DEFICIENCIES OF LIGHTING CODES AND ORDINANCES IN CONTROLLING LIGHT POLLUTION FROM PARKING LOT LIGHTING INSTALLATIONS

By

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ABSTRACT

The purpose of this research was to identify the main causes of light pollution from parking lot electric lighting installations and highlight the deficiencies of lighting ordinances in preventing light pollution. Using an industry-accepted lighting modeling program, AGi32, several site lighting designs were analyzed using three LED site lighting fixture lines. The effects of light fixture mounting height, light fixture distribution pattern, ground surface reflectance, light fixture spacing, and lumen output were modeled in a sample parking lot area and in an example commercial retail site. This thesis discusses the impact that these variables have on the contribution to sky glow and light trespass. This study demonstrates that lighting ordinances that limit the mounting height for parking lot light fixtures will cause a greater contribution to sky glow than an unrestricted mounting height. It was also determined that the Model Lighting Ordinance (MLO) limitations for total site lumens are disproportionately liberal compared to the number of lumens required to adequately illuminate a parking lot to meet industry-accepted light levels.

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CHAPTER 1 BACKGROUND AND PREVIOUS RESEARCH

1.1 Introduction

Parking lot lighting is installed to allow businesses or other institutions to operate after sunset. Safety for vehicular traffic, pedestrians, and crime prevention are key factors that influence a business owner to install a site lighting system. The Illuminating Engineering Society (IES) has established and published the industry standards for design in the field of commercial parking lot lighting, as well as related interior and exterior lighting applications. Lighting designers and engineers follow these standards as well as local lighting ordinances for creating and maintaining safe and secure parking lot lighting environments.

1.2 Background

1.2.1 Standards for Site Lighting Design

For uncovered parking areas, the first "Recommended Practice of Outdoor Parking Area Lighting" was published in 1960. This standard recommended an average maintained horizontal illuminance of 1 footcandle (fc) with maximum of 4:1 average/minimum ratio (Subcommittee on Lighting of Service Stations and Parking Areas of the Store Lighting Committee of the IES, 1960). For entrances and exits, the average horizontal illuminance was proposed to be doubled. This standard, although updated regularly, has not changed much in the past 50 years. Recommendations for active parking lots of the current version – IESNA RP-20-98 – are shown in Table 1

(Subcommittee on Off-Road Facilities of the IESNA Roadway Lighting Committee, 1998).

As summarized in Table 1, the maintained horizontal and vertical illuminances have minimum requirements of 0.2 fc and 0.1 fc. These minimum light levels are what the IES believes will allow for orderly passage of vehicles and pedestrians. The uniformity ratio (maximum to minimum) of illuminance, which has recommended values of 20:1, is the metric used in design for enhancement of safety and security on a site. A driver or pedestrian is likely to look at the brightest spot in their field of vision, which increases the adaptation level of his/her eyes to the ambient light. Often, high contrast between the brightest area and a pedestrian or vehicle in the darkest spot of the site will leave them undetectable.

Table 1 Recommended Maintained Illuminance Values for Parking Lots

	Basic (fc)	Enhanced Security (fc)
Minimum Horizontal Illuminance[1]	0.2	0.5
Average Horizontal Illuminance	1	2.5
Uniformity Ratio, Maximum to Minimum	20:1	15:1
Minimum Vertical Illuminance[2]	0.1	0.25

1 Horizontal illuminance is calculated at the parking surface

2 Vertical illuminance is calculated at 5' above the parking surface at the point of lowest horizontal illuminance, excluding facing outward along boundaries.

The definition of a “good” site lighting design varies from owner to owner; some owners are satisfied with the minimum recommended light levels while others want a site to be as bright as possible. While most owners do not have an owner’s project requirement document for site lighting design expectations, a good site lighting design minimizes the cost to the owner of the site, including the cost of materials and installation, the energy cost to operate the light fixtures, and maintenance and replacement cost across life of the installation. To reduce the cost, a lighting designer would optimize a design to have the fewest number of fixtures, least number of poles, and lowest number of watts per square foot to appease the owner. The energy efficiency of a design must also meet all applicable energy code requirements.

Owners expect that a lighting design will meet the performance standards that are widely accepted in the industry and it is also an obligation of professional practice for the engineer. A few owners take control of their site lighting designs and require any additional light for safety or aesthetic appeal. An owner concerned with safety that wishes to have security cameras might care that the vertical illuminance levels be higher for facial recognition. An owner that is concerned with the public image of their business, and sometimes sustainability of the environment as well, may care to minimize light trespass and glare to their neighboring businesses or residences.

For the purpose of this study, the Site Lighting Design and Coordination Criteria document of one of the major retailers in the U.S. was used as an example of an owner's lighting standard (Owner[1], 2011). This standard is more detailed than the RP-20-98 and focuses on creating a safe-feeling parking lot environment for their patrons by requiring higher light levels in high traffic areas. This retailer also sets limits for light trespass, sky glow, and glare. The owner's parking lot lighting criteria are shown in Table 2.

Table 2 Example Owner's Site Lighting Design Criteria

Parking Lot Maintained Illuminance				
Zone[1]	Minimum Horizontal (fc)[2]	Minimum Horizontal Average (fc)[2]	Minimum Vertical (fc)[3]	Uniformity Maximum/Minimum
Main Parking	0.75	2	0.4	5:1
Remote Parking	0.75	N.A.	N.A.	10:1
Front Aisle	1.5	2.75	N.A.	5:1
Entry Drive	0.4	N.A.	N.A.	10:1

1 As defined by Owner's Site Lighting parameters

2 Horizontal illuminance is calculated at the parking surface

3 Vertical illuminance is calculated at the center of Main Parking Area at 5' above the parking surface.

1.2.2 Light Pollution

The desired night-time lighting effect can be reached with a variety of different light sources types, mounting heights, spacing, etc., but the lighting will always affect a larger area than just the area intended to be lit. A single point of light is visible to all neighboring residents and business owners; the amount of ambient light around that

[1] Owner name not disclosed. For the purpose of this study, the owner name may remain private without altering this report

point source plays a role in how much that source stands out. Light pollution can be classified by three categories: light trespass, glare, and sky glow (Obtrusive Light Subcommittee of the IESNA Roadway Lighting Committee, 2000a). Light trespass is light that strays from its intended purpose and becomes a visual annoyance. Glare is an extreme form of light trespass and can cause discomfort for the viewer or even disability. Sky glow is the added sky brightness caused by the scattering of electric lighting into the atmosphere (Obtrusive Light Subcommittee of the IESNA Roadway Lighting Committee, 2000a). All three categories are unwanted effects that can be caused by exterior lighting.

The scattering of light from ground electric lighting installations into the atmosphere causes sky glow light pollution; it reduces the luminous contrast of the night sky. As the number of acres of lit parking lot increases due to urban sprawl, it becomes harder to see stars in the night sky. This indirect sky glow effect is considered light pollution due to its unintentional, but potentially harmful effect on all neighboring residents and nocturnal animals. Light pollution to the sky affects not only those who have an interest in astronomy, but also casual observers who wish to see the stars. Light pollution is more diffuse, in a larger scale, and more difficult to deal with than light trespass. It has wide ranging effects over long distances: across a town, a city, or metropolitan area. To get away from this effect, one must travel outside of populated areas and further from cities. Some state, county, and city municipalities have responded to this pollution with lighting ordinances that limit certain factors involved in a site lighting design such as mounting height of light fixtures or total light output of fixtures.

Light trespass is another version of light pollution, but at a smaller scale than sky glow; light trespass occurs at a nearby property line. When the light from one property directly falls on another property or building, it is considered light trespass. The careful selection, positioning, and aiming of luminaries with appropriate luminous intensity distributions can eliminate light trespass. In most applications, shielding devices can be used to reduce the light levels at and beyond a property line. Some municipalities set a limit on how much light can fall on a neighboring property defined by either horizontal or vertical illuminance (foot-candles).

Having a point of light in the field of vision with a much higher luminance than the rest of the visual field may cause disability or discomfort glare. Disability glare reduces the ability to see or identify objects while discomfort glare produces ocular discomfort, but does not reduce the ability to see (Subcommittee on Off-Road Facilities of the IESNA Roadway Lighting Committee, 1998). Glare is especially problematic for drivers exposed to oncoming headlights; a bright source of glare could leave a driver momentarily unable see or identify objects in front of their vehicle. A quantitative measurement of glare is the ratio of the average veiling luminance of the lighting system and the average pavement luminance.

Glare in parking areas may render a driver unable to recognize or identify a pedestrian, moving or parked vehicle, curbs or other pavement-level structures. Extreme variations of field luminance and high brightness on axis or close to the field of vision are two situations that affect parking lot traffic. Un-shielded light sources with lower mounting heights are the primary cause of parking lot glare.

1.2.3 Site Lighting Ordinances and Codes

The definition of an acceptable site lighting design is different for several affected parties. A site lighting design cannot be installed unless it meets all city, county, and state lighting ordinances, or overlay district requirements. In most states, the design must also meet applicable energy code requirements. The Authority Having Jurisdiction (AHJ) will review all construction documents for compliance with applicable lighting ordinances and energy codes. A design deemed non-compliant will be returned to the engineer with comments that need to be addressed before re-submittal.

An example of an energy code is ASNI/ASHRAE/IESNA Standard 90.1-2007, which states that the exterior buildings grounds luminaires must have a minimum efficacy of 60 lm/W unless controlled by a motion sensor (Standing Standard Project Committee 90.1, 2007). ASHRAE 90.1-2007 also defines the lighting power density allowance for uncovered parking areas to be 0.15 W/ft^2 of hardscape. In most jurisdictions the requirements for the energy usage of light fixtures are completely separate from the ordinances that specify light levels on the parking surface or light pollution from the luminaires.

The previously mentioned example of an owner's lighting standard places its own requirement on the amount of light to be used on a design. The owner allows 5

lm/ft^2 to be used with an extra allowance of 600 square feet of hardscape for each entrance. The owner intends to save energy and not install wasteful, unnecessary lighting on its property by limiting the light output of the luminaires, not the power consumption.

Each energy code has different limits for exterior lighting applications. Some common energy codes, such as: ASHRAE 90.1 (2007), ASHRAE 90.1 (2010), IECC (2012), California Energy Code (2010), and Florida Building Code (2007), have either a luminaire efficacy requirement, a lighting power density requirement, or both, while other lighting standards such as Owner's (2011) and Pima County (2006) have lumen limits instead. Both a lumen limit and a lighting power density allowance place a cap on the amount of light that may be used on a site.

Table 3 Lighting Efficacies, LPDs, and Lumen Limits

Code/Standard	Efficacy of 60 lm/W or Greater, Unless Controlled by Motion Sensor	LPD	Allowed Total Initial Luminaire Lumens per Site
Owner's Standard	Not Required	No Limit	5 lm/ft^2 + 3,000 lm per entrance
ASHRAE 90.1-2007	Required	0.15 W/ft^2 + 5%	No Limit
ASHRAE 90.1-2010	Not Required	No Limit	No Limit
IECC 2012[1]	Required	0.10 W/ft^2 + 750 W	No Limit
2010 California Energy Code	Required	No Limit	No Limit
Florida Building Code 2007	Required	0.15 W/ft^2	No Limit
Pima County Arizona Outdoor Lighting Code[2,3]	Not Required	No Limit	300,000 lm/acre (full cut-off)
	Not Required	No Limit	200,000 lm/acre (full cut-off) + 12,000 lm/acre (unshielded)

1 For areas of moderately high ambient lighting levels

2 For urban area with primary land uses for commercial, business, industrial activity, apartments, surrounded by suburban residential uses.

3 Pima County defines a full cutoff fixture as a luminaire where no candela occur at or above an angle of 90 degrees above the nadir.

The AHJ often keep the needs of all residences and business owners in mind when reviewing the design for code compliance. Each of these parties has its own interest in the quality of a site lighting design: building occupants, general public, patrons to adjacent buildings, building owner, developer, city occupants who wish to have a dark sky without light pollution, neighboring businesses and residences who wish to not have light trespass or off-site glare. Most lighting ordinances address the desires and needs of all of these parties by requiring all exterior luminaires to be installed in such a manner to keep direct light from falling on an adjacent property. These lighting ordinances occasionally define a maximum illuminance for the property line, but often do not specify whether the measurement is vertical or horizontal, or the height of the measurement above the parking surface.

Some example site lighting ordinances are shown in Table 4 from the following jurisdictions: Orange County, FL (Orange County Board of Commissioners, 2003); Code of Miami-Dade County, FL (Board of County Commissioners, 2011); Surprise Arizona Code of Ordinances (Order of the Common Council, 2007); and Rock Hill Zoning Ordinance (Order of the City Council, 2001). The restrictions listed are the only light pollution requirements that a site lighting design must meet.

Table 4 Lighting Ordinances for Limiting Light Pollution (LLF=light loss factor, MH=mounting height)

Jurisdiction	Summary Light Trespass Restrictions	Pole Height Requirements
Orange County Florida	Lighting to be designed to meet recommendations of IESNA LLF not less than 0.72 Maximum of 0.5 fc at a residential property line Maximum of 1.0 fc at a commercial property line	30' MH
Code of Miami-Dade County, Florida	Maximum of 0.5 fc vertical and 0.5 fc horizontal on any adjacent residential property	None
Surprise Arizona Code of Ordinances	Maximum of 0.5 fc horizontal on any adjacent residential property or public right-of-way Minimum of 1.0 fc horizontal in all parking areas	Maximum of 25' MH for parking lot installations, Maximum of 16' MH for lights within 50' of a residential lot line
Rock Hill Zoning Ordinance	Maximum Illumination of 0.5 fc at property line shared with residential Maximum illumination of 2.5 fc at property line shared with commercial	Maximum of 42' MH for large commercial installations, Maximum of 22' MH for lights within 50' of a residential lot line

1.3 Objective and Research Scope

The purpose of this study was to obtain additional information about the correlation between factors of parking lot lighting design using LED luminaires and light pollution. To this end, this study has three objectives. First, computer simulation was used to examine the effect of light fixture mounting height and pavement reflectance on sky glow and light trespass. Second, lighting layouts were designed to meet the standards of the MLO and were focused on causing the largest and smallest amount of sky glow. Third, site lumen limits were evaluated to identify a baseline standard for designing a site with minimal sky glow effect. LED luminaires were used in this study because they are the future of energy efficient parking lot lighting design; as lighting power densities become more limited through energy codes, LED fixtures are capable of meeting strict energy efficiency limits. The luminaires used in this study are LED equivalents to the popular 1000 watt metal halide parking lot luminaires.

A long-term study is necessary to realize all these objectives, using both field mock-up experiments and computer simulations. This thesis study was only an initial research effort. To make this thesis study feasible within a brief time period, this study was focusing on computer simulations using AGi32 of typical parking lot electric lighting installation, which was assumed applicable everywhere given similar site sizes and types of LED luminaires. Full-scale parking lot lighting installations for various luminaires and layouts, and the tremendous light level measurements on different parking lots in different locations across the country, were not covered in this thesis study.

A review of related literature is summarized in Chapter 2 of this thesis. Chapter 3 explains the methodology of the computer simulations used to study light pollution. The results from these computer simulations are summarized and analyzed in Chapter 4. Chapter 5 closes with the conclusions that can be taken from the simulations, discusses developments from this thesis that can be implemented in lighting ordinances to prevent light pollution, and describes future research that would benefit this field.

CHAPTER 2 LITERATURE SEARCH

2.1 Introduction

Previous research studies have been conducted on light pollution prevention in roadway and parking lot lighting. The results and recommendations for design, including: TM-10 (Obtrusive Light Subcommittee of the IESNA Roadway Lighting Committee, 2000a), TM-11 (Obtrusive Light Subcommittee of the IESNA Roadway Lighting Committee, 2000b), Outdoor Lighting Code Handbook (International Dark-Sky Association, 2000), and Model Lighting Ordinance (MLO) (International Dark-Sky Association and Illuminating Engineering Society, 2011) are expounded below.

2.2 TM-10 (2000) and TM-11 (2000)

IESNA Technical Memorandum 10 Addressing Obtrusive Light (Urban Sky Glow and Light Trespass) In Conjunction with Roadway Lighting (TM-10) was published to inform designers of the definitions and design application recommendations to dispel obtrusive light (Obtrusive Light Subcommittee of the IESNA Roadway Lighting Committee, 2000a). Although directed toward roadway applications, this research correlates closely to parking lot applications and addressing light pollution. In TM-10, it is stated that horizontal illuminance limitations do not address the light trespass issue as much as vertical illuminance or light source luminance limits. There are design recommendations and considerations for the prevention of light trespass and glare, however TM-10 does not propose solutions for sky glow.

IESNA Technical Memorandum 11 Light Trespass: Research, Results, and Recommendations (TM-11) was based on surveys of individuals subjected to glare and objectionable light sources (Obtrusive Light Subcommittee of the IESNA Roadway Lighting Committee, 2000b). The recommendations for illuminance values on a plane perpendicular to the line of site to the luminaire were based on the idea that the fixture would be in view for frequent or long periods of time in a permanent installation. The recommended light trespass limitations may not still be acceptable in the opinion of a neighboring resident without further experimental validation, but it does set a baseline standard for design.

2.3 Outdoor Lighting Code Handbook

The International Dark-sky Association published this handbook to discuss issues related to site lighting ordinances and what topics can be written into site lighting ordinances. This was a predecessor of the MLO, but unlike the MLO, it does discuss mounting height restrictions. The handbook addresses the two intended results of pole height restrictions: minimizing visual impact of the poles during the day and minimizing the visual impact of the light at night especially the light trespass. It continues on about the unintended results of limiting pole heights: the need for either closer spacing of poles to achieve the same uniformity, the higher angle candlepower to get the same lighting quality, and the efficiency decrease when the light fixtures are mounted lower (International Dark-Sky Association, 2000).

