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St. Ignatius Sports Lighting Proposal
Evaluation of Lighting Impacts

To Whom it May Concern:

My name is Kera Lagios. I am currently the Principal of Atelier Fos, a lighting consultancy and prior to that I was a Principal of Lighting Design at Integral Group in Oakland, CA. I have over 10 years experience designing the lighting for buildings, landscapes and streets, including senior, affordable, and market rate residential projects, transit plazas, airports, schools, universities, and commercial buildings. A large percentage of my work incorporates LEED Platinum and Gold certified and Net Zero projects, and I have practiced in Northern California for 5 years. My education includes a Masters of Architecture from the Harvard University Graduate School of Design. I have won several awards for lighting and daylighting, currently serve as a LEEDUser Expert for the LEED Interior Lighting Credit, and am a LEED Accredited Professional as well as an Associate Member of the International Association of Lighting Designers.

I have conducted an evaluation of the Saint Ignatius Lighting Installation Proposal and provided my analysis in the report below. Please feel free to contact me with any questions. My contact information can be found at the end of the document.

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1. Introduction

It is important to understand that amid benefits to the school and its athletes, the proposal by St. Ignatius Preparatory School to install new, permanent lights for their sports field will have significant adverse effects on the residents of the Sunset Neighborhood. Not only is the school proposing a dramatic increase in the quantity of light installed, but they are also proposing a dramatic increase in the hours and days when these lights will be used.

While it is true that LED technology has improved control and efficiency of lighting installations, it is false to say that this installation will have no negative impacts on the neighborhood.

There are significant ways in which the project is overlit and additional steps must be taken by the school to provide alternative options for the installation in order to mitigate the dramatic and negative impact on the nighttime environment for the residents of the Sunset neighborhood.

The following report is my assessment of the lighting aspects of the project based on the materials presented by Musco.

1.1 Impacts of Outdoor Lighting

Outdoor lighting provides many benefits to our cities and neighborhoods, but it can also be detrimental. Lighting enables an extension of the use of outdoor spaces beyond daylight hours, helps promote the feeling of safety and security, is used for signage and wayfinding, and can provide beautiful accents for buildings and landscaping.

Unfortunately, outdoor lighting also has drawbacks. These include **light pollution, light trespass, glare, excess energy use, degradation of aesthetics, and it may harm human, animal and plant health**. Because of this, it is important to weigh the benefits and costs whenever planning new lighting installations. In addition to considering those who will benefit from the lighting, it is essential to consider the people and environments beyond the property line, to evaluate the impacts, and work together to investigate alternatives that may limit the negative impacts.

Why is darkness important?

Despite the advancements in LED technology, our nights are getting brighter, and in fact, it may be the energy efficiency and cost effectiveness of LEDs that are causing more outdoor lighting to be installed.[1] According to the Illuminating Engineering Society (IES), “The duration of lighting has increased; in some areas there is never any real darkness, which might have a profound impact on natural cycles.”[2]

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[1] Kyba, Christopher, C.M. “Artificially lit surface of Earth at night increasing in radiance and extent.” Science Advances 22 Nov 2017: Vol. 3, no. 11, e1701528.
[2] IES RP-33-14, *Lighting for Exterior Environments*, 2014, p. 1.

Fundamentally, darkness is important because human beings, animals and plants have **evolved biologically to take cues from the daily cycles of light and dark**, and our ability to see evolved over millions of years of relative nighttime darkness[3]

Brighter nighttime environments are a shift from that evolutionary condition, and pose potential problems to our environment and potentially our health. Just as we are concerned about the effects of polluted air and water on our environment and ourselves, the concerns about excessive light at night must be taken seriously.

1.1.1 Light and health

Development in research on the effects of light on human health have increased dramatically over the past few decades and have accelerated quickly in the most recent few years. We now know that **our eyes have two functions: to help us see and to regulate our circadian system**. In turn our circadian system functions like a clock.

Vision versus the circadian system

The circadian system differs from the visual system. While the visual ("photopic") system which functions during daylight, is most sensitive to green light. The melanopic" system which governs circadian response, is **more sensitive to light in the blue part (480nm) of the visual spectrum** (Table 1 and Figure 1).

Table 1. Comparison of visual system and circadian system

	Visual system	Circadian System
Visual response	photopic or scotopic	melanopic
Peak sensitivity	~555nm (green) or ~505nm (blue-green)	~480nm (blue)
Cells in eye	rods and cones	ganglion cells

Circadian regulation

The circadian clock does not regulate itself. It must be reset on a daily basis, and the resetting is done by the natural 24-hour light-dark cycle. Blue-enriched light is one of the factors that suppresses melatonin and cues the reset of the circadian clock each morning. Not enough in the morning may make us drowsy, and too much after dark may keep us awake.

Although much of the attention given to light and health focuses on blue-enriched lighting, it is important to note that the circadian response to light is governed by several factors, of which

[3] IES TM-18-18, *Light and Human Health*, 2018, p. 9.

spectrum is one. In fact, "Multiple optical radiation characteristics (**quantity, spectrum, timing, duration, pattern and prior optical radiation exposure**) all affect the magnitude of the phase-resetting response."[4]

What does the circadian clock do?

The regulation of the circadian clock has been tied to a number of neurobehavioral responses and linked to clocks in the liver and the lungs. Processes include regulation of metabolism, wound healing, mood, reproductive processes and more. According to the IES:

"In mammals, a wide variety of physiological and behavioral events exhibit circadian rhythmicity, ranging from the obvious sleep-wake cycle, to more covert changes in hormone levels, core body temperature, blood pressure and gene expression."[5]

In general, light and darkness are important to our health for the following reasons:

- General exposure to nuisance overlighting and glare can result in discomfort and disrupt sleep, both which affects health and wellbeing in their own right.
- Blue-light at night is particularly problematic because the circadian system is most sensitive to light in the "blue" range of the visible spectrum. "Cooler" color temperatures, such as the 5700K LEDs used in the SI project, are more likely to trigger a circadian response. (See Section 1.2 for discussion of color temperatures).
- Currently there are no defined thresholds for exposure to light at night in terms of the effects on the circadian system, and the IES's position is that normal exposure to light at night is not life-threatening.[6] Although we still don't know the exact thresholds at which the circadian cycle can be disrupted by light at night, there is evidence that even low levels might be capable of triggering a response.[7]

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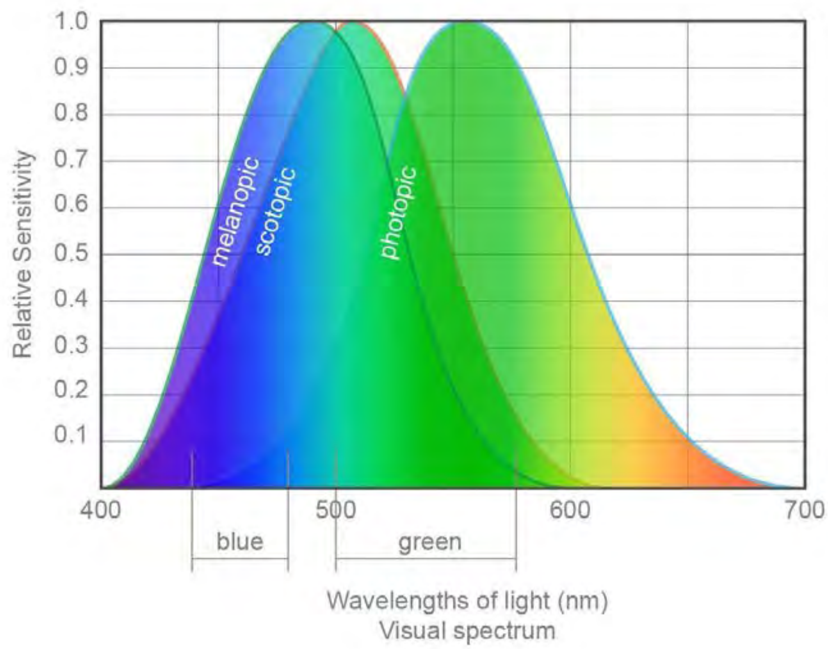
[4] "Multiple optical radiation characteristics (quantity, spectrum, timing, duration, pattern and prior optical radiation exposure) all affect the magnitude of the phase-resetting response.", IES TM-18-18, p. 10.

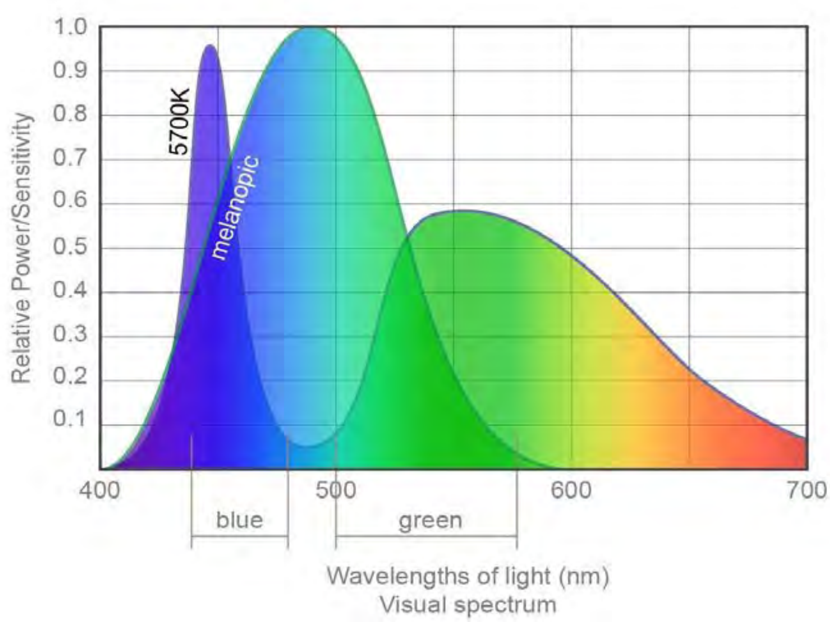
[5] IES TM-18-18, p.11.

[6] IES RP-33-14, p.4

[7] IES TM-18-18, p. 14-15.

Figure 1. Peak sensitivity to different wavelengths of light





Top: *Graph showing the visual (photopic (day)and scotopic (night)) and circadian (melanopic) peak sensitivity curves overlaid with the colors of the visual spectrum (nm). The circadian system is most sensitive around 480nm (blue light), whereas the visual (photopic) system is most sensitive around 555nm (green light).*

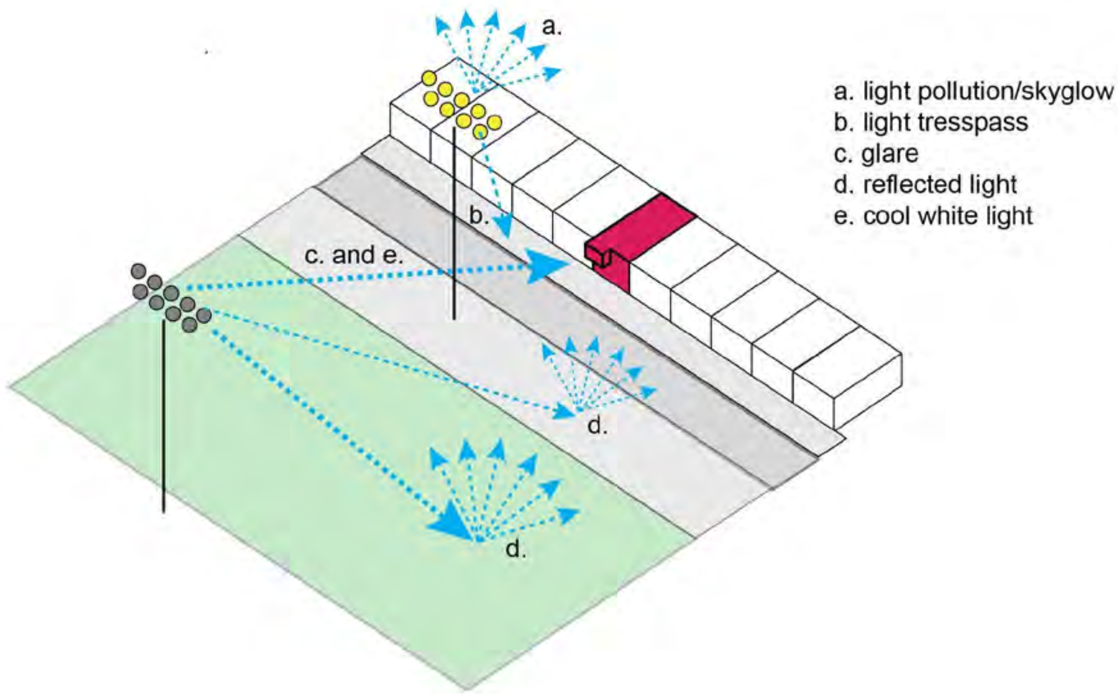
Bottom: *The melanopic response corresponds closely with the blue-enriched light present in 5700K light sources, meaning that cooler color temperatures are more likely to trigger the melanopic response.*

Diagrams by author, based on: https://www.ies.org/fires/simplifying-melanopsin-metrology/

1.1.2 Other impacts of outdoor lighting

There are three aspects of outdoor lighting that are most often used to evaluate the impacts of an installation on the nearby environment: light pollution, light trespass and glare.

Figure 2. Outdoor lighting aspects of importance



Light pollution is defined by the IES as, "**the combination of all the adverse or obtrusive effects of electric light that produces sky glow**."[8]

Light pollution is caused by light that shines upward to the night sky, and is exacerbated as that light reflects off of particles in the air. While light pollution typically is measured as uplight from a luminaire, light from downward pointed luminaires that reflects off of buildings and roads also contributes to sky glow.

Light pollution is important because it:

- is not local. For even small cities, it can be viewed from miles away.
- reduces the darkness of our nighttime environments (see below for more discussion) which carries with it environmental and aesthetic degradation
- obscures the view of the stars and the Milky Way
- negatively impacts reproduction, feeding and habitation of plants and animals

[8] IES RP-33-14, p. 21.

Measurement:

Typically ,light pollution is measured according to how much light from a luminaire or project is emitted upwards, or above horizontal.

Light trespass, **“relates to light that is obtrusive off-site.”**[9] This metric evaluates light that falls outside the project boundary or property line.

Light trespass is important because:

- It is typically an eyesore and a nuisance for neighbors
- It is “wasted light” and energy inefficient

Measurement:

Typically light trespass is measured as the amount of light falling on a plane that extends vertically from the property line upwards.

Figure 3. Light Trespass

These two photos were taken at the same facility, on opposite sides of the access road. (Left) Pointed toward the athletic field. (Right) Pointed toward the neighborhood.

Image Source: IDA-Criteria for Community-Friendly Outdoor Sports Lighting v1.0, November 28, 2018

Glare is, “the sensation produced by luminance within the visual field that is sufficiently greater than the luminance to which the eye is adapted causing annoyance, discomfort or the loss of visual performance and visibility.”[10] The IES breaks glare down into two significant categories: **disability glare** and **discomfort glare**.

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[9] IES RP-33-14, p. 22.
[10] IES RP-33-14, p.53

Glare is problematic because:

- Glare from bright sources can make objects in the foreground harder to see
- Glare is a particular problem for seniors. According to the IES, “the loss of lenticular transparency scatters light and reduces the apparent contrast between objects,” and, “is known as disability glare.”[11]
- Obtrusive lighting can be an eye-sore. “Non shielded outdoor lighting can be observed at great distances; nighttime visual clutter can be aesthetically disruptive”.[12]

<u>*Measurement:*</u>

Glare is one of the most complicated metrics and is currently evaluated in many different ways. In general, the various equations that define glare, all incorporate four factors: **luminance of glare source, size of glare source, scene luminance and position** (see Equation 1.0 below). Various standards use varying methods for characterizing glare. (For more discussion on glare, see Section 2.3).

Equation 1.0. Glare calculation

$$Glare = \sum_{i=1}^{n} \frac{\overbrace{L_{si}^{\exp}}^{\text{Luminance of Glare Source}} \; \overbrace{\omega_{si}}^{\text{Size of Glare Source}}}{\underbrace{L_{b}^{\exp}}_{\text{Scene Luminance}} \; \underbrace{P_{i}^{\exp}}_{\text{Position Index}}}$$

Source: Jakubiec, Alstan and Christoph Reinhart, “The Use of Glare Metrics in the Design of Daylit Spaces: Recommendations for Practice”, 9th International Radiance Workshop; September 20-21, 2010.

Energy use and Aesthetics

Energy use and aesthetics are both side-effects of outdoor lighting. These factors do not have their own associated metrics.

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[11] IES RP-28-07 *Lighting and the visual environment for senior living*, 2007, p.1
[12] IES RP-33-14, p.1

1.2 How is outdoor lighting governed?

Outdoor lighting in the United States, generally, does not have any hard and fast requirements for design. Municipalities can elect to adopt certain standards or implement their own, but more often, outdoor lighting is based on its context and some degree of interpretation.

