# LED SITE LIGHTING PERFORMANCE SPECIFICATION

## PART 1 – GENERAL

### 1.1 REFERENCES

A. The publications listed below form a part of this specification to the extent referenced. Publications are referenced within the text by the basic designation only.

B. American Association of State Highway and Transportation Officials (AASHTO)

1. AASHTO C-HSLTS – Structural Supports for Highway Signs, Luminaires and Traffic Signals.

C. ASTM International (ASTM)

1. ASTM A 36 – Structural Steel
2. ASTM A 123 – Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
3. ASTM A 153 – Zinc Coating (Hot-Dip) on Iron and Steel Hardware
4. ASTM A 595 – Steel Tubes, Low-Carbon, Tapered for Structural Use
5. ASTM F 1554 – Anchor Bolts, Steel, 36, 55, And 105-Ksi Yield Strength
6. ASTM B117-97 – Standard Practice for Operating Salt Spray (Fog) Apparatus
7. ASTM G53 – Standard Practice for Operating Light and Water Exposure Apparatus (Fluorescent UV – Condensation Type) for Exposure of Nonmetallic Materials

D. Illuminating Engineering Society of North America (IESNA)

1. DG-13-98, Guide for the Selection of Photocontrols for Outdoor Lighting Applications
2. G-1-03, Guidelines for Security Lighting
3. LM-64-01, Photometric Measurements of Parking Areas
4. LM-69-95 (R2002), Interpretation of Roadway Luminaire Photometric Reports
5. LM-79-08, IESNA Approved Method for the Electrical and Photometric Measurements of Solid-Sate Lighting Products
6. LM-80-08, IESNA Approved Method for Measuring Lumen Maintenance of LED Light Sources
7. RP-20-98, Recommended Practice for Lighting Parking Facilities
8. RP-33-99, Recommended Practice for Lighting for Exterior Environments
9. TM-15-08, Luminaire Classification System for Outdoor Luminaires

E. ANSI (American National Standards Institute

1. ANSI C62.41.1-2002 – IEEE Guide on the Surge Environment in Low-Voltage (1000V and less) AC Power Circuits

2. ANSI C62.41.2-2002 – IEEE Recommended Practice on Characterization of Surges in Low-Voltage (1000W and less) AC Power Circuits

3. ANSI C82.SSL1 – SSL Drivers (in ANSI development)

F. International Electrotechnical Commission (IEC)

1. IEC 60529 – Degrees of Protection provided by enclosures (IPCode)

G. National Electrical Manufacturers Association (NEMA)

1. ANSI/NEMA/ANSLG 378.377-2008 – American National Standard for the Chromaticity of Solid State Lighting Products

H. National Fire Protection Association (NFPA)

1. NFPA 70 – National Electrical Code

## 1.2 QUALITY ASSURANCE

A. Site owner may request standard production model luminaire samples identical (including LED package) to product proposed to be installed for inspection. Owner may request independent testing of sample luminaires to verify luminaire performance and compliance with the specifications. Testing shall be conducted per the applicable IESNA and ANSI approved methods for products using Solid-State Lighting (SSL) sources. Refer to the DOE SSL web site for a list of approved test laboratories at http://www1.eere.energy.gov/buildings/ssl/test_labs.html.) Owner shall be sole judge regarding acceptability of optical system performance.

B. Site owner may choose to take field measurements to confirm lighting levels in accordance with the site specific photometric analysis between 2,000 and 3,000 operating hours of the completion of installation. If light levels are not ± 5% of the **DAY 1** submittal (see 1.4 A.1), the luminaire manufacturer shall provide additional luminaires to achieve specified light levels. The cost for additional luminaires and poles, if required, including material and labor to install the same, shall be the responsibility of the luminaire manufacturer. Additionally, the luminaire manufacturer shall reimburse Site owner for additional energy costs as a result of the additional luminaires.

C. Guidance for pre and post-installation field measurements (Measurement & Verification (M&V) Plan) can be found at http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/lighting_measurement_evaluation_protocol.pdf.

