Guidelines for Outdoor Lighting
for
Low-Impact Lighting

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Written by

Robert Dick

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1.0 SCOPE

This document presents Guidelines for Outdoor Lighting (GOL) in Dark-Sky Preserves (DSPs, and herein after referred to as Parks) and describes the types of equipment required to satisfy these guidelines. It refers to areas classified as “Lighting Zone 0, and Zone 1” (per IESNA-IDA Model Lighting Ordinance), LZ 0 encompasses areas that are sensitive to artificial lighting and other environmental disruptions. And, LZ 1 that have low ambient lighting levels such as small rural residential areas.

The goal of the DSP Program is to promote the reduction in light pollution, demonstrate good night-time lighting practices, improve the nocturnal environment of wildlife, protect and expand dark observing sites for astronomy, and provide accessible locations for the general public to experience the naturally dark night sky.

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

In Section 3.0 we present the rationale for a DSP and the protection of the urban nighttime environment from the excessive use of artificial lighting. To support these guidelines, this document provides references to useful web sites and to general research into the effects of nocturnal lighting on humans, human activity, flora and fauna.

The general guidelines for outdoor lighting within Dark-Sky Preserves are presented in Section 4. Lighting hardware and signage are described in Section 5 to assist Park managers in minimizing the impact of artificial lighting on the nighttime environment while maintaining a degree of safety for visitors.

A bibliography in Section 6 provides a set of references and useful websites. Supplementary technical information is provided in the appendices to this document.

2.0 GLOSSARY

2.1 Acronyms

ALAN Artificial light at night

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

DSP Dark-sky Preserve

FCO Full Cut-Off luminaires (0% up-light or fully shielded, 10% maximum in glare zone). This is minimum level of shielding. Better shielding (1% in glare zone is preferred a.k.a. "Sharp Cut-off)

GOL RASC Guidelines for Outdoor Lighting

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

IESNA Illumination Engineering Society of North America

LEDs Light Emitting Diodes
LPS Low Pressure Sodium lamps (monochromatic, single colour lamps)
LZ # Lighting Zone as per IESNA-IDA

MH Metal Halide lamps (“white” coloured lamps)

SAD Seasonal Affective Disorder
SCO Semi-Cut-off luminaires (<2% up-light)
ShCO Sharp Cut-off luminaires (<0% up-light, <2% 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.

DSP Buffer Zone - the region within the DSP under control of the park manager, or others within the DSP surrounding the Core area. The Buffer is designed to prevent glare and light trespass from shining into the Core area.

DSP Core - the region under control of the park manager within the DSP surrounded by the Buffer Zone.

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

Foot-candles (fc) - an Imperial unit measure of the amount of light that falls on a defined area[1]. Examples of levels are provided in Appendices A and C.

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

Lux – an illuminance metric unit for the amount of light that falls on a defined area[2]. Examples of levels are provided in Appendix A and C.

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

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

Photopic Vision – vision that uses the lower sensitivity photoreceptors (cones) that have evolved for daytime vision and high illumination levels

Scotobiology – the study of the effects of darkness on biological systems

Scotopic Vision - vision that uses the higher sensitivity photoreceptors (rods) that have evolved for nighttime vision and low illumination levels.

Sky Quality Meter – a light meter designed specifically to measure a value for the brightness of the night sky.

[1] www.physlink.com/Education/AskExperts/ae409.cfm
[2] www.physlink.com/Education/AskExperts/ae409.cfm

3.0 RATIONALE

Most people take artificial nighttime lighting for granted. In cities it is considered to be an acceptable component of our society, and indeed they think it is a necessity for safety and security. Specifications and guidelines for street and roadway lighting[3] address these urban assumptions. This has lead to lighting policies that encourage the illumination of all urban areas to allow the use of human photopic (daytime) vision. (Figure 3.0.1).

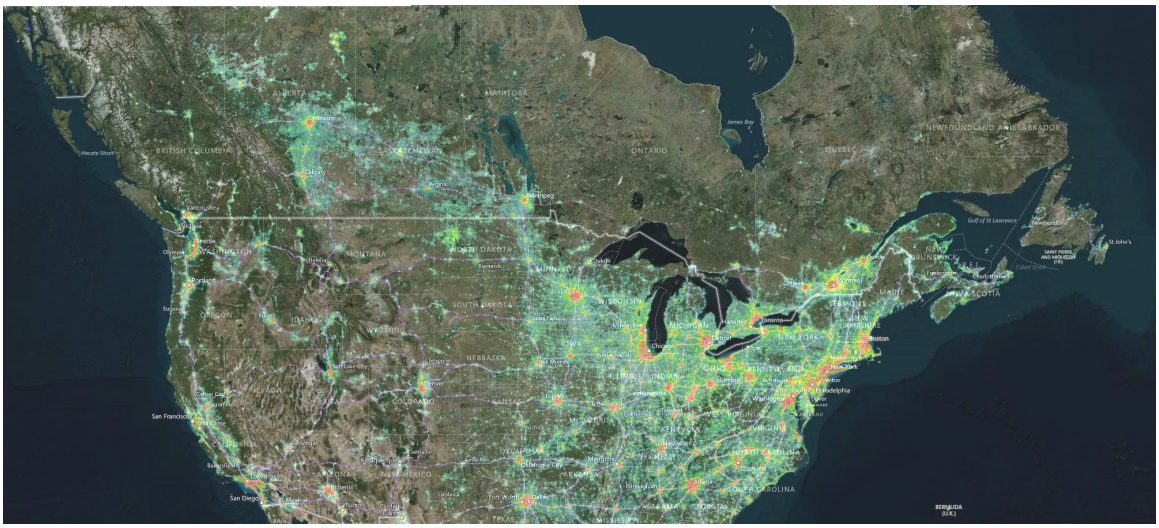
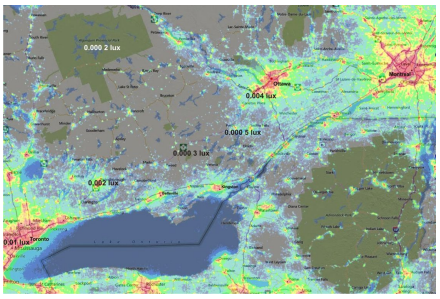


Figure 3.0.1 Mid Latitudes at Night[4]

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 have permitted illumination levels to increase over the last 50 years by a factor 10, with the use of the same amount of electrical energy. The result is that most commercial luminaires are designed for high levels of illumination. Low intensity fixtures are primarily limited to decorative lighting such as Christmas lights.

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 relatively good skies southwest of Ottawa on the Rideau Canal system leading to Kingston. Bright red corresponds to high levels of sky glow (0.010 lux) and green is an intermediate amount (0.000 4 lux). Algonquin Park appears black with very dark skies.



