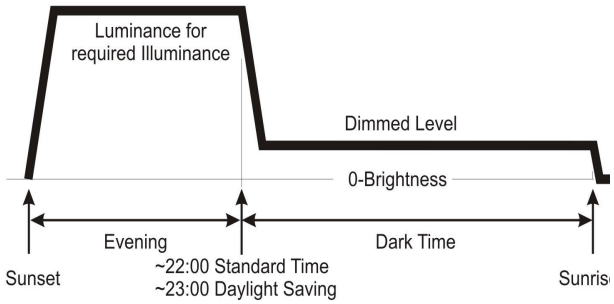


Figure 4.8 *Illumination Schedule. Light may be used during peak activity during twilight and early evening. At the beginning of dark time the outdoor artificial light should be turned off or significantly dimmed (Ref ecolights.ca).*

It is assumed that visitors use flashlights that can be used when necessary during Dark Time.

4.9 Signage

Signs within a Preserve are essential for the efficient navigation of the site. They may display three forms of information: names for sites or buildings (usually mounted in proximity to buildings or other structures), directions (located along roadways or pathways and their intersections) and those meant to convey other information (also located to the side of roadways and pathways). To provide the visibility of signs after dark, their location, colour scheme, and material should permit reading the sign with flashlights or existing compliant pathway or roadway lighting.

When deemed necessary by the Manager, signs may be illuminated to the levels in Table 4.6. Otherwise, illuminated signs shall be prohibited in a Preserve. These include, but are not limited to, back illuminated signs, electronic billboards, signs illuminated from below and above the sign, and in front of the sign.

Table 4.9 Signage Illumination Guidelines (Maximum Values)

4.6 Signage	Type	Light	Level (lux)	Height	Curfew
4.6.1 Building	Reflective, Light colour	Amber LED*, Filtered	~3 lux	1-2 m	Yes
4.6.2 Navigation	Reflective, Light colour	Amber LED*, Filtered	~3 lux	<1 m	N/A
4.6.3 Information	Retro-reflective Light colour	Amber LED*, Filtered	~3 lux	1-2 m	Yes

* Lowest wattage for about 3 lumen/ m^2 (0.3 lumen/ft^2) N/A – not applicable

Pathway and information signs should be located less than one metre above the grade of the path so they may be found and read by pedestrians with flashlights after dark. All bollards and railings should be marked with bright coloured or retro-reflective material so they may be visible to pedestrians after Dark Time. Roadway signs should be mounted in accordance with standard roadway practice.

4.10 Tower Navigation Avoidance Beacons

Some towers for communication (cell phones). Tall structures and wind turbine power generation. Towers that may have heights of hundreds of metres are being erected in otherwise unspoiled areas. Communication towers erected on or near Preserve should not be fitted with night navigation beacons unless strictly required by Transport Canada regulations (CARS 621.19. Managers should be aware of the options available for tower navigation beacons that are regulated by Transport Canada[39] and Industry Canada. The brightness of night navigation beacons should be the minimum required by Transport Canada regulations (CARS 621.19). And, all towers requiring night navigation beacons should use red flashing lights so as not to interfere with the navigation of birds.

There are several types of navigation avoidance beacons that may be used on towers (see Appendix E). A low impact example is a beacon with a collimated rotating beam (Appendix E CL864). In principal, its luminous intensity can be lower than other types of beacons and would emit less total light into the air, resulting in less scattered light into the environment yet it maintains its critical visibility to pilots. Birds are not attracted to red light as much as white light and they appear to be less able to orient themselves to the flashing beacons compared to non-flashing types[40].

Tower and wind turbine lighting may not be required unless the tower exceeds 90 meters unless specifically identified by Transport Canada as a hazard to aviation. For wind farms

[39] Canadian Aviation Regulations (CARS) 621.19
[40] Gehring,J. Aviation Collision Study for the Michigan Public Safety Communications System (MPSCS): Summary of Spring 2005 Field Season, Central Michigan University, August 12, 2005

with several towers, those on the edge of the array and the centre must be illuminated[41].

Managers may not have authority over the illumination of these towers so this subsection is as a guide when discussing tower illumination with tower owners and Transport Canada. Where tower lighting contributes undue glare or illumination within the Preserve, Transport Canada may consider collimated beacons or down-shields.

4.11 "Developed" Properties

These properties include, but are limited to, private-owned and rental properties and towns within the Preserve's boundaries.

Owners of private properties within the Preserve should be informed of the impact of artificial lighting on wildlife. They should be encouraged to remove "dusk to dawn" lights, replace "yard lights" with FCO or ShCO luminaires. And they should replace white LED, MH bulbs with either HPS, Low Pressure Sodium (LPS) fixtures or amber LED or filtered fixtures. They should be encouraged to turn off all exterior lighting when they are indoors.

All municipal lighting should be FCO or ShCO and illumination levels should be no greater than the "minimum" recommended by IESNA Guidelines (RP-08). White light luminaires are not permitted, however 3000K LED luminaires may be approved by the Preserve approval agency if they comply with Section 4.6.