1.2.1 Guiding standards

There are several organizations that publish lighting standards that can be used to design and evaluate lighting. The major entities are the Illuminating Engineering Society (IES) and the International Commission on Illumination (CIE). Both publish recommendations, often on the same topics, however, it should be noted that the IES, sometimes referred to the IESNA (Illuminating Engineering Society of North America) predominates in the United States. The standards, technical manuals and recommended practices produced by the IES and CIE are developed by committees consisting of experts in the field. They provide guidance for target light levels and limits for metrics like light trespass. Exceeding these limits will result in over-lighting, energy misuse, unwanted light, potentially significant adverse aesthetic impacts and a substantial percentage of affected persons finding the visibility unacceptable.

In addition, other organizations like LEED and the IDA (International Dark-Sky Association) have published information which sets targets for certain aspects of outdoor lighting. Of these, the relevant publications are:

- IES RP-33-14 Lighting for Exterior Environments, 2014
- CIE 150 2017 Guide on the limitation of the effects of obtrusive light from outdoor lighting installations, Second Edition, 2017
- LEED v4.1 Light Pollution Reduction Credit
- IDA Criteria for Community-Friendly Outdoor Sports Lighting v1.0, November 28, 2018
- Joint IDA-IES Model Lighting Ordinance, 2011
- California Energy Commission TITLE 24, PART 6, AND ASSOCIATED ADMINISTRATIVE REGULATIONS IN PART 1, Section 130.2 Outdoor Lighting Controls and Equipment
- California Green Buildings Standards Code, Title 24, Part 11 5.106.8

In addition, there are two additional relevant references:

- IES RP-6-1 Sports Lighting, 2015
- IES TM 18-18 Light and Human Health, 2018

1.3 How is lighting measured?

While we are all familiar with lighting in many ways, many of us are not familiar with the technical ways in which lighting is characterized, particularly outdoors.

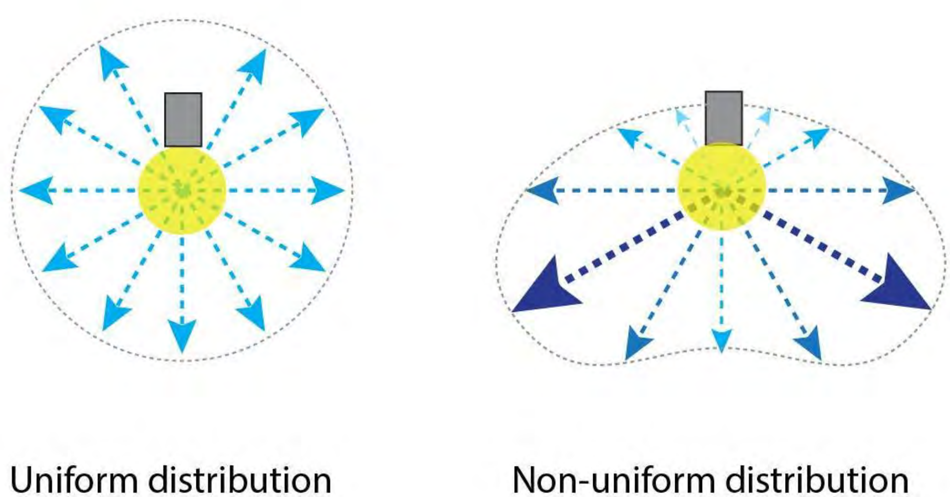
Lighting Zones and the MLO

Because outdoor areas range from nature reserves to places like Times Square, it is first important to characterize the zone in which a project is located. The IES and the IDA developed the "Model Lighting Ordinance" which classifies outdoor nighttime environments into lighting zones 0-4, with LZ0 being a location in which describes the darkest environments (nature preserve), and LZ4 beings the most intensive use of lighting (e.g. Times Square) (see Appendix 1). Once a zone is established for a project, recommendations for appropriate light levels follow from there. Note: the CIE uses a similar, but slightly different classification system, and California's Title 24 previously used a system with 4 zones, however it has now accepted the MLO classification system.

Candelas (cd)

Candelas are defined as "the SI unit of luminous intensity. One candela is the luminous intensity [emitted by a light source (e.g. fixture, bulb, lamp)], in a given direction."[13] If the light distribution is uniform, the same candela distribution will be emitted in all directions. If the light distribution is non-uniform, the candelas in each direction will vary. See Figure 4 below for illustration.

Figure 4. Light Distribution



[13] Oxford Languages Search for: definition of "candela", "Google English Dictionary", 2020 Oxford University Press.

Illustration of candelas for uniform and non-uniform distribution light sources

Illuminance (footcandles(fc) or lux(lx))

Illuminance is the quantity of light falling on a surface. Illuminance varies with angle and distance of the receiving surface. In Figure 5 below, the light source is uniform and emits the same candelas in each direction, however, the illuminance will vary (a v. b) depending on where the light is measured.

Figure 5. Illuminance

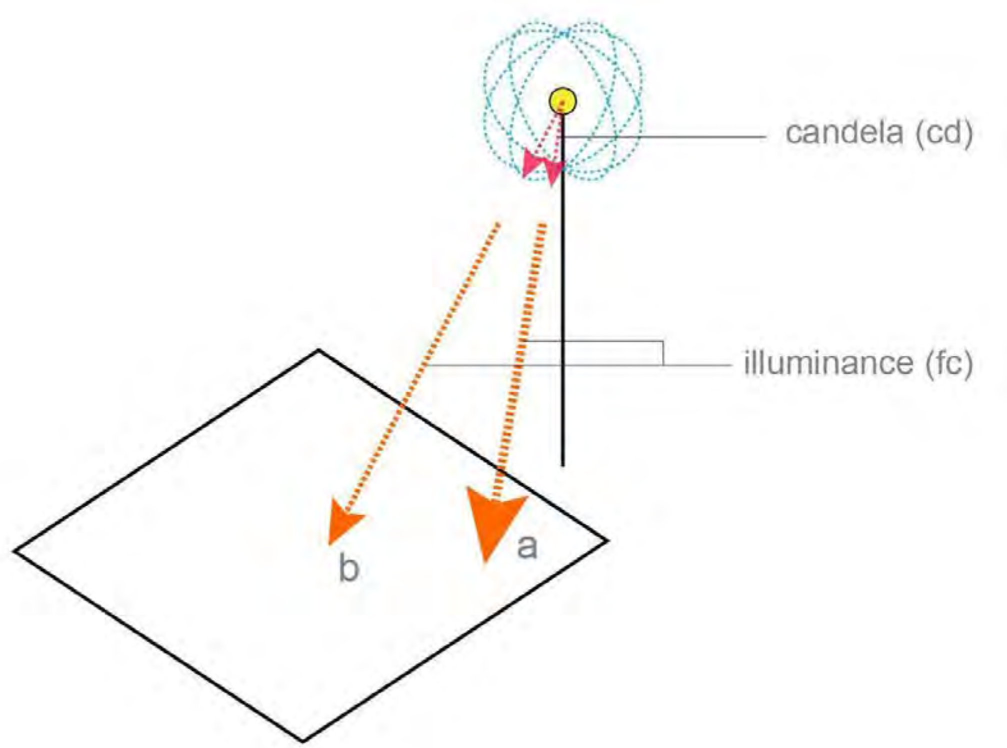


Illustration showing that even while candles are constant,
illuminance can change with distance or angle.
Illustration by author.

Luminance (cd/m^2)

Luminance can be referred to as brightness of a surface (rather than candelas which are sometimes used to qualify glare). Brightness changes with the color (reflectance) of the surface being lit. in Figure 6 below, **the illuminance (b) is the same** for both the white and gray surfaces, but the **luminance (d) is lower for the gray surface than for the white surface (c).**

Figure 6. Luminance

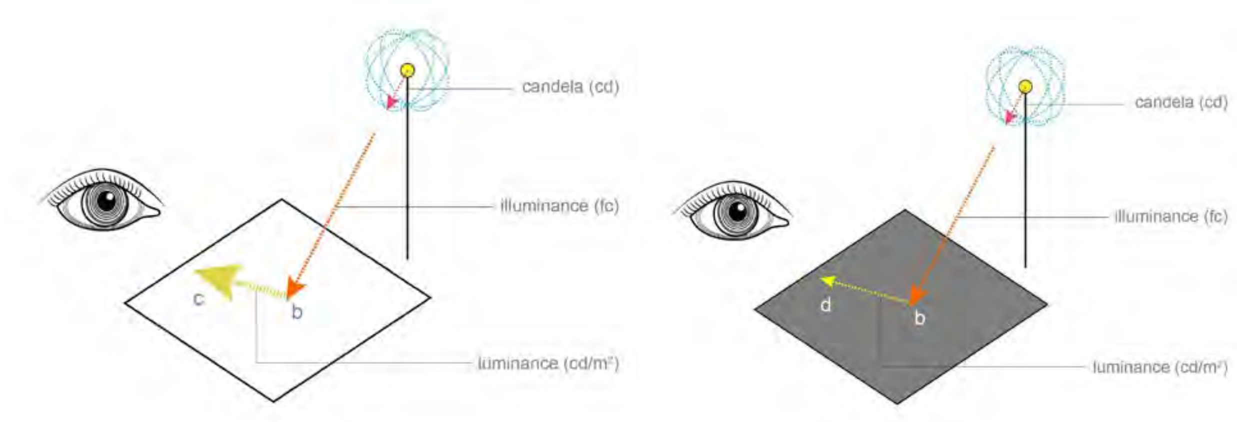


Illustration showing that luminance of two surfaces will change with color, while illuminance remains constant. Illustration by author.

Spectrum, Color Temperature, CCT

While we tend to think of most light as “white”, in reality, light sources can vary in what is called “spectrum” or the color of the light. There is a relationship between ***spectrum and color temperature*** (Figure 7).

Light that appears “cool” tends to have more relative power in the blue part of the visible spectrum. Conversely, light that appears “warm” tends to have more relative power in the yellow and red part of the visible spectrum. LEDs tend to be more blue because their technology makes the bluer range more energy efficient.

Unfortunately, blue light is more triggering for the circadian system, and blue light tends to appear brighter than warmer light of equivalent power (Figure 8).

Figure 7. Color Temperature Scale

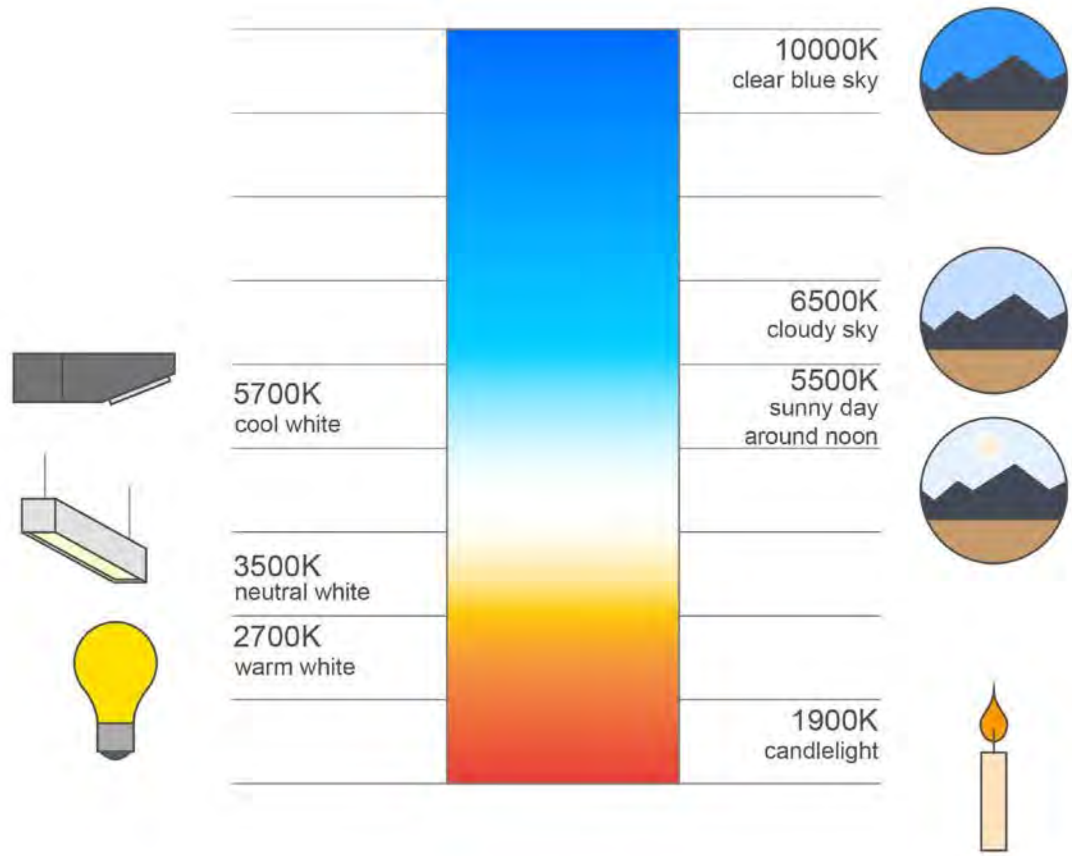
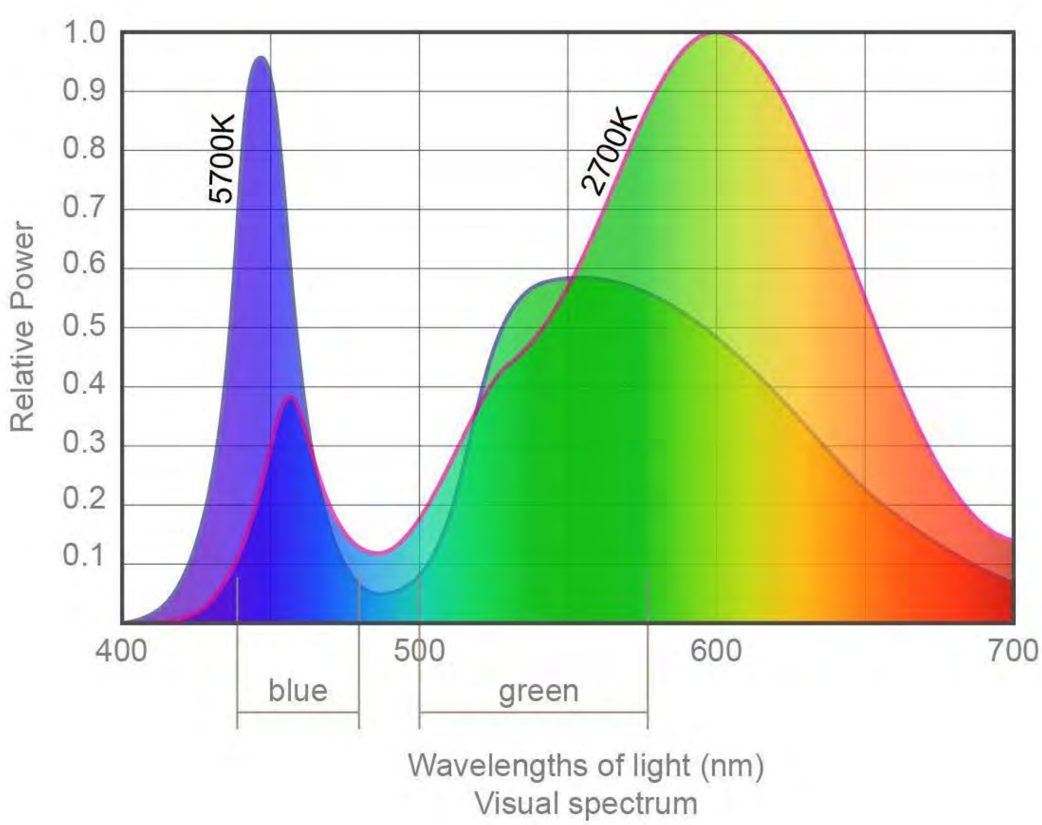


Illustration of color temperatures.
Illustration by author, based on values from https://www.schorsch.com/en/kbase/glossary/cct.html

Figure 8. Visual Spectrum



Notice that the peak of the 5700K source is close to the peak sensitivity of the circadian system shown in Figure 1 in section 1.1.1
Diagram based on: https://www.allthingslighting.org/index.php/2019/02/15/filtered-leds-and-light-pollution/

Angle of measurement

When reviewing lighting calculations, it is important to note that sometimes calculations are measured "horizontally" and sometimes "vertically". This is mostly true when talking about illuminance.

> **Horizontal measurement:** This refers to measuring light on a plane parallel to the ground, such as a sidewalk surface, or a tabletop.
>
> **Vertical measurement:** This refers to measuring light on a plane perpendicular to the ground, such as a wall.

Light is additive

If current light levels on your property are 0.2fc and 0.4fc of additional light are added by a new installation, the new light levels will be 0.6fc, and the light levels will be tripled.

Photometrics

"Photometrics" is a term often used interchangeably to describe two separate things.

- **photometric calculations** are the final "plots" of calculation grids over a project area that show calculations of illuminance, luminance or other metrics.
- **photometric files (a.k.a. "ies files")** are small computer files made for individual luminaires that contain information on the distribution and power of the light emitted in all directions from a source. These files are used in computer models to produce the photometric calculations.

Other factors affecting vision

Several things affect our ability to see. The first is that we need much less light to see in darkness than we do during the day. This is due to how our eyes adjust to lower levels of light, versus higher levels. The classic example of this is when entering or leaving a movie theater, our eyes need to adjust for a short time in order to adapt to either a much lower or much higher level of light. In general, it is inappropriate to light nighttime environments to the same levels we light daytime environments.