[3] Illumination Engineering Society of North American (IESNA) Handbook
[4] http://www.lightpollutionmap.info 2010

3.1 Crime

The most prevalent reason given for nighttime lighting 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 before and after studies of crime statistics, there is no clear evidence that outdoor lighting reduces crime[5]. Although there are anecdotal reports that "improved lighting" (i.e. improved visibility) 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. Theft is more prevalent during daytime hours, whereas violent crime occurs more often in the evening and after midnight.[9] Anecdotal studies report that most property crime occurs during the day and violent crime is usually between persons that know each other. The public's belief in the prevalence of random violence (promoted by Hollywood) is not supported by research.

There was an unconfirmed report that the brightly lit City of Manila found violent crime was still more prevalent after dark but increasing the presence of police was effective at reducing nighttime crime. The city lights were not the deterrent to crime whereas the visible presence of the police were. 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, 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 on display. The feeling of safety provided by the light may have the opposite effect by encouraging unsafe behaviour.

Vandalism is an example where security lighting has the opposite effect of what is generally accepted. 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. When lights are off, there is less gratification in vandalising an area or painting graffiti.

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[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/)

[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

3.2 Human Lighting Needs

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 activities. However our modern fast paced and mechanized activity requires better visual acuity for driving cars, riding bicycles and for avoiding 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, measured times and illuminated roadside distractions create actual reaction times of 1 to 3 seconds[14]. Illumination levels play a small part in reducing driver reactions.

Some level of artificial lighting is required for nighttime activities. But this lighting must be designed to increase visibility. Paradoxically, more light can reduce visibility, especially for persons over 40 years of age[15].

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 adults can be severely degraded by glare. With the aging of our population, it is becoming more important to reduce glare in the urban environment.

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. This hormone regulates the ebb and flow of other hormones in our bodies. These "repair the damage" we do to our bodies 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 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 can be reduced with exposure to bright light[19] in the morning as it shifts

[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 Univeristy, Victoria Australia, June 1982
[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] [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

(or entrains) and resets our biological clock. If this entrainment occurs during the late evening or at night due to artificial outdoor lighting, the biochemistry that controls our physiological well-being will also 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. The same biological clock is found in plants and animals wherein darkness plays a similar role[20]. Wildlife depends on the darkness of the night. The study of this dependence is called "scotobiology".

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 nighttime ecology to artificial lighting. This mounting scientific evidence is documenting the profound impact of artificial light on the ecology of the night.

Plants are affected by the colour and duration of lighting. Whether the effects are considered beneficial or not depends on the desired outcome. Generally, artificial lighting will change the natural growth patterns and may affect the resistance of plants to infestations and disease. Many plants respond to the length of the night and normally recognize it as an indication of the season. Extending light past the evening may slow the plant's biochemistry from changing to prepare for winter[21]. The various affects of colour, duration, type of plant, etc. makes sweeping conclusions impossible, however they indicate that changing the lighting environment will change the natural ecology of the area.

3.5 Animal Behaviour

Artificial sky glow extends well beyond the city boundaries. Therefore in considering urban outdoor lighting, we must also consider its impact on animal behaviour within rural areas in the region.

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 to light can shift (or entrain) their circadian rhythm and modify their behavioural patterns. Minimizing the duration of exposure to artificial light is necessary to limit its impact.

Seasonal variations will shift the time of sunset by over four hours (from roughly 16:30 in winter to 21:00 in summer). During the peak of Park activities in summer, the time of sunset can vary by two hours (see Appendix D). In addition to this, dusk can extend the

[20] "Lighting for the Human Circadian Clock", S. M. Pauley, Medical Hypotheses (2004) 63,588–596
[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

daylight by as much as an hour. Animals have presumably evolved to accommodate this variation.

Artificial lighting changes the nighttime behaviour of species[23]. Over a month, the changing phases of the Moon affect the ground illumination at night. Nocturnal mammals adapt their behaviour over the month in sympathy to moonlight to avoid predators. This behaviour includes, in part, limiting the foraging area and carrying food back to their shelters instead of eating it in the field. This latter adaptation limits how much they can eat[24]. In the natural environment they compensate during the dark time of the month.

Predator and prey behaviour depends on the darkness of the night[25]. Illumination levels that significantly affect wildlife are believed to be at the level of the full Moon, 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 this level (see Appendix A), and illumination by the sky glow from a nearby city can exceed these levels.

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[27]. They may also swarm the light fixture until they are exhausted. The resulting pile of insects must then be cleaned up. The blue light components of typical white light are the main light attractors for insects. Using white light in populated areas 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[28].

Animals separated from their normal foraging grounds by an illuminated road cannot see the area beyond the lights. 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 patterns for new ones, which will impact other species as they compete for resources[29].

[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
[25] ibid., Chapter 2
[26] ibid., Chapter 11
[27] ibid., Chapter 13
[28] 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
[29] Ecological Consequences of Artificial Night Lighting, C. Rich, T. Longcore, Island Press, 2006

3.6 Shorelines

Historically, waterways have been 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, bright lights along the shoreline make it very difficult to navigate the channel. Glare from unshielded shoreline lighting prevents our eyes from becoming adapted to the darkness. At night, a boater will only be able to see the points of light along the shore rendering the channel markers and out-of-channel hazards very difficult to see. Clearly, glare along the shoreline results in a safety hazard that should be corrected.

Illuminated shorelines also impact fish and aquatic plants[30]. Fish are attracted to the light from their natural feeding depths. The increase in the concentration of fish changes 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.

3.7 Cultural Impact

There is a cultural imperative to protect the darkness of the night sky. Throughout recorded history (about 6,000 years) astronomy has 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.

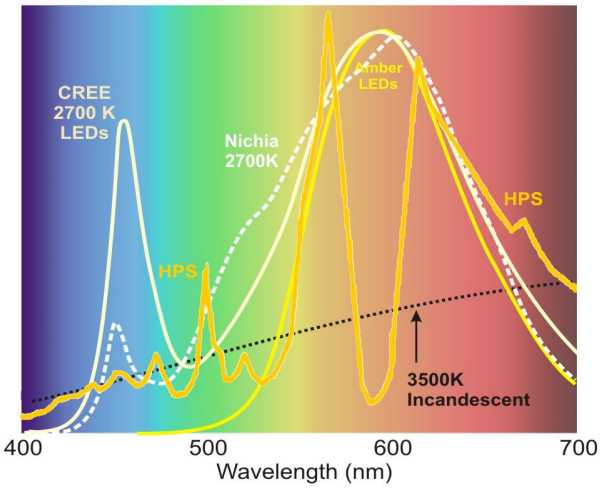
After stepping outside from a lighted room and under a dark rural sky, our initial count of a few stars with photopic vision increases a hundred fold after only 10 minutes. This may increase by another order of magnitude after less than an hour as our eyes become fully dark-adapted. However, urban sky 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 only a few hundred. 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.