## 1.3 SITE LIGHTING SYSTEM PERFORMANCE

A. General:

1. Luminaires shall be classified according to the IESNA TM-15-08 Luminaire Classification System (LCS) using the BUG Ratings. Luminaires shall produce a maximum of lumens (the corresponding BUG value from TM-15 is listed in parenthesis) in each of the listed angular zones in the corresponding lighting zone (LZ):

**Table 1**. Maximum Allowed Lumens in the Uplight Zone for Luminaires

| Lighting Zone | Uplight Low (90° – 100°) | Uplight High (100° – 180°) |
|---|---|---|
| LZ0 | 0 lumens (U0) | 0 lumens (U0) |
| LZ1 | 10 lumens (U1) | 10 lumens (U1) |
| LZ2 | 100 lumens (U2) | 100 lumens (U2) |
| LZ3 | 500 lumens (U3) | 500 lumens (U3) |
| LZ4 | 1000 lumens (U4) | 1000 lumens (U4) |

**Table 2**. Maximum Allowed Lumens in the Glare Zone for Asymmetric Luminaires

| | Forward High (60° – 80°) | Forward Very High (80° – 90°) | Back High (60° – 80°) | Back Very High (80° – 90°) |
|---|---|---|---|---|
| LZ0 | 660 lumens (G0) | 10 lumens (G0) | 110 lumens (G0) | 10 lumens (G0) |
| LZ1 | 1800 lumens (G1) | 250 lumens (G1) | 500 lumens (G1) | 250 lumens (G1) |
| LZ2 | 5000 lumens (G2) | 375 lumens (G2) | 1000 lumens (G2) | 375 lumens (G2) |
| LZ3 | 7500 lumens (G3) | 500 lumens (G3) | 2500 lumens (G3) | 500 lumens (G3) |
| LZ4 | 12000 lumens (G4) | 750 lumens (G4) | 5000 lumens (G4) | 750 lumens (G4) |

**Table 3**. Maximum Allowed Lumens in the Glare Zone for Bilaterally Symmetric Luminaires

| | Forward High (60° – 80°) | Forward Very High (80° – 90°) | Back High (60° – 80°) | Back Very High (80° – 90°) |
|---|---|---|---|---|
| LZ0 | 660 lumens (G0) | 10 lumens (G0) | 660 lumens (G0) | 10 lumens (G0) |
| LZ1 | 1800 lumens (G1) | 250 lumens (G1) | 1800 lumens (G1) | 250 lumens (G1) |
| LZ2 | 5000 lumens (G2) | 375 lumens (G2) | 5000 lumens (G2) | 375 lumens (G2) |
| LZ3 | 7500 lumens (G3) | 500 lumens (G3) | 7500 lumens (G3) | 500 lumens (G3) |
| LZ4 | 12000 lumens (G4) | 750 lumens (G4) | 12000 lumens (G4) | 750 lumens (G4) |

2. Site lighting shall meet the following lighting power density (LPD) requirements:
   a. LZ1 –LPD maximum of 0.04 W/SF
   b. LZ2 –LPD maximum of 0.05 W/SF
   c. LZ3 –LPD maximum of 0.06 W/SF
   d. LZ4 –LPD maximum of 0.08 W/SF
   e. Site lighting uniformity calculations shall not include facade lighting and/or building security lighting contributions.
   f. Assume Lamp Lumen Depreciation (LLD): 0.70 for all luminaires.
   g. Assume Luminaire Dirt Depreciation (LDD): 0.95 for all luminaires.
   h. Lighting system shall meet the requirements in 1.3 B – 1.3 F, as well as, the following requirements:
      1. Mounting Height: ___[to be determined by retailer and inserted here] feet

2. Spacing between measurement points should be one-half the mounting height of the luminaires, but not greater than 15' on center.
3. See Appendix 1 for diagram of parking lot sections
4. Vertical illuminance values at 5' Above Finished Grade (AFG) normal to the center of the parking lot

B. Site Lighting Requirements – Main Parking Area

1. Defined as the group(s) of parking spots comprising the majority of the site. The zone starts from the edge of the front aisle and extends to the center of the last driving lane

2. Illuminance requirements of area:

**Table 4**. Main Parking Area

| | Minimum Horizontal Illuminance | Uniformity Maximum CV | Minimum Vertical Illuminance |
|---|---|---|---|
| Lighting Zone 0 | N/A | N/A | N/A |
| Lighting Zone 1 | N/A | N/A | N/A |
| Lighting Zone 2 | 0.50 fc | 0.41 | 0.25 fc |
| Lighting Zone 3 | 0.75 fc | 0.41 | 0.50 fc |
| Lighting Zone 4 | 1.00 fc | 0.41 | 0.50 fc |

C. Site Lighting Requirements – Perimeter Parking Areas

1. Defined as the group(s) of parking spots on the perimeter of the site. The zone starts on the center of the farthest driving lane and goes to the boundary of the site.