Table 2. Typical light levels

Typical light levels	
Moonlight	0.01fc
Typical office lighting	30fc
Daylight (no sun)	2,000-12,000 fc

A second important factor in how we see is age. In general, as we age, we need more light to see, but contrast becomes more significant. Disability glare worsened by very bright sources and reflected light can be of particular issue for older individuals in nighttime environments.

2. Evaluation of Proposed Design

This section reviews the proposed design as presented by Musco in the following documents:

- 2020 Musco Photometrics, St Ignatius Prep School FB/SO
- 2020 Musco photo renditions nighttime SI HS VIEWS_01.07.2020.pdf
- Musco light drawings 7-13-20.pdf
- ! candelas Evolution of Light Control-Musco - Saint Ignatius Light Poles.pdf

2.1 Project Lighting Zone

The project lighting zone is LZ2. This is defined in the Model Lighting Ordinance and referenced in IES RP 33-14 *Lighting for Exterior Environments* as, "areas with moderate ambient lighting levels," and which typically include, "multifamily residential uses, institutional residential uses, schools, churches, hospitals, hotels/motels, commercial and/or business areas with evening activities embedded in predominantly residential areas, neighborhood serving recreational and playing fields and/or mixed use development with a predominance of residential uses,"[14] (see Appendix 1). This designation is the basis for the light level targets and limits cited below, unless otherwise noted.

The IES is the predominant lighting standards organization in the United States.

2.2 Light trespass in proposed design

Table 5 of the IES RP-33-14 *Lighting for Exterior Environments* lists "Maximum Vertical Illuminance at any point in the vertical plane of the property line," (see Appendix 2). The values are organized according to Lighting Zone. On page 15 of Musco's Photometrics ("2020 Musco Photometrics, St Ignatius Prep School FB/SO"), the vertical light levels (measured at 3'-0" above grade), have a maximum of 6.93fc. This is over 20 times what is allowed by the IES.

Table 3. Maximum vertical illuminance - IES standard versus Musco

	IES (LZ2)	Musco Photometrics, p. 15
Maximum Vertical Illuminance at any point in the vertical plane of the property line	0.3fc	6.93fc

Another guideline that can be referenced is LEED (Leadership in Energy and Environmental Design). LEED v4.1's Sustainable Sites, Light Pollution Reduction credit sets a more aggressive maximum illuminance value (see Appendix 3), but instead of measuring the light on a vertical plane (up to 33'-0" high) at the property line, they allow a property adjacent to a street

[14] MLO Task Force, *Joint IDA-IES Model Lighting Ordinance*, 2011, p. 7, and IES RP-33-14, *Lighting for Exterior Environments*, 2014, p. 24-25.

(such as St. Ignatius), to use the street centerline as the location of the vertical plane upon which measurements are taken.[15]

Table 4. Maximum vertical illuminance – LEED standard versus Musco

	LEED (LZ2)	Musco Photometrics, p. 6
Maximum Vertical Illuminance at property line or street centerline	0.1fc	2.6 fc

The project's photometrics show as much as 2.6fc at 0'-0" off the ground, 26 times the limit for LZ2. Clearly, even if LEED is not being pursued, this is an excessive amount of light spilling off of the property and is unnecessarily disruptive to the neighbors and their property.

2.3 Glare in proposed design

Glare is one of the major issues with lighting installations, especially ones like sports lighting where the lights are powerful and prominent. Glare is one of the major complaints that people have about lighting installations.

Musco has presented glare from the design based on maximum candela values, however Musco does not cite a source for the scale they use for their Glare Impact Study. That said, even by their own scale, the project produces a glary environment.

Musco's scale:

- High glare: 150,000cd or more
- Significant glare: 25,000-75,000cd
- Minimal to no glare: 500cd or less

Musco has provided no classification for 500-25,000cd.

According to Musco's calculations, the residences across from the school fall into the "yellow" band which encompasses 1,000-5,000cd which is above their own cut-off for "minimal to no glare", and part of which falls into the non-existing category from 500-25,000cd. Clearly the glare at the properties from the installation is non-negligible.

The IES does not use candelas as a way to evaluate glare, and so, to compare Musco's calculations against a published standard, the CIE 150 2017 Guide on the limitation of the effects of obtrusive light from outdoor lighting installations, Second Edition, can be used (Figure 9).

[15] USGBC, "Light Pollution Reduction - Language," LEED BD+C: New Construction v4.1 - LEED v4.1

Figure 9. Glare angles

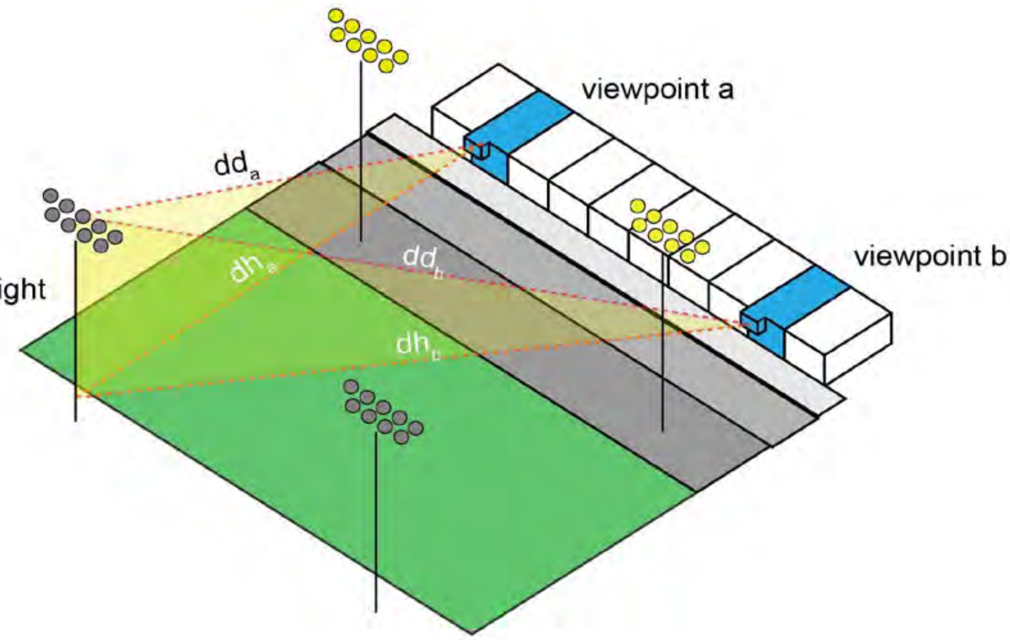


Illustration of CIE 150: 2017, Table 3. Note: not to scale.
Illustration by author.

In CIE 150: 2017, Table 3, “Maximum values for luminous intensity of luminaires in designated directions,” (see Appendix 4) allows users to determine the maximum values for the luminous intensity (cd) of luminaires in designated directions where views of bright surfaces of luminaires are likely to be “troublesome for residents”. This metric takes into account the luminance of the scene (via the lighting zone), the luminance of the source itself (cd), the size of the source (A_p) and the position (d, distance from the observer).

To calculate what the limit on glare is for the houses along 39th Avenue across from the project, we need to determine their distances from the light sources, the area of the luminous part of the light source itself, and then use the table to calculate the maximum candelas.

For this calculation, we can select (2) representative view points, a and b (see Figure 9 above). If the viewpoints from the second story windows are roughly 12’-0” above the ground, the vertical distance becomes: 90ft-12ft =78ft.

We can assume the size of the Musco lights is 0.03 to 0.13 m^2, and the lighting zone is E3 (E2 is shown for comparison), the glare (cd) limit of the luminaire can be calculated as:

Zone E2: Max candela allowed = 5 x distance from light source to the observer (m)
Zone E3: Max candela allowed = 7.5 x distance from light source to the observer (m)

Table 5. CIE Glare standards versus Musco

	Horizontal distance (dh)	Diagonal distance (dd)	CIE Glare limit Zone E2	CIE Glare limit Zone E3	Musco's Glare Impact Report
Viewpoint a	128m	131m	655cd	830cd	1,000-5,000cd
Viewpoint b	164m	166m	982.5cd	1245cd	1,000-5,000cd

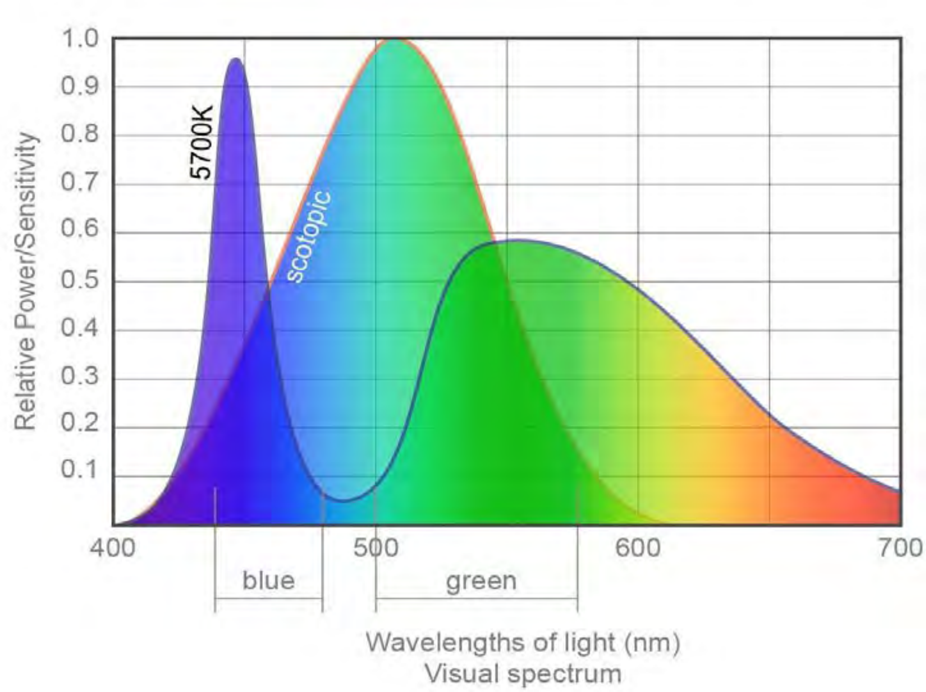
Referring again to Musco's Glare Impact Study, it shows the houses across 39th Avenue from the school as largely falling into the 1,000cd - 5,000cd range, which is much higher than either the E2 or E3 limits.

Other factors regarding glare

Glare is also a factor of the spectrum of the light source. "Discomfort glare, the irritation from bright lights in the field of view, tends to be increased with sources richer in short wavelengths (blue light)."[16] This effect is worsened for seniors and those above age 65.[17]

[16] IES RP-33-14, p. 5
[17] "Light and Vision", IES Ready Reference App, Illuminating Engineering Society, 2020.

Figure 10. Visual Spectrum (copy of Figure 8)



Just as the 5700K color temperature is closer to the melanopic response curve, it is also close to the "scotopic" response curve, which governs vision at low light levels (nighttime).
Illustration by author based on: "Light and Vision", IES Ready Reference App, Illuminating Engineering Society, 2020 and https://www.allthingslighting.org/index.php/2019/02/15/filtered-leds-and-light-pollution/

Other glare metrics

It should also be noted that there are other methods of evaluating glare that could be used to provide a more thorough and complete picture of the project's potential for glare.

Backlight-Uplight-Glare (BUG) Rating Method

The BUG rating method (Figure 11) is used by California's Title 24 & Calgreen, LEED and the MLO (all use the limits set forth by the MLO). This method uses the photometric files of each light source (aka .ies files) and evaluates the quantity of light (in total number of lumens) being emitted from a source in various directions. For the Backlight and Glare portions of the metric, the rating takes into account the height of the fixture and the distance to the property line.

Musco has not provided the .ies files for their fixtures, so it is not possible to independently evaluate the design based on BUG ratings. However, from the perspective of glare, given the wattage of the luminaires, their heights and the distances from the property line, it is unlikely that the design would comply with the limits set forth in the IES.

Figure 11. BUG ratings

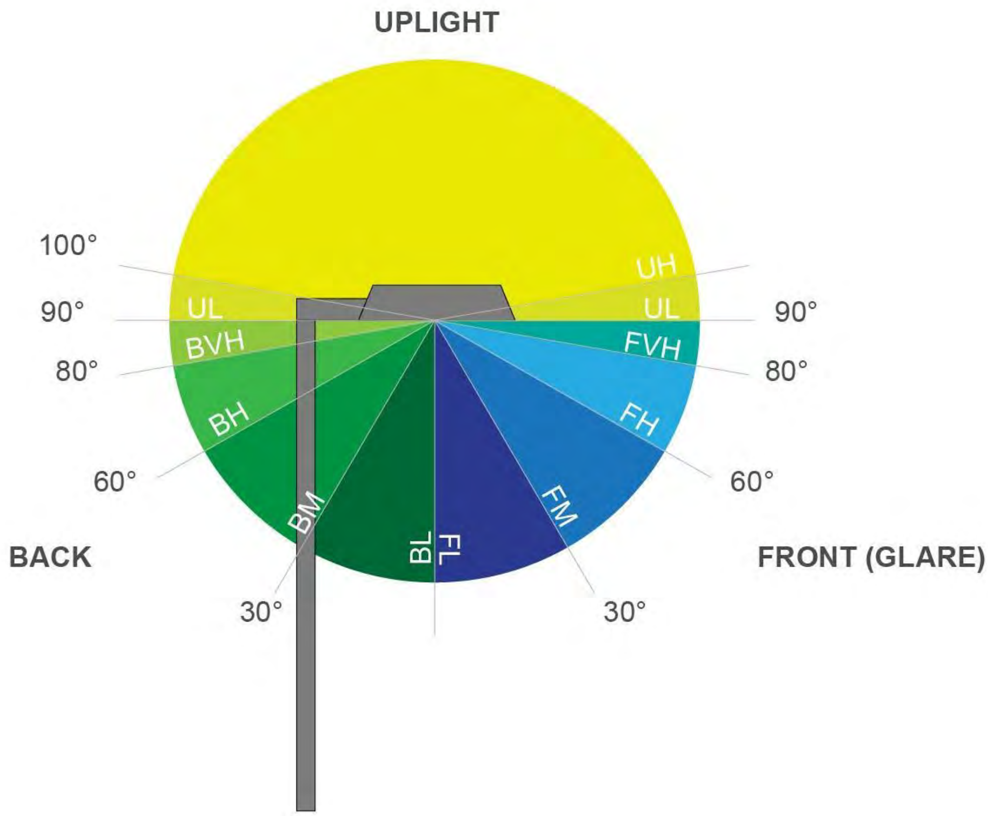


Illustration of BUG rating
Illustration by author.

Calculated glare metrics

Glare is a complex phenomenon and maximum candelas may not entirely encompass. Current technology and software, including the use of HDR images (computer generated or photographed) can be used to conduct view-based analysis to determine the potential for glare more accurately. Programs such as Evalglare (via Radiance) can be used to calculate various metrics including: CGI (CIE Glare Index), VCP (Visual Comfort Probability), and UGR (Unified Glare Rating, a simplification of CGI).[18]

This is not cost prohibitive, and should be considered for a more complete evaluation of the potential for glare in the project, as well as a possible tool for making improvements to the design.

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[18] Note, the metrics cited are specifically applicable to "artificial light sources". Jakubiec, Alstan and Christoph Reinhart ""The Use of Glare Metrics in the Design of Daylit Spaces: Recommendations for Practice," 9th International Radiance Workshop; September 20-21, 2010.

Why does this matter?

Glare can make it hard to see while outdoors, and hard to sleep indoors if a strong light is shining into a bedroom window. It is also unsightly and contributes to overall light pollution.

2.4 General Light Levels at adjacent properties

It should not go without notice that the current environment in the Sunset Neighborhood, adjacent to St. Ignatius, is a relatively low-light environment. There are some street lights, but the low-density housing and open space and nearby ocean leave the neighborhood in relative darkness, not unlike many other neighborhoods in San Francisco.

While light trespass limits help to understand how much light is spilling from the project onto adjacent property, it does not tell the whole story. The IES provides guidelines for what light levels should be targeted so that the majority of users feel the lighting is visually acceptable.

Because it is not necessary to light all parts of a property, the IES only provides recommendations for certain areas, for example pathways. This is important because it is both atypical and not desirable to light all areas around a house (for instance, the front lawn). The IES provides this in RP-33-14, Table 2b: Illumination Values under the designation “Paths to curb,” (see Appendix 5).

Table 6. IES acceptable light levels versus Musco

Paths to curb-low activity (i.e. sidewalks from front door to street)	IES	Musco Photometrics, pp. 11, 12
Horizontal	0.1fc avg	0.33fc
Vertical	0.1fc avg	0.42fc

Musco is showing light levels 3-4 times what is recommended in an LZ2 residential environment.

Why does this matter?

As with the light trespass values, the Musco photometrics show that the installation will significantly impact the light levels for residents, especially those directly across the street from the school. This installation is dramatically changing the character of the neighborhood, particularly for those properties directly across the street. What was once a generally low-light neighborhood is being transformed into a much higher-light-level environment.

