Table Of Contents

Scope

There is a growing need to identify and protect accessible areas that permit the public, novice stargazers and astronomers to enjoy the night sky. There is also a growing need to identify these areas and protect them from light pollution.

To address the need for accessible dark sites near urban centres, and to preserve dark natural sites, there are two types of protected areas: Urban Star Parks (USP) and Dark Sky Preserves (DSP). By promoting the use of these protected areas after dark, these parks will see increased usage and support from the community during non-peak hours.

Background

Our goal at Starlight Theatre is to enhance the public's enjoyment of the night sky and to increase the quality of the night sky and accessibility to dark astronomical observing sites. Sites with very dark skies without urban sky glow are generally found in remote areas but the magnificent view of the star-filled sky is worth the trip.

However, everyone cannot travel great distances to enjoy the night sky. There should be areas close to urban areas (or within them) that affords a reasonable view of the sky. We need a compromise between a remote great sky and a local acceptable sky. The Royal Astronomical Society of Canada defines these as Dark Sky Preserves (DSPs) and Urban Star Parks (USPs), respectively.

These two Dark Sky Sites must require that all lighting fixtures within its borders minimize their contribution to light pollution: glare, light trespass and sky glow. The Goal for DSPs is to minimize the affects of artificial lighting on wildlife. This has the natural result of minimizing its impact on stargazing. However in urban areas, sky glow can be so bad that wildlife has either fled from the region or adapted their behaviour to it.

It is not practical to require an USP to be free of sky glow, but experience shows that the most debilitating form of light pollution in a city is glare and light trespass. So, the critical attribute for an USP, and a DSP for that matter, is strict control of lighting fixtures.

The following guidelines follow these two principals: strict control of lighting for DSPs and USPs, and sky glow limits for DSPs.

Urban Star Park (USPs)

A USP should preserve the quality of the night sky for the enjoyment of visitors. Unshielded lighting fixtures and high levels of artificial illumination significantly degrade our view of the night sky and compromise the natural behaviour of animals. It also affects the flowering and dormancy period of plants.

Courtesy of www.starlight-theatre.ca

Our eyes are very sensitive to light. People have reported that they see “fine” under only the light of the full Moon. For comparison, the Illumination Engineering Society of North America (IESNA) recommends urban illumination levels that are up to 100X brighter. Therefore in a city, people rarely experience the sensitivity of their eyes.

There are three components to light pollution: Glare, light trespass and sky glow.

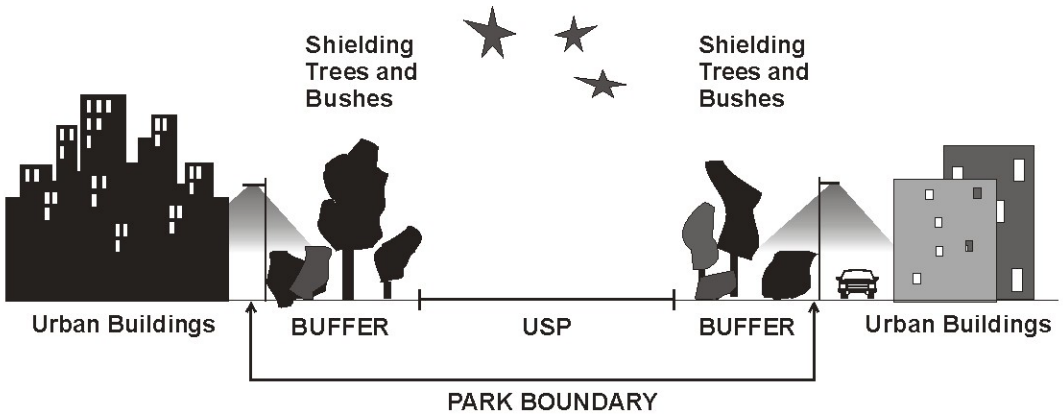
Glare is light that shines horizontally across the area and is most easily prevented with the use properly mounted of shielded fixtures. Fixtures that do not limit the area of illumination will shine light where it was not originally intended causing the nuisance of light trespass. The glare from unshielded fixtures also scatters off dust particles and aerosols above the ground to illuminate the air above the site. This is seen as artificial sky glow.

Sky glow causes the sky to appear with a grey or orange colour. From within a city, this glow covers the sky and overwhelms the light of the stars. It can be seen for hundreds of kilometres as a dome of light above an urban centre. Sky glow illuminates the land and affects the behaviour of wildlife.