2.4 Model Lighting Ordinance

In the midst of city, county, and state lighting ordinances that vary greatly and do not effectively limit light pollution, a standard that is readily available for adoption was needed to start to unifying ordinances. IES and the International Dark-Sky Association (IDA) teamed up to write a model lighting ordinance for cities, counties, and states to adopt into their zoning and planning ordinances. This standard is called the Model Lighting Ordinance (International Dark-Sky Association and Illuminating Engineering Society, 2011) and was made public in June 2011.

To meet the MLO standard, however, there are very few design parameters to follow in order to prove compliance in either the prescriptive or performance methods. To meet using the prescriptive method, the total lumens on the site must be under the lumens per square foot for the appropriate lighting zone, all lights must not emit light upward, and the fixtures' B-U-G ratings must meet the minimum for its location relative to the property line (International Dark-Sky Association and Illuminating Engineering Society, 2011). B-U-G ratings are the backlight, uplight, and glare ratings for a light fixture as defined by the TM-15-07 (Luminaire Classification Task Group of IESNA, 2007). Values range from B0 to B5, U0 to U5, and G0 to G5 with 0 ratings being the lowest and 5 ratings being the highest percentage of light in each area. To follow the performance method, the total lumens on the site must be under the lumens per square foot for the appropriate lighting zone, the total lumens leaving the property must be less than fifteen percent of the total fixture lumens, and the vertical illuminances on the property line must be below a specified maximum level. The method for capturing the total quantity of lumens leaving the site is described as a box of calculation planes. The top of the calculation plane virtual enclosure is to be no higher than 33 ft above the tallest luminaire. The MLO does not require that reflected light be taken into account using this method to determine compliance. These limits do not address the quality of the lighting at the parking surface, the average horizontal illumination on the pavement, the uniformity, etc. The lighting design guidelines in IES RP-20-98 recommend that a basic parking lot have a maintained horizontal illuminance of 0.2 fc, a horizontal illuminance uniformity max/min ratio of 20:1, and a minimum vertical illuminance of 0.1 fc at 5' above the pavement a the lowest horizontal illuminance point (Subcommittee on Off-Road Facilities of the IESNA Roadway Lighting Committee, 1998).

CHAPTER 3 METHODOLOGY

3.1 Introduction

Due to relatively simple layout pattern and tremendous calculation workload, parking lot lighting designs are typically completed using a computer simulation program. There are many lighting simulation software programs available in the lighting industry including: Radiance, Lightscape, Visual, etc. The lighting calculations and visualization for electric lighting prediction program widely used today for this application is Lighting Analyst's AGi32 due to its reputation for having accurate electric lighting simulation. AGi32 is one of the few lighting simulation software programs that output a rendering of the lit environment. Using IES files for various LED parking lot lighting fixtures, point-by-point calculations of incident direct and reflected light on surfaces and imaginary planes were used to quantify the distribution of artificial light and light pollution.

3.2 Computer Simulation and Model Description

Every commercial parking lot site is unique. To be able to methodically compare variables as they relate to light pollution, a standard site must be chosen. The middle portion of a parking lot is relatively similar from site to site. To model this, a square sample area was modeled; this area is described in Figure 1. For comparing an overall site with the lighting ordinances for light pollution, a sample site was used; this site example is described in Figure 2.

3.2.1 Square Sample Area

A grid of light poles, each with four identical fixture heads was arranged with an even spacing in a square, see below in Figure 1. Light fixture types, spacing distances, mounting heights, and ground reflectance values were varied. Three spacing distances were used: 84’, 126’, and 168’. These spacing values correspond to two, three, and four times the common mounting height of 42’. Light fixture spacing recommendations from manufacturers are often given in terms of mounting height. The parking area was extended on the outside of the poles to 2/3 the spacing. This keeps the calculation point area proportional to the fixture spacing. Four common mounting heights were used: 30’, 34’, 38’, and 42’. These mounting heights are based on the standard pole heights available. Two ground reflectance values were used: 0.26 and 0.38. The 0.26 reflectance surface property is an AGi32 representation of medium-grey asphalt. Light-grey asphalt is represented in AGi32 as a surface with a reflectance of 0.38. Asphalt was the material chosen for this model because it is more common than concrete for parking lots; asphalt is strong enough for light-weight vehicles to be parked on it, yet it is less expensive than concrete. With each of these variables accounted for, a total of seventy-two unique simulations were modeled. The full radiosity method of calculation, which accounts for both the direct and indirect components of the light, was utilized to account for light reflected off of the parking surface.

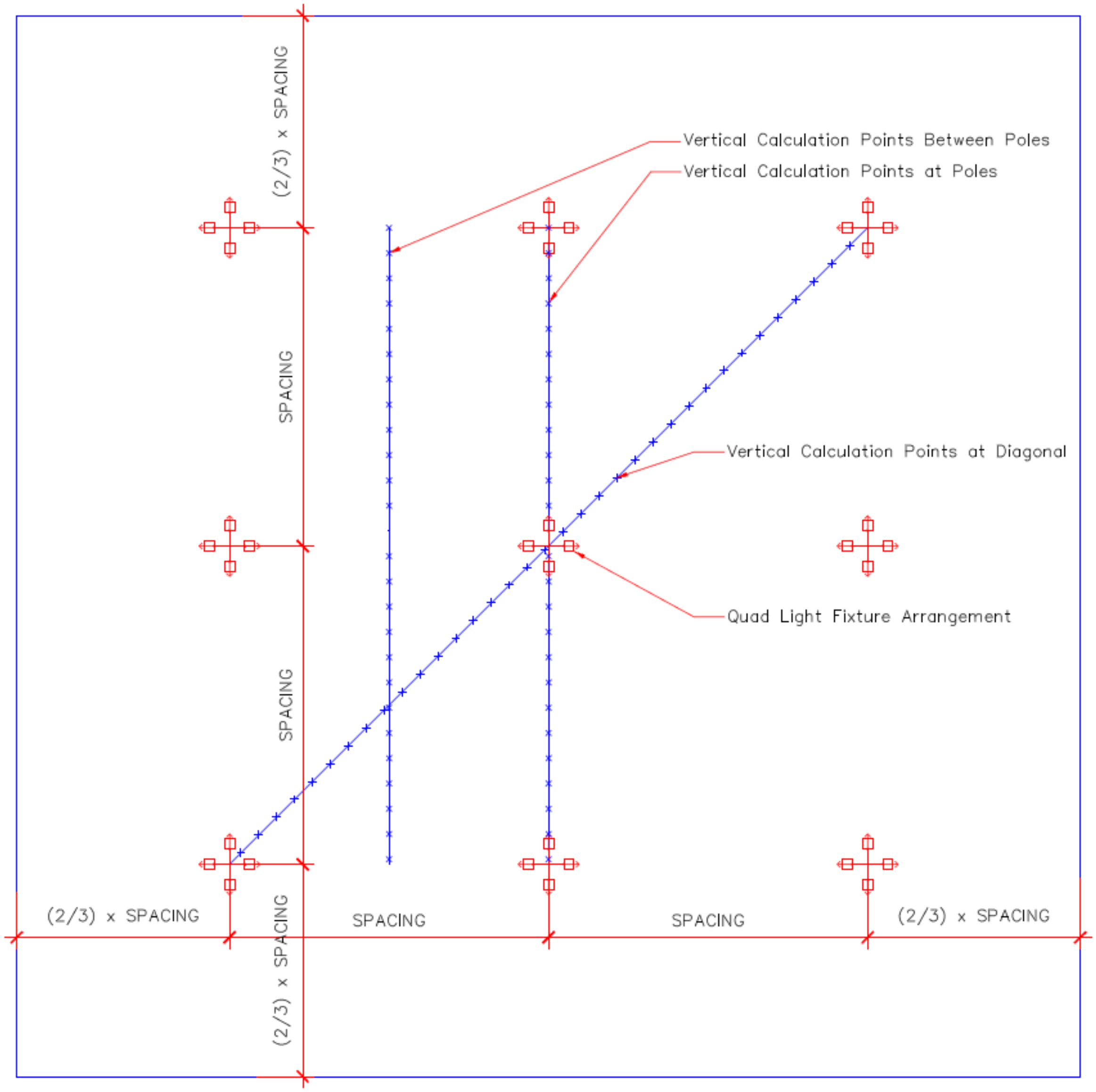


Figure 1 Square Sample Area Layout

3.2.2 Example Retail Parking Lot

An example site layout from a major U.S. retail company was set-up with calculation planes and light fixtures that are typical for design. The parking lot example has these typical properties of a site: the parking spaces are grouped in front of the building entrance, there are multiple entrances from adjoining streets to the parking area, rows of parking spaces are uninterrupted by landscape islands, and there is a drive aisle around the back of the building for truck access. Light fixtures have to be placed at an intersection of parking spaces or in a landscaped area so that they will not interfere with vehicular traffic. The site layout can be seen in Figure 2.

A combination of full radiosity and direct only calculation methods were used to show compliance with different lighting ordinances. Since full radiosity accounts for all of the reflected light, it usually yields higher light levels that contribute to light trespass and sky glow. This can be detrimental when attempting to keep those light levels below the limit. The direct only method does not account for the reflected light. Therefore, a design that may appear to have too much light trespass to meet a lighting ordinance using full radiosity may meet the lighting ordinance using the direct only method. Lighting ordinances do not dictate to a lighting designer which method should be used. Both calculation methods were used in this study for comparison.

Three lighting design intents were modeled. The first was to meet the Owner's Requirements for horizontal and vertical illuminances on the site. This design was optimized to use the fewest number of light fixture heads to accomplish the minimum light levels and meet the uniformity requirements. The second was to meet the recommended horizontal and vertical illuminances described in RP-20-98. The fewest number of light fixtures was used to meet these minimum light levels and meet the uniformity requirements. The third design intent was to meet the minimum horizontal and vertical illuminances described in RP-20-98, meet the uniformity requirements and use the maximum site lumens allowed by the MLO. This site was not optimized, but rather pushed the limit of how many light fixtures could be used.

With all combinations of the two calculation methods and three design intents, a total of six unique design simulations were modeled. All light fixtures were modeled with a 42’ mounting height.

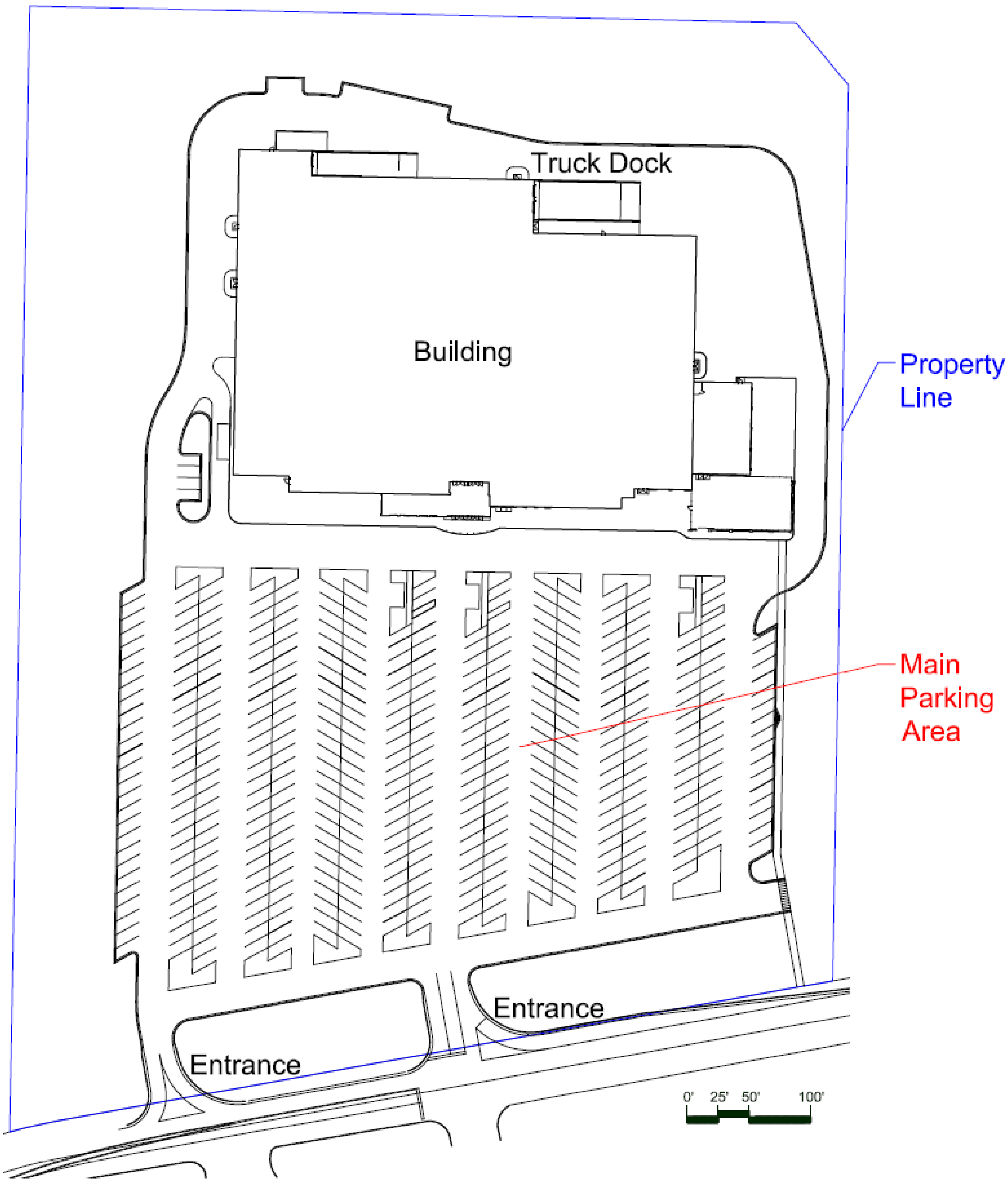


Figure 2 Example Owner[2] Retail Parking Lot Layout

[2] Owner name not disclosed. For the purpose of this study, the owner name may remain private without altering this report

3.3 Light Fixtures

For the square sample area, the three light fixtures used were the GE Evolve LED Area Light Medium Thin Profile (EAMT), GE Evolve LED Area Light Modular Fixture - Medium (EAMM), and BetaLED The Edge LED Area Light. Refer to Appendices A, B, and C, respectively, for cut sheets of these three luminaires. The appearances of these luminaires are shown in Figure 3. Four of each of these luminaires were arranged at each pole location with a separation of 90 degrees as shown in Figure 1. The luminaire photometric information is summarized in Table 5. At the time of this study, these fixtures were the only LED fixtures that are equivalent to 1000 watt metal halide luminaires. Each of these fixtures is commonly used in the middle of a parking lot because they have large distributions. They are not suited for locations near property lines, which is evident in their B-U-G ratings, because they would spill light onto adjacent property.

EAMM

EAMT

EDGE

Figure 3 Square Sample Single Head Luminaire Images

Table 5 Square Sample Area Fixture Data

Fixture type	Model Number	Distribution	Initial Lumens	LLD	LDD	Total LLF	B-U-G Rating
EAMM	EAMM5K4F57A4CBLCKF	Asymmetric Forward	12,800	0.85	0.9	0.765	2-0-3
EAMT	EAMT5D5N57A4CBLCKF	Symmetric Square	19,000	0.85	0.9	0.765	5-0-3
EDGE	ARE-EDG-5M-DA-24-D-UH-35	Symmetric Square	23,671	0.9	0.9	0.81	5-0-4

1 LLD is Lamp Lumen Depreciation factor as defined by the luminaire manufacturer.

2 LDD is the Luminaire Dirt Depreciation factor.

3 Total LLF is the LLD multiplied by the LDD.

A combination of the EAMM and EAMT light fixtures was used in the example retail parking lot. Multiple model numbers of each were used in order to customize the light distributions and lumen outputs for the site. Light pole locations had anywhere from one to four fixture heads.

3.4 Calculation Points

3.4.1 Square Sample Area

The entire parking area had calculation points on a 10’x10’ grid at the level of the parking surface to measure maintained horizontal illuminance values. The same parking area also had a grid of calculation points with a fixed tilt of 180 degrees, or pointing toward the parking surface, in order to measure the maintained horizontal illuminance that exited the site and contributed to sky glow. This plane was located at the mounting height of the light fixtures. Figure 4 illustrates the relationship between the calculation points and the light fixtures.

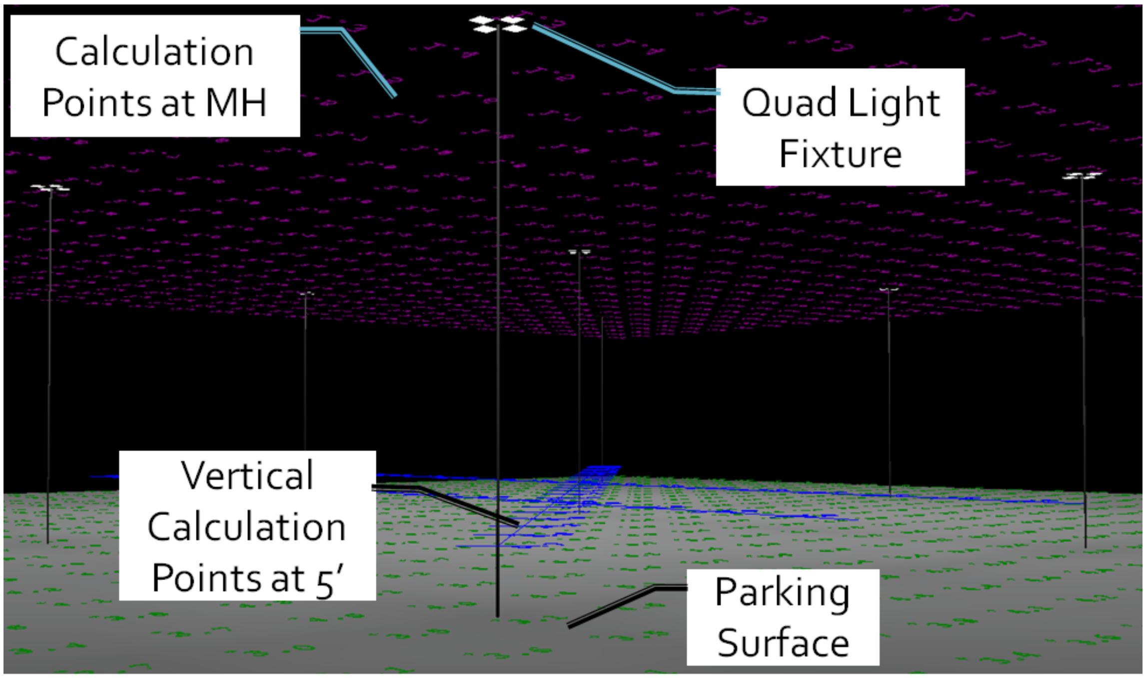


Figure 4 Square Sample Calculation Planes

Three vertical calculation planes, on a 10' spacing, were placed at 5' above the parking surface to measure the minimum vertical illuminance. The spacing of 10' is the industry standard for parking lot-scale calculations for showing compliance with lighting ordinances. The vertical calculations are taken at 5' above the parking surface because it represents a normal level for face height (Subcommittee on Off-Road Facilities of the IESNA Roadway Lighting Committee, 1998). These calculation planes are shown in Figure 1.