2.5 Sports field light levels

The Musco field is currently overlit for the class of play. St. Ignatius has stated an anticipated 800-1,500 spectators for football games. According to IES RP-6-15, high school competition play with facilities up to 2000 spectators falls into Class III play. The IES sets a light level of 30fc average for Class III football and soccer (see Appendix 6). Musco's photometrics show an average of more than 50fc on the field.

The IES RP-6-15 *Sports and Recreational Area Lighting* sets illumination targets for play based on **skill level** and **number of spectators**. This is because, "illuminance is determined by the lighting required for the spectators seated farthest from the playing area. This condition may require several times the illuminance level found to be sufficient to the sport."[19]

According to the IES RP-6-15, Table 2: Class of Play (see Appendix 6):

Class III: High school, facilities with spectator capacity under 2,000
Class IV: High school, facilities with limited or no provision for spectators

In addition, during the other vast majority of times when the field will be used for practice with few or no spectators, light levels should be even lower, at Class IV play.

Table 7 below shows the IES target average illumination levels for Class III and IV football and soccer play (see Appendix 6), as well as Musco's designed average.

Table 7. IES sports field light levels versus Musco

	IES Class III Football and Soccer	IES Class IV Football and Soccer	Musco Photometrics, p. 2
Target Average Illumination Levels	30fc avg	20fc avg	54.71fc avg

Why does this matter?

The current design is overlighting the area. Significant improvements to the project can be made by revising the design to meet the appropriate lighting targets, and by providing a system where light levels can be reduced to the appropriate light level depending on class of play. By reducing the overall field light level, the other lighting metrics will be decreased as well. These include glare, light trespass, and the potential negative effects on health.

2.6 Light Pollution/Sky glow

Completely absent from Musco's presentation of the design is any consideration or quantifiable evidence of the effect of the installation on light pollution (sky glow). In general, an evaluation of

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[19] IES, RP-6-15 *Sports and Recreational Area Lighting*, 2015, p. 8.

light pollution, through a calculation of “uplight”, or light emitted above horizontal, is missing entirely from the report. The IES, Title 24, LEED and the CIE all provide some criteria upon which uplight can be quantified, and it is important that Musco provide evidence of the performance of their installation via photometric reports.

It is also important to note here that any calculation of uplight must take into account the angle at which the fixtures will be aimed upon installation. A particular fixture .ies file may show light above horizontal, but if the fixtures are then tilted, light above horizontal may be emitted.

Why does this matter?

While stargazing and the health of plants and animals may not be the primary concern for this project, it does not mean that the project will not have an adverse effect on this. So far, insufficient attention has been given to the impacts of the project on light pollution, and yet it must be considered as a factor. Light pollution is a significant concern in the effort to conserve our natural environment.

2.7 Light, health and schedule

The SI project must be carefully considered because it affects several factors that are important in resetting the circadian clock: ***quantity, spectrum, timing and duration.***

Quantity: The installation is adding a significant amount of additional light to the area.

Spectrum: The light is a cool-blue-enriched white (5700k) at which the circadian system is more sensitive.

Timing: The residents will be exposed to the lighting after dark

Duration: the lighting will be on regularly for hours at a time. The school is planning on using the lights 150 nights of the year, until 8:30 or 9:00 pm. More or less, this is the entire school year (September through May), and nearly 5 days a week. Based on when the sun sets, this means that the lights will be on between 2 and 4 hours every night of the school year.

Given that many residents likely have young children, who go to bed earlier than when the lights are scheduled to be turned off, this effectively eliminates darkness for their evenings.

Why does this matter?

As stated in the introduction the reduction of darkness at night has the potential to disrupt sleep, keep people awake and may have a direct negative impact on human health. The project should look at alternatives for minimizing the impacts of the lighting installation on the environment and consider the health of the neighborhood residents.

3. Conclusion

I disagree with St. Ignatius and Musco that the impacts of the lighting installation will not be significant. The analysis above shows that the project:

- Exceeds IES limits for light trespass
- Exceeds CIE limits for glare
- Exceeds IES recommendations for light levels near the residences
- Exceeds IES recommendations for Class III competitive play for a lower light level
- Fails to characterize the light pollution and uplight of the project

In my opinion, the foreseeable light pollution caused by the project, as demonstrated by the exceedances of the IES and CIE limits discussed above, is significant. The project will fundamentally change the nature of the neighborhood environment, particularly the residences across the street from the project. The project will adversely affect the aesthetics of the neighborhood by increasing glare and light pollution in the area. The quantity, timing, spectrum and duration of the lighting installation will have a deleterious effect on numerous environmental factors, especially the potential for sleep disruption and overall darkness of the environment.

The project proposal by Saint Ignatius and Musco has failed to adequately provide alternative solutions that will mitigate the most negative aspects of the installation. In several cases, the materials provided were insufficient or inadequate to confirm, independently that all steps have been taken to minimize negative impacts on the neighborhood. In the case of the renderings, the materials were misleading and were not produced in a way in which any reasonable conclusions could be drawn. In sum, the incomplete information provided makes it impossible to determine the extent of light pollution that will occur or what types of mitigation or alternatives could be utilized to avoid or substantially lessen the significant light pollution impacts that are likely to occur.

I recommend the study be revised and re-presented to include the following:

1. Provide .ies files and fixture cut sheets for independent verification/study of design proposal, and for confirmation that the fixtures are as well shielded as possible.
2. Provide aiming angles for the fixtures
3. Provide analysis of uplight caused by lighting
4. Provide information on the purpose and distribution of the lights at the different heights shown in Musco's drawing, particularly the ones at 16 and 65ft
5. Conduct a thorough visual analysis using computer software of the overall luminance and potential for glare from the perspective of the residents
6. Revise calculations to meet IES Class III sports lighting levels and provide ability to reduce further during Class IV play
7. Explore options for reducing the quantity of time and/or number of days in which the installation is used

Please feel free to contact me with any questions.

Signed,

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EXPERIENCE

August 2020-present — **Atelier Fos**, Alameda, CA | Principal and Owner
Founder of independent daylighting and lighting consultancy

June 2015-May 2020 — **Integral Group, Inc.** Oakland, CA | Principal, Daylighting + Lighting
- Daylighting + Lighting team leader for the US West region
- Managed a team of 4 and over 30 active projects
- Lead Daylighting consultant for the US West region responsible for leading all work and directing simulations
- 10+ Net Zero Energy, 2 WELL and 15+ LEED (7 Platinum) lighting projects
- Project sizes ranging from 50,000 to 1,500,000 sq. ft.
- Daylighting design for complex facade and atrium conditions; landscape and exterior projects using daily illuminance values; glare analysis; glazing and shading recommendations; and daylighting for health and wellness
- Integrated design work with the building performance and sustainability teams to balance energy use and performance with daylighting performance
- Lighting and daylighting controls development
- Delivery of full lighting project documentation, specification, QA/QC and construction administration
- Proposal writing and business development
- Budgeting, forecasting, backlog, work planning

Aug 2009-May 2016 — **Solemma, LLC (DIVA-for-Rhino)** Cambridge, MA | CMO, Co-Founder and Developer
- Original team member and core code developer
- Chief Marketing Officer responsible for external relations and website management

Aug 2010-May 2015 — **Lam Partners, Inc.** Cambridge, MA | Lighting Designer and Project Manager
Project Manager and designer for over two dozen local, national and international projects ranging from sculptures to 200,000 square foot laboratories
- Concept design and presentation
- Project development and documentation
- Construction Administration including site visits for aiming
- Project management including budgeting and management of deliverables
- LEED documentation for daylighting and sustainable sites credit
- Advanced simulation of lighting and daylighting strategies

Mar 2008-Jul 2008 — **TEN Arquitectos** Mexico City, Mexico | Architectural Designer
Designer, modeler, and renderer

Jan 2008-Mar 2008 — **Celula Arquitectura** Mexico City, Mexico | Architectural Designer

Designer for the New Sustainable Convention Center in Cabo San Lucas Competition

Oct 2007-Jan 2008 **Machado Silvetti and Associates** Boston, MA | Architectural Designer
Team designer working on a new museum

Jan 2004 – May 2005 **Royer Architects** Newton, MA | Architectural Designer
Principal assistant to the architect for numerous new and renovation residential projects

Apr 2003-Dec 2003 **Community Design Partnership** Boston, MA | Urban Planner
Research and design support for community development plans and urban plans

Aug 2001-Apr 2003 **Kenyon C. Bolton III and Associates** Cambridge, MA | Architectural Designer
Designer for small high-end residential architectural firm

EDUCATION

Fall 2005-Spring 2010 **Harvard University Graduate School of Design** Cambridge, MA
Masters of Architecture, 2010
Thesis | *Architectural Prestidigitation*
Advisor and Reader | Eric Höweler and Eve Blau

Fall 1997-Spring 2001 **The University of Michigan** Ann Arbor, MI
BA in the History of Art, Summa Cum Laude with Highest Honors, 2001
Thesis| *Rafael Moneo: The Architectural Event*, Advisors| Robert Levit, Diane Kirkpatrick

AWARDS

IES Award of Merit, 2020
Half Moon Bay Library, Half Moon Bay, CA

Lighting Magazine 40 Under 40, 2018
International and North America

AL Design Awards, 2017 – Best Use of Daylighting
Baylor University Paul L. Foster Campus for Business and Innovation

IES Award of Merit, 2016
Potamus Trading, Boston, MA

PROFESSIONAL AFFILIATIONS

LEEDUser Expert
Interior Lighting Credit

International Association of Lighting Designers
Associate IALD

Leadership in Energy and Environmental Design (LEED)
LEED BD+C Accredited Professional

PUBLICATIONS / LECTURES

May 2020 **Light and Health in Buildings**
IG Vision Webinar

March 2018 **Lighting the Way to Net-Zero Buildings**
Presented with Sara Lappano
Lightfair International 2018, Chicago, IL

November 2017 **Advanced Lighting Controls – Net Zero Energy Lighting**
Pacific Energy Center

November 2015 ***Light + Health, Research and Practice***
Presented with Celine Vetter and Dieter Lang
ABX Architecture Boston Expo, Boston, MA
Is it worth it? Defending Shading Strategies on your Project
Presented with Alejandra Menchaca and Rufei Wang
ABX Architecture Boston Expo, Boston, MA

August 2015 ***Integrating shading, lighting and glare - Achieving reliable results for clients***
14th International Radiance Workshop, Philadelphia, PA

November 2013 ***Media and Architecture Integration: New Territories for Lighting and Architecture***
Presented with Robert Osten
ABX Architecture Boston Expo, Boston, MA

August 2013 ***Early Phase Simulations & DIVA Demo***
12th International Radiance Workshop, 2013, NREL, Golden, CO

May 2012 ***New Modeling Methods in Daylighting Analysis***
Co-presented with Alstan Jakubiec and Jeff Niemasz
Lightfair 2012, Las Vegas, NV

August 2010 ***Animated Building Performance Simulation (ABPS) –***
Linking Rhinoceros/Grasshopper with Radiance/Daysim
Publication in the Proceedings of SimBuild 2010, New York City, NY
8th International Radiance Workshop, 2009, Cambridge, MA

2012-present **Guest Lecturer and Critic**
Harvard University Graduate School of Design, Cambridge, MA
Boston Architectural College, Boston, MA
MASS College of Art and Design, Boston, MA
UC Berkeley, Berkeley, CA
UCSF, San Francisco, CA
Pacific Energy Center, San Francisco, CA

PROJECT LIST

*Indicates Lead Designer and Lighting Project Manager

ACADEMIC/INSTITUTIONAL

Amherst College New Science Center
Amherst, MA
Behnisch Architekten

The Boston Conservatory
Boston, MA
Utile

Boston Public Library, Jamaica Plain Branch
Boston, MA
Utile

Brown University – Power Station Renovation
Providence, RI
Gensler

Charles River Associates
Boston, MA
Elkus Manfredi Architects

Colgate University Admissions Building
Hamilton, NY
Sasaki Associates, Inc.

Confidential Educational Project*
Loomis, CA
Lake | Flato Architects

Contra Costa Community College
New Science Building*
Smith Group
San Pablo, CA

Dechert Boston
Boston, MA
HOK

Diablo Valley College Kinesiology and Art Buildings*
Pleasant Hill, CA
HMC Architects

Half Moon Bay Library*
Half Moon Bay, CA
Noll & Tam
IES Award of Merit Winner, 2020

Northern Essex Community College
Lawrence, MA
Miller Dyer Spears

Oakland USD Commissary*
Oakland, CA
Cody Andersen Wasney

Presidio Knolls School*
San Francisco, CA
Studio Bondy

Piedmont USD STEAM and Theater Buildings*
Piedmont, CA
HKIT

Rainbow Recreation Center*
Oakland, CA
Byrens Kim

Sacred Heart School*
Atherton, CA
WRNS

UC Merced Downtown Campus*
Merced, CA
Heller Manus

UCSD Pepper Canyon*
San Diego, CA
Safdie Rabines Architects

Westfield State University Dorm
Westfield, MA
ADD, Inc. (now Stantec)

The Westminster Schools
Campbell Hall, Westminster Center Phase 1,
Stadium and Plaza

Atlanta, GA
Ennead

CIVIC + COURTHOUSE
Atherton Police Station and Civic Center*
Atherton, CA
WRNS

Elk Grove Community and Senior Center*
Elk Grove, CA
Group 4 Architects

Salem Probate and Family Court
Salem, MA
Perry Dean Rogers

COMMERCIAL
CBRE Offices
Boston, MA
Elkus Manfredi Architects

Confidential New Company Headquarters*
Vancouver, MA
Morphosis

Confidential New Office Building*
Redmond, WA
WRNS

Dudley Square Municipal Building
Boston, MA
Sasaki Associates, Inc.

East Bay Municipal Utility District*
Oakland, CA
EBMUD

Grande Cheese
Fond-du-Lac, WI
Overland Partners

Alameda County Information
Technology Department*
Oakland, CA
Komorous Towey Architects

Intuit Mountain View*
Mountain View, CA
WRNS

Loomis Sayles
Boston, MA
Gensler

Interface Global Headquarters
LEED and WELL Lighting Consultant*
Atlanta, GA
Perkins + Will

Nonprofits Insurance Alliance of California*
Santa Cruz, CA
EHDD

Potamus Trading
Boston, MA
Elkus Manfredi
IES Award of Merit Winner, 2016

WS Development
Chestnut Hill, MA
Elkus Manfredi Architects

HEALTHCARE
Paradise Valley Estates Senior and Memory Care*
Fairfield, CA
Perkins Eastman

LANDSCAPE
2060 Folsom*
San Francisco, CA
Mithun

Grande Cheese
Fond-du-Lac, WI
Overland Partners

Intuit Mountain View*
Mountain View, CA
WRNS

Maceo May Apartments*
Treasure Island, CA
Mithun

Pier 70 Building E2*
San Francisco, CA
MBH and Kennerly Architects

Nonprofits Insurance Alliance of California*
Santa Cruz, CA
EHDD

South San Francisco Caltrain Station
Pedestrian Plaza and Tunnel*
South San Francisco, CA
SWA Group

UCSD Pepper Canyon*
San Diego, CA
Safdie Rabines Architects

The Westminster Schools
Campbell Hall, Westminster Center Phase 1,
Stadium and Plaza
Atlanta, GA
Ennead

RESIDENTIAL

1700 Webster*
Oakland, CA
Perkins + Will

2060 Folsom*
San Francisco, CA
Mithun

Altamira Apartments*
Sonoma, CA
Pyatok Architects

Caritas Village*
Sonoma, CA
Pyatok Architects

Camp Southern Ground*
Fayetteville, GA
Perkins + Will

The Laureate*
Berkeley, CA
Pyatok

Maceo May Apartments*
Treasure Island, CA
Mithun

Paradise Valley Estates Senior and Memory Care*
Fairfield, CA
Perkins Eastman

Pier 70 Building E2*
San Francisco, CA
MBH and Kennerly Architects

Stanford University Faculty Housing*
Palo Alto, CA
Lum Architects

LABORATORY

CCC New Science Building
San Pablo, CA
Smith Group

LBNL Integrated Genomics Lab*
Berkeley, CA
Smith Group

Quest Diagnostics
Marlborough, MA
Gensler

Santa Rosa Junior College
New Science Building
Santa Rosa, CA
Smith Group

MUSEUM, GALLERY AND SCULPTURE

205 Alice Street*
Oakland, CA
Amato Architects

American Civil War Museum
Richmond, VA
Baskervill

Marriott Lobby Sculpture
New Delhi, India
Nikolas Weinstein

Peirce Hill
Singapore
Nikolas Weinstein

San Francisco Public Safety Building
Fallen Officer's Memorial
San Francisco, CA
Shimon Attie

Stubbs Road
Hong Kong
Nikolas Weinstein

RETAIL
Market Basket #66
Hooksett, NH
Prellwitz/Chilinski Associates, Inc.

URBAN and FAÇADE
Liberty Mutual Headquarters
Boston, MA
CBT/Childs Bertman Tseckares, Inc.