The outdoor lighting on built facilities under the control of the Manager should use FCO or ShCO fixtures. Area lighting fixtures, such as "yard lights" and "dusk to dawn" fixtures or similar luminaires, are not permitted. White LED, Metal Halide (MH) or mercury vapour lamps are not permitted. These products produce excessive glare and light trespass and emit short wavelength light that affects wildlife and our night vision.

Use of outdoor lighting on all built facilities within Preserve should be discouraged during the Dark Time, and should be turned off when people are indoors. The Preserve-approval agency may approve some lighting on a case-by-case basis but this must be specifically requested in the Preserve application.

Table 4.8 Other Properties Illumination Guidelines (Maximum Values*)

4.8 Other Properties	Type	Light*	Level (lux)	Height	Curfew
4.8.1 Door Lights	FCO	Amber Incandescent, CFL or LED, Filtered	<3	1.5 m	Yes
4.8.2 Yard Lights	FCO	LPS, HPS, Amber CFL or LED, Filtered	<3	6 m	Yes
4.8.3 Municipal Lights	FCO	LPS, HPS, Amber CFL or LED, Filtered	IESNA minimums	TBD	No

* Wattage of lamps should be based on illumination limits.

[41] Wind Turbine and Windfarm Lighting, CAR621.19 Advisory Circular 1/06 - DRAFT 9, Transport Canada

4.12 LPA Beyond Preserve Boundaries

As with air and water pollution, light pollution respects no boundaries. Light pollution is best reduced at the source by decreasing the light emitted. Some cities are actively promoting the replacement of luminaires that contribute to sky glow but these policies are not wide spread. Preserves may influence the producers of air and water pollution and this influence should be extended to include light pollution.

- Managers should introduce and encourage programs of light pollution abatement in neighbouring municipalities around the Preserve with the goal of reducing glare across the Preserve boundaries and sky glow visible from within the Preserve.
- Managers should approach individuals whose lights shine into the Preserve. The goal is to have those lights shielded, reduced in brightness or removed.

4.13 Historic Sites

These guidelines give priority to wildlife in the Preserve; but historic sites may be located within urban areas where light pollution is generally so bad that lighting to the above standards will have no significant improvement. However the philosophy of not over-lighting the area is prudent for better visibility, which leads directly to safety, aesthetics, and it will reduce operating costs.

Outdoor lighting at historic sites should use FCO or ShCO fixtures and should illuminate the faculties to the minimum levels of standards and guidelines in the surrounding area. If “Period Lighting Fixtures” are used on the site, then the FCO or ShCO varieties should be used where possible. Historic lighting rarely included "white light, so amber light should be used because perceptually it is also more historically accurate.

4.14 Wilderness Areas

Wilderness areas are all “undeveloped” properties in their natural state. No artificial lights shall be installed in wilderness areas.

The use of personal red or amber flashlights may be used but high power flashlights (> 300 lumens) should not be allowed. As with permanent lighting, amber and red light flashlights will reduce glare and help maintain dark adaptation. The use of white flashlights should be discouraged or used sparingly. Installation and extended use of portable outdoor lighting is strictly prohibited.

5.0 LIMITATIONS

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6.2 Web Sites

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APPENDIX A – Luminance and Illuminance Levels

Luminance Condition	Lumination * (cd/m^2)
Clear dark night sky (no Moon)	0.000 4†
Clear Urban Sky with Light Pollution	~0.007†
Twilight (clear sky)	~0.25†
Overcast Urban Sky with Light Pollution	~0.25†
Full Moon	4,500 (maximum)
Venus (typical)	~1 †††
Urban Road Surface Artificial Illumination	0.3 ††††
Sirius	0.12†††
Streetlight	~ 1×10^6
Traffic Light	~ 2×10^6
Full Sunlight	1.6×10^9

† Reference http://unihedron.com/projects/darksky/magconv.php
†† https://en.wikipedia.org/wiki/Orders_of_magnitude_(luminance)
††† from RASC Observers Handbook by scaling from Sun (2021)
†††† IESNA RP-08

Illuminance Condition	Illumination * (lux)**
Clear night sky (no Moon)	0.000 05
Clear Urban Sky with Light Pollution	0.015
Twilight	0.1
Overcast Urban Sky with Light Pollution	0.15
Full Moon	0.26 max. (0.1 typical)
Urban Road Artificial Illumination	3-4***
Open Urban Parking Lot	11-22
Car Dealership Lot	200
Full Sunlight	130,000

* Clarity of the atmosphere is highly variable over hours and days. These values are presented to provide only a rough guide to approximate illumination levels.

** "lux" is a Système internationale (SI) unit of illumination equal to 1 lumen/m^2 = 0.093 foot-candles (fc)

*** IESNA RP-8-00

To place these levels in context, people have reported seeing "fine" at full Moon illumination levels in the absence of glare[42] and most people can read at 1-3 lux.

[42] Preliminary Recommendations: Outdoor Lighting at Highlands Center, Cape Cod National Seashore, Chad Moore, March 25, 2006

APPENDIX B - Colour of Various Light Sources

This table lists six lamps that convey “colour” from bright white to deep yellow and amber. LEDs can be designed to provide a range of different colours so they have two entries.