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

3.8 Spectrum of Artificial Light at Night

As discussed in Section 4 and Appendix 3, only non-white light sources are permitted in Dark Sky Preserves. There are three reasons for the prohibition of white light that refer to the biology of animals and plants and human and animal vision.

Most lamps used in parks are based on incandescent bulbs, HPS bulbs and LEDs.



Incandescent bulbs emit a broad band "warm" light with a correlated colour temperature (CCT) of about 2700K. HPS lamps have a "spiky" 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 and amber. The white-light LED luminaires are available with "3000K" LEDs. However the amount of blue in these lamps can vary considerably between companies. The amber LEDs emit virtually no blue light, but due to the smooth variation of colour over the spectrum they provide 2X the colour rendering of HPS lamps.

White light is not permitted in Dark Sky Preserves because of its impact on wildlife, vision and its scattering properties. The blue spectral components affect the circadian rhythm of plants and animals, artificially altering their biology and providing subconscious lighting cues that may lead to inappropriate behaviours.

The blue spectral components attract insects to the light by approximately 50% over amber light. Apart from being a nuisance, insects can carry diseases that may be transmitted to park visitors.

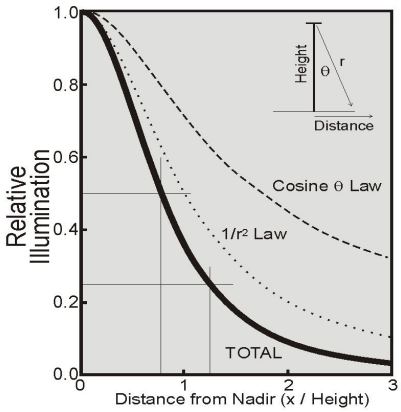
The blue light components increase the impact of glare - 10X that of amber light, and when the LEDs are exposed, they will "bleach" the rod cells in our retina and undermine our night vision. With a compromised night vision, we are less able to see into dim areas - reducing safety by limiting our awareness of the surroundings (creating hazards) and affecting our ability to navigate at night.

On a case-by-case basis the RASC may allow 3000K LEDs. However, they will require more aggressive shielding than full cut-off, and lower illumination to reduce the impact of the glare. No light shall shine at or above the horizon, and more than 1% of the total emitted light shall be emitted in the "glare zone" between 90-80 degrees from nadir. Also, the illumination level must be less than 1/4 the levels specified in Section 4 of this document to help preserve our night vision, and to limit the extent of the ecological impact.

3.9 Luminaire Shields

Shielding of the luminaire is critical for limiting the light's impact on the environment beyond the target areas and improving visibility. It reduces the impact of glare and limits the extent of the affected area.

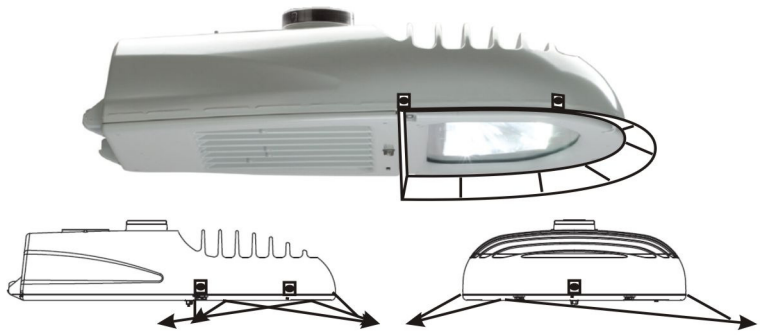
Although unshielded lights will illuminate a very large area, the illumination level more than 2 mounting heights from nadir is, quite literally, negligible - <1/10 that at nadir, due to the cosine law and the $1/r^2$ law. So without appropriately designed optics, to "throw light" from nadir into the periphery, the total useful spread of the light is only 1.5 X mounting height from nadir.



However the light that shines within 10° below the horizon can affect the aesthetic appearance of the night for more than a kilometre and can undermine our night vision more than 100 meters away. Full cut-off fixtures limit the amount of light in this glare zone to <10%. And, Sharp cut-off fixtures limit it to <1%.

Amber light (spectrum is >500 nm) provides low exposure to the action spectrum of our sensitive night vision and the cells that cause our iris to constrict in bright light. So amber light results in relatively low impact on our night vision. Wavelengths <500 nm (blue spectral components) cause about 10X the impact of glare. This is the reason that white light luminaires seem to be much more "glaring" than the older HPS in their flat-glass fixtures. Therefore the amount of blue light in the glare zone should be reduced to 1/10 that of amber light. The bright points of the LED emitters compared to the much larger HPS bulb exacerbate the effect of glare.

The blue spectral components also impact plant biology and the vision of wildlife so the affected area must be reduced as much as practical to minimize its ecological impact. Therefore, white light lamps require at least Sharp cut-off shielding for them to equal the effective of glare by amber light. Existing commercial luminaires (circ 2016) approach FCO but extra shields are required to convert them into Sharp cut-off.



This is a sketch of what a 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 should be designed to limit light trespass.

3.10 Scheduling of Light

Any use of artificial light at night (ALAN) will alter the ecosystem, so the amount of light that this emitted, the extent of the affected area and the spectrum of the light must be minimized and defined. A good reference and discussion of this impact is listed in the Reference Section 6.1 (R. Dick).

Since humans are the only creatures that want the light, its use must be moderated by its resulting impact. Many Parks have a defined Dark Time during which all unnecessary lighting should be turned off. However many installed lights remain turned on because there are no switches or timing circuits. Older lights were selected before our understanding of the impact of ALAN on the ecosystem and have particularly high impact.

There are four uses for outdoor lighting.

Navigation - It assists in wayfinding
Aesthetics - It is a visual cultural display
Safety - It renders hazards more visible
Security - Assists security personnel to protect persons and property

"Best practice" in urban areas with a full-time police force and security guards is for high-illumination levels for safety and security.

However in Dark Sky Preserves, the aesthetic is the natural night. And, the role of artificial light at night is to only identify hazards and wayfinding. There are usually no security personnel that make regular security sweeps of campgrounds or other areas throughout the night. To protect the night environment and satisfy the need for wayfinding requires the minimum amount of light necessary.

A significant cost to Park infrastructure is the laying of power lines and installation of luminaires. The supply of electricity and the maintenance of these lights are an on-going expense. However LEDs save considerable power over the much older incandescent lamps. Appendix C compares the light output from these light sources.

Where reduction in power usage costs is being considered as a reason for converting to LED lights, similar cost savings can be found by implementing periods were lights are turned completely off to save power, or motion sensed lighting implemented to use light only when use is triggered. In this way, considerable power can be saved even when using amber lighting, which is slightly less efficient than white-light LEDs.

Implementing a Dark Time policy for installed lighting, will more than compensate for the 1-5% energy cost of amber LEDs. And, the illumination will have little ecological impact and will preserve visibility for visitors.

Virtually all visitors to a park after dark use flashlights. So visitors have light when necessary during Dark Time. Convenient signage compliments the use of these personal lights (See Section 4.6).