New Orleans Arena Façade Lighting
New Orleans, LA
Eskew Dumez + Ripple

New York Port Authority Bus Terminal
New York, NY
A2a Media

TRANSPORTATION
Greenville-Spartanburg Int'l Airport
Terminal Improvement Program
Greer, SC
Gensler

South San Francisco Caltrain Station
Pedestrian Plaza and Tunnel*
South San Francisco, CA
SWA Group

DAYLIGHTING

Arizona State University
Tempe, AZ
KPF

Baylor University
Paul L. Foster Campus for
Business and Innovation
Waco, TX
Overland Partners
A|L Awards Best Use of Daylighting, 2017

Cholera Treatment Center Pavilions*
Port-au-Prince, Haiti
MASS Design Group

Confidential New Company Headquarters*
Vancouver, MA
Morphosis

Confidential New Office Building*
Redmond, WA
WRNS

Confidential Office Building Renovation/Expansion*
Silicon Valley, CA
WRNS

Denver Water*
Denver, CO
RNL Architects

Harker School
San Jose, CA
Studio Bondy

Martin Luther King School*
Net Zero Energy Target
Cambridge, MA
Perkins Eastman

Oakland USD Madison*
Oakland, CA
Byrens Kim

Regen Projects Gallery
Los Angeles, CA
Michael Maltzan Architects

Ross School of Business – Phase 2
Ann Arbor, MI
KPF

Snowmass Condominiums*
Snowmass, CO
4240 Architecture

UMass Lowell Student Center
Lowell, MA
Perkins + Will

Appendix 1

Lighting Zone Definitions

IES Outdoor Environmental Lighting Committee, *Lighting for Exterior Environments*, RP-33-14. New York: Illuminating Engineering Society, 2014.

Lighting for Exterior Environments

Publication of this Recommended Practice
has been approved by IES.
Suggestions for revisions
should be directed to IES.

Prepared by:
The IES Outdoor Environmental Lighting Committee

Lighting zones are best implemented as an overlay to the established zoning especially in communities where a variety of zone districts exist within a defined area or along an arterial street. Where zone districts are cohesive, it may be possible to assign lighting zones to established land use zoning. It is recommended that the lighting zone includes churches, schools, parks, and other uses embedded within residential communities.

Lighting zones help communities minimize the contrast (and conflict) between extremes in lighting such as a brightly lighted car dealership adjacent to or within line of sight to a residential neighborhood, or a lighted sports facility in the middle of a residential neighborhood. Lighting zones may also determine restrictions on outdoor lighting that impact "places of sleep" such as residential areas, hospitals, and long term care facilities. Lighting zones may also employ vertical distinctions such as in mixed use facilities where the commercial aspects are on the street with residential units on the higher levels. Zones also encourage minimal changes in visual adaptation when traveling from site to site.

However, if an adjacent use could be adversely impacted by allowable lighting, the adopting authority may require that a particular site meet the requirements for a lower lighting zone. For example, the authority could specify Lighting Zone 1 or 2 requirements if a commercial development were adjacent to a residence, hospital or open space, or to any land assigned to a lower zone.

Community involvement is important in determining lighting zone issues, such as whether and how to light churches, schools, ice rinks, or playing fields. Among the factors that should be considered are neighborhood ambient conditions, lighting expectations, special environmental concerns, and how interior lighting may affect the exterior environment. Curfews and controls are appropriate for all lighting zones, and should be specified.

2.5.1 Lighting Zone Definitions Because identifying the appropriate outdoor lighting zone is a matter of judgment and consensus, there is no means of determining which zone is appropriate for a given area. The same type of lighting application may fall into different lighting zones in different jurisdictions or using different standards. As used in the *Joint IDA-IES Model Lighting Ordinance (MLO)*, the lighting zones are defined with suggested uses as follows:

- **LZ0:** No ambient light
  Areas where the natural environment could be seriously and adversely affected by small amounts of electric lighting at night. This includes biological cycles of flora and fauna, and human enjoyment and appreciation of the natural environment. The vision of human residents and users is adapted to the total darkness, and they do not expect to see electric lighting. Human activity is sparse and is subordinate in importance to the natural environment. There is no expectation for electric lighting. Although some lighting is allowed, it is required to be controlled.

LZ-0	Lighting Zone 0 should be applied to areas in which permanent lighting is not expected and when used, is limited in the amount of lighting and the period of operation. LZ-0 typically includes undeveloped areas of open space, wilderness parks and preserves, areas near astronomical observatories, or any other area where the protection of a dark environment is critical. Special review should be required for any permanent lighting in this zone. Some rural communities mav choose to adopt LZ-0 for residential areas.	Recommended default zone for wilderness areas, parks and preserves, and undeveloped rural areas. Includes protected wildlife areas and corridors.

- **LZ1:** Low ambient light
  Developed areas within a natural environment and areas of human activity that are inherently dark at night. Electric lighting at night could adversely affect the biological cycles of flora and fauna, or could interrupt the quiet, dark character of the area. The vision of human residents and users is adapted to the low light levels, and they do not expect to see electric lighting except where absolutely necessary to improve visibility and safety. In these limited areas, low light levels are appropriate. Lighting is expected to be non-continuous (i.e., pools of light rather than uniform lighting along a path or roadway). After curfew, both light levels and uniformity may be reduced in some areas.

LZ-1	Lighting Zone 1 pertains to areas that desire low ambient lighting levels. These typically include single and two family residential communities, rural town centers, business parks, and other commercial or industrial/ storage areas typically with limited nighttime activity. May also include the developed areas in parks and other natural settings.	Recommended default zone for rural and low density residential areas. Includes residential single or two family; agricultural zone districts; rural residential zone districts; business parks; open space include preserves in developed areas.

Figure 11: Parking Lot located in a Lighting Zone 1 community. Aspen, CO. (Image courtesy of N. Clanton)

› **LZ2:** Moderate ambient light
Areas of human activity (i.e., habitation, recreation and/or work) where electric lighting may be required for safety and convenience at night. The vision of human residents and users is adapted to moderate light levels, and they have moderate expectations of electric lighting. Lighting is expected to be non-continuous (e.g., pools of light at crosswalks or intersections, rather than uniform lighting along a path or street). After curfew, both light levels and uniformity may be reduced in some areas as activity levels decline.

LZ-2	Lighting Zone 2 pertains to areas with moderate ambient lighting levels. These typically include multifamily residential uses, institutional residential uses, schools, churches, hospitals, hotels/motels, commercial and/or businesses areas with evening activities embedded in predominately residential areas, neighborhood serving recreational and playing fields and/or mixed use development with a predominance of residential uses. Can be used to accommodate a district of outdoor sales or industry in an area otherwise zoned LZ-1.	Recommended default zone for light commercial business districts and high density or mixed use residentialdistricts. Includes neighborhood business districts; churches, schools and neighborhood recreation facilities; and light industrial zoning with modest nighttime uses or lighting requirements.

Figure 12: Parking Lot in LZ 2 - Fully shielded, uniform distribution. Anchorage, AK (Image courtesy of N. Clanton)

› **LZ3:** Moderately high ambient light
Areas of human activity (i.e., habitation, recreation and/or work) where electric lighting may be continuous and is required for safety and convenience at night. The vision of human residents and users is adapted to moderately high light levels, and they have moderate to high expectations of electric lighting. Lighting is expected to be continuous (e.g. lighting delivered fairly evenly along the length of a path or street). After curfew, both light levels and uniformity may be reduced in some areas as activity levels decline.

LZ-3	Lighting Zone 3 pertains to areas with moderately high lighting levels. These typically include commercial corridors, high intensity suburban commercial areas, town centers, mixed use areas, industrial uses and shipping and rail yards with high night time activity, high use recreational and playing fields, regional shopping malls, car dealerships, gas stations, and other nighttime active exterior retail areas.	Recommended default zone for large cities' business district. Includes business zone districts; commercial mixed use; and heavy industrial and/or manufacturing zone districts.

Figure 13: A Long Term Care Facility in LZ 3 with well-shielded lighting – no uplight. (Image courtesy of David Roederer)

› **LZ4:** High ambient light
Areas of high levels of human activity at night including significant interaction among pedestrians and/or vehicles. The vision of humans when outside is typically adapted to moderate light levels. Lighting is continuous and is required for safety and convenience. Expectations for man-made lighting are high, both in terms of light levels and uniformity along pathways or streets. However, both light levels and uniformity may be reduced after curfew hours in some areas as activity levels decline.

LZ-4	Lighting zone 4 pertains to areas of very high ambient lighting levels. LZ-4 should only be used for special cases and is not appropriate for most cities. LZ-4 may be used for extremely unusual installations such as high density entertainment districts, and heavy industrial uses.	Not a default zone. Includes high intensity business or industrial zone districts.

Figure 14: Entertainment district in urban area in LZ 4. (Image courtesy of N. Clanton)

Appendix 2

IES Lighting for Exterior Environments,
Table 5: Minimum Vertical Illuminance at any point
in the vertical plane of the property line

IES Outdoor Environmental Lighting Committee, *Lighting for Exterior Environments*, RP-33-14. New York: Illuminating Engineering Society, 2014.

IES RP-33-14

Lighting for Exterior Environments

Publication of this Recommended Practice
has been approved by IES.
Suggestions for revisions
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Prepared by:
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Figure 10: Light Trespass. Decorative globe allows light to spill onto the façade and also into residential windows. (Image courtesy of Clanton & Associates)

underlie any restrictions. Refer to the *Joint IDA-IES Model Lighting Ordinance (MLO)* and *TM-15-11* for limits on luminaire BUG ratings, property line maximum illuminance, and lumen density per lighting zone. Lighting zones and the BUG rating system can provide the basis for restricting the brightness that should be tolerated in a specific environment. Within any category, a curfew time may be established, allowing higher lighting levels during those hours when the curfew is not in effect.

Since light trespass is extremely subjective, there is no single set of values or limits that will work in every situation. The report *IES TM-11-00/R11 Light Trespass: Research, Results and Recommendations*[26] suggests that light trespass can be evaluated by illuminance values measured at the eye in a plane perpendicular to the line-of-sight when looking at the brightest source in the field of view. This report also stresses the subjectivity of the research and how it may be affected by the personalities and desires of different individuals.

While these recommendations serve to reduce serious light trespass, their implementation is not a guarantee against objections. In some situations, such as a sports field in a small park closely surrounded by residences, no methods and combinations of lighting design, aiming, or control can provide for both safe play and satisfy some neighbors' desires for limited light trespass. Consensus solutions involving field locations, curfews to restrict the hours of nighttime use, glare abatement, or landscape screens should be reached by all the parties involved. Refer to **Table 5** below.

Table 5 : Maximum Vertical Illuminance at any point in the vertical plane of the property line. (From Table F *Joint IDA-IES MLO*)

Lighting Zone 0	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
0.05 FC or 0.5 LUX	0.1 FC or 1.0 LUX	0.3 FC or 3.0 LUX	0.8 FC or 8.0 LUX	1.5 FC or 15.0 LUX

2.5 Lighting Zones

Zoning is a well–established practice in community planning. The fundamental idea behind zoning is that it allows a community to determine and regulate appropriate types of use in different areas within its jurisdiction, for example to define acceptable land uses in different areas. Lighting zones, which reflect the base (or ambient) light levels desired by a community, work well with land use zones in setting limits on the type and amount of lighting that can be used in different areas. Using lighting zones allows a great deal of flexibility and customization without the burden of excessive regulation.

The choice of an appropriate lighting zone is a matter of judgment based on community priorities for any given area. It is recommended that the lowest reasonable lighting zone(s) be adopted. Selection of lighting zone or zones should be based not on existing conditions but rather on the type of lighting environments the jurisdiction seeks to achieve. For instance, new development on previously rural or undeveloped land may be zoned as LZ-1.

Appendix 3

LEED v4.1 Light Pollution Reduction
Table 4, Maximum vertical illuminance at lighting boundary, by lighting zone
USGBC, “Light Pollution Reduction,” LEED BD+C New Construction, v4.1, 2020.

Table 4. maximum vertical illuminance at lighting boundary, by lighting zone

MLO lighting zone	Vertical illuminance
LZ0	0.05 fc (0.5 lux)
LZ1	0.05 fc (0.5 lux)
LZ2	0.10 fc (1 lux)
LZ3	0.20 fc (2 lux)
LZ4	0.60 fc (6 lux)

Appendix 4

CIE 150, 2017

Table 3, Maximum values for luminous intensity of luminaires in designated directions

Members of TC 5-28 "Guide on the Limitation of the Effects of Obtrusive Light", *Guide on the limitation of the effects of obtrusive light from outdoor lighting installations, Second Edition*, CIE 150 2017. Vienna: Commission Internationale de L'Eclairage, 2017.

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International Commission on Illumination
Commission Internationale de l'Eclairage
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TECHNICAL REPORT

Guide on the Limitation of the Effects of Obtrusive Light, 2nd Edition

CIE 150:2017

UDC:	628.931	Descriptor:	Artificial lighting: Design and calculation
	628.971		Exterior lighting

Table 3 – Maximum values for luminous intensity of luminaires in designated directions

Light Technical Parameter	Application Conditions	Luminaire group (projected area A_p in m²)				
		$0 < A_p \leq 0{,}002$	$0{,}002 < A_p \leq 0{,}01$	$0{,}01 < A_p \leq 0{,}03$	$0{,}03 < A_p \leq 0{,}13$	$0{,}13 < A_p \leq 0{,}50$
Maximum luminous intensity emitted by luminaire (I in cd)	**Environmental Zone E0** Pre-curfew: Post-curfew:	0 0	0 0	0 0	0 0	0 0
	Environmental Zone E1 Pre-curfew: Post-curfew:	$0{,}29 \cdot d$ 0	$0{,}63 \cdot d$ 0	$1{,}3 \cdot d$ 0	$2{,}5 \cdot d$ 0	$5{,}1 \cdot d$ 0
	Environmental Zone E2 Pre-curfew: Post-curfew:	$0{,}57 \cdot d$ $0{,}29 \cdot d$	$1{,}3 \cdot d$ $0{,}63\, d$	$2{,}5 \cdot d$ $1{,}3 \cdot d$	$5{,}0 \cdot d$ $2{,}5 \cdot d$	$10 \cdot d$ $5{,}1 \cdot d$
	Environmental Zone E3 Pre-curfew: Post-curfew:	$0{,}86 \cdot d$ $0{,}29 \cdot d$	$1{,}9 \cdot d$ $0{,}63 \cdot d$	$3{,}8 \cdot d$ $1{,}3 \cdot d$	$7{,}5 \cdot d$ $2{,}5 \cdot d$	$15 \cdot d$ $5{,}1 \cdot d$
	Environmental Zone E4 Pre-curfew: Post-curfew:	$1{,}4 \cdot d$ $0{,}29 \cdot d$	$3{,}1 \cdot d$ $0{,}63 \cdot d$	$6{,}3 \cdot d$ $1{,}3 \cdot d$	$13 \cdot d$ $2{,}5 \cdot d$	$26 \cdot d$ $5{,}1 \cdot d$

NOTE 1 d is the distance between the observer and the glare source in metres.
NOTE 2 A luminous intensity of 0 cd can only be realized by a luminaire with a complete cut-off in the designated directions.
NOTE 3 For further information, please refer to Annex C.

3.6.5.3 Limitation of the effects on transport systems

Limits apply where users of transport systems are subject to a reduction in the ability to see essential information. Table 4 gives values that are for relevant positions and for viewing directions in the path of travel.

Table 4 – Maximum values of threshold increment and veiling luminance from non-road lighting installation

Light Technical Parameter	Road Classification[1]			
	No road lighting	M6 / M5	M4/ M3	M2 / M1
Veiling luminance[2] (L_v)	0,037 cd/m²	0,23 cd/m²	0,40 cd/m²	0,84 cd/m²
Threshold increment	15 % based on adaptation luminance of 0,1 cd/m²	15 % based on adaptation luminance of 1 cd/m²	15 % based on adaptation luminance of 2 cd/m²	15 % based on adaptation luminance of 5 cd/m²

[1] Road Classifications as given in CIE 115:2010 (CIE, 2010).
[2] The veiling luminance values specified in this table are based on a permissible TI value of 15 %.

3.6.5.4 Limitation of sky glow

Table 5 specifies maximum values of upward light ratio (ULR) of luminaires, without taking into account the effect of light reflected upwards from the ground that also contributes to sky glow. This is the traditional method to limit sky glow and suitable to compare different single luminaires.

Appendix 5

IES Lighting for Exterior Environments
Table 2b, Illumination Values

IES Outdoor Environmental Lighting Committee, *Lighting for Exterior Environments*, RP-33-14. New York: Illuminating Engineering Society, 2014.

IES RP-33-14

Lighting for Exterior Environments

Publication of this Recommended Practice
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Suggestions for revisions
should be directed to IES.

Prepared by:
The IES Outdoor Environmental Lighting Committee

Table 2a: Illumination Values.