White Light LEDs	Available in a range of CCT with 10% to >50% blue light. Blue light components impact the biology and behaviour of wildlife and plants. Undermines night vision. Should not be used in a PRESERVE due to ecological impact and vision degradation. White light gives very good colour recognition.
MH – Metal Halide	HID lamp that must be warmed up before it can reach full brightness. MH has high blue spectral content, produces a significant amount of UV and therefore its use should be avoided in all Preserves.
Incandescent bulbs	These emit a warm white light (~2700K CCT) and have very low energy efficiency. They can be turned off and on very quickly so they can be used for motion detection systems. Should be considered only if amber LED or amber CFL lamps are not available with low enough brightness.
HPS - High Pressure Sodium	These are bright yellow and allow fair colour recognition. A HPS bulb has a small light-emitting region for very good control over where the light is focused. As a HID source, they require a few minutes to heat up before they reach their design brightness.
Amber CF – Compact Fluorescent Lamps	These produce filtered light and are commercially sold as bug and party lights. They may be identified as yellow and orange but their colour and quality vary greatly. Choose darker yellow and orange whenever possible to avoid flying insect attraction. They typically do not perform as well in cold temperatures and may take several minutes to warm up in sub-zero temperatures.
LPS - Low Pressure Sodium	Deep yellow light is virtually a single colour offering very poor colour recognition. It is the most energy efficient of the above lamps. They are so efficient that even low wattages may produce too much light for use in Preserves. The light-emitting region in the lamp is quite large compared to other HID lamps.
Amber and Red Light Emitting Diodes	Amber and red LEDs have low impact on the environment. They can produce very focused illumination, which is very desirable for Preserve applications. For Preserve purposes, “Amber” is defined as light in the wavelength of 500 – 700 nm and “Red” is 600 - 660nm and corresponds to AMBER = WHITE-BLUE. Most people can see "better" with amber than red LEDs.

APPENDIX C - Light Output from Typical Bulbs

Bulb Types	Lumens	Lux at 6 m	Lux at 2 m	Lux at 1 m
Incandescent*				
7 watt	60	0.13	1.2	4.8
15 watt	128	0.28	2.6	10.2
40 watt	342	0.8	6.8	27.2
60 watt	513	1.1	10.2	40.8
100 watt	855	1.9	17.0	68.0
Metal Halide (MH)				
70 watt	3,000	6.6	59.7	238.7
100 watt	5,800	12.8	115.4	461.6
High Pressure Sodium (HPS)				
35 watts	2025	4.5	40.3	161.1
50 watts	3600	8.0	71.6	286.5
70 watts	5450	12.1	108.4	433.7
100 watts	8550	18.9	170.1	680.4
Low Pressure Sodium (LPS)				
18 watts	1570	3.5	31.2	124.9
35 watts	4000	8.8	79.6	318.3
55 watts	6655	14.7	132.4	529.6
Compact Florescent (CF)				
9 watt (40 w equivalent)	550	1.2	10.9	43.8
13 watt (60 w equivalent)	850	1.9	17.9	71.6
LED**				
1 watt (amber) ***	75	2.	19	75
3 watt amber A19	90	0.5	4.0	12
3 watt amber PAR16	90	1.8	16	50
7 watt amber PAR30	200	5.5	50	200
13 watt amber PAR38	400	11	100	400

Note:
Fixture and bulb degradation before cleaning or replacement may decrease these to as low as 50%.
Fire has an approximate efficacy of 0.5 lumens/watt
* The luminous efficiency of incandescent light is approximated as 1/10 that of HPS for photopic vision
** Supplied by IDA
*** Assumes a 1 steradian illumination angle and no external optics, typical for many inexpensive lights
Lumens is the total amount of light emitted in all directions (over 4π steradians)
Lux is the amount of light illuminating a surface of one metre square

$1 \text{ lux} = 1 \text{ Lumen} / (4\pi \text{ dist}^2)$ where distance is in metres

References:

IDA Information Sheet 4, Operating Data and Economics of Different Lamps, (08/96)
CAN/CSA-C653-94 (2000) - Performance Standard for Roadway Lighting Luminaires
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APPENDIX D - Approximate Times of Sunset

The time of sunset depends on the time of year and the latitude for a site and altitude (very minor). The following table lists the approximate time of sunset (Daylight Saving Time) for latitudes of about +50° and +40° and 100-meter altitude from May to the end of October. Times are for approximately the centre of the time zones.

Southern Canada +50° Latitude		Middle USA +40° Latitude	
May	1 20:19	May	1 19:55
	8 20:30		8 20:02
	15 20:40		15 20:09
	22 20:49		22 20:15
	29 20:58		29 20:21
June	1 21:01	June	1 20:23
	8 21:07		8 20:27
	15 21:11		15 20:31
	22 21:13		22 20:33
	29 21:13		29 20:33
July	1 21:12	July	1 20:33
	8 21:09		8 20:31
	15 21:03		15 20:28
	22 20:56		22 20:23
	29 20:46		29 20:16
August	1 20:42	August	1 20:13
	8 20:30		8 20:05
	15 20:18		15 19:56
	22 20:04		22 19:46
	29 19:50		29 19:36
September	1 19:43	September	1 19:31
	8 19:28		8 19:20
	15 19:13		15 19:08
	22 18:57		22 18:57
	29 18:42		29 18:45
October	1 18:38	October	1 18:42
	8 18:23		8 18:31
	15 18:08		15 18:20
	22 17:54		22 18:10
	29 17:41		29 18:01