3.11 Summary

There is growing evidence for the degradation of human health with the illumination of the night. The reduction in day-night contrast can uncouple the circadian rhythm from our normal daytime activities that may be causing an increase in chronic diseases.

It is clearly shown in published research, that artificial outdoor lighting affects ecology by disrupting food webs. Although the actual mechanism for this disruption is 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.

White light sources are not permitted because of their impact on the wildlife, human vision, and attraction for insects.

Education is the key to correcting this degradation of the nocturnal environment by artificial light at night. As the main source of light pollution, cities are key components in education and solving this problem. Establishing Dark-sky Preserves is an obvious way to help inform the public about the virtues of a dark night. And, by drawing their attention to the vitality of night animals in the Dark-sky Preserves they will begin to understand the importance of reducing artificial light at night.

Artificial lighting that is installed for human activity is altering the natural environment. This environmental degradation continues without resistance, and is indeed supported by human nighttime culture. Primarily due to ignorance, civic policies and the legal system are strongly biased in favour of human demands at the expense of the natural environment. New research is revealing how artificial lighting degrades both human health and the health of wildlife within and well outside our cities. Wildlife has no voice and cannot control their environment. We must act on their behalf. Cities must take action and advocate against change in their environment.

4.0 GUIDELINES FOR OUTDOOR LIGHTING

A Dark-sky Preserve (DSP) is defined as an area whose night sky has little or no sky glow and lighting within the DSP complies with this RASC-GOL. If there is significant sky glow due to close proximity to an urban area, it may be classified as an Urban Star Park. Park and Conservation area Managers interested in USP Designations are should refer to the documents: RASC-USP GUIDELINES and RASC-USP-GOL. A Nocturnal Preserve (NP) is a region set aside for biological conservation; there is no general requirement that there is nighttime public access for astronomy or eco-tourism, though both maybe part of the park's outreach.

There may be several operations and visitor facilities within a DSP. The illumination levels for these facilities are summarized in tables in this section for each area and application. The rationales for the limits are provided previously in Section 3.

Before determining what type of lighting should be installed or retrofitted, it is important to ask the basic question, "Is the lighting necessary?". If no valid reason for lighting can be found, the current lighting should be removed rather than replaced with better technology. Don't assume that the mere fact that lighting is currently installed means that there was or currently is a valid reason to light the area.

This section provides guidelines that should be followed to minimize light pollution within a Park. Adopting similar fixture hardware is recommended to minimize the inventory for repairs or replacement.

Where necessary for basic safety and navigation:

1. Illumination should be to the minimum practical level,
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. Illumination should minimize the amount of blue spectral components in the light (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 urban areas for which most luminaires have been designed. This restricts the type of light sources that may be used. Although High Intensity Discharge (HID) 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 more advanced yellow or amber light emitting diode (LED) luminaires may be installed.

These guidelines address the use of the facility and expected pedestrian and vehicle traffic. Priority is given to respecting and protecting the natural environment.

Park managers have the discretion to assess what levels are most appropriate for each park facility within the limits outlined in this Section. Lighting is limited to provide only what is required for navigation in built up areas. The artificial lighting is restricted to these areas and for the periods of human activity unless otherwise noted.

"Dark Time" is a term used in some parks to identify the end of significant activity within an area. This term is used herein to identify when the use of light should be discouraged. In this document, Dark Time is further assumed as initiating 2-hours after sunset. Appendix D contains a reference table with the approximate times of sunset for parks in southern Canada. Park managers may define Dark Time that is suitable for their facility.

The following tenets have been used in developing these specifications.

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

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 specification should provide only enough light needed for a safe transition between lit structures and the surrounding unlighted area, and to assist in navigation.

4. To minimize the ecological impact of light pollution, the extent of illumination should be strictly limited.

5. To limit the duration of light exposure on the ecosystem and to save energy, light activated timing circuits should turn off outdoor lighting. The use of light may begin at sunset and extend to an appropriate time into the evening to permit scheduled activity to end.

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 this shielding is in Table 4.1. Appendix F has the definitions for the BUG lighting zones.

Table 4.0a BUG System Designation for DSP Compliant Luminaires

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

In addition to these guidelines, compliant luminaires with abbreviated BUG designations should be have B=0, U=0 and G=0.

4.1 Buildings

This section identifies six types of structures that may require illumination within a park. In all cases, full cut-off (FCO) luminaires should be used and illumination should be controlled to prevent light scattering beyond the immediate area of the light fixture. Further, the colour of this light should have minimal blue (short wavelength) content and lighting curfews should apply (See Section 3.8).

Interior and exterior lighting that remains on for extended periods after operating hours not only wastes energy but can also be a nuisance. Insects are attracted to exterior building lights and interior lighting that shines through windows. In addition to the the light distracting insects from their normal activity, it creates the need for cleaning up dead flies before the building opens in the morning for the public.

Illumination levels and luminaire types for various buildings are listed in Table 4.1. Signage on buildings is discussed in Section 4.6.

This document uses five classifications for buildings:

- Administration Buildings,
- Public Buildings,
- Retail Outlets,
- Vending Machine Enclosures, and
- Toilet and Washroom Facilities.

4.1.1 Administration Buildings

Park 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 early spring late autumn and winter. 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 timing circuits should turn off all outdoor lighting within 30 minutes of the office being closed. Manual reset switches may be used to extend this period for late-working staff.

4.1.2 Public Buildings

Public buildings are defined as those open to the public during business hours and may also contain private offices. Due to the public nature of these buildings with high pedestrian traffic, exterior illumination may be higher than for park administration buildings.

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 timing circuits should turn the lighting on after sunset and off after a period of time specified by Park manager and subject to the building use. Manual reset switches or motion detectors may be used to extend this period by a pre-programmed duration.

4.1.3 Retail Outlets

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

Window coverings should be used so that interior lighting will not shine outside after sunset. Exterior light is permitted, and restricted to, the area around the door using Full Cut-off (FCO) fixtures. All exterior lighting should be turned off within 30 minutes after business hours.

4.1.4 Vending Machines

Vending machines should be located in 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 fixtures should be used to illuminate the area outside the entrances. The extent of this outside illuminated ground area is restricted to less than 5 metres from the entrance.

Light from vending machines is usually from a number of fluorescent tubes behind the translucent display and may emit significant amounts of white and blue light. This light undermines our night vision. Therefore, the illumination levels outside these enclosures may be higher than for other buildings to allow the transition for visitors from the bright interior to the dark surroundings.