Glare and sky glow affects how much we can see at night. Our eyes can adapt to darkness in two ways. The iris in our eyes open to let in more light and the photoreceptors in the retina increase in sensitivity. The glare from a single unshielded light can prevent this dark adaptation. Bright light prevents the iris from opening and high illumination levels prevent the retina from adapting to faint light. Indeed, in the presence of glare under a relatively dark sky, few stars may be visible. But if light fixtures are shielded, our eyes will adapt to the dark to a sufficient degree to see many stars even from within an urban area.

Sky Glow versus Glare

To help shield the USP from surrounding urban lighting, there should be a buffer zone to block the external light as shown in this figure.

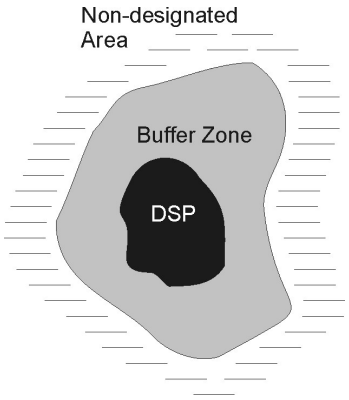


Generic USP Lavout

Cities are dynamic places with demolition and construction, and with bylaw changes that may alter the local lighting around a USP. Requesting a change, after new construction has begun is very difficult and expensive. It is much more effective to help guide local development towards respecting the USP. For this reason a program of public and municipal outreach is necessary to protect the USP from future urban development. And, it will increase the popularity of the area as a star gazing site.

Dark Sky Preserves (DSPs)

Since people have reported that they see “fine” under only the light of the full Moon, illumination levels within a DSP should not exceed the light of the full moon – less than about 1 lux (see Appendix A). Although wildlife have adapted to this level, it puts stress on their natural behaviour (foraging). Therefore, all illuminated areas must be strictly limit this illumination to as small an area as practical around the light fixture by using bushes, tree lines, berms, buildings and fences as light breaks.

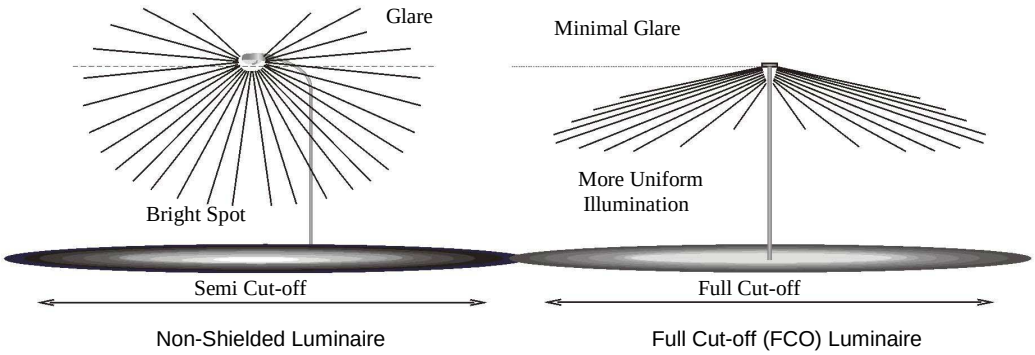


To protect the DSP from lighting in the area, there should be a buffer zone surrounding the DSP as shown in the figure. So, a DSP is located within a larger area under the control of the park manager.

The remote location from urban areas protects the site from sky glow, and the strict lighting in the DSP and the Buffer Zone restricts any glare and light trespass.

The most practical fixtures for a DSP, and USPs for that matter are “Full Cut-off” (FCO) fixtures. They prevent any light from shining above the fixture, and strictly limit low angled lighting. These fixtures focus most of their light onto the immediate area. The light that reflects off the ground should be absorbed by the surrounding light breaks.

Careful selection of the lighting fixtures for their purpose will also make it both easy to protect the night sky, and it will reduce the use of electricity.



Semi Cut-off and Full Cut-off Luminaires

In order for the Park to be protected from the future encroachment of light from beyond the Park boundaries, park managers should maintain a good working relationship with neighbouring landowners and municipalities to help protect the area from the increase in sky glow visible from within DSP. This requires an effective outreach program to help avoid increases in sky glow and glare before construction projects are started and to encourage better lighting when renovations are made.

Lighting Protocols

There are four guidelines for lighting within a USP and a DSP as well as their Buffer Zone. Lighting should be used only for navigation of the site.:

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 at the time.

Level of Illumination

The following illumination levels are suggested as a guide to limit the impact of artificial lighting with in the Park. For reference, see Appendix C.

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 1 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.

Extent of Illumination

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 nominal 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.

Duration of Illumination

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.

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 – See Appendix D). 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 Dark Sky Site and Buffer Zone 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.

Colour of Illumination

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). See Appendix B.

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.

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[1].

[1] 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 (Guidelines recommend ≈ 1 lux)

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