From the MICA Version 2.2.2

APPENDIX E - Navigation Beacon Photometrics[43]

			Minimum Intensity (candelas) **(a)**				Intensity (candelas) at given elevation angles when the light is levelled **(c)**				
Light Type	Colour	Signal type	day	twilight	night	Vert. beam spread **(b)**	- 10deg **(d)**	- 1deg **(e)**	± 0deg **(e)**	+ 2.5deg	+12.5deg
CL810	red	fixed	N/A	32min	32min	10deg	-----	-----	-----	32 min	32 min
CL864	red	flashing 20-40fpm	N/A	N/A	2,000 ±25%	3 deg min	-----	50% min 75% max	100% min	-----	-----
CL865 **(f)**	white **(f)**	flashing 40fpm	20,000 ±25%	20,000 ±25%	2,000 ±25%	3 deg min	3% max	50% min 75% max	100% min	-----	-----
CL866	white	flashing 60fpm	20,000 ±25%	20,000 ±25%	2,000 ±25%	3 deg min	3% max	50% min 75% max	100% min	-----	-----
CL885 Catenary	red	flashing 60fpm	N/A	N/A	2,000 ±25%	3 deg min	-----	50% min 75% max	100% min	-----	-----
CL856	white	flashing 40fpm	270,000 ±25%	20,000 ±25%	2,000 ±25%	3 deg min	3% max	50% min 75% max	100% min	-----	-----
CL857 Catenary	white	flashing 60fpm	140,000 ±25%	20,000 ±25%	2,000 ±25%	3 deg min	3% max	50% min 75% max	100% min	-----	-----

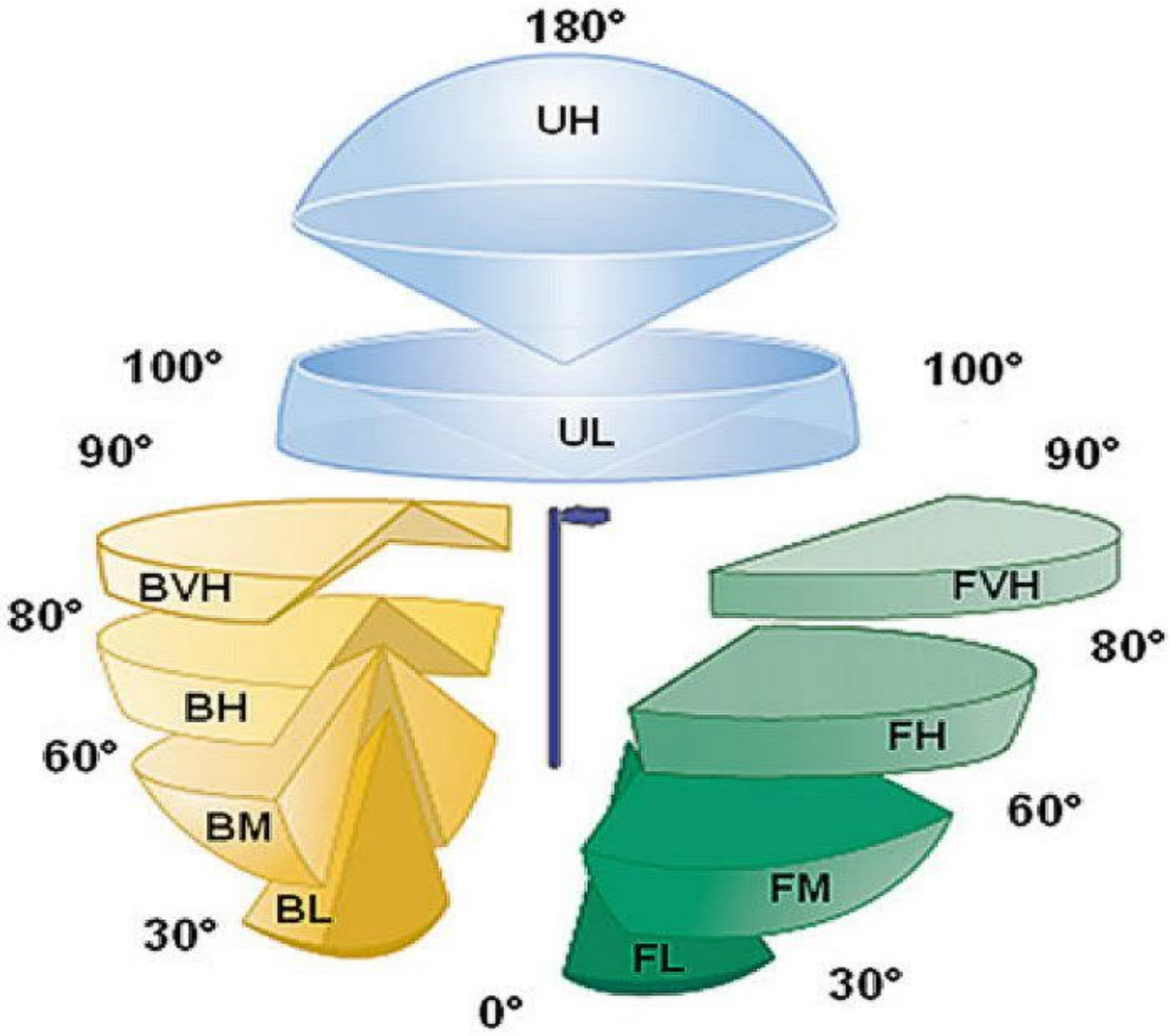
(a) Effective intensity, as determined in accordance with External Transport Canada Document
(b) Beam spread is defined as the angle between two directions in a plane for which the intensity is equal to 50% of the lower tolerance value of the intensity shown in columns 4, 5 and 6. The beam pattern is not necessarily symmetrical about the elevation angle at which the peak intensity occurs.
(c) Elevation (vertical) angles are referenced to the horizontal.
(d) Intensity at any specified horizontal radial as a percentage of the actual peak intensity at the same radial when operated at each of the intensities shown in columns 4, 5 and 6.
(e) Intensity at any specified horizontal radial as a percentage of the lower tolerance value of the intensity shown in columns 4, 5 and 6.
(f) In the case of rotating type CL865 one third of the flash display should be red in colour. e.g. WWR