3.4.2 Example Retail Parking Lot

The retail parking lot lighting designs were evaluated using two different methods of calculation point placement to test for compliance with RP-20-98 and illustrate that a single parking lot lighting design can meet more than one standard. First, the MLO standard was used. The single calculation plane covers all drive aisles, parking spaces, and intersections. The calculation points are shown in Figure 5. RP-20-08 parking lot lighting standards were used for design: the maintained horizontal illuminance minimum value was 0.2 fc, the maintained vertical illuminance measured at the point of lowest horizontal illuminance was to reach a minimum of 0.1 fc at 5' above the parking surface, and the uniformity ratio was to be less than 20:1. Second, the Owner's Parking Lot Lighting Requirement, shown in Table 2, was used to differentiate between areas that require more and less light for safety, but in some areas, the light level could fall to 0.0 fc. These calculation zones are shown in Figure 6.

Each site was evaluated using both the direct only method and the full radiosity method. For the purpose of this example, a reflectance of 0.38 was used for the parking surface due to its worst-case contribution to light pollution. When switching between the two calculation methods, no changes were made to the locations of calculation points, luminaires, mounting heights, etc., therefore, the difference of the results showed only the impact of the light reflected from the ground.

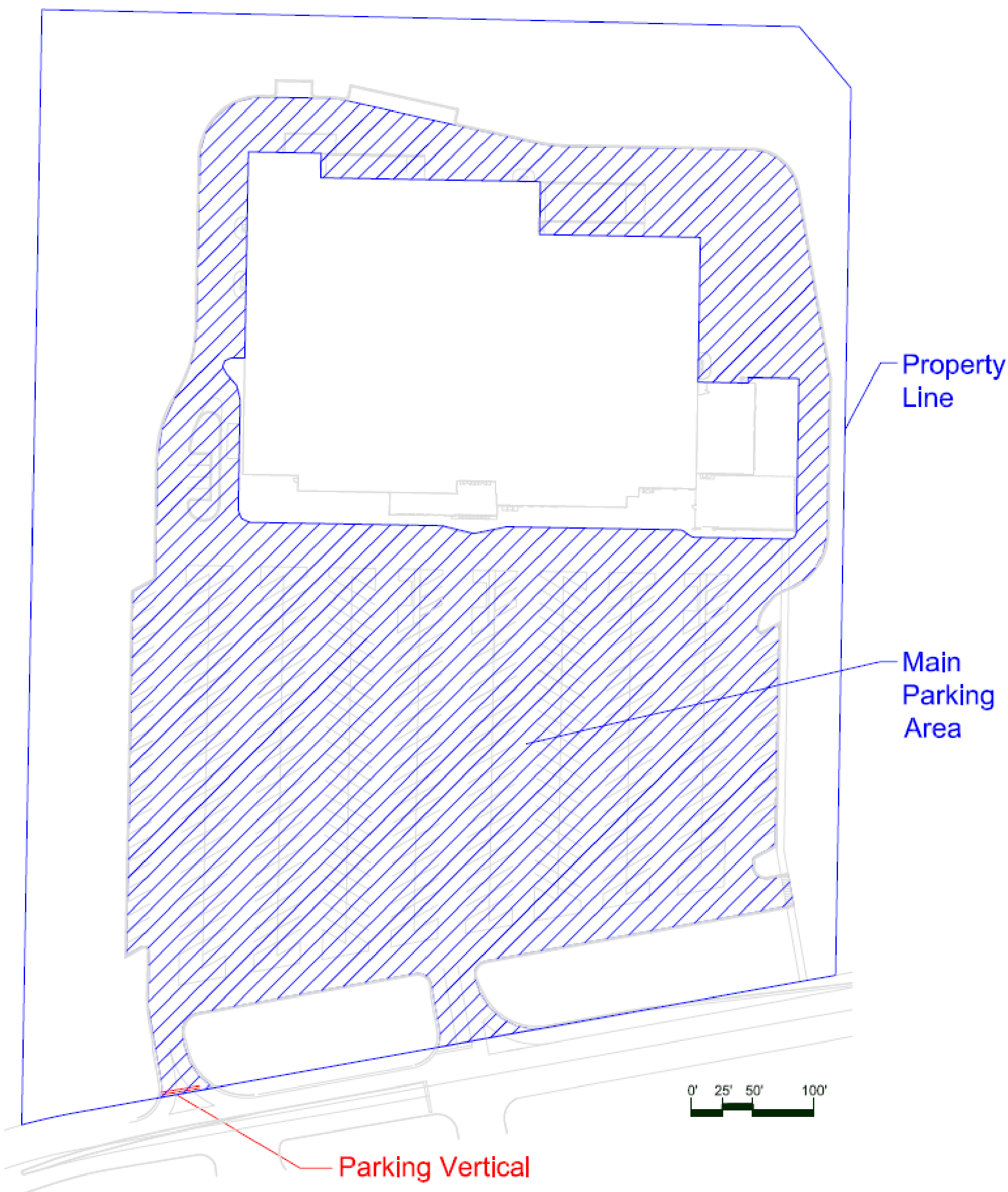


Figure 5 Example Retail Lot – MLO Requirements Calculation Zones

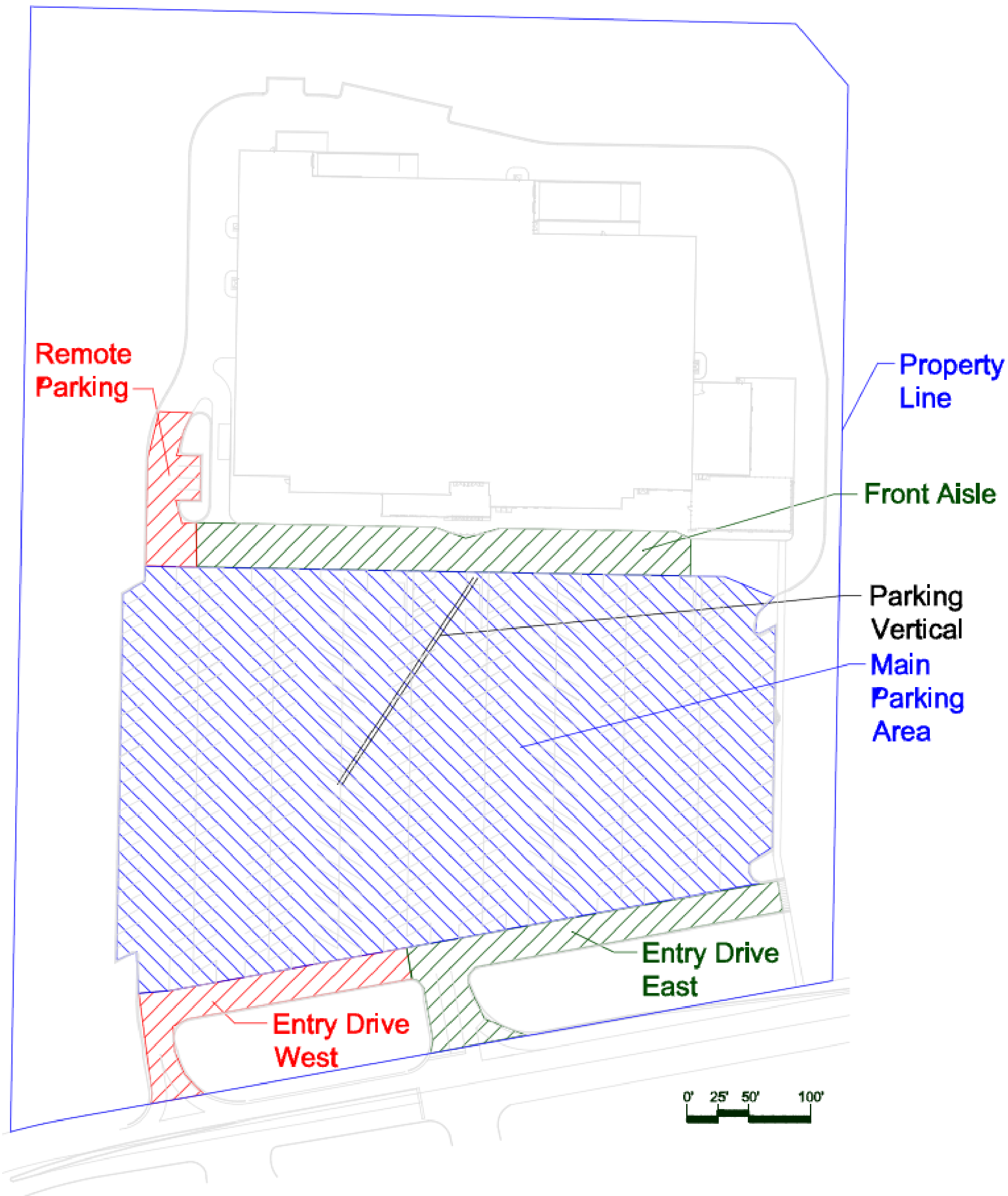


Figure 6 Example Retail Lot – Owner's Requirements Calculation Zones

3.5 Light Pollution Assessment and Controls

A plane of calculation points was located at the mounting height of the light fixtures to capture the amount of light reflected into the sky on the square sample area calculations. Two typical reflectance values for asphalt parking surfaces for darker and lighter asphalt, 0.26 and 0.38 respectively, were used to determine reflected light pollution that contributes to sky glow.

For the example retail site, vertical illuminance was calculated at 5' above the parking level at the each of the property lines, which is the MLO accepted placement of vertical calculation points in determining light trespass. The parking lot reflectance was set at 0.38 for worst-case when determining the amount of reflected light pollution. A plane of calculation points was also located at the mounting height of the light fixtures to capture the amount of light reflected into the sky on the square sample area calculations as shown in Figure 7.

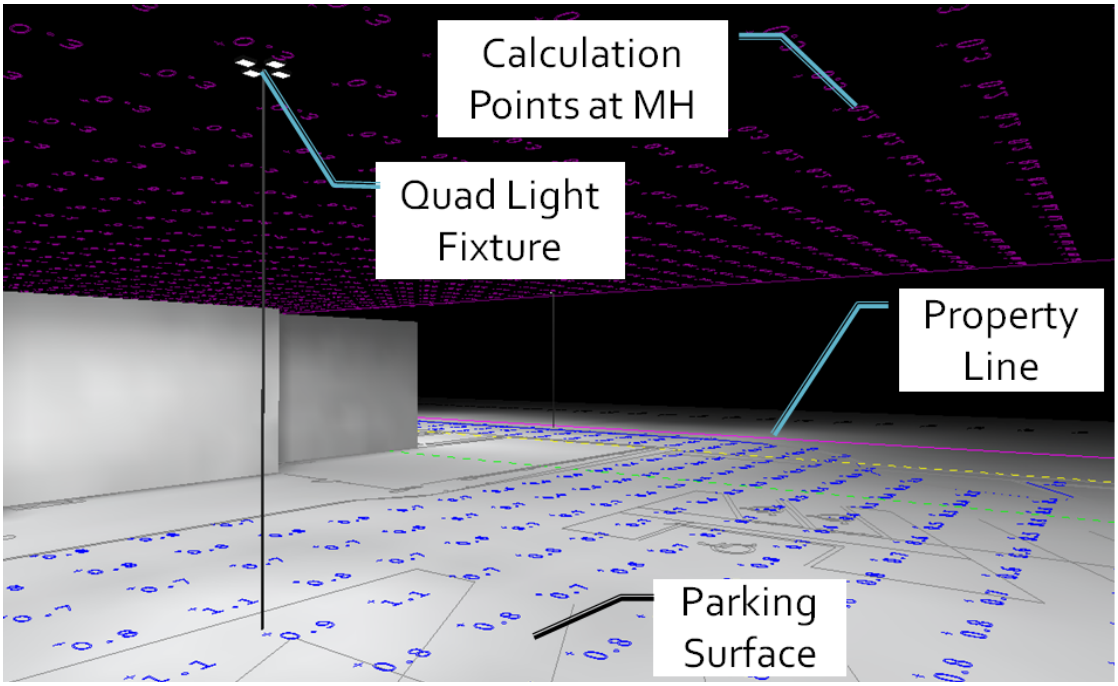


Figure 7 Example Retail Lot Vertical Calculation Zones in Elevation

CHAPTER 4 RESULTS AND ANALYSES

4.1 Introduction

Seventy-two iterations of a square sample area lighting layout and six different versions of an example site lighting design were modeled using AGi32. Results from each of these simulations are shown as maintained illuminance values.

4.2 Simulation Results – Square Sample Area

4.2.1 Parking Surface Light Levels

The average, maximum, and minimum horizontal illuminance values and maximum/minimum uniformity ratio for each of the configurations are shown in Table 6. Light reflectance of the parking surface is negligible in these results since the horizontal light at the parking surface is only from the fixtures directly. As the mounting heights of each fixture decreased from 42 ft to 30 ft, the maximum/minimum ratio increased. For example the maximum/minimum ratio increased from 4.12 to 5.67 for QD5 at 84’ spacing; from 5.00 to 5.40 for QF10 at 84’ spacing; and from 4.95 to 6.81 for EDGE at 84’ spacing. The average horizontal illuminance increased with lower mounting heights. For example, it increased from 1.40 fc to 1.59 fc for QD5 at 168’ spacing; from 1.02 fc to 1.07 fc for QF10 at 168’ spacing; and from 1.93 fc to 2.05 fc for EDGE at 168’ spacing.

Table 6 Square Sample Area Parking Surface Light Levels

280'x280' Calculation Area			Illuminance at Parking Surface			
Fixture Type	MH (ft)	Fixture Spacing (ft)	Average Horizontal at Ground (fc)	Max (fc)	Min (fc)	Max/Min Ratio at Ground
QD5	42	84'	4.18	7.00	1.70	4.12
QD5	38	84'	4.46	7.40	1.60	4.63
QD5	34	84'	4.74	8.10	1.60	5.06
QD5	30	84'	5.05	8.50	1.50	5.67
QF10	42	84'	3.06	5.00	1.00	5.00
QF10	38	84'	3.24	5.30	1.00	5.30
QF10	34	84'	3.42	5.40	1.00	5.40
QF10	30	84'	3.62	5.40	1.00	5.40
EDGE	42	84'	5.99	9.40	1.90	4.95
EDGE	38	84'	6.29	10.00	1.80	5.56
EDGE	34	84'	6.59	10.60	1.70	6.24
EDGE	30	84'	6.92	10.90	1.60	6.81

420'x420' Calculation Area			Illuminance at Parking Surface			
Fixture Type	MH (ft)	Fixture Spacing (ft)	Average Horizontal at Ground (fc)	Max (fc)	Min (fc)	Max/Min Ratio at Ground
QD5	42	126'	2.43	3.70	0.60	6.17
QD5	38	126'	2.52	3.70	0.60	6.17
QD5	34	126'	2.61	3.80	0.50	7.60
QD5	30	126'	2.71	3.80	0.40	9.50
QF10	42	126'	1.67	2.50	0.40	6.25
QF10	38	126'	1.74	2.60	0.40	6.50
QF10	34	126'	1.81	2.70	0.30	9.00
QF10	30	126'	1.86	3.20	0.20	16.00
EDGE	42	126'	3.20	5.20	0.70	7.43
EDGE	38	126'	3.31	5.60	0.60	9.33
EDGE	34	126'	3.42	6.40	0.50	12.80
EDGE	30	126'	3.52	7.40	0.40	18.50

560'x560' Calculation Area			Illuminance at Parking Surface			
Fixture Type	MH (ft)	Fixture Spacing (ft)	Average Horizontal at Ground (fc)	Max (fc)	Min (fc)	Max/Min Ratio at Ground
QD5	42	168'	1.40	2.10	0.20	10.50
QD5	38	168'	1.45	2.40	0.20	12.00
QD5	34	168'	1.48	2.80	0.10	28.00
QD5	30	168'	1.59	3.40	0.10	34.00
QF10	42	168'	1.02	1.80	0.10	18.00
QF10	38	168'	1.04	2.10	0.10	21.00
QF10	34	168'	1.06	2.40	0.10	24.00
QF10	30	168'	1.07	3.00	0.10	30.00
EDGE	42	168'	1.93	3.90	0.20	19.50
EDGE	38	168'	1.98	4.50	0.20	22.50
EDGE	34	168'	2.01	5.50	0.10	55.00
EDGE	30	168'	2.05	6.90	0.10	69.00

4.2.2 Light Levels at Mounting Height

The average illuminance at the calculation plane located at the mounting height of the light fixtures is affected by the parking surface reflectance. The averages for each configuration of light fixture type, spacing, mounting height, and ground reflectance are shown in Tables 7a, b, c. For every light fixture type, spacing, and ground reflectance the average horizontal illuminance at the fixture mounting height increased as the mounting height decreased. For example, in Table 7a as the mounting height of the fixtures decreased from 42 ft to 30 ft the average horizontal illuminance increased from 1.38 fc to 1.76 fc for QD5 with a 0.38 ground reflectance; from 0.95 fc to 1.21 fc for QF10 with a 0.38 ground reflectance; and from 1.89 fc to 2.37 fc for EDGE with a 0.38 ground reflectance. Likewise in Table 7b as the mounting height of the fixtures decreased from 42 ft to 30 ft, the average horizontal illuminance increased from 0.82 fc to 0.97 fc for QD5 with a 0.38 ground reflectance; from 0.56 fc to 0.66 fc for QF10 with a 0.38 ground reflectance; and from 1.10 fc to 1.28 fc for EDGE with a 0.38 ground reflectance. Also, in Table 7c as the mounting height of the fixtures decreased from 42 ft to 30 ft, the average horizontal illuminance increased from 0.52 fc to 0.58 fc for QD5 with a 0.38 ground reflectance; from 0.36 fc to 0.48 fc for QF10 with a 0.38 ground reflectance; and from 0.70 fc to 0.76 fc for EDGE with a 0.38 ground reflectance.