Applications and Tasks[a]	Notes	Recommended Maintained Illuminance Targets (lux)[b,c,d] — Horizontal (E_h) Targets — Category	Visual Ages of Observers (years) where at least half are <25	25-65	>65	Gauge	Vertical (E_v) Targets — Category	Visual Ages of Observers (years) where at least half are <25	25-65	>65	Gauge	Uniformity Targets[e] — Over Area of Coverage [f] — 1st ratio E_h/2nd ratio E_v if different uniformities apply — Max:Avg	Avg:Min	Max:Min	Typical Area of Coverage[g] — Task Area	Area
ACCENTING	**Accenting influences observers' overall brightness perceptions and provides visual relief. Accenting is also used for visual attraction and wayfinding. Ref. to the *IES Lighting Handbook, 10th Edition Ch. 15*. These are criteria for consideration in any application. Extinguish at curfew.**															
• Art	**On artwork plane (typically vertical)**						see **IES HB 10e Table 15.2**									
• Feature	**On wall plane or trees**						see **IES HB 10e Table 15.2**									
• Important Focal Point	**On focal point plane (typically vertical)**						see **IES HB 10e Table 15.2**									
• Performance Areas	**E_h @pavement; E_v @5' AFG**	see **IES HB 10e Table 15.2**					see **IES HB 10e Table 15.2**									
• Perimeter	**On wall plane or trees**						see **IES HB 10e Table 15.2**									
BUILDING ENTRIES	**OUTDOOR**															
• Canopied Entries/Exits	**At dropoff curbs to entries under canopy. Also see BUILDING ENTRIES/No Cover and BUILDING ENTRIES/Porte Cocheres.**															
• High Activity[i]	**Curbs typified by periods of high pedestrian and vehicular traffic; E_h @grade; E_v @5' AFG in directions of ingress/egress**															
· LZ4[j]		J	20	40	80	Avg	H	10	20	40	Avg	4:1	2:1			
· LZ3[j] (and LZ4 curfew)		I	15	30	60	Avg	G	7.5	15	30	Avg	4:1	2:1 (4:1)			
· LZ2[j] (and LZ3 curfew)		H	10	20	40	Avg	F	5	10	20	Avg	3:1	2:1 (4:1)			
· LZ1[j] (and LZ2 curfew)		G	7.5	15	30	Avg	E	4	8	16	Avg	3:1	2:1 (4:1)			
· LZ0[j] (and LZ1 curfew)	Control with motion sensors	F	5	10	20	Avg	D	3	6	12	Avg	2:1				
• Medium Activity[i]	**Curbs typified by periods of medium pedestrian and vehicular traffic; E_h @grade; E_v @5' AFG in directions of ingress/egress**															
· LZ4[j]		H	10	20	40	Avg	F	5	10	20	Avg	4:1	2:1			
· LZ3[j] (and LZ4 curfew)		G	7.5	15	30	Avg	E	4	8	16	Avg	4:1	2:1 (4:1)			
· LZ2[j] (and LZ3 curfew)		F	5	10	20	Avg	D	3	6	12	Avg	3:1	2:1 (4:1)			
· LZ1[j] (and LZ2 curfew)		E	4	8	16	Avg	C	2	4	8	Avg	3:1	2:1 (4:1)			
· LZ0[j] (and LZ1 curfew)	Control with motion sensors	D	3	6	12	Avg	B	1	2	4	Avg	2:1				
• Low Activity[i]	**Curbs typified by periods of low pedestrian and vehicular traffic; E_h @grade; E_v @5' AFG in directions of ingress/egress**															
· LZ4[j]		F	5	10	20	Avg	D	3	6	12	Avg	4:1	2:1			
· LZ3[j] (and LZ4 curfew)		E	4	8	16	Avg	C	2	4	8	Avg	4:1	2:1 (4:1)			
· LZ2[j] (and LZ3 curfew)		D	3	6	12	Avg	B	1	2	4	Avg	3:1	2:1 (4:1)			
· LZ1[j] (and LZ2 curfew)		C	2	4	8	Avg	A	0.5	1	2	Avg	3:1	2:1 (4:1)			
· LZ0[j] (and LZ1 curfew)	Control with motion sensors	B	1	2	4	Avg	-	0	0	0		2:1				
• Intercom call system access	**E_v on call-interface device, unless self-illuminated**						H	10	20	40	Avg		2:1			
• Non-covered Entries/Exits																
• Immediate Exterior	**Width of door; E_h @grade at threshold; E_v within 3' of threshold and @5' AFG in direction of ingress or security camera**															
· High activity[i]	**Entries/Exits typified by periods of high pedestrian traffic**															
LZ4[j]			10	10	10	Min	H	10	20	40	Avg	4:1	2:1			
· LZ3[j] (and LZ4 curfew)			10	10	10	Min	G	7.5	15	30	Avg	4:1	2:1 (4:1)			
· LZ2[j] (and LZ3 curfew)			10	10	10	Min	F	5	10	20	Avg	3:1	2:1 (4:1)			
· LZ1[j] (and LZ2 curfew)			10	10	10	Min	E	4	8	16	Avg	3:1	2:1 (4:1)			
LZ0[j] (and LZ1 curfew)	Control with motion sensors		10	10	10	Min	D	3	6	12	Avg	2:1				
· Medium Activity[i]	**Entries/Exits typified by periods of medium pedestrian traffic**															
· LZ4[j]			10	10	10	Min	F	5	10	20	Avg	4:1	2:1			
· LZ3[j] (and LZ4 curfew)			10	10	10	Min	E	4	8	16	Avg	4:1	2:1 (4:1)			
· LZ2[j] (and LZ3 curfew)			10	10	10	Min	D	3	6	12	Avg	3:1	2:1 (4:1)			
· LZ1[j] (and LZ2 curfew)			10	10	10	Min	C	2	4	8	Avg	3:1	2:1 (4:1)			
· LZ0[j] (and LZ1 curfew)	Control with motion sensors		10	10	10	Min	B	1	2	4	Avg	2:1				

Table 2b: Illumination Values.

Applications and Tasks[a]	Notes	Horizontal (E_h) Targets: Category	Visual Ages of Observers (years) where at least half are: <25	25-65	>65	Gauge	Vertical (E_v) Targets: Category	Visual Ages of Observers (years) where at least half are: <25	25-65	>65	Gauge	Uniformity Targets[e] Over Area of Coverage[f] (1st ratio E_h/2nd ratio E_v if different uniformities apply): Max:Avg	Avg:Min	Max:Min	Typical Area of Coverage[g]: Task Area	Area
Recommended Maintained Illuminance Targets (lux)[b,c,d]																
• Non-covered Entries/Exits	(continued)															
• Low Activity[i]	**Entries/Exits typified by periods of low pedestrian traffic**															
• LZ4[j]			10	10	10	Min	E	4	8	16	Avg	4:1	2:1			
• LZ3[j] (and LZ4 curfew)			10	10	10	Min	D	3	6	12	Avg	4:1	2:1 (4:1)			
• LZ2[j] (and LZ3 curfew)			10	10	10	Min	C	2	4	8	Avg	3:1	2:1 (4:1)			
• LZ1[j] (and LZ2 curfew)			10	10	10	Min	B	1	2	4	Avg	3:1	2:1 (4:1)			
• LZ0[j] (and LZ1 curfew)	Control with motion sensors		10	10	10	Min	A	0.5	1	2	Avg	2:1				
• Paths to Curb																
• High activity[i]	**Entry paths typified by periods of high pedestrian traffic**															
• LZ4[j]		G	7.5	15	30	Avg	E	4	8	16	Avg		3:1			
• LZ3[j] (and LZ4 curfew)		F	5	10	20	Avg	D	3	6	12	Avg		3:1 (6:1)			
• LZ2[j] (and LZ3 curfew)		E	4	8	16	Avg	C	2	4	8	Avg		3:1 (6:1)			
• LZ1[j] (and LZ2 curfew)		D	3	6	12	Avg	B	1	2	4	Avg		3:1 (6:1)			
• LZ0[j] (and LZ1 curfew)	Control with motion sensors	C	2	4	8	Avg	A	0.5	1	2	Avg		3:1 (6:1)			
• Medium Activity[i]	**Entry paths typified by periods of medium pedestrian traffic**															
• LZ4[j]		E	4	8	16	Avg	C	2	4	8	Avg		3:1			
• LZ3[j] (and LZ4 curfew)		D	3	6	12	Avg	B	1	2	4	Avg		3:1 (6:1)			
• LZ2[j] (and LZ3 curfew)		C	2	4	8	Avg	A	0.5	1	2	Avg		3:1 (6:1)			
• LZ1[j] (and LZ2 curfew)		B	1	2	4	Avg	-	0	0	0			3:1 (6:1)			
• LZ0[j] (and LZ1 curfew)	Control with motion sensors	A	0.5	1	2	Avg	-	0	0	0			3:1 (6:1)			
• Low Activity[i]	**Entry paths typified by periods of low pedestrian traffic**															
• LZ4[j]		C	2	4	8	Avg	C	2	4	8	Avg		3:1			
• LZ3[j] (and LZ4 curfew)		B	1	2	4	Avg	B	1	2	4	Avg		3:1 (6:1)			
• LZ2[j] (and LZ3 curfew)		A	0.5	1	2	Avg	A	0.5	1	2	Avg		3:1 (6:1)			
• LZ1[j] (and LZ2 curfew)		A	0.5	1	2	Avg	-	0	0	0			3:1 (6:1)			
• LZ0[j] (and LZ1 curfew)	Control with motion sensors	A	0.5	1	2	Avg	-	0	0	0			3:1 (6:1)			
• Porte Cocheres	**E_h @grade; E_v @5' AFG in directions of ingress/egress and security camera**															
• High Activity[i]	**Porte cocheres typified by periods of high pedestrian and vehicular traffic**															
• LZ4[j]		L	37.5	75	150	Avg	J	20	40	80	Avg		2:1			
• LZ3[j] (and LZ4 curfew)		K	25	50	100	Avg	I	15	30	60	Avg		2:1 (4:1)			
• LZ2[j] (and LZ3 curfew)		J	20	40	80	Avg	H	10	20	40	Avg		2:1 (4:1)			
• LZ1[j] (and LZ2 curfew)		H	10	20	40	Avg	G	7.5	15	30	Avg		2:1 (4:1)			
• LZ0[j] (and LZ1 curfew)	Control with motion sensors	G	7.5	15	30	Avg	F	5	10	20	Avg		2:1 (4:1)			
• Medium Activity[i]	**Porte cocheres typified by periods of medium pedestrian and vehicular traffic**															
• LZ4[j]		J	20	40	80	Avg	H	10	20	40	Avg		2:1			
• LZ3[j] (and LZ4 curfew)		I	15	30	60	Avg	G	7.5	15	30	Avg		2:1 (4:1)			
• LZ2[j] (and LZ3 curfew)		H	10	20	40	Avg	F	5	10	20	Avg		2:1 (4:1)			
• LZ1[j] (and LZ2 curfew)		G	7.5	15	30	Avg	E	4	8	16	Avg		2:1 (4:1)			
• LZ0[j] (and LZ1 curfew)	Control with motion sensors	F	5	10	20	Avg	D	3	6	12	Avg		2:1 (4:1)			
• Low Activity[i]	**Porte cocheres typified by periods of low pedestrian and vehicular traffic**															
• LZ4[j]		H	10	20	40	Avg	F	5	10	20	Avg		2:1			
• LZ3[j] (and LZ4 curfew)		G	7.5	15	30	Avg	E	4	8	16	Avg		2:1 (4:1)			
• LZ2[j] (and LZ3 curfew)		F	5	10	20	Avg	D	3	6	12	Avg		2:1 (4:1)			

Table 2c: Illumination Values.

Applications and Tasks[a]	Notes	Recommended Maintained Illuminance Targets (lux)[b,c,d] — Horizontal (E_h) Targets: Category	Visual Ages of Observers (years) where at least half are <25	25-65	>65	Gauge	Vertical (E_v) Targets: Category	Visual Ages of Observers (years) where at least half are <25	25-65	>65	Gauge	Uniformity Targets[e] Over Area of Coverage[f] (1st ratio E_h/2nd ratio E_v if different uniformities apply): Max:Avg	Avg:Min	Max:Min	Typical Area of Coverage[g]: Task Area	Area
• Porte Cocheres	(continued)															
· LZ1[j] (and LZ2 curfew)		E	4	8	16	Avg	C	2	4	8	Avg		2:1 (4:1)			
· LZ0[j] (and LZ1 curfew)	Control with motion sensors	D	3	6	12	Avg	B	1	2	4	Avg		2:1 (4:1)			
• Site Gated Entries																
· Manned																
· Pedestrians																
Credentialing area																
LZ4[j]	E_h @3' AFG; E_v @3'-5' AFG	F	5	10	20	Avg	F	5	10	20	Avg	2:1	2:1			
LZ3[j] (and LZ4 curfew)	E_h @3' AFG; E_v @3'-5' AFG	E	4	8	16	Avg	E	4	8	16	Avg	2:1	2:1 (4:1)			
LZ2[j] (and LZ3 curfew)	E_h @3' AFG; E_v @3'-5' AFG	D	3	6	12	Avg	D	3	6	12	Avg	2:1	2:1 (4:1)			
LZ1[j] (and LZ2 curfew)	E_h @3' AFG; E_v @3'-5' AFG	C	2	4	8	Avg	B	1	2	4	Avg	2:1	2:1 (4:1)			
LZ0[j] (and LZ1 curfew)		B	1	2	4	Avg	A	0.5	1	2	Avg	2:1	2:1 (4:1)			
General area																
LZ4[j]	E_h @3' AFG; E_v @3'-5' AFG	D	3	6	12	Avg	D	3	6	12	Avg	3:1	3:1			
LZ3[j] (and LZ4 curfew)	E_h @3' AFG; E_v @3'-5' AFG	C	2	4	8	Avg	C	2	4	8	Avg	3:1	3:1 (6:1)			
LZ2[j] (and LZ3 curfew)	E_h @3' AFG; E_v @3'-5' AFG	B	1	2	4	Avg	B	1	2	4	Avg	3:1	3:1 (6:1)			
LZ1[j] (and LZ2 curfew)	E_h @3' AFG; E_v @3'-5' AFG	B	1	2	4	Avg	A	0.5	1	2	Avg	3:1	3:1 (6:1)			
LZ0[j] (and LZ1 curfew)		A	0.5	1	2	Avg	-	0	0	0		3:1	3:1 (6:1)			
· Vehicles																
· Cars and light trucks	**E_v at height range representing windshield and driver's side window elevations for most cars and light trucks.**															
Credentialing area																
LZ4[j]	E_h @4' AFG; E_v @3'-5' AFG	H	10	20	40	Avg	G	7.5	15	30	Avg	2:1	2:1			
LZ3[j] (and LZ4 curfew)	E_h @4' AFG; E_v @3'-5' AFG	G	7.5	15	30	Avg	F	5	10	20	Avg	2:1	2:1 (4:1)			
LZ2[j] (and LZ3 curfew)	E_h @4' AFG; E_v @3'-5' AFG	F	5	10	20	Avg	E	4	8	16	Avg	2:1	2:1 (4:1)			
LZ1[j] (and LZ2 curfew)	E_h @4' AFG; E_v @3'-5' AFG	E	4	8	16	Avg	D	3	6	12	Avg	2:1	2:1 (4:1)			
LZ0[j] (and LZ1 curfew)		D	3	6	12	Avg	C	2	4	8	Avg	2:1	2:1 (4:1)			
General area																
LZ4[j]	E_h @5' AFG; E_v @3'-5' AFG	F	5	10	20	Avg	F	5	10	20	Avg	3:1	3:1			
LZ3[j] (and LZ4 curfew)	E_h @5' AFG; E_v @3'-5' AFG	E	4	8	16	Avg	E	4	8	16	Avg	3:1	3:1 (6:1)			
LZ2[j] (and LZ3 curfew)	E_h @5' AFG; E_v @3'-5' AFG	D	3	6	12	Avg	D	3	6	12	Avg	3:1	3:1 (6:1)			
LZ1[j] (and LZ2 curfew)	E_h @5' AFG; E_v @3'-5' AFG	C	2	4	8	Avg	B	1	2	4	Avg	3:1	3:1 (6:1)			
LZ0[j] (and LZ1 curfew)		B	1	2	4	Avg	A	0.5	1	2	Avg	3:1	3:1 (6:1)			
· Commercial vans/trucks	**E_v at height range representing windshield and driver's side window elevations for most commercial vans and trucks.**															
Credentialing area																
LZ4[j]	E_h @8' AFG; E_v @6'-9' AFG	H	10	20	40	Avg	G	7.5	15	30	Avg	2:1	2:1			
LZ3[j] (and LZ4 curfew)	E_h @8' AFG; E_v @6'-9' AFG	G	7.5	15	30	Avg	F	5	10	20	Avg	2:1	2:1 (4:1)			
LZ2[j] (and LZ3 curfew)	E_h @8' AFG; E_v @6'-9' AFG	F	5	10	20	Avg	E	4	8	16	Avg	2:1	2:1 (4:1)			
LZ1[j] (and LZ2 curfew)	E_h @8' AFG; E_v @6'-9' AFG	E	4	8	16	Avg	D	3	6	12	Avg	2:1	2:1 (4:1)			
LZ0[j] (and LZ1 curfew)		D	3	6	12	Avg	C	2	4	8	Avg	2:1	2:1 (4:1)			
General area																
LZ4[j]	E_h @10' AFG; E_v @6'-9' AFG	F	5	10	20	Avg	F	5	10	20	Avg	3:1	3:1			
LZ3[j] (and LZ4 curfew)	E_h @10' AFG; E_v @6'-9' AFG	E	4	8	16	Avg	E	4	8	16	Avg	3:1	3:1 (6:1)			
LZ2[j] (and LZ3 curfew)	E_h @10' AFG; E_v @6'-9' AFG	D	3	6	12	Avg	D	3	6	12	Avg	3:1	3:1 (6:1)			

Table 2d: Illumination Values.