[43]Wind Turbine and Windfarm Lighting, CAR621.19 Advisory Circular 1/06 - DRAFT 9, Transport Canada

APPENDIX F - IESNA BUG Designation System

The IESNA BUG System has been developed to more specifically define the illumination from a luminaire. Ten zones have been defined that affect the shielding and glare from a light fixture.

The Addendum A for IESNA TM-15-07 provides examples of this system for a given luminaire. The diagram below (IDA Specifier Bulletin for Dark Sky Applications, Vol. 2(1), 2009) visually defines the different zones.



FCO luminaire preclude any up light (UH and UL = 0% of total emitted light). To minimize glare and light trespass that increases the impact area of the illumination should have BVH and FVH as close to 0% as possible. FCO fixtures allow 10% of the total light to be emitted in the zone from 80° to 90° of nadir (Glare Zone). However the preferred Sharp Cut-off designation only permits 1% in the Glare Zone, which can be achieved with FCO using and additive shield.

APPENDIX G - Summary of Recommended Lighting

This summary applies to all property and structures within the Preserve.

1. No additional light fixtures should be installed.

If additional light fixtures are considered necessary by the Park Manager, and with approval by the Preserve-approving agency, additional fixtures may be installed. All new fixtures should conform to the requirements of Items 3-8 below.

2. Signage should not use active lighting.

Signage should use retro reflective materials. Pedestrian signs should be mounted at a height suitable for illumination with flashlights (<1 metre from the ground).

3. Only full cut-off (FCO) and Sharp cut-off (ShCO) fixtures should be used.

All existing light fixtures should be replaced with FCO or ShCO fixtures or shielded to prevent light from shining above the horizon or beyond the immediate area requiring illumination.

4. The illumination level produced by all light fixtures should be as low as practical.

Dusk and night pedestrian and vehicle traffic densities should be used in assessing the level of illumination within the limits of this Guideline. For vehicles, typically < 70-watt HPS at 6-m is sufficient (3 lux) for large parking lots and high traffic density areas where low speed limits are in effect. Major pedestrian routes may be illuminated by typically < 8-watt incandescent light or <1 watt amber LED (< 5 lux). With the use of vehicle headlights and pedestrian flashlights, lower power lamps can be used with the understanding that they are used only as marker lights. Phosphorescent markers may be used.

5. Structures and barriers should be used to confine illumination to the immediate area.

Illuminated areas should be bordered by trees and bushes, or other barriers, to prevent the light from shining and scattering beyond the area being illuminated.

6. All light sources should be turned off within 2-hours of sunset (Dark Time)

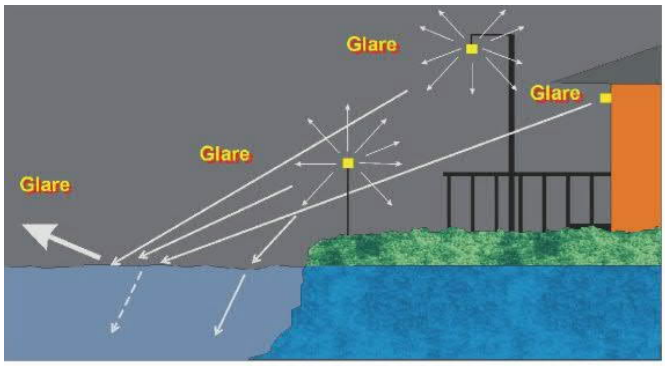
Automatic timers should be used to avoid the need for staff to turn off the lights. The timers should detect nightfall and should turn the lights off within 2-hours. If the Park Manager considers lights will occasionally be required after this time, the timer should be capable of being reset by staff.

