Royal Astronomical Society of Canada

Guidelines for Outdoor Lighting in Urban Star Parks (RASC-USP-GOL)

Adopted by the RASC

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1.0 SCOPE

This document presents Guidelines for Outdoor Lighting (GOL) in Urban Star Parks (USPs, and herein after referred to as Parks) and describes the types of equipment required to satisfy these guidelines.

This USP-GOL has three objectives: to limit glare across the USP that is visible from within the Park, provide a guide for adequate lighting used for navigation within the Park, and it suggests lighting policies that may be applied to urban areas beyond the Park boundaries. This will protect the USP from deterioration by surrounding light pollution.

We present in Section 3.0 the rationale for the need for an USP and the protection of the urban nighttime environment from the excessive use of artificial lighting. To support these guidelines, this document presents references to useful web sites and to general research into the effects of nocturnal lighting on humans, human activity and wildlife.

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

A bibliography 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

CARS Canadian Aviation Regulations
CF Compact Florescent lamps
CO Cut-off luminaires (<2% up-light)

DSP Dark Sky Preserve

FCO Full Cut-Off luminaires (0% up-light or Fully Shielded)

GOL 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)

MH Metal Halide lamps ("white" coloured lamps)

NC Non cut-off (no restriction on up-light)

SCO Semi Cut-off luminaires (<2% and <5% up-light)
SAD Seasonal Affective Disorder

USP Urban Star Park

2.2 Definitions

Lux – a measure of the amount of light that falls on a defined area[1]. Examples of levels are provided in Appendix A and C.

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

Photopic Vision – vision that uses the lower sensitivity photoreceptors 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 that have evolved for nighttime vision and low illumination levels.

[1] 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[2] 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).

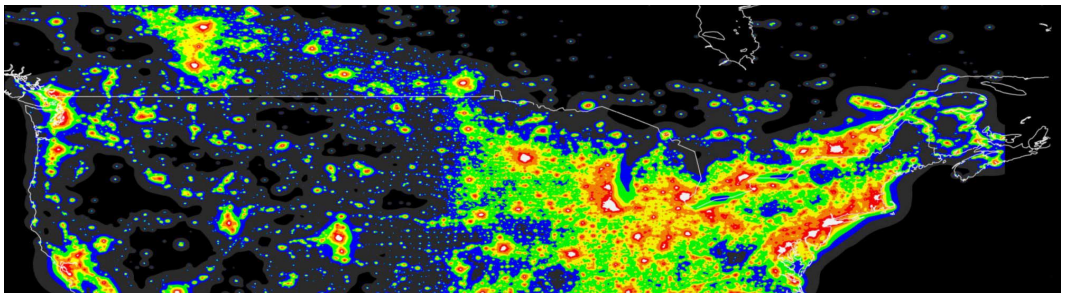

Figure 3.0.1 Mid Latitudes at Night[3]

The availability of electrical energy and efficient lighting fixtures have enabled the current urban lifestyle of non-stop "24-7" activity. Further, 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 has lead to commercial luminaires that 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. Bright red corresponds to high levels of sky glow (0.010 lux) and green is an intermediate amount (0.00025 lux). The area of Algonquin Park appears black with very dark skies.

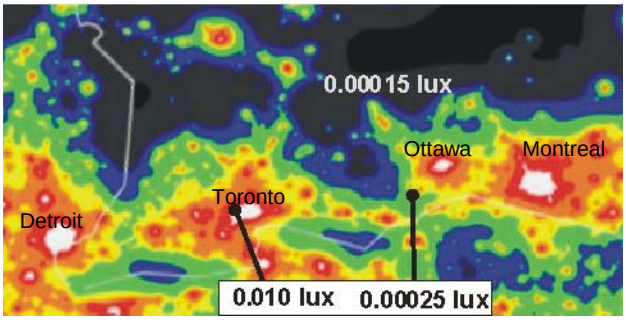

Figure 3.0.2 Light Pollution in Southern Ontario[2]

In Toronto only the brightest stars are visible. On the Rideau Lake, the Milky Way is easy to see but the glow from Ottawa extends half way up the sky in the northeast and

[2] Illumination Engineering Society of North American (IESNA) Handbook
[3] P. Cinzano, et. al. 2001

with sky glow from Kingston on the southwestern horizon. From Algonquin Park, there is virtually no visible sky glow and the Milky Way dominates the skyscape after dark.