Applications and Tasks[a]	Notes	Horizontal (E_h) Targets: Category	Horizontal (E_h) Targets: Visual Ages of Observers (years) where at least half are <25	25-65	>65	Gauge	Vertical (E_v) Targets: Category	Vertical (E_v) Targets: Visual Ages of Observers (years) where at least half are <25	25-65	>65	Gauge	Uniformity Targets[e] Over Area of Coverage [f] (1st ratio E_h/2nd ratio E_v if different uniformities apply): Max:Avg	Avg:Min	Max:Min	Typical Area of Coverage[g]: Task Area	Area
Site Gated Entries	(continued)															
LZ1[i] (and LZ2 curfew)	E_h @10' AFG; E_v @6'-9' AFG	C	2	4	8	Avg	B	1	2	4	Avg	3:1	3:1 (6:1)			
LZ0[i] (and LZ1 curfew)		B	1	2	4	Avg	A	0.5	1	2	Avg	3:1	3:1 (6:1)			
Remote Monitored																
Intercom call system	Highlight intercom call system unless internally illuminated. Coordinate lighting with camera location to avoid image washout.															
LZ4[j]	E_v on system hardware.						G	7.5	15	30	Avg	2:1	2:1			
LZ3[j] (and LZ4 curfew)	E_v on system hardware.						F	5	10	20	Avg	2:1	2:1 (4:1)			
LZ2[j] (and LZ3 curfew)	E_v on system hardware.						E	4	8	16	Avg	2:1	2:1 (4:1)			
LZ1[j] (and LZ2 curfew)	E_v on system hardware.						D	3	6	12	Avg	2:1	2:1 (4:1)			
LZ0[j] (and LZ1 curfew)							C	2	4	8	Avg	2:1	2:1 (4:1)			
Pedestrians																
LZ4[j]	E_h @3' AFG; E_v @5' AFG	G	7.5	15	30	Avg	F	5	10	20	Avg	2:1	2:1			
LZ3[j] (and LZ4 curfew)	E_h @3' AFG; E_v @5' AFG	F	5	10	20	Avg	E	4	8	16	Avg	2:1	2:1 (4:1)			
LZ2[j] (and LZ3 curfew)	E_h @3' AFG; E_v @5' AFG	E	4	8	16	Avg	D	3	6	12	Avg	2:1	2:1 (4:1)			
LZ1[j] (and LZ2 curfew)	E_h @3' AFG; E_v @5' AFG	D	3	6	12	Avg	C	2	4	8	Avg	2:1	2:1 (4:1)			
Vehicles																
LZ4[j]	E_v on system hardware.	I	15	30	60	Avg	H	10	20	40	Avg	2:1	2:1			
LZ3[j] (and LZ4 curfew)	E_v on system hardware.	H	10	20	40	Avg	G	7.5	15	30	Avg	2:1	2:1 (4:1)			
LZ2[j] (and LZ3 curfew)	E_v on system hardware.	G	7.5	15	30	Avg	F	5	10	20	Avg	2:1	2:1 (4:1)			
LZ1[j] (and LZ2 curfew)	E_v on system hardware.	F	5	10	20	Avg	E	4	8	16	Avg	2:1	2:1 (4:1)			
LZ0[j] (and LZ1 curfew)		E	4	8	16	Avg	D	3	6	12	Avg	2:1	2:1 (4:1)			
Unmanned/unmonitored																
Intercom call system access	Highlight security call system unless internally illuminated.															
LZ4[j]	E_v on system hardware, unless self-illuminated						H	10	20	40	Avg		2:1			
LZ3[j] (and LZ4 curfew)	E_v on system hardware, unless self-illuminated						G	7.5	15	30	Avg		2:1			
LZ2[j] (and LZ3 curfew)	E_v on system hardware, unless self-illuminated						F	5	10	20	Avg		2:1			
LZ1[j] (and LZ2 curfew)	E_v on system hardware, unless self-illuminated						E	4	8	16	Avg		2:1			
LZ0[j] (and LZ1 curfew)							D	3	6	12	Avg		2:1			
Pedestrians	Lighting should address an area 5' by 5' centered on the intercom call system.															
LZ4[j]	E_h @grade	E	4	8	16	Avg						2:1	3:1			
LZ3[j] (and LZ4 curfew)	E_h @grade	D	3	6	12	Avg						2:1	3:1 (6:1)			
LZ2[j] (and LZ3 curfew)	E_h @grade	C	2	4	8	Avg						2:1	3:1 (6:1)			
LZ1[j] (and LZ2 curfew)	E_h @grade	B	1	2	4	Avg						2:1	3:1 (6:1)			
LZ0[j] (and LZ1 curfew)		A	0.5	1	2	Avg						2:1	3:1 (6:1)			
Vehicles	Lighting should address an area 5' by 5' centered on the intercom call system.															
LZ4[j]	E_h @grade	F	5	10	20	Avg						2:1	3:1			
LZ3[j] (and LZ4 curfew)	E_h @grade	E	4	8	16	Avg						2:1	3:1 (6:1)			
LZ2[j] (and LZ3 curfew)	E_h @grade	D	3	6	12	Avg						2:1	3:1 (6:1)			
LZ1[j] (and LZ2 curfew)	E_h @grade	C	2	4	8	Avg						2:1	3:1 (6:1)			
LZ0[j] (and LZ1 curfew)		B	1	2	4	Avg						2:1	3:1 (6:1)			

Table 2e: Illumination Values.

Applications and Tasks[a]	Notes	Horizontal (E_h) Targets: Category	<25	25-65	>65	Gauge	Vertical (E_v) Targets: Category	<25	25-65	>65	Gauge	Max:Avg	Avg:Min	Max:Min	Task Area	Area
	Recommended Maintained Illuminance Targets (lux)[b,c,d] — Visual Ages of Observers (years) where at least half are											Uniformity Targets[e] Over Area of Coverage[f] — 1st ratio E_h/2nd ratio E_v if different uniformities apply			Typical Area of Coverage[g]	
FACADES																
• Facade Details or Features	Key elements or details. Apply strategically to ≤25% of area of building facade. Uniformity ratios are cited here as guides when relatively uniform appearance is desired over the area of application.															
• With Surface Reflectance ≥0.5	Lighter-toned facade materials															
· High Activity[i]																
· LZ4[j]	Apply strategically to ≤25% of area of building facade.						O	100	200	400	Max					
· LZ3[j] (and LZ4 curfew)	Apply strategically to ≤20% of area of building facade.						N	75	150	300	Max					
· LZ2[j] (and LZ3 curfew)	Apply strategically to ≤15% of area of building facade.						M	50	100	200	Max					
· LZ1[j] (and LZ2 curfew)	Apply strategically to ≤10% of area of building facade.						L	37.5	75	150	Max					
· LZ0[j] (and LZ1 curfew)							-	0	0	0						
· Medium Activity[i]																
· LZ4[j]	Apply strategically to ≤25% of area of building facade.						M	50	100	200	Max					
· LZ3[j] (and LZ4 curfew)	Apply strategically to ≤20% of area of building facade.						L	37.5	75	150	Max					
· LZ2[j] (and LZ3 curfew)	Apply strategically to ≤15% of area of building facade.						K	25	50	100	Max					
· LZ1[j] (and LZ2 curfew)	Apply strategically to ≤10% of area of building facade.						J	20	40	80	Max					
· LZ0[j] (and LZ1 curfew)							-	0	0	0						
· Low Activity[i]																
· LZ4[j]	Apply strategically to ≤25% of area of building facade.						K	25	50	100	Max					
· LZ3[j] (and LZ4 curfew)	Apply strategically to ≤20% of area of building facade.						J	20	40	80	Max					
· LZ2[j] (and LZ3 curfew)	Apply strategically to ≤15% of area of building facade.						I	15	30	60	Max					
· LZ1[j] (and LZ2 curfew)	Apply strategically to ≤10% of area of building facade.						H	10	20	40	Max					
· LZ0[j] (and LZ1 curfew)							-	0	0	0						
• With Surface Reflectance <0.5	Darker-toned facade materials															
· LZ4[j]	Apply strategically to ≤25% of area of building facade.						Q	200	400	800	Max					
· LZ3[j] (and LZ4 curfew)	Apply strategically to ≤20% of area of building facade.						P	150	300	600	Max					
· LZ2[j] (and LZ3 curfew)	Apply strategically to ≤15% of area of building facade.						O	100	200	400	Max					
· LZ1[j] (and LZ2 curfew)	Apply strategically to ≤10% of area of building facade.						N	75	150	300	Max					
· LZ0[j] (and LZ1 curfew)							-	0	0	0						
· Medium Activity[i]																
· LZ4[j]	Apply strategically to ≤25% of area of building facade.						O	100	200	400	Max					
· LZ3[j] (and LZ4 curfew)	Apply strategically to ≤20% of area of building facade.						N	75	150	300	Max					
· LZ2[j] (and LZ3 curfew)	Apply strategically to ≤15% of area of building facade.						M	50	100	200	Max					
· LZ1[j] (and LZ2 curfew)	Apply strategically to ≤10% of area of building facade.						L	37.5	75	150	Max					
· LZ0[j] (and LZ1 curfew)							-	0	0	0						
· Low Activity[i]																
· LZ4[j]	Apply strategically to ≤25% of area of building facade.						M	50	100	200	Max					
· LZ3[j] (and LZ4 curfew)	Apply strategically to ≤20% of area of building facade.						L	37.5	75	150	Max					
· LZ2[j] (and LZ3 curfew)	Apply strategically to ≤15% of area of building facade.						K	25	50	100	Max					
· LZ1[j] (and LZ2 curfew)	Apply strategically to ≤10% of area of building facade.						J	20	40	80	Max					
· LZ0[j] (and LZ1 curfew)							-	0	0	0						

Table 2f: Illumination Values.

Applications and Tasks[a]	Notes	Recommended Maintained Illuminance Targets (lux)[b,c,d] Horizontal (E_h) Targets					Vertical (E_v) Targets					Uniformity Targets[e] Over Area of Coverage[f]			Typical Area of Coverage[g]	
		Category	Visual Ages of Observers (years) where at least half are <25	25-65	>65	Gauge	Category	Visual Ages of Observers (years) where at least half are <25	25-65	>65	Gauge	1st ratio E_h/2nd ratio E_v if different uniformities apply Max:Avg	Avg:Min	Max:Min	Task Area	Area
FACADES	**Facade Details or Features (continued)**															
• Facade Fields	**Relatively large areas of facade or entire facade. Uniformity ratios are cited here as guides when relatively uniform appearance is desired over the area of application.**															
• With Surface Reflectance ≥0.5	**Lighter-toned facade materials**															
• High Activity[i]																
• LZ4[j]							L	37.5	75	150	Avg		3:1	10:1		
• LZ3[j] (and LZ4 curfew)							K	25	50	100	Avg		3:1	10:1		
• LZ2[j] (and LZ3 curfew)							J	20	40	80	Avg		3:1	10:1		
• LZ1[j] (and LZ2 curfew)							I	15	30	60	Avg		3:1	10:1		
• LZ0[j] (and LZ1 curfew)							-	0	0	0						
• Medium Activity[i]																
• LZ4[j]							J	20	40	80	Avg		3:1	10:1		
• LZ3[j] (and LZ4 curfew)							I	15	30	60	Avg		3:1	10:1		
• LZ2[j] (and LZ3 curfew)							H	10	20	40	Avg		3:1	10:1		
• LZ1[j] (and LZ2 curfew)							G	7.5	15	30	Avg		3:1	10:1		
• LZ0[j] (and LZ1 curfew)							-	0	0	0						
• Low Activity[i]																
• LZ4[j]							H	10	20	40	Avg		3:1	10:1		
• LZ3[j] (and LZ4 curfew)							G	7.5	15	30	Avg		3:1	10:1		
• LZ2[j] (and LZ3 curfew)							F	5	10	20	Avg		3:1	10:1		
• LZ1[j] (and LZ2 curfew)							E	4	8	16	Avg		3:1	10:1		
• LZ0[j] (and LZ1 curfew)							-	0	0	0						
• With Surface Reflectance <0.5	**Darker-toned facade materials**															
• LZ4[j]							N	75	150	300	Avg		3:1	10:1		
• LZ3[j] (and LZ4 curfew)							M	50	100	200	Avg		3:1	10:1		
• LZ2[j] (and LZ3 curfew)							L	37.5	75	150	Avg		3:1	10:1		
• LZ1[j] (and LZ2 curfew)							K	25	50	100	Avg		3:1	10:1		
• LZ0[j] (and LZ1 curfew)							-	0	0	0						
• Medium Activity[i]																
• LZ4[j]							L	37.5	75	150	Avg		3:1	10:1		
• LZ3[j] (and LZ4 curfew)							K	25	50	100	Avg		3:1	10:1		
• LZ2[j] (and LZ3 curfew)							J	20	40	80	Avg		3:1	10:1		
• LZ1[j] (and LZ2 curfew)							I	15	30	60	Avg		3:1	10:1		
• LZ0[j] (and LZ1 curfew)							-	0	0	0						
• Low Activity[i]																
• LZ4[j]							J	20	40	80	Avg		3:1	10:1		
• LZ3[j] (and LZ4 curfew)							I	15	30	60	Avg		3:1	10:1		
• LZ2[j] (and LZ3 curfew)							H	10	20	40	Avg		3:1	10:1		
• LZ1[j] (and LZ2 curfew)							G	7.5	15	30	Avg		3:1	10:1		
• LZ0[j] (and LZ1 curfew)							-	0	0	0						

Notes for Table 2.

Notes

The table column headings are discussed in detail in the Illuminance Criteria Section. Refer to the discussion on procedures for establishing illuminance targets for a project.

a. Applications, tasks, or viewing specifics encountered on any given project may be different from these and may warrant different criteria. Refer to IES Lighting Handbook, Section 29.3.1 Applications and Tasks. The designer is responsible for making final determinations of applications, tasks, and illuminance criteria. Outdoor tasks are so noted.

b. Values cited are to be maintained over time on the area of coverage.

c. Values cited are consensus and deemed appropriate for respective functional activity. In a few situations, code requirements are within 10% of IES recommendations. This is apparently an artifact of metrification. Footcandle conversions of any values cited in this table should be made at 1 fc to 10 lx. Regardless, codes, ordinances, or mandates may supersede any of the IES criteria for any of the applications and tasks and the designer must design accordingly.

d. Targets are intended to apply to the respective plane or planes of the task.

e. Illuminance uniformity targets offer best results when planned in conjunction with luminance ratios and surface reflectances. Any parenthetical uniformity values reference respective parenthetical applications or tasks, such as a curfew situation associated with nighttime outdoor lighting.

f. Applications and tasks cited with a sunburst icon are candidates for strategies employing any combination of daylighting and electric lighting to achieve target values during daylight hours. Daylighting may require unconventional approaches.

g. The designer must establish areas of coverage to which targets apply. Green highlight identifies task proper or task area as the typical area of coverage for respective cited targets. Amber highlight identifies room or designated areas as the typical area of coverage for respective cited targets.

h. Nighttime illuminance targets are intended for application during dark hours of operations where lighting is deemed necessary or desirable. At curfew (client-or-jurisdiction-defined), if lighting is still deemed necessary or desirable, then reduce lighting as indicated.

i. See IES Lighting Handbook, 10th Edition, Table 22.4 - Indoor and Nighttime Outdoor Activity Level Definitions.

j. See IES Lighting Handbook, 10th Edition, Table 26.4 Nighttime Outdoor Lighting Zone Definitions. Nighttime illuminance targets are intended for application during dark hours of operation where lighting is deemed necessary or desirable. At curfew (client or jurisdiction defined), if lighting is still deemed necessary or desirable, then reduce lighting as indicated. See IES Lighting Handbook, 10th Edition, Table 26.5 Recommended Light Trespass Iluminance Limits.

Appendix 6

IES Sport and Recreational Area Lighting
Lighting for Outdoor Sports, 8.10 Football and 8.27 Soccer

IES Sport and Recreational Area Lighting Committee, *Sports and Recreational Area Lighting*, RP-6-15. New York: Illuminating Engineering Society, 2015.

IES RP-6-15

Sports and Recreational Area Lighting

Publication of this Recommended Practice
has been approved by IES.
Suggestions for revisions
should be directed to IES.

Prepared by:
The Sports and Recreational Area Lighting Committee of
the Illuminating Engineering Society of North America

directional ground level sports the playing object is aimed at a fixed target near ground level (usually the target is in a vertical position). Vertical illuminance is critical at the target. It is normally provided by aiming luminaires (shielded from the players and spectators field of view) toward the target.

4.2 Players Skill and Performance

As the skill and performance of players increase, speed and accuracy also increases which in turn calls for higher illuminance levels and/or higher contrasts between the target and the background.