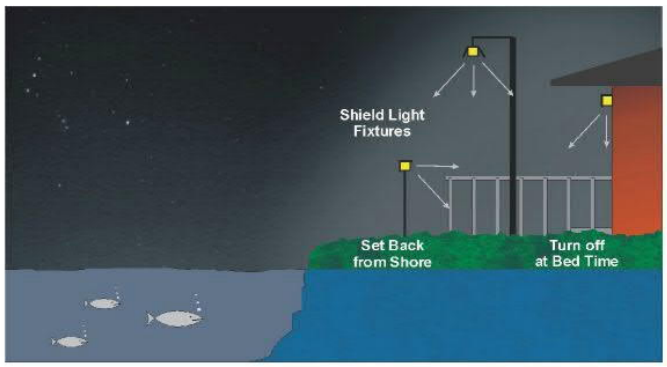
7. Indoor lighting should be prevented from shining through exterior windows.

If interior lights must be used after sunset, window curtains should be closed within 30-minutes of sunset or interior illumination levels must be reduced significantly so as not to produce glare or light trespass.

8. The colour of all light fixtures should emit <1% blue light in their spectrum.

“White” light sources such as metal halide lamps and white LEDs should not be used. High-pressure, and low-pressure sodium lamps, incandescent and CFL bulbs, and amber LEDs may be used as long as they are in FCO fixtures and they provide amber light at the required illumination levels.





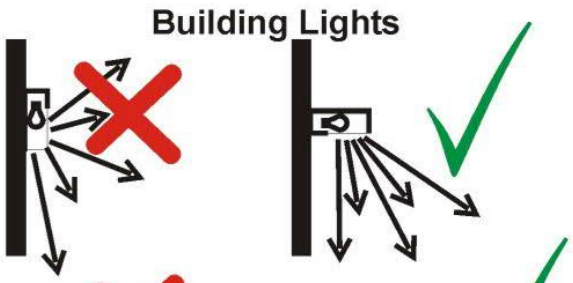
The Bad and the Good
Shoreline Lighting

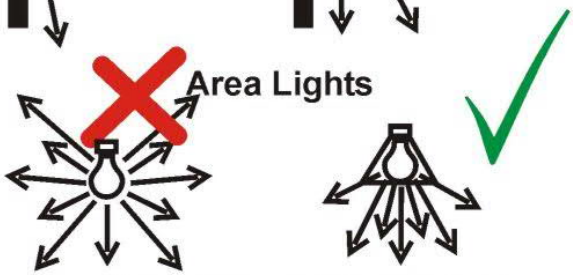
White Stone on Pathway
and Shielded Bollard

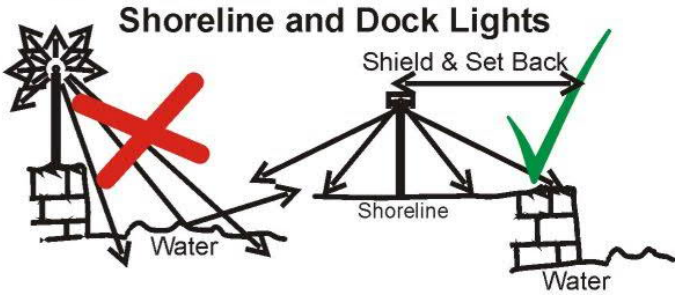
Use "Warm Light"
- not white light

Use Timers
- on at sunset
- off 2-hours later

Use Motion Sensors
- lights on only when needed







APPENDIX H - Critical Outdoor Lighting Attributes

Colour and Spectrum

Only amber light should be used. No white light should be permitted. The energy spectrum of amber light (>500 nm) shall contain less than 2% of the total emitted light as shown in Figure G.1

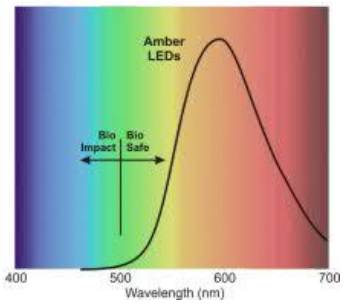
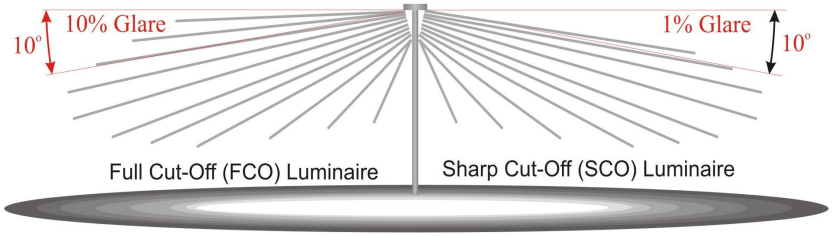


Figure G.1: *The spectrum of compliant amber light for* Preserves.

Shielding

All luminaires shall have Full Cut-Off or Sharp Cut-Off shielding or better. The industry definition of FCO shielding is for only 10% of the total light the luminaire shall be emitted within the zone between 80-degrees and 90-degrees from nadir. And, zero light shall be emitted above 90-degrees from nadir. ShCO shielding allows only 1% of the light in the glare zone. This is presented in figure G.2

Figure G.2
Definition of Full Cut-Off and Sharp Cut-Off shielding.



Brightness

The illumination levels (brightness) shall be limited to those tabulated in Chapter 4 and compiled in APPENDIX I. These lux values require selecting lamps with the correct wattage. We provide a guide to these wattages in the table of APPENDIX J.