In each case, the average illuminance at the fixture mounting height increases as the ground reflectance increases from 0.26 to 0.38. For example, in Table 7a as the ground reflectance increases, the average horizontal illuminance increases from 0.93 fc to 1.38 fc for QD5 at a 42 ft mounting height; from 0.64 fc to 0.95 fc for QF10 at a 42 ft mounting height; and from 1.30 fc to 1.89 fc for EDGE at a 42 ft mounting height. Similarly, in Table 7b as the ground reflectance increases, the average horizontal illuminance increases from 0.56 fc to 0.82 fc for QD5 at a 42 ft mounting height; from 0.39 to 0.56 for QF10 at a 42 ft mounting height; and from 0.75 fc to 1.10 fc for EDGE at a 42 ft mounting height. Also, in Table 7c as the ground reflectance increases, the average horizontal illuminance increases from 0.36 fc to 0.52 fc for QD5 at a 42 ft mounting height; from 0.24 fc to 0.36 fc for QF10 at a 42 ft mounting height; and from 0.48 fc to 0.70 fc for EDGE at a 42 ft mounting height.

Table 7a Square Sample Area Mounting Height Light Levels – 84' Spacing

280'x280' Calculation Area				Illuminance at Mounting Height
Fixture Type	MH (ft)	Ground Reflectance	Fixture Spacing (ft)	Average Horizontal (fc)
QD5	42	0.38	84'	1.38
QD5	38	0.38	84'	1.49
QD5	34	0.38	84'	1.62
QD5	30	0.38	84'	1.76
QD5	42	0.26	84'	0.93
QD5	38	0.26	84'	1.01
QD5	34	0.26	84'	1.10
QD5	30	0.26	84'	1.20
QF10	42	0.38	84'	0.95
QF10	38	0.38	84'	1.03
QF10	34	0.38	84'	1.11
QF10	30	0.38	84'	1.21
QF10	42	0.26	84'	0.64
QF10	38	0.26	84'	0.70
QF10	34	0.26	84'	0.76
QF10	30	0.26	84'	0.82
EDGE	42	0.38	84'	1.89
EDGE	38	0.38	84'	2.03
EDGE	34	0.38	84'	2.19
EDGE	30	0.38	84'	2.37
EDGE	42	0.26	84'	1.30
EDGE	38	0.26	84'	1.39
EDGE	34	0.26	84'	1.49
EDGE	30	0.26	84'	1.62

Table 7b Square Sample Area Mounting Height Light Levels – 126’ Spacing

420'x420' Calculation Area				Illuminance at Mounting Height
Fixture Type	MH (ft)	Ground Reflectance	Fixture Spacing (ft)	Average Horizontal (fc)
QD5	42	0.38	126'	0.82
QD5	38	0.38	126'	0.87
QD5	34	0.38	126'	0.92
QD5	30	0.38	126'	0.97
QD5	42	0.26	126'	0.56
QD5	38	0.26	126'	0.59
QD5	34	0.26	126'	0.63
QD5	30	0.26	126'	0.66
QF10	42	0.38	126'	0.56
QF10	38	0.38	126'	0.60
QF10	34	0.38	126'	0.63
QF10	30	0.38	126'	0.66
QF10	42	0.26	126'	0.39
QF10	38	0.26	126'	0.41
QF10	34	0.26	126'	0.43
QF10	30	0.26	126'	0.45
EDGE	42	0.38	126'	1.10
EDGE	38	0.38	126'	1.16
EDGE	34	0.38	126'	1.22
EDGE	30	0.38	126'	1.28
EDGE	42	0.26	126'	0.75
EDGE	38	0.26	126'	0.79
EDGE	34	0.26	126'	0.83
EDGE	30	0.26	126'	0.87

Table 7c Square Sample Area Mounting Height Light Levels – 168’ Spacing

560'x560' Calculation Area				Illuminance at Mounting Height
Fixture Type	MH (ft)	Ground Reflectance	Fixture Spacing (ft)	Average Horizontal (fc)
QD5	42	0.38	168'	0.52
QD5	38	0.38	168'	0.54
QD5	34	0.38	168'	0.56
QD5	30	0.38	168'	0.58
QD5	42	0.26	168'	0.36
QD5	38	0.26	168'	0.37
QD5	34	0.26	168'	0.38
QD5	30	0.26	168'	0.40
QF10	42	0.38	168'	0.36
QF10	38	0.38	168'	0.38
QF10	34	0.38	168'	0.39
QF10	30	0.38	168'	0.40
QF10	42	0.26	168'	0.24
QF10	38	0.26	168'	0.25
QF10	34	0.26	168'	0.26
QF10	30	0.26	168'	0.27
EDGE	42	0.38	168'	0.70
EDGE	38	0.38	168'	0.72
EDGE	34	0.38	168'	0.74
EDGE	30	0.38	168'	0.76
EDGE	42	0.26	168'	0.48
EDGE	38	0.26	168'	0.49
EDGE	34	0.26	168'	0.50
EDGE	30	0.26	168'	0.52

4.2.3 Sky Glow Contribution Analysis

The average illuminance of an area can be converted to lumens by multiplying by the area in square feet ($\varphi = E_{avg} * A$). The quantity of lumens that are leaving the site and contributing to sky glow was compared to the total fixture lumens being used to illuminate the site. The percentage of site lumens that is contributing to sky glow is summarized in Figures 8a, b, c. For all three of the light fixtures, the percentage of lumens reflected upward increased as the mounting height decreased. For example, Figure 8a shows that as the mounting height decreases from 42 ft to 30 ft for the QF10 light fixture, the percentage of site lumens that contribute to sky glow increases from 13.85% to 15.98% for a 126 ft spacing with a ground reflectance of 0.26 and from 19.88% to 23.43% for a 126 ft spacing with a ground reflectance of 0.38. Similarly, in Figure 8b as the mounting height decreases from 42 ft to 30 ft for the QD5 light fixture, the percentage of site lumens that contribute to sky glow increases from 14.44% to 17.02% for a 126 ft spacing with a ground reflectance of 0.26 and from 21.15% to 25.02% for a 126 ft spacing with a ground reflectance of 0.38. In Figure 8c as the mounting height decreases from 42 ft to 30 ft for the EDGE light fixture, the percentage of site lumens that contribute to sky glow increases from 15.53% to 18.01% for a 126 ft spacing with a ground reflectance of 0.26 and from 22.77% to 26.5% for a 126 ft spacing with a ground reflectance of 0.38.

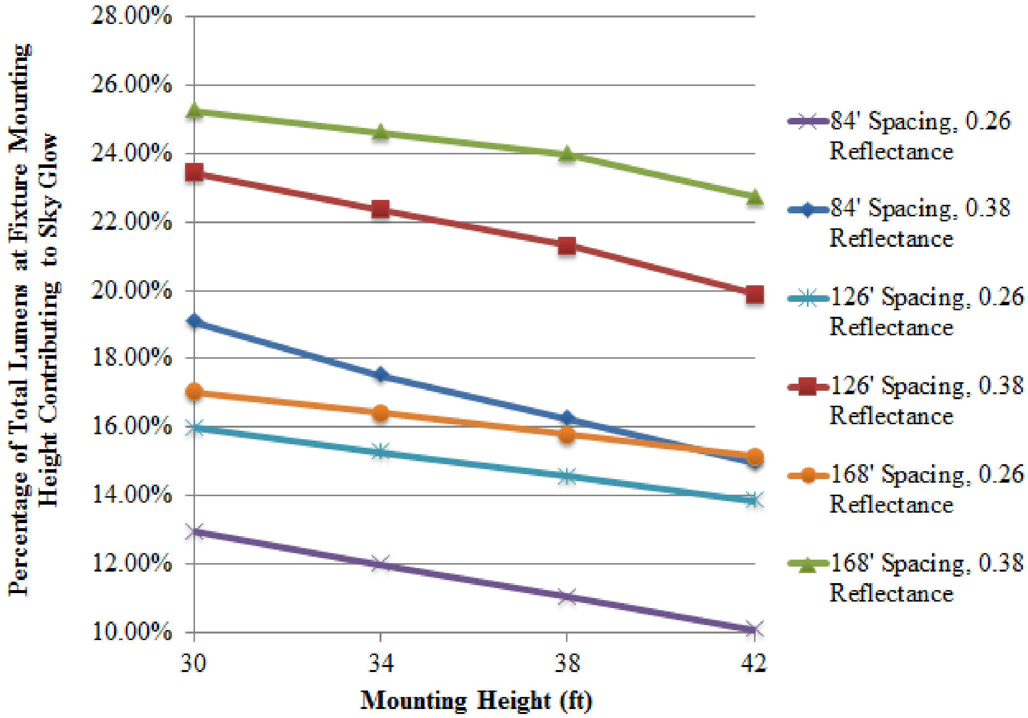


Figure 8a Square Sample Area MH vs. Sky Glow – QF10 Luminaire

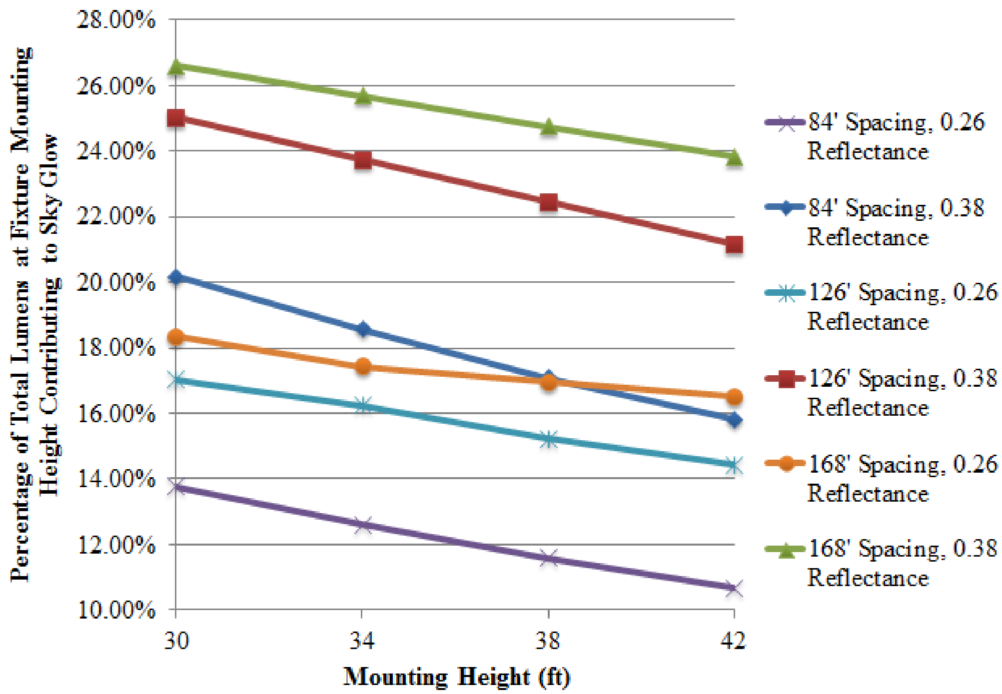


Figure 8b Square Sample Area MH vs. Sky Glow – QD5 Luminaire

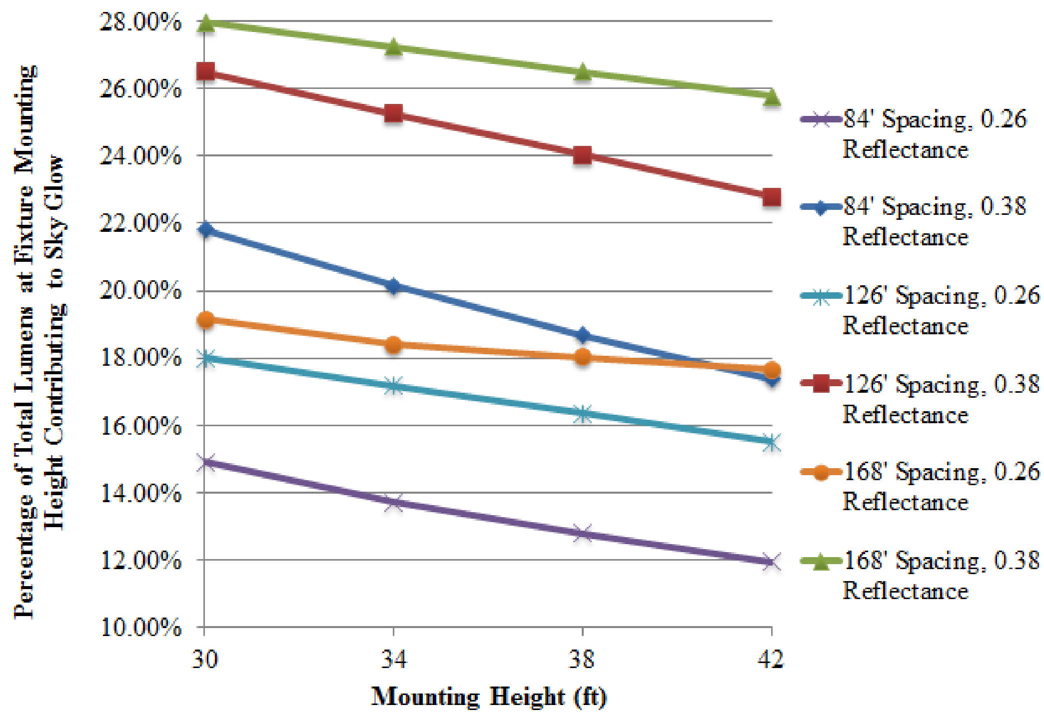


Figure 8c Square Sample Area MH vs. Sky Glow – EDGE Luminaire

4.3 Simulation Results II – Example Retail Parking Lot

4.3.1 Parking Surface Light Levels

The example retail site was optimized two ways: to meet the Owner's standard, and the MLO with both of calculation methods. The third design for the retail parking lot lighting was to meet all of the requirements of the MLO and use the maximum allowable luminaire lumens for the site in order to illustrate the deficiencies of this standard. The results for the site designed and optimized to meet the Owner's requirements are shown in Table 8. The maximum vertical illuminance at 5' above the property line for the optimized Owner's standard site was 0.7 fc using the direct only method and 0.8 fc using the full radiosity method. The optimized site uniformity and light distribution are shown in renderings in Figures 9a, b. The highest light levels are concentrated in the main parking areas and the light quickly tapers off toward the property lines. The light levels are fairly uniform and the light poles cast shadows on the parking lot. The design constraint for the optimized site for meeting the Owner's requirements was the minimum horizontal illuminance. Once enough fixtures were used to meet the minimum of 0.75 fc, the minimum average horizontal illuminance, minimum uniformity, and minimum vertical illuminance were easily met.