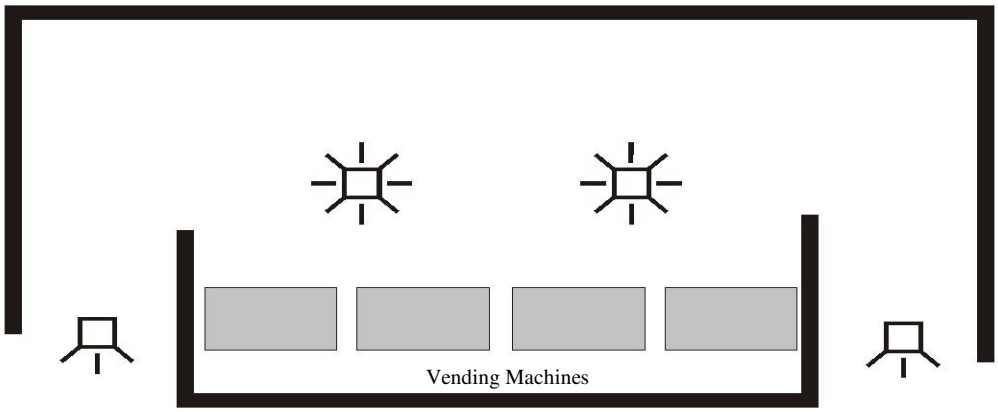


Figure 4.1.4 – Sample Vending Machine Enclosure

FCO doorway lighting should be turned off 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 Administrative Bldgs.	FCO	Incandescent, Amber CFL or LED	~2 lux	2.5 m	Yes
4.1.2 Public Bldgs.	FCO	Incandescent, Amber CFL or LED	~2 lux	2.5 m	Yes
4.1.3 Retail Stores	FCO	Incandescent, Amber CFL or LED	~2 lux	2.5 m	Yes
4.1.4 Vending Machine	FCO	Incandescent, Amber CFL or LED	~2 lux	2.5 m	Yes
4.1.5 Toilet & Washroom Facilities	Marker (FCO)	Incandescent, Amber CFL or LED	~2 lux	2 m	No

* Wattages for individual lamp types are not specified due to differences in efficacy. Park Managers should consult Appendix C for guidance in meeting the recommended illumination level in all tables in Section 4.
Note: 2 lux = illumination by clear sky about 20 minutes after sunset

4.1.5 Toilet and Washroom Facilities

If toilet and washroom facilities are available throughout the night, Full Cut-off (FCO) fixtures should be used to illuminate the entrance and any steps leading to the doorway. The illuminated door should be used as the "marker light".

Interior lighting in these facilities must also be considered. Excessive interior lighting levels can produce serious glare that impairs exterior visibility if windows are present. After sunset, interior lighting should use bug light or yellow colour whenever possible and lighting levels as measured horizontally at the floor should not exceed 10 lux.

4.2 Parking Lots

Generally, parking lots have less traffic at night than during the day. Parking lots may require lighting due to scheduled after-dusk activities. This lighting may be necessary until gate closure or Dark Time, which ever occurs first.

Where required, pole mounted Full Cut-off (FCO) luminaires should be placed 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. If necessary for larger parking lots, poles may be located within the parking lot area.

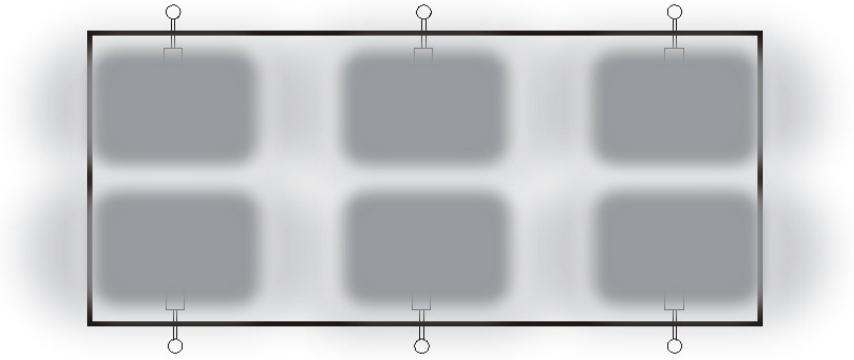


Figure 4.2 Parking Lot

4.2.1 Administration Parking Lots

Administrative personnel will generally leave when offices close. Luminaires in administration parking lots should be turned off within 30 minutes of the office closure. A timing circuit should control the lights with a manual reset for employees working late.

4.2.2 Visitor Parking Lots (Small)

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

4.2.3 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 Park 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	LPS, HPS or amber LED	~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	LPS, HPS or amber LED	~3	6 m	Yes

N/A – not applicable

4.3 Roadways

Intersections are some of the most dangerous areas for drivers. Drivers of high-speed vehicles require sufficient time to react when they approach an intersection (approximately 3 seconds). Therefore, major intersections should be marked with signage or luminaires. Illumination of adjacent areas should be minimized.

Where Federal or Provincial roadways run through DSPs, lighting of these roadways should be evaluated, and if lighting will affect the quality of the DSP, then the Park should request the Federal or Provincial government to change or shield lighting to comply with DSP requirements, but still comply to Federal or Provincial standards for roadway lighting. As a minimum, the Park should form an agreement with the Federal Government or the Province that they be alerted to any changes planned for the roadways to assure they have input into the type of luminaires that are selected.

4.3.1 Class 1 to Class 3 Roadways

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

Where applicable, marker lights should be installed at intersections between Class 1 to Class 3 roadways. Where necessary, marker lights may be installed at intersections between Class 1 to Class 3 roadways.

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

To further minimize the impact of these luminaires on the environment, the luminaire should be mounted no higher than six metres and the bulb should be no greater than a 35 watt Low Pressure Sodium (LPS) or amber LED to minimize the exposure to the environment of blue light.

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 4.6).

Where federal and provincial highway standards take precedence, the minimum-allowable illumination should be chosen.

4.3.2 Class 4 to Class 6 Roadways

Class 4 to Class 6 roadways have low traffic volumes with class 6 roads seeing occasional and local traffic. These roads provide access to large areas of the Park. Recognizing the infrequent use of these roads and the potential impact they may have on remote areas, these roads and intersections should not be illuminated.

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 LED	~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

4.4 Pathways

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 situational awareness. Although visitors might use flashlights, additional pathway lighting may be required to guide visitors to public facilities.

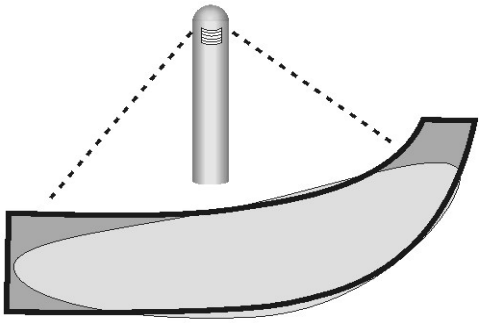


Figure 4.4.1 Bollard Luminaire

Paths are also used by wildlife. Therefore, pathway lighting should be restricted to only those paths near buildings, parking lots and campgrounds. Only those paths that the Park Manager considers appropriate should be illuminated.