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 that this visibility discourages criminals. Based on before and after studies of crime statistics, there is no clear evidence that outdoor lighting reduces crime[4]. Although there are anecdotal reports that "improved lighting" (i.e. improved visibility) reduces crime[5], there is no evidence that crime is reduced with "more or brighter lighting"[6]. In some cases crime was simply displaced, or the altered lighting was prompted by or caused a change in use of the streets by "…strengthening informal social control and community cohesion"[7] and this may have affected the pattern of crime.

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 is not proven by the research.

There are different types of crime. Theft is more prevalent during daytime hours, violent crime occurs more often in the evening and after midnight.[8] There was an unconfirmed report that the brightly lit City of Manila found violent crime was more prevalent after dark and the presence of police was effective at reducing nighttime crime. The city lights were not the deterrent to crime. In a lengthy Report to Congress, by the National Institute of Justice[9] it is stated 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. They state that: "We can have very little confidence that improved lighting prevents crime". It further reports that lighting can assist in the crime by putting the victim on display. The feeling of safety provided by the light may have the opposite effect.

Vandalism provides an example of the opposite effect of securing lighting than is generally accepted. Studies conclude that lighted areas are more subject to vandalism and graffiti. Anecdotal evidence[10] and more focused studies[11] 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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[4] 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

[5] 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

[6] The Indiana Council on Outdoor Lighting Education (ICOLE), P.O. Box 17351, Indianapolis, IN 46217

[7] ibid, page 2.

[8] www.bpap.org/bpap/research/DCA_briefing_dtd.pdf

[9] National Institute of Justice Grant Number 96MUMU0019 (www.ncjrs.gov/works/)

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

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

3.2 Urban 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, bicycles and avoiding urban hazards.

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[12].

The average age of our population is getting older. 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

This proliferation of outdoor lighting has a significant impact on the health and behaviour of humans[13]. "Biological clocks control our sleep patterns, alertness, mood, physical strength, blood pressure, and other aspects of our physiology"[14]. 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 proper release of these hormones, healing takes longer and our bodies are less able to fend off disease[15].

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[16] as it shifts (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 is shifted away from the proper daytime hours.

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. It is found in planets and animals wherein it plays a similar role[17].

[12] Work, Aging, and Vision: Report of a Conference, National Academy Press, Washington, DC, 1987, ISBN-10: 0-309-07793-1
[13] Light Research Organization, Electric Power Research Institute, (www.epri.com/LRO/index.html)
[14] WebMD, March 06, 2007, www.webmd.com/cancer/news/20040908/light-at-night-may-be-linked-to-cancer
[15] "Light at night and cancer risk", Schernhammer E, et.al., Photochem Photobiol. 2004 Apr;79(4):316-8.
[16] "Shutting Off the Night", H. Marano, Psychology Today, Sep/Oct 2002
[17] "Lighting for the Human Circadian Clock", S. M. Pauley, Medical Hypotheses (2004) 63,588–596

Wildlife depends on the darkness of the night and the study of this dependence is called "scotobiology".

Research into the nocturnal environment is relatively recent compared to research into the daytime environment. Consequently there is far less published literature documenting the sensitivity of the general nighttime ecology to artificial lighting. Most of the research is on specific species in the wild or laboratory studies. However, 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 day and normally recognize it as an indication of the season. By extending light past the evening, may slow the plant's biochemistry from changing to prepare for winter[18]. 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 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[19]. 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 daylight by as much as an hour. Although no references were found in the published literature that documents how wildlife accommodates for this variation, their behaviour has presumably adapted to it.

Artificial lighting changes the nighttime behaviour of species[20]. 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[21].

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

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[24]. They may swarm the light fixture until they fall to the ground exhausted. The resulting pile of insects must then be cleaned up.

Animals separated from their normal foraging grounds by an illuminated road cannot see the area beyond the lights. Even the occasional passing car can temporarily blind them with headlights. 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 abandon their established foraging patterns for new ones, which will impact other species as they compete for resources[25].

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. This impacts the river and lakes in two ways.

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.