Table 8 Example Retail Lot Owner's Requirements Illuminances

Calculation Method	At Parking Surface			Minimum Vertical Illuminance (fc)[1]
	Minimum Horizontal Illuminance (fc)	Average Horizontal Illuminance (fc)	Uniformity Maximum/Minimum	
Direct Only	0.8	2.18	4.13	0.9
Full Radiosity	0.75	2.12	4.43	1.2

1 Vertical illuminance is calculated at the center of Main Parking Area at 5' above parking surface.

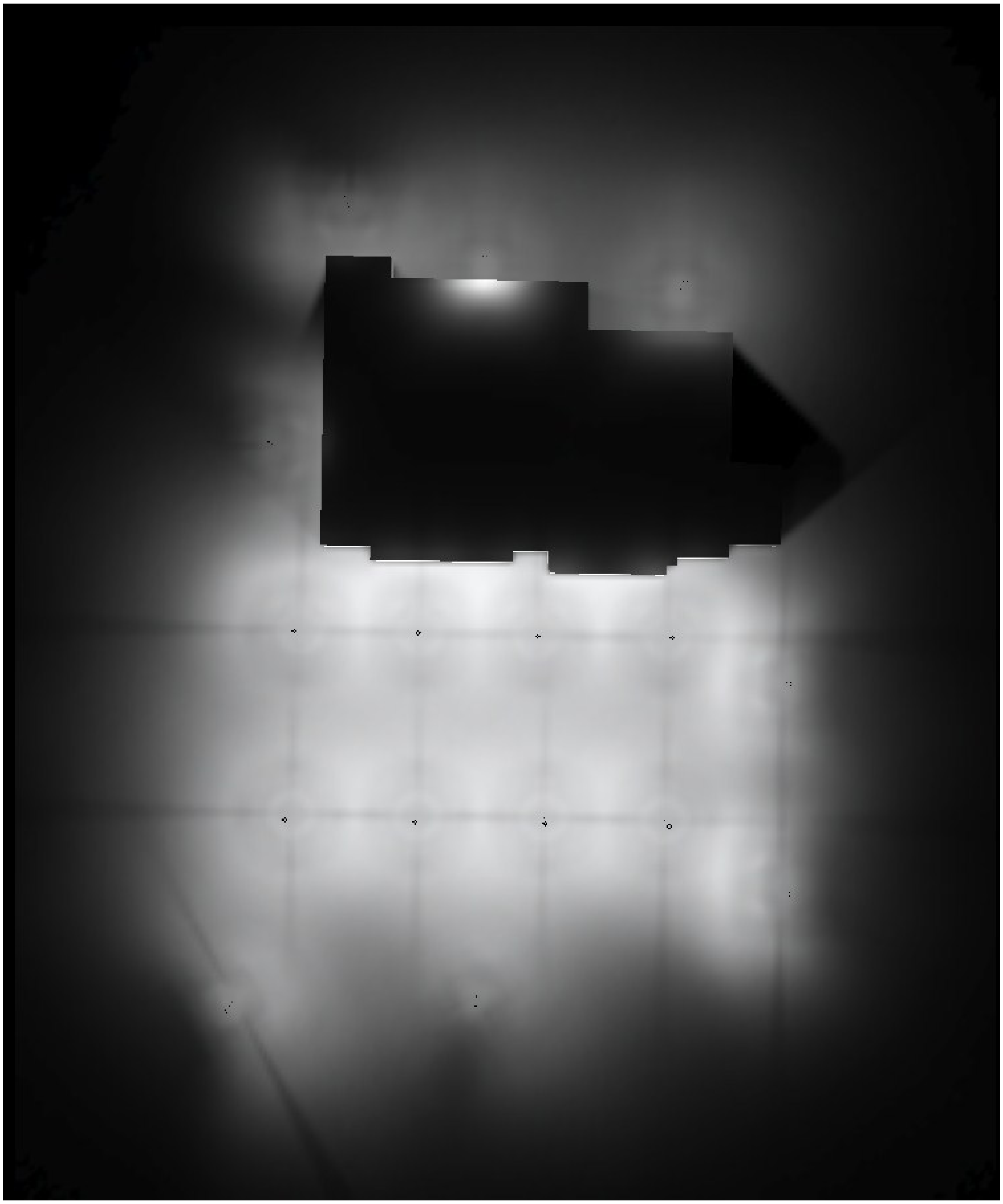


Figure 9a Example Retail Lot – Owner’s Requirements in Grayscale

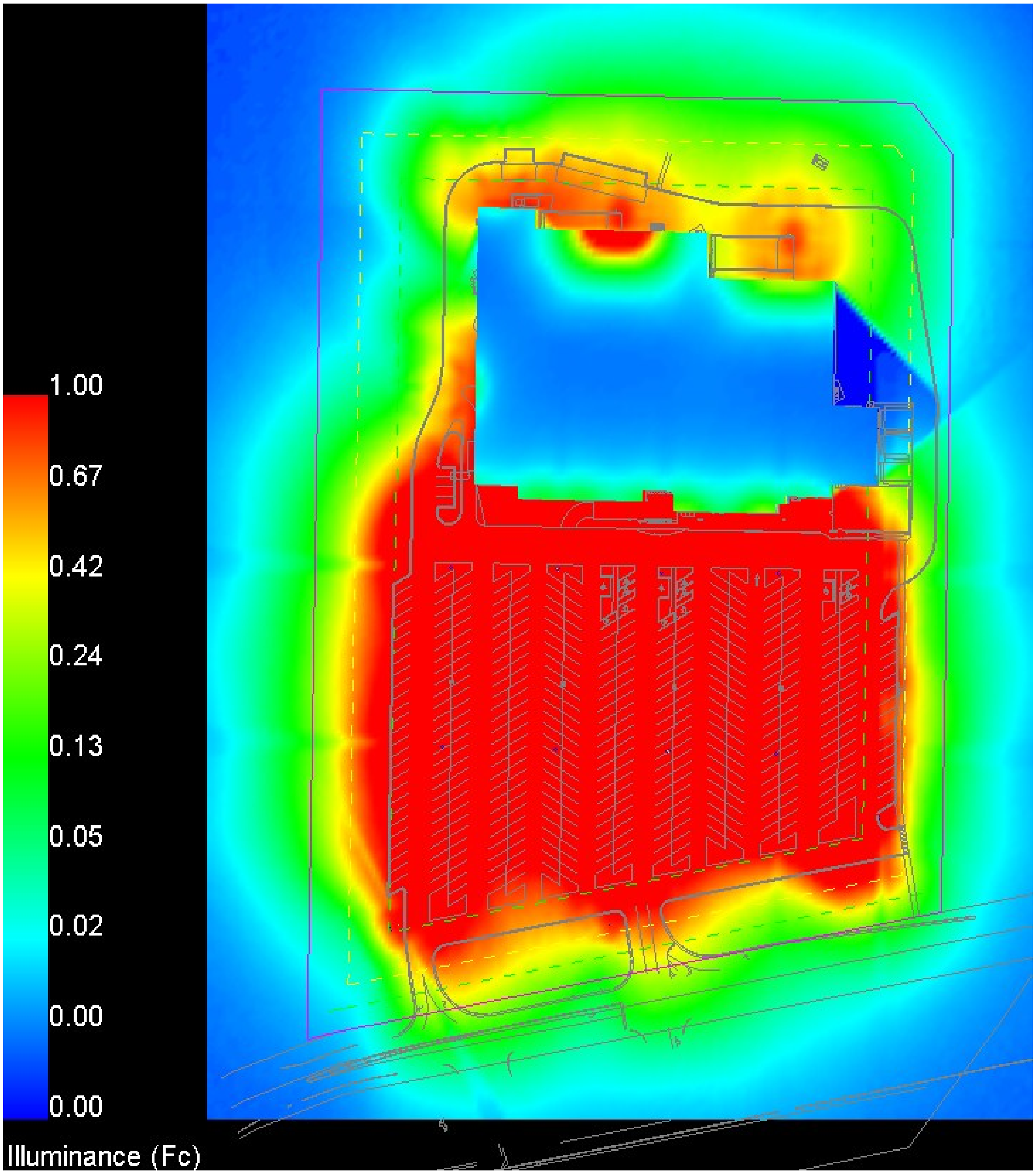


Figure 9b Example Retail Lot – Owner's Requirements in Pseudo Color

The sites designed to meet MLO and RP-20-98 calculation results are shown in Table 9. The maximum vertical illuminance at 5’ above the property line for the optimized MLO standard site was 0.3 fc for direct only and 0.5 fc for full radiosity. The maximum vertical illuminance at 5’ above the property line for the maximum lumen MLO standard site was 0.8 fc for direct only and 1.1 fc for full radiosity. Site uniformity and light distributions for the optimized site and the maximum lumen site are shown in renderings in Figures 10a, b and Figures 11a, b. Figures 10a, b show how the light levels drop to 0.2 fc between the light poles. The bright spots under each pole are very obvious and the lighting design is not uniform. In Figures 11a, b, the site with maximum allowable lumens appears uniformly lit and extremely bright in contrast to the optimized sites. The even, high illuminance is on all paved surfaces, not just the parking areas. The design constraint for the optimized site for meeting the MLO and RP-20-98 was the minimum horizontal illuminance. Once enough fixtures were used to meet the minimum of 0.2 fc, minimum uniformity and the minimum vertical far exceeded their requirements. Even though the MLO requirement site with the maximum allowable lumens used more than four times the number of lumens than the optimized site, the uniformity was worse and the minimum horizontal and minimum vertical illuminances were barely increased.

Table 9 Example Retail Lot MLO Requirements Illuminances

Design Objective	Calculation Method	At Parking Surface: Minimum Horizontal Illuminance (fc)	Average Horizontal Illuminance (fc)	Uniformity Maximum/Minimum	Minimum Vertical Illuminance (fc)[1]
Optimized	Direct Only	0.2	0.53	9.5	0.3
Optimized	Full Radiosity	0.2	0.53	9.5	0.3
Maximum Lumens	Direct Only	0.4	2.7	11.75	0.3
Maximum Lumens	Full Radiosity	0.4	2.65	11.5	0.4