Since overhead FCO 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. The fixture should be FCO and shielded or lensed such that the illumination pattern is approximately limited to the path width.

Pathways should use white or light coloured crushed stone (limestone) instead of asphalt to help reflect ambient light. Passive fluorescent markers may also be used to mark the extent and direction of the pathway. These may be mounted on bollards or in the pathway surface.

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 may 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 illumination portion of the path.

The closeness of the luminaires to the ground necessitates very low intensity lights. This limits the current products available to low wattage incandescent bulbs and amber LEDs.

1. Whenever possible pathways in the DSP should not be illuminated. If deemed necessary by the Park manager, specific pathways may be illuminated or lined with fluorescent markers.
2. Illuminated pathways should have full cut-off low-height pole mounted or bollard/railing mounted lighting fixtures.
3. Pathway lighting should be turned off at the Dark Time lighting curfew. Retro-reflective markers on the bollards/railing may assist pedestrians after Dark Time.
4. Main pathways leading to night facilities may be illuminated throughout the night at the discretion of the Park manager.

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	Incandescent Amber CFL or LED	~1 lux	1 m	Yes
4.4.3 Main Pathways	FCO	Incandescent Amber CFL or LED	~1 lux	1 m	No

N/A – not applicable

4.5 Shoreline Areas

Shoreline areas consist of docks, jetties, lock facilities, boat launching areas, beaches, homes, cottages and undeveloped lands. The direct illumination of the shallow water near shore alters the behaviour of aquatic species and the foraging patterns of landed species and insects.

This Section provides guidance to Park managers for reducing the impact of lighting along a waterway. These guidelines are relatively general due to the limited authority of Park managers over some of these properties. Where applicable, the illumination height shall minimize their impact on the ecosystem.

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. The public should be advised to shield all outdoor lighting to comply with Full Cut-off (FCO) 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 Park manager deems them necessary. Overhead luminaires that shine into the water are not permitted.
5. High traffic areas and near machinery (lock facilities) may require higher levels of illumination at the discretion of the Park manager.

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	Incandescent, Amber CFL or LED	~1 lux	1m	No
4.5.3 Lock Facilities	FCO	LPS, HPS*, Amber CFL or LED	~1 lux	6 m	Yes

* - lowest practical wattage N/A – not applicable

4.6 Signage

Signs within a Park are essential to 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 (located to the side of roadways and pathways).

Illuminated signs shall not be prohibited in a DSP. 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. To improve the visibility of signs after dark, their location, colour scheme, and material should permit reading the sign with flashlights or existing pathway or roadway lighting.

Retro-reflective signage should be used to ensure signs are visible only when necessary. Signs may be mounted on or near buildings such that exterior building lighting may provide some illumination, and they should use colours consistent with retro-reflective materials and illumination with flashlights.

Signs should be located so pedestrians can easily see them. Elevated signs are less likely to be illuminated by Full Cut-off (FCO) luminaires. Pathway and information signs should be located less than one metre above the grade of the path so that they may be found and read by pedestrians with flashlights after dark. All bollards and railings should be marked with retro-reflective material so they may be visible to pedestrians after Dark Time. Signs mounted at a higher elevation may be missed as flashlights are aimed at the ground. Roadway signs should be mounted in accordance with standard roadway practice.

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*	<1 lux	1-2 m	Yes
4.6.2 Navigation	Reflective, Light colour	Amber LED*	<1 lux	<1 m	N/A
4.6.3 Information	Retro-reflective Light colour	Amber LED*	<1 lux	1-2 m	Yes

* Lowest wattage for 1 lumen/ m^2 (0.1 lumen/ft^2) N/A – not applicable

4.7 Tower Navigation Avoidance Beacons

There is a proliferation of communication towers for cell phones and for wind turbine power generation. Towers that may have heights of hundreds of metres are being erected in otherwise unspoiled areas. Park managers should be aware of the options available for tower navigation beacons that are regulated by Transport Canada[31] and Industry Canada. Park Managers may not have authority over the illumination of these towers so these guidelines are provided as a guide when discussing tower illumination with tower owners and Transport Canada. Where a tower lighting contributes undue glare or illumination within the DSP, Transport Canada may consider or allow the installation of down-shields.

Tower and wind turbine lighting may not be required unless the tower exceeds a specific height. Consult applicable national aviation standards for the location. Single wind turbine towers less than 90 metres high do not have to be lighted unless specifically identified by Transport Canada as a hazard to aviation. For wind farms with several towers, the towers on the edge of the array and the central tower must be illuminated[32].

There are several types of navigation avoidance beacons that may be used on towers (see Appendix E). For example 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 light into the air, resulting in less scattered light into the environment. 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[33].

Communication towers erected on or near Parks should not be fitted with nighttime navigation beacons unless strictly required by Transport Canada regulations (CARS 621.19). Communication towers and other structures do not require lighting if their maximum height is less than 90 metres. The brightness of nighttime navigation beacons should be the minimum required by Transport Canada regulations (CARS 621.19). And, all towers requiring nighttime navigation beacons should use red flashing lights.

4.8 "Developed" Properties within Park Facilities

These properties include, but are limited to, privately owned and rental properties and towns within Park boundaries.

Owners of private properties within the Park 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 Full Cut-off (FCO) luminaires and replace white LED, MH bulbs with either HPS, Low Pressure Sodium (LPS) fixtures or amber LED fixtures. They should be encouraged to turn off all exterior lighting when they are indoors. All municipal lighting should be FCO and illumination levels should be no greater than minimum recommended IESNA Guidelines.

[31] Canadian Aviation Regulations (CARS) 621.19
[32] Wind Turbine and Windfarm Lighting, CAR621.19 Advisory Circular 1/06 - DRAFT 9, Transport Canada
[33] 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

The outdoor lighting on properties under the control of Park managers should use Full Cut-off (FCO) fixtures. Area lighting fixtures, such as "yard lights" and “dusk to dawn” fixtures or similar luminaires, should not be permitted nor should white LED, Metal Halide (MH) or mercury vapour lamps be permitted. These products produce excessive glare and light trespass and emit short wavelength light that affects wildlife.

Use of outdoor lighting on private properties within Parks should be discouraged 2-hours after sunset, and should be turned off when people are indoors. Outdoor lights should not be permitted to remain on throughout the night.

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	Incandescent, amber CFL or LED	<3	1.5 m	Yes
4.8.2 Yard Lights	FCO	LPS, HPS, amber CFL or LED	<3	6 m	Yes
4.8.3 Municipal Lights	FCO	LPS, HPS, amber CFL or LED	≤ minimum IESNA	TBD	No

* Wattage of lamps should be based on illumination limits.

4.9 Light Pollution Abatement Beyond Park Boundaries

As with air and water pollution, light pollution has no boundaries. It is only reduced by decreasing the light emitted at the source and increasing the distance to the source. Some cities are actively promoting the replacement of luminaires that contribute to sky glow but these policies are not wide spread. Parks may influence the producers of air and water pollution that passes through Parks. This influence should be extended to include light pollution.