The second impact is on fish and aquatic plants[26]. The effect of light on fish is not clear. 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

[22] ibid., Chapter 2
[23] ibid., Chapter 11
[24] ibid., Chapter 13
[25] Ecological Consequences of Artificial Night Lighting, C. Rich, T. Longcore, Island Press, 2006
[26] Ecological Consequences of Artificial Night Lighting, C. Rich, T. Longcore, Island Press, 2006, Part V

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.

3.8 Summary

Generally there is limited research on the environmental benefits and costs of artificial lighting. In the absence of clear conclusions, the best policy is to minimize its effects on the ecosystem.

Studies have been published that present conflicting conclusions about outdoor lighting and the reduction of crime. The fact that these studies cannot reach a consensus undermines the argument that more light makes a safer environment. It has not been shown that the cost of lamping, or re-lamping, large areas of a city will result in reduced crime. Yet, the cost of lighting an area may cause funds to be redirected away from other more effective measures.

There is growing medical 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 cause an increase in chronic diseases.

It is clearly shown in published research, that artificial outdoor lighting affects the ecology over the entire food chain. 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.

Public education is the key to correcting this degradation of the nocturnal environment by our nighttime culture. As one of the main sources of light pollution, cities must show leadership in solving this problem, and Urban Star Parks are an obvious way to show the public the virtues of a dark night.

In cases where technology may impact society (i.e. medicine, power generation, etc.), we have not required proof of an adverse effect but require proof that there is *NO* adverse effect. This precautionary principal must extend to the continued use of outdoor lighting. Evidence for its affect on human and animal health has been shown and outdoor lighting must now be recognized as putting human health at risk. The precedent has been set with the programs to reduce air and water pollution and the reduction in toxic chemicals in consumer products.

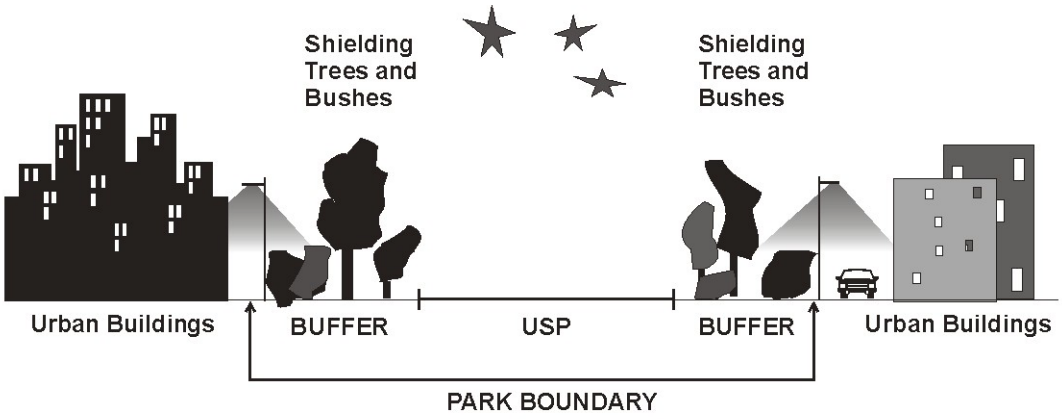
Artificial lighting that is installed for human activity is altering the natural environment. This environmental degradation continues without resistance and is indeed supported by human nighttime culture. Our civic policies and the legal system is strongly biased in favour of human demands. Unfortunately, we are now discovering how nocturnal lighting degrades both human health and the health of wildlife well outside our cities. Wildlife has no voice in law. Others must act on their behalf. Cities must take action and be their advocate against change in their environment.

4.0 GENERAL GUIDELINES

An Urban Star Park (USP) is defined as an area within or near an urban area. An USP may be a relatively confined enclave inside a city, or beyond city limits but close enough for its night sky to be impacted by artificial sky glow.

Very dark rural sites may be classified as Dark Sky Preserves (DSP). Persons interested in DSP Designations are should refer to the document: RASC-DSP- GOL.

The USP is identified as the area from which artificial lighting outside the Park is not directly visible. In order to prevent light from the adjacent neighbourhood from shining directly into the USP, coniferous trees, buildings, berms and bushes may be used to as natural light shields (Figure 4.1 USP Layout). These form a Buffer Area around the USP.