2. Illuminance requirements of area:

**Table 5**. Perimeter Parking Area

| | Minimum Horizontal Illuminance | Uniformity Maximum CV | Minimum Vertical Illuminance |
|---|---|---|---|
| Lighting Zone 0 | N/A | N/A | N/A |
| Lighting Zone 1 | N/A | N/A | N/A |
| Lighting Zone 2 | 0.20 fc | 0.41 | 0.25 fc |
| Lighting Zone 3 | 0.40 fc | 0.41 | 0.50 fc |
| Lighting Zone 4 | 0.50 fc | 0.41 | 0.50 fc |

D. Site Lighting Requirements – Front Aisle

1. Defined as the driving/walking area from the façade of the building to the exterior edge of the nearest parking spot(s)

2. Illuminance requirements of area:

**Table 6**. Front Aisle

| | Minimum Horizontal Illuminance | Uniformity Maximum CV | Minimum Vertical Illuminance |
|---|---|---|---|
| Lighting Zone 0 | N/A | N/A | N/A |
| Lighting Zone 1 | N/A | N/A | N/A |
| Lighting Zone 2 | 1.00 fc | 0.41 | 0.25 fc |
| Lighting Zone 3 | 1.50 fc | 0.41 | 0.50 fc |
| Lighting Zone 4 | 2.00 fc | 0.41 | 0.50 fc |

E. Site Lighting Requirements – Entry Drives, Bale and Pallet Areas, Rear Drives

1. Entry drive defined as the roadway for entering and leaving the parking lot. The zone starts at the end of the public road and ends where the perimeter parking zone starts.
2. Pallet area defined as the roadway along the façade where loading and unloading for the building occur
3. Rear drive defined as the roadway behind the building, where customer parking does not occur, and extends from the façade of the building to the edge of the site
4. Illuminance requirements of area:

**Table 7**. Entry Drives, Bale and Pallet Areas, Rear Drives

| | Minimum Horizontal Illuminance | Uniformity Maximum CV | Minimum Vertical Illuminance |
|---|---|---|---|
| Lighting Zone 0 | N/A | N/A | N/A |
| Lighting Zone 1 | N/A | N/A | N/A |
| Lighting Zone 2 | 0.20 fc | 10:1 | 0.25 fc |
| Lighting Zone 3 | 0.40 fc | 10:1 | 0.50 fc |
| Lighting Zone 4 | 0.50 fc | 10:1 | 0.50 fc |

F. Site Lighting Requirements – Spill Light Control (Light Trespass)

1. The Lighting System shall produce less than the vertical illuminance listed in the table below at a point 5’ AFG along the site boundary normal to the site per each Lighting Zone:

**Table 8**. Site Lighting Trespass Maximum Vertical Illuminance Values

| Lighting Zone | Maximum Illuminance |
|---|---|
| LZ0 | 0.05 fc |
| LZ1 | 0.10 fc |
| LZ2 | 0.30 fc |
| LZ3 | 0.80 fc |
| LZ4 | 1.50 fc |

G. When Security is an issue – Note that increased light levels are not the only or necessarily the best way to improve security in parking lots. Considerations include improved

security camera equipment and placement, use of motion detectors to trigger increased light levels, increased lighting uniformity, etc. However when specific security issues requiring light levels exceeding recommendations in A through F above are identified by the site owner, reference IESNA document G-1-03, section 4. If all the requirements are met in G-1-03, use an LPD multiplier of 1.25 for each of the Lighting Zones (LZ).