It is obvious that these powers are considerably less than typical luminaires. There are two reasons for this.

1) The illumination in a Preserve is based on protecting the ecology, not maximizing visual impact.
2) Shielding to either FCO or ShCO and using non-white light preserves visitor night vision providing good visibility.

Tests performed with these levels provide good visibility for visitors in a park setting.

APPENDIX I - Summary of CGOL Illumination Tables

Table 4.1 Building Illumination Guidelines (Maximum Values)					
4.1 Area	Type	Light*	Level (lux)**	Height	Curfew
4.1.1 Admin. Bldgs.	FCO ShCO	Amber Incandescent, CFL or LED, Filtered	~3 lux	2.5 m	Yes
4.1.2 Public Bldgs.	FCO ShCO	Amber Incandescent, CFL or LED, Filtered	~3 lux	2.5 m	Yes
4.1.3 Retail Stores	FCO ShCO	Amber Incandescent, CFL or LED, Filtered	~3 lux	2.5 m	Yes
4.1.4 Vending Machine	FCO ShCO	Amber Incandescent, CFL or LED, Filtered	~3 lux	2.5 m	Yes
4.1.5 Toilet, Washroom, Shower Facilities	Marker (FCO)	Amber Incandescent, CFL or LED, Filtered	~3 lux	2 m	No

* Wattages for individual lamp types are not specified due to differences in efficacy.
Park Managers should consult Appendix C of the CGOL for guidance in meeting the recommended illumination level for all tables in Section 4.
**May be as high as 5 lux with Sharp Cut-off Shielding and 3:1 uniformity over area.
Note: 1 lux = limit for reading printed text in brochure
2 lux = illumination by clear sky about 20 minutes after sunset

Table 4.2 Parking Lot Illumination Guidelines (Maximum Values)					
4.2 Parking Area	Type	Light	Level (lux)	Height	Curfew
4.2.1 Administration Lot	FCO ShCO	LPS, HPS, Amber CFL or LED, Filtered	~3	6 m	Yes
4.2.2 Visitor Lot < 10 cars	N/A	None	N/A	N/A	N/A
4.2.3 Visitor Lot > 10 cars	FCO ShCO	LPS, HPS, Amber CFL or LED, Filtered	~3	6 m	Yes

N/A – not applicable

Table 4.3 Roadway Illumination Guidelines (Maximum Values)					
4.3 Roadways	Type	Light	Level (lux)	Height	Curfew
4.3.1 Class 1-3 roadways	None	N/A	N/A	N/A	N/A
4.3.2 Class 1-3 roads & intersections	SCO Marker	LPS, HPS, Amber CFL or LED, Filtered	~3	6 m	No
4.3.3 Class 4-6 Roads & intersections	Signage only	N/A	N/A	N/A	N/A

N/A – not applicable

Table 4.4 Pathway Illumination Guidelines (Maximum Values)					
4.4 Pathways	Type	Light	Level (lux)	Height	Curfew
4.4.1 Pathways	None	None	N/A	N/A	N/A
4.4.2 Illuminated Paths	FCO ShCO	Amber Incandescent, CFL or LED, Filtered	~1 lux	1 m	Yes
4.4.3 Main Pathways	FCO ShCO	Amber Incandescent, CFL or LED, Filtered	~1 lux	1 m	No

N/A – not applicable

Table 4.5 Shoreline Illumination Guidelines (Maximum Values*)					
4.5 Waterways	Type	Light	Level (lux)	Height	Curfew
4.5.1 General Areas	N/A	None	N/A	N/A	N/A
4.5.2 Dock Bollards	FCO ShCO	Amber Incandescent, CFL or LED, Filtered	~1 lux	1m	No
4.5.3 Lock Facilities	FCO ShCO	Amber Incandescent, CFL or LED, Filtered	~3 lux	6 m	Yes

* - lowest practical wattage N/A – not applicable

Table 4.6 Signage Illumination Guidelines (Maximum Values)					
4.6 Signage	Type	Light	Level (lux)	Height	Curfew
4.6.1 Building	Reflective, Light colour	Amber LED*, Filtered	~3 lux	1-2 m	Yes
4.6.2 Navigation	Reflective, Light colour	Amber LED*, Filtered	~3 lux	<1 m	N/A
4.6.3 Information	Retro-reflective Light colour	Amber LED*, Filtered	~3 lux	1-2 m	Yes

* Lowest wattage for about 3 lumen/ m^2 (0.3 lumen/ft^2) N/A – not applicable

Table 4.8 Other Properties Illumination Guidelines (Maximum Values*)					
4.8 Other Properties	Type	Light*	Level (lux)	Height	Curfew
4.8.1 Door Lights	FCO	Amber Incandescent, CFL or LED, Filtered	<3	1.5 m	Yes
4.8.2 Yard Lights	FCO	LPS, HPS, Amber CFL or LED, Filtered	<3	6 m	Yes
4.8.3 Municipal Lights	FCO	LPS, HPS, Amber CFL or LED, Filtered	IESNA minimums	TBD	No

* Wattage of lamps should be based on illumination limits.