1 Vertical illuminance is calculated at 5' above parking surface at the point of lowest horizontal

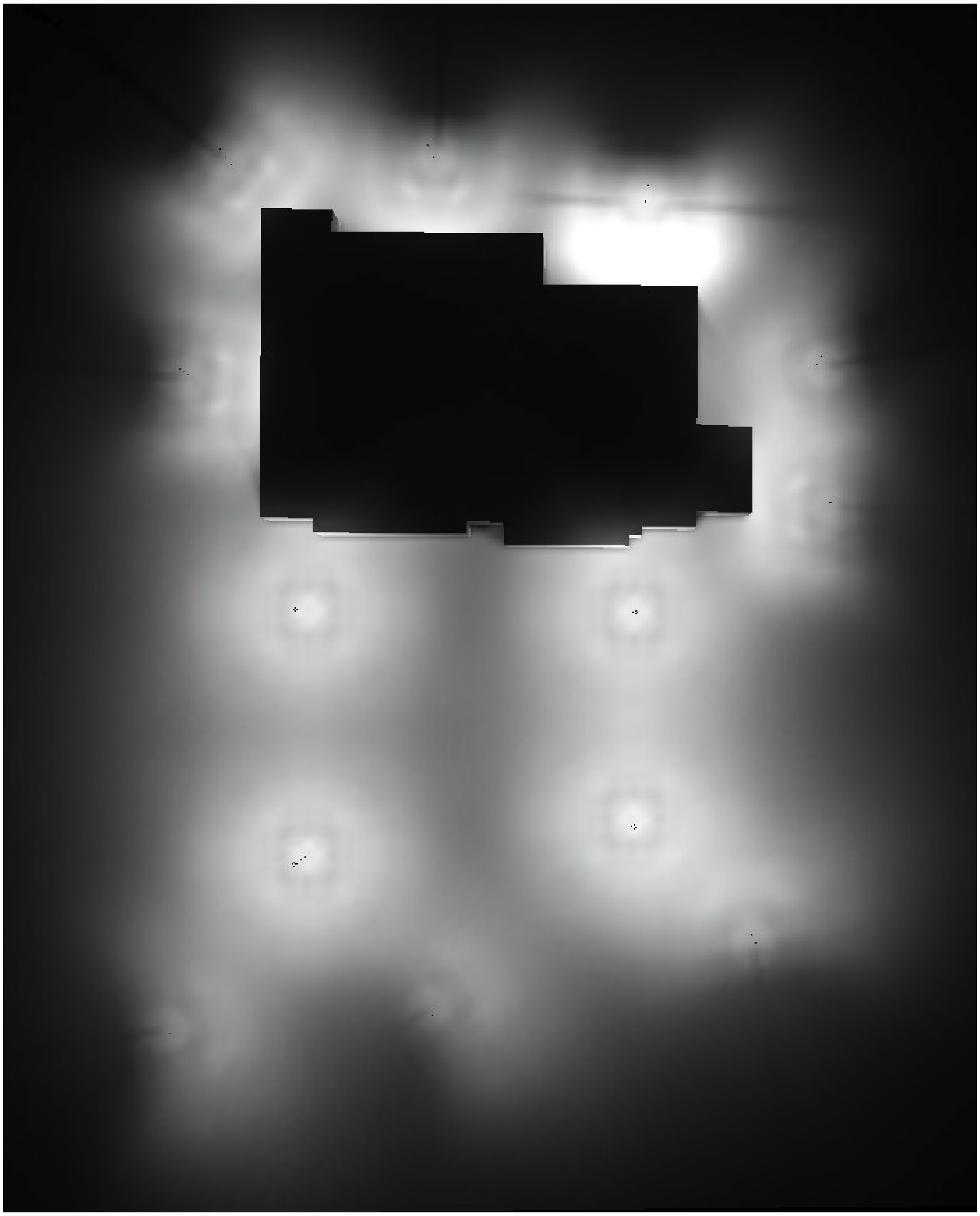


Figure 10a Example Retail Lot – MLO Requirements in Grayscale

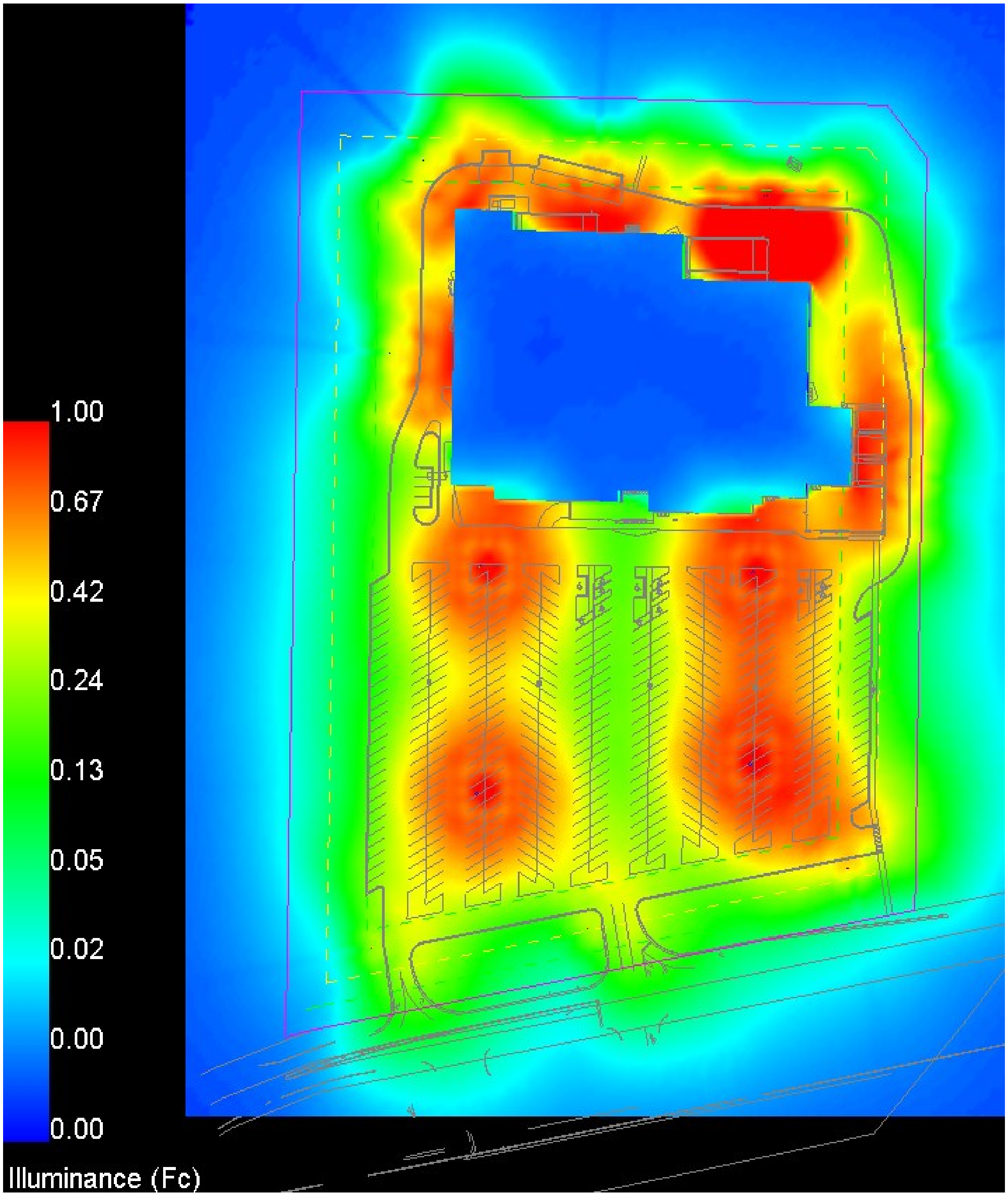


Figure 10b Example Retail Lot – MLO Requirements in Pseudo Color

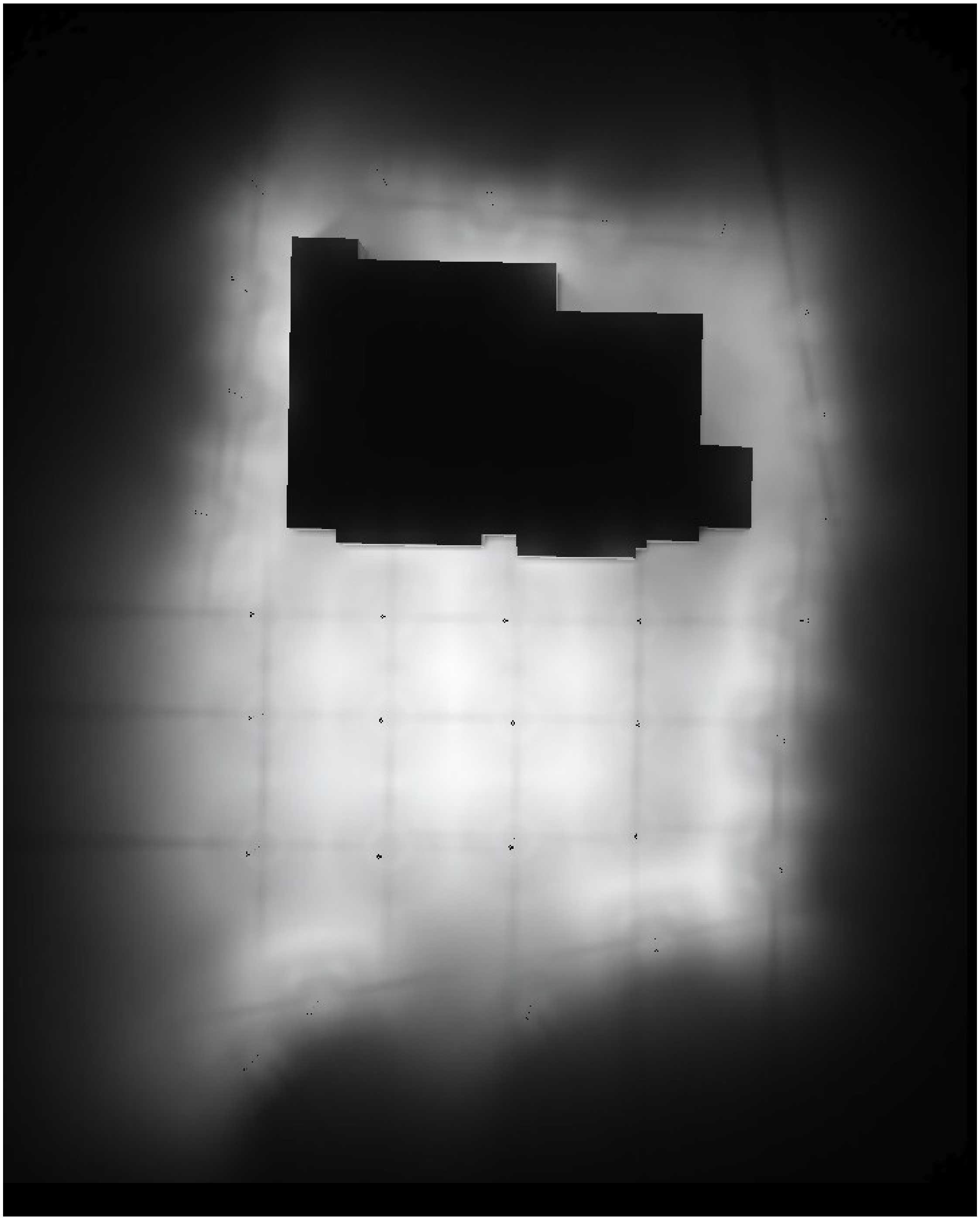


Figure 11a Example Retail Lot – MLO Requirements, Maximum Lumens in Grayscale

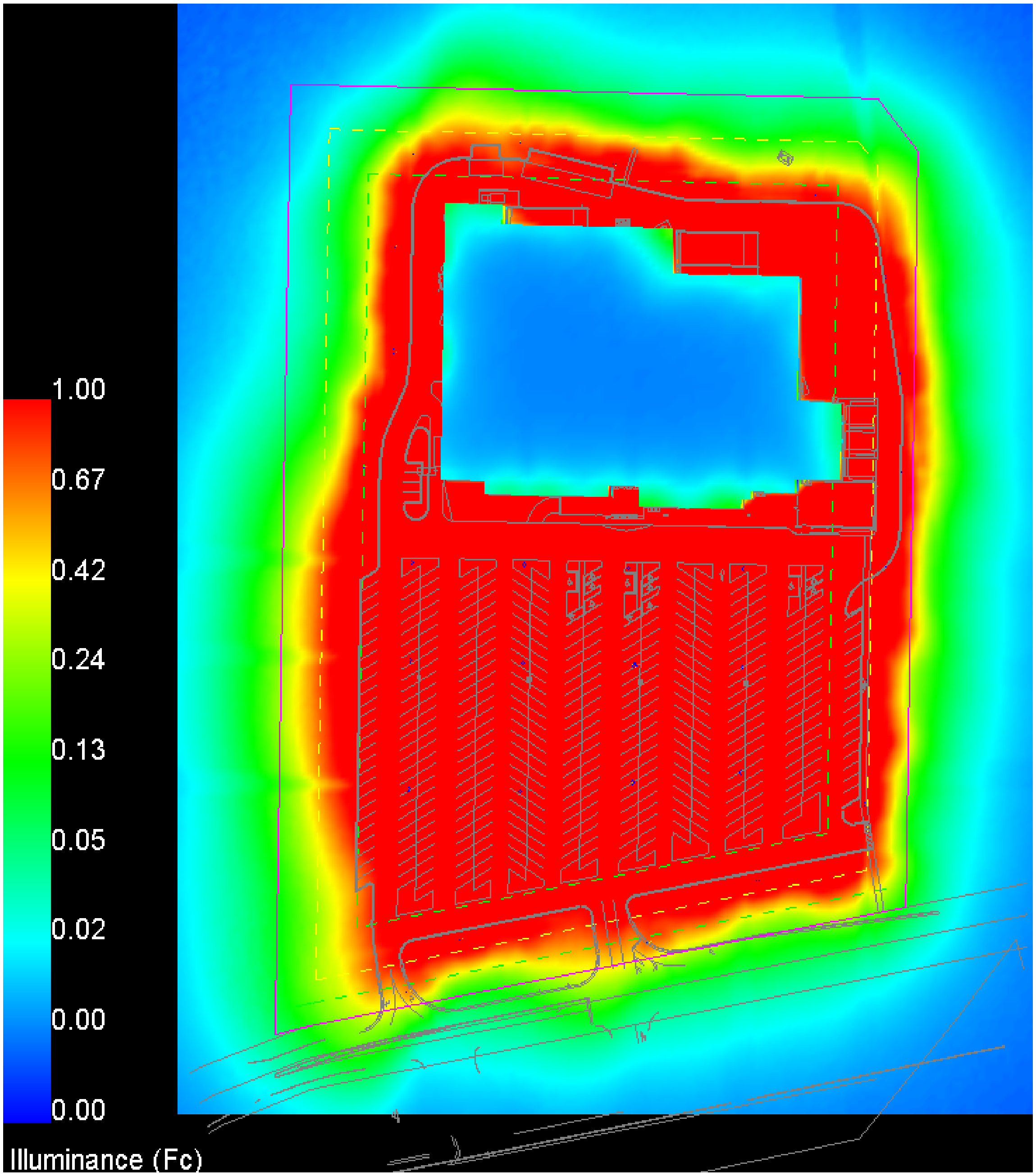


Figure 11b Example Retail Lot – MLO Requirements, Maximum Lumens in Pseudo Color

4.3.2 Comparison to Lighting Design Standards

For the Owner's requirements, the average horizontal illuminance must be greater than 2.0 fc, the minimum horizontal illuminance is 0.75 fc, the uniformity ratio was to be less than 5:1, and the minimum vertical illuminance is 0.4. The maximum allowable vertical illuminance at the property line is 0.8 fc. The optimized design meets or exceeds these requirements: the average was 2.18 fc, the minimum was 0.8 fc, the uniformity was 4.13 and the minimum vertical was 0.9 fc for the direct only method; and the average was 2.12 fc, the minimum was 0.75 fc, the uniformity was 4.43 and the minimum vertical was 1.2 fc for the full radiosity method.

The MLO and RP-20-98 parking lot lighting design requirements are that the maintained horizontal illuminance minimum value is 0.2 fc, the maintained vertical illuminance measured at the point of lowest horizontal illuminance has to reach a minimum of 0.1 fc at 5' above the parking surface, and the uniformity ratio has to be less than 20:1. The maximum allowable vertical illuminance at the property line is 0.8 fc. The optimized site design meets or exceeds these requirements: the minimum was 0.2 fc, the uniformity was 9.5, the minimum vertical was 0.3 fc, and the maximum vertical at the property line was 0.3 fc for the direct only method; and the minimum was 0.2 fc, the uniformity was 9.5, the minimum vertical was 0.3 fc, and the maximum vertical at the property line was 0.5 fc for the full radiosity method. The maximum allowable lumen site design meets or exceeds these requirements using the direct only method; the minimum was 0.4 fc, the uniformity was 11.75, the minimum vertical was 0.3 fc, and the maximum vertical at the property line was 0.8 fc. The maximum allowable lumen site design met all requirements except for the maximum vertical at the property line using the full radiosity method; the minimum was 0.4 fc, the uniformity was 11.5, and the minimum vertical was 0.4 fc. The reflected light was taken into account with the full radiosity calculation method for the maximum lumen design; the vertical illuminance at the property line exceeded the limit with a value of 1.1 fc.

4.3.3 Light Levels at Mounting Height

The average illuminances for each of the three example parking lot lighting designs are shown in Table 10. The number of lumens varies with the design intentions; the minimal required light levels for an MLO optimized site require far fewer lumens than the Owner's parking lot requirements for higher light levels. The optimized Owner's standard design used 762,400 lumens or 61.6% of the allowable lumens. The optimized MLO standard design used 262,200 lumens or 21.2% of the allowable lumens. The MLO standard with maximum lumens design used 1,233,600 lumens or 99.6% of the allowable lumens.

Table 10 Example Retail Lot Mounting Height Light Levels and Lumens

Site Calculation Type	Calculation Method	Average Horizontal (fc)	Total Lumens	Max Allowable Lumens	Unused Lumens
Owner Standard, Optimized	Full Radiosity	0.36	762,400	1,238,305	475,905
MLO Standard, Optimized	Full Radiosity	0.11	262,000	1,238,305	976,305
MLO Standard, Maximum Allowable Lumens	Full Radiosity	1.6	1,233,600	1,238,305	4,705

4.3.4 Sky Glow Contribution Analysis

The quantity of lumens that are leaving the site and contributing to sky glow is compared to the total fixture lumens being used to illuminate the site for the purpose of identifying efficient lighting designs. The percentage of site lumens that contribute to sky glow is summarized in Table 11 for each of the three site designs. The MLO standard optimized site design used the fewest total lumens and the percentage of those lumens that contribute to sky glow is also the smallest at 23.41%. The Owner standard optimized site loses 26.33% of the total site lumens upward. The maximum allowable lumen site not only uses the most total lumens, but it also contributes the largest percentage of those lumens to sky glow at 72.33%.

Table 11 Example Retail Lot Mounting Height Lumens Contributing to Sky Glow

Site Calculation Type	Calculation Method	Total Lumens	Percentage of Lumens Upward
Owner Standard, Optimized	Full Radiosity	762,400	26.33%
MLO Standard, Optimized	Full Radiosity	262,000	23.41%
MLO Standard, Maximum Allowable Lumens	Full Radiosity	1,233,600	72.33%

CHAPTER 5 CONCLUSIONS AND DISCUSSION

5.1 Conclusions

Based on the data analyses, three conclusions about lighting standards and light pollution can be drawn as following:

1. The MLO allowable lumens for commercial parking areas is significantly greater than needed to fulfill the lighting standards of RP-20-98 or the Owner's Site Lighting Standard.
2. The MLO could incorporate measured sky glow contribution limits as an option for jurisdictions that have the need for sky glow prevention.
3. The RP-20-98 is in need of updating to have lighting design recommendations for the different lighting zones defined in the MLO. Having one recommendation for all parking facilities does not foster good design practices. Not all owners will take the initiative to set their own standard for their specific needs, and the recommended practices from the IES should be able to fill that role.
4. Ordinances that limit light fixture mounting height are decreasing the efficiency in terms of the LPD and cause unwanted contribution to sky glow. Limiting mounting heights decreases uniformity by causing higher contrast between the bright areas underneath light poles and darker areas between light poles.

5.2 Discussion

The updates to the RP-20-98 may consider multiple site design comparisons to standardize a recommended minimum average horizontal illuminance, minimum horizontal illuminance, minimum vertical illuminance, and maximum uniformity ratio for each lighting zone. These lighting zones would logically be the same as those addressed in the MLO for lumen limits with proportional light level recommendations. The zones could not only take the ambient light levels into account, but rather the goal ambient light level of surrounding areas.

While the MLO addresses what a lighting ordinance should be, it does not specifically address the mounting height of light fixtures. Suggesting mounting heights based on light fixture lumen output would help limit sky glow and maximize efficiency.

Once specific light level recommendations are determined for each lighting zone, the allowable lumen values may be adjusted down to limit the amount of light pollution while still being able to design with reasonably flexibility. With the large assortment of light distributions of the current LED light fixtures on the market, fewer site lumens are needed to achieve uniform lighting designs. By requiring lower lumen limits, jurisdictions that adopt a stricter version of the MLO will force designers to use each lumen wisely and optimize each site lighting design.

5.3 Further Research

Further research is needed in modernizing recommended practice documents for the latest available LED light fixture technology. Computer simulation cannot accurately model the reflectance properties of a parking lot; additional research in this area is necessary to analyze the effect of parking lot pavement materials with different reflectance properties to consider recommending a better material for mitigation of sky glow. Also, full-scale parking lot lighting installations should be analyzed to validate changes to the existing standards and Model Lighting Ordinance.

APPENDIX A

GE
Lighting Solutions

Evolve™ LED Area Light

Medium Thin Profile (EAMT)

imagination at work

Product Features

GE Lighting Solutions designed this luminaire using both fixture and LED application expertise to bring unmatched product quality and reliability with optical leadership and understanding of customer needs. This product can easily achieve IESNA RP-20 horizontal illuminance requirements while exceeding MAX/MIN uniformity requirements. This sleek and robust fixture is now available with a new, higher light output Type V option (D5) that produces 19,000 lumens.

Applications

- For site, area, and general lighting utilizing advanced LED optical system providing high uniformity, excellent vertical light distribution, reduced offsite visibility, reduced on-site glare and effective security light levels.
- Ideal for commercial and medical properties, large malls, and big box retailers.

Housing

- Die-cast aluminum housing.
- Slim architectural design incorporates a heat sink directly into the unit ensuring maximum heat transfer, long LED life and a reduced Effective Projected Area (EPA).
- Meets 2G vibration standards per ANSI C136.32-2001. For 3G rating contact factory.

LED & Optical Assembly

- Optimized LED array based on distribution pattern.
- Utilizes high brightness LEDs, 70 CRI at 6000K typical. D5 available in 4000K and 5700K typical.
- LM-79 tests and reports are performed in accordance with IESNA standards.

Lumen Maintenance

- System rating is 50,000 hours at L85.
- Contact factory for L rating (Lumen Depreciation) beyond 50,000 hours.

Ratings

- UL/cUL listed, suitable for wet locations.
- IP 65 rated optical assembly per ANSI C136.25-2009.
- Temperature rated at -40°C to 50°C.
- RoHS compliant, contains no lead or mercury.

Mounting

Option A

- 10-inch (254mm) mounting arm for square pole with easy-connect terminal board.

Option B

- 10-inch (254mm) mounting arm for round pole with easy-connect terminal board.

Option C

- Slipfitter mounting for 2 3/8-inch (60mm) O.D. pipe prewired with 24-inch (610mm) leads.

Finish

- Corrosion resistant polyester powder painted, minimum 2.0 mil. thickness.
- Standard colors: Black & Dark Bronze.
- RAL & custom colors available.

Electrical

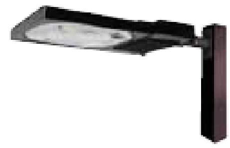
- 120-277 volt and 347-480 volt available.
- System power factor is >90% and THD <20%.
- Class "A" Sound rating.
- Integral surge protection non-dimming:
  - For 120-277VAC per IEEE/ANSI C62.41.-1991, 4kV/2kA Location Category B2 (120 Events)
  - For 347-480VAC per IEEE/ANSI C62.41.-1991, 6kV/3kA Location Category B3 (120 Events)
- Integral surge protection GE dimming:
  - For 120-480VAC per IEEE/ANSI C62.41.2-2002, 6kV/3kA Location Category B (120 Events)
- EMI: Title 47 CFR Part 15 Class A
- Photo Electric Sensors (PE) available for all voltages.

Warranty

- 5-year limited system warranty standard.

Ordering Number Logic

Medium Thin Profile Fixtures (EAMT)



E A M T _ - _ - _ _ - _ - _ _ - A - _ - _ - _ - _ _ _ _ - _

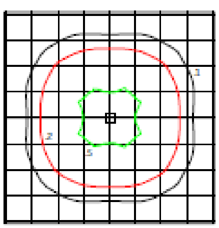
PROD. ID	VOLTAGE	OPTICAL CODE	DISTRIBUTION ORIENTATION	LED COLOR TEMP	LENS TYPE	PE FUNCTION	MOUNTING ARM	COLOR	OPTIONS
E – Evolve **A** – Area **M** – Medium **T** – Thin	**0** – 120 - 277 **H** – 347 - 480 **1** – 120* **2** – 208* **3** – 240* **4** – 277* **5** – 480* **D** – 347* *Specify single voltage only if fuse option is selected		**F** – Front **L** – Left **R** – Right **N** – Not Applicable* *Not applicable when pattern is symmetric	**40** – 4000K* **57** – 5700K* **60** – 6000K** *D5 Distribution Only **Not available in D5 distribution	**A** – Acrylic	**1** – None **2** – PE Rec. **4** – PE Rec. with Shorting Cap **5** – PE Rec. with Control PE control not available for 347-480V. Must be a discrete voltage.	**A** – 10" Arm for Square Pole supplied with Terminal Block **B** – 10" Arm for Round Pole supplied with Terminal Block **C** – EXT Slipfitter 2" PIPE (2.375 in. OD) supplied with leads	**BLCK** – Black **DKBZ** – Dark Bronze Contact factory for other colors	**D** – Dimmable (0-10Volt Input)* **F** – Fusing **T** – Extra Surge Protection* *Contact factory for availability.

Light pattern thrown in direction specified in relation to Pole and Fixture.