Visual targets (i.e., balls or pucks) of various sports are played at a wide range of speeds against various luminances and color backgrounds. In general, when the visual target is small, the difficulty of the seeing task increases. When the target travels at high speed and is viewed at close range, such as baseball, tennis, and racquetball, higher illuminance levels are required. However, when a golf ball is traveling in the air at high speed, its relative speed with respect to the observer is slow. Thus, lower illuminance levels are adequate for golf driving ranges and similar applications.

4.3 Spectators

Many sports are performed in the presence of spectators, particularly at high skill levels. As the number of spectators increases, seating becomes more remote from the playing area. The size of the visual target is then diminished in proportion to the square of the distance. This requires increased illuminance to compensate for the visual difficulty for the spectator. For large sport stadiums, illuminance is determined by the lighting required for the spectators seated farthest from the playing area. This condition may require several times the illuminance level found to be sufficient to the sport.

4.4 Classification of Play

The required quantity and quality of illuminance for a particular sport varies depending on the participant's skill level, age and the number of spectators attending the event. Additional considerations may include any requirements by individual sports organizations, video broadcasting, or TV broadcast.

In general, as the skill level is elevated, players and spectators require a better and more sophisticated luminous environment. A correlation exists between the size of a facility and the level of play; for example, a higher skill level attracts a greater number of spectators. In addition, a higher skill level may also have faster play, requiring increased illumination levels for the players, spectators, and broadcasting.

As the number of spectators increases, their distance from the playing surface increases; as a result, their need for higher illuminance to see players and tasks also increases. Accordingly, facilities should be designed to satisfy the most talented players and accommodate the greatest potential spectator capacity. It is important to note that in large facilities which seat over 5,000 spectators the lighting criteria are usually governed by the needs of television broadcasting requirements. Recommendations for such facilities are not covered in detail in this publication. To determine illumination criteria, this chapter groups facilities into four classes based on the skill levels of the players and the anticipated number of spectators.

- ***Class I*** *- Competition play before a large group (5000 or more spectators). Lighting criteria for major stadiums and arenas require special design considerations such as vertical and horizontal illuminance values not covered by this practice, which may be defined by individual sports governing bodies and/or broadcasting organizations.*

- ***Class II*** *- Competition play with facilities for up to 5000 spectators.*
- ***Class III*** *- Competition play with facilities for up to 2,000 spectators.*
- ***Class IV*** *- Competition or recreational play only (limited or no provision for spectators).*

Class IV lighting levels are suitable for play at fields that do not draw a large number of spectators. Many fields that host competitive play for adult recreational leagues will have very few spectators. Games for youth leagues will typically only be attended by family members of the participants.

FACILITY	CLASS			
	I	II	III	IV
Professional	X			
College	X	X		
Semi-Professional	X	X		
Sports Clubs	X	X	X	
Amateaur Leagues		X	X	X
High School		X	X	X
Training Facilities			X	X
Elementary School				X
Receational Event				X
Social Event				X

Class I: Facilities with spectator capacity over 5,000
Class II: Facilities with spectator capacity under 5,000
Class III: Facilities with some provision for spectators
Class IV: Facilities with limited or no provision for spectators

Table 2: Class of Play

Luminaire aiming should be from perpendicular to, or in the direction of travel, whenever possible to prevent disability glare for participants. Also, it is critical that the driver has an unhampered view of the staging lights at the starting line.

8.9.1 Field Hockey Field hockey is a multi-directional ground-level sport played at moderate speed with a ball approximately the size of a baseball.

Pole arrangements are similar to football. Spacing of poles should be proportionally similar starting from the end line.

Recommended illuminance levels are:

Class II *- Horizontal illuminance: 500 lux. (50 fc.)*
CV = 0.21 or less. (E_{max}/E_{min} = 2.5:1 or less)

Class III *- Horizontal illuminance: 300 lux. (30 fc.)*
CV = 0.25 or less. (E_{max}/E_{min} = 3:1 or less)

Class IV *- Horizontal illuminance: 200 lux. (20 fc.)*
CV = 0.30 or less. (E_{max}/E_{min} = 4:1 or less)

Illuminance readings should be taken at a 1m (3') elevation on a 9m x 9m (30' x 30') grid.

8.10 Football

Football is a multi-directional sport that combines aerial and ground play. The entire area should be uniformly illuminated. Canadian football is similar to American football with slightly different rules and field dimensions. Illuminance criteria and design considerations are similar.

Figure 46: High School Football Field with 4 Pole Layout.

Typical pole quantities vary from 4 – 8 poles. Poles should be set back behind the bleachers so spectator views are not obstructed. Locating poles in the corners of major stadiums is also an acceptable method, thus avoiding the long setback behind the grandstands. The main drawback to using a four pole layout is the need for taller poles and longer aiming throws for the floodlights. The height, offset and setback of pols may also be determined via stadium and site configurations.

Recommended illuminance levels are:

Class I *- Horizontal illuminance: 1000 lux. (100 fc.)*
CV = 0.13 or less. (E_{max}/E_{min} = 1.7:1 or less)

Class II *- Horizontal illuminance: 500 lux. (50 fc.)*
CV = 0.17 or less. (E_{max}/E_{min} = 2.0:1 or less)

Class III *- Horizontal illuminance: 300 lux. (30 fc.)*
CV = 0.21 or less. (E_{max}/E_{min} = 2.5:1 or less)

Class IV *- Horizontal illuminance: 200 lux. (20 fc.)*
CV = 0.25 or less. (E_{max}/E_{min} = 3:1 or less)

Illuminance readings should be taken at a 1m (3') elevation on a 9m x 9m (30' x 30') grid.

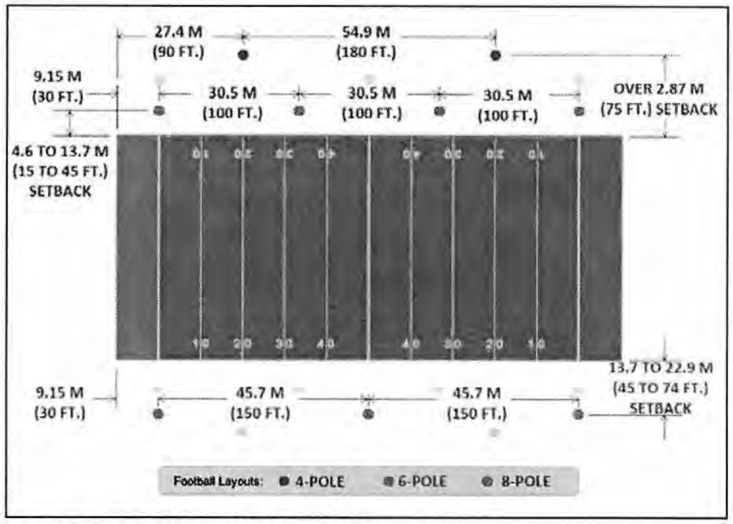

Figure 47: Football Typical Pole Layouts.

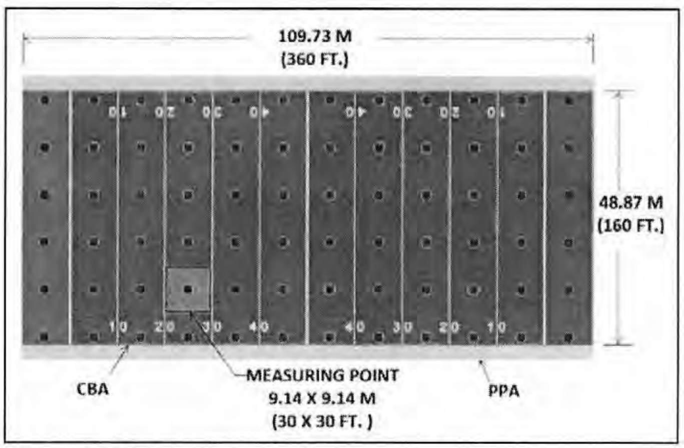

Figure 48: Football calculation grid layout.

8.11 Golf Courses

Golf is fundamentally a unidirectional and an aerial sport. The playing is divided into three separate parts: tee box, fairway, and green. The sport includes recreational and televised professional levels of play but night time play is limited to recreational levels. Recommendations for lighting are for participants only. The length of the golf holes this section are based on the guide lines developed by the National Ski Areas Association (NSAA) in association with the IES as shown in **Figure 73**.

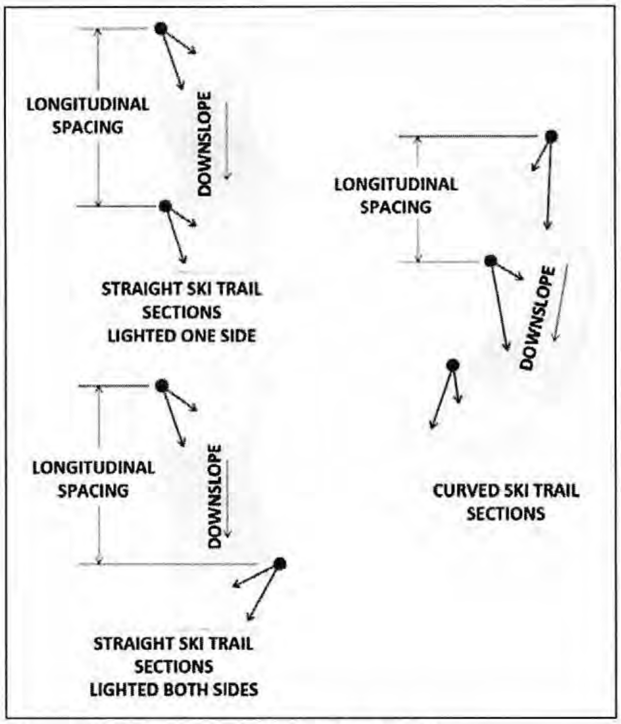

Figure 73: Downhill Skiing pole locations.

Vertical illuminance calculation should be undertaken at 1 meter (3.3') above the slope with the light meter pointing up the slope.

Uniform illuminance on all surfaces is not essential, and in fact, the terrain will be made more visible by the directionality of the light and its non-uniformity within the above parameters. Semi-directional illumination provides shading and modeling which aids in seeing the ski slope.

At ski areas where foggy conditions are common, it may be desirable to increase the minimum illuminance design to 3 lux (.3 fc). This will compensate for snowy or foggy conditions.

High pressure sodium is sometimes used for improved color contrast.

Aiming is generally a function of ski slope width, curvature and gradient. Aiming of luminaires should be in the general downhill direction (the direction of travel of the skier). Certain slope conditions and layouts may require aiming of luminaires other than downhill. Care should be used in aiming luminaires so as to minimize white-out and glare.

The effective pole height is used to determine longitudinal pole spacing. On slopes, the effective pole height should be as illustrated in **Figure 74**. This includes pole height above snow, snow depth and vertical differential between poles.

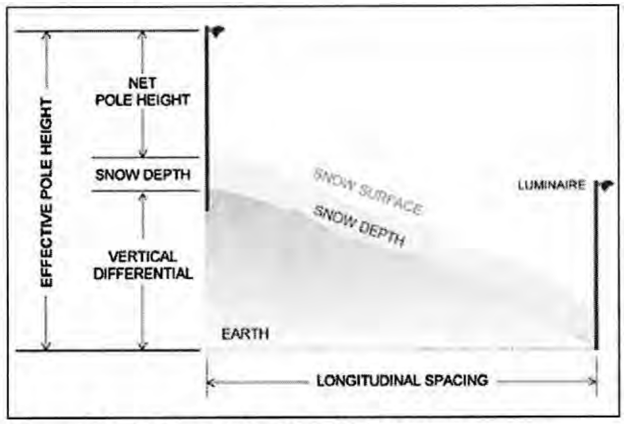

Figure 74: Skiing - Effective Pole Height.

Net pole heights should be determined from the requirements of coverage, beam spread, terrain and other conditions peculiar to the particular slope being lighted. In general, pole heights should not be less than 7.6 meters (25') above the average snow surface.

Recommended illuminance levels are:

Class IV

Average maintained vertical illuminance: *5 lux (0.5 fc)*

Minimum vertical illuminance: *2 lux (0.2 fc.)*

Readings should be taken at 1m (3') elevation on a 9m x 9m (30' x 30') grid with the light meter pointing up the slope.

8.27 Soccer

Soccer is a multi-directional ground level sport with the ball frequently being kicked very high into the air. Regulation soccer field size varies from a width of 59 to 69 meters and a length of 100 to 110 meters (328 to 361').

Figure 75: Multi-field soccer complex.

Recommended illuminance levels are:

Class I *– Horizontal illuminance: 1000 lux (100fc.) CV= 0.13 or less. (E_{max}/E_{min} = 1.7:1 or less)*

Class II *- Horizontal illuminance: 500 lux (50 fc.) CV = 0.21 or less. (E_{max}/E_{min} = 2.0:1 or less)*

Class III *- Horizontal illuminance: 300 lux (30 fc.) CV = 0.25 or less. (E_{max}/E_{min} = 2.5:1 or less)*

Class IV *- Horizontal illuminance: 200 lux (20 fc.) CV = 0.30 or less. (E_{max}/E_{min} = 3:1 or less)*

Illuminance readings should be taken at a 1m (3') elevation on a 9m x 9m (30' x 30') grid.

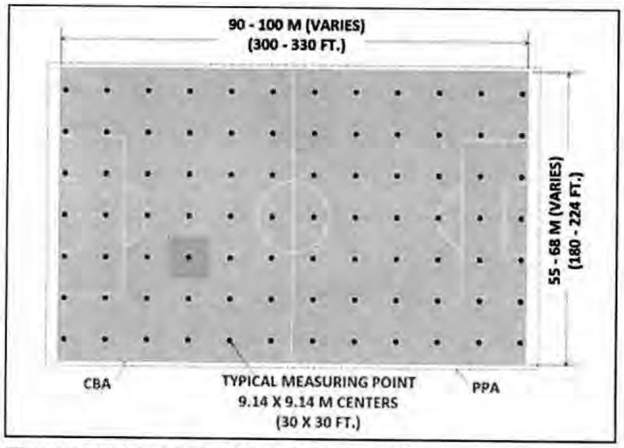

Figure 76: Soccer - Calculation Grid.

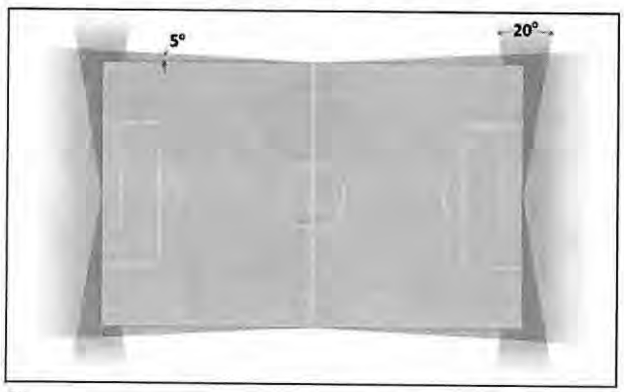

Figure 77: Soccer Field Glare Zones.

Poles or luminaires should not be placed in glare zones defined in **Figure 77**.

8.28 Softball

Softball is a multi-directional aerial sport similar to baseball except that it is played with a larger diameter ball on a smaller field. Softball field dimensions for either fast-pitch or slow-pitch vary with the league. The baselines are generally either 18.3 or 19.8 meters (60 or 65') and the outfield radius is usually between 61 and 91 meters (200 to 300').

Illuminance criteria are similar to those for baseball.

8.29 Swimming

Class IV *– Private Community and Apartment Pool Decks:*

Class II

Water Surface Luminance 161 candela per square meter

Water Surface Illuminance 300 lux (30 fc) CV = 0.21 or less. (Emax/Emin = 2.5:1 or less)

Deck Surface Illuminance 200 lux (20 fc) CV = 0.30 or less. (Emax/Emin = 4:1 or less)

Class III

Water Surface Luminance 108 candela per square meter

Water Surface Illuminance - 300 lux (30 fc) CV = 0.25 or less. (Emax/Emin = 3:1 or less)

Deck Surface Illuminance 100lux (10 fc) CV = 0.30 or less. (Emax/Emin = 4:1 or less)

Class IV

Water Surface Luminance 54 candela per square meter

Water Surface Illuminance 100 lux (10 fc) CV = 0.30 or less. (Emax/Emin = 4:1 or less)

Deck Surface Illuminance 100 lux (10 fc) CV = 0.30 or less. (Emax/Emin = 4:1 or less)

Illuminance readings should be taken at water and deck surface.

Private community and apartment pools do not have the same lighting needs as public pools as they are for a more controlled group of users, familiar with the space and typically in smaller numbers. Adequate lighting is more of a security issue for observation with user safety being the prime consideration. Most security codes will use a minimum value of 1.0 fc on the deck surface as adequate lighting.

Illuminance readings should be taken on the deck surface, where people are looking when they move around (refer to **Section 5.5 Underwater Luminaires**.)

8.30 Tennis

Refer to **Section 7.28** for a general description of the sport, classification of play/facilities, definition of playing areas, and recommended reflectance value of surfaces. The illuminance values and uniformity ratios defined within the primary playing area (PPA–refer to **Annex D3** and **Annex G**) as shown are in general agreement with the United States Tennis Association (USTA).