This section provides guidelines that should be followed to minimize light pollution within a Park. The suggested equipment and illumination levels are described more fully in the Section 5.0 (Equipment).

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 colour in the light (avoid white),

What is “practical” depends upon the specific conditions of the area concerned and the technology available to illuminate the area.

4.1 Illumination Levels

Visitors should expect the Park environment to be as natural as possible. Therefore, they should not expect urban roadway lighting standards to apply within the USP.

In this document, illumination levels for all Park facilities should be designed to minimize the impact of artificial lighting on the natural environment. This runs counter to

standard practice of lighting to IESNA urban standards. Artificial lighting should be used only where deemed to be critical for the safety of visitors and where other safety systems are not practical. To the extent practical, flashlights should be used as an alternative to permanent lighting fixtures.

In order to minimize the disruption to plants and wildlife by artificial lights, maximum illumination levels should be comparable to that of the full Moon. Placing these levels in context, people have reported seeing "fine" at full Moon illumination levels in the absence of glare[27]. Although the Moon produces a degree of glare, it is above our horizontal field of view. For example, about two hours after sunset the full Moon will be approximately 45 degrees above the horizon.

The following illumination levels are suggested as a guide to limit the impact of artificial lighting with in the Park.

1. No artificial illumination should be installed unless there are buildings, roads and pathways in the vicinity.

2. Illumination levels from artificial lights should be no greater than the full Moon (less than 0.5 lux) except in specified areas.

3. Where vehicle and pedestrian traffic volume is known to be high after dark, illumination levels should be no more than about 2 lux.

4. A lighting curfew should be imposed in all areas except where specifically identified by the Park manager.

4.2 Extent of Illumination

Where illumination is required, its impact on the nocturnal environment should be minimized by limiting the extent of the affected area.

The light from non-shielded fixtures can be seen, literally, as far as the eye can see. Tall trees around a lighted area will significantly restrict the extent of the illumination, however it is more effective to use light fixtures that are engineered to limit the extent of the illumination.

Full Cut-off (FCO) fixtures (also called fully shielded fixtures) prevent light from shining beyond the immediate area and up into the sky (see Figure 4.2). Since no light shines horizontally, the amount of glare at a distance from the fixture is significantly reduced from that of semi cut-off or unshielded luminaires. This increases visibility. By reducing glare, eyes of both animals and people can become more accustomed to the darkness allowing them to see into areas with lower illumination levels farther from the fixture.

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

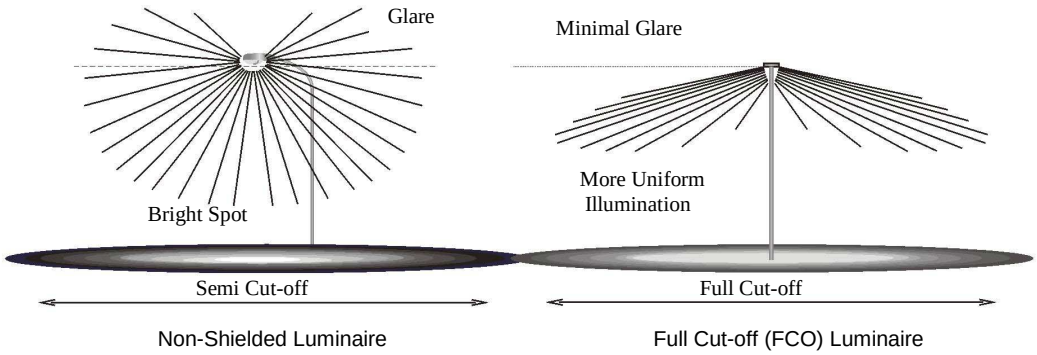


Figure 4.2 Luminaires

The improvement in visibility with FCO fixtures permits the use of lower wattage bulbs that in turn reduces energy consumption. By lowering the illumination levels, less light will reflect off the ground into the surrounding trees, and into the sky. This also reduces the extent, and impact, of the artificial light on the night environment.

To further limit the extent of the illuminated area, pole heights should be limited to below the surrounding trees or berms so that the stray light will be contained. To minimize excessive lighting:

1. All luminaires should use full cut-off fixtures.

2. Fixtures should not be mounted more than 6 meters above the USP grade.

3. Where it is not practical to replace fixtures, durable shields should be securely affixed to the existing luminaires such that no light shines from the fixture above the horizon, and so that it provides reduced illumination within 10 degrees of the horizon.