- Park managers should introduce and encourage programs of light pollution abatement in municipalities around the Park facilities with the goal of reducing glare across Park boundaries and sky glow from artificial lighting.
- Park managers should approach individuals whose lights shine onto Park facilities. The goal of these contacts is to have those lights shielded, reduced in brightness or removed.

4.10 Historic Sites

The guidelines in this document give priority to wildlife in Parks; but historic sites may be located within urban areas where light pollution is generally so bad that lighting to the above standards will not improve the situation. 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 Full Cut-off (FCO) fixtures and should be lighted to the minimum levels of standards and guidelines in the surrounding area. If

"Period Lighting Fixtures" are used on the site, then the FCO variety should be used where possible.

4.11 Wilderness Areas

Wilderness areas are all "undeveloped" property in their natural state. The use of red or amber flashlights should be encouraged 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.

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6.2 Web Sites

International Dark Sky Association
www.darksky.org

Royal Astronomical Society of Canada (RASC) Light Pollution Abatement Program
www.rasc.ca/light-pollution-abatement

Canadian Aviation Regulations (CARS) 621.19
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www.flap.org

The Urban Wildlands Group
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www.starlight-thatre.com

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APPENDIX A - Reference Illumination Levels

Condition	Illumination Levels* (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 candela/m^2 (cd/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[34].

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

APPENDIX B - Colour from Various Light Sources

There six lights that convey "colour" from bright white to deep yellow. The last light source, LEDs can be designed to provide a range of colour. The accompanying table lists these sources in order from white to amber.

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 DSPs. White light gives very good colour recognition
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 DSPs. The light-emitting region in the lamp is quite large compared to other HID lamps.
Amber and Red Light Emitting Diodes	These are available in a range of colours, amber and red LEDs minimizes their impact on the environment. They can produce very focused illumination, which is very desirable for DSP applications. For DSP purposes "Amber" is defined as light in the wavelength of 500 – 700 nm and "Red" is 600 - 660nm.
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 DSP due to ecological impact and vision degradation.

APPENDIX C - Light Output from Typical Bulbs for Comparison Purposes

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%.

* 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 2011

. 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 lux = 1 Lumen / (4π 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
Mesopic Street Lighting Demonstration, Lighting Research Centre, Jan. 31, 2008, (Rensseaer), Table 2, 5

APPENDIX D - Approximate Times of Sunset for Areas in Southern Canada

The time of sunset depends on the time of year and the latitude for a site. The following table lists the approximate time of sunset (DST) for latitude of about +50 degrees from May to the end of September.

May 1	8:17
8	8:29
15	8:38
22	8:48
29	8:57
June 1	9:00
8	9:08
15	9:11
22	9:13
29	9:13
July 1	9:13
8	9:09
15	9:04
22	8:57
29	8:48
August 1	8:42
8	8:31
15	8:19
22	8:06
29	7:50
September 1	7:45
8	7:30
15	7:15
22	6:59
29	6:44

From the Royal Astronomical Society of Canada
Observers Handbook

APPENDIX E - Navigation Light Photometric Distribution[35]

			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	-----	-----

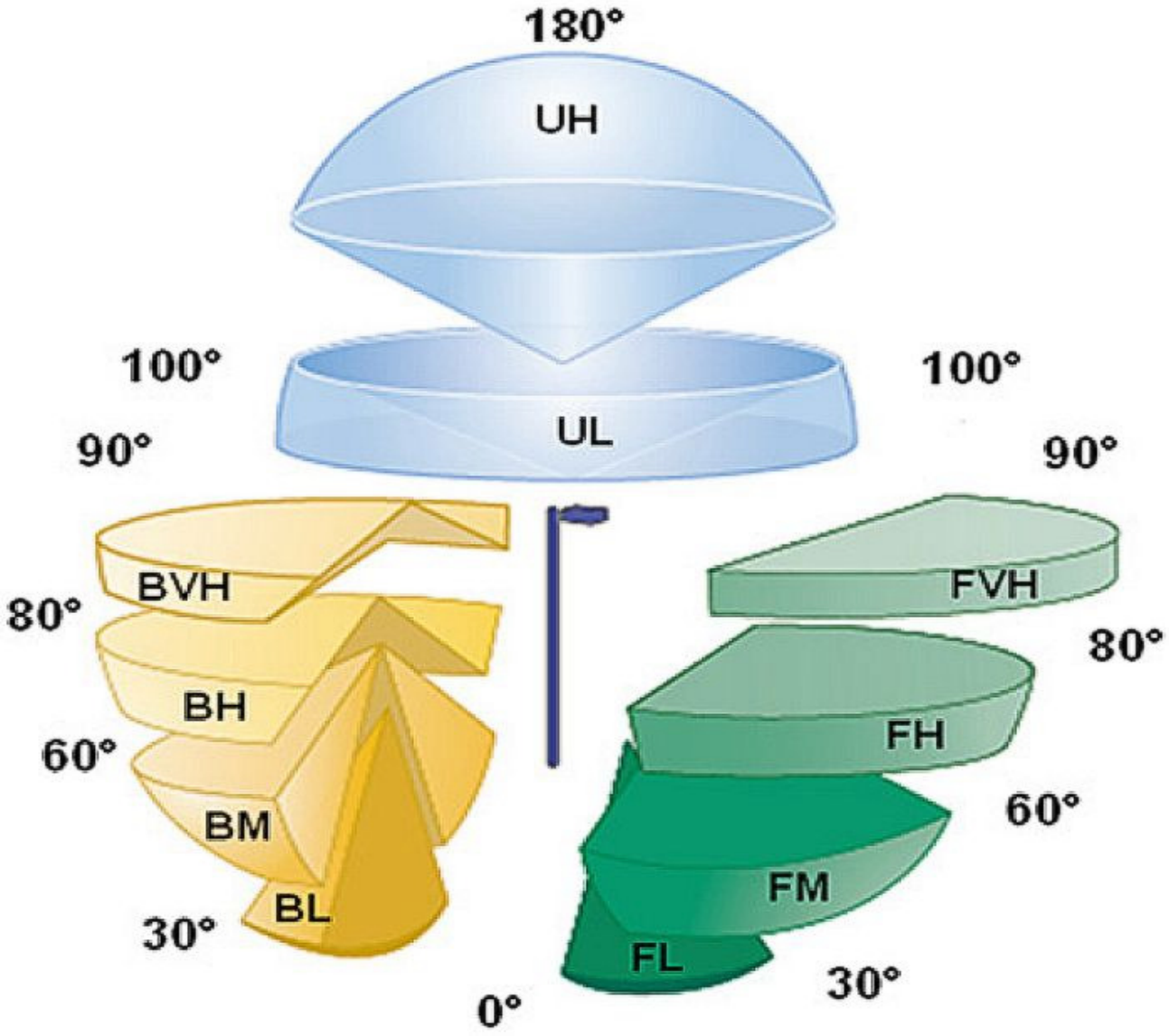
(a) Effective intensity, as determined in accordance with External Transport Canada Document
(b) Beam spread is defined as the angle between two directions in a plane for which the intensity is equal to 50% of the lower tolerance value of the intensity shown in columns 4, 5 and 6. The beam pattern is 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

[35]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[36] 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%. However the preferred Sharp Cut-off designation only permits 1%.