## 1.4 SUBMITTALS

A. Performance Reports – Submit the following for approval when required by the Site owner:

1. Computer generated photometric analysis of proposed **DAY 1** (defined as the initial illuminance values), of the lighting installation, submittal should include the following requirements:

    a. Provide horizontal illuminance measurements (in footcandles) at grade. Spacing between measurement points should be one-half the mounting height of the luminaires, but not greater than 15' on center.

    b. For compliance with light trespass requirements (see 1.3 F), provide summary of vertical measurements (in footcandles) at 5' AFG normal to the site boundary, along the site boundary. Vertical measurements should occur parallel to the pole and ½ the distance between the poles along the site boundary.

    c. Computer calculation should use the following applicable LLF values: 1.0 LLD and 1.0 LDD.

2. Computer generated photometric analysis of proposed **FUTURE DATE** (defined as assuming numerous thousands of hours of operation) of the lighting installation, submittal should include the following requirements:

    a. Provide horizontal illuminance measurements (in footcandles) at grade. Per IESNA LM-64-01, measurement points should be ½ of the mounting height of the luminaire apart, but no greater than 15' on center.

    b. For compliance with site lighting performance vertical illuminance requirements (see 1.3 B-E), provide summary of vertical measurements (in footcandles) at 5' AFG normal to the center of the parking lot. Vertical measurements should be taken in the center of the parking lot area.

    c. Computer calculation should use the following applicable LLF values: 0.70 LLD and 0.95 LDD.

3. Luminaire photometric reports per IESNA LM-79-08 including: laboratory name, report number, date, luminaire catalog number, luminaire, and light source specifications. Report shall contain IESNA LCS, BUG Ratings per IESNA TM-15-07 and Roadway Type classifications, luminous Intensity, zonal lumen summary, and an iso-footcandle diagram per LM-64-05 as well as documentation that specified standards and test methods were followed.

4. Provide safety certification and file number as required for the luminaire family which shall be listed, labeled, or identified per the National Electric Code (NEC). Applicable testing bodies are determined by the US Occupational Safety Health Administration (OSHA) as Nationally Recognized Testing Laboratories (NRTL)

and include: CSA (Canadian Standards Association), ETL (Edison Testing Laboratory), and UL (Underwriters Laboratory).

1.5 WARRANTY

A. Standard Warranty – Note: Life of LED parking lot lighting (primarily the luminaire) is not yet well understood given the relative newness of the technology for this application. Projected life of LED luminaires is a key component to payback scenarios in buyers' purchase evaluations, therefore prospective buyers are looking for ways help assure products perform as anticipated. Since life claims provided by suppliers is typically 50,000 hours or greater and the first cost of LED parking lot luminaires can be significant, site owners are looking for assurances that the product will perform as claimed in terms of life.

1. Provide a written **ten year** on-site replacement material, fixture finish, and workmanship. On-site replacement includes transportation, removal, and installation of new products. Finish warranty shall include warranty against failure or substantial deterioration such as blistering, cracking, peeling, chalking, or fading.
2. Provide a written **ten year** replacement material warranty for defective or non-starting LED source assemblies.
3. Provide a written **ten year** replacement material warranty on all power supply units (PSU's).
4. Warranty period shall begin on date of possession. The supplier will provide the site owner with appropriate signed warranty certificates. Certificates shall be received by the site owner prior to final payment.

PART 2 – PRODUCTS

A. General Requirements

1. The weatherproofing seal shall not be directly exposed to sunlight, shall not be the sole means to prevent water intrusion, and will be designed to last the life of the luminaire.
2. The coating shall be capable of surviving ASTM B117 Salt Fog environment for 500 hrs minimum without blistering of peeling. The coating shall demonstrate gloss retention of greater than or equal to 90% for 500 Hrs exposure QUV test per ASTM G53 UVB313, 4 Hr UV-B 60 ˚C/4 hr Condensation 50 ˚C.
3. If a lens not integral to the LED is used, the luminaire optical enclosure (lens/window) shall be constructed of a one piece, UV resistant, clear, non-PVC acrylic or glass.
4. The luminaire optical system shall be factory sealed to IEC 60529/IP65 standards and shall not support field entry to optical or LED source assemblies.
5. Luminaires shall be fully assembled and electrically tested before shipment from factory.
6. Luminaire arm bolts shall be 304 stainless steel or zinc plated steel.