4.3 Duration of the Illumination

Artificial illumination should not persist past a reasonable time after dark to avoid the need for plants and animals to over extend their accommodation period.

Park activity is significantly reduced in campgrounds during dusk. Just after sunset, natural illumination levels are approximately 0.1% that of full sunlight (100 lux) or less than 100X that of a full Moon (see Appendix A). At that time, indoor illumination (approximately 200 lux) is higher than the outdoor levels. After about 30 minutes, the natural illumination level due to dusk is about that of a full Moon (less than 1 lux)[28].

If indoor lighting, especially for offices and stores, shines through windows it will have a considerable impact on the non-lighted areas outside. It will also produce glare that will prevent dark adaptation for people and animals. This has no effect until after sunset, at which time the sky illuminates the ground to a lower level. Window coverings should then be used to prevent continued spillage of the indoor light through the windows.

[28] R. Dick, Carleton University, Ottawa, 2006

Park managers may define a "dark time" after which illuminated activity and noise is discouraged. This recognizes that low-level activity may continue after sunset and dusk. Exterior Park lighting may remain on during this time, after which there should be a lighting curfew. The time of this curfew will depend on the nature of the Park and type of activity permitted within the Park. Park managers should determine a reasonable lighting curfew time (such as 2 hours after sunset). Therefore:

1. No lighting should be installed for areas with minimal pedestrian traffic. Pedestrians should be expected to use their own flashlights.

2. There should be a lighting curfew within 2 hours of sunset.

3. Timing circuits should turn off all exterior lighting fixtures within the Park at the beginning of the lighting curfew except where identified in this document. A light detector that is triggered by sunset should activate a timing circuit to control the light fixtures. Manually activated switches should also be available to turn off exterior lighting.

4. In areas with high volume of pedestrian traffic and where limited activity continues after dark that requires illumination, motion detectors should control light fixtures. Automatic timers should be used to turn them off after a reasonable period of time.

On a technical note, only Light Emitting Diodes (LEDs), compact fluorescent and incandescent lamps can be switched on for short periods of time. High Intensity Discharge (HID) lamps (Low Pressure Sodium and High Pressure Sodium) require several minutes to heat up before they will reach full brightness.

4.4 Colour of Illumination

Various light sources (lamps) have different colour content. These are discussed in Appendix B.

Humans, plants and animals are affected by the colour of light. Blue light (short wavelengths) affects animal low-level scotopic vision whereas red light (long wavelengths) is seen well by our photopic vision. The use of long wavelength light allows animals to see without degrading their sensitive scotopic vision.

Specifically, insects and birds[29] are affected more by white than red lights. The effect of lighting on birds has been documented in studies of bird mortality around communication towers that have navigation avoidance beacons[30], and by members of the Fatal Light Awareness Program (FLAP)[31].

[29] Ecological Consequences of Artificial Night Lighting, Rich, Longcore, Island Press, 2006, Part II, V
[30] 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
[31] www.flap.org

The colour and type of light that is used may vary depending on the extent and use of the illuminated area. The colour content of light (spectral content) assists in identifying cars or persons by the colour of their clothing. When artificial lighting is deemed necessary due to high pedestrian or vehicle traffic, the colour content of the light source should provide sufficient colour content to allow fair colour recognition (HPS fixtures).

1. Where low illumination levels are necessary (pathways), lighting may only be possible with incandescent bulbs or either yellow or LEDs.

2. Where there is high volume pedestrian or vehicle traffic, FCO LEDs, incandescent or High Pressure Sodium (HPS) lamps should be used. The level of required illumination should determine the specific type of lamp.