[36] IDA Specifier Bulletin for Dark Sky Applications, Vol. 2(1), 2009

APPENDIX G – Summary of RASC DSP Lighting Protocol

This summary applies to all property and structures within the Dark-sky 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 DSP nominators, 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) fixtures should be used.

All existing light fixtures should be replaced with FCO 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 nighttime pedestrian and vehicle traffic densities should be used in assessing the level of illumination. 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 < 5-watt incandescent light or <1 watt amber LED (1 lux). Due to the use of vehicle headlights and pedestrian flashlights, lower light wattages 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)

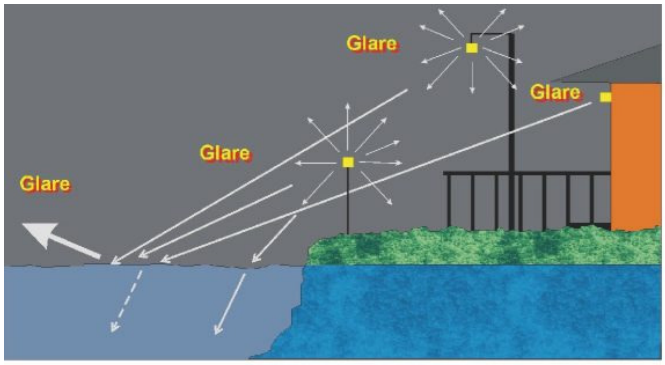
Automatic timers should be used to avoid the need for staff to turn off the lights. The timers should detect nightfall and should turn the lights off within 2-hours. If the park manager considers lights will occasionally be required after this time, the timer should be capable of being reset by staff.

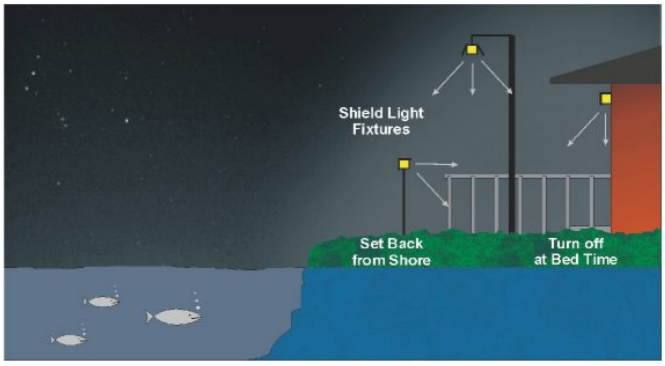
7. Indoor lighting should be prevented from shining through exterior windows.

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 <2% blue 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 bulbs and amber LEDs may be used as long as they are in FCO fixtures and they provide the required illumination levels.





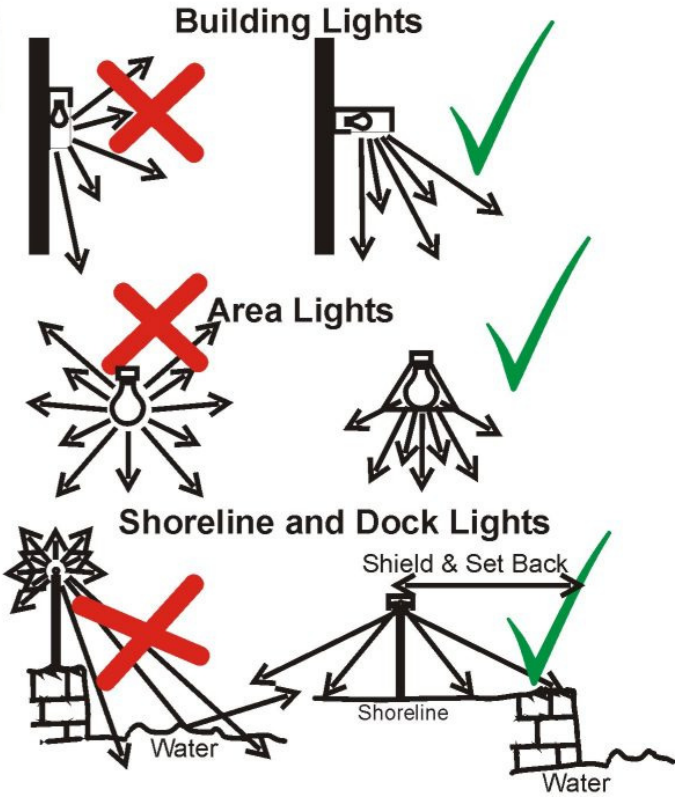
The Bad and the Good
Shoreline Lighting

White Stone on Pathway
and Shielded Bollard

Use "Warm Light"
- not white light

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

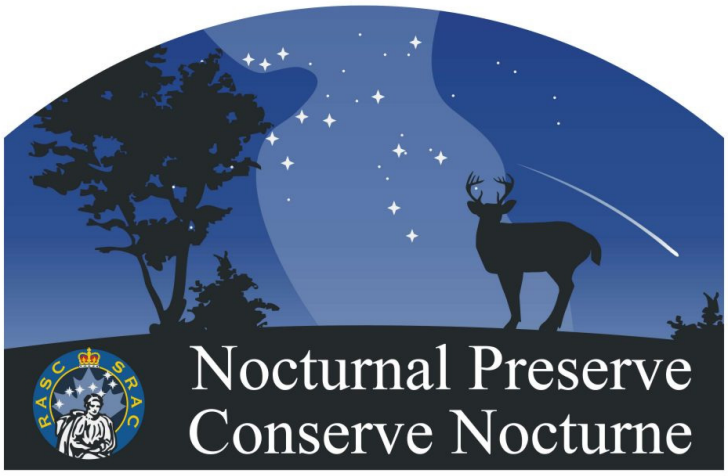
Use Motion Sensors
- lights on only
when needed



APPENDIX H - RASC Dark Sky Protection Programs

Nocturnal Preserve
Limited use of artificial light at night
May have visitor facilities
May have visitor access at night
Limiting artificial sky glow
Promotion of nocturnal environment

Dark-sky Preserves
Limited use of artificial light at night
Visitor facilities
Visitor access at night
Limiting artificial sky glow
Stargazing and astronomy outreach programs
Promotion of light pollution Abatement



Urban Star Park
Limited use of artificial light at night
Visitor facilities
Visitor access at night
Noticeable impact of artificial sky glow
Stargazing and astronomy outreach programs
Promotion of light pollution Abatement