7. Luminaire mounting arm shall have … (TBD based on final configurations and options).
8. Luminaires shall have country appropriate governing mark and certification.
9. Luminaires shall be rated for continuous service at an ambient temperature of 25° C.
10. Luminaires shall be rated for 6 weeks of continuous operation at +60° C with no negative impact.
11. Color of the luminaire shall be as specified by the site owner.
12. Luminaire shall be Reduction of Hazardous Substances (RoHS) compliant. (see http://www.rohs.eu/english/index.html)

B. Housing Requirements

1. The Luminaire housing shall support, without modification, the following:
   a. Electrical system cavity shall meet a minimum IEC 60529/IP65 standard and be field accessible for service or repair needs.

C. Electrical System Requirements

1. The electrical system shall meet the following criteria:
   a. Starting Temperature: -40° C
   b. Power Factor: > 90 percent
   c. Input Voltage: capable of 100 to 480 volt, single phase or as required by the site
   d. Surge Protection: The system must survive 250 repetitive strikes of "C Low" (C Low – 10kV/1.2 x 50 µs, 10kA/8 x 20 µs) waveforms at 1 minute intervals with less than 10% degradation in clamping voltage. "C Low" waveforms are as defined in IEEE/ASNI C62.41.2-2002, Scenario 1 Location Category C
   e. Primary Fuse Protection: Provide Double Fusing with Fuse Holder appropriately sized to the current. Fuse voltage shall be ≥ than the voltage indicated in section 2.D.1.c. Fuses shall be easily accessible in the base of the pole or remotely-located. If remotely-located, the housing shall be labeled identifying fused fixture and fuse information
   f. Operating frequency shall be 50/60 Hz
   g. EMI/RFI emissions shall be Federal Communications Commission (FCC) Part 18 Class A compliant
   h. Efficiency (power out/power in) for the power supplies shall exceed 85%
   i. Power supplies can be UL Class I or II output
   j. Total harmonic distortion for the power supply must not exceed 20%
   k. Under voltage protection via shutoff and short circuit protection via current limitation
   l. Internal luminaire design should include modular electrical connections

D. Light Source Requirements

1. The Site Lighting Luminaire light source shall satisfy the following criteria:

a. A minimum of 50,000 operating hours before $L_{70}$ with no catastrophic failures

b. Operating temperature rating shall be between -40°C and +50°C

c. Correlated Color Temperature (CCT): 2700-6500K

d. Color Rendering Index (CRI): ≥ 70

E. 80% of the luminaire material by weight should be recyclable at end of life.

## PART 3 – RELIABILITY AND TESTING

### 3.1 Product Submittals

A. Luminaire manufacturer shall submit reliability reports indicating that the manufacturer of the LED (chip, diode, or package) has performed JEDEC (Joint Electron Devices Engineering Council) reliability tests on the LEDs as follows:

1. High Temperature Operating Life (HTOL)
2. Room Temperature Operating Life (RTOL)
3. Low Temperature Operating Life (LTOL)
4. Powered Temperature Cycle (PTMCL)
5. Non-Operating Thermal Shock (TMSK)
6. Mechanical Shock
7. Variable Vibration Frequency
8. Solder Heat Resistance (SHR)
9. Autoclave

### 3.2 Mechanical Vibration

A. The luminaire must be subjected to 100,000 cycles of 2 Gs applied at the center of gravity of the luminaire on 3 primary axis

1. No damage to the luminaire is allowed
2. The luminaire must be fully functional upon completing the test

B. The luminaire must be subjected to 1,000 cycles of 4Gs applied at the center of gravity of the luminaire on 2 horizontal axis

1. No damage to the luminaire is allowed
2. The luminaire must be fully functional upon completing the test

3.3 Light Source Expected Life

A. The luminaire must be subjected to testing per LM-80-08. Although LM-80 is for LED light sources (dies, packages, arrays,…) the procedure is being adopted to extrapolate lumen maintenance on the luminaire level. The test is pass/fail passed on a measurement taken in early in the LED luminaire's life. Manufacturer shall follow the following steps to verify $L_{70}$ after 50,000 hours:The luminaire shall be tested using LM-79 conditions at both time intervals of 0 hours and $\geq$ 6,000 hours.

B. The luminaire shall be operated continuously in the appropriate UL 1598/153 environment expect when it is removed to perform the LM-79 light output tests.