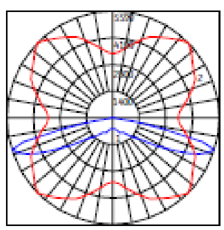
OPTICAL CODE	TYPE	TYPICAL INITIAL LUMENS			TYPICAL SYSTEM WATTAGE		DISTRIBUTION ORIENTATION AVAILABLE	BUG RATINGS 4000K			BUG RATINGS 5700K			BUG RATINGS 6000K			IES FILE NUMBER		
		4000K	5700K	6000K	120-277V	347-480V		B	U	G	B	U	G	B	U	G	4000K	5700K	6000K
D5	Symmetric Square	17,500	19,000	N/A	270	285	N	5	3	3	5	3	3	N/A	N/A	N/A	454564	454566	N/A
S5	Symmetric Square	N/A	N/A	12,300	210	220	N	N/A	N/A	N/A	N/A	N/A	N/A	4	2	2	N/A	N/A	454058
F4	Asymmetric Forward	N/A	N/A	5,400	94	99	F, L, R	N/A	N/A	N/A	N/A	N/A	N/A	1	3	2	N/A	N/A	454062
W3	Asymmetric Wide	N/A	N/A	7,200	132	138	F, L, R	N/A	N/A	N/A	N/A	N/A	N/A	3	1	3	N/A	N/A	454060

Photometrics

EAMT Type V - Symmetric Square (S5)
12,300 Lumens, 6000K (GE454058.ies)

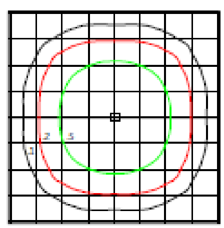


Grid Distance in Units of Mounting Height at 30'
Initial Footcandle Values at Grade

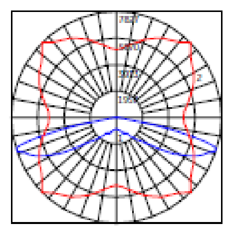


Polar Trace Vertical and Horizontal Plane through Horizontal Angle of Maximum Candlepower

EAMT Type V - Symmetric Square (D5)
19,000 Lumens, 5700K (GE454566.ies)

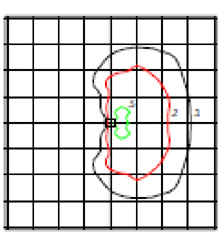


Grid Distance in Units of Mounting Height at 30'
Initial Footcandle Values at Grade

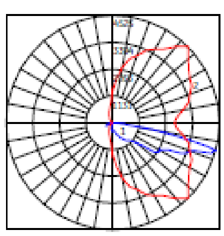


Polar Trace Vertical and Horizontal Plane through Horizontal Angle of Maximum Candlepower

EAMT Type IV - Asymmetric Forward (F4)
5,400 Lumens, 6000K (GE454062.ies)

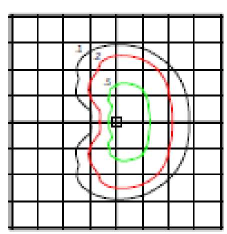


Grid Distance in Units of Mounting Height at 30'
Initial Footcandle Values at Grade

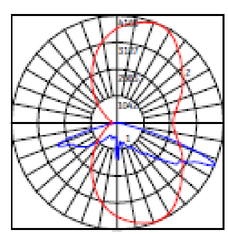


Polar Trace Vertical and Horizontal Plane through Horizontal Angle of Maximum Candlepower

EAMT Type III - Asymmetric Wide (W3)
7,200 Lumens, 6000K (GE454060.ies)



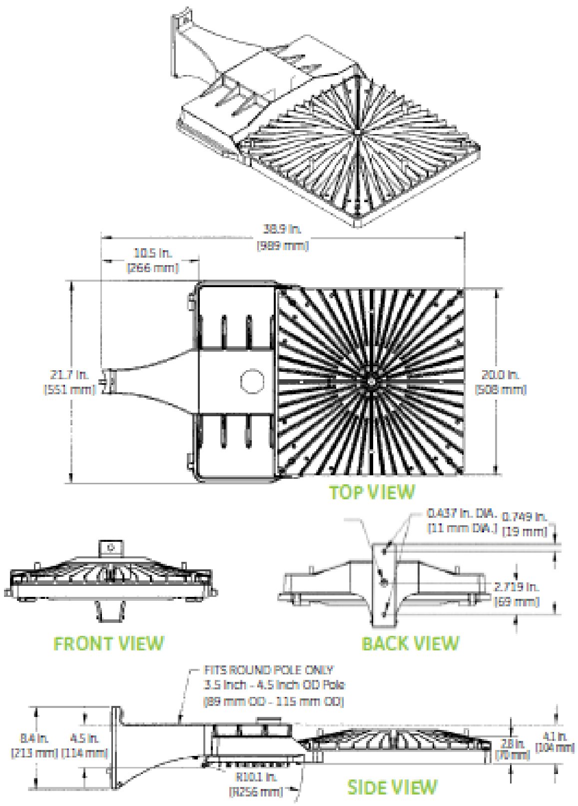
Grid Distance in Units of Mounting Height at 30'
Initial Footcandle Values at Grade



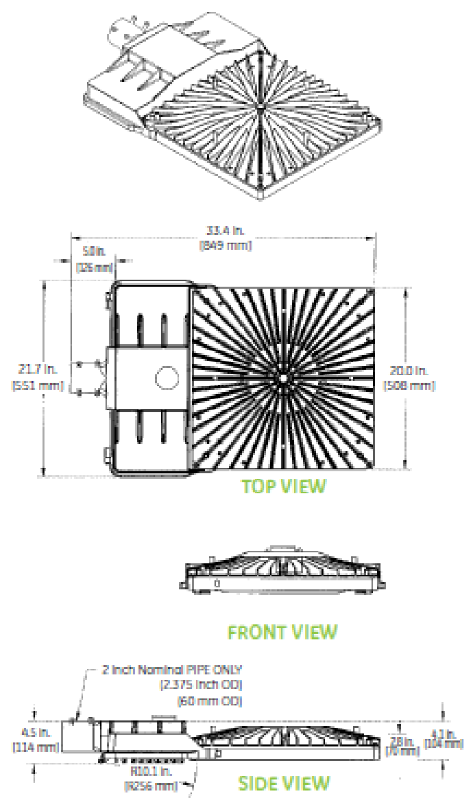
Polar Trace Vertical and Horizontal Plane through Horizontal Angle of Maximum Candlepower

Product Dimensions

10" Arm for Round Pole Mount (Option B)



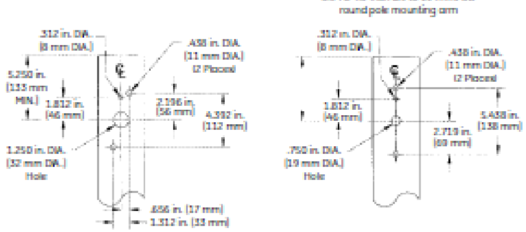
Slipfitter Arm Mount (Option C)



Drilling Templates for Slipfitter Arms & Arm Mount

SQUARE POLE MOUNTING

ROUND POLE MOUNTING
3.5 TO 4.5 inch (89 to 114mm) OD round pole mounting arm

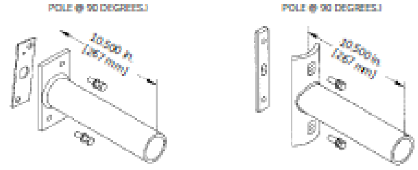


Mounting Arms for Slipfitter

Order separately with Mounting Option C (External Slipfitter)

SQUARE POLE MOUNTING ARM
3.5 TO 4.5-inch (89 to 114mm) SQUARE
(WILL ALLOW 4 FIXTURES PER
POLE @ 90 DEGREES.)

ROUND POLE MOUNTING ARM
3.5 TO 4.5-inch (89 to 114mm) OD
(WILL ALLOW 4 FIXTURES PER
POLE @ 90 DEGREES.)



ORDER SEPARATELY FROM FIXTURE
AS CATALOG NUMBER
SPA-EAMT10BLCK "Black"
SPA-EAMT10DKBZ "Dark Bronze"

ORDER SEPARATELY FROM FIXTURE
AS CATALOG NUMBER
RPA-EAMT10BLCK "Black"
RPA-EAMT10DKBZ "Dark Bronze"

(FOR RETROFITS INSTALLATIONS OTHER MOUNTING PATTERNS ARE AVAILABLE) CONTACT FACTORY FOR OTHER AVAILABLE MOUNTING PATTERNS

DATA
- Approximate Net Weight: 51-57 lbs (23-26 kgs)
- Effective Projected Area (EPA) with 10" Mounting Arm: 1.35 sq ft max (0.13 sq m)
- Effective Projected Area (EPA) with Slipfitter: 1.19 sq ft max (0.11 sq m)

GE Lighting Solutions • 1-888-MY-GE-LED • www.gelightingsolutions.com
1-888-69-43-533

OLP-2849C (Rev 03/25/11)

APPENDIX B

GE
Lighting Solutions

Evolve™ LED Area Light

Modular Fixture - Small & Medium (EASM & EAMM)

imagination at work

Product Features

The next evolution of the GE Evolve™ LED Area Light continues to deliver the same outstanding features associated with the original Evolve product, while now adding greater flexibility and style. The European styling offers a sleek, modern look, and balances the needs for photometric scalability with reliable workhorse performance. The new modular design provides 34 photometric combinations, available in two color temperatures, to meet a wide range of area lighting needs.

GE's exclusive optical ring design produces superior vertical illuminance and efficiently directs the light without wasteful and unwelcomed light spill into neighboring properties. Additionally, reduced energy consumption, combined with a long rated life that virtually eliminates ongoing maintenance expenses, enables the Evolve LED Area Light to provide significant operating cost benefits over the life of each fixture.

Applications

- Single and double modules for site, area, and general lighting utilizing advanced LED optical system providing high uniformity, excellent vertical light distribution, reduced offsite visibility, reduced on-site glare and effective security light levels.
- Scalable design makes this product ideal for small to medium retailers, commercial to medical properties, strip malls to large malls, and big box retailers.

Housing

- Die-cast aluminum housing.
- Slim architectural design incorporates modular heat sink light engine directly into the unit ensuring maximum heat transfer, long LED life and a reduced Effective Projected Area (EPA).
- Meets 2G vibration standards per ANSI C136.32-2001. For 3G rating contact factory.

LED & Optical Assembly

- Structured LED arrays for optimized area light photometric distribution.
- Evolve modular light engine consisting of nested concentric directional reflectors designed to optimize application efficiency and minimize glare.
- Utilizes high brightness LEDs, 70 CRI at 4000K and 5700K typical.
- LM-79 tests and reports are performed in accordance with IESNA standards.

Lumen Maintenance

- System rating is 50,000 hours at L85. Contact factory for L rating (Lumen Depreciation) beyond 50,000 hours.

Ratings

- UL/cUL listed, suitable for wet locations.
- IP 65 rated optical enclosure per ANSI C136.25-2009.
- Temperature rated at -40° to 50°C.
- RoHS compliant, contains no lead or mercury.

Mounting

Option A

- 10-inch (254mm) mounting arm for square pole with easy-connect terminal board.

Option B

- 10-inch (254mm) mounting arm for round pole with easy-connect terminal board.

Option C

- Slipfitter mounting for 2 3/8-inch (60mm) O.D. pipe prewired with 24-inch (610mm) leads.

Finish

- Corrosion resistant polyester powder painted, minimum 2.0 mil. thickness.
- Standard colors: Black & Dark Bronze.
- RAL & custom colors available.

Electrical

- 120-277 volt and 347-480 volt available.
- System power factor is >90% and THD <20%.
- Class "A" sound rating.
- Integral surge protection non-dimming:
  - For 120-277VAC per IEEE/ANSI C62.41.-1991, 4kV/2kA Location Category B2 (120 Events)
  - For 347-480VAC per IEEE/ANSI C62.41.-1991, 6kV/3kA Location Category B3 (120 Events)
- Integral surge protection GE dimming:
  - For 120-480VAC per IEEE/ANSI C62.41.2-2002, 6kV/3kA Location Category B (120 Events)
- Optional high capability surge protection per IEEE/ANSI C62.41.2-2002.
  - Rating 1 - 10kV/5kA Location Category (120 events)
  - Rating 2 - 6kV/3kA Location Category C-Low (5000 events)
- EMI: Title 47 CFR Part 15 Class A
- Photo electric sensors (PE) available for all voltages.

Warranty

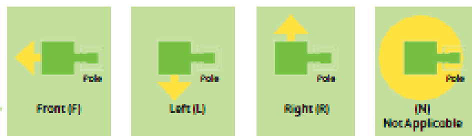
- 5-year limited system warranty standard.

Ordering Number Logic

Medium / Double Module Fixture (EAMM)

E A M M _ - _ - _ _ - _ - _ _ - A - _ - _ - _ _ _ _ - _

PROD. ID	VOLTAGE	OPTICAL CODE	DISTRIBUTION ORIENTATION	LED COLOR TEMP	LENS TYPE	PE FUNCTION	MOUNTING ARM	COLOR	OPTIONS
E = Evolve A = Area M = Medium M = Modular	0 = 120 - 277 1 = 120* 2 = 208* 3 = 240* 4 = 277* 5 = 480* D = 347* *Specify single voltage if fuse option is selected.		F = Front L = Left R = Right N = Not Applicable	40 = 4000K 57 = 5700K	A = Acrylic	1 = None 2 = PE Rec. 4 = PE Rec. with Shorting Cap 5 = PE Rec. with Control PE control not available for 347-480V. Must be a discrete voltage.	A = 10" Arm for Square Pole supplied with Terminal Block B = 10" Arm for Round Pole supplied with Terminal Block C = EXT Slipfitter 2" PIPE (2.375 in. OD) supplied with leads	BLCK = Black DKBZ = Dark Bronze Contact factory for other colors	D = Dimmable (0-10Volt Input)* F = Fusing S = Shield* T = Extra Surge Protection* XXX = Special Options *Contact factory for availability.



Light pattern thrown in direction specified in relation to Pole and Fixture.

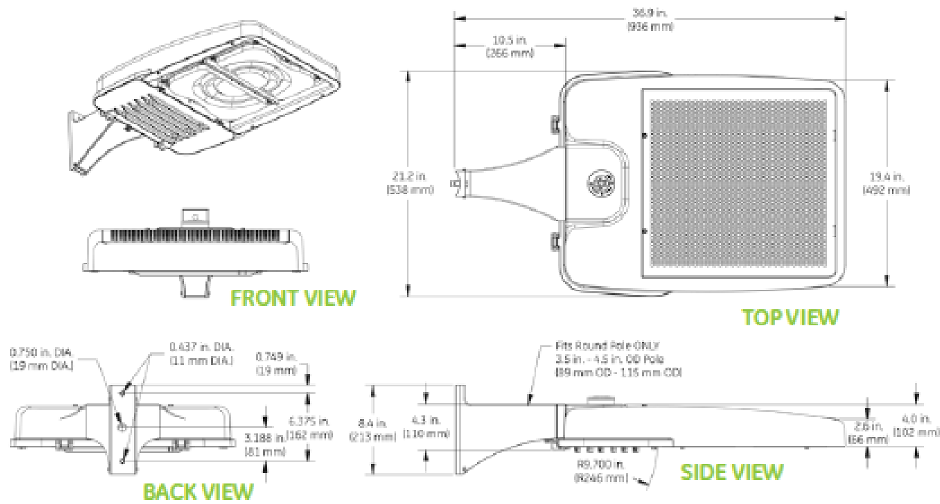
	OPTICAL CODE	TYPE	TYPICAL INITIAL LUMENS 4000K	TYPICAL INITIAL LUMENS 5700K	TYPICAL SYSTEM WATTAGE 120-277V	TYPICAL SYSTEM WATTAGE 347-480V	DISTRIBUTION ORIENTATION AVAILABLE	BUG RATINGS 4000K B	4000K U	4000K G	5700K B	5700K U	5700K G	IES FILE NUMBER* 4000K	IES FILE NUMBER* 5700K
TYPE V	A5	Symmetric Medium	6260	6800	100	105	N	3	1	1	3	2	2	454457	454487
	B5	Symmetric Medium	8100	8800	126	133	N	3	2	2	3	2	2	454458	454488
	C5	Symmetric Medium	9940	10800	152	160	N	4	2	2	4	2	2	454459	454489
	D5	Symmetric Medium	11780	12800	178	187	N	4	2	2	4	3	2	454460	454490
	E5	Symmetric Medium	13620	14800	202	213	N	4	3	2	4	3	2	454461	454491
	K5	Symmetric Short	6260	6800	100	105	N	3	1	1	3	1	1	454471	454513
	L5	Symmetric Short	8100	8800	126	133	N	3	1	1	3	1	1	454472	454514
	M5	Symmetric Short	9940	10800	152	160	N	3	1	2	3	1	2	454473	454515
	N5	Symmetric Short	11780	12800	178	187	N	3	1	2	4	1	2	454474	454516
	P5	Symmetric Short	13620	14800	202	213	N	4	1	2	4	1	2	454475	454517
TYPE IV	F4	Asymmetric Forward	8100	8800	126	133	F, L, R	2	3	2	2	3	2	454409	454396
	G4	Asymmetric Forward	9020	9800	139	146	F, L, R	2	3	2	2	3	2	454448	454476
	H4	Asymmetric Forward	9940	10800	152	160	F, L, R	2	3	2	2	3	3	454412	454405
	J4	Asymmetric Forward	10860	11800	165	174	F, L, R	2	3	3	2	3	3	454451	454479
	K4	Asymmetric Forward	11780	12800	178	187	F, L, R	2	3	3	2	3	3	454415	454426
	L4	Asymmetric Forward	12700	13800	190	200	F, L, R	2	3	3	2	3	3	454454	454482
	M4	Asymmetric Forward	13620	14800	202	213	F, L, R	2	3	3	3	3	3	454418	454435
TYPE III	F3	Asymmetric Wide	8100	8800	126	133	F, L, R	1	1	2	1	1	2	454436	454492
	G3	Asymmetric Wide	9020	9800	139	146	F, L, R	2	1	2	2	1	2	454462	454495
	H3	Asymmetric Wide	9940	10800	152	160	F, L, R	2	1	2	2	1	2	454439	454498
	J3	Asymmetric Wide	10860	11800	165	174	F, L, R	2	1	2	2	1	2	454465	454501
	K3	Asymmetric Wide	11780	12800	178	187	F, L, R	2	1	2	2	1	2	454442	454504
	L3	Asymmetric Wide	12700	13800	190	200	F, L, R	2	1	2	2	1	2	454468	454507
	M3	Asymmetric Wide	13620	14800	202	213	F, L, R	2	1	2	2	1	2	454445	454510

*Shielded options available. Contact factory for IES files.