APPENDIX J - Power and Lumens to Comply with CGOL

The following table provides a convenient guide for the selection of luminaires that will provide illumination that is compliant to this CGOL.

The power levels are based on five mounting heights that correspond to typical applications. The power levels are further given for the two levels of average illumination (1 lx and 3 lx), which also correspond to applications typical of Preserves. Other levels may be interpolated.

To use the table,
1) Identify the application (mounting height and illumination).
2) Select the corresponding column for application and the row for lamp type.
3) The lamp power is printed in the shaded part of the table.

Applications										
	1m height =	bollard or pathway light								
	2.5m height =	over-door light								
	3m height =	under-eve light								
	4m height =	over-head pathway light								
	6m height =	roadway and parking lot light								
Height	**1m**		**2.5m**		**3m**		**4m**		**6m**	
Lux (GOL)	**1**	**3**	**1**	**3**	**1**	**3**	**1**	**3**	**1**	**3**
LED (watts)	0.065	0.19	.40	1.22	.58	1.75	1.04	3.11	2.33	7.00
HPS (watts)	No lamps available. Do not use.									
CFL (watts)	No lamps available. Do not use.									8.7
Incandescent	0.65	1.9	4.0	12.2	5.8	17.5	10.4	31.1	23.3	70.0
Lumens (ave)	6.5	19	40	122	58	175	10.4	311	23.3	700
Notes:	Pick lamp wattage closest to that in the table									
	Lamp power based on average lux assuming 20% of light is "lost" in fixture									
	and includes 20% losses in power supplies (actual = 5%-30%)									
	Approx. coverage area = 1.5 x 3 mounting-heights = 4.5 x MH^2									
	Uniformity 3:1 => Max = 1.5 x ave. lux and Min = 0.5 x ave. lux									
Efficacies Used (lm/W)	LEDs - 100		HPS - 100		CFL - 80		Incandescent - 10			

These powers are only approximate and can be affected by the type of fixture, shielding, optics and degree of in-use degradation. However lamps using more than 2X these levels should not be used. Note that all lamps must only emit amber light.

"No lamps available" means these lamps are not available in low-enough wattages. Lumens are the amount of light emitted by the luminaire, not just the lamp.

APPENDIX K - Converting Non-Compliant Fixtures for CGOL

Converting existing light fixtures to comply with the CGOL may be done on a case-by-case basis. We will begin with an Edison screw socket. These take the standard consumer incandescent and compact fluorescent bulbs (E27 base).

The simplest way to convert from non-compliant to compliant lamps is to replace the white light incandescent, compact florescent and LED bulbs with amber bulbs - usually referred to as bug lights. The challenge with using off-the-shelf bug lights is that they tend to be too bright. Most applications in a Preserve require less than 50 lumens.

25W Incandescent	~200 lumens
13W CFL	~550 lumens
9W LED	~800 lumens

Therefore, they require careful shielding to reduce the impact of the glare. Since they have very low wattage, they generate relatively little heat. Only the incandescent bulb may be too hot to touch (~55C). (Smaller incandescent bulbs are available at 8W.) This simplifies the materials that may be used for shields.

This example is made from cardboard with a coat of outdoor paint to protect it against weather. The exterior colour may be selected for it to blend in with the surroundings, the interior colour may be white to maximize the illumination, or black to reduce the brightness of the ground. If metal is used, care must be taken to prevent touching the electrical contacts at the bottom of the bulb.

Larger lamps, such as florescent tubes, may be filtered. The photographic filter material by Roscolux (Deep Straw #15) will filter out the blue light of typical white lamps. A comparison of lamps with this filter can be viewed at: www.csbg.ca/BLOG.HTM#25. This amber coloured plastic foil can be purchased in sheets from www.bhphotovideo.com.

To assemble, line the interior of the U-shaped diffuser on a typical florescent tube fixture. To further reduce the glare and light trespass from the fixture, the interior sides of the diffusing plastic should be lined with light-blocking material (cardboard).

APPENDIX L - Luminance of Light Sources

Some applications require a light to mark a location. It is designed for the lamp to be seen. Therefore the shielding should allow the light to shine horizontally. An example of this is the aviation navigation beacon in CL864 in Appendix E.

The brightness of the light source is difficult to determine without in situ testing, however referring to typical light sources will give the user a better sense for luminance values.

Celestial Object	Luminance [cd/m^2]
Sun	1.6 x 10^9
Full Moon	4,500
Half Moon	1,000
Venus	1.0
Sirius	0.12
Polaris	0.005

For reference, the following table gives the typical luminance of a road surface. The "Local "road designation is used in these guidelines because of the very low vehicle traffic density in Preserves at night but with some persistent pedestrian traffic along the roads.

Road Surface and Use (Local)	Surface Luminance [cd/m^2]
High Pedestrian Conflict	0.6
Medium Pedestrian Conflict	0.5
Low Pedestrian Conflict	0.4

Note: From IESNA RP-08-2000 Table 3

Using the Small Target Visibility criteria, the Surface Luminance for High Pedestrian Conflict is 0.5 cd/m^2. The luminance of a “marker light” need not be greater than the appearance of the planet Venus unless there is considerable glare from surrounding lights.