C. If the light output determined at $\geq$ 6,000 hours divided by the light output at 0 hours multiplied by 100 yields $\geq$ 96%, the luminaire is expected to reach $L_{70}$ at or after 50,000 hours.

3.4 Other Tests

A. Site owner can request additional tests per extreme environmental condition (e.g. sea salt near water, extreme cold weather operation in Alaska, etc…)

PART 4 – CONTROLS

4.1 Minimum Required Control

A. All exterior parking lot, drive, and front aisle areas shall be controlled with a combination Photocell plus Time Switch control system that allows automatic on and off based on daylighting plus timed off after expected parking lot activity ends.

B. Switches shall be furnished in NEMA I General purpose enclosure unless noted otherwise. Switches located on the exterior or in "wet" locations shall have NEMA 3R, 4 or 4X enclosures as noted or required.

C. The Photocell plus Time Switch control system shall have the following characteristics:

1. The photocell shall provide the "on" function at dusk and have the following capabilities and features:

a. 15 to 30 second built-in time delay to prevent response to momentary lightning flashes, car headlights or cloud movements.

b. Settings to energize the lighting system when the north sky light decreases to approximately XX footcandles, and maintains the system energized until the north sky light increases to approximately XX footcandles (XX values to be supplied by Site Owner. Actual value will depend on the lighting zone/required illuminance. A TURN-ON/TURN-OFF ratio $\leq$ 5:1 (the lights either turn on or off when the photocell measures 5x the required illuminace) should be used.).

c. Mounted in an un-obscured location for measuring the available north sky daylight with a separate control/calibration module mounted separately and in an accessible location.

d. Use relays that are UL 773 or UL 773A listed and designed to fail in the on position.

2. The time switch(s) shall control specific circuit "off" functions during dark hours and be:

a. Digital microprocessor-based with battery backup capable of retaining programmed settings for at least 10 hours.

b. 7-day, 24-hour astronomic capable.

4.2 Optional Controls

A. Optional controls installed in addition to the Photocell plus Time Switch control system may include but are not limited to:

1. After hours dimming control – dims light levels to X% [specify between 10% – 50% of full lumen output] after expected parking lot activity ends (a.k.a. “curfew” control)

2. After hours switching control – turns off or reduces light levels after expected parking lot activity ends (a.k.a. “curfew” control)

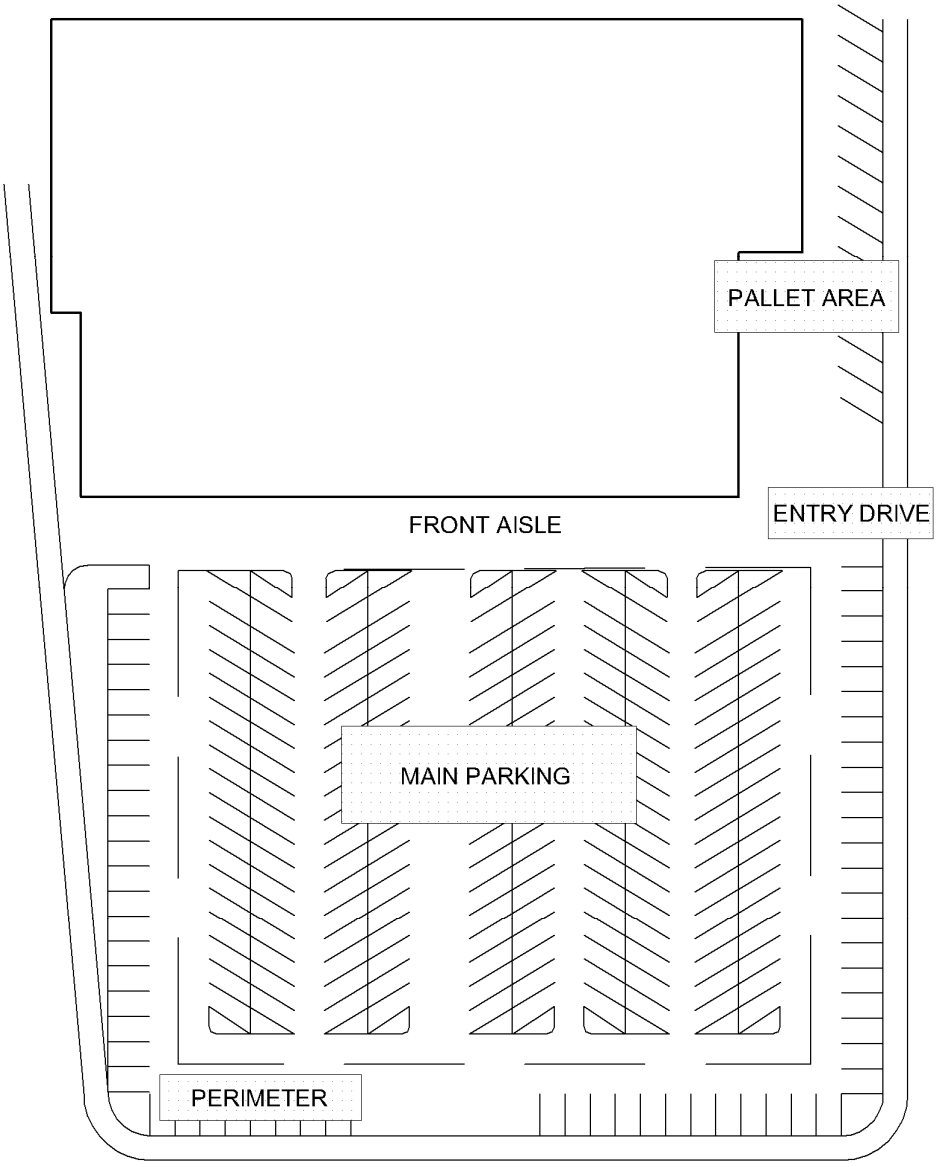
a. Specific areas turned off after expected parking lot activity ends