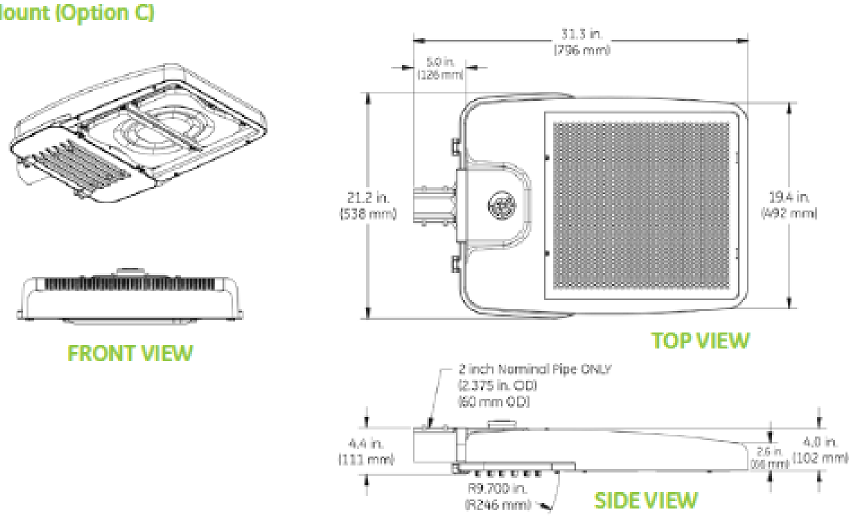
Product Dimensions

Medium / Double Module Fixture (EAMM)

10" Arm for Round Pole Mount (Option B)



Slipfitter Arm Mount (Option C)



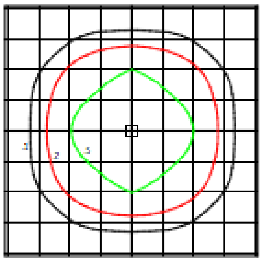
DATA

- Approximate Net Weight: 46-49 lbs (21-22 kgs)
- Effective Projected Area (EPA) with 10" Mounting Arm: 1.35 sq ft max (0.13 sq m)
- Effective Projected Area (EPA) with Slipfitter: 0.86 sq ft max (0.08 sq m)

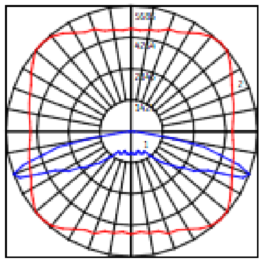
Photometrics

Medium / Double Module Fixture (EAMM)

EAMM Type V – Symmetric Medium (E5)
14,800 Lumens, 5700K (GE454491.ies)

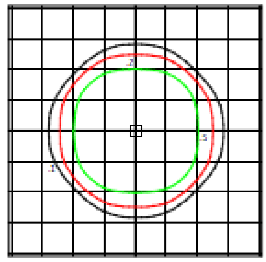


Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade

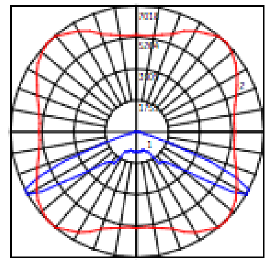


Polar Trace Vertical and Horizontal Plane through Horizontal Angle of Maximum Candlepower

EAMM Type V - Symmetric Short (P5)
14,800 Lumens, 5700K (GE454517.ies)

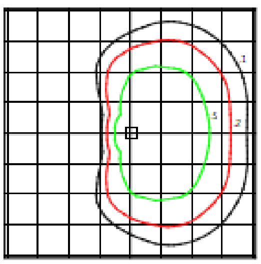


Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade

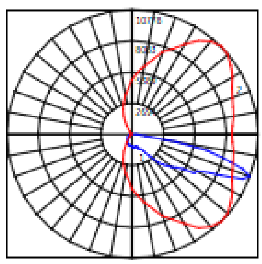


Polar Trace Vertical and Horizontal Plane through Horizontal Angle of Maximum Candlepower

EAMM Type IV - Asymmetric Forward (M4)
14,800 Lumens, 5700K (GE454435.ies)

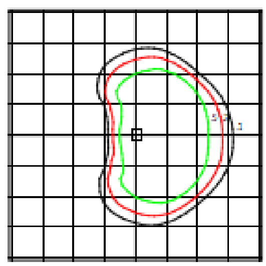


Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade

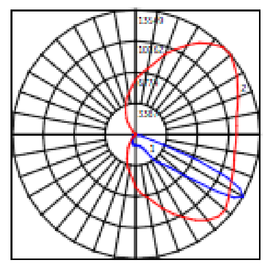


Polar Trace Vertical and Horizontal Plane through Horizontal Angle of Maximum Candlepower

EAMM Type III - Asymmetric Wide (M3)
14,800 Lumens, 5700K (GE454510.ies)



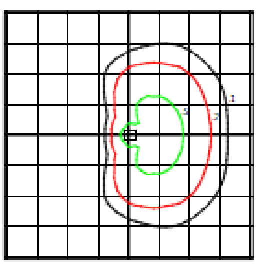
Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade



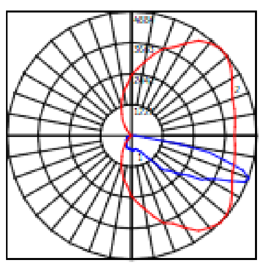
Polar Trace Vertical and Horizontal Plane through Horizontal Angle of Maximum Candlepower

Small / Single Module Fixture (EASM)

EASM Type IV - Asymmetric Forward (E4)
7,400 Lumens, 5700K (GE454407.ies)

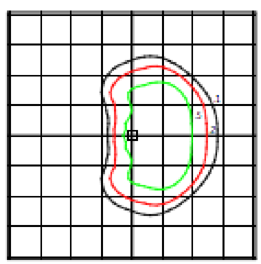


Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade

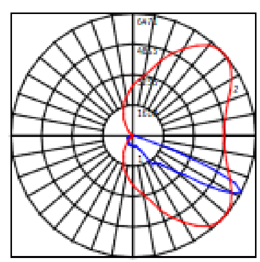


Polar Trace Vertical and Horizontal Plane through Horizontal Angle of Maximum Candlepower

EASM Type III - Asymmetric Wide (E3)
7,400 Lumens, 5700K (GE454434.ies)



Grid Distance in Units of Mounting Height at 30' Initial Footcandle Values at Grade



Polar Trace Vertical and Horizontal Plane through Horizontal Angle of Maximum Candlepower

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OLP-2893 (Rev. 03/25/11)

APPENDIX C

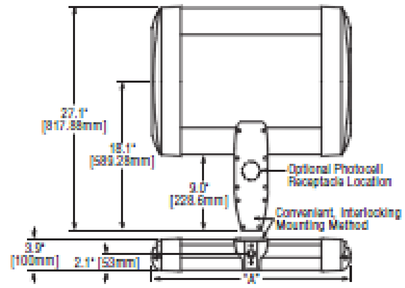
ARE-EDG-5M-DA THE EDGE® LED Area Light – Type V Medium

Rev. Date: 8/24/11

BetaLED Catalog #: ARE - EDG - 5M - DA - - D - - - - -

Reset

Notes:



# of LEDs	Dim. "A"
20	12.06" [306mm]
40	12.06" [306mm]
60	14.06" [357mm]
80	16.06" [408mm]
100	18.06" [459mm]
120	20.06" [510mm]
140	22.06" [560mm]
160	24.06" [611mm]
200	28.06" [713mm]
240	32.06" [814mm]

Product	Family	Optic	Mounting	# of LEDs (x 10)	LED Series	Voltage	Color Options	Drive Current Not Field Adjustable	Factory-Installed Options Please type additional options in manually on the lines provided above.
ARE	EDG	5M[1]	DA[2]	☐ 02 ☐ 04 ☐ 06 ☐ 08 ☐ 10 ☐ 12 ☐ 14 ☐ 16 ☐ 20 ☐ 24	D	☐ UL Universal 120–277V ☐ UH Universal 347–480V ☐ 34 347V	☐ SV Silver ☐ BK Black ☐ BZ Bronze ☐ PB Platinum Bronze ☐ WH White	☐ 350 350mA ☐ 525[3] 525mA ☐ 700[4] 700mA	☐ 43K 4300K Color Temperature[5] ☐ DIM 0–10V Dimming[6,7,8] ☐ F Fuse[9,10,11] ☐ HL Hi/Low (175/350/525, dual circuit input)[12] ☐ P Photocell[11,13] ☐ R NEMA Photocell Receptacle[11,13] ☐ ML Multi-Level (75/525)[12]

Footnotes

1. IESNA Type V Medium distribution
2. Direct mounting arm for use with 3–6" (76–152mm) square or round pole
3. Available on fixtures with 20–160 LEDs
4. Available on fixtures with 20–60 LEDs
5. Color temperature per fixture; 6000K standard; minimum 70 CRI
6. Control by others
7. Refer to dimming spec sheet for availability and additional information
8. Can't exceed specified drive current. Consult factory if exceeding drive current is necessary
9. Not available when UH voltage is selected
10. When code dictates fusing use time delay fuse
11. Not available with all multi-level options. Refer to the multi-level spec sheet for availability and additional information
12. Refer to multi-level spec sheet for availability and additional information
13. Must specify voltage other than UH
14. Intended for horizontal mounting

LED PERFORMANCE SPECS

# of LEDs	Initial Delivered Lumens – Type V Medium @ 6000K	B	U	G	Initial Delivered Lumens – Type V Medium @ 4300K	B	U	G	System Watts 120–480V	Total Current @ 120V	Total Current @ 230V	Total Current @ 277V	Total Current @ 347V	Total Current @ 480V	L_{70} Hours* @ 25° C (77° F)	50K Hours Lumen Maintenance Factor* @ 15° C (59° F)
		Rating**				Rating**										
350mA Fixture Operating at 25° C (77° F)																
20	2,013 (02)	1	1	1	1,855 (02)	1	1	1	26	0.20	0.11	0.10	0.09	0.07	>150,000	93%
40	4,025 (04)	2	1	1	3,710 (04)	2	1	1	47	0.40	0.21	0.19	0.15	0.12	>150,000	
60	5,960 (06)	3	2	1	5,493 (06)	3	2	1	68	0.58	0.30	0.26	0.20	0.16	>150,000	
80	7,946 (08)	3	2	2	7,324 (08)	3	2	2	90	0.77	0.38	0.34	0.26	0.20	>150,000	
100	9,908 (10)	4	3	2	9,131 (10)	3	3	2	111	0.95	0.47	0.42	0.32	0.24	>150,000	
120	11,889 (12)	4	3	2	10,958 (12)	4	3	2	132	1.15	0.56	0.50	0.38	0.28	>150,000	
140	13,808 (14)	4	3	2	12,726 (14)	4	3	2	157	1.34	0.67	0.61	0.47	0.35	149,000	
160	15,781 (16)	4	3	2	14,544 (16)	4	3	2	179	1.54	0.76	0.68	0.53	0.39	149,000	
200	19,726 (20)	4	3	2	18,180 (20)	4	3	2	221	1.92	0.95	0.84	0.65	0.48	149,000	
240	23,671 (24)	5	3	3	21,816 (24)	5	3	3	264	2.30	1.12	1.00	0.77	0.56	149,000	
525mA Fixture Operating at 25° C (77° F)																
20	2,818 (02)	2	1	1	2,597 (02)	2	1	1	37	0.31	0.17	0.16	0.12	0.10	136,000	92%
40	5,635 (04)	3	2	1	5,194 (04)	3	2	1	70	0.57	0.29	0.26	0.21	0.16	136,000	
60	8,344 (06)	3	2	2	7,690 (06)	3	2	2	102	0.87	0.44	0.39	0.30	0.22	129,000	
80	11,125 (08)	4	3	2	10,253 (08)	4	3	2	133	1.14	0.56	0.49	0.39	0.29	129,000	
100	13,871 (10)	4	3	2	12,784 (10)	4	3	2	172	1.47	0.75	0.67	0.51	0.38	128,000	
120	16,645 (12)	4	3	2	15,341 (12)	4	3	2	204	1.76	0.88	0.78	0.60	0.44	128,000	
140	19,331 (14)	4	3	2	17,817 (14)	4	3	2	233	2.01	0.99	0.87	0.69	0.51	123,000	
160	22,092 (16)	5	3	3	20,362 (16)	5	3	3	265	2.29	1.11	0.98	0.78	0.57	123,000	
700mA Fixture Operating at 25° C (77° F)																
20	3,441 (02)	2	1	1	3,172 (02)	2	1	1	50	0.42	0.22	0.20	0.15	0.12	111,000	90%
40	6,883 (04)	3	2	1	6,344 (04)	3	2	1	93	0.79	0.40	0.35	0.27	0.20	111,000	
60	10,191 (06)	4	3	2	9,393 (06)	3	3	2	137	1.18	0.59	0.51	0.39	0.29	111,000	

* For recommended lumen maintenance factor data see TD-13

** For more information on the IES BUG (Backlight-Uplight-Glare) Rating visit www.iesna.org/PDF/Erratas/TM-15-07BugRatingsAddendum.pdf

NOTE: All data subject to change without notice.

Made in the U.S.A. of U.S. and imported parts.
Meets Buy American requirements within the ARRA.

ARE-EDG-5M-DA THE EDGE® LED Area Light – Type V Medium

Rev. Date: 8/24/11

General Description

Slim, low profile design minimizes wind load requirements. Fixture sides are rugged cast aluminum with integral, weather-tight LED driver compartments and high performance aluminum heatsinks. Convenient, interlocking mounting method. Mounting housing is rugged die cast aluminum and mounts to 3–6" (76–152mm) square or round pole. Fixture is secured by two (2) 5/16-18 UNC bolts spaced on 2" (51mm) centers. Includes leaf/debris guard. Five year limited warranty on fixture.

Electrical

Modular design accommodates varied lighting output from high power, white, 6000K (+/- 500K per full fixture), minimum 70 CRI, long life LED sources. Optional 4300K (+/- 300K per full fixture) also available. 120–277V 50/60 Hz, Class 1 LED drivers are standard. 347–480V 50/60 Hz driver is optional. LED drivers have power factor >90% and THD <20% at full load. Units provided with integral 10kV surge suppression protection standard. Integral weather-tight electrical box with terminal strips (12Ga - 20Ga) for easy power hook-up. Surge protection tested in accordance with IEEE/ANSI C62.41.2.

Testing & Compliance

UL listed in the U.S. and Canada for wet locations and enclosure rated IP66 per IEC 60529 when ordered without P or R options. Consult factory for CE Certified products. Certified to ANSI C136.31-2001, 3G bridge and overpass vibration standards.
Dark Sky Friendly, IDA Approved. RoHS Compliant.

Product qualified on the Design Lights Consortium ("DLC") Qualified Products List ("QPL") when ordered without backlight control shield.

Finish

Exclusive Colorfast DeltaGuard® finish features an E-Coat epoxy primer with an ultra-durable silver powder topcoat, providing excellent resistance to corrosion, ultraviolet degradation and abrasion. Bronze, black, white and platinum bronze powder topcoats are also available. The finish is covered by our 10 year limited warranty.

Fixture and finish are endurance tested to withstand 5,000 hours of elevated ambient salt fog conditions as defined in ASTM Standard B 117.

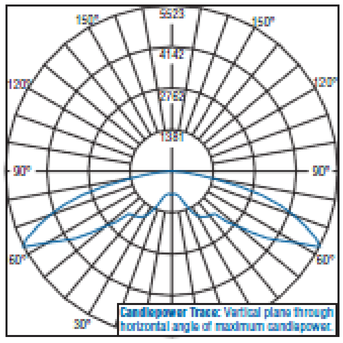
Patents

U.S. and international patents granted and pending. BetaLED is a division of Ruud Lighting, Inc. For a listing of Ruud Lighting, Inc. patents, visit www.uspto.gov.

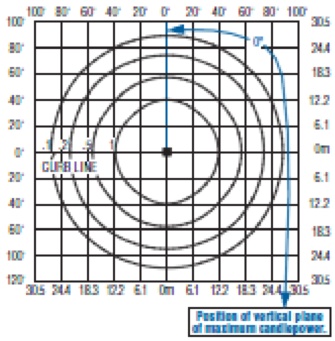
Field-Installed Accessories

Bird Spikes
☐ XA-BRDSPK

Photometrics



Independent Testing Laboratories certified test. Report No. ITL68282. Candlepower trace of 4300K, 120 LED Type V Medium area luminaire with 16,029 initial delivered lumens operating at 525mA. **All published luminaire photometric testing performed to IESNA LM-79-08 standards.**



Isofootcandle plot of 4300K, 120 LED Type V Medium area luminaire at 25' (7.6m) A.F.G. Luminaire with 15,341 initial delivered lumens operating at 525mA. Initial FC at grade.

THE EDGE® EPA & Weight Calculations

# of LEDs	Approximate Weight 120–480V[1]	Single	2@ 180°	2@ 90°	3@ 90	4@ 90°
Fixed Arm Mount						
20	21.0 lbs. (9.5kg)	0.60	1.20	0.87	1.47	1.75
40	23.7 lbs. (10.8g)	0.60	1.20	0.87	1.47	1.75
60	27.0 lbs. (12.3kg)	0.60	1.20	0.92	1.51	1.83
80	28.1 lbs. (12.8kg)	0.60	1.20	0.96	1.55	1.91
100	32.3 lbs. (14.7kg)	0.60	1.20	1.00	1.60	2.00
120	33.5 lbs. (15.2kg)	0.60	1.20	1.04	1.64	2.08
140	36.9 lbs. (16.7kg)	0.60	1.20	1.08	1.68	2.16
160	41.4 lbs. (18.8kg)	0.60	1.20	1.12	1.72	2.24
200	43.3 lbs. (19.6kg)	0.61	1.21	n/a[2]	n/a[2]	n/a[2]
240	47.8 lbs. (21.7kg)	0.69	1.38	n/a[2]	n/a[2]	n/a[2]

1. Add 5 lbs. (2.3kg) for transformer in 347–480V fixtures when multi-level options are selected.
2. For applications requiring 200 or more LEDs at 90 degrees refer to the DL mount version of our spec sheet.

NOTE: All data subject to change without notice.

Made in the U.S.A. of U.S. and imported parts.
Meets Buy American requirements within the ARRA.

REFERENCES

Board of County Commissioners. (2011). *Miami-Dade County Florida Outdoor Lighting Code*.

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[3] Owner name not disclosed. For the purpose of this study, the owner name may remain private without altering this report.

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