3. Where vehicular traffic requires HPS fixtures, the lowest practical wattage shall be used.

5.0 LIMITATIONS

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

6.2 Web Sites

International Dark Sky Association
www.darksky.org

Royal Astronomical Society of Canada (RASC) Light Pollution Abatement Program
www.rasc.ca/lpa/index.shtml

National Crime Prevention Council
www.ncpc.org/ncpc/ncpc/?pg=2088-10802
National Institute of Justice Grant Number 96MUMU0019
www.bpap.org/bpap/research/DCA_briefing_dtd.pdf

Canadian Aviation Regulations (CARS) 621.19
www.tc.gc.ca/CivilAviation/publications/tp14371/AGA/6-0.htm

Shoreline Booklet downloadable from IDA
www.uwsp.edu/cnr/uwexlakes/humanimpact/lighting.pdf

Ecology of the Night Conference Proceedings
www.muskokaheritage.org/ecology-night/

Light Pollution by Pierantonio Cinzano
www.lightpollution.it/indexen.html/

WebMD, March 06, 2007,
www.webmd.com/cancer/news/20040908/light-at-night-may-be-linked-to-cancer

Psychology Today, Sep/Oct 2002
http://psychologytoday.com/articles/pto-20021002-000003.html

BC Hydro Power Smart Program – 42 watt LED sufficient for urban pathway
http://dmdeng.com/pdf/learning/Power_Smart_Roadway_Lighting,_BCH.pdf

Light Research Organization, Electric Power Research Institute,
www.epri.com/LRO/index.html

The Indiana Council on Outdoor Lighting Education (ICOLE),
P.O. Box 17351, Indianapolis, IN 46217, USA
http://home.att.net/~icole/crime_ref_guide.html

Fatal Light Awareness Program
www.flap.org/new/nestegg_3.htm/

Florida Fish and Wildlife Conservation Commission
www.floridamarine.org/publications/default.asp

Web Sites (continued)

The Urban Wildlands Group
www.urbanwildlands.org/abstracts.html

Sample of Luminaire Product Sources
http://store.starrynightlights.com/depali.html

LED Landscape Lighting
www.superbrightleds.com/malibu.htm

Astronomy Outreach and Education Materials
www.starlight-thatre.ca

Wildlife Lighting
www.state.hi.us/dlnr/dofaw/fbrp/sos.htm

Work, Aging, and Vision: Report of a Conference, National Academy Press, Washington, DC, 1987, ISBN-10: 0-309-07793-1, http://books.nap.edu/openbook.php?isbn=POD252

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	0.2 (typical) to 1 max.
Urban Road Artificial Illumination	2
Open Parking Lot	11-22
Car Dealership Lot	200
Full Sunlight	100,000

* 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)

To place these levels in context, people have reported seeing "fine" at full Moon illumination levels in the absence of glare[32].

[32] 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 yellow.

MH – Metal Halide	They allow very good colour recognition because of the wide spectrum emission (blue to red) from the bulb. It is a "High Intensity Discharge' (HID) bulb that must be warmed up before it can design brightness. The light-emitting region in the bulb is small so lenses and shields can control where the light is projected. The white light gives very good colour recognition.
CF – Compact Fluorescent	These produce white light but their light-emitting region is very large compared to MH so their light is difficult to control with optics and shields. They perform well in cool temperatures and can be used for motion detection systems, but they take several minutes to warm up in sub-zero temperatures.
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.
Incandescent bulbs	These emit a yellowish light and are available in a very wide range of light outputs but they have very low energy efficiency. Two characteristics make them desirable for some applications. They can be turned off and on very quickly so they can be used for motion detection systems. Very low wattage bulbs are readily available if low illumination levels are required
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 so efficient that even low wattages may produce too much light our purposes. The light-emitting region in the bulb is quite large compared to other HID bulbs. In this document they are recommended for use as roadway marker lights.
LEDs - Light Emitting Diodes	These can produce a range of colours but currently (2007) only relatively low illumination levels. However, they produce very directed illumination, which is very desirable for a number of applications identified in this document. They are currently more expensive than the other types of bulbs but their cost is falling quickly.

APPENDIX C - Light Output from Typical Bulbs for Comparison Purposes

Bulb Types	Lumens† (Intensity)	Lux†† at 6 m (no losses*)	Lux†† at 2 m (no losses*)	Lux†† at 1 m (no losses*)
Incandescent				
7 watt	46	0.1	0.9	3.7
15 watt	112	0.25	2.3	9.1
40 watt	365	0.8	7.3	29.0
60 watt	740	1.4	12.7	50.9
100 watt	1530	3.8	34.0	136.1
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

* The fixture and bulb degradation before cleaning or replacement may decrease these to as low as 50%.

† 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-meter square

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

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[33]

			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

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