b. Overall reduction of light level after expected parking lot activity ends

3. Lumen maintenance – When luminaires are first installed, start out dimming the luminaire and gradually increasing output over time to compensate for the lumen depreciation.

END OF SECTION

# Appendix A – Diagram of Parking Areas Identified in This Specification



# Appendix B – Definitions and Related Terms

Lighting Zones:

1. To provide as much information about the lighting zone, both the ASHRAE/IESNA Std. 90.1 and IESNA RP-33 exterior lighting zone definitions are listed below, no ASHRAE/IESNA definition exists for LZ0.Lighting Zone (LZ0) –Areas where the natural environment will be seriously and adversely affected by lighting. Impacts include disturbing the biological cycles of flora and fauna and/pr detracting from human enjoyment and appreciation of the natural environment. Human activity is subordinate in importance to nature. The vision of human residents and users is adapted to the total darkness, and they expect to see little or no lighting. When not needed, lighting should be extinguished.
2. Lighting Zone (LZ1) – Developed areas of National Parks, State Parks, Forest Land, and Rural areas. Areas where lighting might adversely affect flora and fauna or disturb the character of the area. The vision of human residents and users is adapted to low light levels. Lighting may be used for safety and convenience but it is not necessarily uniform or continuous. After curfew, most lighting should be extinguished or reduced as activity levels decline.
3. Lighting Zone (LZ2) – Areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited nighttime use and residential mixed use areas. Lighting may typically be used for safety and convenience but it is not necessarily uniform or continuous. After curfew, lighting may be extinguished or reduced as activity levels decline.
4. Lighting Zone (LZ3) – All other areas. Areas of human activity where the vision of human residents and users is adapted to moderately high light levels. Lighting is generally desired for safety, security and/or convenience and it is often uniform and/or continuous. After curfew, lighting may be extinguished or reduced in most areas as activity levels decline.
5. Lighting Zone (LZ4) – High activity commercial districts in major metropolitan areas as designated by the local jurisdiction. Areas of human activity where the vision of human residents and users is adapted to high light levels. Lighting is generally considered necessary for safety, security and/or convenience and it is mostly uniform and/or continuous. After curfew, lighting may be extinguished or reduced in some areas as activity levels decline.

Coefficient of Variation (CV):

This method is a measure of the weighted average of all relevant illuminance values and is commonly used in statistics, where the variance of a set of values is calculated as the ratio of standard deviation s of all values to the mean *x*.

$x_i$ = illuminance at point i,
N = number of points measured
$\bar{x}$ = mean illuminance

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n}}$$

$CV = \sigma / \bar{x}$